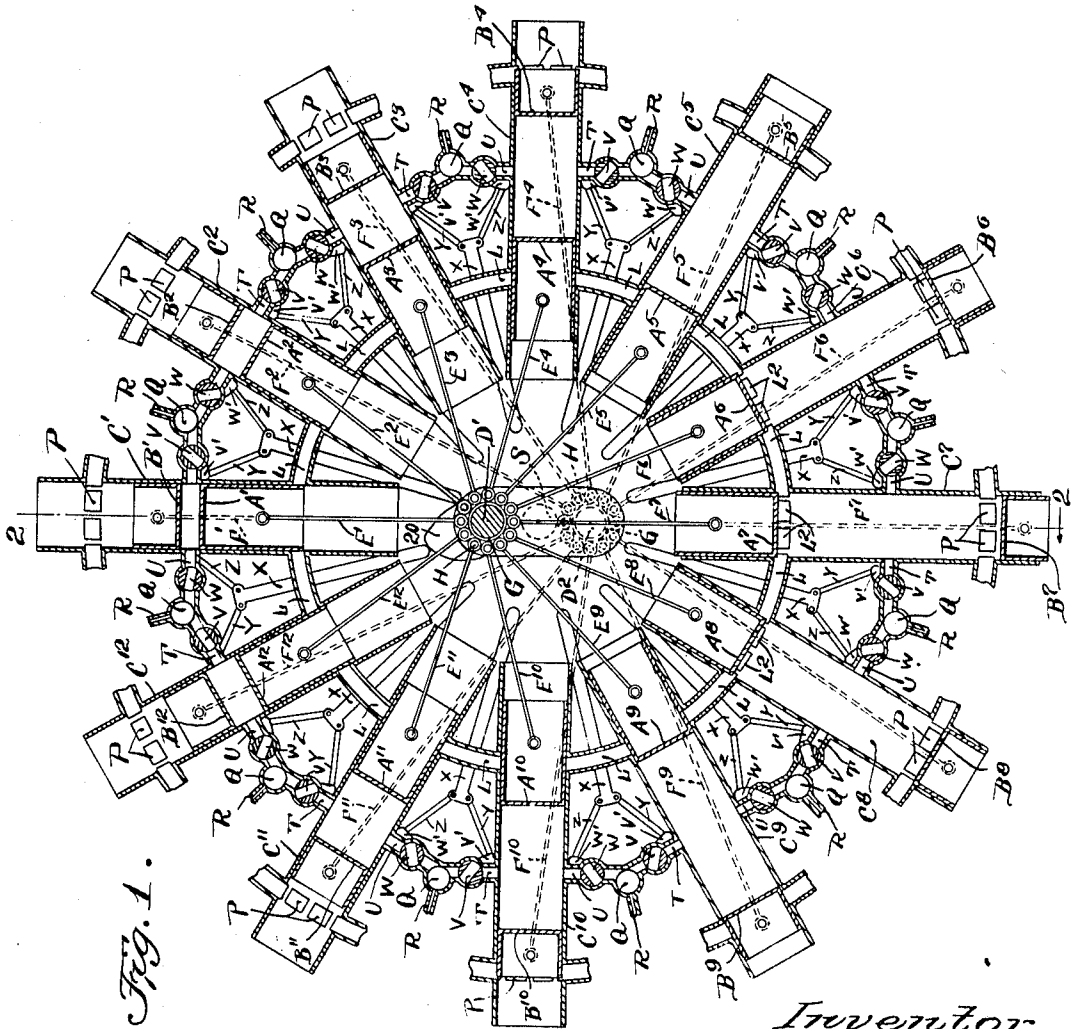
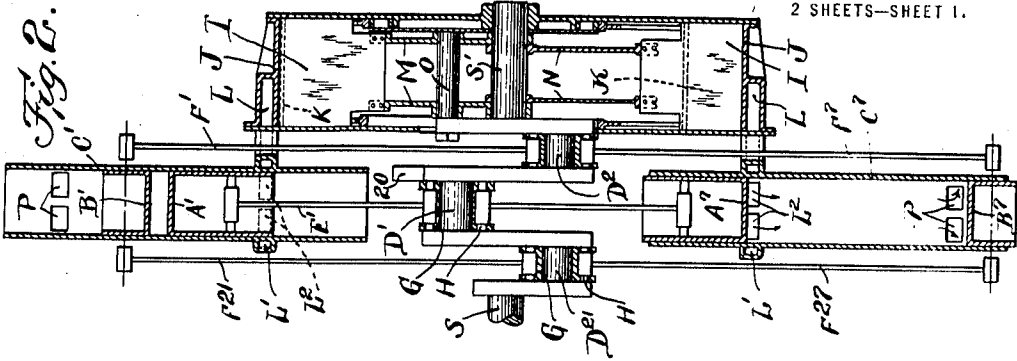


E. A. FORD.
INTERNAL COMBUSTION MOTOR.
APPLICATION FILED SEPT. 25, 1918.

1,314,640.

Patented Sept. 2, 1919.

2 SHEETS—SHEET 1.



Inventor
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2 SHEETS—SHEET 2.

Fig. 5.

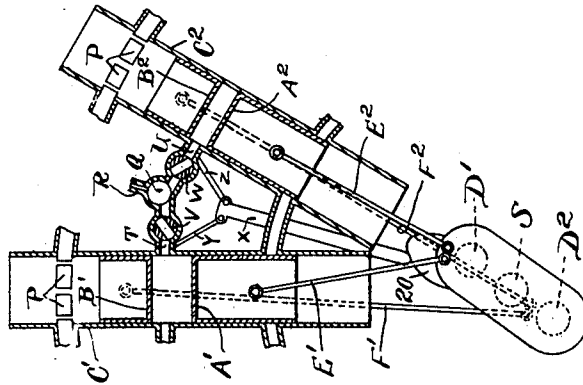


Fig. 4.

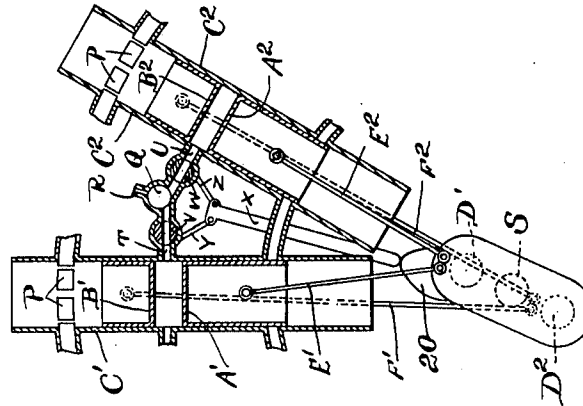
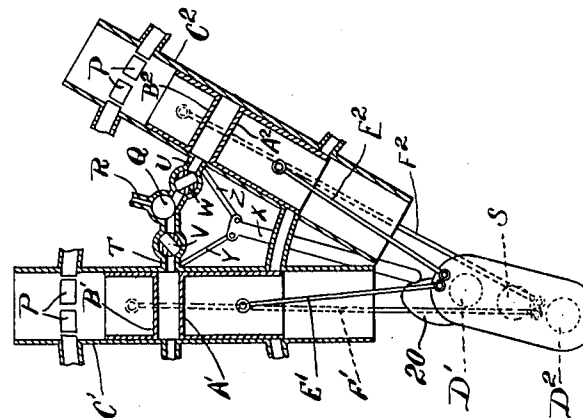


Fig. 3.



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UNITED STATES PATENT OFFICE.

EUGENE A. FORD, OF NEWTON, MASSACHUSETTS, ASSIGNOR TO R. E. D. ENGINE COMPANY, INC., OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

INTERNAL-COMBUSTION MOTOR.

1,314,640.

Specification of Letters Patent.

Patented Sept. 2, 1919.

Application filed September 25, 1918. Serial No. 255,600.

To all whom it may concern:

Be it known that I, EUGENE A. FORD, a citizen of the United States, residing at Newton, in the county of Middlesex and State of Massachusetts, have invented new and useful Improvements in Internal-Combustion Motors, of which the following is a specification.

The present invention relates to plural cylinder internal combustion motors and has among its principal objects the following:—first, to produce a motor designed to develop large powers and having comparatively light weight, with consequent high power per unit of weight, whereby it is particularly well adapted for use in aviation. Second, to provide a novel and improved means of ignition effective to cause certain ignition of the combustible charge in each cylinder and avoiding necessity of electric ignition means. Third, to combine such ignition means with provisions for admission of the fuel component of the combustible working charge, whereby simultaneous fuel admission and ignition are to be effected at given times, and danger of pre-ignition as well as of necessity for a carbureter are avoided. Fourth, to enable successively acting cylinders of the motor to serve to a degree as a storage reservoir of compressed working fluid for one another. Fifth, to apply in a motor having a multiplicity of radially arranged cylinders the idea of double opposed pistons in each cylinder. Sixth, to make an internal combustion motor having cylinders arranged about the axis of the shaft in substantially the same plane transverse to such axis and operating on the two stroke cycle. The invention consists in the means, and the principles underlying such means, which I have devised and provided to accomplish the foregoing and other objects, explained in the following specification.

In the drawings accompanying this specification, I have illustrated in a diagrammatic manner the principal parts, in their preferred arrangement and method of coaction one with another, of a motor embodying my invention and effective to fulfil the objects above set forth. Of these drawings,

Figure 1 is a diagrammatic cross sectional view of the motor. Fig. 2 is a diagrammatic longitudinal sectional view of the motor on line 2—2 of Fig. 1. Figs. 3, 4, and 5

are diagrammatic fragmentary views of two adjacent cylinders and of the cranks and pistons associated therewith in respectively different closely-following successive positions.

The same reference characters indicate the same parts in all the figures.

At the outset I will explain that my purpose in making the present application is to protect the fundamental ideas of means for accomplishing the objects hereinbefore stated, rather than any specific detailed forms of such means; and that the principles underlying the combinations, arrangements, and operation of such means can be more clearly shown and explained with reference to drawings illustrating the same in a diagrammatic manner than by drawings showing all mechanical details necessary to a motor in condition for instant operation. Therefore, in making the present drawings I have contented myself with showing diagrammatically only the parts essential to a description and understanding of my present invention as hereinafter claimed, omitting all details which, although practically necessary to an instantly operative motor, yet are either not novel with me, or are not claimed as parts of the present invention, and embodiments of which, suitable for building such an operative motor may be supplied by persons skilled in the art from constructions already known and in common use. The omitted details consist merely of supports, bearings, guides, and connections.

The motor here shown has twelve cylinders $C^1, C^2 \dots C^{12}$ all substantially radial to a single main shaft S and spaced substantially equiangularly about the axis of the shaft similarly to the spokes of a wheel, preferably in the same plane perpendicular to the shaft. In each cylinder are two opposed and oppositely reciprocating pistons; the inner pistons, those nearer the shaft, being designated $A^1, A^2 \dots A^{12}$, and the outer pistons, those more distant from the shaft, being designated $B^1, B^2 \dots B^{12}$. On the shaft are a crank D^1 , to which all the inner pistons are connected by connecting rods $E^1, E^2, \dots E^{12}$, respectively, and cranks D^2 and D^{21} at the opposite side of the shaft axis from crank D^1 , to both of which all of the outer pistons are connected. The latter cranks are located not only at the opposite side of the shaft from crank D^1 but

also at respectively opposite sides of the zone in which crank D^1 travels. Their connections with the outer pistons are made by connecting rods at opposite sides of the cylinders; the rods from the several outer pistons to crank D^2 being designated F^1 , F^2 , . . . F^{12} , respectively, and the rods from crank D^{21} to pistons B^1 and B^6 (the only ones of this series of connecting rods herein shown) being designated F^{21} and F^{27} , respectively, in Fig. 2. This arrangement of the cranks D^2 and D^{21} and the connecting rods between the same and the outer pistons is made for the obvious purpose of avoiding interference with the inner pistons and of balancing the transmitted stresses. In order to connect so large a number of connecting rods with each of the cranks, each crank pin is provided with a bushing G having flanges in which are mounted pins H equal in number to the cylinders, and to each of said pins H is connected one of the connecting rods, as clearly appears from Fig. 1.

It will be understood that in consequence of the arrangement described, the pistons in each cylinder reciprocate simultaneously, equally and oppositely to one another; and this condition is fully illustrated by Fig. 1, wherein by comparing the successive cylinders with one another, the successive stages in the operation of the pistons in each cylinder may be seen. The motor here shown is of the type operating on the two stroke cycle, and I have therefore provided inlet and exhaust ports which are controlled by the pistons in their travel, and means for furnishing air under moderate pressure for scavenging the cylinders and filling them with fresh air after each working stroke. Such air-supplying means, comprises, in the combination here shown, a rotary pump or blower of the type having substantially radial pistons or blades I , I which travel in an outer fixed cylindrical casing J with an inner cylindrical wall K which is eccentric to the outer wall and rotates about its own axis. Thus a substantially crescent shaped space is provided between the outer casing and inner cylindrical wall, into which air is drawn by the traveling piston blades from the outer atmosphere through suitably arranged ports in the wall J , and from which air is discharged, after being compressed by the blades, through outlet ports into an annular surrounding chamber or air chest L . The piston blades are carried by arms M and N which turn about a shaft S^1 in line with the main shaft S , and are driven by a pin O from the outer arm of crank D^2 . This is a familiar and well tested type of rotary blower, the principles of which are illustrated in numerous Letters Patent, wherefore illustration of it in complete detail is deemed unnecessary.

I may state, without in any wise limiting

the scope of the protection claimed herein, that the pump is preferably designed to compress to a pressure of about four pounds per square inch a quantity of air about 33% greater than that required for compression in the cylinders, and that the cylinder admission ports have a large enough area to permit such excess of air to flow through the cylinders when the ports are open. As the blower is driven synchronously with the motor, substantially the same excess of air is provided whatever the actual speed of running may be.

The air chest L is in communication with annular passages L^1 surrounding the several cylinders and from which the admission ports L^2 (Fig. 1) open into the interior of the cylinder, these ports being located where they are uncovered by the inner piston shortly before the latter reaches the dead point at the end of its working stroke. The exhaust ports P are located to be controlled by the outer piston and be uncovered by the latter shortly before the inlet ports L^2 are uncovered. Thus the exhausted working fluid begins to escape before fresh air is blown into the cylinder, and such air continues to be admitted as long as the admission ports remain open. As the ports are at the extreme opposite ends of the working chamber of each cylinder, the fresh air thus blown in completely drives out the exhaust gases before being compressed, wherefore the compressed gas, into which fuel is later injected, consists of pure air.

Method of firing.—Between each two successively operating cylinders there is a fuel vaporizing chamber Q , having a fuel supply connection indicated at R , and to which are connected conduits T and U leading to the combustion spaces of the adjacent cylinders respectively, into which they open approximately midway between the two pistons in each. These conduits contain plug cocks V and W , which are adapted to be automatically opened and closed at the required times by any suitable mechanism driven synchronously with the crank shaft. For the purpose of illustrating an operating mechanism for this purpose, I have shown diagrammatically valve-operating means comprising a plunger rod X adapted to move endwise radially of the shaft and connected by links Y and Z with arms V^1 and W^1 , respectively, of which the former is connected to the valve cock V and the latter to the valve cock W . All of the plunger rods X which operate the several sets of valves are arranged in the same plane with one of the arms of crank D^2 , and on such arm is a cam 20 arranged to engage said rods in turn and move them outwardly, it being understood that the rods are or may be constantly acted upon by springs or other

yieldable pressure-applying means tending to move them inwardly toward the shaft. The normal position of the valves is the closed position, the plunger rod being then displaced toward the shaft. The action and effect of the cam is to displace the valve-operating rod outwardly and open the valves controlled thereby. This effect is accomplished in turn for each successive valve-operating mechanism.

Liquid fuel, which may be crude oil, fuel oil, kerosene, or other combustible liquid, is admitted to each of the vaporizing chambers Q at some time when the valves controlling the conduits to and from the chamber are closed, preferably just after the closing of such valves. Any sort of pump or other injecting means adapted to deliver regulated quantities of fuel into the chambers, overcoming the pneumatic pressure therein, may be used in conjunction with the motor. As I do not claim any specific pump or injecting means as a part of the invention for which I seek protection herein, I have not shown such means, but have shown inlet connections R to represent and typify any practicable means which may be employed for supplying or admitting fuel to the vaporizing chambers Q. Such fuel is vaporized more or less completely by the heat of the gas which is trapped in the chamber or chambers.

Shortly before the crank reaches the dead center with any cylinder in the compression stroke, the valves in the conduits between that cylinder and the one in which the working stroke next precedes in the cycle of the motor begin to open, and they remain open until the crank has somewhat passed the dead center. For convenience of further description, I will call the associated cylinders just referred to the "preceding cylinder" and the "following cylinder," in the order of their action in the cycle of the motor. When opening of the valves occurs, the pistons in the preceding cylinder have passed the dead center and commenced their working stroke, and that cylinder contains burning gas at a high pressure, while the following cylinder contains pure air at a somewhat lower pressure. The burning gas is caused by this pressure difference to flow at a high rate of speed through the conduits and vaporizing chamber and to carry with it the fuel previously entrapped in such chamber. Preferably the vaporizing chamber is circular in outline with the conduits T and U tangential thereto, wherefore the rapidly flowing gas is caused to whirl about in the vaporizing chamber and to displace all of the fuel therein. Preferably also the opening of the conduit into the following cylinder is shaped to cause spreading of the inflowing gas and fuel vapor over as much of the clearance space as possible. Es-

entially the parts hereinbefore designated as conduits T and U and a chamber Q constitute one continuous conduit having a fuel inlet and a fuel vaporizing space, and containing valves at opposite sides of such inlet and space; wherefore the term "conduit" as used in certain of the following claims is defined as including such parts, as well as equivalent means having like functions and result but possibly differing in structure or form. But my claim to protection is not, however, entirely limited to the combination in which fuel is injected into such conduits rather than directly into the several cylinders by other means, wherefore those claims which do not in express terms call for the admission or presence of fuel in the conduits are to be construed as protecting my invention in means for ignition or means for temporarily equalizing pressures to a greater or less extent between two cylinders, in any motor whatever the provisions for supplying fuel to the cylinders thereof may be.

Reference is directed to Fig. 3, 4, and 5 for illustration of the timing of the fuel valves with respect to the movements of the motor pistons. Two of the adjacent cylinders as C¹ and C² are shown in these figures for illustration, and of these C¹ is the cylinder distinguished by the term "preceding" cylinder and C² is the "following" cylinder. The valves begin to open when the crank has passed the dead point with cylinder C¹ and is about 15 degrees before the dead point with cylinder C² (Fig. 3), and the opening is complete when it is nearly at the dead point or preferably within 5 degrees of that point (Fig. 4). When the crank has passed about 5 degrees beyond this dead point, the valves are again closed (Fig. 5.)

It is not absolutely necessary to open the valves as much as 15 degrees before the dead center in the following cylinder since a pressure difference of no more than 25 pounds per square inch is enough to drive the gas from a vaporizing chamber to the next following cylinder as described, within the time of 3 degrees of the cycle of the crank at a running speed of 1800 revolutions per minute; but it is desirable to do so because then a greater quantity of gas will flow into the cylinder containing air, making a more complete mixture of fuel vapor and air. Combustion takes place almost instantaneously upon entrance of the fuel vapor into the following cylinder and, in the arrangement here shown, the pressure due to the consequent heat generation would become excessive before the piston in this cylinder has reached the end of its compression stroke, if it were not for the fact that the valves remain open until the crank has passed the dead center. But, as the combustion space in the preceding

cylinder is now increasing in volume and the pressure therein is diminishing, a back flow of gas into this cylinder takes place through the still open connection from the following cylinder, which will maintain the pressure in both cylinders at an approximately constant moderate maximum until the valves close. In one engine which I have designed according to the principles just described, the charge of air in the following cylinder is compressed to a pressure of about 350 pounds per square inch when the connection with the preceding cylinder is opened. The burning gas in the latter is at a pressure of about 500 pounds, which makes a pressure difference amply sufficient to inject fuel into the following cylinder with the desired rapidity. Thereafter during the combustion of the fuel the pressure in both cylinders is maintained at approximately 500 pounds. Although the high point of the combustion pressure is reached in the following cylinder before the dead point, no energy is lost because the pressure in this cylinder is communicated to the preceding cylinder as to which the crank has passed beyond the dead center. The figures above given are stated for the purpose of explaining the principle of the invention by specific illustration and without limiting intent or effect. After closing of the valves, expansion of the hot gases takes place in the preceding cylinder until the exhaust ports of that cylinder are opened; and commences in the following cylinder, but without going far enough to cause any material lessening of pressure, until the valves in the like connection to the cylinder next following in the cycle of the motor are opened, when the whole cycle before described at length is repeated. So each successively acting cylinder of the motor becomes in turn, first, the "following" cylinder of the foregoing definition, and then the "preceding" cylinder relatively to the one next following, throughout the whole cycle of the motor in constantly repeated rotational sequence.

50 An important advantage following from the before described method of firing is that the ignition is certain because it is effected by the direct flow of burning gas from one cylinder to the next with the vaporized fuel, into a charge of pure air which is already somewhat heated by reason of its compression. This ignition means is free from the numerous defects inherent in electrical ignition means, and is under the control of valves which prevent pre-ignition. And, since ignition is not wholly dependent upon the heat of compression, there is no danger of the fuel failing to ignite on account of loss of pressure by leakage past the pistons.

65 A further advantage results from the same

cause, namely that it is not necessary to use a highly volatile and inflammable fuel, since such comparatively inert liquid fuels as crude oil or kerosene may be as certainly ignited as the lighter hydrocarbons. Fouling of the passages by carbon deposits is prevented by high velocity flow of the gas, which keeps the passages clean by its scouring action.

The characteristics hereinbefore described adapt the motor particularly for use with flying machines because (a) the reliability of the firing means overcomes or avoids the principal causes of engine trouble for such machines; (b) the ability to burn non-volatile oil eliminates danger of tank explosions and of the machine going down in flames; (c) the motor is light in weight per unit of power and has high efficiency and therefore a large radius of action; (d) it has great altitude possibilities because it will run after getting hot with a compression of less than 200 pounds, and further because the blower supplies an excess quantity of air; (e) it contains no puppet valves, while the only valve-operating mechanism which it possesses is of a type not liable to get out of order; (f) the power generation is more efficient and more smoothly applied by reason of the communication which is opened between two cylinders at the time of ignition; (g) no carbureter is required; (h) all forces of the compression and working strokes, of inertia, and of centrifugal force are balanced, wherefore the motor runs smoothly and may be mounted on a light bed or support; (i) due to its simplicity, small frame, and short crank shaft, it can be made at low cost.

While the ignition means which I have hereinbefore particularly described is shown as applied to a two-stroke cycle motor in which the cylinders are arranged as spokes of a wheel, I do not limit my claims covering the principle of this invention to either a motor operating on this cycle or to one having necessarily that arrangement of cylinders as distinguished from one having cylinders in the same plane with, and at one side of, the shaft. The essential principle may be adapted to any plural cylinder motor having either opposed or single pistons by appropriately arranging the conduits between successively acting cylinders and providing suitable valves and operating means therefor to open the communications between such cylinders at the proper times. Hence, the term "in rotation", or any term of equivalent import used in the foregoing description and following claims with reference to the sequence of actions, does not state or imply any limitation in the arrangement of cylinders or other structural feature of the motor, but means simply that the operations of the different cylinders occur

one after the other in recurring cycles. And also, the terms "preceding" and "following" as applied to the cylinders have no limiting significance as to the mechanical arrangement or sequence, but define only the functional sequence or corresponding events of their individual cycles.

The motor may be started when cold by priming one or more of the vaporizing chambers with a volatile inflammable liquid which will ignite at the temperature to which air is raised by the compression. Ether is one such liquid suitable for this purpose. When hot, no priming is necessary.

Having now described the principles of my invention and explained an operative mode of putting them to use sufficient to enable those skilled in the art to apply and use the same, but without having attempted to explain all the possible forms thereof or all possible modes of their use, or to show certain of the purely mechanical adjuncts which, while in some form necessary to the mechanical functioning of the motor, are not yet essential to an explanation of the invention, I declare that

What I claim and desire to secure by Letters Patent is:

1. In an internal combustion motor, the combination with two cylinders operating in succession, of means for transferring burning gas from one cylinder, and unburned fuel at the same time, into a compressed body of air in the other of said cylinders.

2. In an internal combustion plural cylinder motor, a fuel chamber, and means for simultaneously conducting burning gas from a preceding cylinder and fuel from said fuel chamber to a following cylinder of the motor, said following cylinder meanwhile containing a charge of air under pressure and being in or near condition to commence a working stroke.

3. A plural cylinder internal combustion motor having a crank and pistons in the several cylinders connected to said crank, conduits between the cylinders which successively follow one another in the cycle of the motor, a fuel chamber in connection with each of said conduits, valves interposed in each conduit between the fuel chamber and the cylinders at each side thereof, and means for opening said valves in the conduit from each following cylinder to the preceding cylinder when the crank is approaching in the compression stroke the dead point with the following cylinder.

4. An internal combustion motor comprising a series of cylinders, a fuel chamber between two cylinders of the series having a fuel inlet and adapted to confine a quantity of gas, conduits from said chamber to each of said cylinders, through which gas may flow to and from the chamber, a valve in

each of said conduits, and means for opening said valves at such times as to cause flow of burning gas through said conduits and chamber, and propulsion thereby of the fuel in the chamber, from one into the other of said cylinders.

5. An internal combustion motor comprising a series of cylinders arranged to operate in rotation, and means for causing transfer of burning gas from each precedently operating cylinder, and simultaneously causing injection of fuel, into the next succeeding operating cylinder in turn.

6. An internal combustion motor comprising a series of pistons arranged to operate in rotation, and means for causing transfer of burning gas from each precedently operating cylinder, with simultaneous injection of fuel, into the next succeeding operating cylinder in turn at times following the commencement of the working stroke in said precedently operating cylinder and at or immediately prior to the maximum compression in said succeeding operating cylinder, respectively.

7. An internal combustion motor comprising a series of cylinders arranged to operate successively in rotation, conduits between the successively acting cylinders, valves in said conduits, and means for operating the valves in said conduits successively at such times that when combustion occurs in each cylinder a communicating passage for the transmission of pressure is open therefrom to the next preceding cylinder.

8. An internal combustion motor comprising a crank shaft, a series of cylinders having pistons and connections arranged to apply power impulses successively in rotation to said shaft, means for admitting air to said cylinders when the combustion spaces therein are enlarged by displacement of said pistons, conduits extending from the combustion chamber of each cylinder to that of the next in the order of operation, fuel chambers opening into each of said conduits, valves in each conduit between the fuel chamber and each of the cylinders with which the conduit is connected, means for admitting fuel to said chambers when the valves are closed, and means for opening the valves in the several conduits successively when the piston in one of the cylinders into which the conduit opens is in course of making its working stroke and the piston in the other cylinder connected to the same conduit is close to the dead point in its compression stroke; whereby injection and ignition of the fuel in the successively acting cylinders is effected by flow of burning gas from the respectively precedently operating cylinders.

9. In an internal combustion motor of the character described the combination with two successively operating cylinders and a conduit opening into the combustion cham-

bers of both cylinders and connecting one with the other, a fuel chamber interposed in said conduit, being formed and arranged to cause gas flowing through the conduit to enter and scour the interior of said chamber in its passage, means for admitting liquid fuel into said chamber, valves interposed in said conduit between the fuel chamber and each of said cylinders, and an automatic valve-operating means arranged to cause opening and closing of said valves at given times in the cycle of the motor.

10. In an internal combustion motor the combination with two successively acting cylinders of a cylindrical fuel chamber intermediate said cylinders, means for admitting liquid fuel into said chamber, conduits leading from the combustion spaces of both cylinders to said fuel chamber, the conduit from the preceding cylinder entering the chamber tangentially, whereby gas flowing through that conduit toward the chamber is caused to enter and scour the chamber in passing to the other conduit, and a valve in each conduit between said chamber and the cylinder into which the conduit opens.

11. In an internal combustion motor the combination with two successively acting cylinders of a cylindrical fuel chamber intermediate said cylinders, means for admitting liquid fuel into said chamber, conduits leading from the combustion spaces of both cylinders to said fuel chamber and entering the latter tangentially, whereby gas flowing through either of said conduits toward the chamber is caused to enter and scour the chamber in passing to the other conduit, and a valve in each conduit between said chamber and the cylinder into which the conduit opens.

12. An internal combustion motor comprising a crank shaft, a series of cylinders arranged radially of said shaft and spaced equiangularly about a common point, a crank on said shaft, pistons in the several cylinders all connected to said crank, conduits between the combustion spaces of the successive cylinders in said series, means for admitting fuel into said conduits, valves in the several conduits, and means for operating said valves in said conduits to open the latter successively after the commencement of the working stroke in each preceding cylinder and immediately prior to commencement of such stroke in the next following cylinder, whereby fuel is injected into and ignited in each cylinder by the pressure and flow of the burning gas in each respectively preceding cylinder.

13. An internal combustion motor comprising a shaft, a series of cylinders having pistons connected to said shaft and arranged to operate successively in rotation, conduits connecting the combustion space of each cylinder with that of the cylinder immedi-

ately preceding in the cycle of the motor, said motor having provisions for separately admitting air and fuel, and valve means arranged and operable to open such conduits in succession between each cylinder and the preceding cylinder at the time of ignition of the charge in the former cylinder whereby the pressures therein and in the preceding cylinder are to a certain extent equalized.

14. An internal combustion motor comprising a crank shaft having opposed cranks, a series of cylinders surrounding said shaft in substantially radial arrangement, opposed pistons reciprocally mounted in each of said cylinders, connecting rods joining the inner pistons of all the cylinders to one of said cranks and other connecting rods joining the outer pistons of all the cylinders to the other of said cranks, means for admitting air to the several cylinders when the pistons therein are widely separated, and means for injecting fuel and transferring burning gas from a preceding cylinder, into each cylinder when the pistons therein are near together in compression.

15. An internal combustion motor comprising a crank shaft having opposed cranks, a series of cylinders in radial arrangement with substantially equiangular spacing around the axis of said shaft, and opposed inner and outer pistons in said cylinders, the inner pistons of all the cylinders being connected to one crank and the outer pistons of all the cylinders being connected to the other of said cranks.

16. An internal combustion motor comprising a crank shaft having opposed cranks, a series of cylinders in radial arrangement with substantially equiangular spacing around the axis of said shaft, opposed inner and outer pistons in said cylinders, the inner pistons of all the cylinders being connected to one crank and the outer pistons of all the cylinders being connected to the other of said cranks, an annular air trunk communicating with all of the cylinders through ports which are arranged to be uncovered in each when one of the pistons therein is near the end of its working stroke, and an air pump or blower driven by said shaft arranged to supply air under pressure to said air trunk.

17. An internal combustion motor comprising a shaft having opposed cranks, cylinders radially arranged and substantially equiangularly spaced around the axis of said shaft, opposed reciprocating inner and outer pistons in each cylinder, the inner pistons of all the cylinders being connected to one of said cranks and the outer pistons of all the cylinders connected to the other of said cranks, ports near the opposite ends of each cylinder controlled by the movement of the inner and outer pistons respectively and opened and closed thereby when the

pistons are approaching and receding from their extreme displaced positions, the port at one end being an admission port and that at the other end an exhaust port, means for supplying fresh air to the admission ports of the several cylinders, and means for separately admitting fuel to each cylinder at an intermediate point when the pistons therein are relatively near together.

10 18. An internal combustion motor comprising a shaft having opposed cranks, cylinders radially arranged and substantially equiangularly spaced around the axis of said shaft, opposed reciprocating inner
15 and outer pistons in each cylinder, the inner pistons of all the cylinders being connected to one of said cranks and the outer pistons of all the cylinders connected to the other of said cranks, ports near the opposite ends of
20 each cylinder controlled by the movement of the inner and outer pistons respectively and opened and closed thereby when the pistons are approaching and receding from their extreme displaced positions, the port at one end
25 being an admission port and that at the other end an exhaust port, means for supplying fresh air to the admission ports of the several cylinders, a fuel inlet to each cylinder at a point substantially midway between the op-
30 posed pistons therein, and means for causing injection of fuel through said inlet when the pistons are at or near their point of closest approach to one another.

35 19. An internal combustion motor comprising a shaft having opposed cranks, cylinders radially arranged and substantially equiangularly spaced around the axis of said shaft, opposed reciprocating inner and outer
40 pistons in each cylinder, the inner pistons of all the cylinders being connected to one of said cranks and the outer pistons of all the cylinders connected to the other of said cranks, ports near the opposite ends of each
45 cylinder controlled by the movement of the inner and outer pistons respectively and opened and closed thereby when the pistons are approaching and receding from their extreme displaced positions, the port at one
50 end being an admission port and that at the other end an exhaust port, means for supplying fresh air to the admission ports of the several cylinders, conduits each opening

into two cylinders substantially midway between the pistons therein, means for delivering fuel to said conduit, and means for causing burning gas from each preceding cylinder to flow into the conduit leading to the next following cylinder when the pistons in the latter are at or near their point of closest approach to one another.

60 20. An internal combustion motor comprising a crank shaft having opposed cranks, a series of cylinders radially arranged and substantially equiangularly spaced around said shaft, inner and outer opposed reciprocating pistons in each cylinder, the inner
65 pistons of all the cylinders being connected with one crank and the outer pistons of all the cylinders being connected to the other of said cranks, conduits between the successive
70 pistons of the series, means for admitting fuel to said conduits, valves in said conduits, and means for operating the valves in the several conduits in turn to open the same
75 when the pistons in one of the cylinders with which the respective conduit connects are in course of their working stroke and those in the other cylinder with which the same conduit connects are at or near the end of the
80 compression stroke.

21. An internal combustion motor comprising a shaft, a crank on said shaft, two cranks on the same shaft opposed to and arranged on respectively opposite sides of the first named crank, radially arranged and
85 equiangularly spaced cylinders surrounding said shaft, inner and outer opposed reciprocating pistons in each of the cylinders, connecting rods from each of the inner pistons to the first named of said cranks, connecting rods from all of the outer pistons to
90 each of the two opposed cranks, admission and exhaust ports in the cylinders controlled by the inner and outer pistons, an air pump or blower driven by said shaft, connections
95 for delivering air from said pump to the admission ports of the several cylinders when the latter are opened, and means for admitting fuel to each cylinder and igniting the fuel when the pistons are at or near the end
110 of their compression stroke.

In testimony whereof I have affixed my signature.

EUGENE A. FORD.