

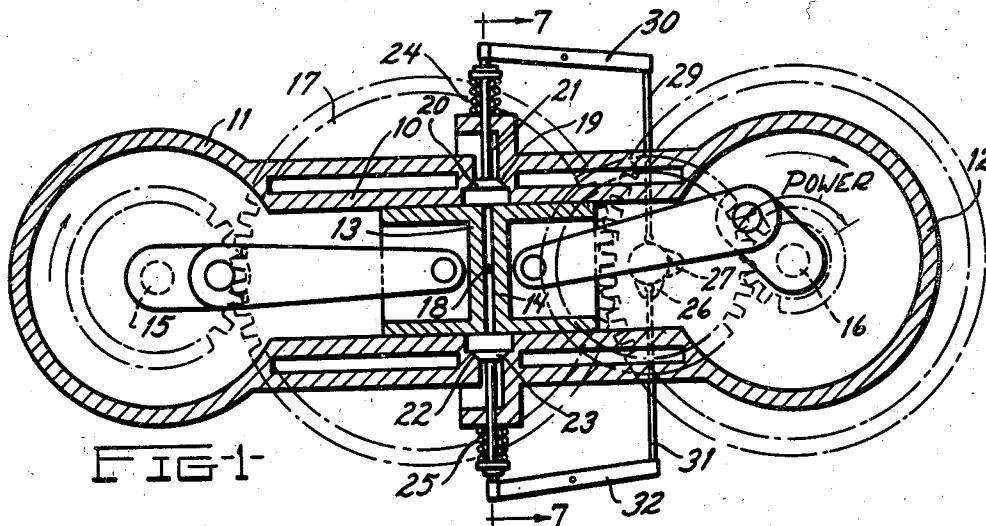
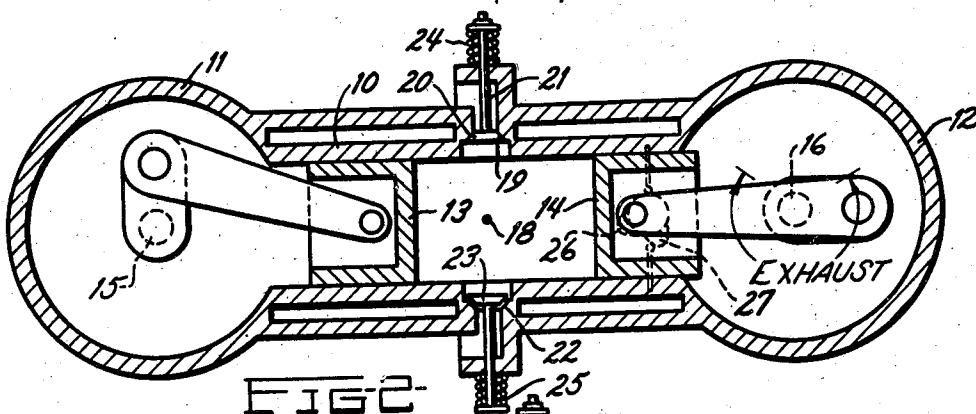
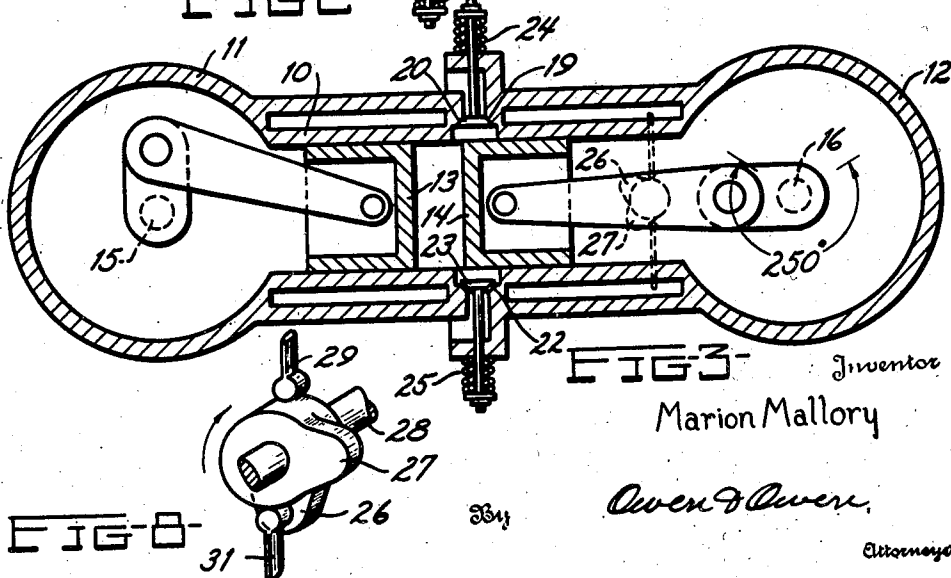
Jan. 17, 1950

M. MALLORY
INTERNAL-COMBUSTION ENGINE

2,494,890

Filed April 18, 1946

8 Sheets-Sheet 1



Inventor
Marion Mallory

Owen & Owen,

Attorneys.

Jan. 17, 1950

M. MALLORY
INTERNAL-COMBUSTION ENGINE

2,494,890

Filed April 18, 1946

8 Sheets-Sheet 2

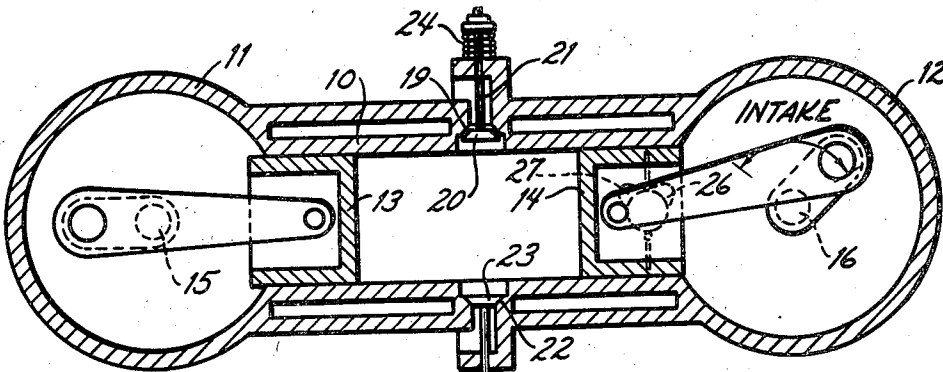


FIG-4

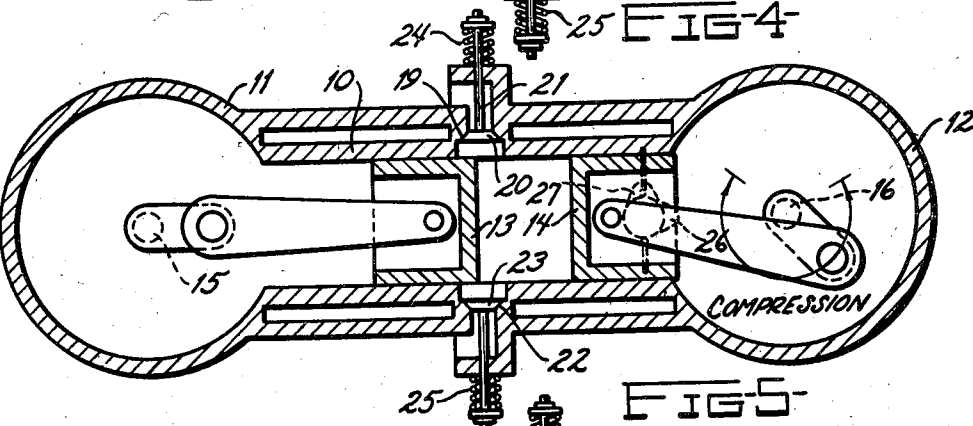


FIG-5

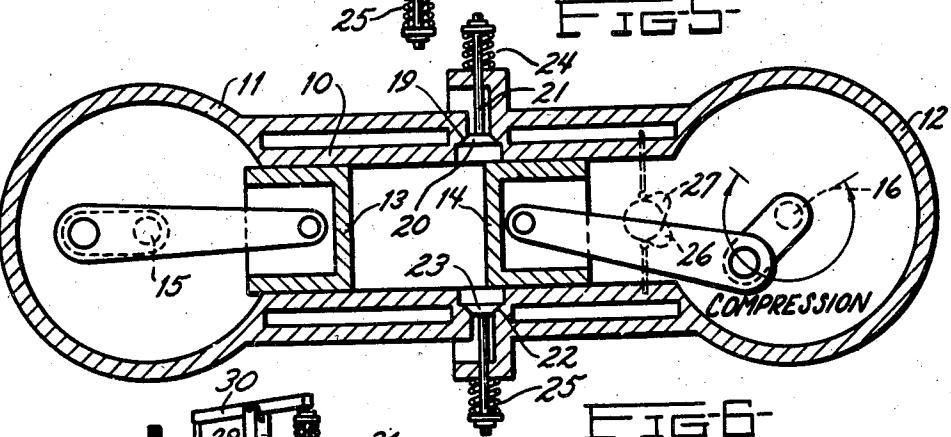


FIG-6

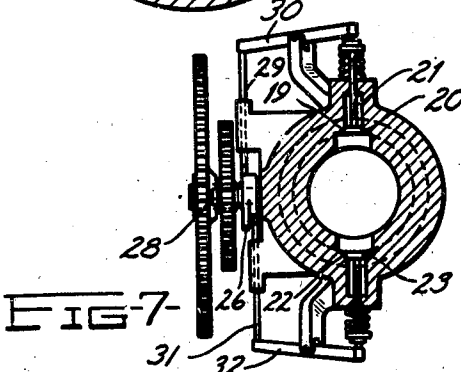


FIG-7

Inventor
Marion Mallory
Owen & Owen,
Attorneys

Jan. 17, 1950

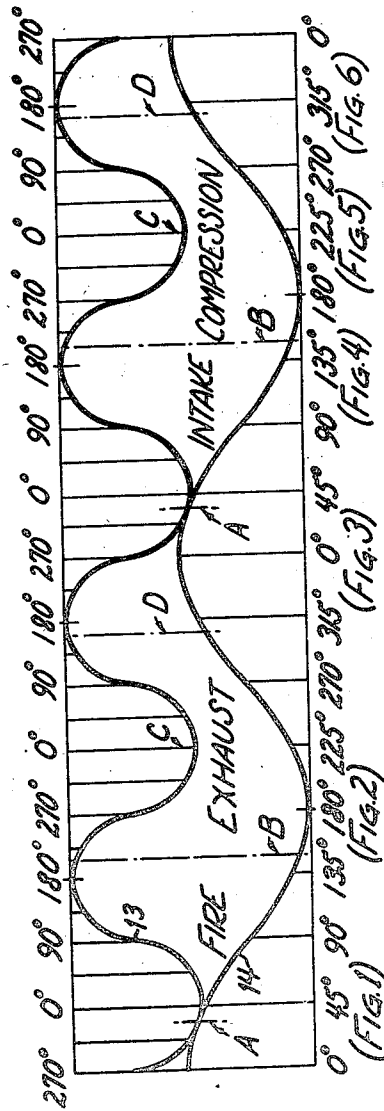
M. MALLORY
INTERNAL-COMBUSTION ENGINE

2,494,890

Filed April 18, 1946

8 Sheets-Sheet 3

FAST PISTON



SLOW PISTON

FIG-9-

Inventor

Marion Mallory

Robert D. Owen

Attorney

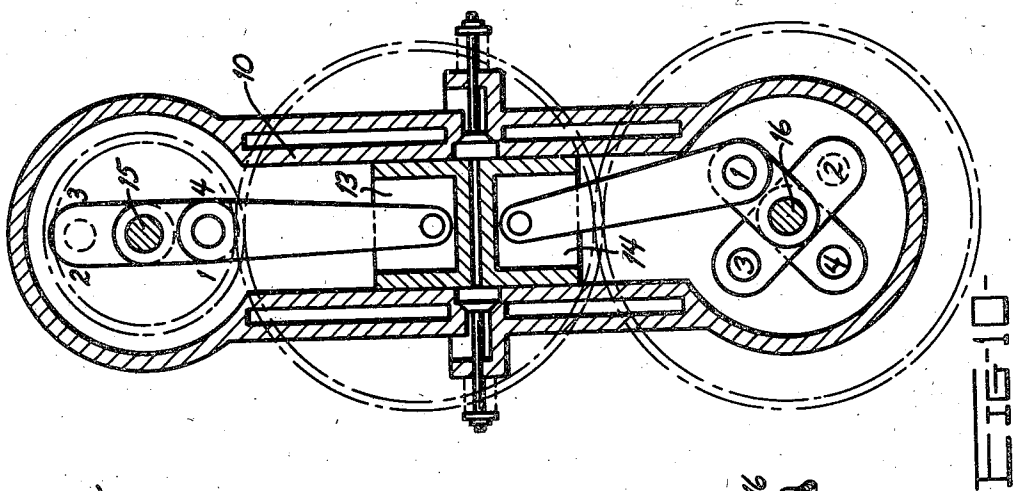
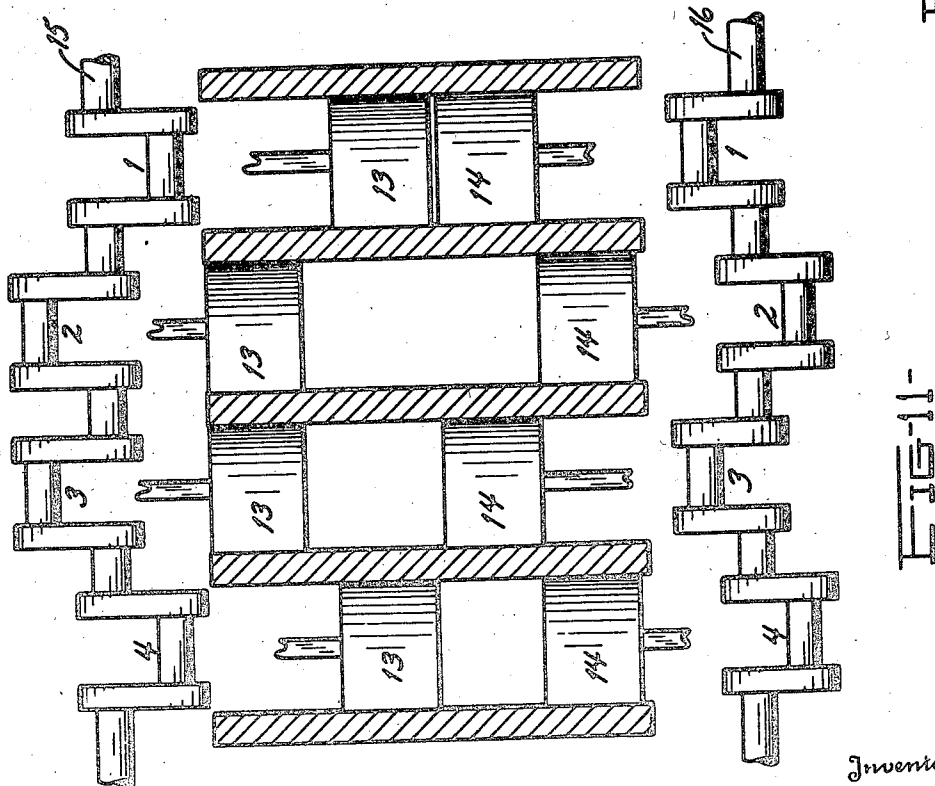
Jan. 17, 1950

M. MALLORY
INTERNAL-COMBUSTION ENGINE

2,494,890

Filed April 18, 1946

8 Sheets-Sheet 4



Inventor

Marion Mallory

By

Owen & Owen.

Attorneys

Jan. 17, 1950

M. MALLORY
INTERNAL-COMBUSTION ENGINE

2,494,890

Filed April 18, 1946

8 Sheets-Sheet 5

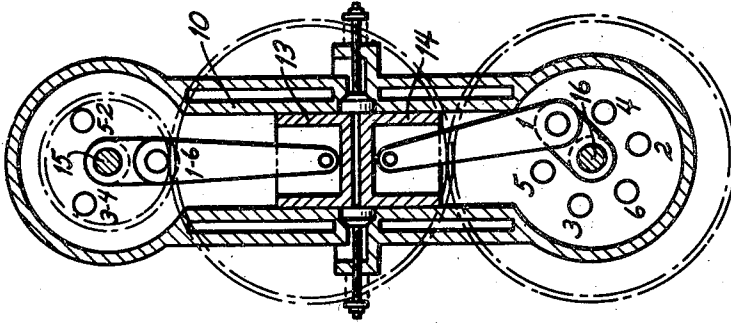


FIG. 12-

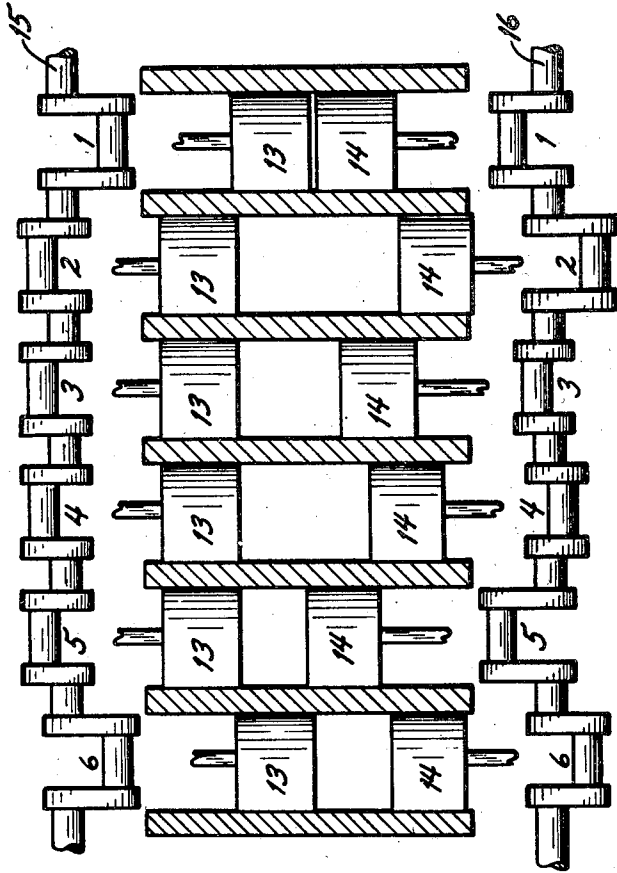


FIG. 13-

Inventor

Marion Mallory

By

Owen & Owen.

Attorneys.

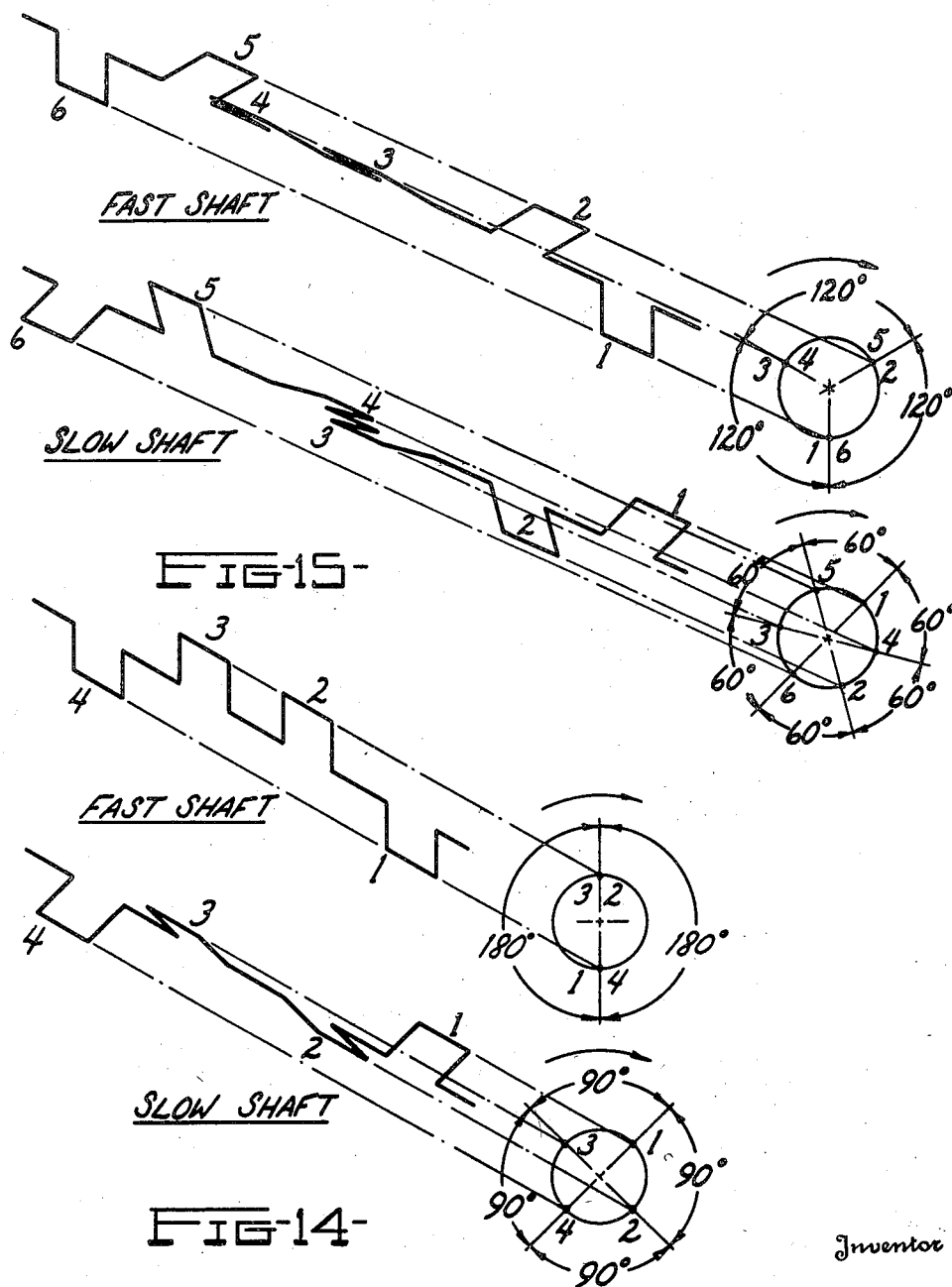
Jan. 17, 1950

M. MALLORY
INTERNAL-COMBUSTION ENGINE

2,494,890

Filed April 18, 1946

8 Sheets-Sheet 6



Inventor

Marion Mallory

Querk & Querk,

Attorneys.

Jan. 17, 1950

M. MALLORY
INTERNAL-COMBUSTION ENGINE

2,494,890

Filed April 18, 1946

8 Sheets-Sheet 7

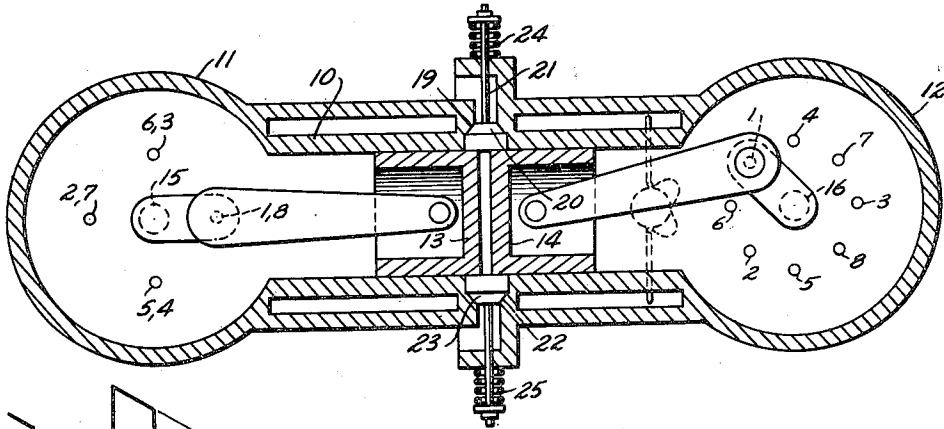


Fig. 16

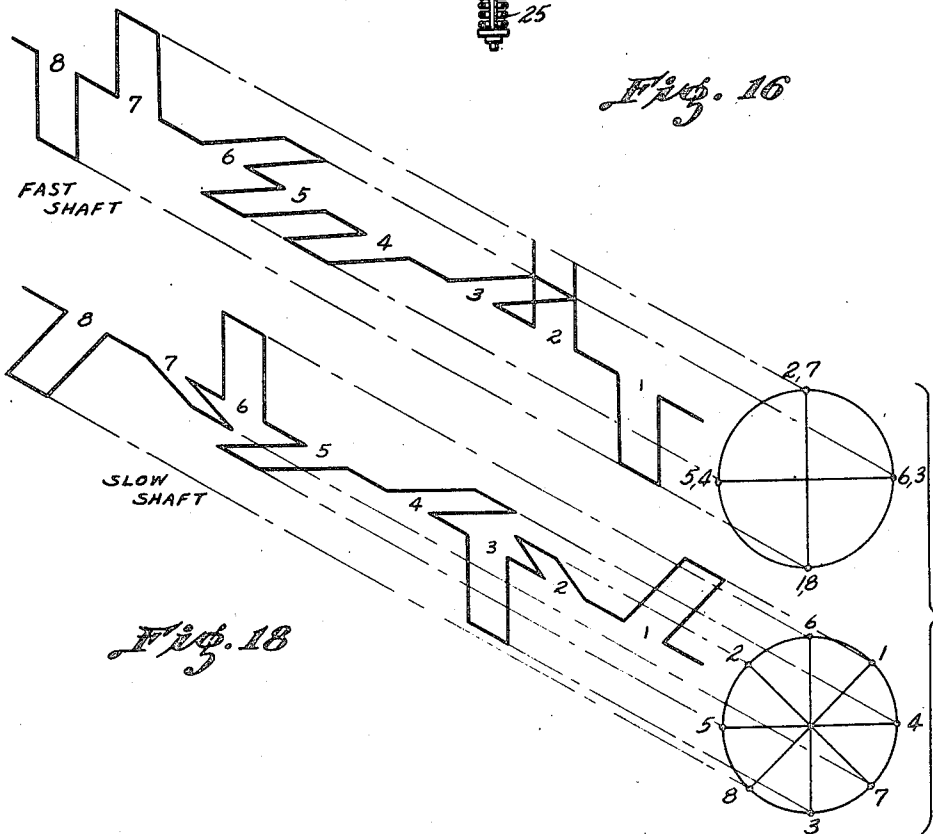


Fig. 18

Inventor:
MARION MALLORY
By Owen D. Owen,
Attorneys

Jan. 17, 1950

M. MALLORY

2,494,890

INTERNAL-COMBUSTION ENGINE

Filed April 18, 1946

8 Sheets-Sheet 8

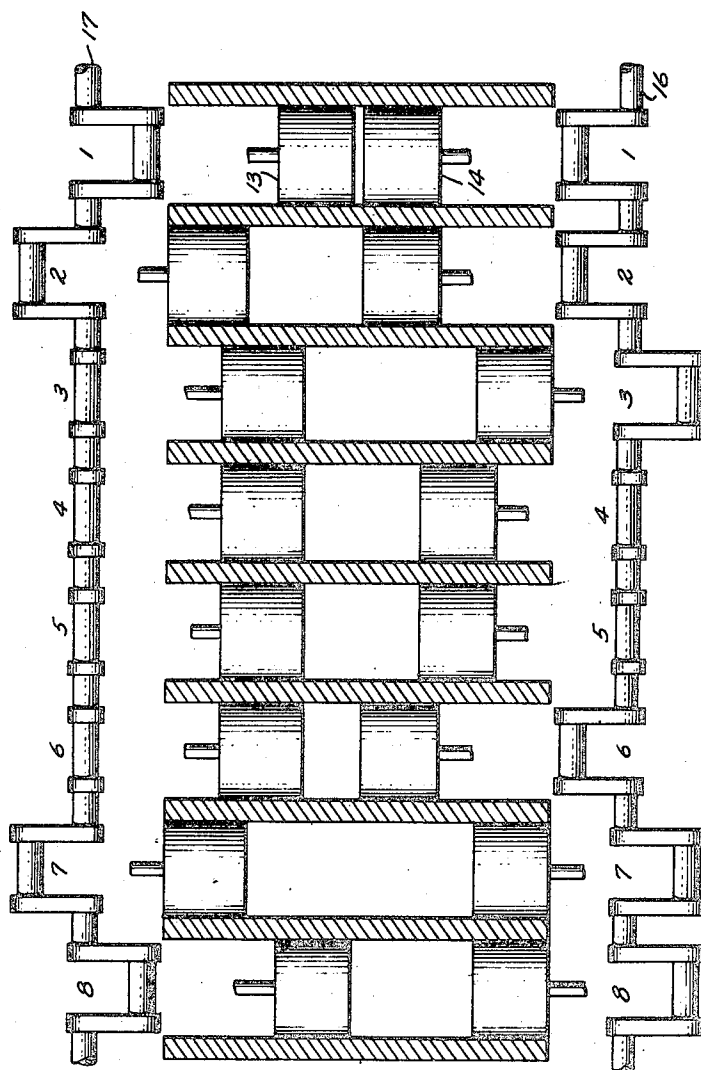


Fig. 18

Inventor:
MARION MALLORY

By *Owen J. Davenport*
Attorneys

UNITED STATES PATENT OFFICE

2,494,890

INTERNAL-COMBUSTION ENGINE

Marion Mallory, Detroit, Mich., assignor to The Mallory Research Company, Detroit, Mich., a corporation of Michigan

Application April 18, 1946, Serial No. 663,039

27 Claims. (Cl. 123—51)

1

This invention relates to internal combustion engines, and particularly to those of the type employing opposing pistons operating in a common cycle and between which the compression and combustion of the charges take place, and which pistons are connected to respective crankshafts that turn at different predetermined proportional speeds, one piston preferably completing two cycles while the other is completing one cycle.

An object of the invention is the provision of an engine of this character which is devoid of piston-controlled intake and exhaust ports and operates in a manner similar to a four-cycle engine, and wherein the exhaust valve opens late, thus providing for the maximum utilization of the explosive charges during the power strokes.

Another object of the invention is to time the relative movements of the pistons and the firing and the exhaust and inlet valves so that the crank of at least one of the pistons will be at an advantageous angle when the charge is fired, so that the firing and the start of the intake occur when the pistons are nearest together, and so that exhaust and compression begin with the pistons farthest apart, so that full advantage of the entire stroke is utilized for each purpose.

Another object of the invention is the provision of a prolonged exhaust period after each explosion for the spent gases, whereby free breathing and exhausting of the engine are permitted and a resulting increase in the power output obtained. In the operation of the ordinary engine, considerable power is required to force out the exhaust gases, and in order to overcome this objection it has been necessary to provide an early opening of the exhaust valve. In some present-day four-cycle engines, it is necessary to open the exhaust valve as early as 60° before the end of the firing stroke in order for a complete exhaust to occur by the end of the succeeding exhaust stroke. This early release of the exhaust materially reduces the power efficiency of the engine by releasing to the atmosphere power which might be utilized to advantage in turning the crank.

Another object of the invention is the provision of an engine of this character wherein an explosion occurs every second revolution of the slow traveling crankshaft and every fourth revolution of the fast traveling crankshaft, thereby materially enhancing the power and economical running efficiency of the ordinary four-cycle engine and also engines of the same general opposing piston type heretofore used.

Another object of the invention is to effect such a relative movement of the two pistons during a compression of a charge that a churning or agitating condition is imparted to the combined atomized fuel and air charge tending to prevent

2

condensation and separation of the mixture, which is found to occur if the charge is not kept in a turbulent or moving state.

Another object of the invention is to provide such a relative movement of the pistons during an exhaust stroke of the slow traveling piston that one piston assists the other in effecting a complete discharge of the exhaust gases from the cylinder without creating any undue back pressure on the engine either during the exhaust stroke or at the beginning of the intake stroke.

Another object of the present invention is the provision of an arrangement and operation of parts in an engine of the character described, which permits an opening of the intake valve after a closing of the exhaust valve, thereby preventing the objectionable momentary backflow of exhaust gases through the intake port into the manifold that takes place in the ordinary four-cycle engine and which some times causes spit-back through the carburetor if there is still some burning of the exhaust at the time the intake valve is opened.

Other objects and advantages of the invention will be apparent from the following detailed description, and from the accompanying drawings, illustrating a preferred embodiment of the invention, and in which—

Fig. 1 is a diagrammatical view of an engine in central longitudinal section embodying the invention, with the moving parts approximately in firing position and the intake and exhaust valves closed; Fig. 2 is a similar section showing the position of the moving parts shortly after the end of the power stroke, with the crank of the slow moving piston at outer or bottom dead center and the exhaust valve beginning to open; Fig. 3 is a similar view, with parts omitted, showing the slow piston approaching the end of its exhaust stroke, at approximately which point the exhaust valve closes; Fig. 4 is a view showing the position of the parts with the slow moving piston near the end of its intake or suction stroke, with the exhaust valve closed and the intake valve nearly closed; Fig. 5 is a similar view with the slow moving piston moved a short distance on its compression stroke and the crank of the fast moving piston in top dead center position, with both intake and exhaust valves closed; Fig. 6 is a similar view with the slow moving piston at about the middle of its compression stroke and the crank of the fast moving piston at bottom dead center; Fig. 7 is a diagrammatical cross-sectional view of the engine illustrating the valve operating means; Fig. 8 is a perspective detail of the valve control cam and operating parts; Fig. 9 is a diagrammatic view showing the operation of a single cylinder of the engine, and indicating the stages of the cycle illustrated in Figs. 1 to 6; Fig. 10 is a section of a four-cylinder engine embody-

ing the invention showing the relative positions of the cranks for the two shafts; Fig. 11 is a projected diagrammatical view thereof showing the different cylinders and the relative positions of their pistons; Fig. 12 is a section of a six-cylinder engine embodying the invention showing the relative positions of the cranks for the two shafts; Fig. 13 is a projected diagrammatical view thereof showing the different cylinders and the relative positions of their pistons; Fig. 14 is a diagrammatical view of the fast and slow crankshafts of a four-cylinder engine illustrating the firing order with respect to each shaft, and Fig. 15 is a diagrammatical view of the fast and slow crankshafts of a six-cylinder engine illustrating the firing order with respect to each shaft. Figure 16 is a section of an 8 cylinder engine embodying the invention showing the relative positions of the cranks for 2 shafts; Figure 17 is a projected diagrammatical view thereof showing the different cylinders and the relative positions of their pistons; and Figure 18 is a diagrammatical view of the fast and slow crank shafts of an 8 cylinder engine illustrating the firing order with respect to each shaft.

Referring to the drawings, 10 designates an engine cylinder the ends of which open into respective crank cases 11 and 12. Pistons 13 and 14 of the same diameter operate in opposite ends of the cylinder and are connected to respective crankshafts 15 and 16, the former in the case 11 and the latter in the case 12. The crankshafts are connected in any suitable manner as by a gear train 17 (Fig. 1) to have a turning ratio of two-to-one, so that the shaft 15 makes two complete revolutions to one of the shaft 16. The shafts are shown so arranged that when piston 13 is at top dead center, as shown in Fig. 1, piston 14 is about 45° past dead center. 18 indicates a spark plug for firing a charge.

The cylinder has a centrally located intake port 19 controlled by an inwardly opening valve 20 and receives its charges through a passage 21 from a connected carburetor (not shown) the same as in any ordinary engine. The cylinder is also provided with a centrally located exhaust port 22 shown, in the present instance, as in a position diametrically opposite the intake port, and as controlled by an inwardly opening valve 23.

The valves 19 and 22 are normally closed, as by respective springs 24 and 25 acting on their stems, and are opened by the action of respective cams 26 and 27 on a shaft 28 that is geared to turn once every two revolutions of the shaft 16, or in other words once each complete cycle of operations of the engine. In the present instance, the cam 26 is connected by a tappet rod 29 and rocker member 30 to the stem of the intake valve 19, while the cam 27 is connected by a tappet rod 31 and rocker member 32 to the stem of the exhaust valve 22.

The operation of the engine thus far described will be given in detail in connection with Fig. 9, which is a diagrammatic showing of the operation of the two pistons 13 and 14. As indicated in Fig. 9, each piston follows approximately a sinusoidal curve. In the actual apparatus the pistons do not follow such a curve exactly, because of the change of angle of the connecting rod, but this variation will depend upon the relative length of crank and connecting rod and may be calculated in actual production of the apparatus for the particular proportions to be used. For simplicity in the diagram, the regular sinusoidal curves are employed.

As indicated on the diagram, Fig. 9, the piston 14 is advanced about 45° from dead center when the piston 13 reaches dead center in their respective inner positions. It will be noted that as piston 13 approaches dead center position in which it is shown in Fig. 1, there is a point where the pistons approach each other most nearly. This point on the diagram is indicated by line A. It will be seen that at this point the paths of the two pistons are parallel and that they move nearly parallel for an appreciable distance. This means that the two pistons are moving in the same direction and for some little time at nearly the same speed so that the space between them remains nearly constant for an appreciable length of travel. It is during this time that the charge is fired in the manner usual in four-cycle engines by means of a spark plug, not shown. It will be noted (Fig. 1) that the connecting rod and crank of piston 14 are at such an angle as to take advantage of the power exerted by the fired charge immediately upon firing. At first the piston 13 may move slightly against the pressure of the charge, but it is so near dead center that its movement is relatively slight, and the expansion of the chamber begins at once because of the relative separation of the two pistons.

The power stroke continues as long as the pistons are separating. Since piston 14 continues to move outwardly after piston 13 has reached its outer dead center, the expansion of the chamber between the two pistons continues until the return movement of the piston 13 acquires a speed equalling that of the piston 14, which is slowing down as it approaches its dead center at the same time that piston 13 is speeding up at its leaves its dead center. The greatest distance between the pistons, and consequently the largest capacity of the firing chamber, is reached when the directions of the two pistons, as indicated on the diagram at line B, are parallel. It will be seen that this position is reached somewhat before the position indicated in Fig. 2, and somewhat after the position indicated in Fig. 4.

The exhaust need not be opened until about the time this line B on the diagram is reached. The opening of the exhaust valve may be slightly before or after this exact point, but advantageously may be very close to this point so as to take full advantage of the entire working stroke and also give as long a time for exhaust as can be readily secured after the full working stroke has been completed.

The exhaust valve remains open while shaft 15 makes one complete revolution and shaft 16 makes one-half turn from the position shown in Fig. 2 to that shown in Fig. 3. As explained above, the exhaust opens before the position in Fig. 2 is reached and continues after the position in Fig. 3 is reached until the pistons return once more to the position in which firing took place, as indicated by the line A near the middle of Fig. 9. At this point the exhaust valve is closed and the intake valve is opened. The intake valve remains open during the movement of the pistons through the position shown in Fig. 4 and slightly beyond that position to line B on the diagram, where the parts occupy the same position as at the end of the power stroke. Thereupon the intake valve is closed and the compression begins. Fig. 5 indicates a position where compression has begun. As will be noted from the diagram, the movements of the piston are such that when piston 13 is in its inner position, as shown in Fig. 5, the pistons are still approaching each other,

continuing to approach until their movements are equal and in the same direction as indicated at line C on Fig. 5. From this point on piston 13 recedes more rapidly than piston 14 moves inwardly, so that the space between them is temporarily expanded. This expansion continues until the outward movement of piston 13 is nearly completed so that its outward movement slows down to equal the inward movement of piston 14, as indicated at line D on Fig. 9. Thereafter the pistons approach each other and complete the compression until they once more assume their positions at line A where the firing takes place.

It will be seen that the above described cycle makes possible the utilization of the working stroke with plenty of time for complete discharge of the exhaust gases, and that after the new charge has been received, it is pumped back and forth by the relative movement of the pistons and there is a churning action given it by first a partial compression and then a partial expansion before the final compression takes place. This assists in keeping the fuel thoroughly dispersed throughout the gaseous charge and facilitates combustion.

Since the firing and each of the valve operations occurs while the pistons are moving in the same direction at substantially the same speed, the exact timing may be varied somewhat, and the exact dimensions of cranks and connecting rods introduce other variations, but the operation substantially as indicated on the diagram is that preferred. It will be seen that the firing stroke and the intake stroke are each substantially 112.5° of the slow moving piston, while the exhaust and the compression each covers about 247.5° travel of the slow piston crank.

In the construction illustrated, the throw of the two cranks is the same. By examination of Fig. 9 it may be noted that making the throw of the fast turning crank shorter would reduce the movement of piston 13 and so would make its travel equal that of piston 14 earlier at the firing point and later at the beginning of the exhaust, making the firing stroke longer in proportion to the exhaust. Lengthening the throw of the fast turning crank has the opposite effect, making the firing stroke approach nearer to 90° for the slow moving crank or 180° for the fast moving crank.

Also, it will be seen that advancing the lead of piston 14 over piston 13 will bring piston 13 lower and to the right at the firing point and at point C, while reducing the lead of piston 14 below 45° has the opposite effect. Thus not only the angle of the crank of piston 14, but also the distance of the pistons apart at point C, and therefore the churning action, may be varied by changing the lead of piston 14 over piston 13. When operating the engine as a four-cycle engine with respect to the slow moving piston, it is preferable to have but one point where the pistons are nearest together and about one point where they are widest apart during one revolution of the slow shaft. If there was a lead of 90° of the slow shaft over the fast shaft at the firing point, there would be another point when the fast shaft had made one complete revolution, when the pistons would be as near together. If the two pistons reached inner dead center at the same time, there would be two times during each revolution of the slow shaft when the pistons were widest apart. Therefore, while the lead may be varied from the 45° shown, it should be substantial, and should be less than 90°.

Therefore, while equal throws of the two crank-

shafts and a 45° lead of piston 14 over piston 13 are illustrated, the invention covers some variation therefrom. It is clear that these operations result in improved breathing and exhausting conditions and freer and more efficient running of the engine than is possible with the ordinary type of four-cycle engine.

While, for the purpose of illustration of the invention, only a single cylinder is shown, it will, of course, be understood that any convenient number of cylinders may be used together in a single engine, the same as in the ordinary four-cycle engine, with the slow traveling pistons all connected to one crankshaft and the fast traveling pistons all connected to the other crankshaft. In a four or eight cylinder engine, for instance, it is found for practical operation that the crank throws or pins for the slow traveling pistons must be located 90° apart, while those of the fast traveling pistons are located 180° apart. Likewise, in a six-cylinder engine of this type, the crank throws or pins for the slow traveling pistons should be 60° apart with those of the fast traveling pistons 120° apart. This is illustrated in Figs. 10 and 11 and diagrammatically in Fig. 14 for a four-cycle engine, and in Figs. 12 and 13 and diagrammatically in Fig. 15 for a six-cylinder engine.

In a four-cylinder engine the movements of the cranks of the fast shaft and their pistons are so coordinated with those of the slow shaft and their pistons that firing for the fast shaft during two revolutions is in the order of 1-3-4-2, while at the same time the firing order for the cranks of the slow shaft is likewise 1-3-4-2, as indicated diagrammatically in Fig. 14. This also indicates that the explosion impulses on the fast shaft are 180° apart, while those on the slow shaft are 90° apart.

In the case of a six-cylinder engine the coordination of the cranks of the two shafts is such that the firing order for the cylinders is 1-5-3-6-2-4, as indicated in Fig. 15, with the explosion of the impulses for the fast shaft 120° apart and those for the slow shaft 60° apart.

If an eight-cylinder engine is employed, the crank of the fast shaft will have a 45° spacing and those of the slow shaft a 90° spacing, or one-half that of the shafts of a four-cylinder engine, and the firing order will be 1-6-2-5-8-3-7-4.

I wish it understood that my invention is not limited to any specific construction, arrangement or form of the parts, as it is capable of numerous modifications and changes without departing from the spirit of the claims.

Having thus described my invention, what I claim as new, and desire to secure by United States Letters Patent, is:

1. In an internal combustion engine, a cylinder having centrally disposed intake and exhaust ports, valves controlling said ports, two opposed differentially operating pistons in said cylinder, a separate crankshaft for each piston, means connecting said shafts to cause them to turn with a two-to-one ratio with the slow traveling piston operating in the manner of a four-cycle engine piston, and means operating in unison with a running of the engine to operate said valves and open the inlet port to admit a charge during each intake stroke and to open the exhaust port to permit an exhaust discharge during each exhaust stroke of the slow traveling piston.

2. An internal combustion engine comprising a cylinder, two opposed pistons in the cylinder, a separate crankshaft for each piston, means con-

7

necting the shafts to make them rotate in a two-to-one ratio and in an angular relation of their cranks so that the pistons approach nearest each other once during each rotation of the slow shaft with the slow traveling crank having a lead over the fast moving crank at the point of said nearest approach, said lead being substantial but less than 90°, and means timing a four-cycle operation with respect to the slow traveling crank.

3. In an internal combustion engine, a cylinder having centrally disposed intake and exhaust ports, port controlling valves outside of the cylinder, two opposed differentially operating pistons in said cylinder, a separate crankshaft for each piston, means connecting said shafts to cause them to turn with a two-to-one ratio with the slow traveling piston operating in the manner of a four-cycle engine piston, and means operated by the engine to operate said valves and open the intake port to admit a charge during substantially the entire intake stroke of the slow traveling piston and to open the exhaust port for more than a 135° movement of said piston on its exhaust stroke.

4. In an internal combustion engine, a stationary cylinder having valve controlled centrally disposed intake and exhaust ports, two opposed differentially operating pistons in said cylinder, a separate crankshaft for each piston, means connecting said shafts to cause them to turn with a two-to-one ratio with the slow traveling piston operating in the manner of a four-cycle engine piston, and means operated by the engine to open the intake port to admit a charge during more than a 100° movement of the crank of the slow traveling piston on its intake stroke and to open the exhaust port at the beginning of the exhaust stroke of such piston and to maintain it open for at least a 225° movement of the slow piston crank.

5. In an internal combustion engine, a cylinder having valve controlled centrally disposed intake and exhaust ports, two opposed differentially operating pistons in said cylinder and contacting the walls thereof, a separate crankshaft for each piston, means connecting said shafts to cause them to turn with a two-to-one ratio with the slow traveling piston operating in the manner of a four-cycle engine piston, and means operated by the engine to open the exhaust port when the pistons are substantially the farthest apart, to close the exhaust port and open the intake port when the pistons are substantially the nearest together and to close the intake port when the pistons are once more substantially the farthest apart.

6. In an internal combustion engine, a cylinder having valve controlled centrally disposed intake and exhaust ports, two opposed differentially operating pistons in said cylinder, a separate crankshaft for each piston, means connecting said shafts to cause them to turn with a two-to-one ratio with the slow traveling piston operating in the manner of a four-cycle engine piston and having a lead over the fast moving piston when the pistons are nearest together, and means operated by the engine to open the exhaust port before the beginning of the instroke of the slow traveling piston and continue it open until after the end of the instroke of such piston, and to then close the exhaust and open the intake port and maintain it open until after the end of the outstroke of the fast moving piston.

7. In an internal combustion engine, a cylinder having valve controlled centrally disposed intake

8

and exhaust ports, two opposed differentially operating pistons in said cylinder, a separate crankshaft for each piston, means connecting said shafts to cause them to operate at a two-to-one ratio with the slow piston operating in the manner of a four-cycle engine piston, with the crank of the slow traveling piston substantially 45° past inner dead center when the crank of the fast traveling piston is at inner dead center whereby during the compression stroke of the slow piston the differential movements of the pistons cause a charge first to be compressed, then to be partially relieved and then finally compressed for firing whereby a churning of the charge to prevent condensation occurs, and means to open the intake port to admit a charge during the intake stroke of the slow traveling piston and to open the exhaust valve to permit exhaust during the exhaust stroke of said slow traveling piston.

8. In an internal combustion engine, a cylinder having valve controlled centrally located intake and exhaust ports, two opposed differentially operating pistons in said cylinder, a separate crankshaft for and connected to each piston, means connecting the shafts to cause them to turn at a two-to-one ratio with the slow traveling piston making two revolutions for each explosion and with its crank slightly past inner dead center when the fast traveling piston crank is at its inner dead center whereby compression begins before and ends after the inward stroke of the slow piston with a partial relieving of the compression midway of such stroke to cause churning of the charge due to the differential movements of the two pistons, and means operable by the engine to open the intake port when the exhaust port closes.

9. In an internal combustion engine, a cylinder having centrally located valve controlled intake and exhaust ports, two opposed differentially operating pistons in said cylinder, a separate crankshaft connected to each piston, means connecting the shafts to turn at a two-to-one ratio with the strokes of the slow traveling piston corresponding to those of a four-cycle engine and with the crank connections of the two pistons such that during the compression stroke of the slow traveling piston the differential movements of the pistons cause a predetermined initial compression of a charge, then a predetermined release of such compression and then a final compression for firing.

10. In an internal combustion engine, a cylinder having centrally located valve controlled intake and exhaust ports, two opposing differentially operating pistons in said cylinder, a separate crankshaft connecting the pistons, means connecting the crankshafts to turn in unison at a two-to-one ratio with the strokes of the slow traveling piston corresponding to those of a four-cycle engine and with the crank connections of the two pistons such that during the exhaust stroke of the slow piston the two pistons first move toward each other to assist initial exhaust, then recede from each other due to a concurrent outstroke of the fast piston at twice the speed of movement of the slow piston and then toward each other on the succeeding stroke of the fast piston to effect a final exhaust of gases from the cylinder, and means for effecting predetermined timed opening of the intake and exhaust ports.

11. In an internal combustion engine, a cylinder having centrally located valve controlled

intake and exhaust ports, two opposing differentially operating pistons in said cylinder, a separate crankshaft connecting the pistons, means connecting the crankshafts to turn at a two-to-one ratio with the strokes of the slow traveling piston corresponding to those of a four-cycle engine and with the crank connections of the two pistons such that during the exhaust stroke of the slow piston the two pistons first move toward each other to assist initial exhaust, then recede from each other due to a concurrent outstroke of the fast piston at twice the speed of movement of the slow piston and then toward each other on the succeeding stroke of the fast piston to effect a final exhaust of gases from the cylinder, and means operable to open the exhaust port before the beginning and close it after the end of the inward stroke of the slow piston.

12. A cylinder having centrally located valve controlled intake and exhaust ports, two opposing differentially operating pistons in said cylinder, a separate crankshaft connected to each piston, means connecting the shafts to turn at a two-to-one ratio with the crank of the slow traveling piston past inner dead center when the other crank is at inner dead center, and means operable by the engine to open the exhaust valve before the beginning and close it after the end of the inward stroke of the slow piston.

13. A cylinder having centrally located valve controlled intake and exhaust ports, two opposing differentially operating pistons in said cylinder, a separate crankshaft connected to each piston, means connecting the shafts to turn at a two-to-one ratio with the crank of the slow traveling piston past inner dead center when the other crank is at inner dead center, and means operable by the engine to open the exhaust port at substantially the beginning of the exhaust stroke of the slow traveling piston and to cause it to remain open during more than 180° of movement of the slow crank and 360° of movement of the fast piston crank.

14. In an internal combustion engine, a cylinder having centrally located valve controlled intake and exhaust ports, two opposing differentially operated pistons in the cylinder, a separate crankshaft connected to each cylinder, a connection between the shafts causing them to turn at a two-to-one ratio with the crank of the slow traveling piston past inner dead center when the crank of the other piston is at inner dead center, the slow traveling piston making separate power, exhaust, intake and compression strokes for each explosion, and means including a cam shaft operable by the engine to turn once for each two revolutions of the slow crankshaft and operable to open the exhaust port when the pistons are approximately the widest apart, and to close the exhaust and to open the intake port when the pistons are approximately the nearest together.

15. In an internal combustion engine, a plurality of cylinders each having valve-controlled centrally disposed intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to a crank of the fast turning shaft, the cranks of the slow shaft in a four-cylinder engine having a 90° spacing and those of the fast shaft having a 180° spacing with the

firing occurring in each cylinder at each second revolution of its slow crankshaft with a cylinder firing order of 1-4-3-2.

16. In an internal combustion engine, a plurality of cylinders each having valve-controlled centrally disposed intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to a crank of the fast turning shaft, the cranks of the slow shaft in an eight-cylinder engine having a 45° spacing and those of the fast shaft having a 90° spacing with the firing occurring in each cylinder at each second revolution of its slow crankshaft with a cylinder firing order of 1-6-2-5-8-3-7-4.

17. In an internal combustion engine, a plurality of cylinders each having valve-controlled centrally disposed intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to the crank of the fast turning shaft, the cranks of the slow shaft in a six-cylinder engine having a 120° spacing and those of the fast shaft having a 60° spacing with the firing occurring in each cylinder at each second revolution of the slow crank shaft with a cylinder firing order of 1-5-3-6-2-4.

18. In an internal combustion engine, a plurality of cylinders each having valve-controlled centrally disposed intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to the crank of the fast turning shaft, the cranks of the slow shaft in a four-cylinder engine having a 90° spacing and those of the fast shaft having a 180° spacing with the slow moving pistons in the successive order of the cylinders connected respectively to cranks 1-2-4 and 3 with the firing occurring in each cylinder at each second revolution of the slow crankshaft with a cylinder firing order of 1-3-4-2.

19. In an internal combustion engine, a plurality of cylinders each having valve-controlled centrally disposed intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to the crank of the fast turning shaft, the cranks of the slow shaft in an eight-cylinder engine having a 45° spacing and those of the fast shaft having a 90° spacing, with the slow moving pistons, in the successive order of the cylinders, connected respectively to cranks 1-2-3-4-5-6-7-8, with the firing occurring in each cylinder at each revolution of the slow crankshaft, the cylinder firing order being 1-6-2-5-8-3-7-4.

20. In an internal combustion engine, a plurality of cylinders each having valve-controlled centrally disposed intake and exhaust

ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to the crank of the fast turning shaft, the cranks of the slow shaft in a six-cylinder engine having a 60° spacing and those of the fast shaft a 120° spacing, with the slow moving pistons, in the successive order of the cylinders, connected respectively to cranks 1-2-3-4-5-6, with the firing occurring in each cylinder at each revolution of the slow crankshaft and the firing order being 1-5-3-6-2-4.

21. An internal combustion engine comprising a cylinder, two opposed pistons in opposite ends of the cylinder, a separate crankshaft for each piston, means connecting the two shafts to make them turn in a two-to-one ratio and with an angular relation between them to bring the pistons closest together but once, and farthest apart but once, during each rotation of the slow shaft and two rotations of the fast shaft, an intake valve, an exhaust valve, a firing means, and means timed by the turning of said shafts to actuate the firing means at one nearest approach of the pistons, to open the exhaust valve when the pistons next reach their farthest apart position, to close the exhaust and open the intake valve when next the pistons reach their position nearest together, to close the intake valve when the pistons are next farthest apart, and to actuate the firing means when the pistons are again nearest each other, whereby there is one working stroke during each two rotations of the slow moving shaft.

22. In an internal combustion engine, a plurality of cylinders each having intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to a crank of the fast turning shaft, the cranks of the slow shaft in a four-cylinder engine having a 90° spacing and those of the fast shaft having 180° spacing with the firing occurring in each cylinder at each second revolution of its slow crankshaft with a cylinder firing order of 1-4-3-2.

23. In an internal combustion engine, a plurality of cylinders each having intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to a crank of the fast turning shaft, the cranks of the slow shaft in an eight-cylinder engine having a 45° spacing and those of the fast shaft having a 90° spacing with the firing occurring in each cylinder at each second revolution of its slow crankshaft with a cylinder firing order of 1-6-2-5-8-3-7-4.

24. In an internal combustion engine, a plurality of cylinders each having intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning

shaft and the other to the crank of the fast turning shaft, the cranks of the slow shaft in a six-cylinder engine having a 120° spacing and those of the fast shaft having a 60° spacing with the firing occurring in each cylinder at each second revolution of the slow crank shaft with a cylinder firing order of 1-5-3-6-2-4.

25. In an internal combustion engine, a plurality of cylinders each having intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to the crank of the fast turning shaft, the cranks of the slow shaft in a four-cylinder engine having a 90° spacing and those of the fast shaft having a 180° spacing with the slow moving pistons in the successive order of the cylinders connected respectively to cranks 1-2-4 and 3 with the firing occurring in each cylinder at each second revolution of the slow crankshaft with a cylinder firing order of 1-3-4-2.

26. In an internal combustion engine, a plurality of cylinders each having intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft and the other to the crank of the fast turning shaft, the cranks of the slow shaft in an eight-cylinder engine having a 45° spacing and those of the fast shaft having a 90° spacing, with the slow moving pistons, in the successive order of the cylinders, connected respectively to cranks 1-2-3-4-5-6-7-8, with the firing occurring in each cylinder at each revolution of the slow crankshaft, the cylinder firing order being 1-6-2-5-8-3-7-4.

27. In an internal combustion engine, a plurality of cylinders each having intake and exhaust ports, two crankshafts, one at each end of the cylinders, and each having a crank for each cylinder, means connecting said crankshafts to cause them to turn in unison with a two-to-one ratio, two opposed pistons in each cylinder with one connected to a crank of the slow turning shaft, the cranks of the slow shaft in a six-cylinder engine having a 60° spacing and those of the fast shaft a 120° spacing, with the slow moving pistons, in successive order of the cylinders, connected respectively to cranks 1-2-3-4-5-6, with the firing occurring in each cylinder at each revolution of the slow crankshaft and the firing order being 1-5-3-6-2-4.

MARION MALLORY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,099,576	Slaby	June 9, 1914
1,237,696	Rayl	Aug. 21, 1917
1,808,083	Tibbetts	June 2, 1931

FOREIGN PATENTS

Number	Country	Date
169,444	Great Britain	1921
169,699	Great Britain	1921
216,209	Great Britain	1924