April 5, 1949. E. F. MERCIER ET AL 2,466,255

BALANCED DOUBLE-ACTING ENGINE

Filed Oct. 27, 1942 6 Sheets-Sheet 1

FIG. 1

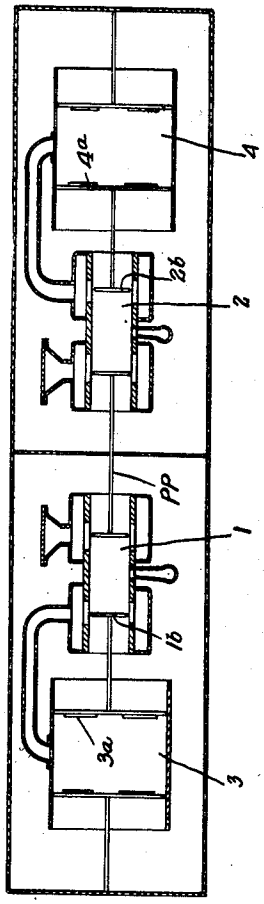
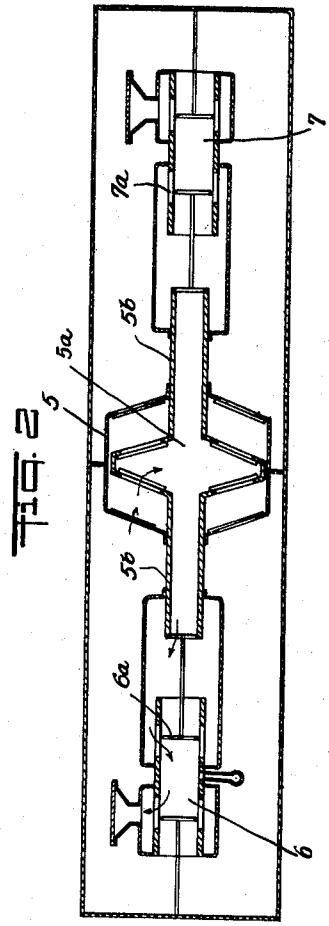


FIG. 2



Pierre Ernest Mercier &
Ernest Frederic Mercier
INVENTORS

BY Haseltine, Lake & Co.
ATTORNEYS

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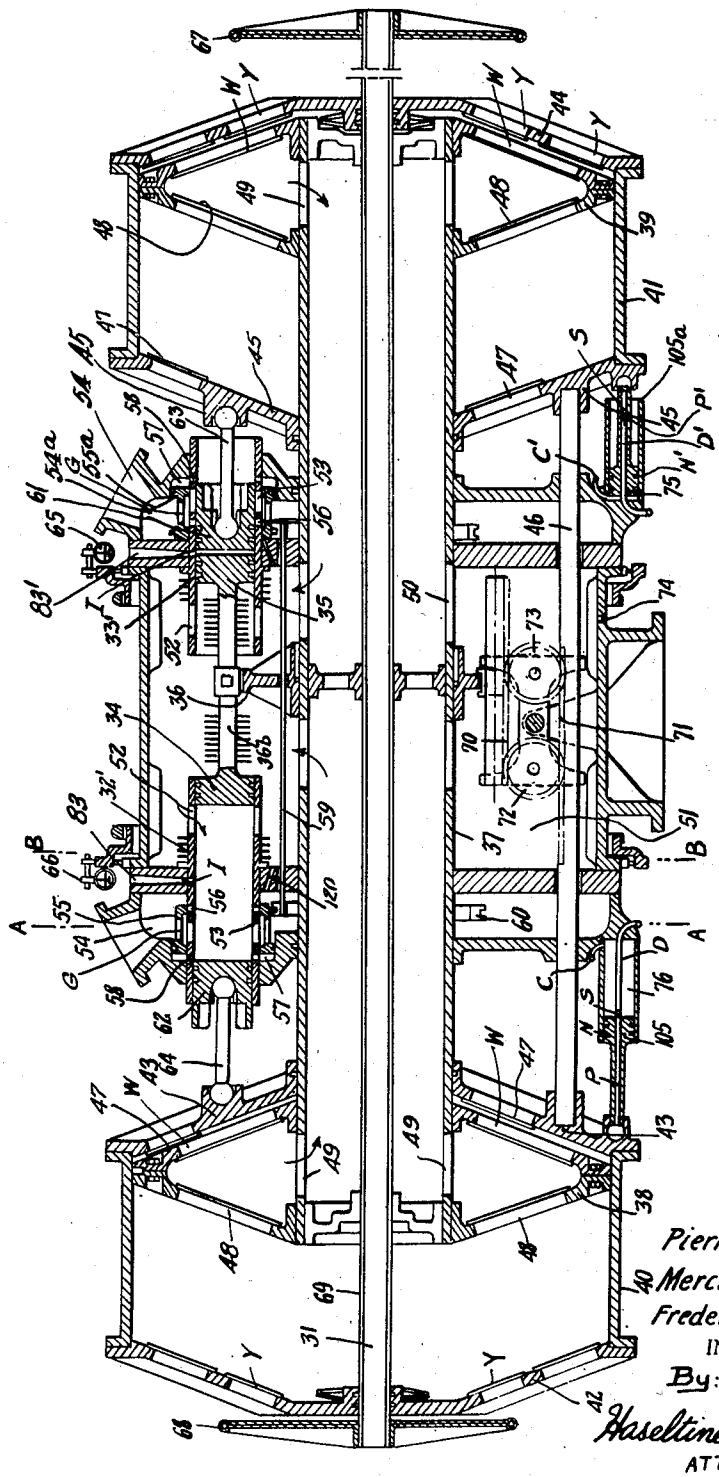


FIG 3

Pierre Ernest Mercier & Ernest Frederic Mercier
INVENTORS
By: Haseltine, Lake & Co.
ATTORNEYS

April 5, 1949. E. F. MERCIER ET AL 2,466,255

BALANCED DOUBLE-ACTING ENGINE

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FIG. 6

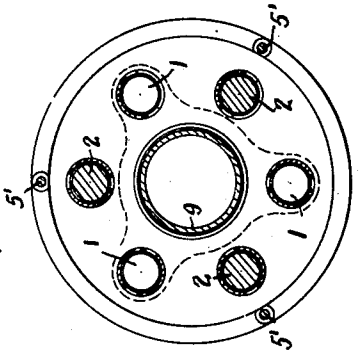


FIG. 7

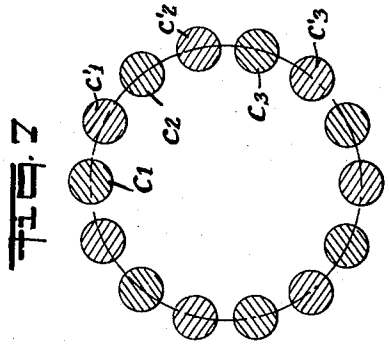


FIG. 4

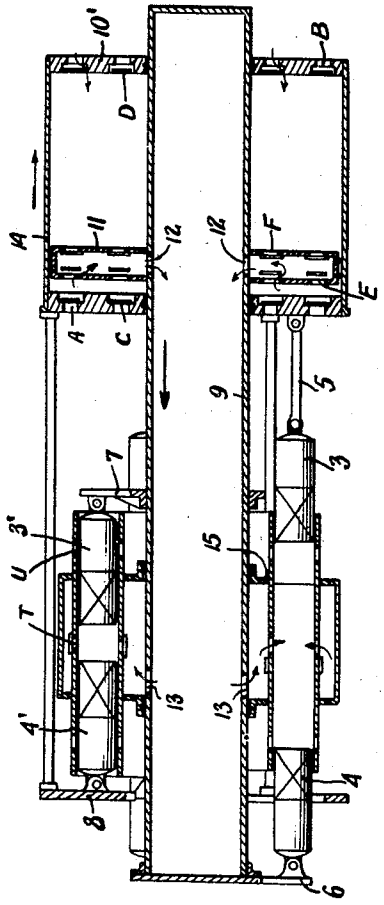
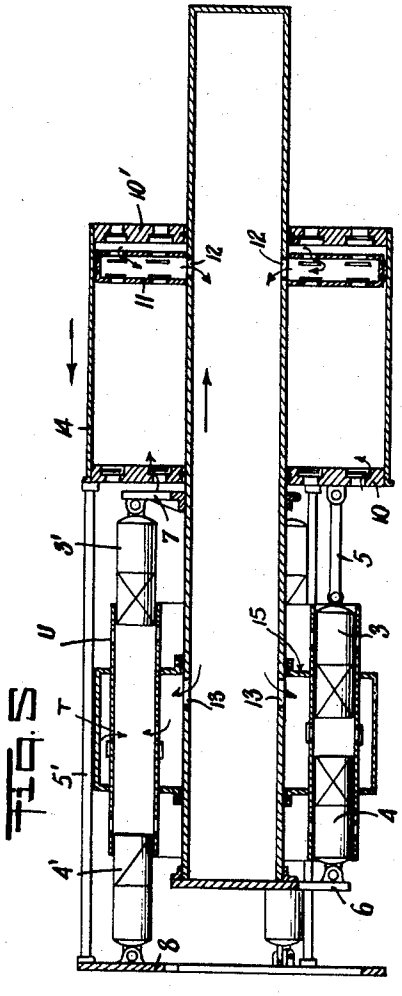


FIG. 5



INVENTORS
Pierre Ernest Mercier & Ernest Frederic Mercier
BY Haseltine, Lake & Co.
ATTORNEYS

April 5, 1949. E. F. MERCIER ET AL 2,466,255

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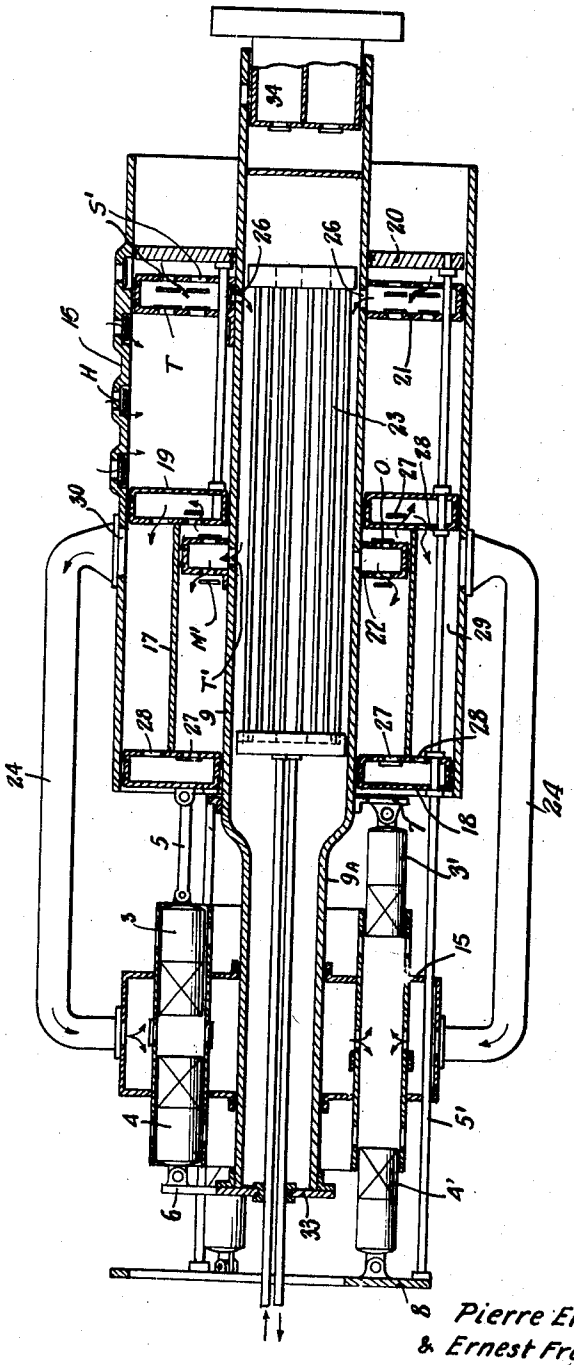


FIG 8

Pierre Ernest Mercier
& Ernest Frederic Mercier
INVENTORS

BY Haseltine, Lake & Co.
ATTORNEYS

April 5, 1949. E. F. MERCIER ET AL 2,466,255

BALANCED DOUBLE-ACTING ENGINE

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Fig. 10

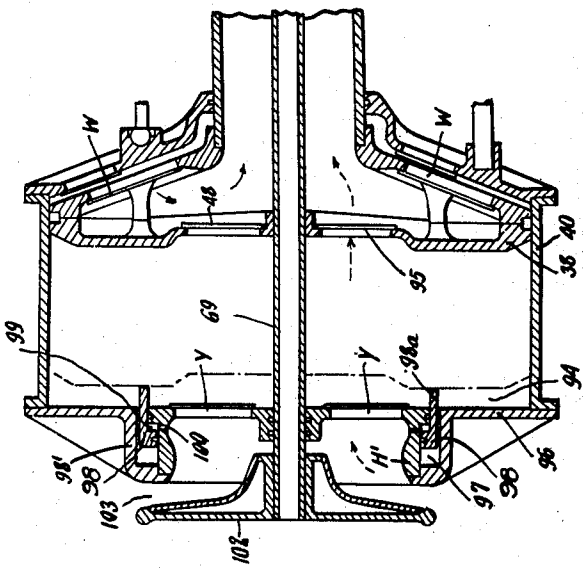
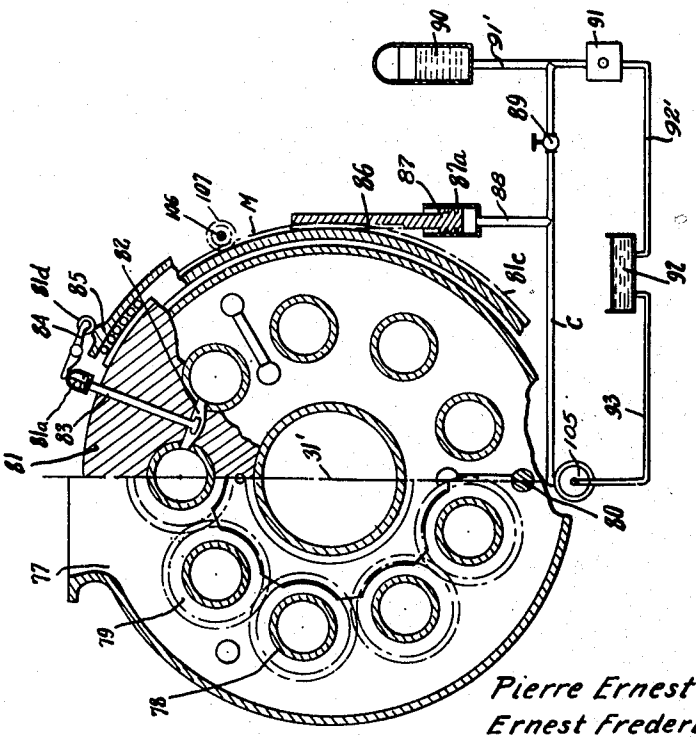


Fig. 9



Pierre Ernest Mercier &
Ernest Frederic Mercier
INVENTORS

BY Haseltine, Lake & Co.
ATTORNEYS

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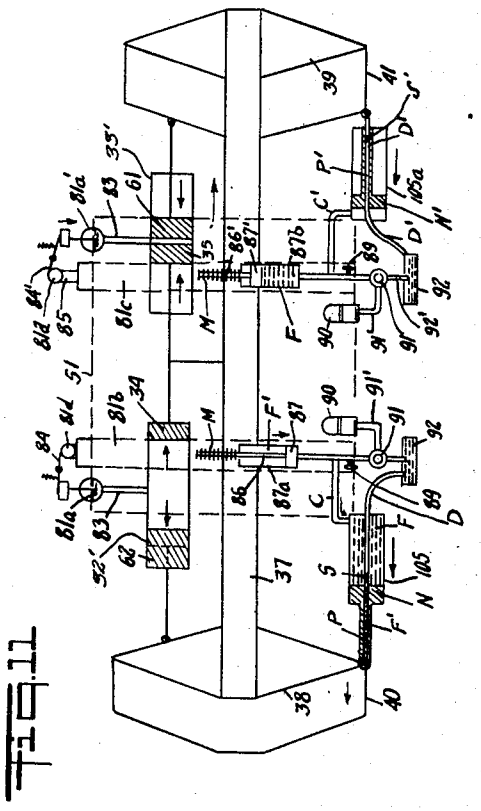


Fig. 11

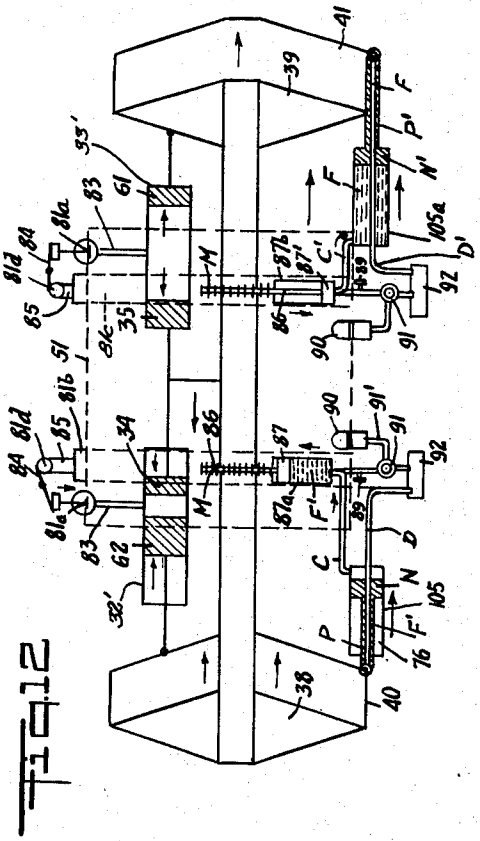


Fig. 12

Pierre Ernest Mercier &
Ernest Frederic Mercier
INVENTORS

BY Haseltine, Lake & Co.
ATTORNEYS

Patented Apr. 5, 1949

2,466,255

UNITED STATES PATENT OFFICE

2,466,255

BALANCED DOUBLE-ACTING ENGINE

Ernest Frederic Mercier, Eguzon, France, and
Pierre Ernest Mercier, New York, N. Y.

Application October 27, 1942, Serial No. 464,433
In France November 23, 1940

Section 1, Public Law 690, August 8, 1946
Patent expires November 23, 1960

3 Claims. (Cl. 123—46)

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The present invention relates to improvements in prime mover apparatus and especially to a gas generating and air compressor apparatus. The invention relates more particularly to a combination including a balanced double-acting internal combustion engine and air compressing means which cooperate to supply hot compressed gases which may be used in a gas turbine, a gas propulsion nozzle or other prime mover.

A problem of long standing in the use of gas turbines has been the production in an economical manner of a dependable supply of highly compressed gases at a temperature low enough to avoid damage to the turbine blading or undue wear and maintenance problems in connection therewith, while at the same time conserving the heat energy of said gases so that it may be utilized to maximum effect in the turbine.

One of the principal objects of this invention is to provide an apparatus capable of supplying to a turbine or other prime mover, a mixture of compressed gases of regulated temperature and pressure while conserving the energy developed therein during the generating and compressing steps.

A further object of the invention is to provide a gas generating and compressor apparatus in which a plurality of internal combustion engine firing chambers are provided as power and gas generating units and are connected together with their complementary moving parts disposed in balanced relation and cooperating to insure a maximum degree of freedom from vibration.

Still another object of the invention is to provide, in an apparatus of the class described, an arrangement whereby a plurality of firing chambers are so connected with one or more gas compressor units as to obtain an increased efficiency in the utilization of the power and heat energy developed in said firing chambers, while at the same time simplifying incidental operations such as control of flow of compressed gas to and through the firing chambers, cooling of the firing chambers, and feeding of fluid fuel thereto.

A still further object of the invention is to provide an apparatus of the class described which is characterized by compactness and light weight for a given power output and wherein many of the linkages, connecting rods, cranks, and other auxiliary elements necessary to the operation of conventional internal combustion engines and the transfer of their power to a driven machine are eliminated.

The above and other objects and advantages are obtained according to the invention by associating one or preferably a plurality of sets of free pistons in open-ended firing cylinders so disposed with relation to one another and to a double-acting air compressor as to insure that the several pistons will move synchronously in balanced relation. In other words, the arrangement is such that the essential elements partaking in the synchronous movements are so distributed between two opposing assemblies of the free pistons and the correlated elements of the air compressor that each movable member of one assembly will have in the other assembly a corresponding member movable in the opposite direction. In this way thrusts and counter-thrusts which in prior constructions are transmitted to stationary supporting members are neutralized without loss of energy from the system, but instead such energy is transferred to the air undergoing pressure in the system and which is ultimately discharged with and as a part of the gases passing from the firing cylinders.

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The invention will now be described more particularly with reference to the accompanying drawings, wherein similar reference characters designate similar parts throughout the respective views:

Figs. 1 and 2 respectively are diagrammatic views in longitudinal section of two forms of gas generating and compressing assemblies embodying certain of the broader principles of the invention;

Fig. 3 is a longitudinal section of another modified form of the invention;

Figs. 4 and 5 are longitudinal sections of a further modified form of the invention showing the same machine in two extreme positions;

Fig. 6 is a diagrammatic view from the end of a six cylinder machine which otherwise may conform either to the structure of Fig. 4 or Fig. 5;

Fig. 7 is a diagram showing still another disposition of the firing cylinders;

Fig. 8 is a view in longitudinal section of another modification of the invention;

Fig. 9 shows two transverse half-sections taken respectively along the lines A—A and B—B of Fig. 3;

Fig. 10 is a partial view, in longitudinal section, of a variation of one of the compressor cylinders of Fig. 3, and

Figs. 11 and 12 are diagrammatic views showing the disposition of two assemblies in two different positions with reference to a hydraulic fluid fuel injector-operating means.

In the drawings, which are merely illustrative

of the invention, we disclose a form of power plant designed to promote economy of space and fuel consumption. A characteristic feature of such power plant resides in the arrangement whereby the movable parts of the air compressors are connected for coordinated movement with the moving parts of the power and gas generating units, and in the grouping of these units into two opposing sets to permit imparting staggered strokes to the pistons of both groups.

There are various ways of accomplishing this. For example, Fig. 1 shows a type wherein a pair of open-ended engine cylinders 1 and 2 and a pair of compressors 3 and 4 are arranged along one and the same axis with the two coaxial engine cylinders disposed adjacent to one another. A double piston PP is mounted for reciprocation in the adjacent ends of the cylinders and cooperates with pistons 1*b* and 2*b* in defining the combustion chambers of the respective cylinders. The pistons 1*b* and 2*b* are respectively connected with pistons 3*a* and 4*a* and reciprocate the latter in their respective compressor cylinders which are arranged respectively at the outer ends of the engine cylinders. Fig. 2 shows a double acting compressor unit 5 which occupies the central position occupied by the adjacent engine cylinders in Fig. 1. The double-acting piston 5*a* of the compressor has hollow extensions 5*b* extending on each side of the piston toward the cylinders 6 and 7 and these extensions are connected to pistons 6*a* and 7*a* disposed in the cylinders.

Figure 3 shows a pair of double acting compressor cylinders 40 and 41 arranged in spaced relation and mounted for movement axially as a unit. Combined therewith are two sets of cylinders 32' and 33', only one cylinder of each set being shown in Figure 3, the two cylinders being arranged in opposed relation, the sets being distributed as shown in Fig. 9 around the longitudinal axis of the compressor intermediate the compressor cylinders and cooperating with pistons 34, 35, 61 and 62 reciprocating within the ends thereof to form firing chambers.

Figure 4 shows a plurality of adjacent internal combustion cylinders, arranged about a common central axis and all of which are connected so as to actuate a double acting compressor, located laterally of the cylinders on the central axis.

The difference between the disclosures of Figures 3 and 4 is this: In Figure 3, there are compressor cylinders at each end of the machine with intervening motor cylinders arranged in two sets, each set being a distinct circular series, while in Figure 4 there is but one compressor at one end of the machine and only one set of motor cylinders is provided arranged into a circular series. The difference goes further: In Figure 3, one circular set of motor cylinders has in each cylinder oppositely stroking pistons with one piston of a cylinder of one set in coaxial alignment with the piston of a cylinder of the second set—this arrangement being true of the succeeding pairs of aligned cylinders in the various positions circumferentially in these two sets. But in Figure 4, one half of the total number of cylinders of a circular set or series of motor cylinders have their pistons stroking in opposing directions with reference to the pistons of the remaining half of the cylinders of said set. The reason for this will be explained hereinafter.

Figure 8 discloses a still further departure from the foregoing in that, while it shows the same disposition of motor cylinders as Figure 4, there are two coaxial sets of compressor assemblies cooperating therewith instead of one. The advantage of division of the power of the motor cylinders thus obtained finds particular application to Diesel engines in which the ignition speed of the fuel atomized is limited so that large bulky cylinders cannot be used.

In Figures 4 and 5, the entire series of motor cylinders are arranged into two groups, the cylinders of one group alternating with respect to those of the other group. In Figure 7, this arrangement is shown diagrammatically where it will be seen that one group of cylinders C^1, C^2, C^3, etc. alternate between another group C'1, C'2, and C'3, all of the cylinders being arranged in a circle so that the various cylinders making up the two internal combustion engines are situated in a plane perpendicular to the direction of the common axis of such engines. Each cylinder has a pair of oppositely arranged pistons which are unconnected to each other and are adapted to reciprocate in the open ends of the cylinder. Six engine cylinders are contemplated in Figures 4 and 5 and are shown diagrammatically in Figure 6, where one group, three in number designated 1 are disposed in alternate relationship with respect to the other group 2, the entire series being arranged around and concentrically of the tubular piston rod 9 which serves as a compressed air conduit to feed the cylinders with compressed air.

It is proposed to give the pistons of one group a staggered stroke with respect to those of the other group so that while the one group perform their power stroke the other group will perform their compressor stroke, and vice versa.

The arrangement is such that all the pistons of one group 1, at one and the same end of their cylinders are constrained to move in a direction counter to all the pistons of the other group 2 which are at the same end of their cylinders as the first group. This is also true of the two groups of pistons 1 and 2 which are disposed at the other end of the foregoing two groups of cylinders. These groups of pistons will move in opposite directions. In Figures 4 and 5, when the oppositely arranged pistons 3' and 4' are completely within their respective cylinders after having completed their compression stroke, the oppositely arranged pistons 3 and 4 of adjacent cylinders are projected beyond the opposing ends of their cylinders, having completed their expansion stroke. In other words, pistons 3' and 4' disposed in one of the cylinders respectively move in one and the same direction as pistons 4 and 3, disposed in the alternate cylinders at the opposite ends thereof. Hence when pistons 4 and 3, of one cylinder of one group follow their compression stroke, pistons 4' and 3' of the other cylinder follow their expansion stroke, there being one power impulse for each stroke.

The means for actuating these pistons to impart the foregoing movements consists of the movable parts of the compressor device and their connections. The engine cylinders are fixed in position and project through an annular closed fluid admission jacket 15. Slidably projecting concentrically in said jacket is a tubular conduit 9 which serves as a piston rod. The six engine cylinders are coupled to a single compressor device to provide a unitary generator, the circle circumscribed by the cylinders being preferably of a diameter less than that of the compressor cylinder, 14.

The compressor cylinder 14 is positioned concentrically of the tubular piston rod or conduit 9 by means of disks or cylinder heads 10 and 10' which close opposite ends of this cylinder and which slidably engage tubular piston rod 9. A hollow piston 11 is carried by tube 9 short of one end and traverses snugly in the compressor cylinder 14. A series of vent ports A is formed in one disk 10 and another series B formed in the other disk 10'. Check valves C control vents A and check valves D control vents B. In hollow piston 11 on one wall are check valve controlled vents E and on the other wall are check-valve controlled vents F. This hollow piston communicates with bore of tube 9 by means of a port 12, and tube 9 communicates with jacket 15 by means of ports 13.

A yoke or saddle piece 8 encircling tube 9 has pivotal connections with three pistons 4' of one group 1, which are on the same side of jacket 15, being connected rigidly peripherally of said jacket by connecting rod 5' to the end wall 10 of compressor cylinder 14. The pistons 4 of the other group, which are on the same side of jacket 15 as pistons 4', are pivotally connected to a yoke 6 carried by tube 9 at one end thereof.

The pistons 3' of the group on the other side of jacket 15 which are in the same cylinders with pistons 4' are pivotally secured to a yoke 7 fixed on tube 9 at a point intermediate its ends. Finally the pistons 3 of the second group on the said other side of jacket 15 which are in the same cylinders as pistons 4 are pivotally connected to the terminals of link rods 5 the inner ends of which are secured to the end wall 10 of compressor cylinder 14.

This construction of intercoupled motor and compressor assemblies assures that every clement comprised in each of the two moving bodies has in the other moving body a corresponding element geometrically identical and subject (in the opposite direction) to exactly the same pressures, in normal or in abnormal operation. It is obvious that, if desired, the median planes of all the motors, instead of coinciding as in the example described in the preceding text can be arranged parallel and in spaced relation, this requiring, however, lengthening of the machine.

The same underlying principle of construction can be adapted in connection with providing a two-stage compressor for feeding internal combustion cylinders with compressed air at a high pressure, say at a pressure from 8 to 10 kilograms. Such an arrangement of parts is shown in Figure 8, where provision is also made for cooling the air compressed in the compressor.

In Figure 8 the construction and arrangement of parts of the motor assembly is similar to what has already been described, except that the reduced end 9A of the tube 9 is surrounded concentrically by the two groups of cylinders, this reduced end not having the office of communicating directly with jacket 15. In the main length of tube 9 is fixedly positioned, a cooler device for the air, the inlet and outlet water passages of which extend into reduced end 9A of this tube and slidably project through stuffing boxes located in the adjacent closed end 33 of this tube.

The compressor cylinder 16 of the low pressure stage is disposed concentrically of tube 9, being provided with check-valve controlled vents H. Slidably closing one end of this cylinder 16 is a hollow piston wall 18 carrying exhaust valves 27 controlling adjacent vents which communicate with the interior of a high pressure cylindrical

chamber 17 between which and cylinder 16 is the annular cylindrical space 29. Chamber 17 is attached at one end to movable piston wall 18 and at its opposite end is attached to and closed by another hollow piston wall 19 also slidable in cylinder 16. The hollow space of first piston 18 communicates with the annular space 29 by means of ports 28, which annular space, in turn, communicates with pipes 24 which establish lines of flow of compressed fluid directly into the jacket 15.

Also slidably positioned in cylinder 16 is a piston 20 spaced a convenient distance from hollow piston 19 in fixed relationship thereto. It will be seen that connecting rods 5' which connect piston 18 to yoke 8 that operate piston 4' is made of a length suitable to simultaneously interconnect the hollow pistons 18 and 19 as well as the solid piston 20 so all three pistons will move at the same time along tube 9, carrying cylindrical high pressure chamber 17 along with them.

Hollow piston wall 19 has vent ports 28 which communicate with the interior of the annular space 29. The wall 19 also carries exhaust valves 27 controlling ports that communicate through the hollow wall 19 and the ports 28 with the interior of the cylindrical jacket 17. This hollow piston wall 19 divides the high pressure from the low pressure zone of the multi-stage compressor. The hollow piston 21 of the low pressure zone is keyed onto tube 9 and makes a traverse between hollow piston 19 and solid piston 20, both slidable in cylinder 16. This hollow piston 21 has check valve controlled ports S' on one side wall and check valve controlled ports T on its opposite wall. Communication between hollow piston 21 and tube 9 is had by means of ports 26 formed in this tube 9 in a plane with said piston. A smaller hollow piston 22 is also keyed to tube 9 and has a traverse in cylindrical chamber 17. It has, on one wall, check-valve controlled ports M' and on its opposite wall check-valve controlled ports O both sets of ports communicating with the interior of cylindrical chamber 17 respectively at opposite sides of piston 22.

In the device just described, the pistons operate in two adjacent compartments, one being the high pressure chamber 17; one piston, 22, of the pair of pistons carried by tube 9 operating in the chamber 17, while the other piston, 21, operates in the other low pressure compartment. It will be seen that tube piston 21 slides relatively to and over connecting rod 5'.

In Fig. 3, the compressor cylinders 40 and 41 are supported at their adjacent sides by the tube 37 which is arranged concentrically of a shaft 31 and is supported for sliding movement in the closed cylindrical jacket or air chamber 51. The tube 37 fixedly carries at one end a hollow piston 38 and a similarly fixed hollow piston 39 at the other end. Piston 38 is adapted to make a stroke in compressor cylinder 40 between oppositely inclined walls 42 and 43. Piston 39 similarly moves between the oppositely inclined walls 44 and 45 of cylinder 41. A rigid connecting rod 46 is attached at opposite ends to end walls 43 and 45, respectively, of cylinders 40 and 41.

One wall of each piston 38, 39 carries pressure valves 48, while the other wall carries check valves W. The wall 42 of the cylinder 40 facing the valves 48 of piston 38 carries check valves Y while that wall 45 of cylinder 41 which faces valves 48 of piston 39 carries check valves 47. The compressor pistons 38, 39 connect with the interior of tube 37 by means of passages 49

formed in tube 37 in a plane with the pistons. Tube 37 in turn communicates with the central chamber 51 by means of ports 50. Tube 37 carries fixed thereto centrally thereof a yoke 36 which supports at its lower part a horizontal rack 70 meshing with pinions 72 and 73 supported in fixed position by a suitable frame mounted on casing 74. Meshing with these pinions 72 and 73 is another rack 71 carried by the slidable connecting rod 46, which arrangement insures that when either rack moves in one direction it will rotate the pinions, causing these pinions in turn to move the other rack in a counter direction. The racks and pinions also give central support to the movable tube 37.

As previously mentioned, two series of firing cylinders are arranged in circular rows around tube 37, with the adjacent ends of the cylinders of the two rows projecting into the jacket 51 as shown in Figs. 3 and 9. The cylinders of the two sets are disposed in horizontal, coaxial alignment with one another, two of such cylinders 32' and 33' being shown in Fig. 3. A pair of oppositely movable pistons 62 and 34 move in cylinder 32' while a similar set designated 61 and 35 move in cylinder 33'. The pistons 62 and 61 at the opposite ends of the aligned cylinders are connected for linear movement to cylinder walls 43 and 45, respectively, of cylinders 40 and 41 by short links 64 and 63. The inner pistons 34 and 35 moving in these same cylinders are connected together for joint movement by a common piston rod 36b to which is attached centrally the yoke 36, which in turn is secured to the tube 37.

It will thus be seen that in this construction of parts, provision is made for moving the compressor pistons carried by the central tube 37 in one direction of reciprocation in their encasing compressor cylinders, while, at the same time, means are provided for reciprocating these compressor cylinders relatively to the tube in a counter direction. As a result the end walls of the cylinder behave as pistons in cooperating with the compressor pistons 38 and 39, moving towards or away from the pistons 38 and 39 associated with them, and regardless of the direction of reciprocation, compressing air in the spaces between the pistons and the compressor cylinder walls in that stage of the cycle when they are approaching one another. As the compression reaches the desired value determined by the setting of the valves 48 or W, as the case may be, these valves respectively open and close permitting the compressed air to pass into the tube 37 and thence through the openings 53 to the central chamber 51.

As the tube 37 is moved back and forth concomitantly with movement of the pistons 34 and 35, the cylinders 40 and 41 are moved in the opposite direction to tube 37 in each stroke of said tube 37 by virtue of the movement imparted to the cylinders 40 and 41 through the short links 63 and 64 and the rigid connecting rod 46. It will be understood from the above description that in each such stroke, both of the tubes 37 and the pistons 38 and 39 carried thereby and of the cylinders 40 and 41, a power impulse is given thereto produced by the combustion of the fuel alternately in the cylinders 32' and 33'.

The means provided for imparting to the oppositely arranged pistons of cylinders of the two groups a full free expansion stroke and a partial, interrupted compression stroke is shown by Figure 3 to be adapted to the type of motor and compressor assemblies disclosed in this figure.

At the center of the length of each cylinder 32', 33' as shown in Figure 3 is the inlet port I for the fluid fuel coming from the injector 83 or 83'. On the opposite sides of each inlet port I along the length of each cylinder are ports 52 and 53 defining admission and exhaust passages, respectively, for reception of compressed air and for exhausting the combustion gases. Between the exhaust ports 53 and the injector inlet ports I are relatively restricted supplementary or auxiliary exhaust ports 56. A pair of valvular sleeves 55 and 55a, mounted for limited sliding movement along the cylinders 32' and 33', serve respectively to control the covering and uncovering of the ports 56 of both cylinders in synchronism with the movement of the pistons. The inner parts of these sleeves move, piston-like, in annular chambers 57 surrounding the cylinders and bored out of the adjacent cylinder frames, the latter being provided with exhaust outlets 54 and 54a with which the exhaust passages 53 and ports 56 communicate. The two sleeves 55 and 55a are coupled together for conjoint movement by a tie rod 59. It will be seen that when the tube compressor pistons 38 and 39 are positioned, as shown in Figure 3, their greatest distance apart from the walls 42 and 45 of compressor cylinders 40 and 41, pistons 35 and 61 in cylinder 33' will be positioned in close proximity at the center thereof, while pistons 62 and 34 in cylinder 32' will be separated their greatest distance apart.

Similarly in Figures 4 and 8 pistons 3', 4', in one cylinder there shown will be positioned in close proximity, while pistons 3 and 4 of the other cylinder shown will be separated their greatest distance apart. In these figures the valves or valvular sleeves which control the admission of fluid to, as well as exhaust of fluid from the cylinders may be synchronously operated by any desirable means, not shown.

Supplying the cylinders shown in Figure 3 with hot fuel gases or other fluid fuel is done by any desirable means as is also regulation of the intervals of injection. As one way to accomplish this function we disclose a hydraulically operated mechanism for actuating an injector or injectors which feed hot fuel gases into the firing cylinders. Two injectors 83 and 83' are provided for the two cylinders shown in Figure 3. Poppet valves 81a and 81a', Figs. 9, 11 and 12, move in the fuel injectors and are controlled in the conventional way by springs (not shown). Reference being made to Figure 11, it will be seen that when poppet valve 81a is closed, pistons 62 and 34 have been completing their expansion stroke, while poppet valve 81a' has opened to admit hot gases in order to impel pistons 35 and 61 outwardly in a corresponding expansion stroke. A pair of rack rings 81b and 81c are operably mounted for oscillatory movement around cylindrical jacket 51. An accurate series of teeth M are formed peripherally of each ring. Adapted to mesh with the teeth on the rings are rack-bars 86 attached to an actuating piston 87 operating in cylinder 87a, and rack-bar 86' attached to piston 87' operating in cylinder 87b. Rocker arms 84 and 84' are pivoted so as to present each a roller 81d opposite ring 81b and ring 81c. The outer ends of the rocker engage the outer ends of the poppet valves 81a and 81a' which control the flow of fluid fuel through the injectors.

Fixedly disposed at the opposite ends of jacket 51 are a pair of cylinders 105 and 105a in which

operate pistons N and N' having tubular piston rods P and P' closed at their points of attachment to the adjacent walls **43** and **45** respectively of compressor cylinders **40** and **41** respectively. There are fixed tubes D, D', extending each concentrically in each cylinder **105** and **105***a* over which each piston rod N, N' with its tubular piston P, P' slides as it moves in its enclosing cylinder. The tubes D, D' extend beyond these cylinders, tube D connecting with the sump **92** while tube D' connects with another sump **92**. A pipe C connects the inner end of cylinder **105** with cylindner **87***a*, Figs. 9, 11 and 12, while pipe C' connects inner end of cylinder **105***a* with the cylinder **87***b*. Pipe C also connects with a pump **91** which connects by pipe **91'** to an accumulator cylinder **90**, while pump **91** has a pipe **92'** which connects it to sump **92**. Similarly pipe C' has the connection to a pump **91**, which pump has a pipe **92'** extending from a sump **92** and also a pipe **91'** which connects to an accumulator cylinder **90**.

Oil or any other suitable fluid fills each cylinder **105**, **105***a*, but not at the same time. In Figure 3 at S is shown a port in tube D, just in advance of the final outer position in which piston N has moved; similarly tube D' in cylinder **105***a* has a similar port S in the same relative position. When the pistons N, N' are in the positions shown in Figures 3 and 11, piston rod N' and its tubular piston P are encased by cylinder **105***a* and there is no oil in this cylinder. In cylinder **87***a* piston **87**, Figs. 9 and 11, is in down position when piston N is in the position at the left in cylinder **105** and there is oil F in the bottom of cylinder **87***b* whose piston **87'** is at the top end of this cylinder.

It may be desirable to cushion the hollow pistons **38** and **39** as they reach the end of their stroke in the compressor cylinders in either direction. In Figure 10 are disclosed the details. An annular flange **98'** extends outwardly from the wall **96** of the compressor cylinder **40** and cooperates with an inner spaced concentric band H' in defining an annular chamber **97** closed at its outer end but communicating at its inner end with the interior of the compressor cylinder **40**. There is a piston **98** movable in this chamber **97**—the latter being reduced in width where it opens out into cylinder **40** and in this restricted annular orifice moves a flange **98***a* formed on piston **98**. A compression chamber **99** is provided between piston **98** and the wall **96** of cylinder **40**. Check valves Y are carried by this wall. The band H' is formed with a series of ports **100** which communicate with compression chamber **99**.

I will now describe the operation of the machine, in all of its varied forms.

Referring to Figure 4, the compressed air delivered by tube **9** from the compressor cylinder **14** has already been compressed in the chamber between inwardly-moved pistons **4'** and **3'** and reacts now, under influence of pressure, to move these pistons outwardly, and in doing so piston **3'** moves to the right outwardly carrying yoke **7** with it, hence moving tube **9** to the right as shown in Figure 5, and as this tube moves by means of its yoke **6** it moves outwardly disposed piston **4** inwardly of its cylinder towards the right. But piston **4'** is also moved outwardly of its cylinder towards the left, and as it moves, carries yoke **8** along with it, thus causing compressor cylinder **14** to move to the left, hence causing piston **3** to move towards the left inwardly of its cylinder. Pistons **3'**, **4'** are making an expansion stroke while pistons **3**, **4** thus make a compression stroke. As pistons **3'**, **4'** expand compressed air is drawn in as indicated by the arrows, into admission ports T which have been opened by appropriate mechanism for this purpose. As pistons **3**, **4** move towards each other, these admission ports T close. As the pistons reach the end of their expansion stroke the fluid is exhausted out of ports U.

As tube **9** moves to the right and cylinder **14** moves towards the left, hollow piston **11** carried by tube **9** and end wall **10** carried by cylinder **14** move away from each other, while piston **11** and end wall **10'** move towards each other. In moving to the right air is being sucked in by the ports controlled by valves A, which valves have opened because there is a suction being created in cylinder **14** between wall **10** and piston **11**. This is shown by arrows in Figure 5. The suction has closed valves E on piston **11**, but inasmuch as piston **11** is compressing air in cooperation with wall **10'** as they approach, valves F in piston **11** are opened so the air is forced into hollow piston **11** and injected by way of ports **12** into tube **9** and thence it passes by way of ports **13** into jacket **15** and may be led off for any desired use. The valves A and F which opened during this stroke of piston **11** to the right, close when this piston moves in a counter direction shown in Figure 4, while the previously closed valves E are now open, and as pistons **10** and **11** are now compressing air, the latter enters into hollow piston **11** again and is ejected by tube into the jacket by the means just now set forth. The action of the movable parts of this compressor is thus double-acting.

Now the result of the movement of these parts is to stagger the strokes of the pairs of double pistons contained in the cylinders shown in Figures 4 and 5, which are arranged oppositely to each other. This is also true of the pistons shown in Figure 8. In this figure the compressed air delivered out of the compound high and low pressure compressor is cooled by the coils of radiator **23** where it passes through tube **9** enroute to the motor cylinders.

In Figure 8, the direction of movement of the mobile parts is as follows: pistons **18**, **19** and **20** together with cylinder **17** are just completing their movement towards the left, while tube pistons **21** and **22** are completing their movement towards the right. In doing so pistons **21** and **20** compress air, closing intake valves H in cylinder **16** until piston **21** has passed, thereby opening valves S' and closing valves T in hollow piston **21**, causing compressed air to flow by way of ports **26** out of piston **21** into tube **9**, to be cooled by radiator **23** on its way out to ports T' into small hollow piston **22**. Pistons **21** and **19** are separating so atmospheric air enters as valves H open after these pistons have passed thereon, this being the admission stroke in the low pressure area. As this takes place pistons **18** and **22** are also separating, as pistons **22** and **19** approach and are compressing air in cylinder **17**, so a suction is created between pistons **18** and **22**, and the compressed air in hollow piston **22** which came out of hollow piston **21** rushes from piston **22**, unseating check valves M' and enters chamber **17**, this being the admission stroke in the high pressure section or stage—valves **27** in piston **18** closing at this time. Now, as pistons **22** and **19** approach, the air they

compress causes valves O in hollow piston 22 to close, so this compressed air is forced out of chamber 17 through ports controlled by valves 27 in hollow piston 19, as the latter have been forced open by the air pressure. The compressed air is now driven out of hollow piston 19 through ports into the annular space 29 surrounding chamber or cylinder 17, and out through delivery pipes 24 into jacket 15 for feeding the engine cylinders and also for any other useful purpose requiring compressed gas.

During the reverse strokes of the compressor cylinder pistons and the tube pistons those valves previously open are closed and those previously closed are open, so now the air ultimately increased in compressive power when compressed in chamber 17, will be driven out through the vents controlled by check valves 27 in hollow piston 18, which valves are open for this purpose; hence the compressed air will be forced out of vents 28 into the annular space 29 and thence out of delivery pipes 24 to the jacket 15 for further supplying the engine cylinders.

The operation of the power plant shown in Figure 3 where the two circular groups of engine cylinders are arranged in parallel relation instead of in staggered relation as in Figures 4 and 8 will now be explained.

Injection of hot combustible gases or other fluid fuel will take place in the narrow combustion chamber between the closely contiguous ends of the pistons 35 and 61, Figs. 3 and 11. When these parts are thus positioned, pistons 62, 34 have reached the limit of their expansion strokes, the cam 85, (Fig. 9) on oscillating ring 81b has receded from a position under the roller 81d of rocker 84, while the cam 85 of the other oscillating ring 81c engaged roller 81d of the rocker 84', and during the movement of this cam, the rocker has been tilted, causing poppet valve 81a' in injector 83' to be pressed open, thereby admitting hot gases into the combustion chamber between pistons 35 and 61. At this time poppet valve 81a in injector 83 is closed under influence of its spring (not shown).

It will be seen that rack bar 86 meshing with teeth M on ring 81b has oscillated this ring in a direction to move cam 85 out of the range of rocker 84, by moving downwardly in cylinder 87a, which action causes piston 87 on this rack bar to eject the oil or other fluid out of this cylinder into pipe C and it enters cylinder 105, as piston N therein is moved toward its extreme left hand position. The pump 91 keeps up a constant circulation of this oil or fluid in all the parts where same is needed, this excess oil delivered through pipe C being discharged to sump 92 through port S in pipe D.

While this is taking place, and as compressor cylinder 41 also moves towards the left, piston N' in cylinder 105a has moved to its extreme left end position in this cylinder, thereby closing port S in pipe D' and ejecting the oil or other fluid F out of cylinder 105a into pipe C' by which it is conducted into cylinder 87b, causing this oil as it rises in cylinder 87b to lift the piston 87' operating therein, with the aid of the pump pressure, so that as piston 87' moves upwardly, so does ring 81c, causing its cam 85 to engage and trip rocker 84' into poppet-valve opening position.

As hot fluid fuel is introduced into the firing or combustion chamber of cylinder 33' and there intermingled with the highly compressed air introduced from the air compressors the fuel ignites and the resulting combustion gases exert a strong expansive force, thereby driving pistons 35 and 61 in opposite directions from the center towards the ends of this cylinder, as illustrated in Figure 12. Fins on the cylinder and on piston connector 36b (see Fig. 3) tend to radiate some of the heat from these cylinders into the compressed air atmosphere in the chamber 51. As these pistons separate, piston 61 impels link 63, causing it to move compressor cylinder 41 to the right as shown by the arrows in Fig. 12, and as this cylinder moves, its connecting rod 46 pulls the other cylinder 40 in the same direction to the right. Connecting rod 46 carries the rack bar 71 which meshes with fixed pinions 72 and 73 so these pinions are turned counter clock-wise, and as these pinions mesh also with rack bar 70 carried by tube 37, this rack bar is moved in the opposite direction, to the left as shown in Fig. 3, thereby insuring synchronous movement of tube 37 in the same direction towards the left. However, the main propulsive force for causing this movement is coordinately produced by the piston rod 36b, since it is impelled towards the left by piston 35 as it moves outwardly and away from piston 61 in the firing or expansion stroke. As previously noted the piston rod 36b is connected to the yoke 36 which is connected in turn to the tube 37 carrying the hollow pistons 38 and 39. The yoke also carries the rack bar 70 which, being responsive to forces imparted through the yoke 36 or through the pinions 72 and 73, insures that the relative movements of the tube 37 and the connected compressor cylinders 40 and 41 will be coordinated and synchronous.

It will be seen from Figure 3 that, before injection of fluid fuel occurs between contiguous pistons 35 and 61, the ports 58 of their cylinder 33' are exposed for communication with air chamber 57 through the interior of this cylinder at the rear of the advanced piston, these ports having just been uncovered by piston 61. As a consequence air at the pressure of the surrounding atmosphere will fill the space 57. The quick outwardly-directed movement of this piston 61, when expansion of the gases takes place, first closes the ports 58 and then successively uncovers the ports 56 and 53, and finally reopens the ports 58 as the piston 61 moves to the extreme right, to a position corresponding to that of piston 62 in Fig. 3. When the extreme position is reached, gases at the relatively high pressure obtaining in the firing chamber will pass into the space 57 causing the valvular members 55, 55a to slide lengthwise of the cylinders. In Fig. 3 of the drawing the members 55, 55a are shown in the positions assumed by them at the end of the previous firing or expansion stroke of the pistons 35, 61 and which position is maintained until these pistons have reached the limit of their compression stroke and the ports 58 have been again exposed, that at the right communicating with the surrounding atmosphere and that at the left communicating with the firing chamber of cylinder 32'. Owing to the difference in pressure of the atmosphere and the gases in the firing chamber of cylinder 32', as the ports are uncovered and high pressure gases pass into the space 57 behind the valve 55 at the left of Fig. 3, they will urge the valves 55 and 55a, which are tied together by the link 59, to the right, thus establishing an outlet of the gases from the firing chamber of the cylinder 32' through port 56 and the opening G in valve 55 to the discharge passage 54.

As the piston 61 moves sufficiently to the right to open the ports 53, the opposing piston 35 moves

correspondingly to the left and eventually the piston 35 uncovers the air inlet ports 52. It will be observed, however, that the ports 52 and 53 are relatively so positioned with respect to the distances travelled by the opposing pistons that the discharge ports 53 will have partially opened before the air inlet ports 52 begin to become uncovered. This will insure that part of the combustion gases developed in the firing step shall have been permitted to discharge to the exhaust chamber 54 and that the pressure of the remaining gases will have been greatly reduced before the air inlet ports are opened and compressed air from chamber 51 is permitted to pass into the cylinder through the ports 52. During the part of the outward stroke of the pistons 61 after the ports 56 and 53 have been uncovered and until the piston approaches the extreme end of its stroke, the combustion gases are permitted to pass outwardly from the firing chamber through both the supplementary ports 56 and the main discharge ports 53 and during the latter part of this intermediate part of the stroke after the air inlet ports 52 have been uncovered, compressed air from the chamber 51 will flow into the firing chamber displacing the combustion gases and thus perform the necessary scavenging operation. When the piston 61 passes to the end of the expansion stroke it finally uncovers the previously covered port 58. At this instant, the corresponding port 58 at the left of the cylinder 32' will be uncovered by the piston 62 which is travelling to the right and thus the gases previously confined in the space 57 behind the valve 55 will be permitted to escape until atmospheric pressure is attained therein. At the same time gases at the pressure obtaining within the firing chamber of the cylinder 33' will enter the space 57 at the rear of the valve 55*a* and cause the latter to shift to the left, carrying with it the valve 55. In this way communication is established through the supplementary port 56 and the passage G in the valve 55*a* and this passage will remain open until the pistons 35 and 61 have been brought to the limit of their compression stroke, as shown in Fig. 3, whereupon the valves 55 and 55*a* will be reciprocated to the right.

It should be borne in mind that just after sleeve 55 has thus been moved to the right, due to the uncovering of the port 58 and entry of compressed gases into space 57, piston 62 in cylinder 32' is also moving to the right, and as piston 61 which is sliding in cylinder 33' is covering ports 58 thereof piston 62 in cylinder 32' is sliding to the right therein covering progressively ports 58 and exhaust ports 53 and 56, and at the same time piston 34 of the same cylinder is approaching piston 62, and is covering air admission ports 52 of this cylinder. During the portion of the compression stroke before the piston 34 completely closes the air inlet ports 52, compressed air supplied by the compressor cylinders to the chamber 51 will enter through the ports 52, sweep through the cylinder and out through the discharge ports 53, thereby exerting a cooling effect on the cylinder walls and the pistons. After the piston 62 completely closes exhaust ports 53 some of the compressed air previously admitted into cylinder 32' through ports 52, and which is being compressed by the approaching pistons 62 and 34, is now free to emerge out of open ports 56, openings G in sleeve 55 and discharge chamber 54 to the inlet connections of a turbine or other prime mover. As a result, all of the admitted air which would otherwise be subjected to a full compression stroke of

the approaching pistons 62 and 34 and confined between them, is not allowed to be compressed and retained in the firing chamber. Accordingly while these pistons in cylinder 32' make a full expansion stroke, they make a restricted compression stroke in the sense that the amount of compressed air retained to partake in the firing of the fuel charge is reduced, and, therefore, the degree of heat that would otherwise be developed in the compression stroke is reduced. The same operation and effect of the pistons 62 and 34 are undergone by pistons 35 and 61 of cylinder 33' when it becomes their turn to make a compression stroke. In the latter event sleeve 55 will be restored, by means of the instrumentalities set forth, to the position it occupies in Figure 3, because, as pistons 62 and 34 approach the limits of their expansion stroke and piston 62 passes ports 58 of cylinder 32', the gas in the chamber 57 at the left with which the port 58 registers is discharged, thus causing sleeve 55 to be moved back into chamber 57 to the left. As this takes place connecting rod 59 in moving to the left pulls sleeve 55*a* in cylinder 33' to the left to the position it has in Figure 3.

As the pistons 38 and 39 approach the compressor cylinder walls which cooperate therewith, the air is compressed between them, and as the same pistons and walls of the compressor cylinders separate air is admitted between them. In Figure 12 it is seen that pistons 38 and 39 have changed their relative positions in cylinders 40 and 41 as illustrated in Figure 11. As these mobile elements are thus moving in the counter directions, cylinder 40 is impelling piston N of cylinder 105 towards the right therein, while cylinder 41 is pulling piston N' of cylinder 105*a* also towards the right therein, but while piston N is ejecting the oil out of its cylinder, by way of pipe C into cylinder 87*a*, piston N' is opening cylinder 105*a* for the admission of oil out of cylinder 87*b* by way of pipe C'. As the oil rises in cylinder 87*a* it raises piston 87 therein, hence elevating the rack bar 86, which in turn engages the teeth M of ring 81*b* and moves the ring upwardly, thus bringing cam 85 associated with this ring into the position shown in Figure 12 where it engages rocker 84, trips or tilts it, causing poppet valve 81*a* in injector 83 to open, just at the time pistons 62 and 34 of cylinder 32' have approached and define the constricted area or combustion chamber into which hot gases or other fluid fuel will be delivered from the injector. As this is taking place, and as piston N' moves to the right in cylinder 105*a*, the suction created in back of it, aided by pressure maintained by pump 91 induces oil to flow out of cylinder 87*b* into cylinder 105*a*.

Figure 9 shows a pinion 107 mounted on a fixed rod or shaft 106, which shaft is associated with a torsional volute spring coiled around it (not shown) with the effect that when ring 81*b* or 81*c*, as the case may be, has moved in one direction to retract its cam from engagement with its rocker 84, as a result of rack bar 86 or 86' of either cylinder 87*a*, 87*b* meshing with the teeth of this ring, the teeth M of the ring associated therewith, meshing also with pinion 107 will rotate it in a direction operative to wind up or tension the volute spring engaging shaft 106 of this pinion. It follows that this particular rack bar, say rack bar 86' of cylinder 87*b* of Figure 12, when resistance against its piston 87' is progressively being diminished due to the oil F being withdrawn out of cylinder 87*b*, is reacted upon by ring 81*c* which has been impelled by pinion 107 to

reverse its former direction of movement, because the torsional spring engaging its shaft 106 is now free to recoil and produce this reverse movement. Thereupon as ring 81c moves downwardly its teeth M, meshing with rack bar 86, impel this rack bar downwardly in cylinder 87b until it reaches the end of its movement in the bottom thereof, as shown in Figure 12. In this way the oil F has been transferred from cylinder 87b to cylinder 105a, and oil F' has been transferred out of cylinder 105 to cylinder 87a. Pistons 35 and 61 are now fully separated to the limit of their expansive stroke, and pistons 62 and 34 fully brought to the limit of their expansive stroke, so now another cycle of the engine takes place in the manner already explained.

The compressed air of cylinders 40 and 41 in Fig. 3 is driven out during the counter movements of these mobile assemblies by way of the ports 49 from within the hollow piston 38 and 39 into tube 37 from which it emerges into feeding jacket 51. Under influence of compression of air between the pistons 38 or 39 and walls 42 or 45 of cylinder 40 or 41, as the case may be, valves 48 in pistons 38 and 39 open to discharge the compressed air, as just explained, into tube 37 while valves 47 remain closed. When the parts are moving in the direction where they come to rest at the extreme right of cylinders 40 and 41 in Figure 11, this action is reversed. Now piston 39 and the opposite wall 44 of cylinder 41, and piston 38 and opposite wall 43 of cylinder 40 are approaching to compress air. Thereupon valves W of the pistons 38 and 39, which were previously closed during the stroke occasioned by separation of the particular pistons and cylinder walls just mentioned, now open, while valves 48 of these pistons previously open now close. Again the compressed air is ejected out thru the open ports 49 controlled by valves W and 48, into tube 37, thence being delivered to the firing cylinders.

It will be seen in Figure 3 that tube D has a leak or opening S so located that it will be uncovered by piston N of cylinder 105 when this piston is in its extreme left position in the cylinder. A similar opening S in the other tube D' is located in the same relative position in cylinder 105a as opening S is in cylinder 105, with relation to the piston N' of cylinder 105a when the latter piston occupies the same position in cylinder 105a that piston N is shown to occupy in its cylinder 105. But in the position of piston N' actually shown in Figure 3, opening S of tube D' is closed by the tubular portion P' of such piston N', whereas opening S of tube D is uncovered by piston N.

It may sometimes happen that either of the tube pistons 38 or 39 will come too close so as to collide with a wall of either compressor cylinder 40 or 41. To prevent this I have provided shock absorbers as an optional feature of this invention. I have also provided means, for the elimination of this hazard, of curtailing the pressures in the particular compressor cylinder in which the affected piston operates.

It should be noted that the suspension and synchronization members formed by the racks 71 and 70 and the pinions 72 and 73 are only designed to distribute the weight of the movable parts when the machine is subjected to unequal accelerations parallel to its axis. When such accelerations cease to exist said members are stressed only by secondary forces that may occasion asymmetry in the functional gliding of the machine elements.

The constantly operated pump 91 associated with each hydraulic cylinder 105 or 105a is responsible for keeping the pressures in the coordinated cylinders, 105, 87a and 105a, 87b adequate to sustain normal as well as abnormal functioning of the machine shown in Figure 3. Reserve pressures are maintained in each of the fluid accumulators 90 for constantly making an adjustable contribution of extra fluid where needed, under influence of the operating pump 91, as well as of the regulator valve or cock 89.

The travel of the compressor cylinders, and consequent movements of the pistons N and 87, on the one hand, and N' and 87' on the other hand is predetermined in accordance with definite pressure valves, valve 89 controlling the adjustment of fluid pressures to meet such valves, while pump 91 and accumulator 90 furnish the reserve pressure for this purpose. It follows that should the compressor cylinders and compressor pistons travel greater distances than they have been set in advance to traverse, an extra amount of liquid or oil will be forced into the appropriate one of the coordinated sets of cylinders as a result. Due to the presence of the safety ports S in the tubes D and D', when the compressor cylinders have stroked their utmost limits at either end of the machine, then that piston N or N', as the case may be, which has moved to its extreme left position in cylinder 105 will have uncovered ports S. Thereupon the increased amount of oil that is being distributed into the space 76 of cylinder 105, is allowed to by-pass out of ports S through tube D so that part of this oil is free to discharge and return to the sump or tank 92 where it is picked up by the pump 91 and recirculated. This relieves the sudden augmentation of pressure due to inordinate feeding of oil into the unadjusted areas of the hydraulic cylinders. This compensation is automatic.

Where the shock absorbing device is used as shown in Figure 10 it operates as follows. When tube piston 38, is moving to the right in cylinder 40, while the cylinder is moving contrariwise, a suction is created which opens valves Y in this cylinder and air rushes into the cylinder 40 through the space within the annular ring H'. The air rushing through this space creates a suction in the pocket 99 connected by opening 100 with the said space provided by the ring H'. This suction pressure in the pocket 99 effects movement toward the right in Fig. 10 of the member 98 having portions 98a projecting into the interior of the compressor cylinder 40. During the counter stroke towards the left of the piston 38, when the hazard exists that it might collide forcibly with cylinder head wall 96 of cylinder 40 when said head and piston 38 are approaching, it will be seen that air is compressed in the compression chamber between these movable parts, which action opens valves 48 of piston 38, but closes valves Y in wall 96 in this cylinder. When the plane surface of piston 38 draws very close to wall 96 it will encounter the barrier of flange 98a of piston 98', thereby forcing this piston back to normal position in its chamber, but under air resistance due to piston 98' compressing air in its chamber. This acts as a cushion which absorbs the shock of this stroke of the movable approaching parts by slightly slowing them down.

It will be seen in Figure 9 that fuel injection chamber 82 therein shown may be made to connect with oppositely arranged firing cylinders, so that each single fuel injector 83 may feed two

such cylinders at the same time. This device may, if desired, be replaced by other mechanical arrangements and especially by approximately calibrated springs lodged in recesses arranged in the thicknesses of the pistons or cylinder walls.

From the foregoing it will be clear that the arrangement made for the compressors of the machine is very compact; it reduces to a minimum the number of members to insure tightness, and on the other hand it secures perfect identity of the stresses by the gases on the homologous elements of the two moving bodies.

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

1. In an apparatus for generating and supplying heated and compressed gases to a gas turbine or other prime mover, in combination, oppositely arranged aligned cylinders, a pair of oppositely movable pistons in each of said cylinders, means causing the pistons of one cylinder to separate as those in the other cylinder approach, said cylinders having inlet passages at the adjacent ends and exhaust passages at their opposite ends, the fully separated pistons of one cylinder being located beyond the respective inlet and exhaust passages of their enclosing cylinder, while one of the contiguous pistons of the other aligned cylinder covers the exhaust passages thereof, each of said cylinders having auxiliary exhaust ports in advance of the exhaust passages covered by that piston which has covered the exhaust passages, and means whereby as the approaching pistons near the center of their cylinder one of them will close the exhaust passages thereof as the exhaust passages of the other cylinder are uncovered, the auxiliary exhaust ports opening as the last mentioned exhaust passages are closing.

2. In an apparatus for generating and supplying heated and compressed gases to a gas turbine or other prime mover, in combination, internal combustion cylinders arranged in axial alignment, a pair of opposed pistons in each cylinder, compressor cylinders having links attached to the outer-end pistons of such cylinders for joint movement therewith, compressor pistons in said compressor cylinders connected for joint movement with each other and with the inner end pistons of said motor cylinders, so that when the pistons of one motor cylinder approach each other the pistons of the other motor cylinder separate and the compressor pistons are respectively at the outer and inner ends of said compressor cylinders, said cylinders

having inlet and exhaust passages uncovered by the separated pistons, and auxiliary exhaust ports which are closed in the mentioned positions of both sets of pistons, the separated pistons approaching each other as the compressor pistons reverse their positions in the compressor cylinders to close the inlet and exhaust passages, while the other pistons separate, and means actuated by one of the separating pistons to close its auxiliary exhaust ports while one of the approaching pistons covers its exhaust passages, and means whereby the auxiliary exhaust ports are automatically opened to the path of movement of the approaching pistons.

3. In an apparatus for generating and supplying heated and compressed gases to a gas turbine or other prime mover, in combination, oppositely movable interacting compressor elements, internal combustion engine cylinders having opposed pistons therein, said cylinders having at opposite ends exhaust and inlet passages, and in advance of said exhaust passages auxiliary exhaust ports, a slidable sleeve on said cylinder having an opening designed to register with said exhaust passages and exhaust ports collectively or separately and means causing said sleeve to act in time with said pistons, whereby said sleeve covers said exhaust ports except when one of said pistons closes the exhaust passages when it moves to uncover these ports to permit the other piston to expel exhaust out of these ports.

PIERRE ERNEST MERCIER.
ERNEST FREDERIC MERCIER.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
658,367	Haynes et al.	Sept. 25, 1900
995,857	Fullagar	June 30, 1911
1,174,560	Fullagar	Mar. 7, 1916
1,514,476	Still	Nov. 4, 1924
1,930,786	Witkiewicz et al.	Oct. 17, 1933
1,950,063	Pescara	Mar. 6, 1934
2,090,709	Steiner	Aug. 24, 1937
2,115,921	Steiner	May 3, 1938
2,132,083	Pescara	Oct. 4, 1938
2,139,425	Steiner	Dec. 6, 1938
2,159,197	Barra-Frauenfelder	May 23, 1939
2,222,260	Janicke	Nov. 19, 1940
2,241,957	Pescara	May 13, 1941

Certificate of Correction

Patent No. 2,466,255 April 5, 1949

ERNEST FREDERIC MERCIER ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 4, lines 71 and 72, strike out the word "device"; column 9, line 7, strike out "rod" and insert the same after "piston", line 8; line 30, strike out "rod" and insert the same after "piston", line 31; column 10, line 2, for "are making" read *thus make*; line 3, for "thus make" read *are making*; line 70, for "out of" read *from*; line 71, for "from" read *out of*; column 14, lines 65, 66, and 67, for "of this ring, the teeth M of the ring associated therewith" read *of the rack associated therewith, the teeth M of this ring*; column 16, lines 65 and 68, for "98'" read *98*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 10th day of January, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.