Sept. 24, 1957 B. W. FOSTER 2,807,136

PISTON TYPE COMPRESSOR

Filed April 23, 1951 4 Sheets-Sheet 1

Fig. 1.

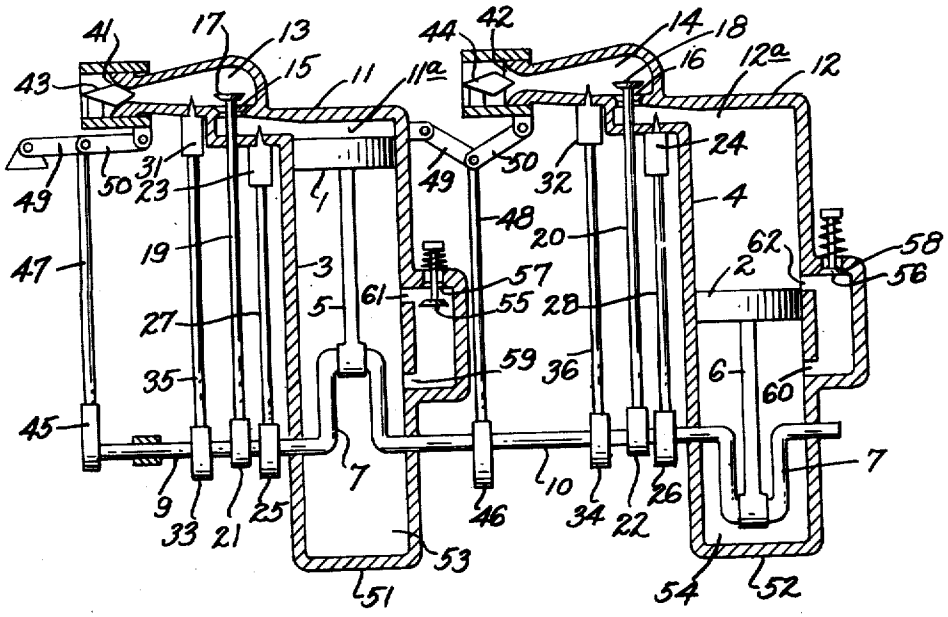
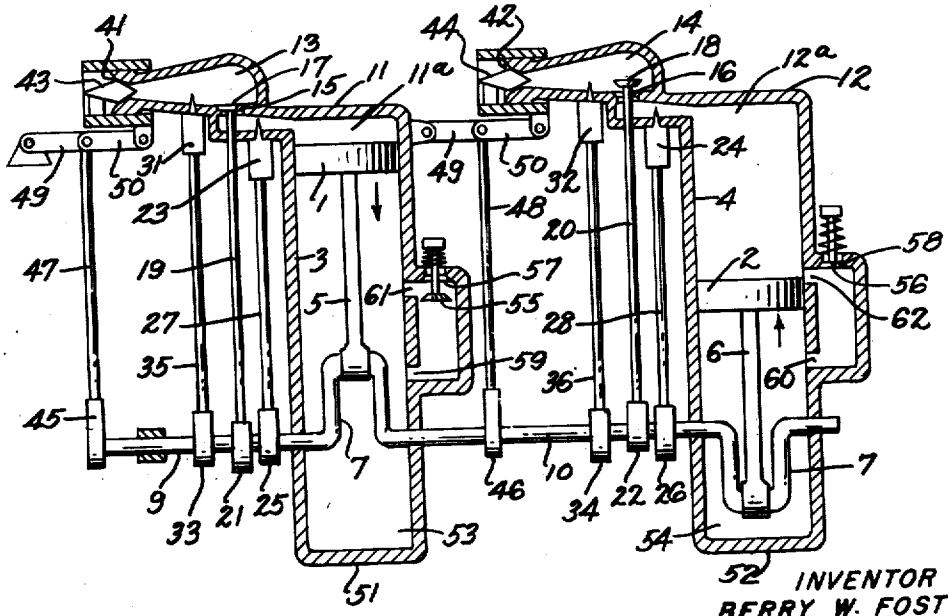


Fig. 2.



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PISTON TYPE COMPRESSOR

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Fig. 3.

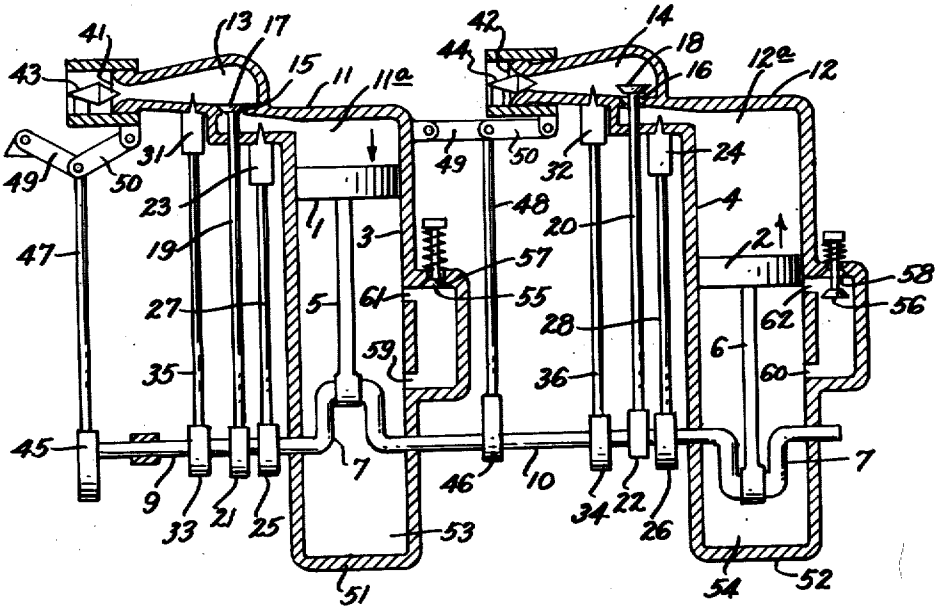
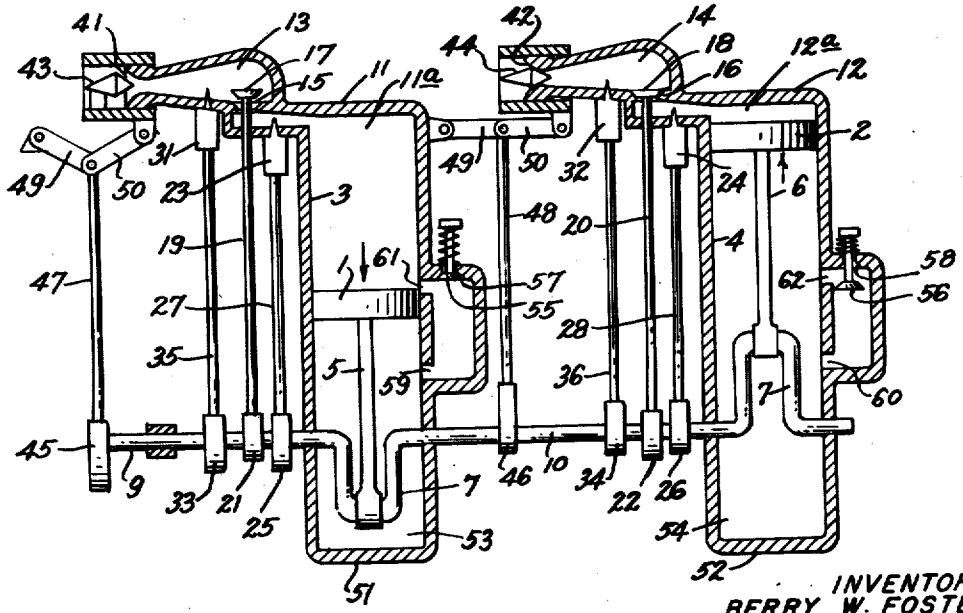


Fig. 4.



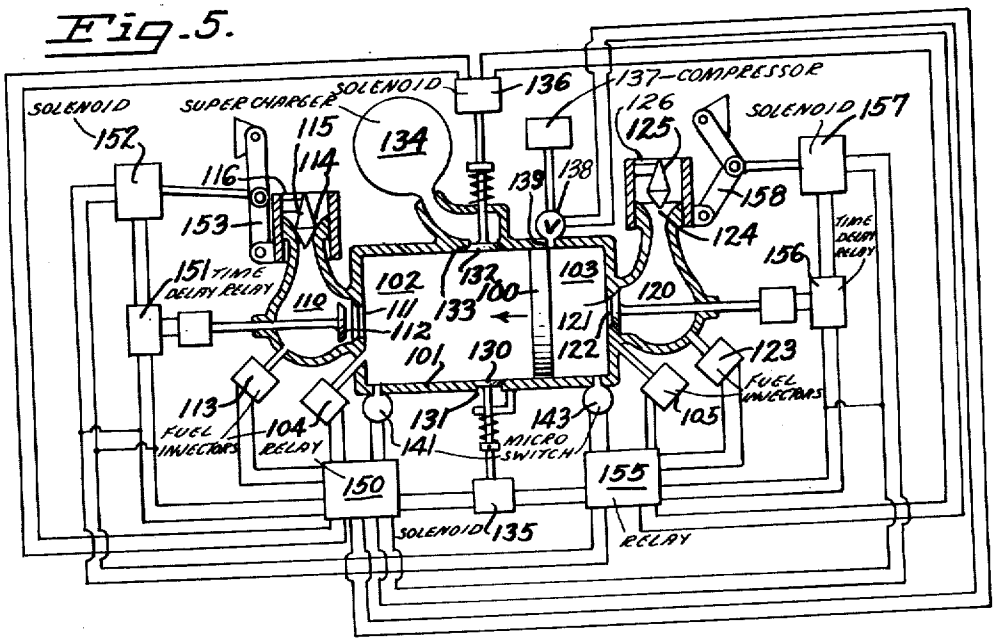
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PISTON TYPE COMPRESSOR

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Fig. 5.



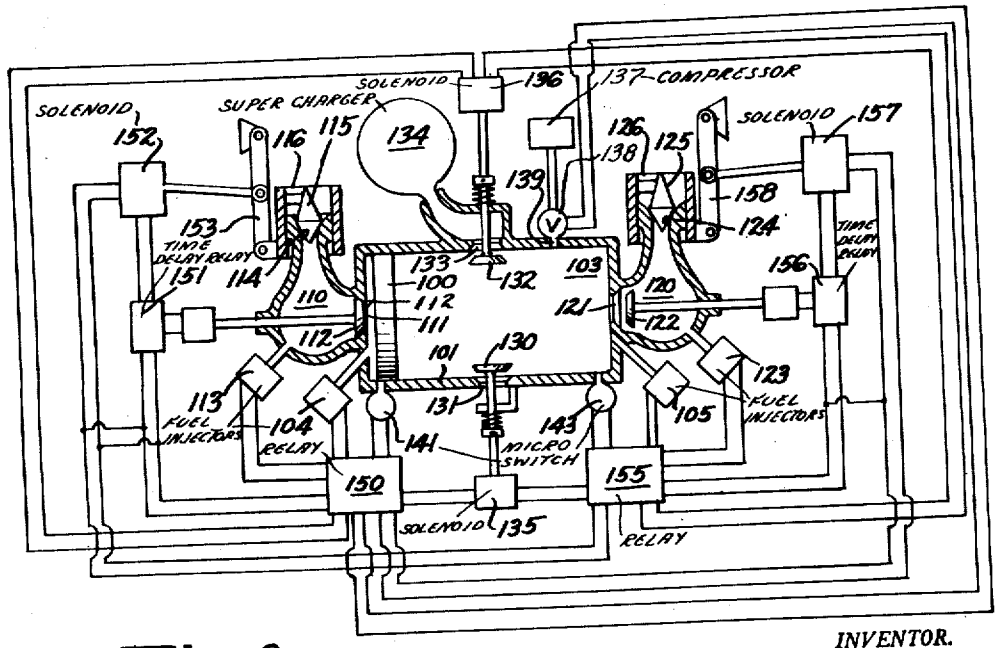


Fig. 6.

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PISTON TYPE COMPRESSOR

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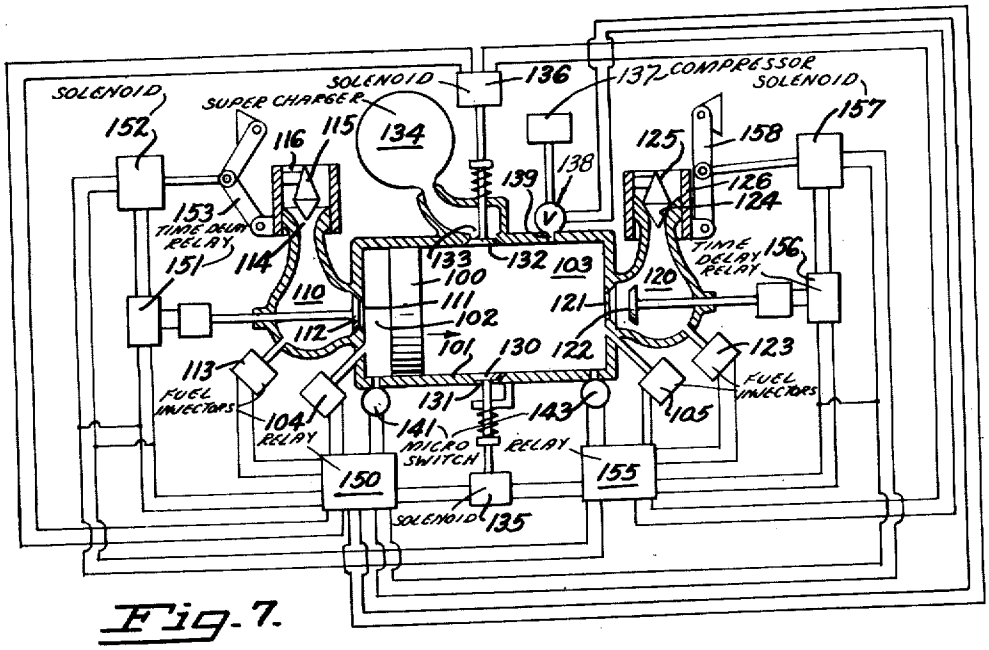


Fig. 7.

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United States Patent Office 2,807,136 Patented Sept. 24, 1957

2,807,136

PISTON TYPE COMPRESSOR

Berry W. Foster, Inglewood, Calif.

Application April 23, 1951, Serial No. 222,368

5 Claims. (Cl. 60—35.6)

This invention relates to an improved compressor of the piston type and to a method of operating compressors and associated mechanisms.

A feature of the invention is the division of the compressed gas into two isolated portions. The internal power that runs the compressor is obtained by burning fuel in one of these two portions. The other portion represents the output of the compressor and the compressed gas therein may be stored, expanded, or be fueled and exploded according to the way the compressor is being used.

For example, my novel piston compressor may be part of a jet engine. In this case fuel is burned in both of the isolated portions of the compressed gas. The energy in the one part operates the compressor, while the energy in the other part propels the airplane or other vehicle.

Heretofore, all the heated gases were expanded together, usually in one chamber, whether the engine was of the piston type or of the turbine type. In the present invention only a portion of the total amount of fuel is burned in the compressor cylinder or in a chamber that is in commuincation with it at the time of burning. The rest of the fuel is burned in an isolated second portion of compressed gas outside the compressor cylinder. The result is an important simplification of engine operation and greater efficiency in the use of its power.

Suppose that the volume of the compressed gas that is isolated outside the compressor cylinder on each compressor stroke is a, and that b is the volume of the compressed gas isolated in the cylinder chamber at the moment of isolation and the addition of energy. Then, if the unit masses of the compressed gas in a and b are m_1 and m_2 respectively, the total mass M of the compressed gas will be: $M=am_1+bm_2$. The energy in the mass bm_2 should be as near as possible to the exact amount which, when energy is added, will compress a second mass M^1 to the same compression ratio, by driving the piston back across the cylinder at the opposite end of the cylinder, or by driving a second piston in a second cylinder by transmitting the power from the first piston through a rod and crank. The output energy am_2 is available as external power, and the operating efficiency of the engine is at its peak when am_1 is large in proportion to bm_2.

The invention may also be used to supply a storage tank with compressed gas. Again, at each stroke (or each alternate stroke) a portion of the compressed gas is isolated, energy is added, and the resultant expansion of this portion of the gas drives the compressor piston, while the rest of the compressed gas is conducted into the storage tank. The energy in the gas that drives the piston is sufficient to move it toward the other end of the cylinder and compress a like amount there.

My novel compressor unit may employ a free piston instead of a piston having a connecting rod and crankshaft, but the invention differs from other free-piston engines in several particulars, including the following: (1) The compressor air is separated from the external-power air before heat is added, so that only a fraction of the total amount compressed is expanded in the compressor engine. (2) The external-power air performs no work on the piston. (3) The compressor air does all the work on the piston. (4) The piston itself does no external work, although the heated gases which are expanded in the compressor engine may do some external work if that is desirable. Usually, however, this is kept to a minimum.

In all modifications of the invention, the compressor piston preferably does no external work and supplies none of the external power, acting only: (1) to compress the gases, and (2) in some instances to precompress the intake air to a small pressure ratio for scavenging the burnt gases. All or practically all the external power is supplied by the separate portion of the air which is isolated from the compressor cylinder.

Other objects and advantages of the invention can be better understood from the following description of several embodiments thereof illustrated in the accompanying drawings. However, it is to be understood that the drawings and descriptions are illustrative only and are not definitive of the invention, the scope of which is stated in the appended claims.

In the drawings:

Fig. 1 is a diagrammatic view of one form of a jet-type engine employing a compressor embodying the principles of this invention. The engine shown here has two cylinders whose pistons are joined on a common crank shaft. This view shows the engine being started with the piston at the left approaching the head end of its cylinder, while the other piston is approaching the crank end of its cylinder.

Fig. 2 is a view similar to Fig. 1, with the pistons now moving in the opposite directions, and with the valves and other parts in their proper position for this stage of the cycle.

Fig. 3 is a view similar to Fig. 2, with the pistons further advanced on this stroke, and with the valves and other parts in the position which they then assume.

Fig. 4 is a view similar to Fig. 1, with the pistons in positions approximately the extreme opposites from the Fig. 1 positions.

Fig. 5 is a diagrammatic view of a modified form of engine embodying the invention and employing a single free piston. The engine is shown at the beginning of operation, with the piston moving toward the left.

Fig. 6 is a view similar to Fig. 5, showing the piston at the end of its left hand stroke.

Fig. 7 is a view similar to Fig. 5, showing the piston moving toward the right from its extreme left-hand position.

EXAMPLE 1 (FIGS. 1 TO 4)

A two cylinder engine with crank connection and with precompressors

I shall first show an engine that has a two-stroke, single-acting, compressed-gas generator, with a precompressor. Figs. 1 to 4 illustrate diagrammatically a preferred form of this type of embodiment of the invention, in which there are two compressor cylinders and two pistons linked together by a common crank shaft. There may be more cylinders and pistons, if desired.

Two pistons **1** and **2** reciprocate in their respective cylinders **3** and **4**. Connecting rods **5** and **6** may join the pistons **1** and **2** to a common crankshaft **7**. The crankshaft **7** is connected to or made integral with a pair of camshafts **9** and **10**. The camshafts **9** and **10** control the engine valves, injectors, and other moving parts, by means of the several cams mounted thereon. Although two camshafts **9** and **10** have been shown for purposes of illustration, one camshaft may be sufficient, or there may be more than two camshafts.

Adjacent the head ends **11** and **12** of the cylinders **3** and **4** there may be jet explosion (output) chambers **13** and **14**. The chamber **13** may be connected to the cylinder **3** by a port **15**. The port **15** may be closed by a valve **17** so as to isolate the output chamber **13** from the cylinder **3**. The valve **17** may be moved into and out of its closed position by the reciprocation of a rod **19**, whose movement is controlled by a cam **21** secured to the camshaft **9**.

The chamber **14** and cylinder **4** may similarly be connected by a port **16**, which is opened and closed by a valve **18**. The valve **18** may be operated by the rod **20** and a cam **22** secured to the camshaft **10**.

Each cylinder **3**, **4** has fuel injector nozzles **23**, **24** located in chambers **11***a* and **12***a*, adjacent to the heads **11** and **12**, and controlled by the camshafts **9**, **10**, through cams **25**, **26** and rods **27**, **28** respectively. The nozzle **23** may inject fuel into its cylinder **3** at approximately the time when the piston **1** reaches the head end of its stroke and after the port **15** has been closed by the valve **17**. Similarly, one half cycle later, the nozzle **24** may inject fuel into its cylinder **4**, when the piston **2** reaches the head end of its stroke and after the port **16** has been closed by the valve **18**. The explosion may be similar to that in a diesel engine, in which no special igniting means are required, or spark plugs or other igniting apparatus may be used if desired. The power obtained from the explosions in the cylinders **3**, **4** is preferably not used externally, at least not to any great degree, but is used to operate the compressor unit.

Similar fuel injectors **31**, **32** may be operated in the explosion chambers **13**, **14** by the camshafts **9** and **10** through respective cams **33**, **34** and rods **35**, **36**. Each injector **31**, **32** fires its respective explosion chambers **13**, **14** after its associated valve **17**, **18** has closed its port **15**, **16**.

When the gas in each chamber **13**, **14** explodes, its explosion products may pass out through exhaust ports or nozzles **41**, **42**. Each exhaust port **41**, **42** is closed during the compression stroke of its associated piston **1**, **2** by a valve **43**, **44** which opens at or just after the firing time. The valves **43**, **44** may be controlled by the camshafts **9**, **10** by means of cams **45**, **46**, rods **47**, **48**, and cranks **49**, **50**.

The rush of exhaust gases out of the nozzles **41**, **42** supplies the external power of the engine. This may be the jet which thrusts forward a direct type of jet propulsion power unit or it may turn a turbine whose shaft operates propellers, or any other desired type of unit may be used.

At the crank ends **51**, **52** of the cylinders **2** and **4**, there may be precompression chambers **53**, **54** respectively. On the crank-to-head stroke of each piston **1**, **2**, a check valve **55**, **56** opens and lets atmospheric or supercharged air into its precompression chamber **53**, **54** through ports **57**, **58**. The air in the chamber **53**, which is compressed on the head-to-crank stroke of the piston **1**, flows around the piston **1** through ports **59** and **61** when the piston **1** is near the crank end **51** (ref. Fig. 4). This pre-compressed air scavanges the burnt gases from the head end of the cylinder, forces them out through the port **15**, scavenges the burnt gases from the chamber **13**, and forces all these burnt gases to exhaust through the port **41**. Likewise, when the piston **2** is at its crank end **52**, compressed air flows into chamber **12** through ports **60** and **62** (ref. Fig. 1), scavenges the burnt gases in the chambers **12**, and **14**, and exhausts it through the ports **16** and **42**.

The operation of the device of Figs. 1 to 4 will now be discussed with reference to the different stages of the cycle illustrated in these drawings.

Referring first to Fig. 1, a conventional starter (not shown) may rotate the crankshaft **7** and move the pistons **1** and **2** past the center of the cylinders **3** and **4** so that at least one of them draws in a fresh charge of air. Here

the piston **1** is arbitrarily shown moving to the head end **11** of the cylinder **3**, and the piston **2** is shown moving toward the crank end of the cylinder **4**. Air is being drawn from a supercharger (not shown) or from the atmosphere into the cylinder **3** through the port **57** on the crank-to-head stroke of the piston **1**. The exhaust valve **44** is unseated from the exhaust port **42**. The valve **43** is keeping the port **41** closed, and the valves **17**, **18**, and **55** are open. Since the engine has not yet been started, the valve **56** is also open, because there is no pressure above the cylinder **2** that would cause the valve **56** to close its port **58**.

Referring now to Fig. 2, the piston **1** is in almost the same position as in Fig. 1, but is moving toward the crank end **51** of the cylinder **3**, and the piston **2** is moving toward the head end **12** of the cylinder **4**. The power is still being supplied by the starter. The valve **17** has closed the port **15**, and the exhaust valve **43** still holds the exhaust port **41** closed. The air intake port **57** has been closed by the valve **55**, and the piston **1** is beginning to compress the fresh air in the pre-compressor **53** at the crank end **51** of the cylinder **3**.

In the cylinder **4**, the intake port **58** has been closed by the valve **56**. The isolating valve **18** is open and the exhaust valve **44** is closed, so that the piston **2** is now compressing gas into both the chamber **12***a* and its associated jet explosion chamber **14**.

In Fig. 3, the piston **1** has moved down toward the crank end **51** of its cylinder **3**. The valve **55** has closed the air intake port **57**, and air is being compressed in the precompression chamber. The isolating valve **17** remains closed, but the exhaust valve **43** has opened the exhaust port **41**.

The piston **2** has moved beyond the port **62**, and the air-intake valve **56** has opened the port **58**. Fresh air is admitted from the atmosphere (or a supercharger) into the pre-compressor **54** through the port **60**. The exhaust valve **44** remains closed, and the isolating valve **18** remains open, so that gas is still being compressed into the chamber **14** and into the head end of the cylinder **4**.

As the piston **1** reaches the position shown in Fig. 4, it is near the end of its head-to-crank stroke. The pre-compressed air in the precompressor **53** passed around the piston **1** through the ports **59** and **61**. It scavenges any stale gases from the chamber **11***a*, ejecting them through the port **15**. It then scavenges all the stale gases from the chamber **13** and ejects them through the open exhaust port **41**. Fresh air is in the upper end of the cylinder **3** and in the chamber **13**, ready for the upward or compression stroke, as soon as the exhaust valve **43** closes, which occurs very soon thereafter.

As the piston **2** reaches the position shown in Fig. 4, near head end **12** of cylinder **4**, the valve **18** closes the port **16**, isolating the output chamber **14** from the cylinder **4**. The valve **18** acts very quickly and within a small fraction of a second thereafter the injectors **24** and **32** force fuel into their two chambers **4** and **14**, preferably simultaneously. The explosion of the gas in the chamber **14** acts to heat the compressed air therein and at this instant the valve **44** (shown closed in Fig. 4) open the port **42**, so that the high energy explosion products rush out of the chamber **14** and pass out through the nozzle **42**, to supply the external power.

At the same instant the heated gas in the chamber **12***a* acts to force the piston **2** toward the crank end **52** of the cylinder **4**, where they were in Fig. 1, the explosion providing sufficient power to compress a like mass of air in the chambers **11***a* and **13** of the cylinder **3** to the same compression ratio. This power is transmitted between the two pistons **1**, **2** by the crankshaft **7**. Preferably the crankshaft **7** transmits no external power, although the engine could be designed so that it would deliver crankshaft power. Preferably, all or substantially

all of the external power comes through the exhaust nozzles **41**, **42**.

At the same time, the movement of the piston **2** precompresses air to a small compression ratio in the chamber **54**. When the piston **2** again reaches the crank end **52** of its cylinder **4** (ref. Fig. 1), the precompressed air in the chamber **54** will flow through the ports **60** and **62** and scavenge the burnt gases through the ports **16** and **42**, and a fresh charge of air will be introduced on the head end of the piston **2**.

Meanwhile, the piston **1** is compressing air in the chambers **11***a* and **13**, and when the piston **1** again moves to its Fig. 2 position, fuel is injected into the chambers **11***a* and **13** by the injectors **23** and **31**, and is exploded a moment later.

The engine is now started, and it will continue to run until the fuel supply is cut off.

From now on, whenever the piston **1** moves to the crank end **51** of its cylinder **3** (its Fig. 4 position) the valve **17** will open the port **15**. The old air will be expelled through the ports **15** and **41** with a fresh charge of air from the precompressor chamber **51** that flows into the chamber **11***a* through the ports **59** and **61**. During this time the power from the explosion in the chamber **11***a* is being used up internally and the power from the chamber **13** is being used externally. When the internal power from the explosion in the chamber is used up, the piston **2** has compressed its air into chambers **12***a* and **14** and the fuel is exploded there. The power from the explosion in the chamber **12***a* is transmitted by the crankshaft **7** to the piston **1**. As the piston **1** moves up to the head end **11** of the cylinder **3** (its Fig. 1 position) it compresses air in the chambers **11***a* and **13**.

The piston **2** acts similarly, one half cycle out of phase with the piston **1**. The power of piston **1** is transmitted through its connecting rod **5** to the crankshaft **7**, then to the rod **6** and the piston **2**. Similarly, the power from the piston **2** is transmitted to the piston **1**. Air is precompressed at the crank end of the stroke by one piston, while the other piston is compressing air at the head end of its stroke.

Whenever the piston **1** reaches the end of its crank-to head stroke (ref. Fig. 1), the chamber **11***a* is isolated from the chamber **13**, and the injectors **23** and **31** cause another set of explosions at this end of the cylinder **3**, which move the piston to the crank end again and the nozzle supplies more external power. One half cycle later, the piston **2** will reach the end of its crank-to-head stroke with similar results.

The power supplied by the explosions in the chambers **11***a* and **12***a* is used solely to operate the compressor, its piston, crankshaft, and valves, and no other power is required for this purpose once the engine has been started. All the power generated in the chambers **13** and **14** may be used externally.

EXAMPLE 2 (FIGS. 5–7)

A free-piston engine with Microswitch or brush switch controls

A two-stroke double-acting compressed gas generator is illustrated by Figs. 5 to 7, which show a modified form of the invention having a free piston **100** and a set of electrical connections controlled by a pair of brush switches (or microswitches).

The free piston **100** reciprocates in a cylinder **101**. When the piston **100** moves to the left, it compresses gases into the left-hand engine chamber **102** and into a left-hand jet explosion chamber **110**. When the piston **100** moves to the right, it compresses gas in the right-hand engine chamber **103** and a right-hand jet explosion chamber **120**. The chambers **102**, **103** may have respective electrically actuated fuel injectors **104**, **105**.

The explosion chambers **110**, **120** may be joined to the chambers **102**, **103** by ports **111**, **121** which are opened and closed by electrically actuated valves **112**, **122**. Fuel may be injected by electrically actuated injectors **113**, **123**. The exploded or expanded compressed gas may be exhausted through ports **114**, **124**, which may be opened and closed by electrically actuated valves **115**, **125**. From the ports **114**, **124** the gases may be exhausted through the jet nozzles **116**, **126**.

An electrically actuated exhaust valve **130** may open and close an exhaust port **131** on one side of the central portion of the cylinder **101**, while a similar valve **132** may open and close an inlet valve **133** on the other side of the cylinder, to admit air from a supercharger **134**. These valves may be controlled by respective solenoids **135**, **136**.

At one or both ends of the cylinder **101** there may be an auxiliary compressor or storage tank **137**, that is used only to start the engine and does no work after the engine is started. The air from the tank **137** may be admitted to the cylinder by a valve **138** that opens and closes a port **139**.

In the engine chamber **102** near the end of the stroke of the free piston **100**, there may be a brush switch or microswitch **141**. A second brush switch or microswitch **143** may be located at the opposite end of the cylinder. These switches **141** and **143** may control the valves through a system of direct-action relays and delayed-action relays.

When the piston **100** contacts the brush switch **141**, a relay **150** may be actuated. If this is the first stroke of the piston **100**, the relay may then close the valve **138** against its port **139**, and no further air will be drawn from the compressor **137** so long as the engine is running and until it is started up again. On every such stroke, the relay **150** may open the exhaust valve **130** and intake valve **132**, by actuating the solenoids **135** and **136**. The old air will be exhausted and a new charge of air supplied. When the piston **100** breaks contact with the switch **141**, it will again act on the relay **150** to energize the solenoids **135**, **136** and close the valves **130**, **132**.

When the piston **100** makes contact with the switch **141**, the relay **150** may also operate to close the valve **112**, isolating the chambers **102** and **110**. The relay **150** may simultaneously actuate the fuel injectors **104** and **113** to send charges of fuel into the chambers **102** and **110**. The relay **150** also may actuate a time-delay relay **151**, which is timed so that the valve **115** will be opened the instant the gases in the jet chamber **110** have been heated. At the end of that short interval of time, the relay **151** may actuate a solenoid **152**, which, through a toggle mechanism **153**, may actuate the exhaust valve **115**. The valve **115** will then open the port **114** and permit the gas to pass out the nozzle **116**.

At the same time, when the piston **100** contacts the switch **141**, it also actuates circuits that open the valve **122** and close the valve **125**.

A relay **155** at the opposite end of the engine, controlled by the switch **143**, may perform in the same manner as the relay **150**, the wires generally being in crossed relation except for the operation of the solenoids **135**, **136** controlling the exhaust valve **130** and intake valve **132**. Contact of the piston **100** with the switch **143** will then energize the relay **155**. In addition to actuating the exhaust and intake valves **130**, **132**, the relay **155** closes the valve **122**, actuates the fuel injectors **105** and **123**, opens the valve **112**, closes the valve **115**, and energizes a time-delay relay **156**, that after a short delay opens the valve **125** by means of a solenoid **157** and toggle mechanism **158**.

To start the engine shown in Figs. 5 to 7, compressed air may be forced into the engine chamber **103** through the port **139**. Suppose that the air will then move the piston **100** to the left from its Fig. 5 position to its Fig. 6 position. The valve **112** will be open and the valve **115** will be closed, so that gas is being compressed into the chambers **102** and **110**. Meanwhile, the valve **122**

is closed, as are the valves **115**, **130**, and **132**, and the valve **125** is open.

When the piston **100** reaches its Fig. 6 position, it contacts the switch **141** which causes the relay **150** to close the valve **138**, which remains closed until the engine again has to be started. The relay **150** also actuates a circuit to close the valve **112**, inject fuel through the injectors **104**, **113**, and start the time-delay relay **151** operating. The relay **150** also causes the valves **122**, **130**, and **132** to open and causes the exhaust valve **125** to close. When the fuel in the chambers **102** and **110** explodes, the expansion of gases in the chamber **102** starts the piston **100** moving to the right, while the gases in the chamber **110** supply external power.

When the piston **100** moves to the right to the position shown in Fig. 7, the switch **141** is opened, and the valves **130** and **132** close. The piston **100** begins to compress gas into the engine chamber **103** and the explosion chamber **120**, the valve **122** being open and the valve **125** being closed. The power generated in the chamber **102** is sufficient to compress the large mass of air into these two chambers, but it need do no external work. In the meantime, the time-delay relay **151** has opened the valve **115**, so that the external power gas can flow from the chamber **110** through the port **114** and out the jet nozzle **116**.

The first half cycle is then duplicated on the right hand side of the cylinder **101** in the second half cycle, and then the cycle is repeated.

I claim:

1. A jet-type of engine having means for compressing the air used for the fuel ignition and including in combination a compressor cylinder; a piston reciprocatable therein adapted to compress air alternately toward each of the two ends of said cylinder; a jet combustion chamber adjacent each end of said cylinder and connected therewith by a separating port; valve means for closing said separating port as said piston approaches its end of said cylinder, so as to isolate the air compressed in said jet-combustion chamber from the air compressed in the end of said cylinder; means for substantially simultaneously injecting fuel into the compressed air in said jet-combustion chamber and into the compressed air in said cylinder; means for substantially simultaneously exploding the two said injections of fuel; at least one nozzle exhaust port leading from each said jet combustion chamber; nozzle valve means for closing said nozzle exhaust port while air is being compressed and ignited in said jet combustion chamber; and means for opening said nozzle exhaust port to permit the passage of expanded gases, said separating port remaining closed during the expansion and explosion process, the expanded gases from the jet-combustion chamber being used to supply external power while the expanded gases in the cylinder are used to drive the piston toward the other end of said cylinder, where a similar explosion takes place.

2. A jet-type of engine having means for compressing the air used for the fuel ignition and including in combination a compressor cylinder; a free piston reciprocatable therein adapted to compress air alternately toward each of the two ends of said cylinder; a jet combustion chamber adjacent each end of said cylinder and connected therewith by a port; valve means for closing said port as said piston approaches its end of said cylinder, so as to isolate the air compressed in said jet-combustion chamber from the air compressed in the end of said cylinder; means for substantially simultaneously injecting fuel into the compressed air in said jet-combustion chamber and into the compressed air in said cylinder; means for substantially simultaneously exploding the two said injections of fuel, the expanded gases from the jet-combustion chamber being used to supply external power while the expanded gases in the cylinder are used to drive the piston toward the other end of said cylinder, where a similar explosion takes place; and electric switch means actuated by the movement of said free piston in said cylinder for actuating said valve means, said fuel injection means, and said explosion means.

3. A jet-type of engine having means for compressing the air used for the fuel ignition and including in combination a compressor cylinder; a free piston reciprocatable therein adapted to compress air alternately toward each of the two ends of said cylinder; a jet combustion chamber adjacent each end of said cylinder and connected therewith by a separating port; elecertically operated valve means for closing said separating port as said piston approaches its end of said cylinder, so as to isolate the air compressed in said jet-combustion chamber from the air compressed in the end of said cylinder; electrically-operated means for substantially simultaneously injecting fuel into the compressed air in said jet-combustion chamber and into the compressed air in said cylinder; electrically operated means for substantially simultaneously exploding the two said injections of fuel; at least one nozzle exhaust port leading from each said jet combustion chamber; electrically operated nozzle valve means for closing said nozzle exhaust port while air is being compressed and ignited in said jet combustion chamber; switch means controlling all said electrically operated means and actuated by said free piston; and means for opening said nozzle exhaust port to permit the passage of expanded gases, said separating port remaining closed during the expansion and explosion process, the expanded gases from the jet-combustion chamber being used to supply external power while the expanded gases in the cylinder are used to drive the piston toward the other end of said cylinder, where a similar explosion takes place.

4. An engine of the type described, having its own means for compressing air and including in combination at least one compressor cylinder; piston means reciprocatable therein; at least one generally enclosed chamber means adjacent said cylinder and connected therewith only by a port; valve means actuated by said piston means for closing said port as said piston approaches said port, so as to completely isolate the air compressed thereby in said enclosed chamber from the portion of the air compressed in said cylinder; means for injecting fuel into the compressed air in said cylinder; means for exploding the said injection of fuel, the volume of said chamber and the volume of said cylinder during explosion of said fuel being so related that while the gases from said enclosed chamber are used to supply external power, the expanded gases in the cylinder are used to drive the piston in the opposite direction until a similar explosion again supplies power for driving said piston, said cylinder gases doing no external work; an electric circuit controlling the operation of said valve means, fuel injector, and fuel exploding means; switch means in said circuit actuated by said piston means; and relays in said circuit actuated by said switch means and adapted to time the operation of said valve means, injector and exploding means.

5. An engine of the type described, having its own means for compressing air and including in combination at least one compressor cylinder provided with a closed chamber adjacent each end; piston means reciprocatable therein to alternately compress air toward each of the two ends of said cylinder; at least one generally enclosed chamber means adjacent said cylinder and connected therewith only by a port; valve means actuated by said piston means for closing said port as said piston approaches said port, so as to completely isolate the air compressed thereby in said enclosed chamber from the portion of the air compressed in said cylinder; means for injecting fuel into the compressed air in said cylinder; and means for exploding the said injection of fuel, the volume of said chamber and the volume of said cylinder during explosion of said fuel being so related that while the gases from said enclosed chamber are used to supply external power, the expanded gases in the cylinder are used to drive the piston in the opposite direction until a

similar explosion again supplies power for driving said piston, said cylinder gases doing no external work and whereby the explosion at one end of the cylinder drives the piston to compress toward the other end and vice versa.

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