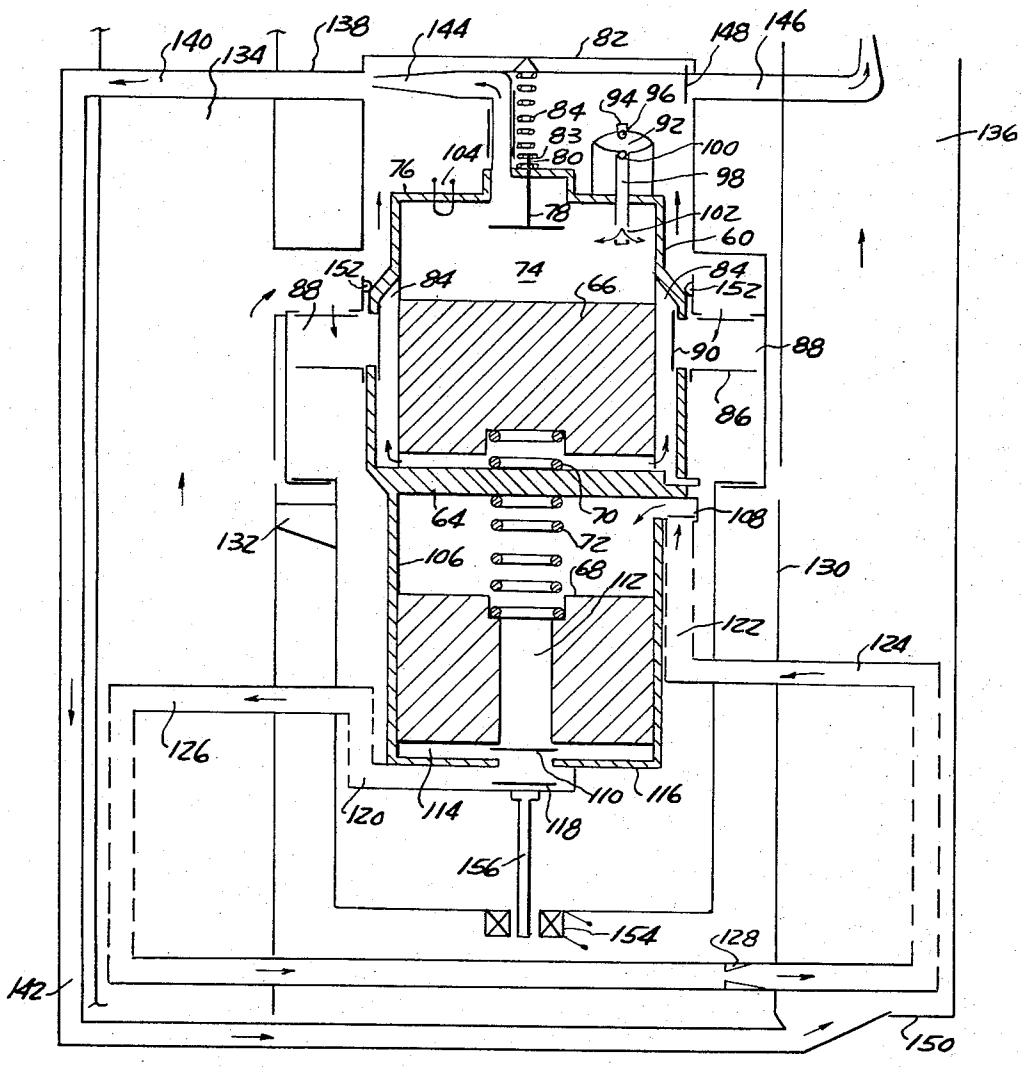
Jan. 2, 1968 P. D. CARLETON 3,361,338

COMBUSTION DRIVEN PUMP

Filed Oct. 23, 1965 2 Sheets-Sheet 1

Fig. 1



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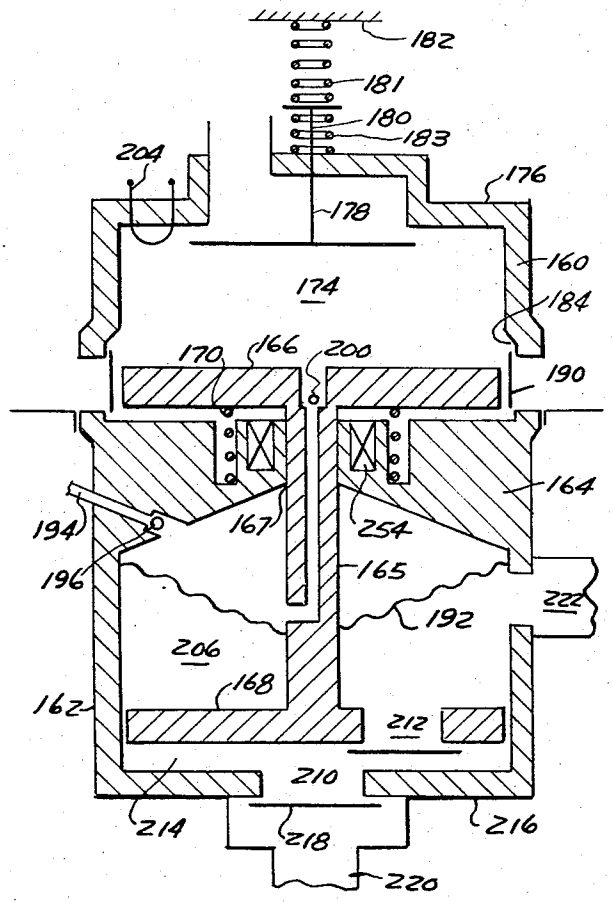
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Fig. 2



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COMBUSTION DRIVEN PUMP

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ABSTRACT OF THE DISCLOSURE

An engine compressor includes a pair of cylinders disposed adjacent to one another along a common axis and sharing a common wall and pistons disposed in each of the cylinders. Either the cylinders or the pistons are fixed and the unfixed members are movable with respect to the fixed members and spring means are included for biasing the movable members toward one position. Fuel means and ignition means are provided to operate it in timed relation to the motion of the movable members in order to cause relative axial reciprociation between the pistons and the cylinders.

This invention relates to compressors and more particularly to a unitary combustion driven refrigerant compressor.

Refrigeration, air conditioning, and heat pump systems employ pumping devices to compress a gas, such as Freon, in a closed circuit refrigeration cycle. These compression devices or pumps have in the past normally comprised an electric motor driving a reciprocating crank-shaft type compressor.

In order to achieve a more efficient use of the total energy consumed in a compressed gas system, it has been proposed to employ a combustion engine to drive the compressor. In order to achieve a reduction in weight and noise and to achieve a greater dependability, free-piston engine-compressors have been developed in which a reciprocating piston refrigerant-gas compressor is integrally constructed with a free piston internal-combustion engine.

The present invention represents an improved unitary combustion engine driven compressor in the form of a highly novel "free cylinder" compressor. A number of features incorporated in the free-cylinder embodiment may also be employed in an improved free-piston version of a combustion engine compressor.

A device of this general nature is described in my copending patent application, U.S. Patent No. 3,236,293, issued Feb. 22, 1966 of which this application represents a continuation-in-part. In that application, the concept of utilizing a free-cylinder type of compressor was introduced as part of a novel heat pump system.

The compressor of the preferred embodiment employs a pair of cylinders which are arranged linearly along a common axis and share a central partition. This cylinder assembly is free to move axially with respect to a pair of restrained pistons, one being disposed in each cylinder. The cylinder normally assumes a medium position wherein each piston is dipsosed centrally within its cylinder section. Spring bias means allow the cylinder to be displaced from this medium position when fuel is exploded in one of the chambers formed between a piston and a cylinder wall. The spring means returns the cylinder past its medium position to accomplish the return stroke. The refrigerant is compressed between the piston which does not directly experience the explosive force and its adjacent cylinder walls. The preferred embodiment includes a fuel system comprising a diaphragm with means responsive to the relative motion of the piston and cylinder to inject fuel for combustion in the engine. The fuel system concept may also be utilized in an improved free-piston type compressor.

It is therefore an object of the present invention to provide an improved refrigerant compressor by providing an efficient, compact free-cylinder combustion engine compressor.

It is another object of the present invention to provide a more efficient unitary combustion engine compressor by providing for an improved fuel pump system that can be incorporated into a free-cylinder or free-piston engine-compressor.

Many other objects, advantages and improvements to unitary combustion-engine compressors will be made apparent following detailed description of preferred embodiments of the invention. The description makes reference to the following drawings in which:

FIGURE 1 represents a schematic drawing of a free-cylinder embodiment of the present invention; and

FIGURE 2 represents a schematic drawing of a free piston embodiment employing modified features of the free cylinder embodiment.

Now referring to FIGURE 1, a preferred embodiment of the present invention is built about a "free cylinder" engine and a compressor. The engine employs a pair of concentric cylinders 60 and 62 which share a common wall 64. A first piston 66 is disposed within the cylinder 60 and a second piston 68 is disposed within the cylinder 62. The cylinder 60, along with its piston 66, acts as a prime mover while the cylinder 62 and its piston 68 acts as a compressor.

The pistons 66 and 68 are designed to remain fixed against longitudinal movement along their axes. This may be accomplished by a mechanical connection between either of both pistons and the frame of the machine or as shown the pistons may be longitudinally movable with sufficient mass to minimize the extent of this movement. This latter technique allows a completely sealed combustion chamber.

In the preferred embodiment, the cylinders 60 and 62 are longitudinally movable with respect to the piston 66 and 68 and the frame 82. The position of the pistons with respect to the cylinder is biased by a spring 70 which extends between piston 66 and the common wall 64 and a spring 72 which extends between the piston 68 and the common wall 64. The basic movement of the engine is an axial reciprocation of the cylinders 60 and 62 with respect to the piston 66 and 68 and common wall 64, powered by explosions occurring in the chamber 74 formed between the piston 66 and one extreme wall 76 of the cylinder 60. The power cycle is of the two-stroke variety and in FIGURE 1 the cycle is illustrated at a point in the end of the power stroke, wherein the cylinder 60 has moved so as to bring the piston 66 immediately adjacent the common wall 64 and compress the spring 70 by a maximum amount.

As the cylinder 60 begins to move downwardly under the force of the spring 70, the combustion products are exhausted through a valve 78 formed in the cylinder wall 76. The stem 80 of the valve extends through the wall 76. Springs 81 and 83 normally urged the valve to a closed position. However, when the cylinder 60 moves upwardly with respect to the piston 66, the springs cause the valve to open. As the cylinder 60 moves downwardly, air is admitted to the chamber 74 through ports 84 located on the sides of the piston. Air is forced into these ports from a simple pump mechanism comprising walls 86 which move with the cylinder 60 and thereby pressurize pump chambers 88. Ports 84 are closed off by pressure-sensitive valves 90 whenever the pressure in the chamber 74 exceeds that in the pumps 88.

On the downstroke of the cylinder 60, fuel is admitted into the chamber 74 by an injection mechanism which includes a diaphragm 92 having input from a fuel

supply line 94 through a check valve 96, and having input from a fuel supply line 94 through a check valve 96, and having output into the chamber 74 through a tube 98 and a check valve 100. When the cylinder 60 lowers sufficiently to cause the end of the tube 98 to abut the top of the piston 66, the diaphragm 92 is closed forcing a measured amount of fuel into the chamber 74 through ports 102 on the sides of the tube 98. At an appropriate point in the cycle, the air fuel mixture in the chamber 74 is ignited by a glow-plug 104 located in the upper wall of the cylinder 60. This action forces the cylinder 60 upwardly against the force of the then opened spring 70 and with the assistance of the then closed spring 72.

On the down stroke of the cylinder 60, refrigerant in a chamber 106 formed between the common wall 64 and the piston 68, is compressed. The refrigerant was previously admitted to the chamber 106 during the up stroke of the cylinder 60 through a valve 108. When the pressure on the refrigerant in the chamber 106 become sufficiently high, a valve 110 situated in a passage 112 which connects the two sides of the piston 68 opens and admits the refrigerant to a chamber 114 formed between piston 68 and the extreme wall 116 of the cylinder. On the up stroke of the cylinder, the refrigerant is compressed in the chamber 114 and when a sufficient pressure has been achieved, a valve 118 opens and admits refrigerant to a passage 120. For purposes of description, the free-cylinder engine compressor is described as it might be expected to function in a heat pump heating and cooling system.

The valve 108 which closes off the refrigerant intake to the chamber 106 is situated at the end of a passage 122. This passage is connected to an evaporator 124 that communicates with a condenser 126 by means of an expansion valve 128. The condenser is, in turn, connected to the passage 120.

Thus the main function of the entire engine is to compress refrigerant into the condenser 126. The refrigerant then expands through the valve 128 and the evaporator 124, from which it is returned to the compressor. The condenser and evaporator structure is supported with respect to the engine by cylindrical walls 130 and supports 132. This entire structure is rotatable with respect to a passage 134 which transmits air to be conditioned and a passage 136 which carries ambient air or engine exhaust. An air propelling mechanism, such as a fan (not shown) is located in the passage 134 and the two ends of the passage are connected to the volume of air to be conditioned. Both of the ends of the passage 136 are connected to the atmosphere. The stationary assembly also includes an exhaust passage 138 which includes a heat exchanger 140 and a conduit 142. The heat exchanger 140 is located in the conditioned air passage 134 and the conduit 142 connects to the output of the heat exchanger 140 and returns the air to the ambient air passage 136.

In FIGURE 1 the engine is illustrated in its heating position. In that position an exhaust nozzle 144 directs the exhaust of the machine from valve 78 through the passage 138 and the heat exchanger 140. An alternate exhaust passage 146 is then blocked by a valve 148. During this heat cycle, indoor air is passed through the passage 134, wherein it absorbs heat from the condenser 126. It then passes over the heat exchanger 140 where it absorbs heat from the exhaust. This somewhat cooled exhaust is then carried through the passage 142 and over the evaporator 124 which absorbs the heat from the exhaust and then allows the exhaust to pass out to the atmosphere.

In order to convert to the cooling cycle, the condenser, evaporator and engine are rotated through 180 degrees so as to position the evaporator in the conditioned air passage 134 and the condenser in the ambient passage 136. This same motion directs the exhaust to the auxiliary exhaust passage 146 and blocks off the exhaust passage 138 with a valve 148.

The auxiliary exhaust passage 146 projects the combustion products into the atmosphere from a location center to the end of the ambient air passage 136. It thus acts as a venturi to aid the flow of air through the passage 136. A valve 150 which is located in the lower end of the passage 136 is opened during cooling and partially closed during heating so as to aid the efficiency of the apparatus.

Air from the pumps 88 is allowed to pass through seals 152 during the up stroke of the cylinder 60 in order to cool the sides of the cylinder. This air is drawn into the passage 138 along with the exhaust products through the exhaust nozzle 144 during the heating process. It thereby dilutes the heat of the exhaust and maintains the machine in a satisfactory thermo-dynamic range.

The engine may be started by reciprocating the cylinder 60 at a frequency consonant with its natural harmonic frequency. This may be accomplished by passing an alternating current of that frequency through a solenoid 154. A ferro-magnetic armature rod 156 which extends through the solenoid 154 and is journalled therein will thus be oscillated within the solenoid at a harmonically varying rate and will transmit its oscillations to the cylinder 60.

FIGURE 2 discloses an embodiment of the present invention which is built around a "free piston" engine and a compressor. Although a free-piston engine-compressor is not, per se, new, the embodiment disclosed in the present application incorporates features that reflect substantial improvements over the past art.

In the free-piston embodiment, a pair of concentric cylinders 160 and 162 share a common wall 164. A first piston 166 is disposed within the cylinder 160 and a second piston 168 is disposed with the cylinder 162. The piston 166 along with its cylinder 160 acts as a prime mover while the piston 168 and its cylinder 162 acts as a compressor.

The pistons 166 and 168 are connected together by a rod 165 passing through an opening 167 in the common wall 164. The opening 167 is provided with a sliding fit for the rod 165 and may be provided with a seal (not shown).

In the preferred embodiment, the pistons 166 and 168 are longitudinally movable with respect to the cylinders 160 and 162 and a frame 182. The position of the pistons with respect to the cylinder is biased by a spring 170 which extends between the piston 166 and the common wall 164.

In normal operation, the pistons 166 and 168 reciprocate axially within the cylinders 160 and 162 powered by explosions taking place in a chamber 174 formed between the piston 166 and one extreme wall 176 of the cylinder 160. The power cycle is in the manner of the conventional two-stroke variety. FIGURE 2 illustrates the cycle at the end of a power stroke wherein the piston 166 has moved so as to compress the spring 170 to a maximum extent.

As the piston 166 begins to move upwardly under the force of the spring 170, the combustion products are exhausted through a valve 178 formed in the cylinder wall 176. The stem 180 of the valve extends through the wall 176. Springs 181 and 183 normally urge the valve to a closed position. However, at the end of the power stroke, the cylinder 160 has sufficient longitudinal freedom of movement to move upward thus compressing the springs 181 and 183 to the point of maximum closure and thereby causing the valve 178 to open. As the piston 166 moves downwardly air is admitted to the chamber 174 through ports 184 located on the sides of the cylinder. Ports 184 are closed off by pressure-sensitive valves 190 whenever the pressure in the chamber 174 exceeds that of the air source.

On the upstroke of the piston **166**, fuel is admitted into the chamber **174** by an injection mechanism which includes a diaphragm **192** which is fixed to the cylinder **162** at its periphery and to the rod **165** at the center. The diaphragm **192** has input from a fuel supply line **194** through a check valve **196** and output into the chamber **174** through an axial passage through the rod **165**, the piston **166** and a check valve **200**. The diaphragm **192** also acts as a seal between the two chambers. When the piston **166** has risen a sufficient distance the diaphragm **192** closes forcing a measured amount of fuel into the chamber **174**. At an appropriate point in the cycle, the air fuel mixture in the chamber **174** is ignited by a glow plug **204** located in the upper wall of the cylinder **160**. This explosion forces the piston **166** downward against the force of the then opened spring **170**.

On the up stroke of the piston **166**, refrigerant in the chamber **206** formed between the diaphragm **192** and the piston **168** is compressed. The refrigerant was previously admitted to the chamber **206** during the downstroke of the piston **168** through a passage **222**. When the pressure on the refrigerant in the chamber **206** becomes sufficiently high a valve **210** situated in a passage **212** which connects the two sides of the piston **168** opens and admits the refrigerant to a chamber **214** formed between the piston **168** and the extreme wall **216** of the cylinder **162**. On the downstroke of the piston, the refrigerant is compressed in the chamber **214** until a sufficient pressure opens a valve **218** to admit the refrigerant to an outlet passage **220**.

The free-piston embodiment of the present invention may be started by reciprocating the piston **166** at a frequency consonant with its natural harmonic frequency. This may be accomplished by passing an alternating current of that frequency through a solenoid **254**. The solenoid **254** is disposed in the common wall **164** so as to surround the piston connecting rod **165**. The rod **165** is of a ferro-magnetic material so as to be oscillated within the solenoid at a harmonically varying rate.

It should be understood that the free-cylinder and the free-piston embodiments of a unitary combustion driven compressor described here are not restricted to a heat-pump application, but are applicable to any system where the pressure of a fluid medium is raised.

Having thus described my invention, I claim:

1. A free-cylinder engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis and sharing a common wall, said cylinders being slidable in an axial direction; pistons disposed within each of said cylinders and restrained with respect to the engine-compressor structure; spring means for biasing said cylinders toward a normal position with respect to the pistons; a fuel intake means operative to inject fuel into the space volumes between a first piston and its adjacent wall at various intervals; a fuel ignition system operative to combust fuel disposed in said space volume, the timing of said fuel intake means and said combustion means being such as to cause the relative axial reciprocation between the pistons and the cylinders; intake and exhaust valve means associated with the other piston and operative to act as a pump; and structural means between the pistons and the frame of the engine-compressor so as to restrain the movement of said pistons.

2. A free-cylinder engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis and sharing a common wall, said cylinders being slidable in an axial direction; pistons disposed within each of said cylinders and restrained with respect to the engine-compressor structure, the pistons having a sufficiently high mass to minimize the extent of their movement with respect to the cylinders; spring means for biasing said cylinders toward a normal position with respect to the pistons; a fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals; a fuel ignition system operative to combust fuel disposed in said space volume, the timing of said fuel intake means and said combustion means being such as to cause relative axial reciprocation between the pistons and the cylinders; and intake and exhaust valve means associated with the other piston and operative to act as a pump.

3. A free-cylinder engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis and sharing a common wall, said cylinders being slidable in an axial direction; pistons disposed within each of said cylinders and restrained with respect to the engine-compressor structure; spring means for biasing said cylinders toward a normal position with respect to the pistons; a fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals; a fuel ignition system operative to combust fuel disposed in said space volume, the timing of said fuel intake means and said combustion means being such as to cause relative axial reciprocation between the pistons and the cylinders; in take and exhaust valve means associated with the other piston and operative to act as a pump; and means responsive to the axial movement of the cylinder containing said first piston operative to direct the products of combustion from said space volume and including a normally closed spring loaded valve disposed in a passage in the end wall of the cylinder forming said space volume actuable to open by spring means responsive to the cylinder end wall moving axially away from said first piston.

4. A free-cylinder engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis and sharing a common wall, said cylinders being slidable in an axial direction; pistons disposed within each of said cylinders and restrained with respect to the engine-compressor structure; spring means for biasing said cylinders toward a normal position with respect to the pistons; a fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals; a fuel ignition system operative to combust fuel disposed in said space volume, the timing of said fuel intake means and said combustion means being such as to cause relative axial reciprocation between the pistons and the cylinders; intake and exhaust valve means associated with the other piston and operative to act as a pump; and pumping means operative to force pressurized air into the space volume formed by said first piston and its adjacent cylinder walls and including an air chamber peripherally located around the cylinder walls containing said first piston and formed by a pair of spaced radially extending walls between the cylinder and the engine-compressor structure with one wall fixed to the structure and the other wall fixed to the cylinder, and with a pressure responsive means communicating said air chamber with said space volume when the air pressure within the air chamber is raised to a value greater than the pressure in the cylinder, said air chamber pressure being raised by axial movement of the wall fixed to the cylinder towards the wall fixed to the engine-compressor structure.

5. A free-cylinder engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis and sharing a common wall, said cylinders being slidable in an axial direction; pistons disposed within each of said cylinders and restrained with respect to the engine-compressor structure; spring means for biasing said cylinders toward a normal position with respect to the pistons; a fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals; a fuel ignition system operative to combust fuel disposed in said space volume, the timing of said fuel intake means and said combustion means being such as to cause relative axial reciprocation between the pistons and the cylinders, said fuel intake means including a diaphragm with a fuel passage communicating with a fuel supply source; a fuel passage com-

municating the diaphragm with the space volume within the cylinder; means responsive to the relative movement of the first piston to actuate the diaphragm to inject fuel into the space volume; and intake and exhaust valve means associated with the other piston and operative to act as a pump.

6. A free-cylinder engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis and sharing a common wall, said cylinders being slidable in an axial direction; pistons disposed within each of said cylinders and restrained with respect to the engine-compressor structure; spring means for biasing said cylinders towards a normal position with respect to the piston; a fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals; a fuel ignition system operative to combust fuel disposed in said space volume, the timing of said fuel intake means and said combustion means being such as to cause relative axial reciprocation between the pistons and the cylinders; intake and exhaust valve means associated with the other piston and operative to act as a pump; and starting means for said engine-compressor comprising a means for reciprocating the cylinders at a frequency consonant with the natural harmonic frequency.

7. The device as defined in claim 6 wherein said starting reciprocating means includes a solenoid surrounding an axially extending ferromagnetic armature rod and operative to cause the armature rod to reciprocate at a harmonically varying rate upon receipt of an electrical signaling means, and the rod disposed so as to reciprocate the cylinders when actuated by the solenoid.

8. A free-piston engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis so as to share a common wall; pistons movable within each of said cylinders; structure connecting said pistons so as to provide them with unitary movement; spring means for normally biasing said pistons to a fixed position within said cylinders; a fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals; combustion means associated with said first piston and operative to cause said pistons to reciprocate with respect to said cylinders; intake and exhaust valve means associated with the other cylinder and operative to cause it to pump fluid; and a diaphragm disposed in the common wall shared by the pair of cylinders, said diaphragm being connected to the strutural means between the pistons to allow relative movement between the pistons and cylinders.

9. A free-piston engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis so as to share a common wall; pistons movable within each of said cylinders; structure connecting said pistons so as to provide them with unitary movement, such structure including an axial rod disposed on the longitudinal axis between the pistons and connecting them, such rod being slidably sealed through an opening in the shared wall; spring means for normally biasing said pistons to a fixed position within said cylinders; fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals, said fuel intake means including a diaphragm spaced from said shared wall and fixed to the cylinder at its periphery and to the rod joining the pistons so as to form a fuel chamber between the shared wall, the diaphragm and the cylinder walls, and including a fuel passage communicating the fuel chamber with the space volume within said cylinder, and with said diaphragm responsive to the movement of the pistons, so as to pump fuel from the fuel chamber into the space volume; combustion means associated with said first piston and operative to cause said

pistons to reciprocate with respect to said cylinders; and intake and exhaust valve means associated with the other cylinder and operative to cause it to pump fluid.

10. A free-piston engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis so as to share a common wall; pistons movable within each of said cylinders; structure connecting said pistons so as to provide them with unitary movement; spring means for normally biasing said pistons to a fixed position within said cylinders; a fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals, said fuel intake means including a diaphragm with fuel inlet passage communicating with a fuel supply source, and a fuel passage communicating the diaphragm with the space volume within the cylinder and means responsive to the movement of said first piston to actuate the diaphragm to inject fuel into the space volume; combustion means associated with said first piston and operative to cause said pistons to reciprocate with respect to said cylinders; and intake and exhaust valve means associated with the other cylinder and operative to cause it to pump fluid.

11. A free-piston engine-compressor including a pair of cylinders disposed adjacent to one another along a common axis so as to share a common wall; pistons movable within each of said cylinders; structure connecting said pistons so as to provide them with unitary movement; spring means for normally biasing said pistons to a fixed position within said cylinders; a fuel intake means operative to inject fuel into the space volume between a first piston and its adjacent wall at various intervals; combustion means associated with said first piston and operative to cause said pistons to reciprocate with respect to said cylinders; intake and exhaust valve means associated with the other cylinder and operative to cause it to pump fluid; and starting means for said engine-compressor comprising a means for reciprocating the pistons at a frequency consonant with their natural harmonic frequency.

12. The structure as denfied in claim 11 wherein said starting reciprocating means includes a solenoid disposed around said piston connecting structure and operative to reciprocate the pistons upon receipt of an electrical signal of a suitable frequency.

13. A free-piston engine-compressor including a pair of cylinders disposed adacent to one another along a common axis so as to share a common wall; pistons movable within each of said cylinders; structure connecting said pistons so as to provide them with unitary movement; spring means for normally biasing said pistons to fixed position within said cylinders; a fuel intake means operative to inject fuel into the space volume between a first piston and and its adjacent wall at various intervals; combustion means associated with said first piston and operative to cause said pistons to reciprocate with respect to said cylinders; intake and exhaust valve means associated with the other cylinder and operative to cause it to pump fluid; and means responsive to the axial motion of the cylinder containing said first piston and operative to direct the products of combustion from said space volume and including a normally closed valve disposed in a passage in the wall of the cylinder forming said space volume, and actuated to open by spring means responsive to the cylinder end wall moving axially away from said first piston.

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