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FREE PISTON MACHINE OPERATION

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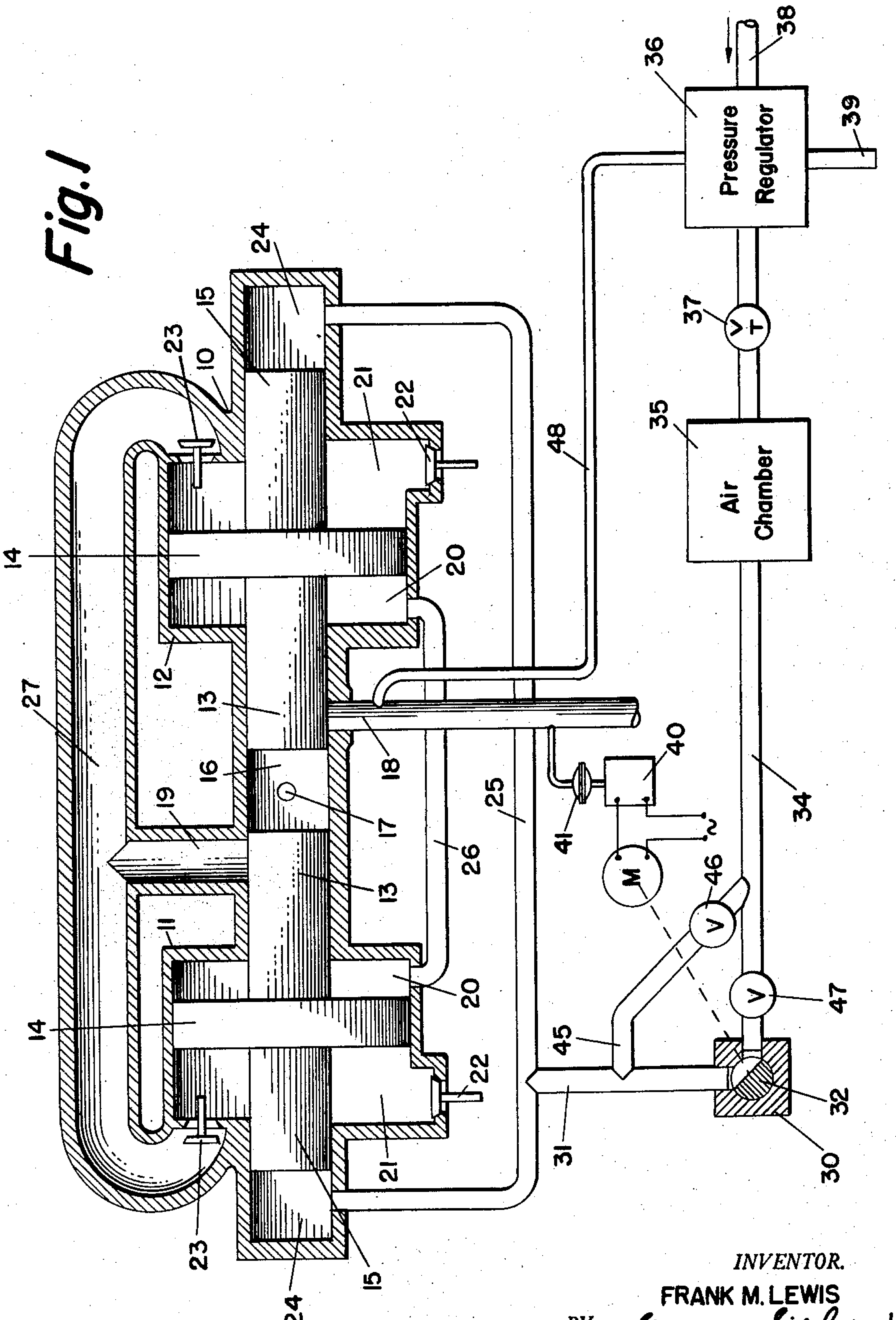

Fig. 1

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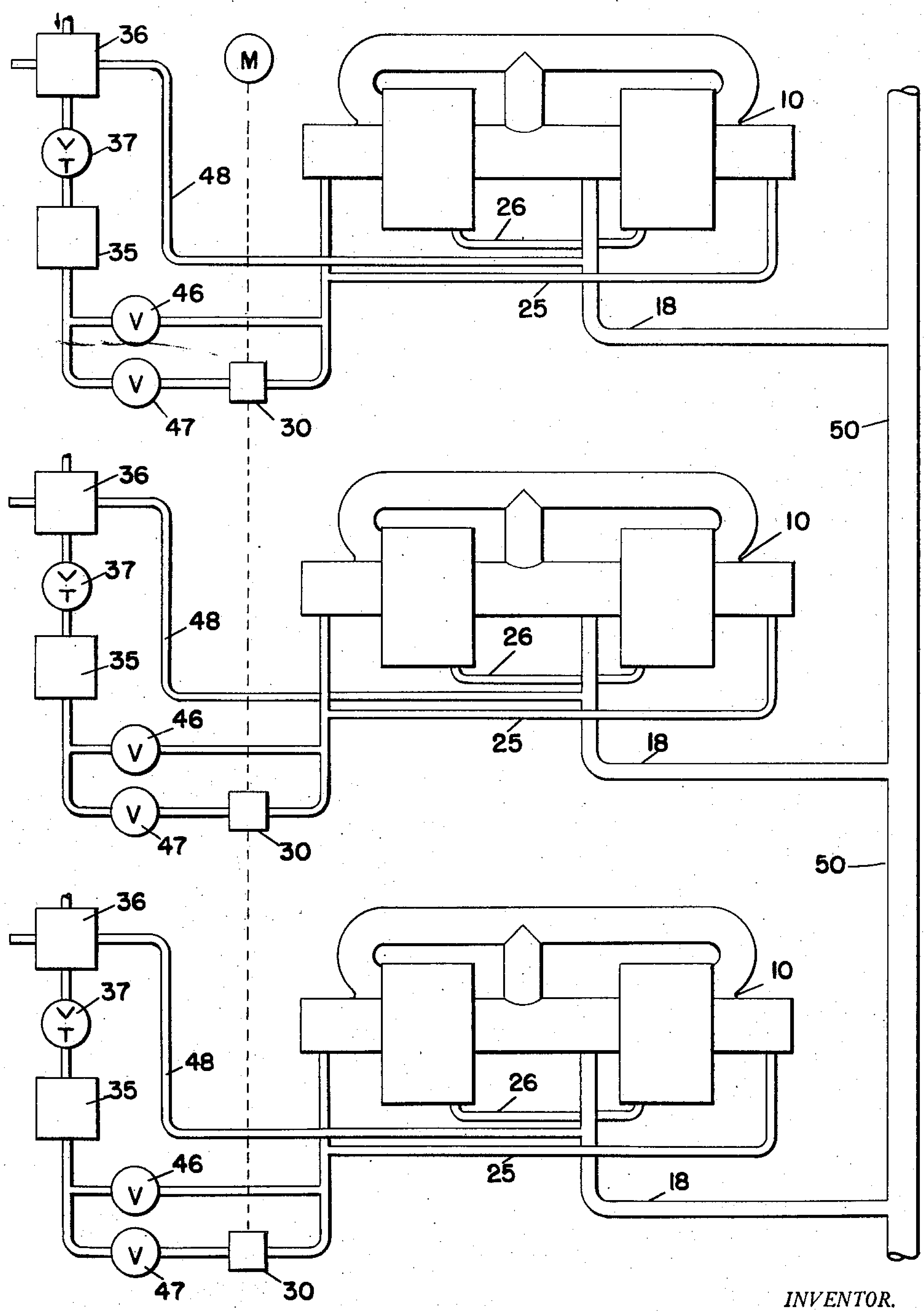

Fig. 2

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FREE PISTON MACHINE OPERATION

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1 Claim. (Cl. 123—46)

This invention relates to internal combustion machines such as air compressors and gas generators of the free piston type and in particular is concerned with a system or apparatus for operating a group of such machines in synchronism.

Free piston machines, as is generally known, include a motor piston and a compressor piston which operate in unison and function to supply air or gas for the operation of other machines such as turbines. A free piston machine as distinguished from other piston machines operates other equipment directly by the developed power rather than through mechanical connections.

Compressed air developed by the compressor portion of a free piston machine is used to scavenge and charge the motor portion of the machine and the motor portion delivers the developed power gas which constitutes a mixture of combustion products and scavenging air to operate other equipment, for example, to drive a turbine.

When a group of two or more free piston gas generators are used to operate a turbine, it is advantageous that they be operated in synchronism. Such synchronous operation requires that all of the free piston machines operate at exactly the same cyclic speed, and that their respective piston positions be in predetermined phase relationship with each other. Such an operation is particularly desirable where a group of such gas generators has a common air intake manifold or a common exhaust or delivery manifold. Synchronized operation provides a substantially uniform pressure within the gas generating system. Also, by operating a group of gas generators in synchronism, the operating noises should tend to be reduced to a minimum.

An object of this invention is to provide apparatus for controlling the operation of free piston machines in accordance with pressure conditions in the machine.

Another object is to provide an arrangement of control elements which simplifies the synchronous operation of a plurality of free piston gas generators.

Still another object of the invention is to utilize inexpensive and readily available control elements for synchronizing the operation of a plurality of free piston gas generators.

Other objects and advantages of the invention will hereinafter become more fully apparent from the following description of the annexed drawings, which illustrate a preferred embodiment, and wherein:

Fig. 1 is a sectional view of a free piston type gas generator with control elements and fluid lines shown in elevation; and

Fig. 2 is a generally diagrammatic view of a plurality of such generators arranged for operation in synchronism.

In Fig. 1 of the drawing is indicated generally a free piston machine of well known structure comprising a casing 10 containing two opposed and identical, diesel type operated, air compressing units 11 and 12. Each of the air compressing units comprises a power piston 13 and an integrally connected air compression piston 14.

On the opposite side of each piston 14 is provided a direct bounce piston 15. The two power pistons 13 cooperate to form, with the casing 10, and generally centrally thereof, a power chamber 16 into which fuel is injected, for example, by way of a nozzle 17 for compression and ignition when the power pistons 13 attain a predetermined inner position as indicated in Fig. 1. The power developed in chamber 16 drives the piston assemblies of both units outwardly to effect the air compression stroke. As the power pistons 13 move outwardly after the ignition stroke, they will uncover an exhaust or outlet conduit 18 for escape of burnt gases from the ignition chamber 16 and a scavenger conduit 19 to allow entry of air to chamber 16 for scavenging purposes and passage therefrom and into conduit 18 from which the gases are directed for useful work. Air is admitted through conduit 19 prior to the compression and ignition step of the cycle along with the supply of fuel through nozzle 17. The piston assemblies are arranged to move equally and oppositely by the usual mechanical connections (not shown).

At the power piston side of each air compression piston 14 is a chamber known as an inner or reverse bounce chamber 20 and on the opposite side of each of these pistons 14 is a compression chamber 21. Each of the compression chambers 21 is provided with intake valves 22 and exhaust valves 23.

The direct bounce pistons 15 form, at opposite ends of casing 10, direct bounce chambers 24 in which air will be compressed on the outward movement of the piston assemblies to provide a cushion for damping or stopping the outward movement of the piston assemblies and also to provide for the return or inward movement of the piston assemblies to effect the compression-ignition step of the cycle of operation.

The direct bounce chambers 24 are in communication with each other through an equalizing line 25, and the reverse bounce chambers 20 are in communication with each other through a second equalizing line 26. After the initial starting of the machine, the piston assemblies will reciprocate under the pressures existing in the various chambers and provide the desired cycle of operation during which the air passing through compression chambers 21 from the inlet valves 22 will, through valves 23, enter the scavenging zone 27 from which it passes to the ignition chamber 16 through conduit 19 and the scavenge gases exhausted through conduit 18 for the desired use.

The apparatus for effecting speed control of the free piston machine is shown in Fig. 1 and is arranged to add to or remove air from the direct bounce chambers 24. This is accomplished in accordance with pressure existing in the free piston machine system. Extraneous control air supplied to the direct bounce chambers 24 will increase the cushioning or compressing effect of these chambers and hence speed up operation of the piston assemblies. Conversely, control air supplied to the reverse bounce chambers 20 through line 26 will decrease the speed of operation of the pistons.

Control air can be supplied by the lines 25 and 26 simultaneously to the direct bounce and reverse bounce chambers, in such ratio that the speed of the piston assemblies may be increased or decreased as desired.

In Fig. 1, the apparatus for controlling the speed of the piston assemblies is shown connected with the equalizing line 25 which is in communication with the direct bounce chambers 24. A control valve 30 is positioned in branch line 31, of the equalizing line 25, and is provided with a rotary valve plug 32 which is in communication with a main air supply line 34. The rotary valve plug 32 is so designed as to pass only a small amount of air from the main conduit 34 to the branch conduit 31 during each of its revolutions. The main air conduit 34 is provided with an air chamber 35, a pressure regulator 36 and therebetween a throttle valve 37. Air from a source is supplied by line 38 to the regulator 36 and excess air may be discharged through line 39.

The operation of the rotary valve 32 is effected, as shown, by means of electric motor M the operation of which is controlled by a rheostat 40 in circuit with a current source and the motor. The position of the arm (not shown) of rheostat 40 is controlled by a diaphragm pressure regulator 41 which is in turn actuated by the pressure in the exhaust conduit 18. The diaphragm regulator 41 may be located in other pressure lines or chambers of the system such as chamber 27, or located in the fuel supply line, turbine lines, etc. A bypass line 45 for the valve 30 is disposed between main air line 34 and branch line 31 and has a valve 46 therein, and another valve 47 is provided between the air chamber 35 and valve 30. These valves are used in starting the free piston machine which is accomplished by closing valve 47 and opening valve 46 to supply air directly to the equalizing line 25 from the air chamber 35 and thence to the direct bounce chambers 24 which moves the piston assemblies inwardly and the compression of air in chamber 16 with the fuel supplied thereto will effect ignition in chamber 16. During this starting operation air pressure in the direct bounce chambers 24 is controlled by the air pressure regulator 36 which is in communication with the exhaust line 18 through line 48.

After the free piston machine is set in operation, the motor M operates through regulator 41 and since it is controlled according to the pressure in the system, the motor will have substantially the same cyclic speed as the free piston machine. Valve 46 is then closed and valve 47 is opened so that air from the main air line 34 is supplied to the equalizing line 25 under control of rotary valve plug 32. This control system provides an arrangement for operating the free piston machine and the valve 30 in synchronism and although there may be some tendency of the cyclic speeds of the motor or the free piston machine to hunt, this hunting tendency can be minimized by varying the size of the air chamber 35 or by adjusting the setting of the valve 37.

Fig. 2 shows a plurality of free piston machines similar to the free piston machine shown in Fig. 1, each of which is provided with the control arrangement of Fig. 1 and arranged to operate in synchronism. Since the control system described in connection with Fig. 1 will synchronize the operation of a free piston machine with the electric motor M, a plurality of such machines can be held in synchronism with one motor. Thus, the pressure existing in one machine, which would be considered the master, can control a single motor and the motor arranged to regulate the supply of control air to the reverse or direct bounce chambers of each free piston machine and provide synchronous operation of the machines. The driving connections between the motor con-

trolled by the master machine and the valves of the other machines of the group can be mechanical as shown schematically in Fig. 2 or the drive may be electrically operated through synchronous or Selsyn motor.

Operation of the motor M will be considered to be controlled by the machine shown in Fig. 1, which will be considered the master machine. The free piston machines shown diagrammatically in Fig. 2 will be considered the slave machines and controlled in accordance with operation of the motor M. The valves 30 of the machines in Fig. 2 will be considered to be mechanically connected in a manner that all are operated through the motor M. Exhaust products from each machine is directed through its exhaust or outlet conduit 18 to a manifold 50 from which it is supplied to a turbine or machine which can be operated directly by air.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claim the invention may be practiced otherwise than as specifically described.

What is claimed is:

In a free piston engine comprising a casing having opposed piston assemblies arranged for reciprocation therein and providing a variable volume central combustion chamber, a pressure system including a pair of outer bounce chambers interconnected by a first pressure equalizing line, a pair of inner bounce chambers interconnected by a second pressure equalizing line, a first compression chamber between one of the outer bounce and inner bounce chambers, a second compression chamber between the other outer bounce and inner bounce chamber, a scavenge conduit providing communication between the first and second compression chambers and the combustion chamber and an exhaust manifold in communication with the combustion chamber, the improved means for regulating the reciprocation of the piston assemblies which comprises an air supply source, a main air conduit and a branch conduit between said air source and the first pressure equalizing line, a motor operated valve between the main and branch conduits, a pressure device in communication with the exhaust manifold for actuating said motor operated valve in accordance with exhaust pressure, a pressure regulator in the main conduit between the motor operated valve and the air supply, a third conduit between the pressure regulator and the exhaust manifold and a by-pass conduit for the valve between the main and branch conduits.

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