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ELECTRICAL RESTRAINING DEVICE FOR FREE-PISTON UNITS

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2 Sheets-Sheet 1

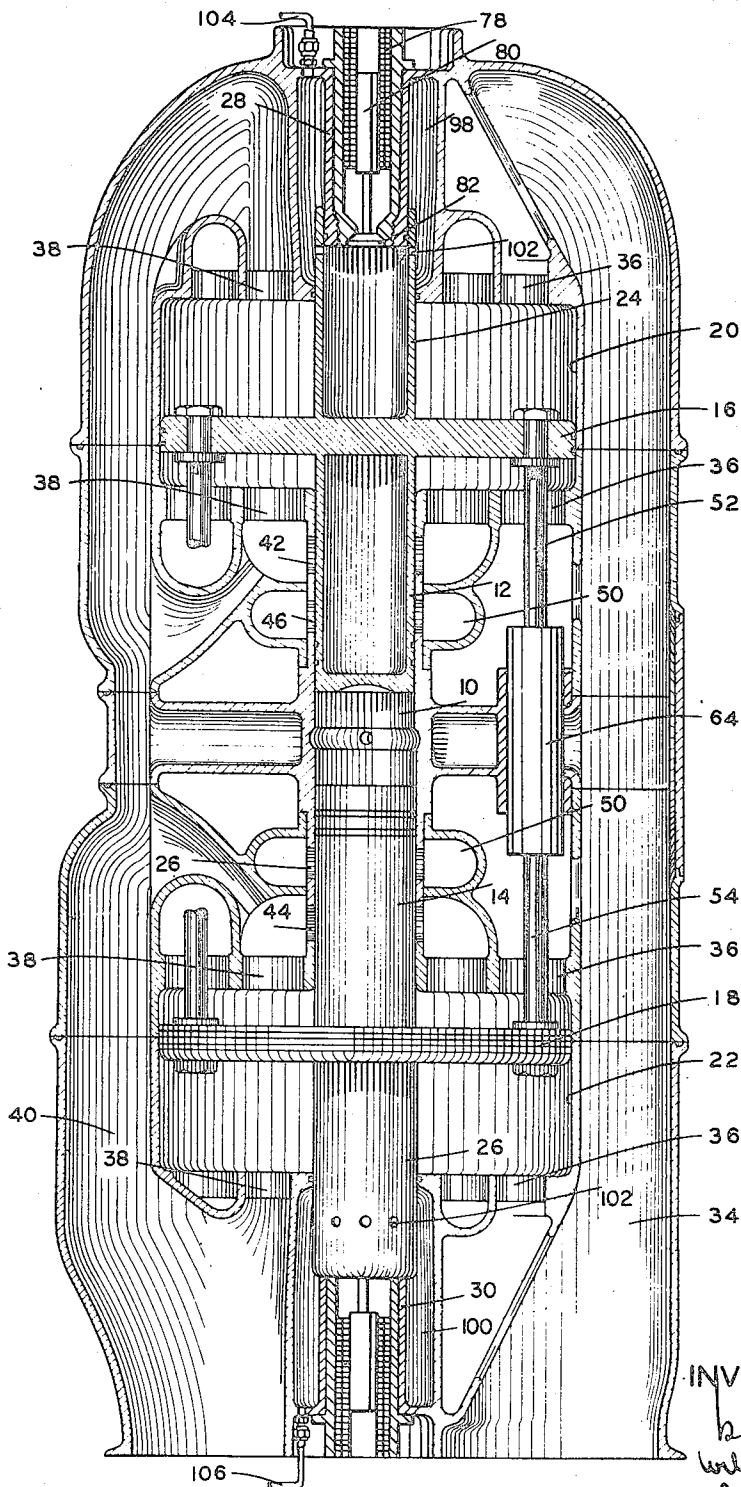


FIG. 1

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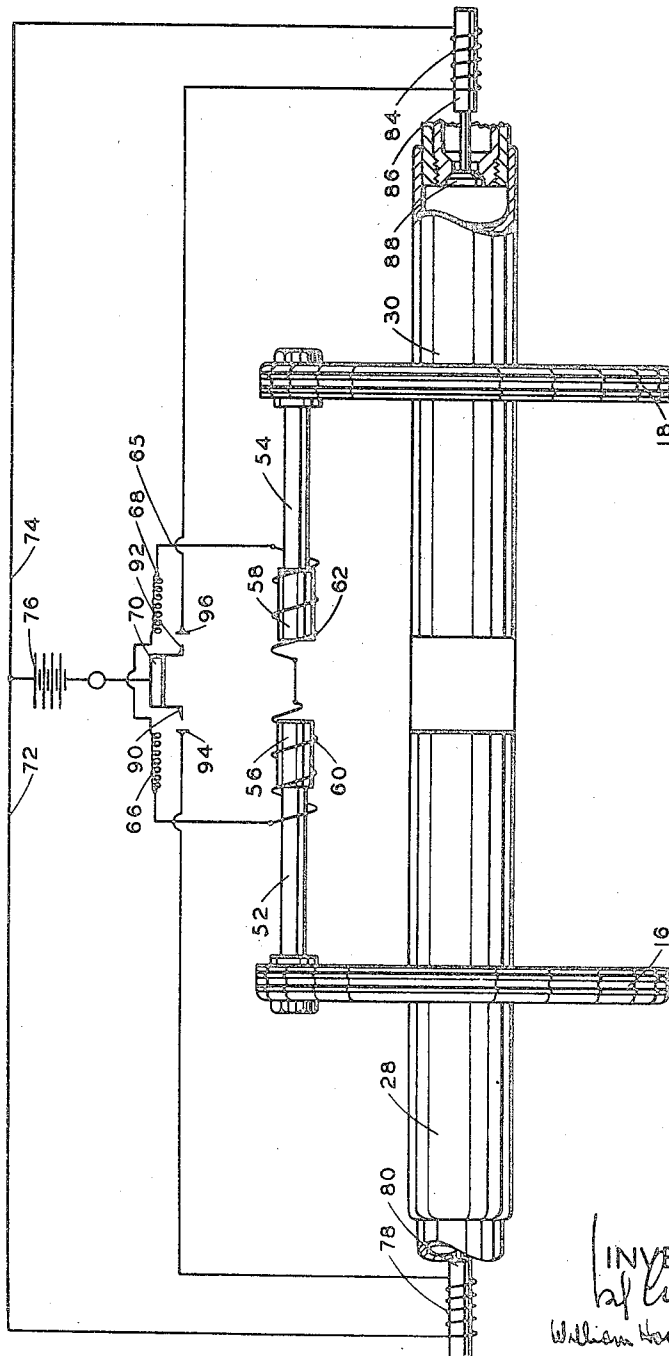
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2 Sheets-Sheet 2



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ELECTRICAL RESTRAINING DEVICE FOR
FREE-PISTON UNITS

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8 Claims. (Cl. 230—56)

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This invention relates to an electrical restraining linkage by which the opposed pistons of a free-piston unit may be caused to move symmetrically.

The opposed pistons have been maintained always at equal distances from the center of the engine by an interconnecting restraining linkage which have been, in general, of two types. One type has a rocking lever with the ends connected by rods to the pistons, and the other has an oscillating pinion engaging with racks on a pair of rods extending from the pistons. A feature of this invention is an electrical restraining device which requires no mechanical connection between the pistons.

Another feature is a device by which changes in an electrical circuit may result from the movement of one of the pistons or from a change in the position of the piston.

Another feature is an electrical device for controlling or changing one or more of the operating conditions of the unit, such as a change in the pressure in the air spring.

Another feature is the electrical control of one or more of the operating conditions affecting the unit, for causing the opposed pistons to move symmetrically. This control may affect only one of the pistons.

Other objects and advantages will be apparent from the specification and claims and from the accompanying drawing which illustrates what is now considered to be a preferred embodiment of the invention.

Fig. 1 is a sectional view through the free-piston engine-and-compressor unit.

Fig. 2 is a diagrammatic view of the electrical system.

The unit shown includes an engine cylinder 10 having reciprocating pistons 12 and 14 to which compressor pistons 16 and 18 in cylinders 20 and 22 are integrally connected. Sleeves 24 and 26 attached to the compressor pistons complete the reciprocating piston assemblies. The sleeves in combination with stationary pistons 28 and 30 form air spring cylinders.

The piston assemblies are moved apart by the burning of fuel injected into engine cylinder 10. Air compressed in the air spring cylinders on the power stroke returns the piston assemblies.

Intake manifold 34 conducts air to intake valves 36 through which air alternately enters opposite ends of the compressor cylinders. The compressed air leaves the cylinders through discharge valves 38, also at opposite ends of the compressor cylinders, and passes through scavenge manifold 40 and through ports 42 and 44 which are uncovered by pistons 12 and 14 at the end of the power stroke, thereby permitting air to be blown through the engine cylinder and exhaust ports 46 and 48 into exhaust manifolds 50.

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The pistons are maintained at equal distances from the center of the engine cylinder by the electrically operated device, shown diagrammatically in Fig. 2, which causes the pistons to move symmetrically. The device may include a pair of rods 52 and 54 extending from pistons 16 and 18 (see also Fig. 1) and carrying permanent magnets or cores 56 and 58, moving in solenoids 60 and 62 in a housing 64, Fig. 1. These solenoids are in opposition to each other in a closed circuit 65 which also has coils 66 and 68 in series. These coils are in a position to act on a magnetic bar 70.

While the pistons move symmetrically, magnets 56 and 58 also move symmetrically within solenoids 60 and 62 and equal power is induced in the solenoids. As a result, no power is supplied to the coils 66 and 68 so that bar 70 remains in the position shown. However, if either piston tends to move out of symmetry, the power induced in one of the coils 60 and 62 will overbalance the other and current will flow through coils 66 and 68, causing bar 70 to move. The circuit is arranged in such a manner that bar 70 will move in one direction if piston 18 moves more rapidly than piston 16 and in the opposite direction if the reverse is true.

Bar 70 forms a part of each of two parallel circuits 72 and 74, both including a source of power which may be a battery 76. Circuit 72 includes a coil 78 surrounding a core 80 to which is connected a valve, not shown, in air spring piston 28. Similarly, circuit 74 includes a coil 84 surrounding a core 86 connected to a valve 88 in the air spring piston 30. Valves connect the air springs to the atmosphere.

Bar 70 carries spaced contacts 90 and 92 engaging alternately with fixed contacts 94 and 96 in circuits 72 and 74 respectively for completing the circuits.

Gas under pressure is supplied to the air springs from chambers 98 and 100 surrounding pistons 28 and 30 and communicating through openings 102 in sleeves 24 and 26, with the space within the sleeves. These openings are arranged to be uncovered when the piston assemblies approach the inner ends of the strokes. Gas may be supplied to chambers 98 and 100 through conduits 104 and 106 to maintain similar pressures in both chambers.

In operation, if piston 18 moves inwardly more rapidly than piston 16, the electromotive force in coil 62 becomes greater than that of coil 60 and moves bar 70 to close circuit 74, thereby opening valve 88 momentarily to reduce the pressure in the air spring acting on piston 18. As a result, the pistons will not move measurably out of symmetry. Similarly, if piston 16 approaches nearer the center than piston 18, circuit 72 will

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be closed to reduce the pressure in the air spring acting on piston 16.

Either solenoid 60 or 62, in conjunction with the core movable therein, constitutes an electrical device in a circuit, the power in which is changed by the movement of the piston. The change in the power of this circuit, by closing either circuit 72 or 74, changes one of the operating conditions affecting the movement of one of the pistons and thus controls the piston movement.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described, but may be used in other ways without departure from its spirit as defined by the following claims.

We claim:

1. A free-piston unit having a cylinder, opposed engine pistons in the cylinder, air springs acting on the pistons for moving said pistons toward each other, said pistons being moved apart by combustion of fuel in the cylinder, an electrical circuit, means responsive to a non-symmetrical movement of the pistons for procuring a change in the electrical circuit, and means controlled by the change in the circuit for adjusting the pressure of the air in one of said springs.

2. In a restraining mechanism for the opposed engine pistons in the engine cylinder of a free-piston unit, said pistons being moved apart by the combustion of fuel in the engine cylinder and being moved together by air springs acting on the opposed pistons, said pistons normally moving symmetrically with respect to the center of the engine cylinder, electrical means connected to said pistons and responsive to a non-symmetrical movement of the pistons for adjusting the pressure in one of said air springs.

3. In a restraining mechanism for the opposed engine pistons in the engine cylinder of a free-piston unit, said pistons being moved apart by the combustion of fuel in the engine cylinder and being moved together by air springs acting on the opposed pistons, said pistons normally moving symmetrically with respect to the center of the engine cylinder, electrical means connected to said pistons and responsive to a non-symmetrical movement of the pistons for changing the effective force of at least one of the air springs.

4. In a free-piston engine-and-compressor unit, an engine cylinder, opposed engine pistons in said cylinder, said pistons being moved apart by the combustion of fuel in the engine cylinder, air springs acting on the pistons for moving said pistons toward each other, a pair of electrical means, one of which is associated with each piston, a pair of similar circuits, each including one of said electrical means, each of said means operating in response to reciprocation of the pistons for procuring changes in the electrical circuit, and means controlled by an unbalance in the changes in the circuits for adjusting the effective force of one of said air springs.

5. In a free-piston engine-and-compressor unit, an engine cylinder, opposed engine pistons in said cylinder, said pistons being moved apart by the combustion of fuel in the engine cylinder, air springs acting on the pistons for moving said pistons toward each other, a pair of solenoids, the cores of which are connected to the pistons, a circuit including the solenoids in opposition, and means controlled by an unbalance in the

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circuit for adjusting the effective force of one of the air springs.

6. In a free-piston engine-and-compressor unit, an engine cylinder, opposed engine pistons in said cylinder, said pistons being moved apart by the combustion of fuel in the engine cylinder, air springs acting on the pistons for moving said pistons toward each other, a compressor piston connected to each of said engine pistons, a compressor cylinder in which each compressor piston reciprocates, the frequency of the cycle of each piston being changed by variations in operating conditions including air spring pressure, compressor inlet pressure, compressor discharge pressure, and effective length of the compressor piston stroke, and electrical means responsive to a non-symmetrical movement of the pistons for adjusting one of said operating conditions affecting one of the pistons.

7. In a free-piston engine-and-compressor unit, an engine cylinder, opposed engine pistons in said cylinder, said pistons being moved apart by the combustion of fuel in the engine cylinder, air springs acting on the pistons for moving said pistons toward each other, a compressor piston connected to each of said engine pistons, a compressor cylinder in which each compressor piston reciprocates, the frequency of the cycle of each piston being changed by variations in operating conditions including air spring pressure, compressor inlet pressure, compressor discharge pressure, and effective length of the compressor piston stroke, a pair of solenoids, the cores of which are connected to the pistons, a circuit including the solenoids in opposition, and means controlled by an unbalance in the circuit for adjusting one of said operating conditions affecting one of the pistons.

8. In a free-piston engine-and-compressor unit, an engine cylinder, opposed engine pistons in said cylinder, said pistons being moved apart by the combustion of fuel in the engine cylinder, air springs acting on the pistons for moving said pistons toward each other, a compressor piston connected to each of said engine pistons, a compressor cylinder in which each compressor piston reciprocates, the frequency of the cycle of each piston being changed by variations in operating conditions including air spring pressure, compressor inlet pressure, compressor discharge pressure, and effective length of the compressor piston stroke, a pair of solenoids, the cores of which are connected to the pistons, a circuit including the solenoids in opposition, and means controlled by an unbalance in the circuit for adjusting the effective force of one of said air springs.

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