BOUNCE CHAMBER CONTROL MECHANISM FOR A FREE PISTON ENGINE

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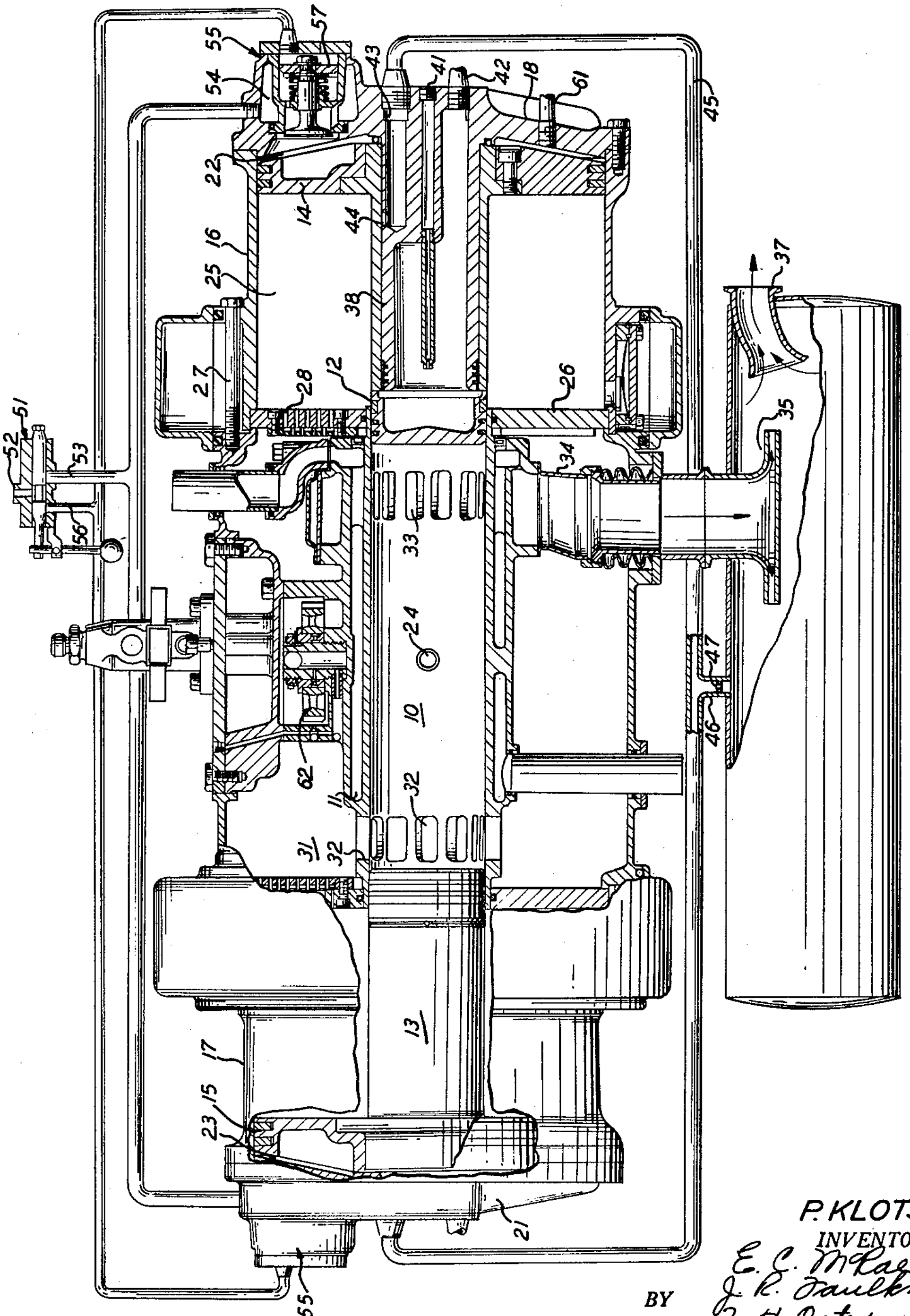

FIG. 1

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Dec. 8, 1959 P. KLOTSCH 2,916,025

BOUNCE CHAMBER CONTROL MECHANISM FOR A FREE PISTON ENGINE

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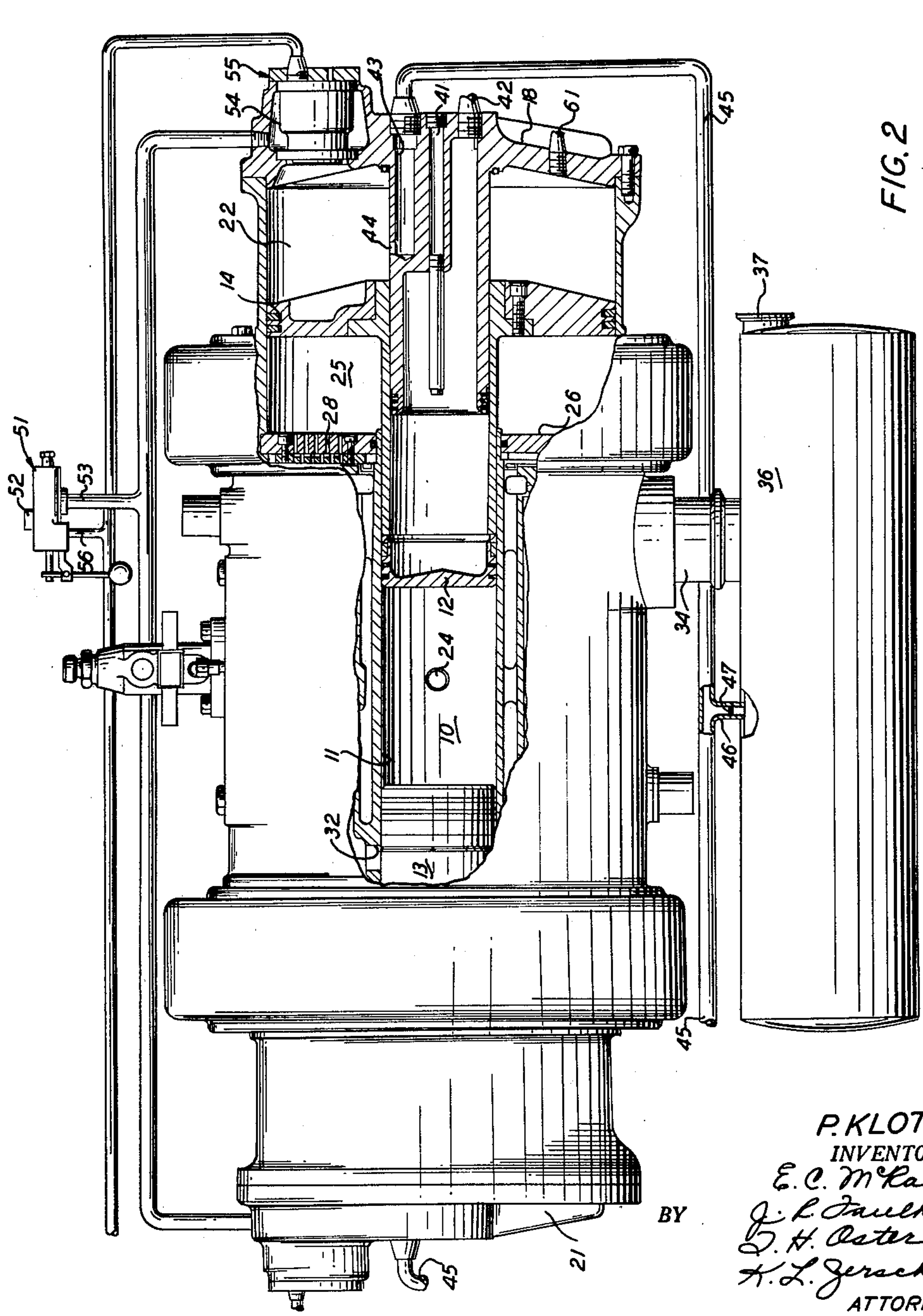


FIG. 2

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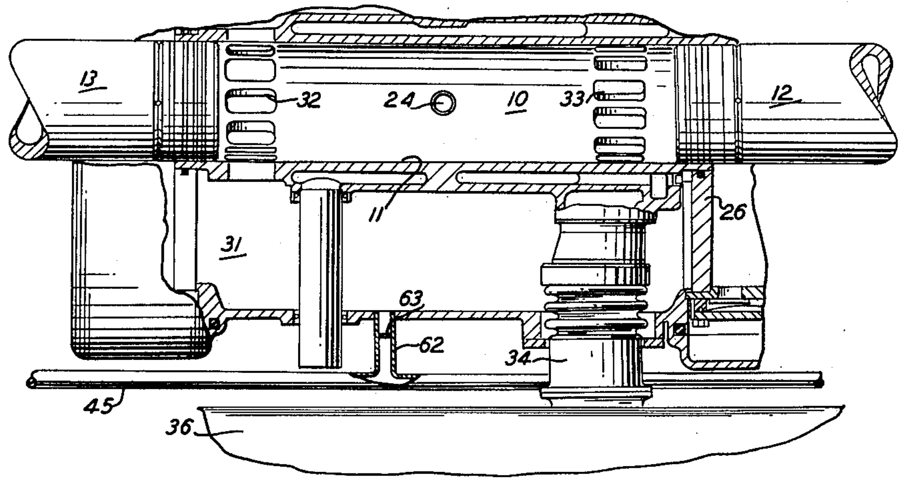


FIG.3

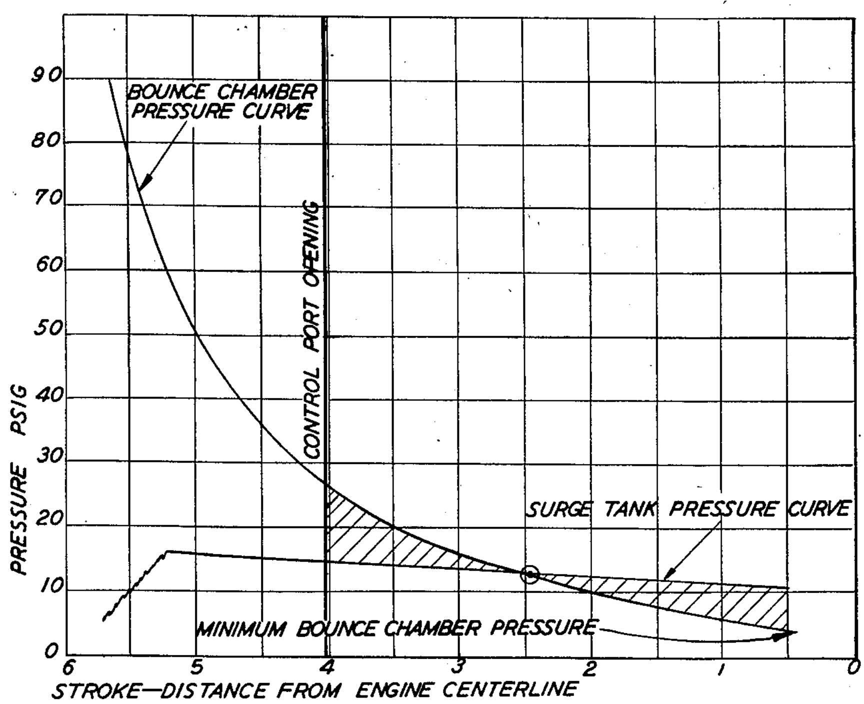


FIG. 4

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2,916,025

# BOUNCE CHAMBER CONTROL MECHANISM FOR A FREE PISTON ENGINE

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9 Claims. (Cl. 123—46)

This invention relates to a bounce chamber control mechanism for a free piston engine and more particularly to such a bounce chamber control mechanism which is simple, reliable and employs a very minimum of moving parts.

The invention can be employed with any conventional free piston engine, for example, it can be employed in a free piston engine comprising two power pistons which work on a diesel two-cycle opposed action. The power pistons may be synchronized by any conventional means known in the art, for example, by a pinion gear meshing with a pair of racks, with each of said racks being connected to one of the pistons. Each power piston may have a compressor piston, of larger diameter than the power piston, attached thereto for supplying air under pressure to scavenge the combustion chamber and for supplying air for the next combustion stroke. A bounce chamber is provided on the outer side of each compressor piston in which fluid is compressed during the combustion stroke. The energy in this compressed fluid then drives the power pistons on the compression stroke, and simultaneously the compressor pistons supply a charge of fluid under pressure to the scavenge box. This fluid, stored under pressure in the scavenge box, is later used to scavenge the combustion chamber and supply the air necessary to support combustion for the succeeding combustion stroke.

It is apparent that in the free piston engine, no restraining mechanism is employed to restrain the movements of the pistons and to return them to the proper points in the various strokes such as is employed in the conventional crank engine. Control of the movement of the power pistons is particularly important during the compression stroke so that the proper compression ratio is maintained.

The bounce system in a free piston engine serves as a means of power piston stroke control, and also serves two important additional functions; that of maintaining a constant energy level for any given load condition, and that of adjusting the energy level to accommodate changes in load. The energy accumulated in the bounce chamber during the combustion stroke of the pistons must return the power pistons to some predetermined inner end clearance during the compression stroke of the engine. At idle, when the pressure in the exhaust system is low, the air charge in the bounce system is at a minimum. As the load is increased, the pressure in the exhaust system rises. This results in an increase in the pressure and in the quantity of fluid present in the power cylinder during the compression stroke. It takes more energy to compress this increased quantity of fluid, and to obtain this energy it is necessary to increase the quantity of fluid in the bounce chambers.

This invention seeks to provide a mechanism whereby fluid may be supplied to or removed from the bounce control system as the load of the engine is varied. It is well known that the scavenging pressure and the exhaust pressure of a free piston engine vary more or less linearly with load; therefore, the present invention provides a



direct connection between the bounce chambers and the scavenge box, or between the bounce chambers and some point in the exhaust system, during a portion of each operating cycle for varying the quantity of fluid present in the bounce chambers in accordance with the load on the engine.

Thus, the bounce chambers are exposed to the exhaust system pressure or the scavenge pressure during a portion of each operating cycle. When the engine has been running at constant load for a period of time and equilibrium conditions have been reached, a certain quantity of fluid will flow both into and out of the bounce chambers during each operating cycle. In the absence of leakage, the net flow during each operating cycle at equilibrium will be equal to zero; however, during the latter portions of the combustion stroke, the pressure in the bounce chambers substantially exceeds the pressure in the compression chambers thereby causing a small amount of fluid to flow from the bounce chambers past the compressor pistons to the compression chambers. Because of this leakage, the pressure in the bounce chamber will be lowered and there will be a small net flow, during equilibrium conditions, from the surge tank or the exhaust system into the bounce chambers thereby resupplying the bounce chambers with fluid which was lost by said leakage.

If the load on the engine or the fuel supply is increased, the exhaust pressure and the scavenge pressure will rise and there will be a net flow of fluid into the bounce chambers. As the quantity of fluid in the bounce chambers increases, the bounce chamber pressure rises until a point is reached where the net flow of fluid into and out of the bounce chambers is again zero with the exception of the small amount of flow necessary to compensate for leakage. During a decrease in load, the scavenge pressure and the exhaust pressure drops so that the net flow of fluid is out of the bounce chambers until the pressure in the bounce chambers have decreased sufficiently to bring conditions once again into equilibrium, where the net flow of fluid into and out of the bounce chambers is zero, again with the exception of the flow necessary to make up for leakage. The control of the quantity of fluid in the bounce chambers and hence the pressures existing therein is accomplished with no extra moving parts over those already present in the engine, thus, an extremely simple, rugged and reliable bounce chamber control system is provided.

An object of the present invention is the provision of a bounce chamber control mechanism for a free piston engine.

Another object of the present invention is the provision of a bounce chamber control mechanism for a free piston engine which controls the stroke of the engine.

A further object of the invention is the provision of a bounce control mechanism for a free piston engine in which the pressure in the exhaust system or the scavenge system of the engine is exposed to the bounce control chambers for a portion of each operating cycle.

Still another object of the invention is the provision of a bounce chamber control mechanism for a free piston engine which is self-compensating and has no moving parts.

A further object of the invention is a bounce chamber control mechanism for a free piston engine which provides a means of discharging excess starting air which has been injected into the bounce chamber during starting operations.

Further objects and attendant advantages will become apparent as the specification is considered in conjunction with the drawings in which:

Figure 1 shows a preferred embodiment of the invention in which the pistons are at their outer dead points and the bounce control ports are covered;

Figure 2 shows the engine of Figure 1 in which the pistons are positioned between the inner and outer dead points and the bounce control ports are uncovered;

Figure 3 shows a partial view of another embodiment of the invention which utilizes scavenge box pressure rather than exhaust system pressure; and,

Figure 4 is a graph showing various pressure relationships of the engine which are pertinent to the operation of the bounce chamber control mechanism of this invention.

Referring now to the drawings in which like reference numerals designate like parts throughout the several views thereof, there is shown in Figures 1 and 2, a free piston engine employing the bounce chamber control system of the present invention, which has a combustion chamber **10** defined by a power cylinder **11** and a pair of opposed power pistons **12** and **13**. As can be appreciated by reference to the drawings, the two halves of the engine are nearly identical, and any departure therefrom will be discussed below. Rigidly attached to the power pistons are a pair of compressor pistons **14** and **15** which are adapted to reciprocate in compressor cylinders **16** and **17**. The compressor cylinders each have a cylinder head designated by the numerals **18** and **21** closing the outboard end thereof to form bounce chambers **22** and **23** which are defined by the cylinders **16** and **17**, the outboard end of the compressor pistons **14** and **15** and the cylinder heads **18** and **21**. On the combustion stroke of the engine, which is caused by the injection of fuel into the combustion chamber **10** through fuel injection nozzle **24** when the power pistons **12** and **13** are at their inner dead points, fluid is compressed in the bounce chambers which prevent the compressor pistons **14** and **15** from striking the cylinder heads **18** and **21**. The energy stored in the compressed fluid in the bounce chambers then drives the pistons inboard on the compression stroke to the inner dead points of the pistons at which time fuel is injected through nozzle **24** and the cycle repeats.

Referring now to the right hand half of the engine, and with the understanding that the left hand half contains similar parts, on the combustion stroke of the engine, air is inducted into the compression chamber **25** which is defined by the compression cylinder **16**, the inboard end of the compressor piston **14** and an annular shaped wall element **26**, through a one-way valve system which may be of the reed type as shown at **27**. A one-way valve system **28** is also positioned in the annular shaped wall element **26** which closes during the combustion stroke of the engine when air is being inducted into the compression chamber **25** through the valve system **27**. During the compression stroke of the engine, the valve system **27** is closed and the forward movement of the compressor piston **14** forces air through the valve system **28** into the scavenge box **31** where it is stored under pressure.

On the combustion stroke of the power pistons **12** and **13**, the one-way valve system **28** is closed and the air which is stored under pressure in the scavenge box **31** remains until the power piston **13** uncovers a plurality of scavenge ports **32** positioned in the power cylinder **11**. When the scavenge ports **32** open, the compressed air in the scavenge box **31** rushes into the combustion chamber **10** and blows the combustion gases from the combustion chamber through gaseous discharge ports **33**, ducting **34**, diffuser plate **35** and into surge tank **36**. The surge tank **36** serves as a reservoir to prevent large fluctuations of pressure at the nozzle of the turbine which the combustion gases of the free piston engine are designed to operate. The outlet from the surge tank which leads to the gas turbine nozzle is designated by the numeral **37**.

The power pistons and the compressor pistons each have axial bores positioned therein which receive a stub shaft piston **38** which may be supported by or integrally formed with the cylinder head **18**. This stub shaft piston serves to support and guide both the compressor piston and the power piston as they reciprocate in the power cylinder and the compressor cylinders respectively. Means are provided in the internal portion of the stub shaft pistons to cool the internal portions of the power cylinder, with the cooling fluid being injected into the internal portion of the power piston by means of a conduit **41** and being evacuated by means of a conduit **42**.

The stub shaft piston has a longitudinal bore or passage **43** positioned therein which terminates in a transverse bore or control port **44** which communicates with the bounce chamber **22** during the initial portion of the combustion stroke and the latter portion of the compression stroke. Figure 1 shows the control port **44** covered by the sleeve of the power piston **12** when the power piston and compressor pistons are in the outboard position, while Figure 2 shows the control port **44** communicating with the bounce chamber **22** when power piston and the compressor pistons are moved toward an inboard position.

The two bounce chambers **22** and **23** are connected by means of a conduit **45** which assists in equalizing the pressure in the two bounce chambers by connecting the two bounce chambers together during a portion of each operating cycle when the control ports **44** are uncovered. Of course, an additional bounce pressure equalizer line is employed which connects the two bounce chambers together during the whole of the operating cycle. This line may conveniently communicate with the bounce chambers through the cylinder heads **18** and **21**; however, since such pressure equalizer lines are so well known in the art, and since it forms no part of the present invention, it has not been illustrated in the drawings.

Referring now to Figures 1 and 2, the conduit **45** may be directly connected to the exhaust system of the engine, for example, the surge tank **36** by means of a conduit **46** which may have an orifice **47** positioned therein. Thus, it is apparent that the bounce chambers **22** and **23** are exposed to the fluid pressure in the exhaust system during a portion of each operating cycle of the engine when the control ports **44** are uncovered and that fluid may flow between the bounce chambers and the exhaust system in accordance with the pressure relationships existing in the bounce chambers and the exhaust system. The graph of Figure 4 depicts these pressure relationships as a function of the stroke of the compressor pistons and the power pistons. The ordinate represents pressure in pounds per square inch gage while the abscissa represents the stroke of the engine in inches as measured from the centerline of the engine. It will be noted that the pressure in the bounce chambers varies approximately exponentially with high pressures existing when the pistons are in the outboard position and low pressures existing in the inboard position. In comparison to the bounce chamber pressures the mean surge tank pressure is fairly constant. If, for example, the control ports are positioned at approximately 4 inches from the centerline of the engine, the bounce chambers and the exhaust system, the surge tank in this instance, will be in communication during that portion of the operating cycle in which the power pistons are between the inner dead points, which are shown here as approximately 0.5 of an inch from the centerline, and a position approximately four inches from the centerline.

The curves shown represent the pressures existing in the engine after equilibrium conditions have been reached and it is evident that the bounce chamber pressure curve crosses the surge tank pressure curve when the power piston is approximately 2½ inches from the centerline of the engine. When the power pistons are between their inner dead points and the position 2½ inches from the centerline, the pressure in the surge tank is greater than the pressure in the bounce chambers and consequently fluid will flow from the surge tank to the bounce chambers. Conversely, while the power pistons are moving between the points where the bounce chamber pressure curve crosses the surge tank pressure curve, at approximately 2½ inches from the centerline, and the position where the control ports **44** are covered, at approximately 4 inches from the centerline, fluid will flow from the bounce control chambers to the surge tank.

The velocity of the power pistons and the compressor pistons varies approximately as a sinusoid with the highest velocity being reached during the middle of the stroke, therefore, the pistons will have a higher velocity between the point where the two curves cross the point where the control ports close, than they do between the point where the two curves cross and the inner dead points. The quantity of fluid flow between the bounce chambers and the surge tank is a function of both the pressure differential between the two and time. It will be noted that a higher pressure differential exists to the left of the point where the two curves cross than to the right of said point; however, the time during which the bounce chambers and the surge tank are in communication is less to the left of said crossover point than to the right thereof because the length of piston travel is less and because the piston velocity over this length is greater than it is to the right of said crossover point. It has been found that when the pressure relationships exist as shown in Figure 4, that the flow of fluid into the bounce chambers from the surge tank equals the flow out of the bounce chambers into the surge tank during each operating cycle with the exception of a small amount of flow from the surge tank to the bounce chambers to compensate for leakage.

If the load or fuel supply to the engine is increased, the surge tank pressure will immediately increase, thus moving the surge tank pressure line upwardly, while that portion of the bounce chamber pressure curve located between the inner dead points of the engine, at approximately 0.5 of an inch from the centerline and the point where the control ports **44** close, at approximately 4 inches from the centerline will remain stationary until an increased quantity of fluid is admitted to the bounce chambers. Thus, it is apparent that appreciably more fluid will flow from the surge tank to the bounce chambers during each operating cycle than flows from the bounce chambers to the surge tank. This will continue until the bounce chamber pressure is increased due to the increased quantity of fluid present, to that point where the pressure differential between the bounce chambers and the surge tank that portion of the operating cycle when control ports **44** are open, reaches the point where the net flow, with the exception of that required to compensate for leakage, is again zero.

If the load or the fuel supply is decreased, then the surge tank pressure will drop and during each cycle more fluid will flow from the bounce chambers to the surge tank than from the surge tank to the bounce chambers. This will continue for a number of cycles until the quantity of fluid present in the bounce chambers has decreased to the point where the bounce chamber pressure, during that portion of the operating cycle when control ports **44** are open, reaches the point where the flow into and out of the bounce chambers during each operating cycle again reaches zero, with the exception of that required to compensate for leakage.

The bounce control chambers may also be connected to communicate with the scavenge box as shown in Figure 3. Here, the conduit **45** may be connected to the scavenge box **31**, rather than to the surge tank, by means of conduit **62** which may have an orifice **63** located therein. Since the mean pressure in the scavenge box also varies almost linearly with load or fuel supply as does the exhaust pressure, the principles of operation are exactly the same as that shown in Figures 1 and 2, and as explained above. Although the curves in Figure 4 may be positioned slightly differently when the scavenge box pressure is employed, the explanation given above holds for the connection shown in Figure 3 with mean scavenge pressure being substituted for the surge tank pressure.



Thus, the present invention provides a simple rugged bounce control system with a minimum of moving parts which is operative to expose the bounce chambers of the engine to exhaust pressure or scavenge pressure thereof during a portion of each operating cycle for increasing or decreasing the quantity of fluid in the bounce chambers in accordance with the load on the engine or the fuel supplied thereto.

A starter system for the free piston engine may also be associated with the bounce control system. The starter system utilizes compressed air to drive the power pistons to their inner dead points through the compressor pistons and the excess starting air is readily exhausted to the surge tank or scavenge box through the series of passages and conduits described above. More specifically, the starter system includes a three-way valve **51** in which conduit **52** is connected to a source of high pressure fluid (not shown) such as compressed air and the conduit **53** is connected to the storage chamber **54** of a pair of valves **55** located in the cylinder heads **18** and **21**. Prior to starting, the storage chambers of the valves **55** are filled with compressed fluid by positioning the valve **51** so that conduit **52** is connected to conduit **53** thereby connecting the source of compressed fluid with the storage chambers in the valves. During the starting operation, the valve **51** is positioned so that the source of compressed air is connected through conduit **52** and valve **51** with a conduit **56**, the pressure of the fluid acting upon a piston **57** thereby opening the valve **55**. The compressed fluid in the storage chambers **54** flows into the bounce chambers **22** and **23** and drives the power pistons to their inner dead points through compressor pistons **14** and **15**. When the power pistons reach the inner dead points, a charge of fuel is injected into the combustion chamber **10** and the engine fires and commences to run. Prior to the time that the power pistons reach the point where fuel is injected, the passages **44** are uncovered and the excess starting air is exhausted from the bounce chambers through control ports **44**, passages **43**, conduit **45**, conduit **46** and orifice **47** into surge tank **36** where it may be exhausted to the atmosphere through outlet **37** by way of the turbine associated with the engine or the excess starting air may be exhausted from the bounce control chambers to the scavenge box of the engine by means of passages **44** and **43**, conduit **45**, conduit **63** and orifice **62**. Of course, it may take several cycles of engine operation before all excess starting air is removed from the bounce chambers.

Prior to starting, the power pistons and compressor pistons may be conveniently moved to their outboard positions as shown in Figure 1 by means of a vacuum pump (not shown) which is driven by an electric motor (not shown).

The vacuum pump is connected to a conduit **61** positioned in one of the cylinder heads, for example, cylinder head **18**, and it exhausts fluid directly from the bounce chamber **22**. The pump also exhausts fluid from the bounce chamber **23** through the pressure equilizing conduit (not shown) previously described and bounce chamber **22**. The compressor pistons **12** and **13** and the power pistons **14** and **15** then move to their outboard positions as shown in Figure 1 through the action of the atmospheric pressure existing in the compression chambers.

It will be understood that the invention is not to be limited to the exact construction shown and described, and that various changes and modifications may be made without departing from the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. In an internal combustion engine of the free piston type the combination comprising, a power cylinder, at least one power piston adapted to reciprocate within said power cylinder, at least one bounce chamber, means operatively associated with said power piston for compressing a fluid in said bounce chamber on the combus-

tion stroke of the power piston, the energy in said compressed fluid driving the power piston on the compression stroke, said power piston having an internal bore positioned therein, a piston guide means positioned within said internal bore, said piston guide means having a passage positioned therein which communicates with the bounce chamber during a portion of each operating cycle, a source of fluid under pressure, the pressure in said source varying as a function of the load on said engine, means connecting the passage in the piston guide means with said source of fluid under pressure for varying the quantity of fluid in said bounce chamber in accordance with the pressure existing in said source of fluid under pressure.

2. In an internal combustion engine of the free piston type the combination comprising, a power cylinder, at least one power piston adapted to reciprocate within said power cylinder, an exhaust system for receiving combustion products from the power cylinder, at least one bounce chamber, means operatively associated with said power piston for compressing a fluid in said bounce chamber on the combustion stroke of the power piston, the energy in said compressed fluid driving the power piston on the compression stroke through said means operatively associated with the power piston, said power piston having an internal bore positioned therein, a piston guide means positioned within said internal bore, said piston guide means having a passage positioned therein which communicates with the bounce chamber during a portion of each operating cycle, means connecting the passage in the piston guide means with the exhaust system for varying the quantity of fluid in said bounce chamber in accordance with the pressure in said exhaust system.

3. In an internal combustion engine of the free piston type the combination comprising, a power cylinder, at least one power piston adapted to reciprocate within said power cylinder, at least one bounce chamber, means operatively associated with said power piston for compressing a fluid in said bounce chamber on the combustion stroke of the power piston, the energy in said compressed fluid driving the power piston on the compression stroke, means operatively associated with said power piston for compressing air, said power piston having an internal bore positioned therein, a piston guide means positioned within said internal bore, said piston guide means having a passage positioned therein which communicates with the bounce chamber during a portion of each operating cycle, a scavenge box for storing the air so compressed, means connecting the passage in the piston guide means with said scavenge box for varying the quantity of fluid in said bounce chamber in accordance with the pressure existing in said scavenge box.

4. In an internal combustion engine of the free piston type, the combination comprising, at least one power piston and at least one compressor piston operatively connected together, a power cylinder and a compressor cylinder for said power piston and said compressor piston respectively, a source of fluid under pressure, the pressure in said source varying as the load on said engine, at least one bounce chamber, said compressor piston compressing fluid in said bounce chamber on the combustion stroke of said power piston, the energy of the compressed fluid in said bounce chamber driving the power piston and the compressor piston on the compression stroke of said power piston, said power piston and said compressor piston having an internal axial bore positioned therein, a piston guide means positioned within the internal bore in said power piston and said compressor piston and supported by said compressor cylinder, said piston guide means having a passage positioned therein which communicates with the bounce chamber during the initial portion of the combustion stroke and the latter portion of the compression stroke, means connecting the passage positioned in the piston guide means with the source of fluid under pressure whereby fluid may flow from said bounce chamber to said source of fluid under pressure and from said source of fluid under pressure to said bounce chamber during a portion of each operating cycle.

5. In an internal combustion engine of the free piston type, the combination comprising, at least one power piston and at least one compressor piston operatively connected together, a power cylinder and a compressor cylinder for said power piston and said compressor piston respectively, an exhaust system for receiving combustion products from said power cylinder, at least one bounce chamber, said compressor piston compressing fluid in said bounce chamber on the combustion stroke of said power piston, the energy of the compressed fluid in said bounce chamber driving the power piston and the compressor piston on the compression stroke of said power piston, said power piston and said compressor piston having an internal axial bore positioned therein, a piston guide means positioned within the internal bore in said power piston and said compressor piston and supported by said compressor cylinder, said piston guide means having a passage positioned therein which communicates with the bounce chamber during the initial portion of the combustion stroke and the latter portion of the compression stroke, means connecting the passage positioned in the piston guide means with the exhaust system of said engine whereby fluid may flow from said bounce chamber to said exhaust system and from said exhaust system to said bounce chamber during a portion of each operating cycle.

6. In an internal combustion engine of the free piston type, the combination comprising, at least one power piston and at least one compressor piston operatively connected together, a power cylinder and a compressor cylinder for said power piston and said compressor piston respectively, a scavenge box, said scavenge box receiving air under pressure from said compressor cylinder and piston, at least one bounce chamber, said compressor piston compressing fluid in said bounce chamber on the combustion stroke of said power piston, the energy of the compressed fluid in said bounce chamber driving the power piston and the compressor piston on the combustion stroke of said power piston, said power piston and said compressor piston having an internal axial bore positioned therein, a piston guide means positioned within the internal bore in said power piston and said compressor piston and supported by said compressor cylinder, said piston guide means having a passage positioned therein which communicates with the bounce chamber during the initial portion of the combustion stroke and the latter portion of the compression stroke, means connecting the passage positioned in the piston guide means with the scavenge box of said engine whereby fluid may flow from said bounce chamber to said scavenge box, and from said scavenge box to said bounce chamber during a portion of each operating cycle.

7. An internal combustion engine of the free piston type comprising, a power cylinder, a pair of opposed power pistons adapted to reciprocate within said power cylinder, a compressor chamber for each of the power pistons, said compressor chamber being connected to the power cylinder to supply compressed air thereto during each cycle of operation, an independent bounce chamber for each of said power pistons, means operatively connected to said power pistons for compressing fluid in said bounce chambers on the combustion stroke of said engine, the energy of the compressed fluid driving said power pistons on the compression stroke, said engine having a source of fluid under pressure operatively associated therewith, the pressure in said source being a function of the load on said engine, a port positioned intermediate the ends of each bounce chamber which communicates with said bounce chamber during a portion of each operating cycle, conduit means connecting the ports for equal-

izing the pressure in said bounce chambers, and means connecting said conduit means with said source of fluid under pressure whereby said source of fluid under pressure is connected with said bounce chambers during a portion of each operating cycle for varying the quantity of fluid in said bounce chambers in accordance with the pressure in said source.

8. An internal combustion engine of the free piston type comprising, a power cylinder, a pair of opposed power pistons positioned within said cylinder adapted for two cycle opposed diesel operation, a bounce chamber for each of said power pistons, means operatively connected to said power pistons for compressing fluid in said bounce chambers on the combustion stroke of said pistons, the energy of the compressed fluid driving said power pistons on the compression stroke, said engine having an exhaust system for receiving combustion products from the combustion cylinder of the engine, a port positioned intermediate the ends of each bounce chamber which communicates with said bounce chamber during a portion of each operating cycle, a conduit means connecting the ports for equalizing the pressure in said bounce chambers and means directly connecting said conduit means with the exhaust system of said engine whereby said exhaust system is connected with the bounce chambers during a portion of each operating cycle for varying the quantity of fluid in said bounce chambers in accordance with the pressure in said exhaust system.

9. An internal combustion engine of the free piston type comprising, a power cylinder, a pair of opposed power pistons adapted to reciprocate within said power cylinder, a compressor chamber for each of the power



pistons, said compressor chamber being connected to the power cylinder to supply compressed air thereto during each cycle of operation, an independent bounce chamber for each of said power pistons, means operatively connected to said power pistons for compressing fluid in said bounce chambers on the combustion stroke of said engine, the energy of the compressed fluid driving said power pistons on the compression stroke, a scavenge box, said means operatively connected to said power pistons also compressing air for storage in said scavenge box, a port positioned intermediate the ends of each bounce chamber which communicates with said bounce chamber during a portion of each operating cycle, conduit means connecting the ports for equalizing the pressure in said bounce chambers, and means connecting said conduit means with said scavenge box whereby said scavenge box is connected with said bounce chambers during a portion of each operating cycle for varying the quantity of fluid in said bounce chambers in accordance with the pressure in said scavenge box.

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