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FREE PISTON ENGINE WITH ROTATING PISTONS

Filed June 22, 1959

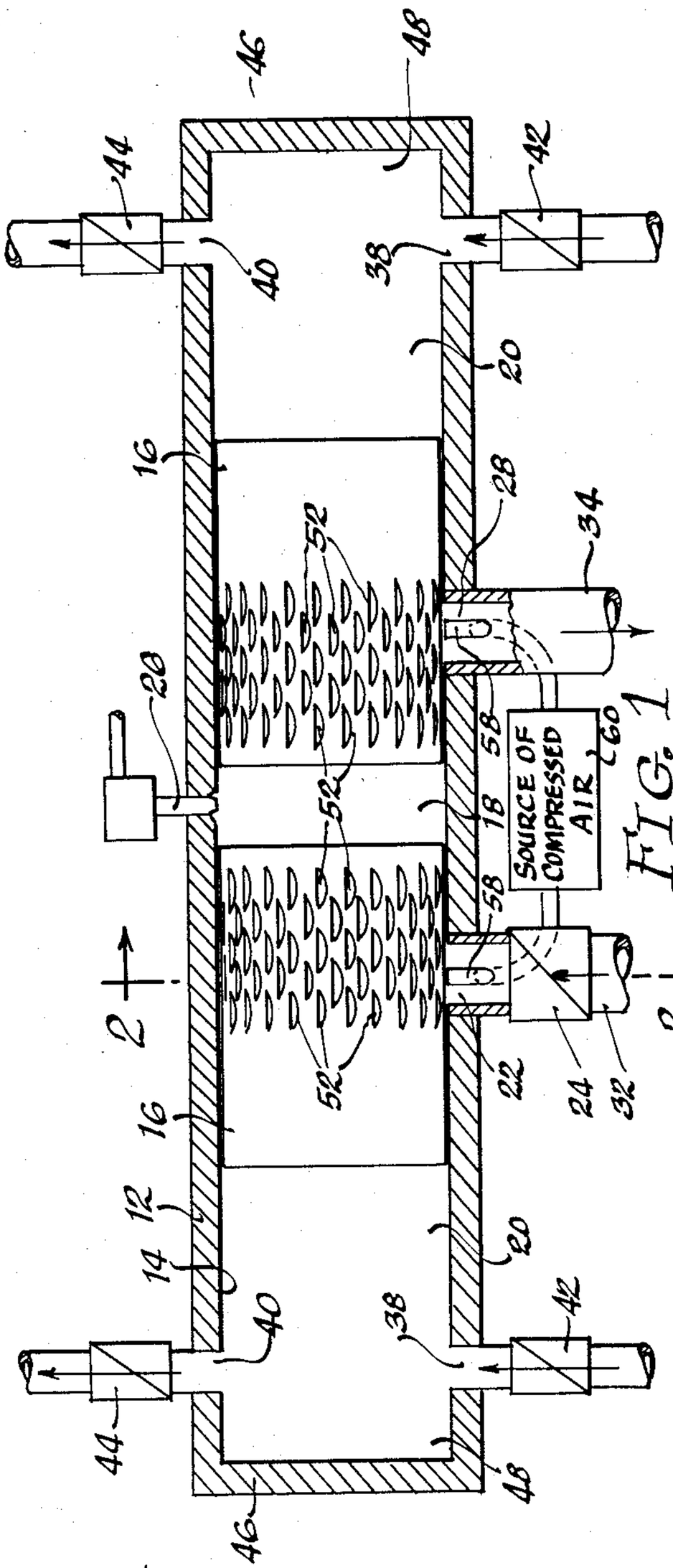

FIG. 1

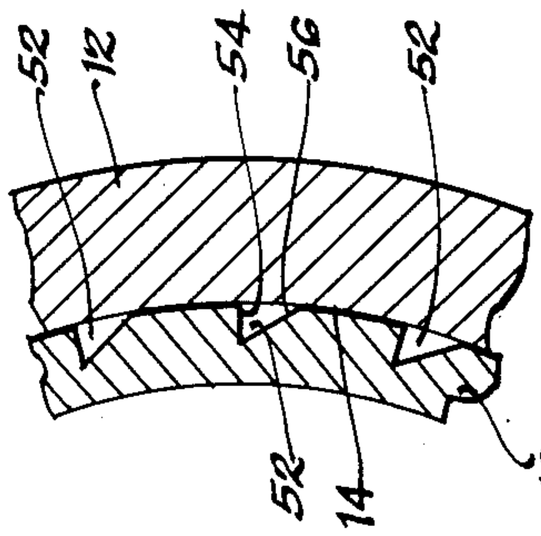

FIG. 3

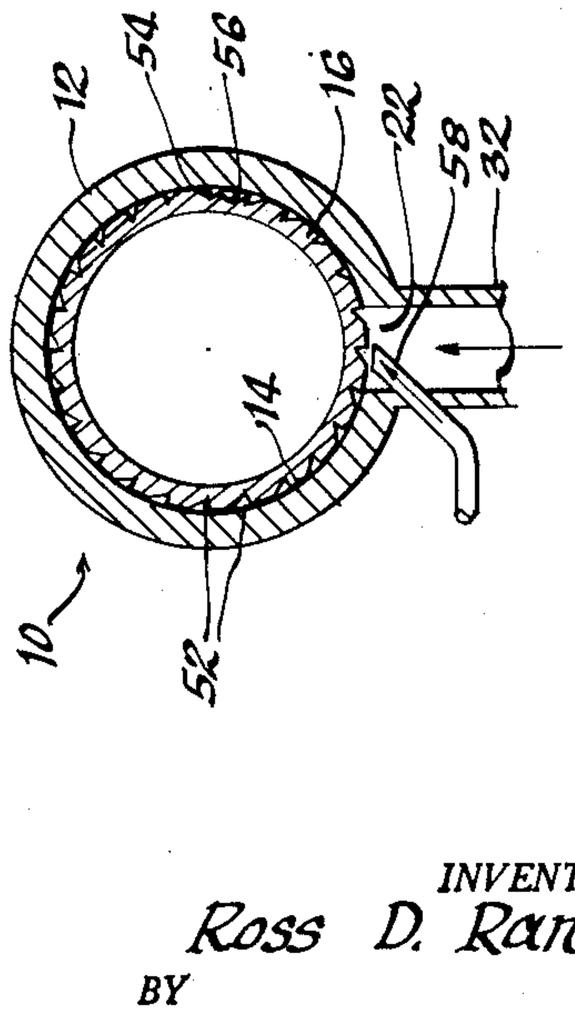

FIG. 2

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FREE PISTON ENGINE WITH ROTATING PISTONS

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9 Claims. (Cl. 123—46)

This invention relates to free piston engines of the type in which two free pistons are adapted to oscillate toward and away from each other in a cylinder.

One object of the present invention is to provide a new and improved free piston engine in which the pistons are lubricated by films of gas developed between the cylinder and the pistons, so that the engine may be operated at higher temperatures than would be permissible if oil were employed to lubricate the pistons.

A further object is to provide a new and improved free piston engine of the foregoing character in which the film of lubricating gas is developed by maintaining the pistons in rapid continuous rotation as they are reciprocated in the cylinder.

Another object is to provide a new and improved free piston engine of the foregoing character in which the pistons are rotated by streams of air or other gas, so as to maintain the pistons truly free, without any mechanical connection thereto.

Further objects and advantages of the present invention will appear from the following description, taken with the accompanying drawings, in which:

FIG. 1 is a diagrammatic longitudinal section taken through a free piston engine to be described as an illustrative embodiment of the present invention.

FIG. 2 is a cross-sectional view taken generally along a line **2—2** in FIG. 1.

FIG. 3 is a fragmentary enlarged cross-sectional view corresponding to a portion of FIG. 2.

The present invention may be regarded as an improvement upon the invention disclosed in the copending United States patent application of Vannevar Bush, Serial Number 483,987, filed January 25, 1955, and entitled "Free Piston Engine." Thus, the present drawings illustrate a free piston engine **10** comprising a cylinder **12** having inside walls defining a bore **14** therein. Preferably, the bore **14** is of substantially the same diameter throughout its length. This is in contrast with the conventional free piston engine, which usually has a stepped bore.

In the present engine, two identical pistons **16** are symmetrically disposed in the bore **14** for reciprocation therein. It will be seen that the pistons **16** are simply in the form of substantially cylindrical slugs, having the same outside diameter along their entire length. This is in contrast with the stepped pistons of many prior, conventional free piston engines. In the present engine, the pistons **16** are adapted to oscillate in synchronism, toward and away from each other. The oscillation of the pistons is symmetrical about the center of the cylinder. The symmetrical oscillation of the pistons balances out the vibrations that would be imparted to the cylinder if the cylinder contained only a single piston. Thus, the engine operates with very little vibration. It will be understood, however, that the invention is applicable to a free piston engine utilizing only one piston adapted to oscillate in a cylinder.

The present pistons **16** are entirely free, in the sense that no mechanical or hydraulic connection is made to the pistons. This arrangement enables the pistons to oscillate with a minimum of friction between the pistons and the wall of the cylinder, as will be discussed in further detail shortly.

The cylinder **12** may be regarded as containing a

combustion chamber **18** and a compression chamber **20** on opposite sides of each piston **16**. In this case, the combustion chamber **18** is located in the center of the cylinder **12**, between the two pistons **16**. Thus, a single combustion chamber serves both pistons. However, there are two compression chambers **20**, in the opposite end portions of the cylinder **12**. For some purposes, the combustion and compression chambers could be interchanged, but the illustrated arrangement is preferable.

Air is introduced into the combustion chamber **18** through an inlet port **22** adapted to be covered and uncovered by the left-hand piston **16**. A check valve **24** may be provided at the inlet port **22** to prevent backflow of air into the inlet port. It will be understood that the inlet port **22** is uncovered when the pistons **16** move apart to the outward limits of their travel. As the pistons **16** move together, the inlet port **22** is covered by the left-hand piston so that the charge of air is compressed between the pistons. The increasing pressure of the charge of air between the pistons slows them down and eventually arrests their inward movement. At this point, fuel is introduced into the combustion chamber **18** by a fuel injector **26**, located at the midpoint of the cylinder **12**. The fuel injector may be timed and controlled in the manner disclosed in the previously mentioned co-pending application, Serial Number 483,-987, filed January 25, 1955. The fuel is ignited as it is injected, due to the high temperature of the compressed air between the pistons **16**. Thus, the illustrated engine utilizes a diesel combustion cycle. The pistons **16** are driven apart by the pressure of the hot products of combustion.

After the products of combustion have expanded to a considerable extent, the right-hand piston **16** uncovers an outlet port **28** through which the products of combustion are discharged. A new charge of air is then introduced through the inlet port **22**. It will be understood that the incoming compressed air scavenges the combustion chamber **18** by forcing the products of combustion out the discharge port **28**. As shown, pipes **32** and **34** are connected to the inlet and outlet ports **22** and **28**.

It will be seen that each compression chamber **20** is provided with inlet and outlet ports **38** and **40**. Air enters each compression chamber **20** through the respective inlet port **38**. Check valves **42** may be provided at the inlet ports **38** to prevent backflow of air. The air is drawn into the compression chambers **20** through the ports **38** as the pistons move inwardly toward the midpoint of the cylinder. When the pistons move outwardly, the air is compressed in the compression chambers **20**. The air leaves the compression chambers **20** through the outlet ports **40**. Check valves **44** may be provided at the outlet ports **40** to prevent backflow of the compressed air into the cylinder. Thus, each compression chamber **20** operates on an air compression cycle.

It will be seen that the inlet and outlet ports **38** and **40** are spaced inwardly from the ends of the cylinder. End walls **46** are provided to close the ends of the cylinder. The space between each end wall **46** and the corresponding ports **38** and **40** constitutes a bounce chamber **48**. After the pistons **16** cover the ports **38** and **40**, the air trapped in the bounce chambers **48** is highly compressed. The pressure of the compressed air in the bounce chambers slows down the pistons and eventuallly drives them inwardly toward the midpoint of the cylinder.

The air compressed in the end chambers **20** may be used to operate a turbine or other machine, not shown, or to charge and scavenge the combustion chamber **18**, or for both purposes. This matter is developed in greater de-

tail in the previously mentioned co-pending application of Vannevar Bush, Serial Number 483,987.

In order to minimize friction, while avoiding the use of lubricating oil or the like, the present invention makes provision for the lubrication of each piston **16** by a film of air or gas between the piston and the walls of the cylinder. It is desirable to dispense with the use of lubricating oil, because the oil imposes a limitation upon the temperature at which the engine may be operated. At sufficiently high temperatures, any lubricating oil will break down to form carbon and other undesirable deposits in the cylinder. Moreover, an excessive amount of lubricating oil will be consumed.

In the present engine, a film of lubricating gas or air is developed around each piston by causing the pistons to rotate continuously and rapidly within the cylinder bore **14**. The rotation of the pistons is easily effected because the pistons are entirely free of any mechanical or hydraulic restraint. Moreover, the initial friction between the piston and the walls of the cylinder is overcome by the reciprocating movement of the pistons. Thus, very little power is required to rotate the pistons at high speed. The rapid rotation of the pistons develops aerodynamic forces which center the pistons in the cylinder, so that the film of air or gas is maintained around each piston. To facilitate the development of the film of gaseous lubricant, the pistons may be made of a lightweight material and may be made hollow in construction. Suitable ceramics or various lightweight alloys may be employed in the pistons.

In this case, the pistons are rotated by directing streams of air or gas against turbo-impeller elements **52** on the outside of the pistons. Thus, each piston rotates in the manner of a turbine wheel. The impeller element **52** may take the form of localized recesses or notches on the outside of the pistons **16**. The notches are localized so that they will not cause leakage of compressed gas or air around the pistons. As shown to best advantage in FIG. 3, each recess **52** has a substantially radial wall **54** which is adapted to receive the force of the air streams which are utilized to rotate the pistons **16**. The other wall **56** of each recess **52** is inclined at an acute angle to the wall **54**.

Streams of air are directed against the pistons **16** by nozzles or jets **58** which extend into the cylinder generally tangentially. The nozzles **58** are located at points along the cylinder which are traversed by the pistons **16** in their reciprocating movement. The impeller elements **52** are located on the portions of the pistons which travel past the nozzles **58**. There is no need to form impeller elements on the other portions of the pistons **16**.

It is preferred to locate the nozzles **58** in the inlet and outlet ports **22** and **28**. As shown, the nozzles **58** are centered in the ports but are inclined so as to direct the air streams in a generally tangential direction into the cylinder. The nozzles **58** are connected to a suitable tank or other source of compressed air **60**. The compressed air may be derived, either directly or indirectly, from the end chambers **20** of the free piston engine. The air is supplied through the nozzles **58** at sufficient pressure and in a sufficient quantity to insure rapid continuous rotation of the pistons **16**. Of course, the inertia of the pistons maintains them in rotation when they move outwardly into the end chambers **20** and thus are out of range of the nozzles **58**.

The rapid rotation of the piston **16** centers them in the cylinder so that a film of air or gas is always maintained between each piston and the walls of the cylinder. This minimizes friction between the pistons and the cylinder, and makes it possible to dispense with the use of lubricating oil. Thus, the engine may be operated at temperatures that would be prohibitively high if it were necessary to use oil. Accordingly, the efficiency and power output of the engine can be increased substantially.

Various modifications, alternative constructions and equivalents may be employed without departing from the true spirit and scope of the invention, as exemplified in the foregoing description and defined in the following claims.

I claim:

1. In a free piston engine, the combination comprising a cylinder having inside walls defining a bore therein of substantially the same diameter throughout its length, said cylinder having end walls substantially closing the opposite ends of said bore, a pair of generally cylindrical pistons freely reciprocable and rotatable in said bore, said pistons defining a central combustion chamber in said bore between said pistons and end chambers in said bore between the end walls and the corresponding pistons, means for introducing fuel and air into said central chamber for combustion therein, said means including an inlet port in said cylinder adapted to be covered and uncovered by one of said pistons, means including an outlet port in said cylinder adapted to be covered and uncovered by the other of said pistons for withdrawing products of combustion from said central chamber, means for introducing air into said end chambers for compression therein, means for withdrawing compressed air from said end chambers, and means for continuously rotating said pistons, said last mentioned means including impeller elements formed at spaced points on the outside of each of said pistons, a pair of nozzles directed into said cylinder through said inlet and outlet ports for directing streams of air against said impeller elements to rotate said pistons, each of said impeller elements comprising a recess formed on the outside of one of said pistons and having a generally radial wall for receiving the force of said air streams from said nozzles, and means for supplying air under pressure to said nozzles.

2. In a free piston engine, the combination comprising a cylinder having walls defining a bore therein, a piston freely reciprocable and rotatable in said bore, and means for rapidly rotating said piston in said bore to develop a gaseous lubricating film between said piston and said walls so as to minimize friction therebetween.

3. In a free piston engine, the combination comprising a cylinder having walls defining a bore therein, a piston freely reciprocable and rotatable in said bore, a plurality of impeller elements formed on the outside of said piston, and means for directing a stream of gas against said impeller elements with a tangential component to cause rapid rotation of said piston and thereby develop a film of lubricating gas between said piston and said walls so as to minimize friction therebetween, each of said impeller elements comprising a recess formed on the outside of said piston for receiving the force of said stream of gas.

4. In a free piston engine, the combination comprising a cylinder having longitudinal walls defining a bore therein, said cylinder having end walls closing the opposite ends of said bore, a pair of pistons freely reciprocable and rotatable in said walls, said pistons defining a central combustion chamber in said bore between said pistons and end chambers in the ends of said bore between said end walls and said pistons, means for introducing gaseous energy into said cylinder for oscillating said pistons toward and away from each other, and means for rapidly rotating said pistons in said bore to develop a film of lubricating gas between said pistons and said bore so as to minimize the friction therebetween, said last mentioned means comprising turbo-impeller elements on the outside of said pistons, and means for directing streams of gas into said cylinder and against said turbo-impeller elements, said streams of gas being directed generally tangentially into said cylinder at points therealong traversed by said pistons.

5. In a free piston engine, the combination comprising a cylinder having walls defining a bore therein, a pair of pistons freely reciprocable and rotatable in said bore, and means for rapidly rotating said pistons in said bore

to develop a gaseous lubricating film between said pistons and said walls so as to minimize friction therebetween.

6. In a free piston engine, the combination comprising a cylinder having walls defining a bore therein, a pair of pistons freely reciprocable and rotatable in said bore, a plurality of impeller elements formed on the outside of each piston, and means for directing streams of gas against said impeller elements with a tangential component to cause rapid rotation of said pistons and thereby develop a film of lubricating gas between each piston and said walls so as to minimize friction therebetween, said impeller elements comprising recesses formed on the outside of said pistons for receiving the force of said streams of gas.

7. In a free piston engine, the combination comprising a cylinder having side walls defining a bore therein, said cylinder having end walls substantially closing the opposite ends of said bore, a pair of pistons freely reciprocable and rotatable in said bore, means for releasing energy in said cylinder for oscillating said pistons toward and away from each other, and means for rapidly rotating said pistons in said bore to develop a film of lubricating gas between said pistons and said side walls so as to minimize the friction therebetween, said last mentioned means comprising turbo-impeller elements on the outside

of said pistons, and means for directing streams of gas into said cylinder and against said turbo-impeller elements, said streams of gas being directed generally tangentially into said cylinder at points therealong traversed by said pistons.

8. A piston comprising a body portion having longitudinal walls defining an outside surface of circular transverse cross-section substantially of uniform diameter, said outside surface having a plurality of longitudinal recesses spaced from each other and extending entirely within the longitudinal ends of the walls.

9. A piston operable to reciprocate and rotate in a circular cylinder, comprising a substantially cylindrical body portion having an outside surface of substantially uniform diameter along its longitudinal center axis, the outside surface having a plurality of longtiudinally extending recesses circumferentially spaced from each other, with none of the recesses communicating with both longitudinal ends of the walls.

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UNITED STATES PATENT OFFICE

CERTIFICATION OF CORRECTION

August 8, 1961

Patent No. 2,995,122

Ross D. Randall

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 57, for "walls" read -- bore --; line 64, for "bore" read -- longitudinal walls --; column 6, line 16, for "longtiudinally" read -- longitudinally --.

Signed and sealed this 3rd day of April 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents