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Hope

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(54) **PISTON VALVE FOR TWO-STROKE ENGINE**

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Related U.S. Application Data

(63) Continuation of application No. 09/616,258, filed on Jul. 14, 2000, now Pat. No. 6,405,691.

(51) **Int. Cl.**[7] **F02B 75/02**
(52) **U.S. Cl.** .... **123/65 VB**; 123/47 A
(58) **Field of Search** .... 123/65 VB, 65 V, 123/47 A, 47 R

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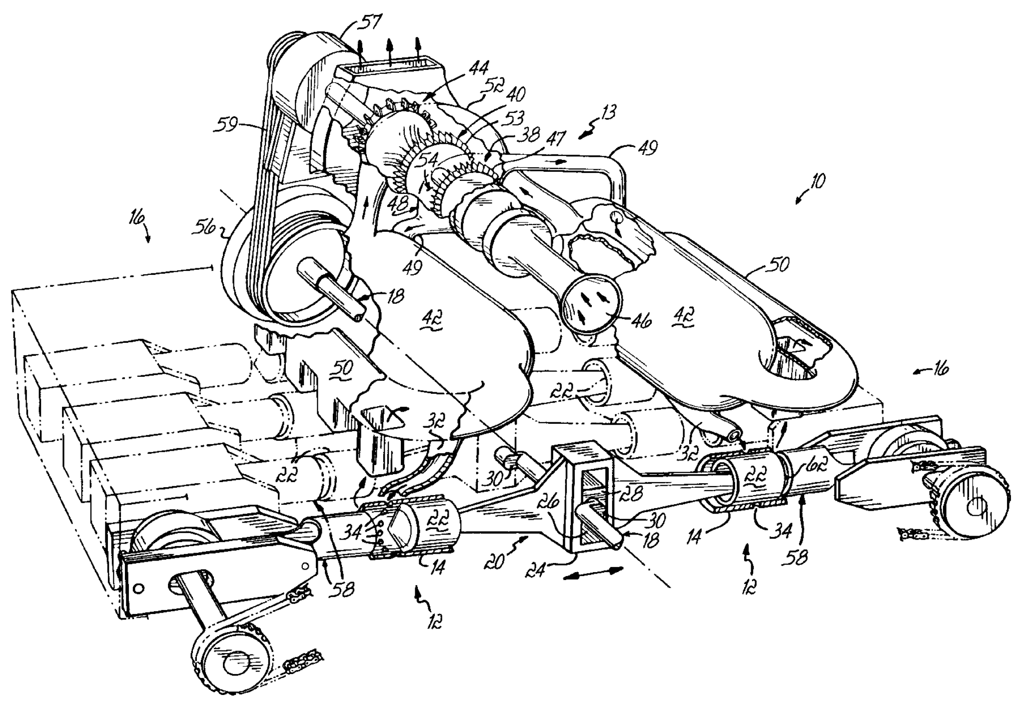
(57) **ABSTRACT**

A two-stroke engine has a piston operatively connected to a crankshaft for reciprocating motion within a cylinder. An annular piston valve is mounted for slidable motion with respect to a centrally located inner body of the piston to control a flow of cycle air through the piston. A cycle air intake opening is located in a wall of the cylinder at a location above a bottom dead center position of the piston. The cycle air intake is blocked and unblocked by the reciprocating motion of the piston. A transition member located between the crankcase and the cylinder has a bore for sealingly receiving the straight body section of the connecting rod.

14 Claims, 6 Drawing Sheets



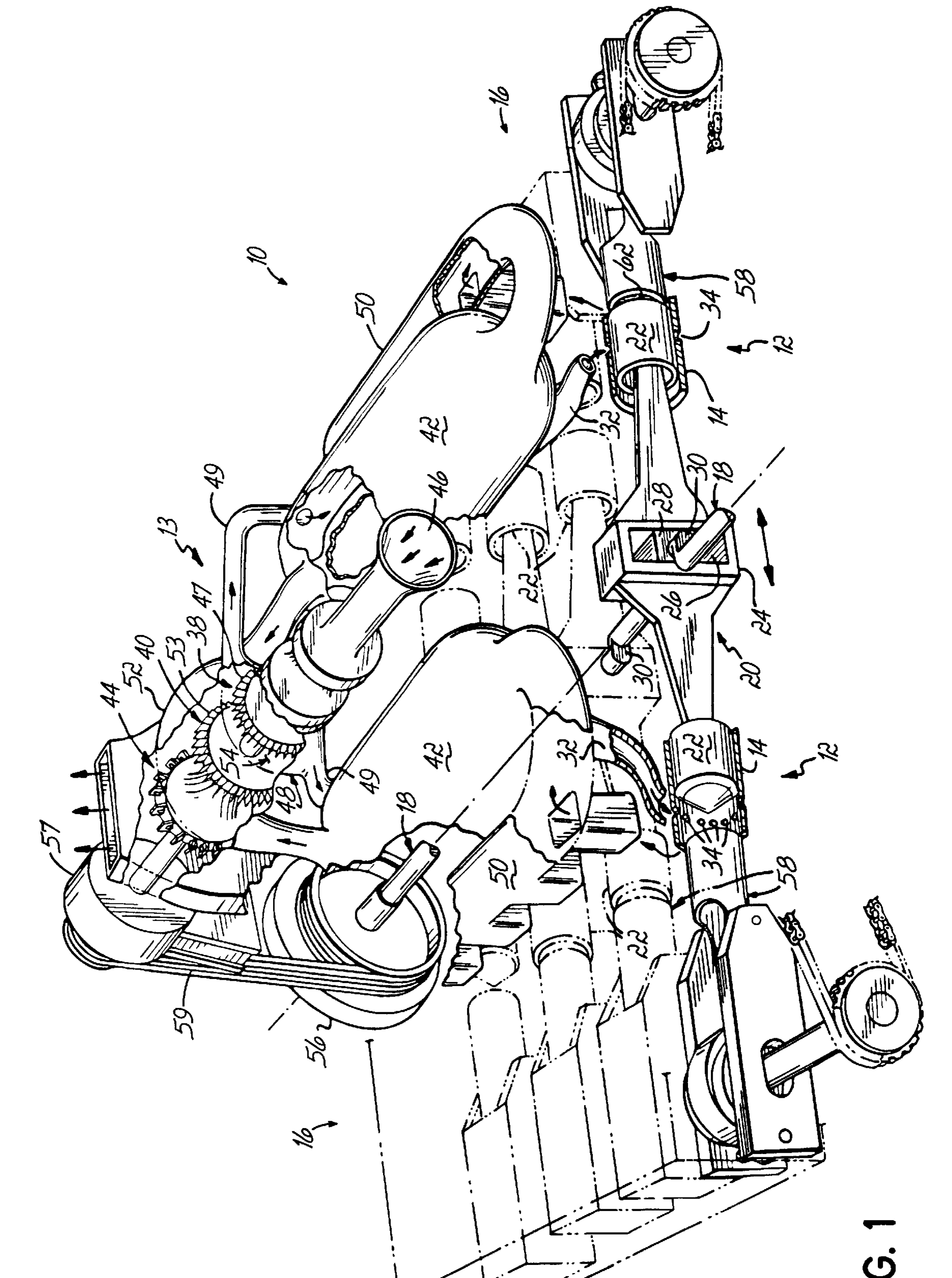


FIG. 1

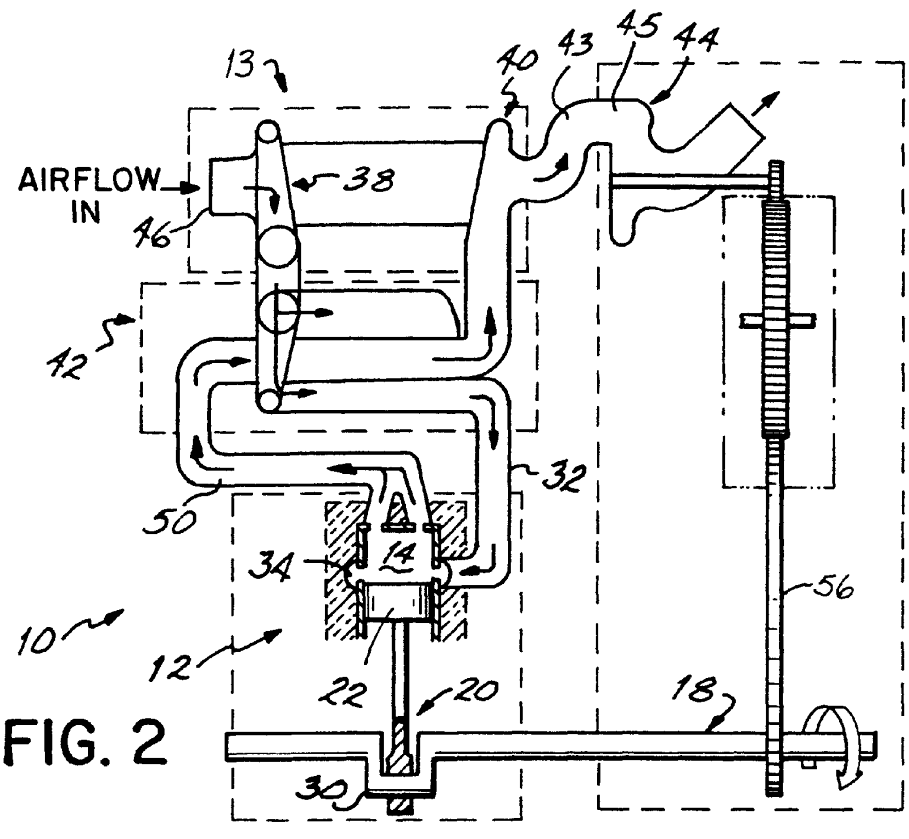


FIG. 2

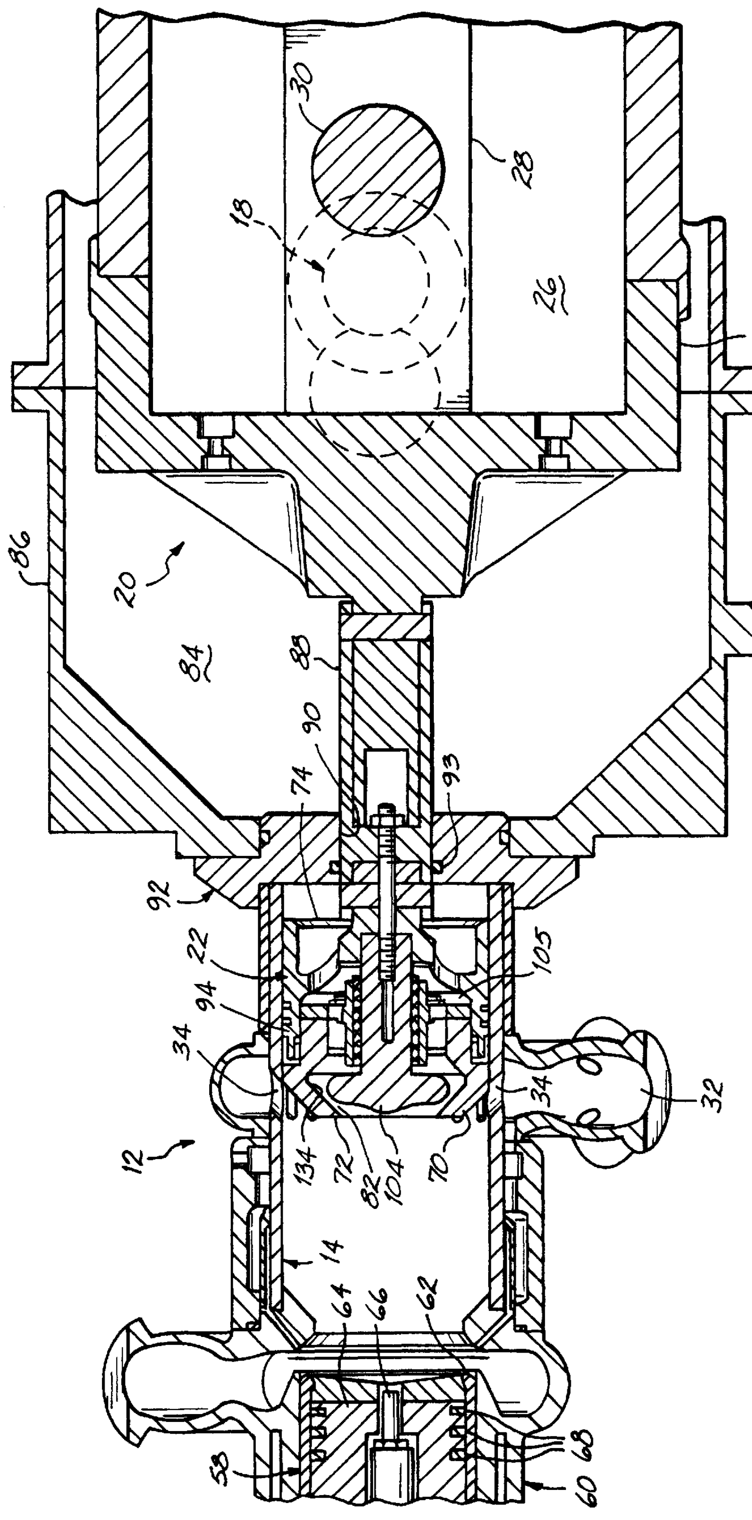

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FIG. 3A

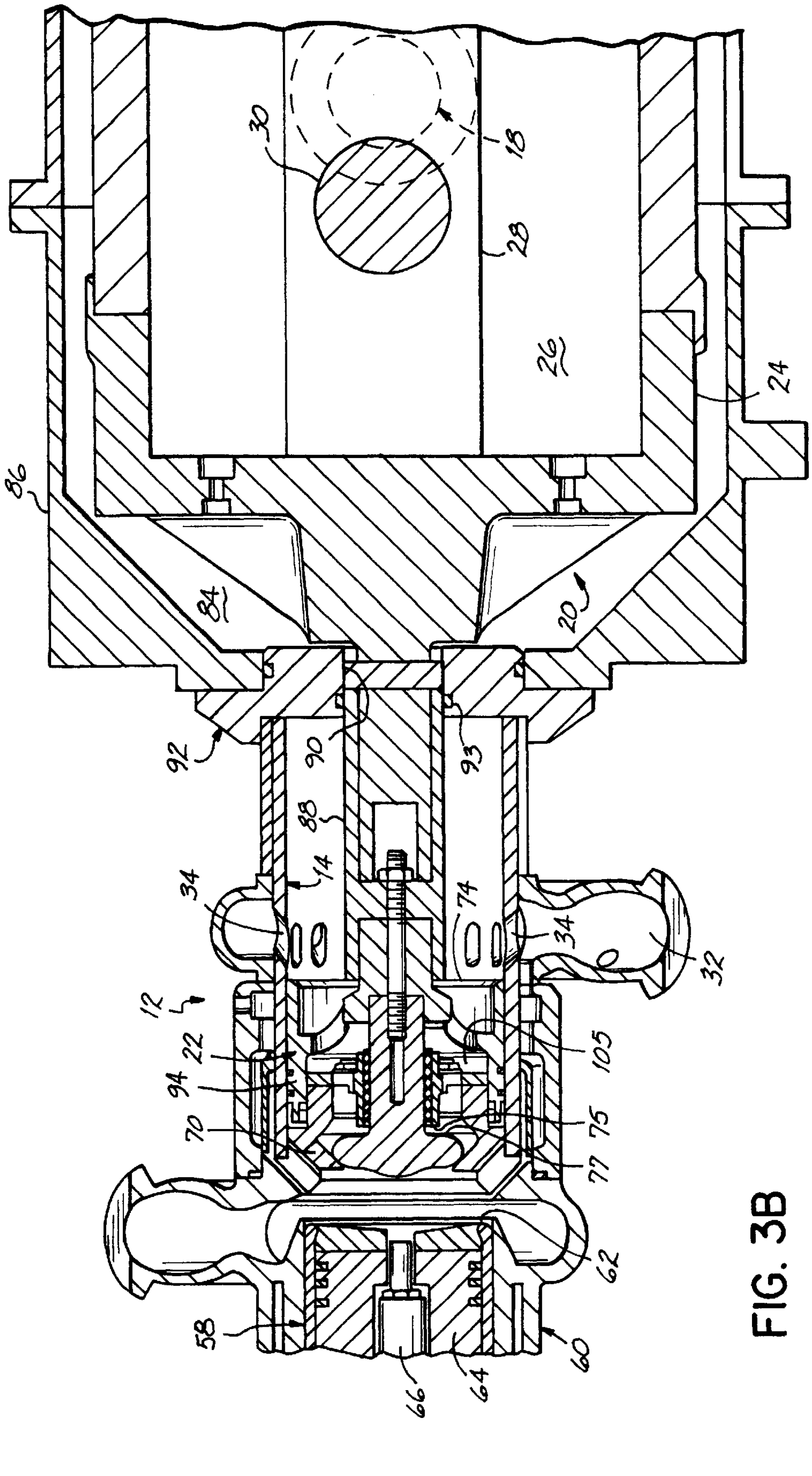
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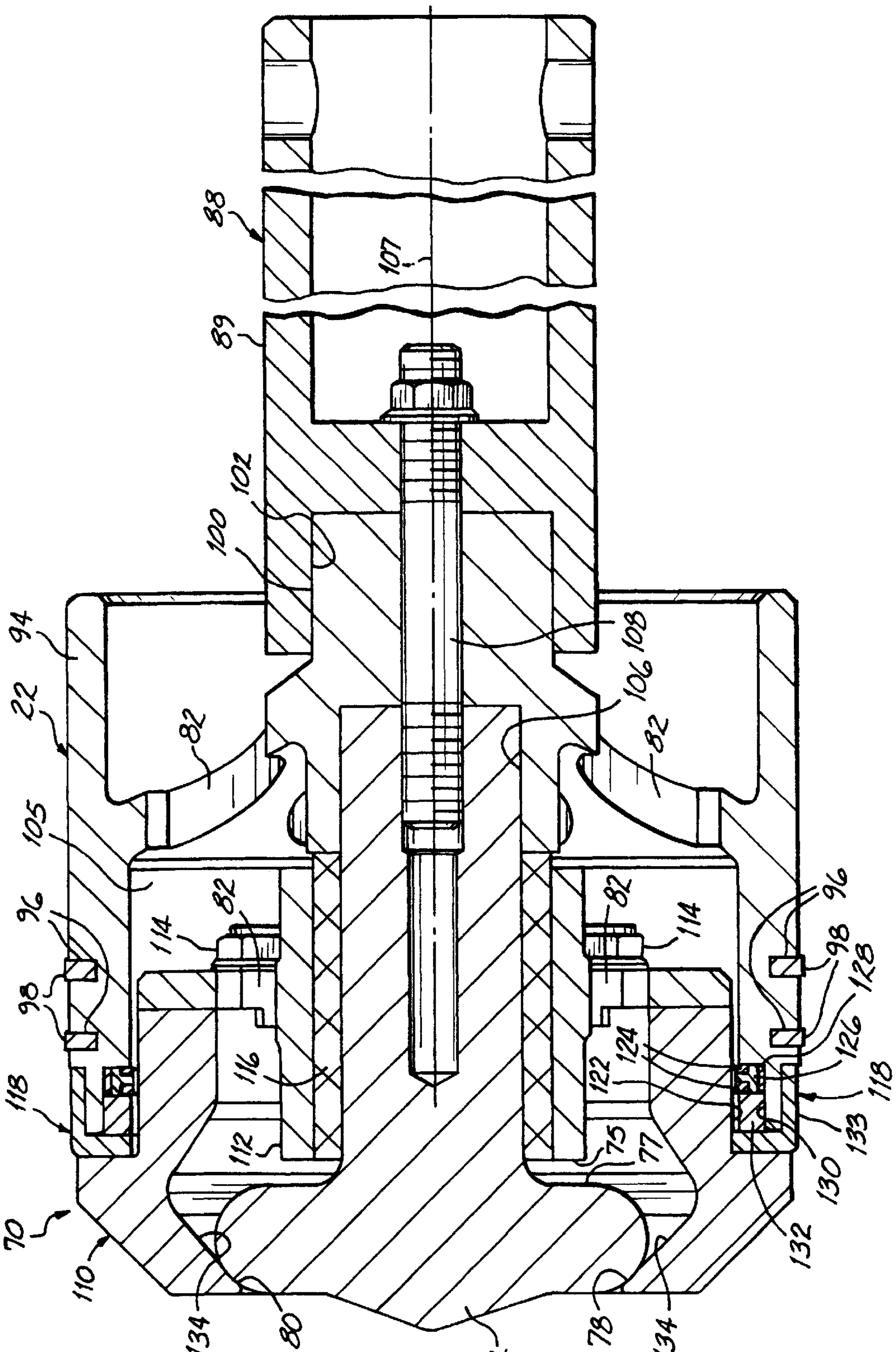
FIG. 3B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128
126
124
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112
75
77
133
130
70
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110
134
80
104
78
134

FIG. 4

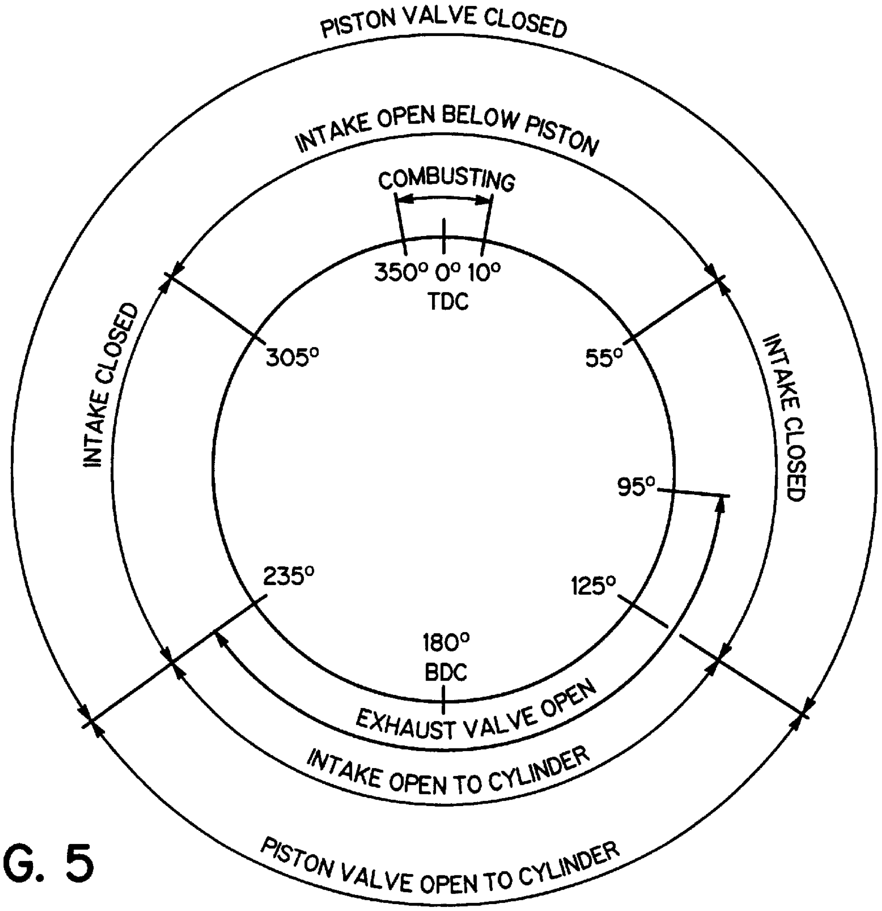
PISTON VALVE CLOSED
INTAKE OPEN BELOW PISTON
COMBUSTING
350° 0° 10°
TDC
305°
55°
INTAKE CLOSED
INTAKE CLOSED
95°
235°
125°
180°
BDC
EXHAUST VALVE OPEN
INTAKE OPEN TO CYLINDER
PISTON VALVE OPEN TO CYLINDER

FIG. 5

PISTON VALVE FOR TWO-STROKE ENGINE

This application is a continuation application of U.S. Ser. No. 09/616,258, entitled "Piston Valve for Two-Stroke Engine", filed Jul. 14, 2000 now U.S. Pat. No. 6,405,691, which is hereby expressly incorporated herein by reference in its entirety.

The invention was made with government support under the terms of Contract No. AMSTA-AQ-SCB awarded by Systems Development Department of the Army, United States Army Tank-Automotive & Armaments Command. The government has certain rights in the invention.

FIELD OF THE INVENTION

This invention relates to internal combustion engines and more particularly, to a piston valve for a two-stroke engine.

BACKGROUND OF THE INVENTION

In all two-stroke engines, a pressure ratio must be maintained across the intake and exhaust manifolds in order to force air through the cylinders. Such pressure ratio may be maintained by a low-pressure turbine, a Roots Blower, a turbocharger, etc. Other engines, for example, small two-stroke engines, pressurize the crankcase during a down stroke of the piston; and when the intake ports are uncovered, the pressurized crankcase forces air through the intake ports by way of a manifold external to the cylinder. During the compression stroke of the piston, a reed valve opens to allow additional air to enter the crankcase. The amount of air which is admitted to a cylinder of a two-stroke engine determines the amount of power that can be developed by the engine. In addition, the performance of a two-cycle engine is related to the ability of the engine to completely empty the cylinder of exhaust gases to permit the maximum amount of intake air to enter the cylinder.

Therefore, there is a need to provide an improved two-stroke engine in which the amount of air supplied to the cylinder is substantially increased.

SUMMARY OF THE INVENTION

The present invention provides an improved two-stroke engine that operates with substantially more cycle air and thus, produces more power. Further, the increased cycle air is effective to provide an improved scavenging of combustion gases from the cylinder. The increase in cycle air is provided by a simple, inexpensive and reliable valve mounted in a piston that is operated by pressure differentials within the cylinder.

According to the principles of the present invention and in accordance with the described embodiments, the present invention provides a two-stroke engine having a crankshaft, a cylinder, and a piston operatively connected to the crankshaft for reciprocating motion within the cylinder. An annular piston valve is mounted for slidable motion with respect to a centrally located inner body of the piston to control a flow of cycle air through the piston. A cycle air intake opening is located in a wall of the cylinder at a location above a bottom dead center position of the piston. The cycle air intake is blocked and unblocked by the reciprocating motion of the piston.

In one aspect of the invention, the connecting rod has a straight body section having a uniform cross-sectional area across its length, and a transition member located between the crankcase and the cylinder has a bore receiving the straight body section of the connecting rod. A seal is disposed between the bore and the straight body section of the connecting rod for blocking a flow of cycle air from the cylinder to the crankcase.

In another aspect of the invention, the annular piston valve is operated by pressure differentials within the bore of the cylinder; and the piston valve has an opened position providing a fluid path between forward and rear sides of the piston, and a closed position blocking the fluid path between the forward and rear sides of the piston. The annular piston valve is forced to the closed position by a greater pressure in the cylinder on the forward side of the piston as the piston moves toward and away from the top dead center position. The cycle air intake supplies cycle air into the bore of the cylinder at the rear side of the piston as the piston moves toward and away from the top dead center position; and the cycle air intake supplies cycle air into the bore of the cylinder at the forward side of the piston as the piston moves toward and away from the bottom dead center position. The annular piston valve is forced to the opened position by a greater pressure in the cylinder on the rear side of the piston as the piston moves toward and away from the bottom dead center position to supply additional cycle air within the bore of the cylinder on the forward side of the piston, thereby providing additional cycle air for compression and combustion.

In accordance with another embodiment of the invention, a method of operating a two-stroke engine includes moving a piston in a bore of a cylinder toward, through and away from a top dead center position at one end of the cylinder. A piston valve mounted for sliding motion in the piston is maintained closed by a greater pressure on a forward side of the piston caused by motion of the piston toward the top dead center position. Cycle air is received through a cycle air intake proximate a rear side of the piston at an opposite end of the cylinder. The piston in the bore of the cylinder is moved toward a bottom dead center position at the opposite end of the cylinder, and cycle air is received into the bore of the cylinder through the cycle air intake at a forward side of the piston. Simultaneously, cycle air proximate a rear side of the piston is compressed at an opposite end of the cylinder, and the piston valve is opened in response to a greater pressure on the rear side of the piston as the piston moves toward the bottom dead center position. The piston valve is maintained open in response to the greater pressure on the rear side of the piston as the piston moves through and away from the bottom dead center position to supply additional cycle air within the bore of the cylinder on the forward side of the piston, thereby improving the scavenging of combusted air from the cylinder through the exhaust valve and providing additional cycle air for compression and combustion. The piston valve is closed in response to a greater pressure on the forward side of the piston as the piston moves toward the top dead center position.

These and other objects and advantages of the present invention will become more readily apparent during the following detailed description taken in conjunction with the drawings herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic perspective view of a compound engine in which a two-stoke engine with a piston valve of the present invention may be used.

FIG. **2** is simplified schematic block diagram of the compound engine illustrated in FIG. **1**.

FIGS. **3**A and **3**B are partial cross-sectional views illustrating one of the two-stroke engines of the compound engine illustrated in FIG. **1** and a piston valve in its respective opened and closed positions in accordance with the principles of the present invention.

FIG. **4** is an enlarged view of the piston and piston valve illustrated in FIGS. **3**A and **3**B.

FIG. **5** is a schematic diagram illustrating the intake of cycle air, the exhaust of combusted gases and the operation of the piston valve as a function of the crankshaft position of the two-stroke engine illustrated in FIGS. **3**A and **3**B.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. **1**, **2** and **3**A, a compound engine **10** is comprised of a piston unit **12** combined with a gas turbine **13**. In one embodiment, the piston unit **12** is a compression ignition, two-stroke, uniflow scavenge diesel engine or unit which includes opposed pairs of cylinders **14**, for example, four opposed pairs of cylinders. The opposed pairs of cylinders **14** are arranged in two banks **16**, one cylinder **14** of one bank **16** is directly opposite one cylinder **14** of the other bank **16**. Each pair of the cylinders **14** is drivably connected to the crankshaft **18** by means of a scotch yoke **20**. Each cylinder **14** contains a piston **22** rigidly connected to one end of the scotch yoke **20**. The scotch yoke **20** has a crosshead **24** with a rectangular slot **26** that has a slider block **28** slidably mounted therein which is rotatably coupled to an eccentric **30** of the crankshaft **18**. The cylinders **14** are generally identical, and each pair of cylinders **14** with interconnecting scotch yoke **20** is generally identical. Similarly the banks **16** of cylinders **14** are generally identical, mirror images of each other. Combustion or cycle air is fed to each cylinder **14** through an intake manifold **32** and air intake ports **34** when its respective piston **22** is in the bottommost portion of its stroke, that is as the piston **22** is moving toward and away from its bottom dead center position.

The cycle air is supplied by a high-pressure gas turbine unit **13** comprised of a steady flow, high-pressure compressor **38**, a high-pressure turbine **40**, a pair of combustors **42** and an axial flow, low-pressure turbine **44**. The high-pressure compressor **38** receives cycle air through an inlet **46**; and the air passes through vanes of a compressor rotor **47** and through a discharge scroll **48** that divides the compressed air into two discharge paths **49**,**49**, each of which routes the air to one of the two combustors **42**. The turbine unit **13** is configured such that exhaust gases from the cylinders **14** of each bank **16** of the piston unit **12** pass through one of a pair of exhaust manifolds **50**, respectively associated with each bank **16**, and through a respective one of the two bypass combustors **42** of the gas turbine unit **13**. The combustors **42** are configured to drive the high-pressure turbine **40** by routing the exhaust gases from the combustors **42** to the two entrances on each side of the engine of a dual inlet variable area turbine nozzle scroll **52** and through the vanes of the high-pressure turbine rotor **53**. The high-pressure turbine **40** output shaft is connected to a bearing and shaft assembly **54** to drivably rotate the high-pressure compressor **38**. The low-pressure turbine **44** is mechanically coupled to the crankshaft **18**. A flywheel **56** is also mounted on the crankshaft **18** which provides rotary shaft output power from the compound engine **10**. The scotch yoke **20** is rigidly connected to the pistons **22** and the centrally located rectangular slot **26** extends longitudinally in a direction perpendicular to the stroke of the opposed pistons **22**.

An exhaust valve **58** is mounted around, and moves longitudinally with respect to, a center body **64** which holds a fuel injector **66**. The exhaust valve **58** has an inside lip **62** which is oriented at an angle of approximately 30° with respect to the horizontal and is used to provide a positive seating force during combustion when there is maximum pressure within the cylinder. An advantage of such a valve design is that combusted gases remaining in the cylinder during exhaust are substantially reduced. Further, depending on a combination of gas turbine and piston unit speed, the scavenge efficiency will reach one hundred percent (100%). Fuel injection is accomplished by utilizing an eight-plunger fuel pump (not shown) with cam plunger springs and governor to drive the eight fuel injectors. All eight high-pressure fuel injection lines are identical in length so that all injector needle lift pressures are approximately the same, for example, 3200 psi. Sealing rings **68** are contained on both the center body and the cylinder head **60** to seal combustion gases from leaking past the exhaust valve **58** that is reciprocating therebetween. A compound engine similar to the compound engine **10** described herein is described in detail in U.S. Pat. Nos. 5,555,730 and 5,653,108 which are assigned to the same assignee as the present application and are hereby incorporated in their entireties by reference herein.

The pressure drop across a typical two-stroke cylinder varies with the valving arrangement, speed and power setting. For a unit with a fixed displacement scavenge compressor, the pressure ratio can vary from very low values at idle to perhaps forty percent (40%) at full power and full speed. For surface applications of the compound engine **10**, a 5:1 pressure ratio, high-pressure compressor **38** with an eighty-seven percent (87%) peak efficiency. The compressor efficiency is an important parameter for a gas turbine and diesel compound engine. Since the compressor **38** provides air to the piston unit at about 400° F. a lower pressure ratio will reduce the exhaust energy recovered in the low-pressure turbine **44**. On the other hand, a higher pressure ratio requires the piston compression ratio to be lowered to maintain reasonable peak cylinder pressure. In addition, as the compressor ratio increases, the air temperature furnished to the piston unit **12** increases, thereby reducing the cooling capabilities of that air. Further, the temperature of the cycle air at the intake manifold has a large effect on the volumetric efficiency, or the ability of the cylinder to obtain a sufficient charge of air on each stroke.

The power that can be developed by the two-stroke piston unit **12** is determined by the amount of air which is admitted to the cylinders **14**. As shown in FIGS. **3**A and **5**, during a rotation of the crankshaft **18** of approximately 55° before and after the piston bottom dead center position, the piston **22** is below the air intake ports **34**; and cycle air is admitted into the cylinder **12** at the forward side **72** of the piston **22**. If the amount of cycle air admitted to the cylinder is increased, for example doubled, the pressures within the cylinder during the compression stroke would be significantly greater. Assuming the amount of fuel injected into the cylinder is optimized for the increased cycle air, the power provided by the two-stroke engine **12** would be increased.

In order to increase the amount of cycle air introduced into the cylinder **12**, a piston valve **70** is mounted within the piston **22**. Referring to FIGS. **3**A and **4**, the piston **22** has an annular or ring-like outer body **94** connected to a centrally located inner body **104**, and an annular cavity **105** is formed in the piston **22** between the outer and inner bodies **94**, **104**, respectively. The annular piston valve **70** is disposed within the cavity **105** and mounted for slidable motion on the inner body **104**. The piston valve **70** is moved between opened and closed positions illustrated in FIGS. **3**A and **3**B, respectively, by pressure differentials within the cylinder **12**, that is, a difference in pressure between forward and rear sides **72**, **74**, respectively, of the piston **22**. During much of the compression and combustion strokes, while the piston **22** is moving toward and away from its top dead center position, the pressure on the forward side **72** of the piston **22** is greater than the pressure on its rear side **74**. Therefore, the annular piston valve **70** is pushed firmly against the piston **22**, and an annular sealing area **78** on the annular piston valve **70** is pushed against an annular sealing area or valve seat **80** on an inner body **104** of the piston **22**, thereby preventing a flow of cycle air past the piston valve **70**.

When the piston **22** is moving toward and away from its top dead center position, the bore of the cylinder **12** at the rear side **74** of the piston **22** is in fluid communication with, and receives cycle air from, the air intake ports **34**. As shown in FIG. **5**, for a period of approximately 55° on both sides of the top dead center position of the piston **22**, the cylinder **12** is receiving cycle air at the rear side **74** of the piston **22**. During the combustion or power stroke, as the piston **22** travels toward the bottom dead center position, the cycle air in the cylinder **12** at the rear side **74** of the piston **22** is compressed. As shown in FIG. **5**, approximately 85° before the bottom dead center position of the piston **22**, the exhaust valve **58** is opened, and the gases of combustion begin to be exhausted from the cylinder **12**.

At approximately 55° before the bottom dead center position of the piston **22**, the forward side **72** of the piston **22** passes the forward edges of the air intake ports **34**, thereby further reducing the pressure on the forward side **72** of the piston **22**. Normally, with the exhaust valve **58** open, when the intake ports **34** are opened to the forward side **72** of the piston **22**, the pressure force on the rear side **74** of the piston **22** exceeds the pressure on the piston's forward side **72**; and the annular piston valve **70** is moved upward toward its open position until an end surface **75** (FIG. **4**) on the piston valve **70** strikes a stop surface **77** on an inner body **104** of the piston **22** as illustrated in FIG. **3**A. When the piston valve **70** is opened, compressed cycle air on the rear side **74** of the piston **22** flows through the path **82** (FIG. **4**) in the piston **22** to the portion of the cylinder **12** at the forward side **72** of the piston **22**. Thus, the amount of cycle air in the cylinder **12** at the forward side **72** of the piston **22** available for compression and combustion is substantially increased.

In the above example, the piston valve **70** is described as opening at approximately 55° before the bottom dead center position. However, as will be appreciated, the operation of the piston valve **70** is controlled by the pressure differential between the front and rear sides, **72**, **74**, respectively, of the piston **22**, and further, the pressure required to move the piston valve **70** will vary with the mass of the piston valve **70**, the friction between the valve guide **112** and the inner body **104** and other factors. Thus, the angle with respect to the bottom dead center position of the piston **22** at which the piston valve **70** opens will vary with each cylinder and engine. What is important is that the piston valve **70** opens at a point in the piston stroke such that the transfer of cycle air from the piston rear side **74** to the piston front side **72** provides more cycle air for compression and combustion and improves the scavenging of combusted gases.

As the piston moves through the bottom dead center position and changes direction, the piston valve is influenced by two forces. First, as the compressed air flow through the path **82**, the pressure on the piston rear side **74** drops. Further, as the connecting rod reverses the direction of motion of the piston **22** and pushes the piston **22** upward in the opposite direction, the inertia of the piston valve **70** and gravity will cause the piston valve **70** to continue its motion downward to its closed position. Normally, the piston valve **22** is moved to the closed position when the piston is approximately 55° after the bottom dead center position. After, the piston valve **70** is closed, gravity will tend to maintain the piston valve **70** in its closed position. In addition, continued upward motion of the piston **22** and the closed piston valve **70** results in a partial vacuum being formed on the rear side **74** of the piston **22**. Thus, the pressure force on the piston's forward side **72** exceeds the force on the piston's rear side **74**, and the piston **22** is held in its closed position. The angle at which the piston valve **70** closes will vary with the magnitude of the inertial force which is a function of the mass of the piston valve **70**. Further, friction between the valve guide **112** and the inner body **104** and other factors will also influence the exact time in the piston stroke at which the piston valve **70** closes. Thus, the angle with respect to the bottom dead center position of the piston **22** at which the piston valve **70** opens will vary with each cylinder and engine. However, the piston valve **70** should remain open for a period of time that permits a flow of cycle air from the piston's rear side **74** to the piston's front side **72**.

In order to compress the cycle air and pull a partial vacuum on the rear side **74** of the piston **22**, it is necessary that the cylinder **12** be sealed from the chamber **84** of the crankcase **86** containing the scotch yoke **20** and crankshaft **18**. A connecting rod **88** is connected at one end to the crosshead **24** of the scotch yoke **20** and is connected at its opposite end to the rear side **74** of the piston **22**. A transition member or crankcase cap **92** separates a respective cylinder **14** from the crankcase **86**, and the cap **92** has a bore **90** providing the only communication between the cylinders **14** and the crankcase **86**. The connecting rod **88** has a straight body section **89** having a constant cross-sectional profile along its length. The length of the straight section **89** of the connecting rod **88** is longer than the stroke of the piston **22**. The cross-sectional profile of the bore **90** matches but is slightly larger than the cross-sectional profile of the straight body section **89**, so that the straight body section **89** passes readily through the bore. The cross-sectional profile of the bore **90** and straight body section **89** of the connecting rod **88** is normally circular but may be square, hexagonal, etc. A sealing ring **93**, for example, a rubber O-ring, bears against, and sealingly engages; an external cylindrical surface of the straight section **89** of the connecting rod **88**. The sealing ring **93** seals and blocks a flow of cycle air from the cylinders **14** to the crankcase chamber **84** as the connecting rod **88** is reciprocated by the piston **22**.

As shown in FIG. **4**, the piston **22** has a generally cylindrical outer body **94** with a plurality of grooves **96**. Piston rings **98** are disposed in the grooves **96** and sealingly engage an interior wall of a respective cylinder in a known manner. The outer body **94** has a centrally located hub **100** disposed in a bore **102** in the end of the connecting rod **88**. A piston inner body **104** is disposed in a bore **106** of the outer body **94** and is centrally located in the piston **22**. The piston inner body **104** is rigidly secured to the piston outer body **94** and the connecting rod **88** by a fastener **108**. The annular piston valve **70** is mounted on the inner body **104** and is slidable in an axial, longitudinal direction with respect to the piston **22**. The annular piston valve **70** includes an annular, outer ring **110** that is attached to a valve guide **112** by fasteners **114**. The outer ring **110** and valve guide **112** of the piston valve **70** slide over a guide bearing **116** that is mounted over the inner body **104** of the piston **22**. The outer and inner bodies **94,104** of the piston **22** and the outer ring **110** and valve guide **112** of the annular piston valve **70** all have a common longitudinal centerline **107**.

For proper operation of the piston valve **70**, it is necessary that there be either no, or minimal, leakage of cycle air between the piston valve **70** and the piston **22**. The relatively close tolerance between the valve guide **112** and bearing **116** as well as the length of the area of contact between the bearing **116** and valve guide **112** insures little, if any, gas leakage therebetween. A piston ring seal assembly **118** is used to provide a seal between an inner cylindrical surface **120** of the piston **22** and an outer cylindrical surface **122** of the piston valve **70**. Rings **124** are mounted at the end of the piston **22** and sealingly engage the outside surface **122** of the piston valve **70**. The rings **124** are supported by an annular support block **126** that, in turn, is supported in place by a wavy washer **128**. The rings **124**, support block **126** and washer **128** are disposed in an internal annular groove **130** in the piston **22**. An annular spacer **132** is also disposed in the groove **130**, and a nut **133** is threaded over, or otherwise fastened to the end of the piston **22**. The piston outer body **94** is normally made of aluminum, and the piston inner body **104**, the outer ring **110** and valve guide **112** are normally made of stainless steel or an R-**41** steel, either of which may have a Stellite coating. As will be appreciated, other heat resistant materials can be used.

The operation of the piston valve **70** admits cycle air into the cylinder over 220° of crank angle versus 110° without the piston valve, thereby doubling the crank angle period during which cycle air is being admitted to the cylinder **12**. Thus, the cycle air is compressed to a higher pressure than was possible without the piston valve **70**, and the pressure ratio is increased by approximately 5%, thereby producing more power from the piston unit **12**.

Further, intake of cycle air from the air intakes **34** in combination with the tapering shape of the cylinder **12** causes the combusted gas to swirl as it flows through the cylinder **12** and out the exhaust valve. While such a swirling is effective to more quickly exhaust combustion gas, the flow of combusted gas near the center of the cylinder **12** tends to lag and does not exhaust as quickly as combustion gas at the periphery of the cylinder **12**. However, the annular sealing area **78** on the annular piston valve **70** is located on an inner directed conical surface **134** of the ring **104** of the annular piston valve **70**. Thus, the inner conical surface **134** directs the flow path **82** of cycle air as it exits the piston **22** toward the center of the cylinder **12**. That center flow of cycle air facilitates an improved exhausting and scavenging of combusted gas from the center of the cylinder **12**.

Because of the requirement for minimal internal cooling, a low-pressure drop through the cylinder **14**, a very high peak cylinder pressure, and hot metal temperatures, the compound engine **10** has several unique design features. First, the piston unit **12** is designed as a uniflow scavenge unit wherein the cylinder **14** and piston **22** are tapered toward the top, thereby reducing the internal volume of the combustion chamber at its upper end in order to provide several advantages. With the location of the intake ports **34** at the bottom of the cylinders and the exhaust valves **58** at the top of the cylinders, the design provides an initial swirl of the cycle air at the intake ports. The swirling pattern of the intake air continues as it rises through the cylinder **14** and accelerates as it is squeezed to a smaller and smaller diameter as it moves up the conical cylinder volume. The combustion chamber takes the shape of a small cylindrical plug with reduced surface-to-volume area ratio for a given clearance volume. These factors, along with the high temperatures of the combustion chamber surfaces, provide for a high heat release configuration. Further, the rate of heat release from the surfaces within the cylinder are greatest at those areas where the temperature is highest. In addition, the reduced volume at the upper end of the cylinder facilitates the compression ignition process. Advantageously, ignition delay is eliminated with operating surface temperatures over 1000° F.

To summarize the operating cycle, referring to FIGS. **1** and **5**, with the above compound engine, high volume, low-pressure air is compressed by a total ratio of approximately 200:1. The cycle air is first compressed by a ratio of approximately 5:1 by the rotating high-pressure compressor **38** after which air flows through the combustors **42**, the intake manifold **32**, intake ports **34** and into the cylinders **14** of the piston units **12**. The air is further compressed by a ratio of approximately 40:1 by the piston units **12** to a higher pressure at nearly one hundred percent (100%) efficiency. The compression ignites fuel injected into the cylinders **14** near the top dead center portion of the piston cycle, and the energy of the combusting and expanding gases is extracted to the maximum extent possible at nearly one hundred percent (100%) efficiency by the piston units **12** through a crankshaft rotation of approximately 95° past top dead center and an additional 30° during the opening of the exhaust valve **58**. When the gases have been fully expanded in the cylinders **14** and combined with the cooling and scavenge air, they are returned through the combustors **42**, to drive the high-pressure turbine **40** which, in turn, rotates the high-pressure compressor **38**. Energy remaining in the exhaust gases from the piston units **12** is extracted in the low-pressure turbine **44** which is connected through the gear reduction unit **57** and a V-belt unit **59** to the output of the crankshaft **18**.

While the invention has been illustrated by the description of one embodiment and while the embodiment has been described in considerable detail, there is no intention to restrict nor in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those who are skilled in the art. For example, in the described embodiment, the invention is described and illustrated as being part of a two-stroke piston unit of a compound engine or unit. As will be appreciated, the piston valve of the present invention can be used in any two-stroke engine of any size.

Therefore, the invention in its broadest aspects is not limited to the specific details shown and described. Consequently, departures may be made from the details described herein without departing from the spirit and scope of the claims which follow.

What is claimed is:

1. A method of operating a two-stroke engine comprising:

moving a piston in a bore of a cylinder toward, through and away from a top dead center position at a combustion end of the cylinder;

maintaining a piston valve mounted for sliding motion in the piston closed by a greater pressure on a forward side of the piston as the piston moves toward the top dead center position;

receiving cycle air through a cycle air intake in an opposite end of the cylinder proximate a rear side of the piston;

moving the piston in the bore of the cylinder toward a bottom dead center position at the opposite end of the cylinder;

receiving cycle air into the bore of the cylinder through the cycle air intake in the combustion end of the cylinder at a forward side of the piston;

simultaneously compressing the cycle air proximate a rear side of the piston in the opposite end of the cylinder;

opening the piston valve in response to a greater pressure on the rear side of the piston as the piston moves toward the bottom dead center position;

maintaining the piston valve open in response to the greater pressure on the rear side of the piston as the piston moves through and away from the bottom dead center position to supply additional cycle air within the bore of the cylinder on the forward side of the piston, thereby improving the scavenging of combusted air from the cylinder through the exhaust valve and providing additional cycle air for compression and combustion; and

closing the piston valve in response to a greater pressure on the forward side of the piston as the piston moves toward the top dead center position.

2. The method of operating a two-stroke engine of claim **1** further comprising continuing to receive cycle air in the combustion end of the cylinder through the cycle air intake at a forward side of the piston while maintaining the piston valve open.

3. The method of operating a two-stroke engine of claim **1** further comprising terminating a reception of cycle air in the combustion end of the cylinder through the cycle air intake at a forward side of the piston after maintaining the piston valve open.

4. The method of operating a two-stroke engine of claim **1** further comprising terminating a reception of cycle air in the combustion end of the cylinder through the cycle air intake at a forward side of the piston substantially simultaneously with the closing of the piston valve.

5. The method of operating a two-stroke engine of claim **1** further comprising providing a greater pressure on the rear side of the piston when the piston is approximately 55° before its bottom dead center position.

6. The method of operating a two-stroke engine of claim **5** further comprising receiving cycle air in the combustion end of the cylinder through the cycle air intake at a forward side of the piston when the piston is approximately 55° before its bottom dead center position.

7. The method of operating a two-stroke engine of claim **1** further comprising providing the greater pressure on the forward side of the piston when the piston is approximately 55° after its bottom dead center position.

8. The method of operating a two-stroke engine of claim **7** further comprising terminating a reception of cycle air in the combustion end of the cylinder through the cycle air intake at a forward side of the piston when the piston is approximately 55° after its bottom dead center position.

9. A two-stroke engine comprising:

a crankshaft;

a cylinder having an internal bore with a combustion end and an opposite end;

a piston mounted for sliding motion within the internal bore of the cylinder and operatively connected to the crankshaft, the piston having a forward side facing the combustion end of the internal bore and a rearward side facing the opposite end of the internal bore;

an intake port in fluid communication with the opposite end of the internal bore and the rearward side of the piston in response to the piston moving toward and away from the combustion end of the internal bore, and the intake port being in fluid communication with the combustion end of the internal bore and the forward side of the piston in response to the piston moving toward and away from the opposite end of the internal bore;

a piston valve mounted in the piston and providing fluid communication between the forward and rearward sides of the piston, the piston valve being opened by a pressure differential between the forward and rearward sides of the piston substantially simultaneously with the intake port being in fluid communication with the combustion end of the internal bore and the forward side of the piston; and

an exhaust port.

10. The two-stroke engine of claim **9** further comprising an exhaust valve mounted at the combustion end of the internal bore.

11. The two-stroke engine of claim **9** further comprising a fuel injector in fluid communication with the internal bore of the cylinder.

12. The two-stroke engine of claim **9** wherein the piston valve is an annular piston valve.

13. The two-stroke engine of claim **9** wherein the piston valve is an annular piston valve mounted in the forward side of the piston.

14. The two-stroke engine of claim **13** wherein the piston comprises a substantially cylindrical outer body connected with a centrally located inner body, and the annular piston valve is mounted in the forward side of the piston between the outer body and the inner body.

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