

Oct. 5, 1965

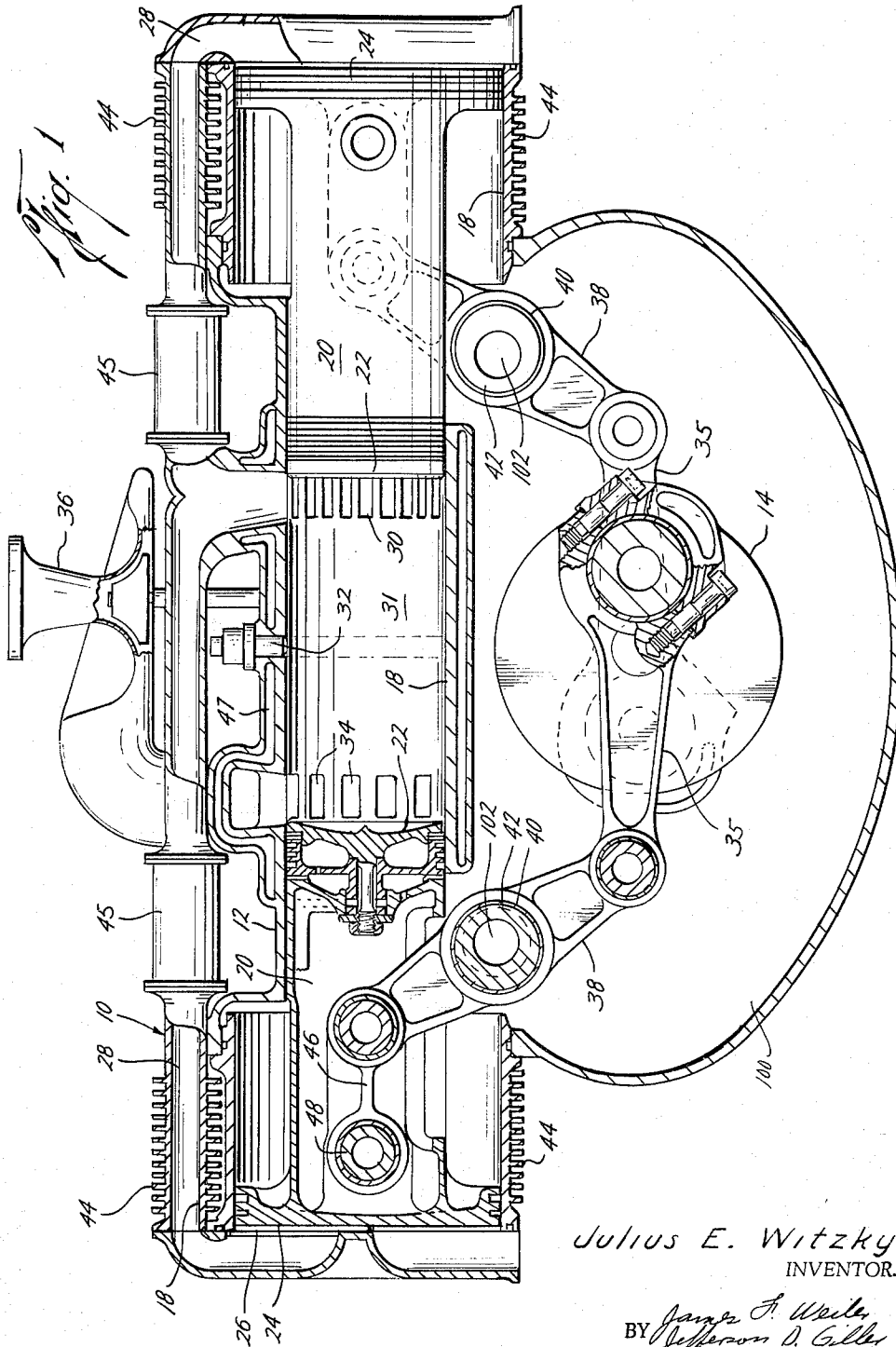
J. E. WITZKY

3,209,736

ENGINE

Filed Jan. 14, 1964

4 Sheets-Sheet 1



Julius E. Witzky
INVENTOR.

BY *James F. White*
Jefferson D. Gilley
William A. Stuntz
Paul L. DeKester II
ATTORNEYS

Oct. 5, 1965

J. E. WITZKY

3,209,736

ENGINE

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Fig. 2

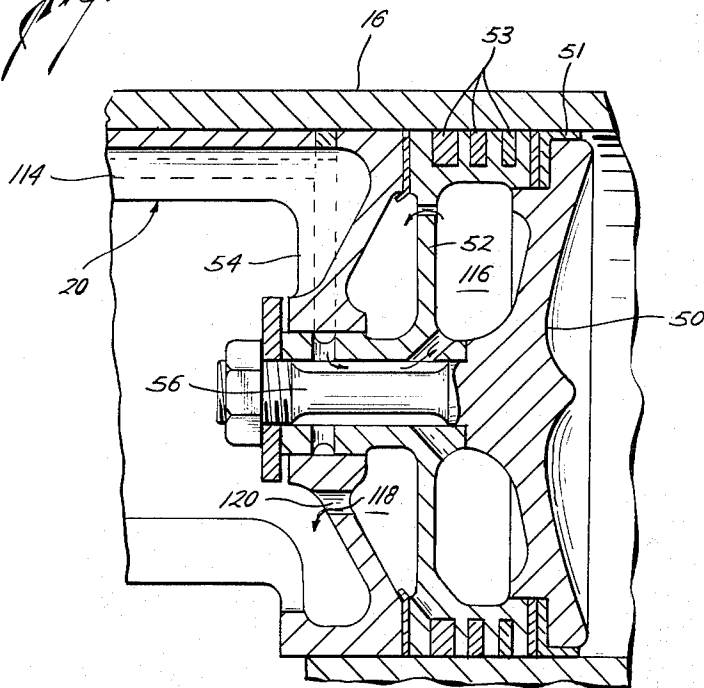


Fig. 3

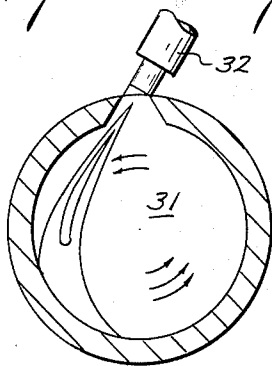


Fig. 4

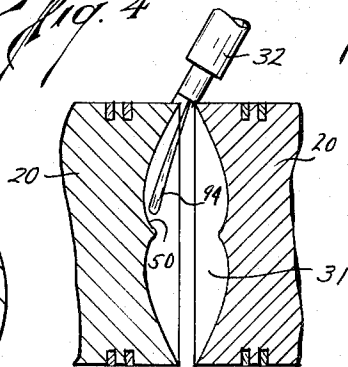
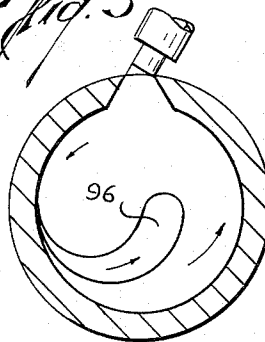


Fig. 5



Julius E. Witzky
INVENTOR.

BY *James F. Weiler*
Jefferson D. Gully
William A. Stout
Paul L. De Venter, II

ATTORNEYS

Oct. 5, 1965

J. E. WITZKY

3,209,736

ENGINE

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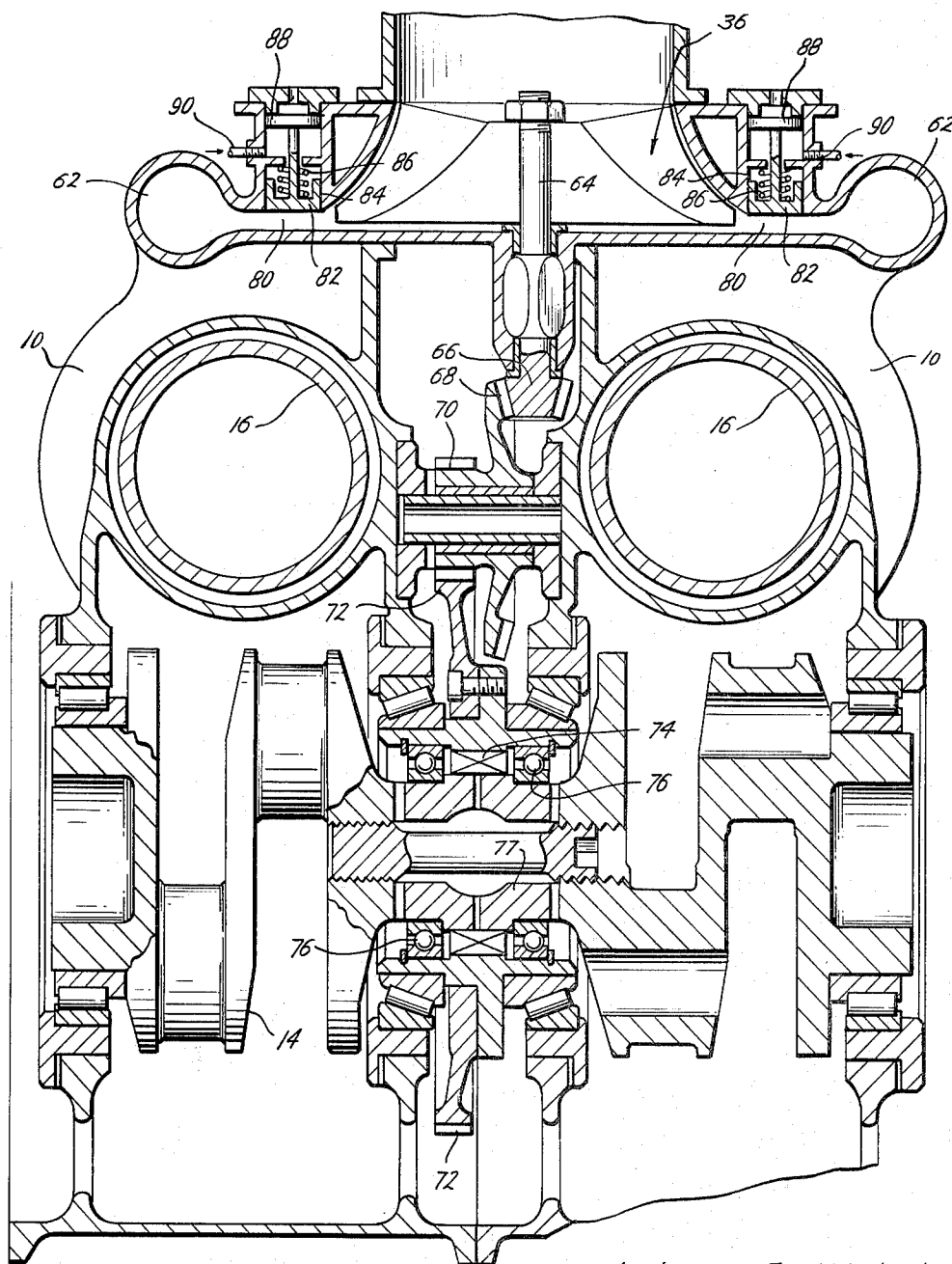


Fig. 6

Julius E. Witzky
INVENTOR.

BY *James F. Weib*
Jefferson D. Gilley
William G. Stout
Paul L. DeKoster II
ATTORNEYS

Oct. 5, 1965

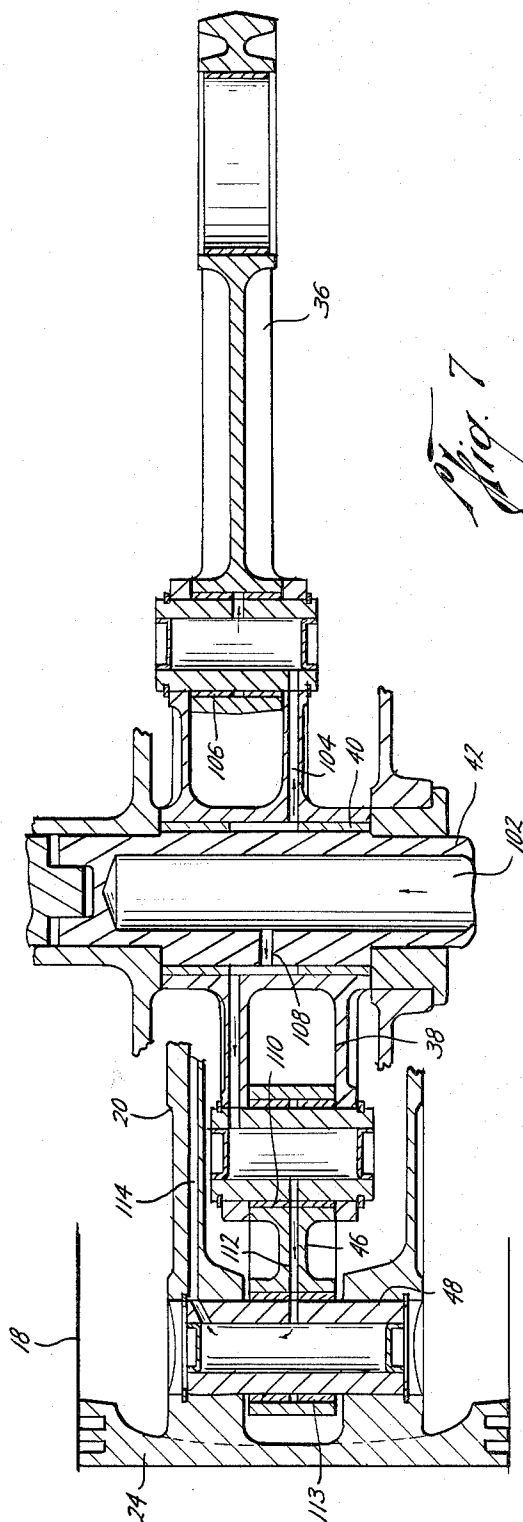
J. E. WITZKY

3,209,736

ENGINE

Filed Jan. 14, 1964

4 Sheets-Sheet 4



Julius E. Witzky
INVENTOR.

INVENTOR.

BY

BY *James F. Weiler*
Jefferson D. Giller
William A. Stuart
Paul L. DeKester II
ATTORNEYS

1

3,209,736
ENGINE

Julius E. Witzky, San Antonio, Tex., assignor to Southwest Research Institute, San Antonio, Tex., a trust estate of Texas

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1 Claim. (Cl. 123-48)

The present invention relates to engines, and more particularly, relates to variable compression ratio type engines. In addition, the present invention is also directed to a piston-turbine compound engine.

The general idea of changing the compression ratio of an engine by rotating an eccentrically mounted shaft is generally described in my patent, Variable Compression Ratio Type Engine, No. 2,910,973. One feature of the present invention is the provision of a variable compression ratio type of engine where the eccentrically mounted rocker arms are connected to the pistons by rotatable connecting links. This has the advantage of eliminating the sliding bearing shown in my above patent and in addition allows the piston pin to be relocated to the cold end of the piston thereby permitting an advantageous redesign and improvement in the piston itself. This results in a piston which may utilize a separate piston crown and ring carrier which could then be fabricated out of a heat resistant material different from the main piston body and would allow round machining of the hot end components of the piston and avoid the characteristic running deformity.

Another feature of the present invention is the compounding of a gas turbine with a piston engine. A gas turbine cannot handle the high initial temperatures and pressures required to produce high thermal efficiency. Therefore, the employment of a piston engine to handle the high pressure-high temperature phase of a combustion cycle and then further expand the exhaust gas by flowing the low pressure-low temperature gas from the piston engine through a gas turbine provides a compound engine in which each portion of the engine compensates for the deficiencies inherent in the other.

It is therefore an object of the present invention to provide an improvement in a variable compression type engine wherein a piston connecting link is rotatably connected to an eccentrically mounted rocker arm and is also rotatably connected to a piston pin located on the piston remote from the hot piston head.

A still further object of the present invention is the provision of an improved piston in a variable compression ratio engine wherein the piston crown is rotatably mounted on the piston body and is fabricated out of a heat resistant material and wherein the piston ring carrier is also rotatably mounted on but separate from the piston body.

Yet a further object of the present invention is the provision of a piston turbine compound engine wherein the power developed by the turbine is fed back to the engine crankshaft by a suitable arrangement such as a reduction gear, and an overriding clutch is provided to avoid driving the turbine.

A still further object of the present invention is the provision of a multi-cylinder, two stroke cycle, opposed piston engine compounded with a turbine wherein the exhaust ports are uncovered prior to the uncovering of the intake ports thereby allowing the high pressure gases in the cylinders to flow down into the turbine before the intake ports open.

A still further object of the present invention is the provision of a multi-cylinder, two stroke cycle, opposed super charged engine in which the intake ports are designed to create a high rate of swirl of combustion air about

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the cylinder axis between the two pistons and an injection nozzle is provided which injects the fuel in high energy jets to impinge preferably upon the hot piston crown adjacent the exhaust ports where a controlled rate of evaporation can be used to slow the rate of energy released to the combustion process.

A further object of the present invention is the provision of a variable compression type engine wherein internal oil passageways are provided through the rocker arm and the piston connecting link to lubricate the bearing surfaces and then to the interior of the piston head to cool the piston crown.

Yet a further object of the present invention is the provision of a piston turbine compound engine wherein a variable nozzle is provided in the turbine so that the turbine is efficient over the range of operating speeds of the engine and the area of the nozzle may be controlled as a function of the exhaust gas pressure from the combustion cylinders.

Yet a further object of the present invention is the provision of a piston turbine compound engine which provides a compact or "folded" configuration by providing connecting rods parallel to the cylinders which in turn allows the use of a lighter overall main engine structure and permits the advantageous uses of both ferrous and non-ferrous materials for the main engine.

Other and further objects, features and advantages of the invention will be apparent from the following description of a presently preferred embodiment of the invention, given for the purposes of disclosure and taken in conjunction with the accompanying drawings, where like character references designate like parts throughout the several views, and where:

FIGURE 1 is an elevational view, in cross-section, illustrating the apparatus of the present invention with the pistons approximately at the end of the firing stroke,

FIGURE 2 is fragmentary elevational view, in cross-section, illustrating the structure and connection of the piston crown and piston ring carrier to the piston body and the provision of cooling passageways therein,

FIGURE 3 is a schematic elevational view, across the combustion chamber, illustrating fuel injection in the direction of the air swirl,

FIGURE 4 is a fragmentary schematic elevational view, longitudinally along the combustion chamber showing the injection of fuel on the hot piston crown,

FIGURE 5 is a fragmentary elevational view, across the combustion chamber, showing the swirling combustible mixture of the fuel and air,

FIGURE 6 is a fragmentary elevational view, in cross-section across dual cylinders, illustrating the connection of the turbine to the engine crankshaft, and

FIGURE 7 is a fragmentary elevational view, in cross-section, across the connecting rod, rocker arm, connecting link and piston showing the lubrication system.

Referring now to the drawings, and specifically to FIGURE 1, the reference numeral 10 generally designates the engine of the present invention which generally includes a block 12 and a crankshaft 14. Preferably, the engine is a multi-cylinder, two stroke cycle, opposed piston super-charged diesel, only a single cylinder being shown for convenience of reference. Thus, horizontally formed in the block 12 is power or combustion cylinder 16 which is in communication with a pair of compressors cylinders 18 at opposite ends of the combustion cylinder 16 for supplying supercharging air to the cylinder 16. Reciprocally mounted in the cylinder 16 are a pair of double ended pistons 20 each one of which has a power portion 22 disposed in the power cylinder 16 and a compressor piston 24 disposed in the adjoining compressor cylinder 18. Each of the compressor cylinders 18 communicate through a valve 26 and duct 28 to an

annular series of intake ports 30 whereby the two compressor pistons 24 provide super-charging air for the cylinder 16 through the intake ports 30. The power pistons 22 face each other in the power cylinder 16 and form together with the cylinder a combustion chamber 31 which receives air under pressure from the air intake ports 30 and fuel through an injection nozzle 32.

The exhaust gases from the combustion chamber are discharged through exhaust ports 34 to a gas turbine 36 as will be more fully described hereinafter.

Conventional cooling fins 44 are provided about the compressor cylinders 18 and air intake ducts 28 to cool the incoming air. In addition, air intercoolers 45 may be provided if desired. For cooling the combustion cylinder 16, conventional water passages 47 are provided.

A connecting rod 35 is connected to the crankshaft 14 for each of the pistons 20. A rocker arm 38 is connected to each of the connecting rods 35 and extends through the cylinder 16 and is eccentrically mounted on a rocker arm bearing 40 by an eccentric shaft 42. The rocker arm bearings 40 are mounted on the eccentric shafts 42 and the shafts may be rotated while the engine is in operation. Rotating the eccentric shaft 42 changes the pivot point of the rocker arms 38 which in turn changes the effective compression ratio of the piston and compressor cylinders. Preferably, the eccentric shaft 42 would be linked together (not shown) and operated by a single lever which would be controlled either by a pressure signal or scheduled on an r.p.m. and/or injection pump rack setting.

The rocker arms 38 are not connected directly to the pistons 20 but each are pivotally connected to a piston connecting link 46 which is in turn rotatably connected to a piston pin 48. The piston connecting link 46 takes care of all the oscillating bearing motion that occurs and avoids the sliding bearing with its lubrication and loading problems as shown in my above named patent. Secondly, the use of the piston connecting link 46 allows the piston pin 48 to be positioned at the cold end or compressor end of the piston 20 thereby permitting the use of an improved piston as will be more fully described hereinafter. With the piston link 46 the length of the piston stroke remains constant, but the outer and inner limits of the stroke can be moved as the variable compression ratio eccentric shaft 42 is rotated.

Referring now to FIGURE 1, the positioning of the piston pin 48 at the end of the piston body 20 remote from the hot head 22 results in several improvements. By moving the pin 48 and boss to the cold end of the piston the disadvantageous characteristic of conventional piston design of requiring an elliptical machined piston skirt so as to make the piston round in the running condition is avoided. The positioning of the pin 48 allows round machining of the hot end components and greatly relieves the stress level in the piston which is both thermally and mechanically the highest stressed part in an opposed piston engine. Referring now to FIGURE 1, the piston crown 50 and the piston ring carrier 52 are preferably made separately and mounted to the piston body 54 with a bolt bearing arrangement 56 such that the crown 50 and carrier 52 are free to rotate and seek their best balanced load running position. By making the crown 50 and piston ring carrier 52 out of separate pieces these parts may be made out of a heat resistant material while the piston body 54 may be fabricated of aluminum. Thus, the heat transfer rate out of the crown 50 would be reduced thereby holding a high energy level in the combustion chamber and reducing the piston cooling requirements. A fire ring 51, made of steel, is mounted on the crown 50 and protects the piston rings 53.

Referring now to FIGURE 6, the connection of the turbine through the crank shaft is best seen. Preferably, a plurality, such as two diesel single cylinder engines 10 are compounded with a single exhaust gas turbine 36 which is mounted between and above the two cylinders

16 with a horizontal plane of rotation. The exhaust manifold 62 from each cylinder 16 feeds approximately half the scroll around the turbine nozzle ring. The power developed by the gas turbine 36 is fed back to the main engine crankshaft 14 through a turbine shaft 64 by means of a speed reducing, overriding, gear and clutch arrangement. For instance, a first reduction gear 66 is connected to the turbine shaft 64 and the turbine output power is fed to a spiral bevel gear 68. However, since the turbine rotates at such a higher speed than the crankshaft 14, a second reduction gear is provided. Thus, gear 70 which is connected to gear 68 will mesh with and drive gear 72. Incorporated in this turbine to crankshaft power train is an overrunning clutch 74 which is connected between the reduction gears and the crankshaft 14.

Clutch 74, which is positioned between crankshaft 14 and gear 72, will prevent any feedback of power from the engines 10 to the turbine 36 and also will prevent shock loading of the gearing and will transmit torque only when the turbine 36 develops power. Suitable bearings 76 are provided to rotatably support gear 72 about the crankshaft.

Any suitable means may be used for varying the turbine nozzle as a function of the exhaust gas pressure from the piston combustion chamber. For instance and referring to FIGURE 6, the area of the nozzle 80 should vary in size, depending on the speed of the engines 10, so as to be efficient over the entire speed range. That is, the nozzle should be small at low speeds and large at high speeds. The nozzle 80 is positioned between the exhaust manifolds 62 from the combustion cylinders 16 and the turbine 36. A movable valve element 82 is provided which is slidable in a cylinder 84 and is thus movable into and out of the nozzle 80 to control the area of the nozzle. A spring 86 normally urges the element 82 downwardly to close the nozzle. A piston 88 is connected to the valve element and an inlet 90 is provided in communication with the exhaust manifold 62 to provide a pressure on the back side of the piston 88 to move the valve element 82 upwardly, increasing the nozzle area, as the exhaust gas pressure increases. The exhaust air inlets 90 are connected to exhaust gas manifolds of the engines 10. Thus, as the speed and thus the air pressure in the exhaust manifold 62 of the engines 10 increases, the area of the nozzle 80 will increase thereby providing for an efficient operation of the turbine 36.

Referring now to FIGURES 1 and 3, the intake ports 30 are designed to impart a high rate of swirl to the incoming air about the cylinder axis. This air swirl will be utilized in the combustion chamber 31, formed by the pistons 20 and cylinder 16, to both mix the air and fuel and to limit the rate of combustion. The injection nozzle 32 is located at the periphery of the cylinder at the center point and injects the fuel in a sharp high energy jet to impinge upon the piston crown 50. This will permit most of the fuel to be deposited on the piston crown where a controlled rate of evaporation can be used to slow the rate of energy released to the combustion process. Preferably, as best seen in FIGURE 4, the fuel 94 from the fuel injector 32 may also be injected at an angle along the longitudinal axis of the combustion chamber 31 and against only the crown of the piston 20 which is at the exhaust end of the combustion chamber 31. This piston will be hotter as it is not cooled by the incoming air and thus better fuel evaporation can be obtained. In any event, injecting the fuel with the air swirl, as shown in FIGURE 3, will provide a swirling mixture of fuel and air 96, as best seen in FIGURE 5, and a thorough mixing of the fuel and air.

One important characteristic to note about the intake and exhaust ports 30 and 34 is the location along the cylinder axis with respect to the engine center line. The ports would normally be placed so that the outer end of their lengths coincide with the outer dead point of the pistons. Because of the variable compression ratio of this

engine, the lengths of the ports have these effective values at a single compression ratio setting and as the compression ratio is increased the effective length of the ports would be decreased. However, when the compression ratio is increased this would occur at only lower engine speeds and therefore while the effective lengths of the ports is shortened the actual elapsed time the ports remain open would tend to increase because of the effect of slower speed.

As shown, the connecting rods 35 are normally connected to the crankshaft 14 at 180 degrees apart. However, it is contemplated that the connecting rods 35 will be phased such that the piston which uncovers the exhaust ports 34 leads the piston uncovering the intake ports 30 by a predetermined amount, for example approximately 15 degrees. This allows the high pressure gases in the diesel cylinder 16 to blow down into the turbine scroll before the intake ports 30 open. It also closes the exhaust ports 34 first which reduces blow through of the charging air and achieves better supercharging through the differential closing of the ports.

It is also desirable that the piston-turbine compound engine have a "folded" or compact shape. This is accomplished by positioning the connecting rods 35 parallel and close to the axis of the cylinder 16. In addition, this also allows the use of a lighter overall main engine 12. The connecting links 46 have only tension forces applied to them, the connecting rods 35 are subject to only compression loads, and the cylinder 16 is required to resist circumferential tension loads of the combustion pressure plus the relatively low tension load imposed by the compressor pistons. This will permit the use of non-ferrous materials for the main structure and the use of stronger ferrous members between the pivot points 42.

Referring now to FIGURES 2 and 7, the lubrication system is best seen. To provide a full pressure lubricating system, a conventional gear-driven oil pump (not shown) may be located close to the oil sump 100 (FIGURE 1). The opening 102 at the rocker arm fulcrum is pressure lubricated and drilled passages are provided in the rocker arm, piston connecting link, and piston 20, which are interconnected and will supply lubrication to the bearings and will also provide oil cooling for the hot end of the pistons if desired. Thus, lubricant is supplied under pressure to opening 102 and flows in one direction through drilled passageway 104 in the rocker arm 38 to lubricate bearing 106 which connects the rocker arm 38 and the connecting rod 36. In addition, lubricant flows from opening 102 through passageway 108 in the rocker arm 38 to lubricate the bearing 110 about the rocker arm pin and then through passageway 112 to lubricate the bearing 113 at the piston pin 48 which connects the connecting link 46 to the piston 20. From the passageway 112, the lubricant flows through passageway 114 in the piston 20 to supply oil for piston cooling if desired. Referring now to FIGURE 2, the lubricant passageway 114 is in communication with chamber 116 to cool the hot piston crown 50. The lubricant flows then to a chamber 118, through a passageway 120, and behind the piston head and back to the sump 100 (FIGURE 1).

In use, the turbo-compounded, multi-cylinder, opposed piston, two cycle engine with a variable compression ratio provides a compactness ratio of about 25 horsepower per cubic foot of installed volume. This compactness ratio is in marked contrast to standard diesel compactness ratios between 5 and 10. The variable compression ratio feature will make possible exceptional cold starting ability while allowing combustion pressures to be maintained at any desired level. This feature makes the engine a true multifuel unit while still designed for lightweight construction.

The compression ratio may be changed by rotating either or both of the eccentric shafts 42 which changes the pivot point of the rocker arms 38 since the rocker

arm journals are eccentrically mounted on the shaft 42. This in turn changes the effective compression ratio of the combustion chamber 31. Preferably, the eccentric shaft 42 for each of the pistons 20 would be linked together and operated by a single lever (not shown) which would be controlled either by a pressure signal or scheduled on a r.p.m.-rack setting ratio.

The use of the piston connecting link 46 provides a desirable connection to the piston 20 at the piston pin 48 which is remote from the hot piston crown 50. While still providing the necessary movement required as the compression ratio is changed, the linkage 46 simplifies the piston 20 construction by allowing the use of a separate piston crown 50, and a separate piston ring carrier 52, both of which are connected to the piston body 54 with a bolt bearing connection 56 such that the crown 50 and carrier 52 are free to rotate and seek their best balanced load running position and in addition can be made of a heat resistant material.

As best seen in FIGURE 6, a plurality such as two diesel cylinders or more may be compounded with a single exhaust gas turbine 36 whereby the power developed by the gas turbine is fed back to the main engine crankcase 14 by a high speed reducing gear arrangement and an over-running clutch 74. Preferably the turbine is a one stage radial inflow turbine. In order to provide a steady inflow condition to the turbine with the exhaust gas from the cylinders 16 being expanded to approximately supercharger level in the exhaust manifolds 62, the diesel cycle should be adjusted to allow maximum practical open time for the exhaust ports in an effort to reach the theoretical optimum of each of the two cylinders having its exhaust ports open for 180 degrees of crank angle. As a practical matter, it is preferred to permit the exhaust ports in the cylinders to be open for approximately 135 degrees of crank shaft rotation. In addition, the diesel is designed such that the piston which uncovers the exhaust ports 34 leads to the piston uncovering the intake ports 30 preferably by approximately 15 degrees. This allows the high pressure gases in the diesel cylinder to blow down into the turbine scroll before the intake ports 30 open.

And as previously described the intake ports are designed to impart a high rate of swirl to the incoming air about the cylinder axis. This air swirl will be utilized in the combustion chamber, formed by the two pistons 20 and the cylinder walls of cylinder 16 to both mix the air and fuel and to limit the rate of combustion. The jets from the injection nozzle 32 may impinge on the crown 50 adjacent to the exhaust ports and produce a combustion mixture as shown on FIGURE 5.

The present invention, therefore, is well suited and adapted to attain the ends and objects mentioned herein as well as others inherent therein. While a presently preferred embodiment of the invention is given for the purpose of disclosure, numerous changes in the details of construction and arrangement of parts may be made which are within the spirit of the invention and the scope of the appended claim.

What is claimed is:

An engine comprising,
an elongated cylinder
a pair of two ended pistons slidably mounted in opposed relation in said cylinder to form a combustion chamber therebetween,
each of said pistons including a piston body, a piston ring carrier, and a crown, the ring carrier and crown being rotatably connected to the piston body,
a crankshaft carried by the engine,
a rocker arm for each piston passing through the cylinder and having one end pivotally connected to said crankshaft,
a connecting link pivotally connected to each piston and to one end of the rocker arm, said connecting link being connected to the piston solely at the end remote from the combustion chamber, and

eccentric means pivotally supporting each of said rocker arms for shifting the pivot axis of the rocker arms whereby the compression ratio of the engine may be varied.

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MARK NEWMAN, *Primary Examiner.*

RICHARD B. WILKINSON, LAWRENCE M. GOOD-
RIDGE, *Examiners.*