Jan. 8, 1957 M. R. FENSKE 2,776,649

TWO CYCLE FUEL INJECTION, OPPOSED PISTON, THRUST PLATE INTERNAL COMBUSTION ENGINE

Filed May 13, 1953 2 Sheets-Sheet 1

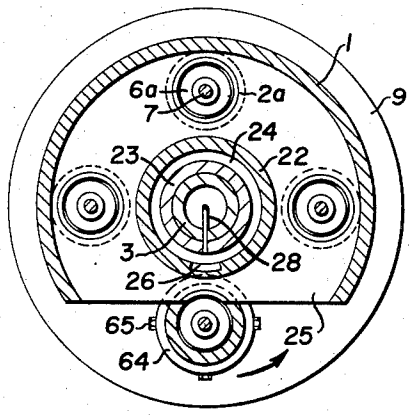


FIG.-4

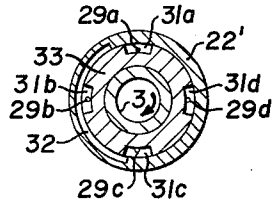


FIG.-5

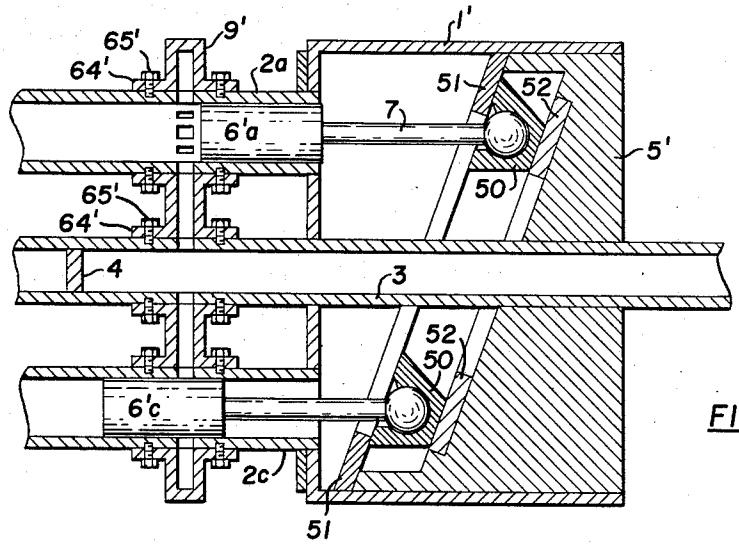


FIG.-6

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TWO CYCLE FUEL INJECTION, OPPOSED PISTON, THRUST PLATE INTERNAL COMBUSTION ENGINE

Filed May 13, 1953 2 Sheets-Sheet 2

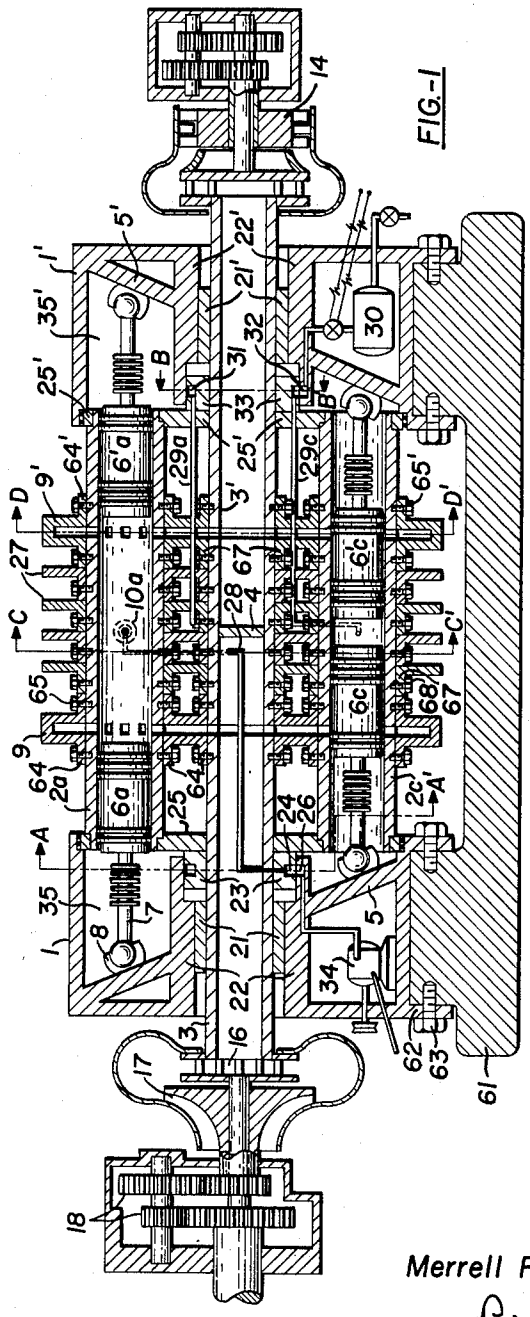


FIG.-1

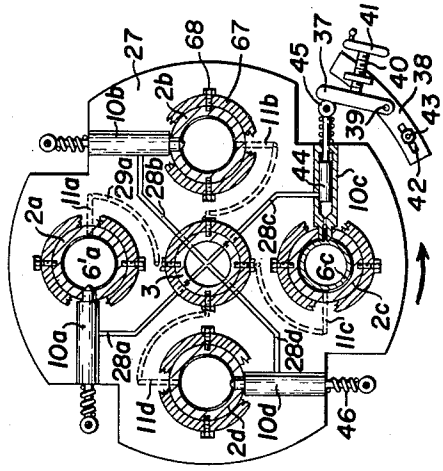


FIG.-3

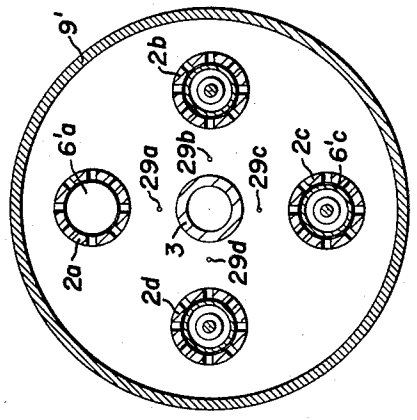


FIG.-2

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United States Patent Office

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Patented Jan. 8, 1957

2,776,649

TWO CYCLE FUEL INJECTION, OPPOSED PISTON, THRUST PLATE INTERNAL COMBUSTION ENGINE

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Application May 13, 1953, Serial No. 354,720

3 Claims. (Cl. 123—58)

This invention relates to a motor unit comprising a two-cycle internal combustion engine equipped with supercharger and an exhaust gas turbine. It is suitable for stationary, automotive, or aircraft use.

The object of my invention is to provide an air cooled, compression ignition, piston-turbine motor unit of high power output, low specific weight, low specific fuel consumption of simplicity and compactness. The fuel used therein may be a low grade gasoline, or distillate or residual hydrocarbon fuel. More specifically, an object of the invention is to provide an engine of novel design wherein the supercharger, pistons, and gas turbines are so arranged that scavenging, fuel injection and exhaust blow-down, are simplified, and wherein the reciprocating motion and power of the pistons is converted to rotary motion using the thrust plate principle.

The overall contour of the motor unit is cylindrical, with the supercharger positioned at one end, and the exhaust gas turbine at the opposite end. A series of pistons are arranged axially about the axis of the cylinder. The thrust of these pistons operates on an inclined thrust plate whereby the reciprocating piston motion is converted to rotary motion which drives the load, for example, a propeller. The pistons are arranged in an opposed manner; the ports for air intake and gas exhaust are slots in the cylinder wall. The piston part of the engine operates on the 2-cycle, compression ignition, direct fuel injection principle, with uniflow scavenging. In one embodiment of the invention, the entire piston and cylinder assembly rotates by virtue of the thrust imposed by the pistons on the inclined stationary thrust plates. In an alternate embodiment the pistons and cylinders do not revolve axially, but are stationary. The piston thrust is imposed on an inclined rotating thrust plate which is connected to the revolving drive or power shaft. In still another embodiment of the invention, the pistons may be free and not mechanically connected at either end; they can be forced or held against the thrust plate by either the supercharge or explosion pressures. However, the pistons can also be retracted mechanically as will be later described.

The aforesaid and other objects of my invention will be more fully understood from the following specification when read with the accompanying drawing in which two embodiments of my invention are illustrated by way of example. In the drawing

Figure 1 shows a longitudinal section of my new motor unit;

Figure 2 is a cross-sectional view along line D—D' in Figure 1 showing the exhaust manifold of the engine cylinders;

Figure 3 is a cross-sectional view along line C—C' of Figure 1 illustrating the location of the fuel injectors and the pipes for compressed air leading into the engine cylinders for starting the engine by compressed air;

Figure 4 is a cross-sectional view along line A—A' of Figure 1 illustrating the fuel distribution in the engine;

Figure 5 is a cross-sectional view along line B—B' of Figure 1 illustrating the starting air distribution; and

Figure 6 shows a cross-sectional view of a detail of a modified embodiment more fully described hereinafter.

The same reference characters indicate the same parts in all figures of the drawing.

The engine has essentially the shape of a circular cylinder mounted with its axis in a horizontal position. Two cylindrical castings **1** and **1'** are mounted rigidly to a base plate **61**, as by means of flanges **62** and bolts **63**. The base in turn is attached to the body to be propelled by the engine. The cylinders **2***a*, **2***b*, **2***c*, and **2***d*, and the hollow shaft **3** (Figure 3) are a rigid structure held together by the plates **25** and **25'**, by the intake and exhaust manifolds **9** and **9'**, and by cooling fins **27** (Figure 1). Any suitable expedient may be employed to connect the cylinders and the manifolds. In the apparatus as illustrated, annular flanges **64** and **64'** on the plates **9** and **9'** respectively are secured to the cylinder and shaft walls by stud bolts such as indicated by the numerals **65** and **65'**. The cylinder assembly unit is supported at the two ends by the bearings **21** and **21'** and is free to rotate about an axis co-axial with the hollow shaft **3**.

Inclined thrust plates **5** and **5'** are mounted in the castings **1** and **1'**, respectively and are integral therewith. As the cylinders **2***a*, **2***b*, **2***c*, and **2***d* rotate, the pistons **6***a*, **6***a'*, **6***b*, **6***b'*, etc., ride on the stationary thrust plates **5** and **5'** and thus move in and out. Each cylinder contains two pistons which operate simultaneously but in opposite directions.

The fuel is injected when the pistons are in their inner position **6***c*—**6***c'*. The thrust on the plates **5** and **5'** forces the piston rods **7** to slide down along the plates and this will effect a rotation of the shaft **3** and of the cylinder unit together with the pistons. In this manner the power generated between a pair of opposed pistons by combustion of the fuel injected through nozzles **10** is transformed from the reciprocating motion of the pistons to the rotary motion of the shaft **3**.

The hollow shaft 3 serves to conduct compressed air from the compressor or supercharger **17** to the intake manifold **9'** and to convey exhaust gases from the exhaust manifold **9'** to the gas turbine **14**, where additional power is extracted and transmitted to the shaft **3**.

As drawn on Figure 1, this engine has the following dimensions:

Bore=6 inches
Stroke=7.5 inches (1 inch "clearance")
Displacement per piston=212 cu. in.
Total displacement=8×212=1696 cu. in.
Compression ratio=8.5 to 1
Overall diameter=26 inches
Overall length=115 inches
Supercharge pressure=30 lbs. per sq. in. absolute
Air inlet pressure=15 lbs. per sq. in. absolute
Turbine inlet gas temperature=1540° F.
Indicated mean effective pressure=142 lbs. per sq. in.
Revolutions per minute=2500
Horsepower=1500
Lbs. fuel per horsepower-hour=0.375
Engine weight, lbs. per H. P.=0.7

It is assumed that this engine drives a propeller not shown in the drawing. The compressor **17** and its gear train are mounted on the forward end of the engine between the propeller and the sump case **1**. The shaft **3** is broken at **16** to provide an inlet to the hollow shaft for the compressor air. At this point the hollow shaft 3 joins an extension shaft for the compressor gears and the propeller. The gears **18** multiply the rate of revolution of the shaft **3** by six to seven times so that the compressor impeller **17** runs at 6 to 7 times the velocity of the main shaft. The compressor supplies air to the cylinders when the intake ports **9** open. The hollow shaft **3**

is partitioned by a wall 4 so that the air does not pass straight through. This air scavenges the combustion products out the exhaust 9'. The exhaust ports open a sufficient length of time ahead of the intake ports so that the pressure in the cylinder blows down to the pressure of the compressor outlet. At this point, the relatively cool compressor air pushes the remaining hot gases out through the manifold 9', through the hollow shaft 3', and to the turbine 14. This turbine extracts energy from the expanding gases which is conveyed to the main shaft 3—3' by the reducing gears 13. This gas turbine runs at 5 to 10 times the rate of rotation of the main shaft.

The temperature of the gases exhausting from the cylinders is limited to about 1600° F. because the turbine blades cannot tolerate much higher temperatures safely. To present cooling of these gases and to keep the bearing 21' at a low temperature, the inside of shaft 3' is preferably covered with an insulating coating.

The exhausting process takes place in two steps. In the first part, the ports in manifold 9' are uncovered to release the hot gas at a relatively high pressure, such as 50 to 100 p. s. i. A considerable amount of this energy is lost in turbulence and unfavorable flow through the turbine, so that only a portion of this part of the exhaust energy is realized in practice. In the second part, the compressor is supplying a steady pressure to the turbine to scavenge the hot combustion gases. This step is the most efficient of the two.

As apparent from Figure 1 the two pistons in each cylinder appear as moving in phase. In order that the exhaust ports 9' be uncovered before the intake ports 9 are uncovered, the pistons must be out of phase. Those pistons which pass over the exhaust ports must be some degrees ahead of those which pass over the intake ports. This phase difference is accomplished by fixing the sump units 1 and 1' so that the elliptical slanted thrust plates 5 and 5' are inclined at slightly different angles rather than being fully symmetrical. An alternate arrangement is to have the exhaust ports closer to the piston's top dead center than the inlet ports.

The quantity of air taken in and compressed in the engine as shown in Figure 1, is about 400 cu. ft. per minute at 90° F. and one atmosphere pressure. The pressure drop in the hollow shaft between the compressor and the cylinders is only about 1 pound per sq. in. The pressure loss in the exhaust manifold, in the exhaust ports, and in the exhaust line to the turbine is only about 2 pounds per sq. in. The pressure drop between the compressor outlet and the turbine inlet during scavenging is less than 5 pounds per sq. in.

The pistons 6 in Figure 1 are not connected mechanically to the slanted thrust plates 5 and 5' but the shoes or sliding heads 8 integral with said pistons ride on these plates as the cylinder unit rotates. The pistons are returned to the most expanded position (*6a*—*6a'*) from the most compressed position (*6c*—*6c'*) only by the gas under pressure in the cylinders between the piston heads. When operating continuously, even though no combustion occurs when the pistons are in the compressed position, the pressure of the compressed gas will push the pistons apart as they turn around the slanted plates.

However, after the engine has been shut down for some time there will be no pressure between the cylinders in the compressed condition (*6c*—*6c'*). Consequently, when the engine in this condition is turned over by an electrical starter, for example, all but the one piston which is open at the instant of starting will remain in a compressed position. Therefore, to facilitate starting the tank 30 for compressed air (Figure 1) together with the distributor 33 (Figure 5), and the lines 29 (Figures 1 and 3), and inlets 11 (Figure 3) are provided.

The piston rods 7 are rigidly fixed to the pistons. There are no conventional connecting rods or wrist pins.

The starting air distributor is shown in end section in Figure 5, and in longitudinal section in Figure 1. It consists of two parts: a rotating ring 33 attached to the main shaft 3, and a stationary ring 22', which is an integral part of the sump case 1'. The rotating ring has four slots 31 ninety degrees apart, which are connected by lines 29 to the center of the cylinders 2. The stationary ring 22' has one long slot 32 of such a length that, at most, only two of the rotating slots 31 can be in communication with 32 at any one time. The slot 32 is connected to the tank of compressed air 30. The valve 36 is open only during the starting period. A check valve may also be provided in addition to valve 36. This would allow the air to flow only out of tank 30.

In starting, the main shaft is rotated by an electric motor in the direction indicated. The cylinder 2*c* is just opened to the compressed air as shown in Figure 5 by the position of 31*c*. The compressed air is acting to push back the pistons 6*b*—6*b'* (located in front of the cutting plane of Figure 1) and pistons 6*c*—6*c'*. The pistons 6*d*—6*d'* (located behind the cutting plane of Figure 1) are in contact with the plates 5 and 5' and are moving in toward one another. Before any one of the pistons uncovers the intake and exhaust ports, the air distributor shuts off the compressed air to that cylinder, so that no air is wasted.

The compressed air received by a cylinder is discharged when the ports are uncovered. But even though firing does not occur for several revolutions and the compressed air is cut off completely by valve 36 after the first revolution, the gas compressed by the pistons is sufficient to push the pistons apart and to uncover the ports on each revolution until firing begins.

Fuel is injected into the cylinders by the injectors 10 shown in section in Figure 3. These injectors are opened once every revolution when the pistons are in the compressed position (6*c*—6*c'*), by a movable cam 37 (Figure 3) on a stationary cam 38. As illustrated, the movable cam 37 covers about 10 degrees of the circumference during its operation on fuel injectors 10. Any number of degrees can be arranged for readily by modifying its length and shape.

Fuel is distributed to the injectors 10*a*, 10*b*, 10*c*, and 10*d*, and to lines 28, 28*a*, 28*b*, 28*c*, and 28*d* by the distributor 23 shown in full section in Figure 4. The ring 23 rotates with the cylinder assembly and has a groove 24, which communicates with slot 26. Slot 26 is connected to the fuel pump 34 which simply supercharges the fuel injectors 10. That is, the pressure generated by this pump is only about 50 p. s. i. It has no metering function as the metering of the fuel takes place in injectors 10.

Referring to Figure 3, the injectors may be of a conventional type comprising a piston 44 whose stroke can be varied. At one end of this piston is a roller 45. The piston 44 is held in the extended position by spring 46.

Cams 37 and 38 are stationary and are attached to the engine frame. When roller 45 contacts cam 37, piston 44 moves in and forces liquid fuel through the injector nozzle into the cylinder 6. The more cam 37 is moved to the left, the longer the piston stroke and more fuel is injected. This obviously increases the power output of the engine. Cam 37 can be moved by screw 40 and hand wheel 41. It pivots on bearing 39. Other mechanisms may be employed.

The part of the cycle during which fuel is injected can be changed by moving cam 38 back and forth. This is provided for by slot 42 and lock nut 43. Normally the fuel is injected at or near the point where the two pistons are closest, i. e., around the point of maximum compression as for any 2-cycle conventional diesel engine.

The rapid rotation of the cylinder assembly provides good air cooling. The fins 27 are circular discs which completely surround the cylinders and the shaft 3 and help hold them rigidly in place. Here again any suitable expedient may be employed to separate and retain the discs in relation to the cylinders. One such means is illustrated as the annular flanges designated by the numeral 67 in the drawings. These flanges may be secured to the

cylinder barrels and to the shaft as by the stud bolts designated by the numeral **68**. Only the middle section of the cylinders where the combustion takes place is shown as finned.

Besides the piston and cylinder walls there are four other important points where lubrication and cooling must be provided. One of the more difficult lubrication problems is the sliding heads or shoes **8** on the inclined thrust plates **5** and **5'**. These elements must take the full load of the explosion and power stroke. By providing the shoes 8 with a large contact area, the pressures are not excessive. However, these shoes could also slide on roller bearings positioned in plates **5** and **5'**.

All four cylinders fire at the same point on the inclined thrust plates. That is, when the pistons are in the positions **6***c*—**6***c'*. The power strokes of all pistons pass over the same path. Wear on this 180 degrees of the cycle will be the highest.

To keep the pistons, cylinders, and shoes lubricated and cool, oil is present in sumps **35** and **35'**. This cool oil is sprayed from the outside in over each piston rod **7**, when it is in the top of the engine, that is, when each is above the plane of the top view section of Figure 1 and as it continues around and emerges from the cylinder. The rods **7** may be hollow and may contain sodium as the medium for rapid transfer of heat from the piston to the oil. The rods are shown finned to provide for extra cooling by the oil.

The oil then flows to the bottom of the engine where a pool or sump is maintained in which further cooling is obtained. The shoes may be lubricated by an oil spray or splash lubrication. The oil may be cooled in a conventional cooler and recirculated to the top spray.

The seals between the sump cases and the plates **25** and **25'** are so constructed that they fix the relative longitudinal positions of the rotating cylinder assembly and the sump cases. A groove and the radial walls provide the seal, and a gap between the cylindrical area of the groove and the periphery of the plate is used for lubrication.

The main bearings **21** and **21'** may be antifriction or journal bearings. The sleeves for the distributors **23** and **33** are lubricated from the oil sumps.

Instead of having the cylinders rotating with inclined thrust plates stationary, the opposite arrangement can be used. In this case the cylinders are stationary and the thrust of the pistons, via their shoes, is imposed on the thrust plate that is now free to revolve around its axis. The drive or power shaft is attached to this thrust plate so it revolves with it. The other general arrangement of the parts would be similar to that shown in Figure 1 except that the injectors are positioned between or around the inside of the cylinders so a rotating cam can be used to actuate the injectors in the proper sequence to inject the fuel. Whether the cylinders rotate or not there is still the same result—namely, a 2-cycle, fuel injection, opposed piston, supercharged engine wherein the axial thrust of the pistons is converted to a rotary thrust by inclined thrust plates located at each end of the cylinders.

Figure 6 shows an alternate method for retracting the pistons. Here parts corresponding to those in Figure 1 are numbered similarly. The shoes **50** at the end of rods **7** are somewhat different in construction but operate similarly to those on Figure 1. These shoes **50** bear on thrust plate **52**. A ring **51**, attached to **1'** and **5'**, makes contact with the outer edges of shoes **50**, as shown. These shoes slide over ring **51** as well as over thrust plate **52**. Thus as shaft **3**, cylinders **2***a* and **2***c*, pistons **6'***a* and **6'***b*, rod **7** and shoes **50** revolve about the axis of shaft **3**, the pistons **6'***a* and **6'***c* are retracted by the thrust created when shoes **50** slide over ring **51**.

Having shown and described specific embodiments of my invention to illustrate the application of the principles thereof, it will be well understood that it may be constructed in various other embodiments which come within the scope of the appended claims.

What I claim as my invention is:

1. In a two cycle internal combustion engine, which includes a pair of opposed annular thrust plates and a substantially circular group of open ended engine cylinders, wherein said cylinder group and said thrust plates are disposed in coaxial relation along a common axis concentric with said cylinder group and said plates, with the cylinders in said group in coextensive parallel relation to each other and to said axis, and with a thrust plate from said pair disposed at each end of said cylinder group in axially spaced relation thereto and in substantially symmetrical and oppositely inclined relation to the line of said common axis; means providing for uni-directional fluid flow through each of said cylinders, comprising a hollow shaft concentric with said group of cylinders and said thrust plates, said shaft extending outwardly at each end beyond said thrust plates and being supported for rotation about said common axis, a pair of annular, hollow, plate-like manifolds disposed concentric with said shaft to extend radially therefrom, a circular group of passageways defined in said manifolds parallel to said axis and corresponding to said group of cylinders, said passageways adapted to receive said cylinders to extend through said manifolds in substantially right angular relation thereto and to be rigidly retained thereby, said manifolds being disposed longitudinally of said common axis in spaced substantially radially parallel relation one to another and to the respective ends of said cylinders; a circumferential series of ports in each end portion of each cylinder opening radially through each cylinder wall into communication with the interior of one of said manifolds; said manifolds in turn each communicating with the interior of said hollow shaft through the wall thereof; a partition interiorly and diametrically of said shaft, located intermediate said manifolds; and means for inducing fluid flow through the respective cylinders in said group by way of said shaft and manifold in one direction longitudinally of said axis.

2. In a two cycle internal combustion engine, the combined structure according to claim 1, and including a mounting base for said engine, wherein said thrust plates are rigidly mounted in fixed relation to said base, said hollow shaft is mounted for rotation axially of said thrust plates, and said cylinders and manifolds are mounted in fixed relation to said shaft for rotation therewith about said common axis.

3. In a two cycle internal combustion engine, the combined structure according to claim 1, wherein said means for inducing fluid flow through the respective cylinders in said group by way of said shaft and in one direction longitudinally of said axis, comprises an extension shaft mounted coaxially with one end of said hollow shaft and in axially spaced relation to said end, providing an inlet to said shaft through said end, a fluid compressor casing having an inlet and an outlet concentric with said shaft said casing outlet enclosing and communicating with said shaft inlet, a compressor impeller mounted for rotation on said extension shaft and disposed in the casing inlet, and gear means driven from said extension shaft for driving said impeller.

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