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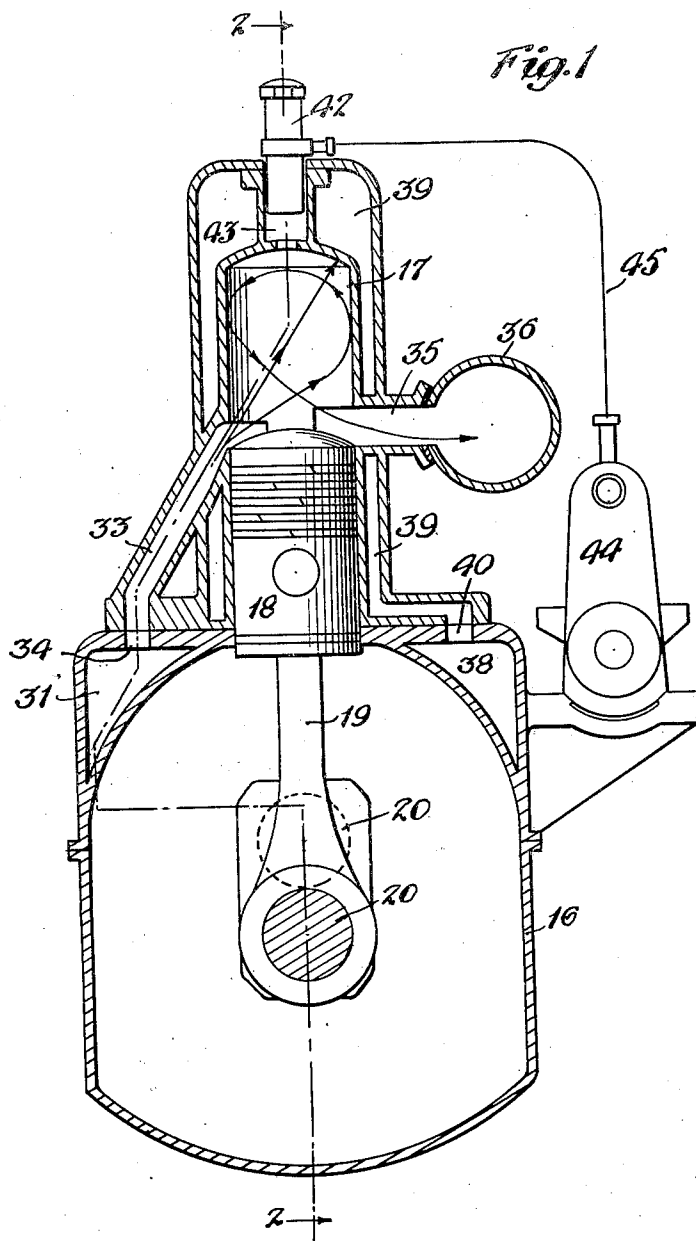
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2,010,296

INTERNAL COMBUSTION ENGINE

Filed Sept. 21, 1933

5 Sheets-Sheet 1



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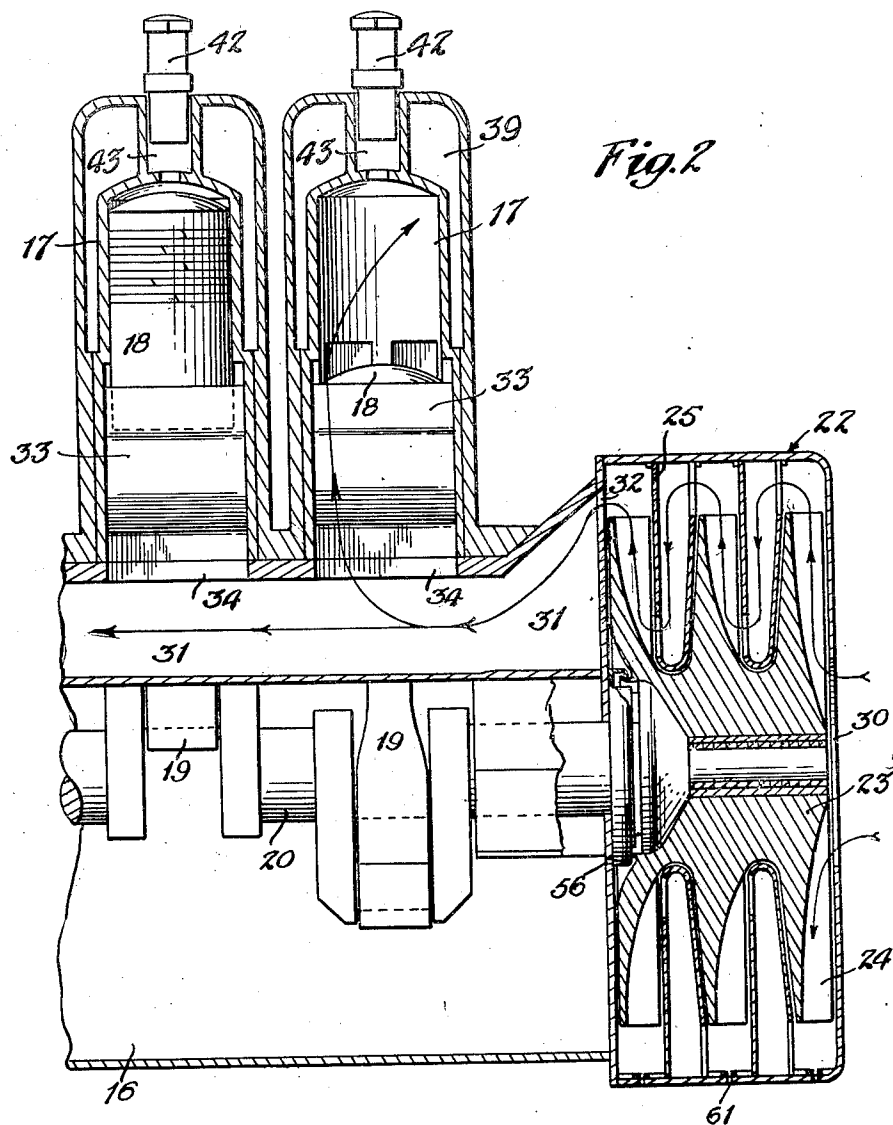
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INTERNAL COMBUSTION ENGINE

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5 Sheets-Sheet 2



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INTERNAL COMBUSTION ENGINE

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Fig. 3

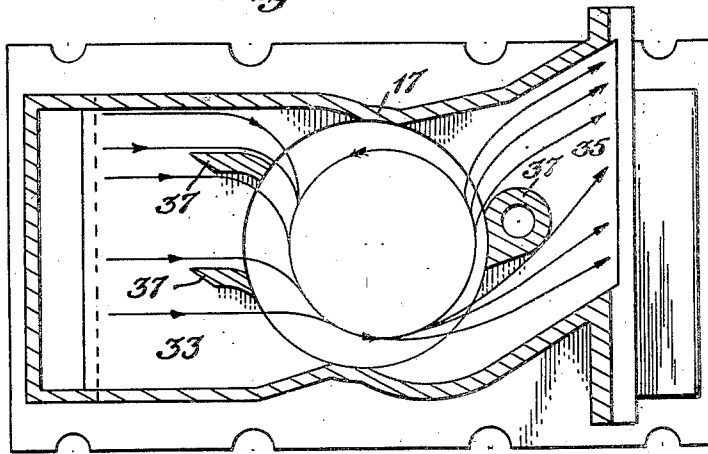
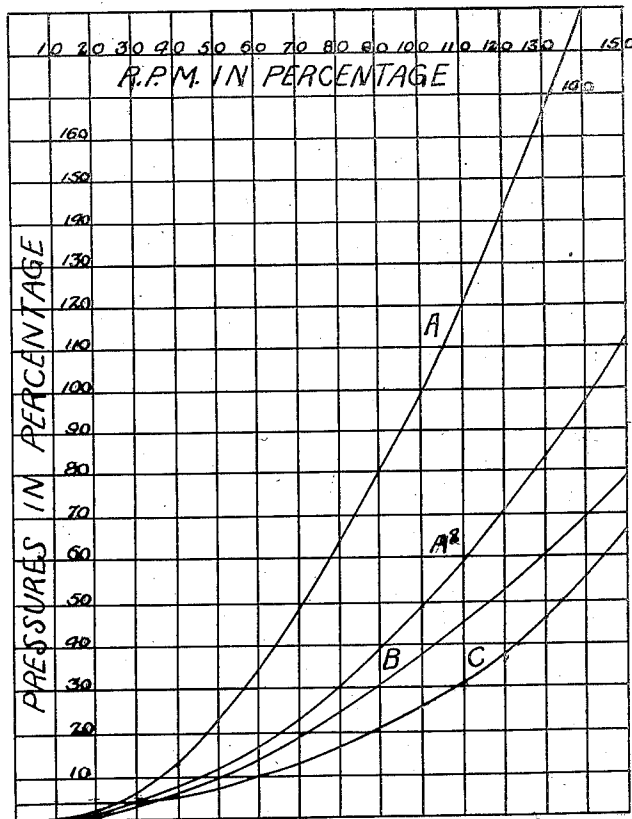


Fig. 15

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Fig. 5

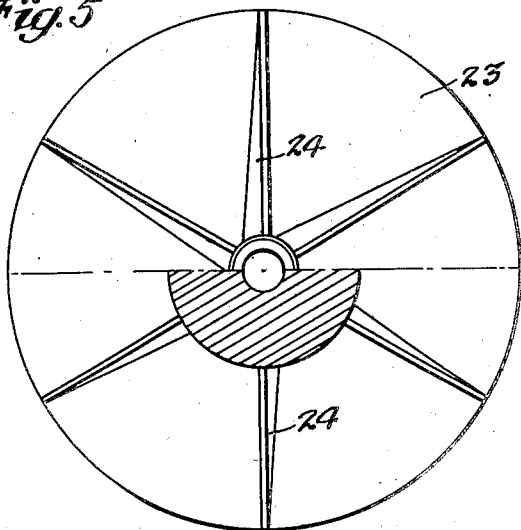


Fig. 4

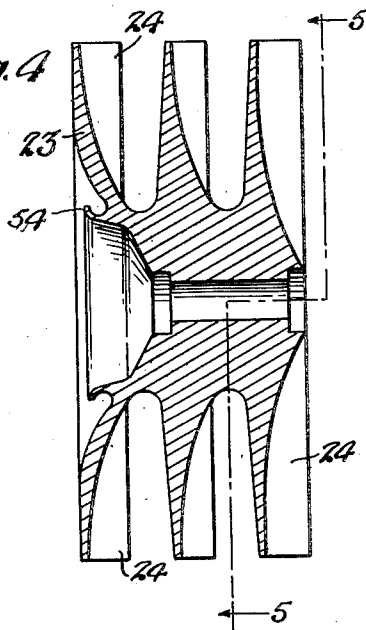


Fig. 6

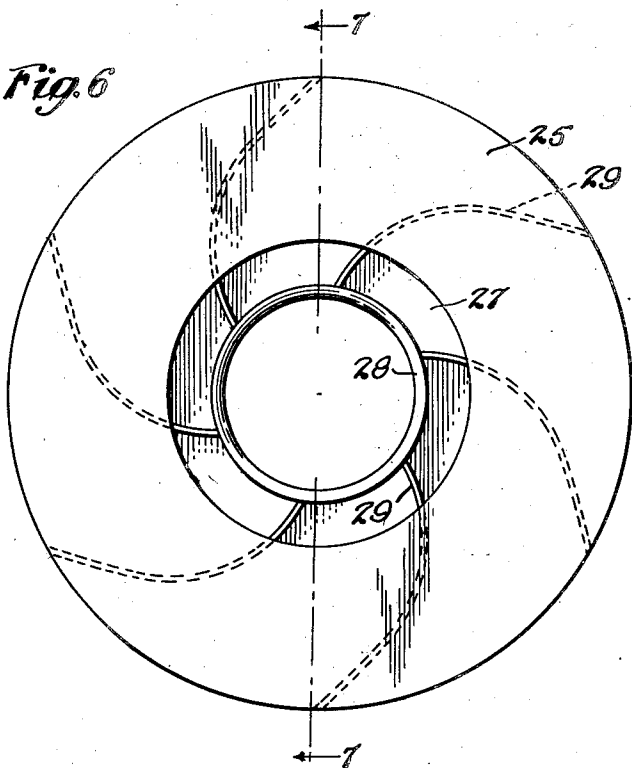
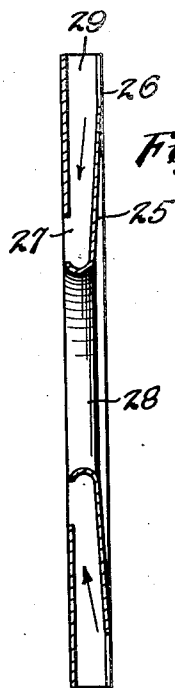


Fig. 7



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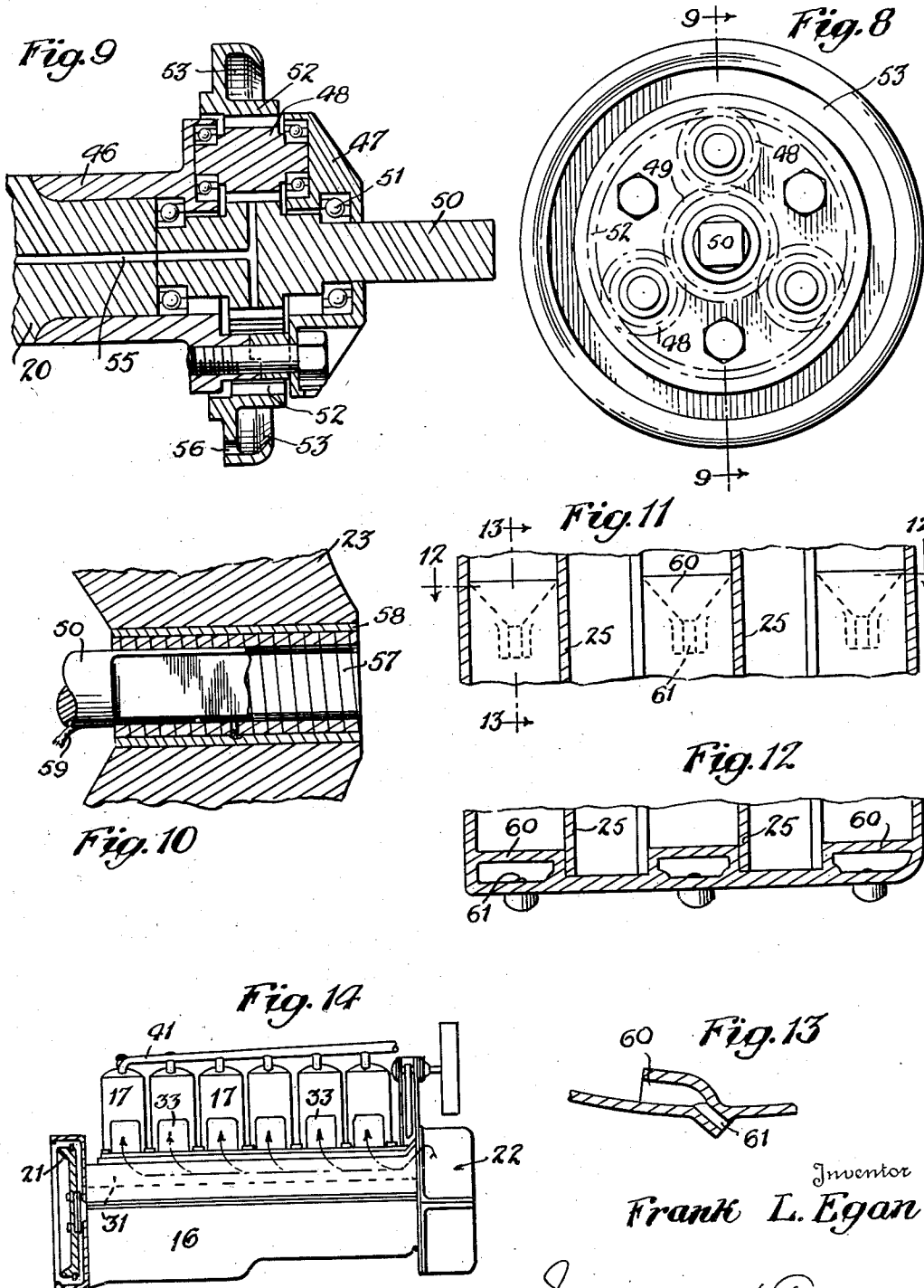
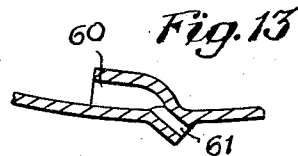
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INTERNAL COMBUSTION ENGINE

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5 Sheets-Sheet 5



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INTERNAL COMBUSTION ENGINE

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Application September 21, 1933, Serial No. 690,461

34 Claims. (Cl. 123—65)

This invention relates and pertains to internal combustion engines of the type or class in which ignition of the fuel is by the temperature of the compressed air in the cylinder, that is, no hot surfaces nor any other ignition means other than the heat of compression, is depended upon for the ignition of the fuel charge. The engine is also of the type or class known conventionally as "two-cycle" and is of the constant compression type.

One object of the invention is to impart better acceleration characteristics to this type of engine in order to adapt it to various services in which variable speed is required. Heretofore, the acceleration of internal combustion engines in such services has been slower than it should be, this being especially true of "two-cycle" engine operation. The reason for this inadequate acceleration resulted, according to my analysis, from inadequate cooperation between the air compressor used on such engines, and the engine. By this I mean that the compressors were of types having poorly chosen characteristics whereby if the compressor furnished sufficient air at sufficient pressure to meet the engine's demands for acceleration, the compressor also consumed too much power. If the compressors were of the type that consumed a reasonable amount of power, the engine was starved for air. Further, the manifolds and ports of such engines were not arranged to handle the air stream in a minimum time and with a minimum of air stream friction.

The essence of my invention lies in adapting a compressor of peculiar and desirable speed volume characteristics, and an engine having excellent internal air handling characteristics to make a combination which has the desired acceleration characteristics.

In usual engines of the "two-cycle" or "four-cycle" type, the volumetric efficiency of the engine decreases as the engine speed increases, due to the gas stream friction which limits the maximum speed of the engine. An object of the present invention is to provide an engine in which the maximum speed and power, together with the acceleration of the unit throughout its entire range, will be maintained, due to a construction which produces an increasing instead of a decreasing volumetric efficiency as the R. P. M. increases throughout the entire range of the engine.

Briefly stated, my combination comprises a "two-cycle" oil engine having its ports and intake manifolds arranged for the shortest possible path and the minimum friction of air for com-

bustion and scavenging, and its air compressor of a multi-stage centrifugal type.

My air supplying unit is of such characteristics that it will supply air with all of the positiveness of the displacement blower, yet the pressure of air supplied to the metered requirements of the engine will increase in the ratio given by the following:

Peripheral velocity of impeller in feet per second, squared, divided by two times gravity which equals 64.32, multiplied by the number of stages in the compressor, and multiplied by the speed ratio between the engine and the compressor, will give the resultant air pressure in feet head of air column. Expressed as a formula, this relation is

$$H = \frac{V^2}{2G} \times \text{stages} \times \text{gear ratio}.$$

Another object of the invention is to produce an internal combustion engine in which throughout the entire operating range of the engine an exact balance is maintained between two elements—(i. e. compressor capacity and combustion volume) and at no point in the entire operating range of the unit can there be a deficiency or an excess of air either in pressure or volume except that at all points in the operating range, there is sufficient excess air pressure to cause rapid acceleration of the engine even after the momentary slip of the torque limiting device is deducted from the acceleration factor. Further, at no point in the operating range of the unit can the compressor element use or require more power to drive it than is required to furnish the volume and pressure of air required by the combustion element at that particular speed power or operating point.

Another object of the invention is the provision of means to drive the air supplying device at a speed metered by the air need of the engine, but which speed is maintained through a torque limiting device, thereby reducing the inertia shocks to safe values.

Another object of the invention is to provide air passages and air ports within the engine which will conduct the air stream created by the compressor through the entire unit with a minimum of friction, and with a maximum of scavenging effect.

A further object of this invention is to provide efficient means to remove foreign particles from the air stream, before the air enters the engine cylinders.

Another object of my invention is the provision of a "two-cycle" internal combustion engine

which will deliver maximum speed and power for the piston displacement and the fuel consumed, which will maintain torques throughout its operating range, and which will have substantially constant acceleration throughout its operating range.

Other objects and advantages of my invention will be apparent during the course of the following descriptions, which with the accompanying drawings form a part of this specification, wherein like characters of reference denote like parts throughout the same:

Fig. 1 is a vertical, transverse, sectional view through a two-cycle engine embodying my invention.

Fig. 2 is a longitudinal sectional view taken on the line 2—2 of Fig. 1, and showing the air supplying unit and two cylinders of a multiple-cylinder engine.

Fig. 3 is a horizontal sectional view through one cylinder and its inlet and exhaust ports.

Fig. 4 is a longitudinal sectional view of the air supplying impeller removed from its casing.

Fig. 5 is the view at right angles to Fig. 4, showing the upper half of the impeller in elevation and the lower half of the impeller in section as indicated by the line 5—5 in Fig. 4.

Fig. 6 is a rear elevation of one of the stage diaphragms of the air supplying unit.

Fig. 7 is a transverse sectional view thereof taken on the line 7—7 of Fig. 6.

Fig. 8 is a front elevation of the planetary gear set which connects the engine crank shaft to the rotary impeller of the air supplying unit.

Fig. 9 is a central longitudinal sectional view thereof, taken on line 9—9 of Fig. 8.

Fig. 10 is a detail sectional view of the torque limiting driving connection between the planetary gear set and the impeller.

Fig. 11 is a horizontal sectional view looking downward upon the bottom of the casing of the air supplying unit.

Fig. 12 is a partial vertical section there-through and taken on the line 12—12 of Fig. 11.

Fig. 13 is a detail sectional view on the line 13—13 of Fig. 11 showing the air cleaning means.

Fig. 14 is a side elevation showing my invention applied to a six cylinder vertical engine; and,

Fig. 15 is a chart showing the characteristic pressure-volume curves of the air stream supplied to the engine.

Discussing Fig. 15, first, the horizontal component of the graph represents revolutions per minute in terms of percentage of engine speed; 100% speed meaning that the engine is turning over at its maximum normal speed. The vertical component is measured in percentages of pressure; 100% pressure meaning that the compressor is at that point delivering air at its maximum normal rated capacity and pressure.

The curve "A" indicates the characteristic pressure curve of the multi-stage centrifugal compressor shown in the drawings under shut-off conditions; that is, with the discharge passage from the compressor closed, the pressures and R. P. M. being shown in percentages. Curve A—2, shows the pressure actually supplied to the combustion portion of the engine with the discharge passages from the air compressor open, and the air being metered from the air compressor by the inlet ports and pistons of the engine.

Curve "C" shows the minus pressures or pressure drops in the manifold of a four-cycle engine at the engine R. P. M. percentages shown. An

engine of the two-cycle type of equal displacement and having intake and exhaust ports controlled by the piston if correctly designed, has the pressure drop through passages intake manifold cylinder and intake ports as shown by curve "B". Curve "C", however, shows minus pressures, that is, pressures below atmospheric, whereas curve "B" illustrates plus pressures or pressures above atmospheric pressure.

As illustrating the varying demands of the engine, the following will be helpful:

In the two-cycle engine starting at 800 R. P. M. combustion plus scavenging air must be supplied in volume to fill the engine at that speed, and all of this air must be supplied at 35/100ths of a pound (.35 lb.) per square inch pressure. If the air pressure drops below this figure, the engine speed will automatically decrease. At 2000 R. P. M. combustion plus scavenging air must be supplied at 1—40/100 of a pound (1.40 lb.) per square inch pressure. If the air pressure drops below this figure, the engine speed will decrease automatically. The operation of any two-cycle engine, therefore, as to speed and acceleration floats on the air stream supplied to the engine, and the volume and pressure of this air stream must equal the demands of the engine at all speeds to insure efficient operation of the engine, and at each speed point in the operation of a variable speed engine there must be a sufficient excess of air pressure to provide for acceleration of the engine, and the speed of such acceleration will be dependent upon the rise of the air pressure at the increased volume as the engine speed increases.

In order to use Fig. 15 to determine engine demands and reserves of potential power at any speed, the following directions can be followed:

The only other item of knowledge necessary to its understanding being that there is a torque limiting device between the compressor and the engine, and this device slips momentarily when the impeller torque becomes so high as to approach what would be the breaking points of the gears, bearings, etc., forming the planetary gear drive.

Checking curve B at 80% R. P. M. start at point where curve B crosses 80% R. P. M. line, then go vertical on the 80% R. P. M. line to the 30% pressure line, and then horizontally on 30% pressure line to the right to the point where curve B intercepts the 30% pressure line, and this interception occurs very close to the 90% R. P. M. line. This shows that at 80% R. P. M. the compressor is supplying air pressure sufficient for 90% R. P. M. operation.

With the engine running at 80% R. P. M. a sudden acceleration causes torque limiting device to slip momentarily. However, there is sufficient air pressure available to run the engine at 90% R. P. M. and the surplus is sufficient to result in rapid acceleration after the effect of the momentary slip of the torque limiting device has been deducted.

The vertical distance between curve A—2, and curve B therefore, shows at any R. P. M. percentage point that the provision for the momentary slip of the torque limiting device, plus an acceleration factor necessary that the engine respond to acceleration at substantially the same acceleration rate in R. P. M. percentage, whether such change is from 80% R. P. M. to 90% R. P. M., or if such change is from 120% R. P. M. to 130% R. P. M. The acceleration rate to be maintained substantially constant, in revolutions per

second, requires a constantly increasing spread or distance between curve A—2, and curve B, as the speed of the unit increases.

The frictional value at which the torque limiting device is set to slip is such that it will operate when strong acceleration of engine speed takes place, rather than at the highest speeds of the engine. In order, therefore, to have enough air available for further acceleration when the torque limiting device is slipping, and to have such air at the pressure demanded by curve B, Fig. 15, it is necessary that a sufficient volume of air be in reserve either in the air passages to the engine, or as a potential added volume and pressure of air to be in storage in the form of energy in the compressor impeller which has a fly-wheel effect to furnish a supply sufficient to take care of such demands when the impeller drive is momentarily slipping. In this invention this effect is attained by the characteristic of the multi-stage centrifugal compressor and the inertia effect of the impeller, although the manifold air storage capacity is a slightly favorable factor.

The action is approximately as follows:

Assuming that the engine is running steadily at 1000 R. P. M., the pressure volume capacity of the compressor is such that the engine demands are met and a slight but definite excess of air at a slight but definite excess of pressure is maintained. If the engine speed is now quickly raised to 1200 R. P. M., the torque limiting device momentarily slips, but nevertheless the compressor is being driven at a steadily mounting speed resultant from the acceleration of the engine and the fixed torque of the torque limiting device. The air output of the compressor is just sufficient during its acceleration to furnish the air needed for the increasing engine R. P. M. yet the compressor can under this condition furnish no slight excess as when the engine speed is steady.

A ratio, such as described between engine and compressor R. P. M. can be provided to fit any properly designed engine and any properly designed compressor by a skilled designer when the desirability of such cooperative design and the means of execution of such design have once been demonstrated to him.

In the practical application of my invention, I designed the characteristics of the multi-stage centrifugal compressor to the demands of the engine, so that the pressure drop of the air entering the space created by the downward stroke of the piston in the cylinder and whatever higher than atmospheric pressure existing in the air passages to the cylinder, cancel each other, so that the net results are a constant or uniform air pressure within the cylinder at the point where the piston is just closing the exhaust port. The air pressure at the start of compression being constant or uniform, the final compression pressure at the end of the compression stroke must necessarily be a constant or uniform pressure irrespective of the speed at which the engine may be running.

The preferred design contemplates air at approximately 15 lbs. per square inch absolute pressure at the point where the piston is just closing the exhaust port, although I do not limit myself thereto, since the invention is equally applicable to the providing of much higher pressures at the start of compression and a consequent change of the compression ratio of the engine.

My centrifugal air compressor furnishes an air stream which when its velocity is reduced or interrupted, as by the shutting of a valve, trans-

forms the velocity into pressure, without appreciable time loss and the action is reversed when the valve is opened, and this conversion is effected at an efficiency of approximately 80%.

These preliminary considerations having been digested, the reasons for the structure as presented in the following pages will now be understood.

In the drawings wherein for the purpose of illustration is shown a preferred embodiment of my invention the numeral 16 designates the crank case of a two-cycle engine embodying my invention, upon which cylinders 17 are mounted. Single acting pistons 18 reciprocate in cylinders 17 and are connected to the crank shaft 20 by means of the usual connecting rods 19. For convenience of illustration, I have shown my invention as applied to an engine having vertical single acting cylinders but I contemplate using my invention in connection with other types of engines such for example, as engines having one or more double acting cylinders or opposed pistons working in a straight line cylinder, or opposed pistons operating in cylinder bores arranged at an angle to each other.

The usual flywheel 21 is arranged at the rearward end of the crank shaft, and the air supplying unit 22 is arranged at the forward end of the crank case and connected to the forward end of the crank shaft. The air supplying unit 22 consists of a centrifugal multi-stage compressor, and in the drawings is shown as having three stages, although any desired number of stages may obviously be used. The compressor impeller 23 is provided with tapered radial vanes 24 shown as six in number for such stage, and the vanes of each stage are arranged in axial alignment. Preferably the vanes of the first stage extend nearer to the center of the impeller than do the vanes of the second and third stages which results in a greater effective length of the vanes of the first stage as seen in Figures 4 and 5.

Stage diaphragms 25 are arranged between the stages of the impeller and are shown in Figures 6 and 7. The forward face of each diaphragm is provided with suitable inlet openings 26 extending around its periphery, and an annular discharge opening 27 extends about the hub 28 of each diaphragm. Suitable curved guide vanes 29 are spaced around the diaphragm between the walls thereof and are shown as corresponding in number to the impeller vanes.

The stage diaphragms in a three stage compressor are two in number and are rigidly secured to the stationary compressor casing, extending between the vanes of adjacent stages of the impeller. A central opening 30 is arranged in the forward face of the compressor casing and serves as an inlet for the air drawn into the compressor by the rotating impeller.

An air passage 31 extends longitudinally of the crank case in an upper corner thereof and communicates with the last stage of the multi-stage centrifugal compressor by means of opening 32. Air inlet ports 33 connect the air passage 31 with the various cylinders through openings 34 in the top of the crank case. Exhaust ports 35 are arranged opposite the intake ports and connect the cylinders with a longitudinally extending exhaust manifold 36.

Both the exhaust and inlet ports are tangentially arranged with respect to the cylinder, and this effect is heightened by the webs 37 which guide the gases in a direction substantially tangentially to the cylinder. By reason of this tan-

gential arrangement of the ports the incoming air will take a circular or swirling path through the cylinder as indicated by the arrows in Figures 1 and 3, thereby effectually sweeping the exhaust gases from the cylinder in a helix. This spiral turbulence is maintained until the piston has reached and passed the dead center point. This helical air stream tends to sweep the cylinder clear of all the products of combustion and utilizes the velocity of the exhaust gases leaving the cylinder through the tangential exhaust ports.

The intake and exhaust ports are opened and closed by the piston, the exhaust port being the first to be uncovered and the last to be closed.

A longitudinal water passage 38 extends along the upper portion of the crank case on the opposite side thereof from the air passage 31, and communicates with the water jackets 39 of each cylinder through ports 40. The water may be removed from the jackets 39 by any suitable means, such as the manifold 41 shown at the top of the cylinders to one side of the fuel injectors in Figure 14.

The fuel injectors 42 are shown as extending into a precombustion chamber 43 above and communicating with each cylinder but if desired they may communicate directly with the cylinders. A suitable fuel pump 44 pumps the fuel through conduit 45 to the injectors which spray it into the precombustion spaces or cylinders to be ignited by the heat of compression.

Air from the multi-stage centrifugal compressor, under the desired pressure and in suitable volume, passes through air passage 31 to the intake ports and thence into the cylinder, sweeping out the exhaust gases and charging the cylinders with combustion air. The piston rises, closing the intake ports and exhaust ports, and then highly compresses the fresh charge of air. Near the top dead center of the piston travel, fuel is sprayed into the cylinder or space 43 and is ignited by the highly heated compressed air, thereby forcing the piston downward in the cylinder. The exhaust port is first uncovered, permitting the escape of sufficient pressure to bring the pressure of the gases in the cylinder below the pressure of the air entering the intake port. A portion of the incoming air serves to scavenge the cylinder, and then the piston again rises with a new charge of air in the cylinder to repeat the cycle.

Any form of fuel injection mechanism, such as the solid injection devices shown may be used to feed fuel to the cylinders, no air pressure being necessary to feed the fuel. Air pressure may be used if desired however, and if such pressure is used, it is preferable to supply the desired high pressure by means of a multi-stage compressor suitably driven.

In oil engines of the prior art difficulty has been experienced in supplying the desired volume and pressure of air to meet the varying demands of the engine, especially at higher speeds, and as a consequence no very high speeds were available in this type of engine. Especially has this been true of engines using the displacement type of air compressor or the simple centrifugal blowers of the prior art. I have discovered that a multi-stage centrifugal compressor of the design shown in the drawings, when suitably driven in a constant ratio with the engine crank shaft speed, will supply the pressure and volume of air demanded by the engine at any speed within the speed range of the engine, notwithstanding

the pressure drop caused by air stream friction through the ports and passages at high engine speeds. While any suitable driving connection may be used to produce the desired constant speed ratio, I prefer to use the planetary gear-set shown in Figures 2, 8 and 9 to connect the crank shaft to the compressor impeller.

The rear portion 46 of the planet gear housing is rigidly secured to the forward end of the crank shaft 20 to rotate therewith and the forward portion 47 of the housing is bolted to the portion 46. The planet gear housing comprising the spaced members 46 and 47 rotatably support the three planet gears 48 arranged in mesh with the central sun gear 49 to which the impeller supporting shaft 50 is secured and extends through the forward portion 47 of the planet gear housing, a roller bearing 51 being arranged between shaft 50 and housing member 47.

A stationary ring gear is in mesh with the teeth of planet gears 48 and is provided with an annular oil pocket 53 into which an oil slinger ring 54 on the impeller 23 extends. The gears are lubricated by oil under pressure from oil duct 55 in the center of crank shaft passing through ducts in sun gear 49 to the face of the sun gear. The oil is sprayed from the meshing gears to the various bearings in the gear set, and is finally caught by the oil slinger ring 54 on the impeller and thrown into annular oil pocket 53, on ring gear 52 and escapes through opening 56 into the crank case of the engine.

The gearset is so designed that the impeller, due to its speed ratio, has its natural critical speeds of vibration points in opposition to the critical speeds of the crank shaft, thereby acting as an effective vibration dampener and relieving the crank shaft from the usual strains incident to the use of a single flywheel arranged at the rear of the crank shaft.

Because of natural laws, if the compressor impeller were connected directly to the sun gear shaft 50 the pressures and shocks due to inertia of the parts would be destructive to gears and bearings, with any reasonable and practical size and space limitations on said gears and bearings. I, therefore, prefer to interpose a torque limiting drive between the impeller and shaft to protect the gears and bearings from the pressures and strains due to the inertia of the parts during acceleration and deceleration. I also provide a hardened steel bushing 57 formed as a tightly wound helical coil having its outer and inner surfaces accurately ground to size, and fastened on the shaft 50. A plain cylindrical, bushing 58 is secured to the central bore of the impeller and is accurately machined to closely fit over the helical bushing 57, as seen in Figure 10. Helical bushing 57 is accurately fitted into plain bushing in such manner as to produce a predetermined unit pressure value, and consequently a predetermined friction value for the surfaces in contact. The contacting surfaces of the two bushings may be lubricated in any suitable manner, as by means of a wick of woolen material as indicated at 59 in Figure 10 and the contacting surfaces consequently have always the same coefficient of friction.

The torque at the impeller is thereby limited to a predetermined maximum value, and under any operating conditions whereby this maximum torque is exceeded, bushing 58 will slip on bushing 57 until the excess inertia effect of the moving parts is absorbed by the friction between bushings 57 and 58.

The shaft 50 may be round and secured to bushing 57 by any suitable manner, as by means of a key or it may have its surface flattened to fit into a correspondingly shaped bore in the bushing, as indicated in Figure 10.

By centrifugal force, any dirt or foreign particles in the air, is thrown into the concentric laminations of air revolving within the discharge chambers of the compressor, moving outward until it is swept around the inner periphery of the discharge chamber. In order to remove this foreign material from the air, I provide accumulator vanes or pockets 60 in the lowest portion of each of the three discharge chambers, and the walls of these pockets converge to small inclined discharge openings 61 drilled in the peripheral wall of the discharge chambers, as indicated in Figures 11, 12, and 13. These accumulator pockets and drilled ports are designed so that although they have ample capacity to remove the dirt or foreign matter in the air supply the air vented through the drilled openings is not in excess of about $\frac{1}{2}$ of one percent of the total air stream.

The multi-stage centrifugal compressor shown in the drawings discharges air at a radial velocity of about one-fifth or one-sixth of the radial velocity of the air discharged from the impellers of the usual commercial compressor units. The shape, extent and disposition of the surfaces of my centrifugal compressor are such that the kinetic energy of the air leaving the impeller is converted into static head or pressure without the use of discharge vanes or a parallel flat ring diffuser. My compressor converts kinetic energy of the air into static head in annular chambers of uniform cross-sectional area throughout by reason of the disposition of the internal surfaces of the discharge chambers. This results in a freedom from pressure surge and shriek, and promotes quiet operation producing static head in accordance with the speed at which the compressor may be operating. This conversion of kinetic energy into static head in the compressor is effected by the skin friction of the interior surface areas of the discharge chambers, and the internal friction of the air as it moves in concentric circular laminations between the outer diameter of the impeller and the inner diameter of the discharge chamber.

The above described action is in direct contrast to the action of conventional discharge chambers of a volute or modified volute form in which static head is produced by eddies or turbulence in the discharge chamber, and to the action of discharge chambers of conventional staged compressor design having stream lined or velocity curved vanes or passages, or compressor discharge chambers using parallel flat diffuser rings.

Considering atmospheric pressure as zero pressure, it will be seen that the air stream leaving the final stage of the centrifugal compressor is under plus pressure in accordance with the curve A-2, on the chart shown in Figure 15 and that it also has a velocity produced, maintained and controlled by the centrifugal compressor working in conjunction with the combustion portion of the engine, which meters the air it requires from the volume and pressure of air produced by the centrifugal compressor.

While I have shown and described the preferred embodiment of my invention for use in present day motor vehicles, it is to be understood that the design can be changed to meet the requirements of diversified uses, the essence

and spirit of my invention being an engine in which, the rotative, the piston speed, and the acceleration, have no maximum values due to insufficient volume and pressure of the air stream.

Having thus described my invention, what I desire to claim and protect by Letters Patent is:—

1. A Diesel engine comprising a multi-stage centrifugal air compressor section and a two cycle displacement combustion section, said air compressor section being arranged to supply internal air to the combustion section, a torque limiting device connecting the two operatively and constituting a positive drive except at abnormal torque values, the capacity and characteristics of said compressor section being such that the requirements of the combustion section for internal air and the compressor sections output of such air keep in substantially fixed ratio at all speeds within the operating range of the Diesel engine even during the time elements when the torque limiting device may act to limit the torque applied to the compressor section.

2. A Diesel engine comprising a multi-stage centrifugal air compressor section and a two cycle displacement combustion section, said air compressor section being arranged to supply internal air to the combustion section, and means to drive the air compressor section by the combustion section, said means including a torque limiting device, the compressor having such supplying characteristics, when so driven by the combustion section as will keep in a fixed ratio with the ability of the combustion section to use said air efficiently, and when the torque limiting device is actually limiting the torque applied to the compressor section, said engine section having a co-operative combination of an air manifold as a part of said combustion section and tangential air inlet ports to the cylinders of said combustion section, said manifold passage and said tangential air inlet ports being adapted to transmit the air stream from said compressor section to the interior of the cylinders of the combustion section, with a minimum of air stream friction and pressure drop and in a minimum time element.

3. A Diesel engine of the two-cycle type having piston controlled intake and exhaust ports, and a centrifugal multi-stage air compressor as a part of said Diesel engine, the air compressor section having its outlet connected directly to the intake ports of the cylinders of said engine, and means to operate said compressor section to maintain pressures above atmospheric pressure thruout the air ports, and at least atmospheric air pressure in the cylinder of said engine at the start of displacement compression at all operating points within the speed range of the engine.

4. A Diesel engine of the two-cycle type having piston controlled ports, the intake ports being inclined to the bore of the cylinder and tangentially disposed to direct the air stream in a definite path and exhaust ports at ninety degrees to the centerline of cylinder and tangentially disposed in the opposite direction to the intake ports, and a high speed centrifugal multi-stage air compressor driven in fixed speed ratio, except at abnormal torque values, by the crankshaft of the engine and means to convey the air stream from said compressor section to and within the cylinder of said engine with a minimum of loss of head or pressure due to friction.

5. A Diesel engine, of the two-cycle type having a cylinder with tangentially disposed ports for

- intake and exhaust, a piston operating in said cylinder, and a high speed centrifugal multi-stage air compressor, driven in fixed speed ratio by said engine except at abnormal torque values and means to convey an air stream from said multi-stage air compressor to the tangential intake ports of said engine, said compressor supplying an air stream the varying pressure of which balances the air friction losses in the ports and passages of said engine, added to the demands of said engine for combustion and scavenging air, at all speeds within the operating range of said engine.
6. A Diesel engine having a multiple of two cycle cylinders having piston controlled tangential intake and exhaust ports and a single crankshaft to which all of the engine pistons are connected, having a flywheel at one end of said crankshaft, and a multi-stage centrifugal air compressor connected to the opposite end of said crankshaft and driven thereby in a fixed speed ratio thereto, except at abnormal torque values, and means to convey the air stream from the centrifugal air compressor to and into the cylinders of said engine with a minimum of friction and pressure drop.
7. A Diesel engine having multiple cylinders of the two cycle type said cylinders having upwardly inclined intake and tangential exhaust ports in the cylinders, and a single crankshaft to which all of the engine pistons are connected, having a flywheel at one end of said crankshaft, and a multi-stage centrifugal air compressor connected to the opposite end of said crankshaft to be operated thereby, and a torque limiting device connection between the crankshaft and the air compressor and means to convey the air stream from the air compressor to the intake ports of said engine.
8. A Diesel engine of the two-cycle type, having piston controlled intake and exhaust ports, and a multi-stage centrifugal compressor operated as a part of said engine and adapted to supply combustion and scavenging air thereto, and means within said compressor to remove foreign particles from the air passing through said compressor.
9. A Diesel engine having a cylinder with tangential inclined intake and exhaust ports, a piston operating therein, a crankshaft connected to said piston, a planetary gearset operatively connected to said crankshaft, a multi-stage centrifugal compressor to supply internal air to the cylinder of said engine, and a torque limiting drive connecting said planetary gearset and the multi-stage centrifugal air compressor.
10. A Diesel engine of the two-cycle type, having piston controlled tangential inclined intake and exhaust ports, and a crankshaft, said engine having a flywheel at one end of said crankshaft, and a planetary gearset at the other end of said crankshaft and operatively connected thereto, and a multi-stage centrifugal air compressor to supply internal air to the cylinder of said engine, and a torque limiting device connection between said planetary gearset and the multi-stage centrifugal air compressor, said torque limiting device being operative only at abnormal torque values, caused by inertia.
11. A Diesel engine of the two-cycle type, having piston controlled intake and exhaust ports with a crankshaft, having a flywheel at one end of said crankshaft, a planetary gearset at the other end of said crankshaft and operatively connected thereto, a multi-stage centrifugal air compressor to supply internal air to the intake ports of said engine, a torque limiting driving connection between said planetary gearset and the multi-stage centrifugal air compressor, and means comprising accumulator vanes provided in said air compressor to remove foreign particles from the air passing therethrough.
12. A Diesel engine of the two-cycle multi-cylinder high speed type having tangentially disposed piston controlled intake and exhaust ports, a high speed multi-stage centrifugal air compressor operated by said engine to supply combustion and scavenging air, to said engine in direct proportion, to the needs of said engine at various engine speeds, and a means to inject fuel into the cylinder of said engine.
13. A Diesel engine of the two-cycle type having tangentially disposed piston controlled intake and exhaust ports, and a multi-stage centrifugal air compressor driven by said engine in a fixed speed ratio to the speed of the engine, except at abnormal torque values caused by inertia, said multi-stage air compressor being connected to the intake ports of said engine to supply a stream of combustion and scavenging air thereto, the volume velocity and pressure of the air stream from said compressor balancing and meeting the needs of the engine including air friction losses at all speeds within the operating range of the engine, the tangentially disposed intake and exhaust ports setting up a helical turbulence of the incoming air, which helical turbulence is maintained during the entire compression stroke of the piston, and means to inject fuel into the air compressed by the piston.
14. A Diesel engine of the two-cycle type, having piston controlled intake and exhaust ports and a multi-stage centrifugal air compressor having its discharge outlet connected to the intake ports of the engine cylinders, said multi-stage centrifugal air compressor comprising a casing, a multi-stage impeller or impellers, rotatably mounted in said casing, said impeller having vanes on each of its stages, the vanes of the first stage being longer than the vanes of the succeeding stages, and a stage diaphragm mounted in the case between each two stages of the compressor.
15. A Diesel engine of the two-cycle type having piston controlled intake and exhaust ports, having a multi-stage centrifugal air compressor as a part thereof, said air compressor having its discharge out-let connected to the intake ports of the engine, said compressor comprising a casing, a multi-stage impeller rotatably mounted in said casing, said impeller having radial vanes on each of its stages, the vanes of the first stage being longer than the vanes of the second stage, a stage diaphragm connected to the casing and extending between the stages of the impeller and means in the compressor casing to remove foreign particles from the air passing through the compressor.
16. A Diesel engine of the two-cycle type, having piston controlled intake and exhaust ports, and having a multi-stage centrifugal air compressor as a part thereof, said compressor having its discharge outlet connected to the intake ports of the engine, said compressor comprising a casing, a multi-stage impeller rotatably mounted in said casing, said impeller having radial vanes on each of its stages, a stage diaphragm connected to the casing and extending between the stages of the impeller, said casing having an opening in its periphery, and an accumulator

vane arranged interiorly in the casing in proximity to the peripheral opening therein to guide foreign particles carried by the air in the compressor to the peripheral opening in the casing.

17. A Diesel engine of the two-cycle type having piston controlled intake and exhaust ports and a multi-stage centrifugal compressor having its discharge outlet connected to the intake ports of the engine, said centrifugal compressor comprising a casing; a multiple stage impeller rotatably mounted in said casing, said impeller having radial vanes on each of its stages, a stage diaphragm connected to the casing and extending between the stages of the impeller, and accumulator pockets arranged interiorly in the casing at the lower portion thereof in line with the impeller stages, there being relatively small openings leading from said pockets through the compressor casing to remove foreign particles from the air within the compressor.

18. A Diesel engine of the two-cycle type having piston controlled intake and exhaust ports, and a multi-stage centrifugal compressor having its discharge outlet connected to the intake ports of the engine, said multi-stage centrifugal compressor comprising a multi-stage impeller rotatably mounted in said casing, said impeller having radial vanes on each of its stages, a staged diaphragm connected to the casing and extending between the stages of the impeller, a driving shaft for said impeller and operatively connected to said engine to be rotated thereby, and a torque limiting friction driving connection between said shaft and the impeller.

19. A Diesel engine of the two-cycle type having piston controlled intake and exhaust ports and a multi-stage centrifugal compressor having its discharge outlet connected to the intake ports of the engine and said multi-stage centrifugal compressor comprising a casing, a multi-stage impeller rotatably mounted in said casing, said impeller having radial vanes on each of its stages, the vanes of its first stage being longer than the vanes of the succeeding stages, and stage diaphragms connected to the casing and extending between the stages of the impeller, each of said diaphragms comprising spaced walls connected by vanes extending from the hub of the diaphragm to a point adjacent its periphery, and the rearward wall of said diaphragm having an annular discharge opening adjacent its hub.

20. A Diesel engine of the two-cycle type having piston controlled intake and exhaust ports and having a multi-stage centrifugal compressor with its discharge outlet connected to the intake ports of the engine, said multi-stage centrifugal compressor comprising a casing, a multi-stage impeller rotatably mounted in said casing, said impeller having radial vanes on each of its stages, the vanes of its first stage being longer than the vanes of the succeeding stages, and stage diaphragms connected to the casing and extending between the stages of the impeller, each of said diaphragms comprising spaced walls connected by vanes extending from the hub of the diaphragm to a point adjacent its periphery, the forward wall of the diaphragm having an inlet opening adjacent its periphery and the rearward wall of said diaphragm having an annular discharge opening adjacent to its hub and means in the compressor casing to remove foreign particles from the air in the compressor.

21. A Diesel engine of the two-cycle type having piston controlled intake and exhaust ports and having a multi-stage centrifugal air com-

pressor with its discharge outlet connected to the intake ports of the engine, said multi-stage centrifugal compressor comprising a casing, a multi-stage impeller rotatably mounted in said casing, said impeller having radial vanes on each of its stages, the vanes of its first stage being longer than the vanes of the succeeding stages; and stage diaphragms connected to the casing and extending between the stages of the impeller, each of said diaphragms comprising spaced walls connected by vanes extending from the hub of the diaphragms to a point adjacent its periphery, the forward wall of the diaphragm having an inlet opening adjacent to its periphery and the rearward wall of said diaphragm having an annular discharge opening adjacent its hub, a driving shaft for said impeller and operatively connected to said engine to be rotated thereby, and a torque limiting friction driving connection between said shaft and the impeller.

22. A Diesel engine of the two-cycle type having piston controlled intake and exhaust ports comprising a crank case, a plurality of cylinders secured to said crank case, pistons in said cylinders being connected to the crank shaft in said crank case, a flywheel arranged at one end of said crank shaft, an air passage extending longitudinally along the upper portion of said crank case, said air passage communicating with the intake ports of the cylinders, a multi-stage centrifugal air compressor having its casing secured to the end of the crank case opposite the flywheel end of the crank case and having its outlet communicating with the air passage in the crank case, a driving connection between the crank shaft and multi-stage centrifugal compressor, and means to inject fuel into the engine cylinders, the intake and exhaust ports of said cylinders being tangentially disposed with respect to the cylinders whereby the incoming air will set up spiral turbulence within the cylinders which will be maintained during the compression stroke of the pistons.

23. A Diesel engine having operatively connected together any number of power generating cylinders, and an internal air furnishing multi-stage centrifugal air compressor, said compressor being adapted to furnish at all engine speeds, sufficient air both in volume and pressure to enable the engine to accelerate rapidly, said air being furnished in a stream the velocity of which is almost instantaneously convertible to pressure at high efficiency, said cylinders having ports arranged and stream-lined to accomplish conversion from air speed to air pressure and vice versa at an efficiency of about eighty per cent.

24. A Diesel engine having operatively connected together any number of power generating cylinders, and a scavenging plus combustion air furnishing multi-stage centrifugal compressor, said compressor being adapted to furnish at any engine speed sufficient air to enable the engine to accelerate rapidly, said air being furnished in a stream the velocity of which is directly convertible into pressure at high efficiency, said cylinder having intake ports tangentially disposed to diffuse the air into a hollow helical cylinder of air within the combustion cylinder bore the center of said helical cylinder of air forcing the spent gases of combustion to and through exhaust ports which are tangentially disposed in a cumulative direction, the structure thereby utilizing the high velocity of the exhaust gases to accelerate the air and exhaust gas streams.

25. A Diesel two-cycle engine comprising a

combustion section and an air supplying section, said combustion section comprising a plurality of cylinders having tangentially arranged upwardly inclined inlet ports and stream-lined cumulative-ly arranged exhaust ports, said air supplying section comprising a centrifugal multi-stage compressor, means for positively driving said compressor except at abnormal torque values, whereby in consequence of the characteristics of said compressor and ports, the air-using capacity of the engine and the air-furnishing capacity of the compressor approximately parallel each other as the speed of the engine increases, the diversity between the two being such that air-furnishing capacity is slightly in excess at the higher speed ranges.

26. A two-cycle Diesel engine comprising a plurality of combustion cylinders arranged in line, a crank shaft, a multi-stage centrifugal air compressor mounted upon one end of said crank shaft, a gearset and a friction controlled torque limiting device, the impeller of said compressor being driven thereby, a crankcase, an inlet air manifold extending through said crankcase and adapted to receive and conduct an air stream from said centrifugal compressor and a plurality of air intake ports, one for each cylinder extending upward into each cylinder at such angle as to point to the upper end of cylinder bore and also tangentially disposed to diffuse the air into a hollow helical cylinder bore, the incoming air displacing the exhaust gases as the wall thickness of the hollow helical cylinder of air increases the exhaust gases are thereby forced down to and through the exhaust ports which are tangentially disposed in a cumulative direction, the structure thereby utilizing the high velocity of both the incoming air stream and the higher velocity of the exhaust gases, to change the contents of the combustion cylinder from spent gases to approximately pure air at over atmospheric pressure in a minimum time element.

27. A two-cycle Diesel engine comprising a plurality of combustion cylinders arranged in line, a crank case under said cylinders, said crank case having as a part thereof a housing for the front-end accessory drive, a crank shaft, the forward end of which carries a gearset at the forward line of front end drive housing, a multi-stage impeller as the rotor of a centrifugal air compressor, mounted on an extension of said gearset, an outwardly cylindrical casing fitting over said impeller, and fastened to the cover of front end drive housing, an inlet air manifold extending through said crank case along said cylinders to communicate with said compressor, and one inlet port for each cylinder, extending upwardly at such an angle as to point to the upper end and opposite side of said cylinder, and also tangentially disposed to diffuse the air into a hollow helical cylinder of air within the combustion cylinder bore the incoming air displacing the exhaust gases with a cyclonic revolution of the cylinder contents, the exhaust gases being thereby forced down to and through the exhaust ports, which are tangentially disposed in a cumulative direction, the entire structure thereby utilizing the velocity of both the incoming air stream and the higher velocity of the exhaust gases, to change the contents of the combustion cylinder from spent gases to pure air at any predetermined pressure over atmospheric pressure, in a minimum time element, and with a minimum of mixing pure air and exhaust gases.

28. A balanced combination in which air furnishing capacity keeps step with air using capac-

ity at all speeds, comprising a two-cycle, multi-cylinder Diesel engine, a crank case therefor, and a multi-stage centrifugal air compressor driven by the crank shaft of said engine, an inlet manifold within the crank case connecting said compressor and the inlet ports of said engine to conduct internal air therinto, said inlet ports being disposed tangentially to the cylinder and pointing upward to swirl the inlet air upwardly and in a spiral as great as the internal cylinder diameter, outlet ports in said cylinders stream-lined in relation to said inlet ports to empty said cylinder of gas in the shortest possible time.

29. The method of operating a two-cycle Diesel internal combustion engine which comprises supplying thereto internal air for scavenging and combustion in such volume and at such pressure, so that there is a definite slight excess of air always available for acceleration of the engine, said excess values growing gradually greater as the engine speed increases.

30. A Diesel engine comprising a multistage centrifugal air compressor and a two-cycle displacement combustion section and means for said air compressor, to supply combustion—plus scavenging air to the engine, in fixed relation to its capacity at all speeds to use said air and means to drive the centrifugal air compressor positively, except at abnormal torque values caused by inertia, and tangential air inlet ports in said engine arranged for maximum scavenging effect while using a minimum excess air volume.

31. A Diesel engine comprising a multi-stage centrifugal air compressor arranged to supply internal air into the engine, means for positively driving the air compressor, said means being adapted to limit abnormal torque values, means to supply air in the same volume ratio and at a constantly increasing pressure ratio during acceleration and adapted to develop a pressure ratio to engine speed such that the air pressure, within the cylinder, at the time when the piston is just closing the exhaust port, is at a constant value at all points in the operating range of the engine.

32. A Diesel engine comprising a multi-stage centrifugal air compressor, and a two-cycle displacement combustion section, said air compressor being arranged to supply internal air to the engine, means to positively drive the compressor except at abnormal torque values, means including a torque limiting device for operatively connecting said compressor to said combustion section, a plurality of rotary impellers within said compressor section, each impeller capable of supplying the total volume of air required, and each impeller capable of supplying its proportional fraction of the total head of air required, the capacity of said compressor section, in both volume and head, being such as to keep step with the capacity of the combustion section to use said air efficiently.

33. A Diesel engine comprising a multi-stage centrifugal air compressor section and a two-cycle displacement combustion section, said air compressor section being arranged to supply internal air to the combustion section, means for positively driving the compressor section, except at abnormal torque values, means by which said combustion section volume constantly equals the volume of the compressor discharge, said means also providing a pressure increase within the compressor having a constantly increasing excess over the friction loss caused by air stream velocity, within the engine at all points in the

acceleration range at which the compressor is positively driven, the equality between volumes being measured at the same temperature and pressure.

5 34. A Diesel engine comprising a multi-stage centrifugal air compressor section and a two cycle displacement combustion section, said air compressor section being arranged to supply internal air to the combustion section, a torque

limiting device connecting the two operatively and constituting a positive drive except at abnormal torque values, means to maintain an air volume increasing in direct ratio and an air pressure increasing in a much larger ratio, as engine speed increases, even during the times when the torque limiting device may act to limit the torque applied to the compressor section.

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