April 30, 1935. J. PAVLECKA 1,999,374

INTERNAL COMBUSTION ENGINE

Filed July 1, 1931 2 Sheets-Sheet 1

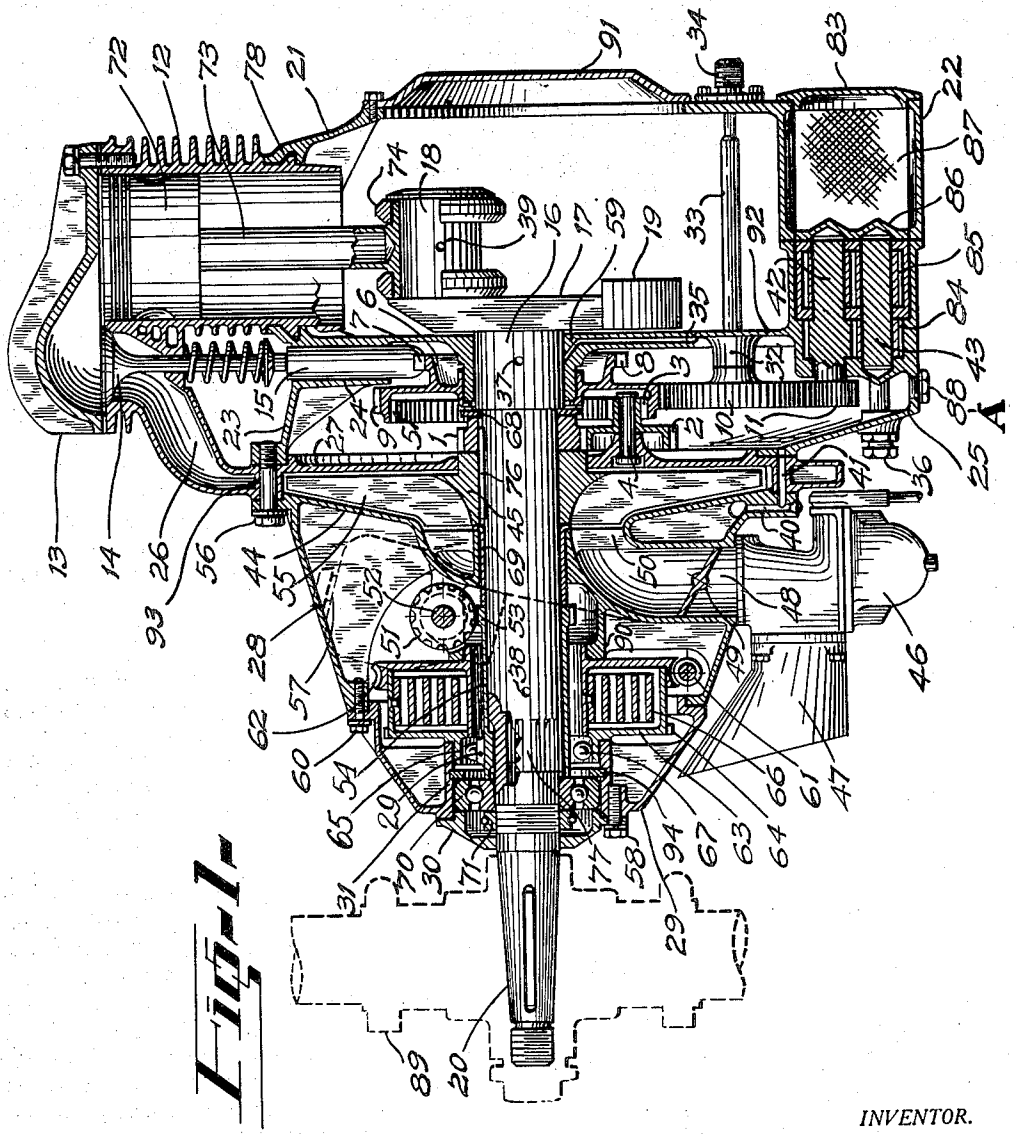

Fig. 1.

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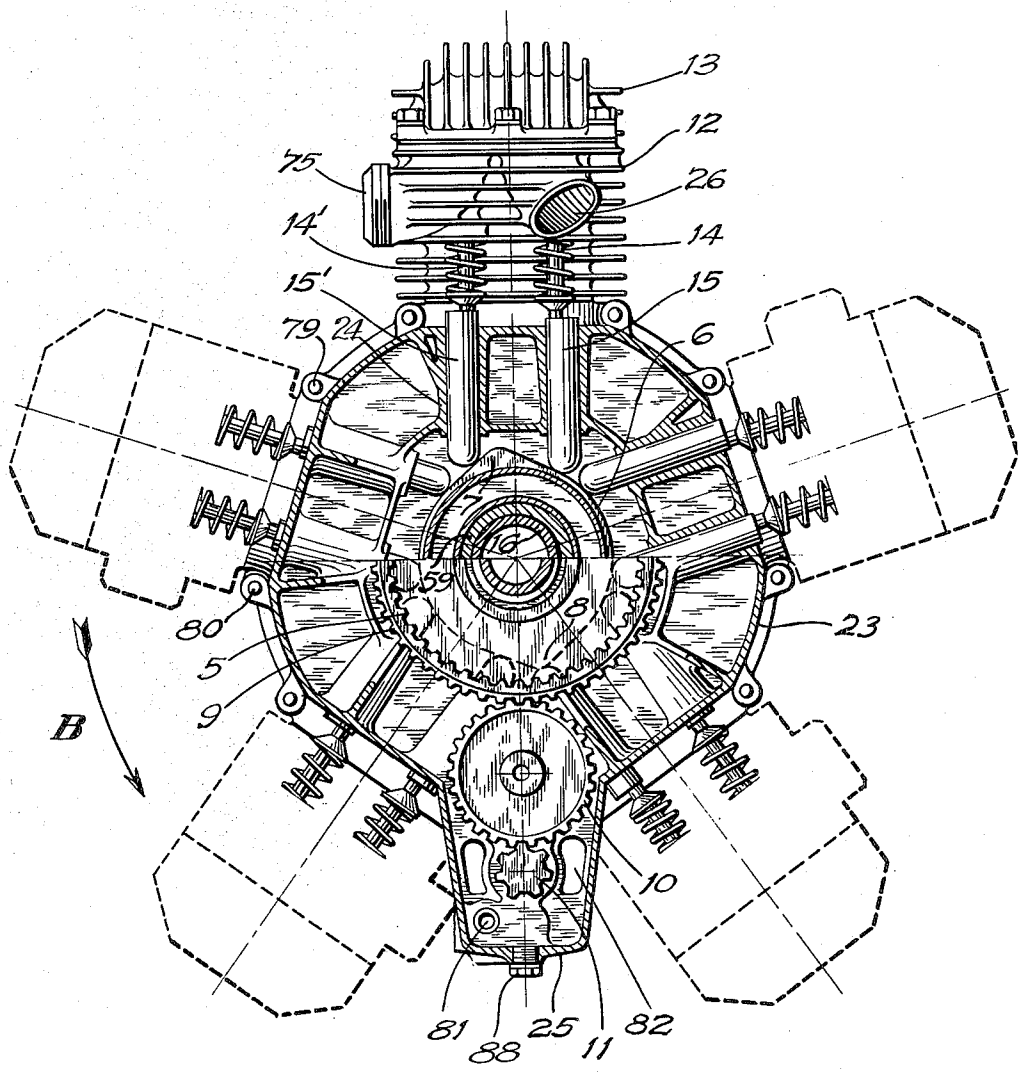
Fig-2-



INVENTOR.

Jan Pavlecka

Patented Apr. 30, 1935 1,999,374

UNITED STATES PATENT OFFICE

1,999,374

INTERNAL COMBUSTION ENGINE

Jan Pavlecka, Detroit, Mich.

Application July 1, 1931, Serial No. 546,127

9 Claims. (Cl. 123—55)

My present invention relates more particularly to an improved radial engine for aircraft.

The principal object of my invention is an engine conceived primarily with regard to the function thereof as a part of an airplane, viz., one so compact as to offer the least resistance in flight.

A further object is to provide a radial engine for aircraft which will afford utmost ease in assembling and accessibility in service.

An important object of my invention is to devise an engine which will embody a starter and an induction impeller in a practical way and thus insure safety and convenience in starting and high efficiency in operation.

These and other objects and aims hitherto not materialized are afforded by my engine which, though operating on but established principles of mechanics and thermodynamics is inherently suitable for aircraft propulsion by virtue of its structural configuration.

Although the all-round advantages of the radial engine for aircraft have been recognized, it is well known that this type, when installed in an airplane, is inferior to the "in-line" engine in the matter of air resistance. In order to eliminate this basic drawback of the radial engine I have resorted to a new arrangement of the engine units, characterized mainly in that all the auxiliary units and all the accessories are disposed between the engine cylinders and the propeller, which is distinctly unanalogous, if not altogether contrary to the generally known and adopted practice of locating the cylinders directly adjacent the propeller. Due to the grouping of the engine units in the aforementioned new order the engine cylinders will be distanced from the nose of the aircraft body into a portion thereof having a diameter so large that the cylinders will be completely or at least from the largest extent enclosed within the streamline contour of said body. The cooling of an engine so enclosed, if either by air or a liquid, is effected preferably by the internal, forced and controllable system of cooling which forms subject matter of my Letters Patent No. 1,779,186; as disclosed therein, a stream of air is forced or induced into the aircraft body through the forward end thereof by means of a conoidal impeller, the air being directed to and around the engine cylinders in said body, or through a liquid radiator therein, and then discharged behind the engine into the slipstream.

Among the novel features embodied in the engine of my invention and hereinfurther referred to is the induction system which forms subject matter of my Letters Patent No. 1,889,262.

The above is a broad account of the subject matter of my present invention to the exclusion of all detail but nevertheless important and distinct features, all of which will now be described with reference to the drawings accompanying this specification and forming an integral part thereof.

In the drawings,

Fig. 1 represents a longitudinal cross-section through the whole engine and shows clearly the novel grouping of the units therein as well as all other essential features.

Fig. 2 is a transverse cross-section through the engine of Fig. 1 looking in the direction from the propeller to the cylinders; the top portion of this view is taken on the center line of the valve tappets 15 (Fig. 1), while the bottom portion is taken at a point slightly ahead as indicated by the letter A in Fig. 1.

The individual units in the engine represented in Fig. 1 may be identified as either well-known or as disclosed in the Letters Patent 1,889,262 above referred to, all being disposed in relation and in combination to one another and in the whole in a novel and original manner to yield the definite and useful results contemplated.

The engine has a number of cylinders 12 arranged substantially radially on a crankcase which, in this particular embodiment, is shown as made up of two halves 21 and 23. The cylinders 12 comprise each the piston 72 and the connecting rod 73; the head of the cylinders is shown as being, by way of example, detachable, and the valves 14—in case the engine is a four-cycle one—as being on the side of the cylinders, the combustion chamber being of the L type. The crankshaft of the engine consists of the straight shaft portion 16 which extends through the whole engine assembly and terminates, at the driven extremity, with the crank arm 17 and the crank pin 18 to which journalled are the connecting rods 73, and with the propeller boss 20 at the driving extremity. On and around the shaft portion 16 between the cylinders 12 and the propeller boss 20 are disposed all the accessories, gear trains and auxiliary units of the engine in approximately the following sequence: the valve mechanism including the gears 1, 2, 3 and 5, the cam ring 6, the valve tappets 15 and the valves 14; the tachometer drive comprising the gears 9 and 10; the oil pump drive gear 11 and the oil pump which consists of the gears 84 and 85 disposed in pairs on the shafts 42 and 43

in the lowest portion of the engine crankcase adjacent the oil filter 87.

Forwardly of the valve mechanism above introduced is the centrifugal impeller 55, and peripherally around it a plurality of induction ducts 26 connecting to the cylinders 12. The ducts 26 are fashioned preferably after the manner disclosed in my Patent No. 1,889,262 for the induction system above cited, their inlet aperture being, briefly for further reference, relatively narrow but angularly greatly extended around the periphery of the impeller 55 while their exit aperture at the associated cylinders is approximately circular, conforming to the intake valve port, and the passage between said two apertures is characterized by a substantially curvilinear formation proceeding outwardly and angularly toward the associated cylinder in a direction given generally by the resultant of the tangential and the normal velocity components of the discharge from the impeller 12.

Next to the impeller 55 is the riser 48 which communicates between an outside carburetor 46 having an intake funnel 47 thereon, and an annular exit channel embracing the shaft 16 and housing a plurality of guide vanes 50 for imparting the charge with an initial angle of whirl; the admission of the charge is controlled by means of the throttle or choke fly 49 in the riser 48. In case the engine operates on the Diesel principle, then, of course, the carburetor 46 is dispensed with.

Follows a pair of helical gears 53 and 51 representing the accessory drive, the accessories being either a magneto, a distributor, a generator or, in a Diesel engine, the fuel supply pump. The gear 53 is on the shaft 16 while its mate 51 is carried on the transverse shaft 52, to which externally coupled is the magneto, distributor, generator or fuel pump 57.

Adjacent the gears 53 and 51 is the starter which is shown as being preferably of the torsion spring type. The essential elements of the starter include the winding worm 61 in engagement with the worm wheel 62, the torsion spring 66 connected at the inner end thereof to said worm wheel 62 and to the control drum 63 at the outer end. The drum 63 is provided with locking and releasing ratchet teeth 64, and through a clutch of the "over-running" type entrains the shaft 16 for starting the engine by the spring 66; the clutch is shown as being, for instance, of the ball or roller variety, the pellets 67 being inserted between the driving cylinder 65 which is integral with the drum 63, and the cams 54' on the sleeve 54 secured to the shaft 16.

Forwardly of the starter cylinder 65 is the bearing 70 held axially fixed in the cylindrical portion 31 of the end casing 29 as by the snap ring 68 on one side and a shoulder on the end cover 31 on the other. The nut 71 having threaded engagement with the shaft 16 secures the bearing thereon.

The shaft portion 16 of the crankshaft is supported rotatably, as for example, in two bearings, 59 and 70, located at the driven and the driving extremities thereof respectively; overhanging the two bearing supports are the propeller boss 20 fore, and the crank arm 17 aft; the latter carries, diametrically opposite to each other, the crank pin 18 and the counterweight 19. The crank pin 18 has a cantilever relation to the arm 17, there being preferably no arm symmetrical to the arm 17 about the axis of the cylinders 12 and, of course, no counterweight or shaft portion corresponding to the elements 18 and 16 respectively.

The valve mechanism as an essential unit of every four-cycle engine is illustrated in Fig. 2, and in the preferred embodiment is characterized in that the cam ring 6 rotates in the direction opposite to that of the impeller 55, which also implies in the direction opposite to that of the crankshaft since the impeller 55 is, in the embodiment shown, mounted directly thereon. This characteristic of the cam ring being related to the impeller in a definite way as to the direction of rotation, although of no significance per se, has a distinct purpose in the engine of my invention, which purpose when viewed from the usefulness of its results, represents a decided innovation. The effect readily recognizable is that the valves of the engine interchange their function, viz., the one which normally would be the exhaust valve becomes the intake valve, and vice versa; and this is the object apparent of the above disclosed characteristic. Assuming that the engine crankshaft rotates in the direction indicated by the arrow B in Fig. 2, then, for certain reasons revealed presently, it is desirable that the cam ring 6 rotate in the direction opposite to that of the arrow B; in that case the intake valve will be the one marked 14, and the exhaust valve will be 14'. The ulterior purpose and the novelty of the aforementioned feature of the cam ring 6 and the particular disposition of the intake and the exhaust valves will become apparent when reference is taken to the divisional patent for the induction system above cited; the curvilinear course and the angular extent and proportions of the induction ducts 26 as specified in said patent cover a considerable area on the engine cylinders 12 and would normally interfere with the cooling of said cylinders and especially their valves by obstructing the access of air thereto from the forward direction. Now by arranging for the intake valve to occupy that side of the cylinders 12 from which the induction ducts 26 approach the same, the induction ducts will assume the position substantially between two adjacent cylinders rather than in front of them, thus leaving the cylinders themselves entirely or from the most part free for the cooling air to impinge upon. In Fig. 2, the impeller 55 rotating counter-clockwise, the induction ducts 26 will approach the cylinders 12 from the right side, and due to the intake valve being situated on the corresponding side as provided through the aforementioned reversal of rotation of the cam ring 6, will conjoin said cylinders readily without shielding the exhaust valve 14' in particular, and without barring access to both of the valves for servicing. In case separate cams are employed for the intake and the exhaust valves, or in case the impeller rotates in the direction opposite to that of the crankshaft, then, of course, the rotation of the cam ring need necessarily not be opposite to that of the crankshaft in order to achieve the desirable and highly advantageous relation between the induction ducts and the cylinders as above, but these are cases involving mechanical complications which cannot be analyzed individually in connection with the present embodiment which is basic and typical.

The reversal of rotation of the cam ring 6 in the particular and preferred embodiment as illustrated, with respect to the shaft 16 and the impeller 55 thereon is accomplished by means of an internal gear in the cam ring drive. On the

shaft 16, Figs. 1 and 2, is secured, as by means of the key 76, the gear 1 which engages the intermediate gear 2 on the stud 4; the gear 2 is integral with the pinion 3 which meshes with the internal gear 5, the gear 5 propels the cam ring 6 concentrically around the shaft 16 on the bearing 59 in a direction opposite to that of the shaft 16. The cam ring 6 is provided on its circumference with cams or lobes 7 and 8 which actuate the valves 15 and 15' respectively. The tappets 15 and 15' are duly spaced about the ring 6 for correct timing of the valves. The speed of the cam ring 6 and the number of lobes thereon are, necessarily, of a definite order and number respectively for any particular number of cylinders and for a given direction of rotation; with the cam ring rotating opposite to the crankshaft, as is essential for instance in the embodiment illustrated for the particular and peculiar reasons aforementioned, the speed of the cam ring is expressed by the formula

$$s = -\frac{1}{N-1}$$

wherein s represents the speed of the cam ring in proportion to that of the crankshaft, N the number of cylinders on one crank; and the number of lobes will be

$$n = \frac{N-1}{2}$$

Thus in the embodiment illustrated, there being five cylinders, the speed of the cam ring 6 will be ¼ of the crankshaft speed in the opposite direction, and the number of lobes will be 2, evenly spaced.

In the engine of my invention the cam ring drive is utilized with advantage for other useful purposes, to wit, for the tachometer and the oil pump drive, after the following fashion: The internal gear 5 is provided with external teeth 9 which are in mesh with the tachometer drive gear 10 supported rotatably by the boss 32 on the diaphragm 92. The shaft 33 is journalled to the gear 10 and therefrom extends into the engine crankcase and therethrough to the rear thereof whereat it is coupled to the tachometer drive fitting 34. The gear 10 is proportioned with respect to the gear 9 so as to readily provide the usual reduction in speed for tachometers, the standard ratio being one half of the crankshaft speed; in the particular embodiment illustrated, the gear 9 rotates with the cam ring 6 at one quarter of the crankshaft speed, therefore, by making the gear 10 one half its size, the specified speed for the tachometer is readily obtained.

The tachometer gear 10 engages with the oil pump drive gear 11 on the shaft 42; the oil pump is shown as being, in this embodiment, of the customary type comprising the shafts 42 and 43 on which a pair of gears 84 serves for pressure feed of oil into the engine, and another pair of like gears 85 for scavenging oil from the sump 25. Adjacent the oil pump is the chamber 22 which houses the oil filter screen 87. The oil lines are all incorporated in the casings of the engine, there being no exterior connections except those to an oil tank. Of the oil leads the most important one, i. e., the pressure feed conduit 35, into which the gears 84 discharge oil, is carried through the diaphragm 92 from the oil pump directly to the shaft 16 through the bearing 59. The pressure of the oil is controlled by means of the adjustable release valve 36 which regulates the opening 81, Fig. 2, from the pressure conduit 35 into the sump 25.

The impeller 55 is driven from the shaft 16 by means of the same key 76 that drives the gear 1.

The drive for the gear 53 and its mate 51 is, as for example, by means of serrations 77 on the shaft 16; the gear 53 is integral with the spacing sleeve 54 which has at its forward end internal serrations complemental to serrations 77 on the shaft 16. The sleeve 54 has also a plurality of uni-directional cams 54' on its circumference within the starter driving cylinder 65, which cams constitute the engaging means for the spring 66 on the shaft 16 through the instrumentality of the pellets 65. The serrations 77 thus serve the double purpose of rotating the shaft 16 by the spring 66 for starting, and for driving the gears 53 and 51 from said shaft through the sleeve 54.

It will now be observed that all of the aforementioned units are, in their particular and novel disposition in the engine of my invention, housed essentially in four principal casings including the engine crankcase 23, the induction casing 26, the intermediate casing 28, and the end casing 29.

The crankcase, though shown as split transversely on the cylinder center line into two portions 23 and 21 in order to suit a special attachment of the cylinders 12, can equally well be made in one piece if any other attachment is preferred. In this particular case the cylinders 12 are provided with a beveled flange 78 by means of which they are clamped in between the casings 23 and 21 held together by a number of bolts 79, Fig. 2. The diaphragm 92 in the portion 23 serves primarily for supporting the bearing 59 centrally, and secondly, for carrying the valve tappets 15, the tachometer gear 10 and the pressure oil conduit 35; openings 82, Fig. 2, in this diaphragm communicate between the crankcase proper and the oil sump 25 in the portion 23.

The intermediate casing 28 is attached to the crankcase 23 by means of a number of bolts 56 with the induction casing consisting of the ducts 26 and the diaphragm 27 included between the said two former casings. The bolts 56 pass through the ducts 26 in guide vanes 93 disposed therein transversely between the fore and aft walls, the guide vanes thus serving, among other purposes, as spacers between the casings 23 and 28 and as streamlines for the said bolts against their causing turbulence in the impeller discharge. The casing 28 furnishes the diaphragm 44 on the forward side of the impeller 55 corresponding to the diaphragm 27 on the rear side.

The end casing 29 together with the cover 30 is bolted directly onto the casing 28 with the starter winding wheel 62 and the control drum 63 held rotatably in the interior therebetween.

Of the units grouped on and around the crankshaft as presented in the foregoing disclosure certain ones are not absolutely essential for the functioning of the engine and may, therefore, in other embodiments be omitted or substituted by others; this applies particularly to the impeller and the starter, though their inclusion in the original manner as shown can be extended with advantage to even the smallest of engines which it has hitherto been deemed unwarranted because of high weight and structural difficulties. The option of employing either magnetos or a fuel pump or a generator, depending upon the working principle of the engine, has already been specified. The inclusion or the omission of the valve mechanism is similarly subject to the type

of the engine, four-cycle or two-cycle, and furthermore, in a Diesel engine the same mechanism can operate injection pumps for the cylinders instead of or in addition to the valves. The impeller may be geared up instead of being mounted directly on the crankshaft; the starter may be substituted by any other type, or by a reduction gearing for the propeller. Through these alternatives I desire to indicate what departures from the exact embodiment as described are contemplated within the scope of the claims appended herebelow.

I claim:

1. In an engine, a central shaft having a crank at one extremity and a driving boss at the other extremity, bearing means for said shaft adjacent said extremities thereof, a plurality of cylinders with valves, pistons and connecting rods therein disposed substantially radially around said crank, said connecting rods being journalled to said crank, a mechanism for operating said valves, an induction system for said cylinders, an accessory drive with accessories coupled thereto, a starting means for said engine, said valve mechanism, said induction system, said accessory drive and said starting means being arranged consecutively on and about said shaft and between said bearing means thereof whereby said cylinders will be spaced furthest away from said driving boss of said shaft.

2. In an engine, a central shaft having a crank and a driving boss at the opposite extremities thereof, bearing means for said shaft adjacent said extremities thereof, a crankcase housing said crank, a plurality of cylinders with valves, pistons and connecting rods therein disposed substantially radially on said crankcase, said connecting rods being journalled to said crank therein, and a series of casings housing a mechanism for operating said valves, an induction system for said cylinders, an accessory drive, and supporting accessories to said cylinders and said bearing means, all of said casings being arranged adjacent one another ahead of said crankcase and between said extremities of said shaft whereby said cylinders will be spaced furthest away from said driving boss.

3. In an engine, a central shaft having a crank and a driving boss at the opposite extremities thereof, bearing means for said shaft adjacent said extremities thereof, a crankcase housing said crank, a plurality of cylinders with valves, pistons and connecting rods therein disposed substantially radially on said crankcase, said connecting rods being journalled to said crank therein, and a plurality of casings housing a mechanism for operating said valves, an oil pump and a tachometer drive, an induction system for said cylinders, an accessory drive, a means for starting said engine, and supporting accessories to said cylinders and said bearing means, all of said casings being arranged adjacent one another ahead of said crankcase and between said extremities of said shaft whereby said cylinders will be spaced furthest away from said driving boss of said shaft.

4. In an engine, a central shaft having a crank and a driving boss at the opposite extremities thereof, bearing means for said shaft adjacent said extremities thereof, a crankcase housing said crank, a plurality of cylinders with valves, pistons and connecting rods therein disposed substantially radially on said crankcase, said connecting rods being journalled to said crank therein, a casing integral with said crankcase on the side toward said driving boss, said casing housing mechanism for operating said valves, a further casing adjacent said latter casing housing an impeller and comprising a series of induction ducts extending outwardly to said cylinders, an intermediate casing adjacent said impeller casing enclosing a riser to said impeller and an accessory drive with accessories coupled thereto, an end casing adjacent said intermediate casing, said bearing means for said shaft being disposed in said valve mechanism casing and in said end casing with all of said units therebetween whereby said cylinders will be spaced furthest away from said driving boss of said shaft.

5. In an engine, a central shaft having a crank and a driving boss at the opposite extremities thereof, bearing means for said shaft adjacent said extremities thereof, a crankcase housing said crank, a plurality of cylinders with valves, pistons and connecting rods therein disposed substantially radially on said crankcase, said connecting rods being journalled to said crank, said crankcase comprising a tachometer drive shaft extending through the fore and aft walls thereof, and an oil pump and an oil filter in the lowest portion thereof; a casing integral with said crankcase on the side toward said driving boss, said casing enclosing a mechanism for operating said valves, for driving said tachometer shaft and said oil pump in said crankcase, a casing adjacent said latter casing housing an impeller and comprising a plurality of ducts extending outwardly to said cylinders, an intermediate casing providing the forward diaphragm for said impeller and a riser thereto and housing an accessory drive with accessories coupled thereto, an end casing secured onto said intermediate casing and supporting a starting means for said engine in conjunction therewith, said bearing means for said shaft being disposed in said valve mechanism casing and in said end casing with all of said units disposed therebetween whereby said cylinders will be spaced furthest away from said driving boss of said shaft.

6. In an engine, a crankcase, a plurality of cylinders disposed on said crankcase, a series of casings housing units auxiliary to said cylinder arranged consecutively ahead of said crankcase, a crankshaft extending centrally through said casings, and bearing means for said crankshaft therein; a mechanism in the casing next adjacent said crankcase comprising a gear train and a spur gear concentric with said crankshaft; a shaft extending between and through the fore and aft walls of said crankcase, a tachometer drive fitting secured to said shaft externally, and a gear journalled to said shaft in said casing next adjacent said crankcase, said gear being in mesh with said spur gear therein for driving said tachometer shaft; an oil pump in said crankcase, a shaft extending from said pump into said casing next adjacent said crankcase, and a pinion on said shaft, said pinion engaging said tachometer shaft drive gear.

7. In an engine, a crankcase, a plurality of cylinders disposed substantially radially on said crankcase, intakes vales in said cylinders, a series of casings housing units auxiliary to said cylinders, said casings being arranged consecutively ahead of said crankcase, a crankshaft extending centrally through said casings, an impeller driven from said crankshaft in one of said casings, and a plurality of induction ducts extending from said impeller casing outwardly and angularly to said valves in the direction of ro-

tation of said impeller; a cam ring concentric with said crankshaft in another one of said casings, and means for positively actuating said valves from said cam ring; said cam ring being geared to said crankshaft in such a manner as to have a direction of rotation with respect to said impeller whereby said intake valves will be located on that side of said cylinders from which the said induction ducts approach the same.

8. In an engine, a crankcase, a plurality of cylinders disposed substantially radially on said crankcase, intake and exhaust valves in said cylinders, a series of casings housing units auxiliary to said cylinders, said casings being arranged consecutively ahead of said crankcase, a crankshaft extending centrally through said casings, an impeller driven from said crankshaft in one of said casings, and induction ducts extending from said impeller casing to said intake valves in said cylinders, said ducts following angularly courses concurrent with the direction of rotation of said impeller; a cam ring concentric with said crankshaft in another one of said casings, and means for positively actuating said intake and said exhaust valves from said cam ring; said cam ring being geared to said crankshaft in such a manner as to have a direction of rotation opposite to that of said impeller whereby said intake valves will be located on that side of said cylinders from which the said induction ducts approach angularly the same.

9. In an engine, a crankcase, a plurality of cylinders disposed substantially radially on said crankcase, intake and exhaust valves in said cylinders, a series of casings housing units auxiliary to said cylinders, said units being arranged consecutively ahead of said crankcase, a crankshaft extending centrally through said casings, an impeller mounted on said crankshaft in one of said casings, and induction ducts extending from said impeller casing to said intake valves in said cylinders, said ducts following angularly courses concurrent with the direction of rotation of said impeller and said crankshaft; a cam ring concentric with said crankshaft in another one of said casings, and means for positively actuating said intake and said exhaust valves from said cam ring; said cam ring being geared to said crankshaft in such a manner as to have a direction of rotation opposite to that of said impeller thereon whereby said intake valves will be located on that side of the said cylinders from which the said induction ducts approach angularly the same.

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