ABSTRACT

Engine apparatus operative to convert the chemical energy of a combustible fuel into mechanical energy, and useful both in propelling automotive vehicles and in other environments in which conventional internal combustion engines have utility. The engine apparatus is divided into three operational phases or modules which are generally independent of each other, thereby permitting improvement in overall engine performance both as respects efficiency or power delivery and as respects more complete combustion of fuel and less noxious exhaust emissions. The operational phases include a compression phase in which atmospheric air is compressed; a storage phase in which the compressed fluids are held captive for subsequent use; and a utilization phase in which the compressed fluids (air and fuel at this point) are ignited to produce combustion gases that are then used in application to a turbine wheel or torque ring to produce output torque.
THREE-PHASE ENGINE APPARATUS

This invention relates to engine apparatus and, more particularly, to three-phase engine apparatus operative to convert the chemical energy of a combustible fuel into mechanical energy and present the same as output torque. Engine apparatus embodying the invention has utility in a great number of environments including essentially all of the environments in which conventional gasoline- and diesel-type internal combustion engines are used — to propel automotive vehicles, for example.

Manufacture, use, and sale of internal combustion engines constitutes a vast industry which currently is undergoing critical survey because of the smog-causing pollutants present in the exhaust emissions of such engines, and also because of the accelerating depletion of the petroleum resources caused by the high fuel consumption of the engines now in use. The present invention is an improvement over conventional engines of this general type, and it represents a sharp departure from the structural and functional characteristics of the conventional engine, having as its foundation the realization that certain of the operations of the standard engine which are now effected in an essentially concurrent manner, or as a continuous function in contradistinction to a discontinuous function, can in fact be segregated and divided into substantially independent operations or phases, thereby materially improving overall engine performance and efficiency so that less fuel will be required per output horsepower delivered, and less noxious emissions will be present in the engine exhaust because of a more complete combustion of the fuel consumed thereby.

Such segregation of engine operations includes first an independent phase in which atmospheric air is compressed either with or without a charge of fuel admixed therewith depending upon the particular embodiment of the engine apparatus and use intended therefor. Following the compression phase is a storage phase in which the compressed fluids are held or retained in a captive state, such as in a manifold or other retainer, for subsequent use which may follow the compression phase very immediately in point of time or may be remote therefrom either in time or in point of use. Finally, the storage phase is followed by a utilization phase in which the compressed fluids which at this time will constitute a combustible admixture of air and fuel (fuel being added if not forming a part of the initially-compressed charge) are ignited to produce combustion gases that are then used in application to a turbine wheel or torque ring (or other utilization means) forming a part of the utilization phase. The resultant torque thereby developed in the turbine is used to drive equipment associated with the engine apparatus as, for example, to propel an automotive vehicle in which the engine is mounted.

Since the compression, storage, and utilization phases of the operational cycle are differentiated and segregated one from another, the engine apparatus lends itself to refined control over the various phases thereof, thereby maximizing the operational efficiency of the engine. In this respect, the periodicity of the compression phase need not be related to combustion in rigidly enforced synchronism therewith, as is the case in conventional engines, so that each combustion cycle can be maintained for any period desired, thereby enabling more complete combustion to be obtained. In this same reference, combustion can be maintained in a generally constant-volume chamber, thereby obviating the enforced cooling that necessarily occurs in the progressively increasing volume of the usual combustion cylinder, which also improves combustion.

Further, after compression of atmospheric air in the compression phase, it can be stored or held captive for any length of time desired and until required for combustion. Therefore, the rate of combustion can be made independent of the compression phase which permits the rate of combustion to be directly related to power demand which avoids fuel waste. Also, since compression and combustion are segregated phases not conducted in the same chamber, the piston-crankshaft-bearing assemblage of a reciprocating engine-compressor need not be sufficiently massive to withstand the explosive forces resulting from ignition of a combustible admixture of fuel and air in a confined piston-cylinder space, as in the ordinary internal combustion engine. Accordingly, a relatively small, lightweight engine apparatus can be provided.

Although it is usually advantageous to have the combustion chamber and utilization phase of the apparatus quite proximate to reduce heat, friction, and other energy losses, the compressed air charges developed in the compression phase can be stored remotely from the compressor. In diesel engine apparatus, however, proximity both in time and distance is beneficial to prevent heat losses which would make function of a diesel cycle tenous.

The provision of engine apparatus having the advantageous features discussed constitutes an object of this invention; and further objects, among others, are to provide: small, compact, simple and inexpensive engine apparatus having few moving parts; which engine apparatus is compatible with the transmission and speed reduction ratios of conventional automotive vehicles; which can reverse the direction of its torque development quickly and at any time so as to permit application of a positive engine-breaking force to rapidly stop the motion of a vehicle having the engine mounted therein; which is especially suited to produce relatively high torque or power output at low RPM, but can be made to deliver a high RPM low torque output; which can provide a great variety of velocity (RPM) differentials among the operational phases thereof (compressor and turbine, for example); and which can deliver full output power at all times.

Additional objects and advantages of the invention, especially as concerns particular features and characteristics thereof will become apparent as the specification continues.

An embodiment of the invention is illustrated in the accompanying drawings, in which:

FIG. 1 is a transverse sectional view of engine apparatus embodying the invention, the view being taken generally along the line 1—1 of FIG. 2;

FIG. 2 is an axial sectional view of the engine apparatus;

FIG. 3 is a broken transverse sectional view taken generally along the line 3—3 of FIG. 5;

FIG. 4 is an enlarged, broken transverse sectional view taken generally through the center of the piston-cylinder structure shown in FIG. 3;

FIG. 5 is a transverse sectional view of the engine apparatus taken along the line 5—5 of FIG. 2; and
FIG. 6 is essentially a transverse sectional view taken through the turbine section of the apparatus but showing only one of the piston-cylinder structures thereof which is illustrated in association with the ejection nozzle through which exhaust gases are directed toward impingement with the turbine wheel.

Engine apparatus constructed in accordance with the present invention is operative to convert the chemical energy present in fuel consumed by the engine into mechanical energy which appears in the form of output torque. The engine apparatus is divisible for purposes hereof into a plurality of separate components or sections which either may be separated from each other or integrated into a composite or unitary mechanical structure, as in the case of the embodiment of the invention illustrated in the drawings. Considering such embodiment in particular together with the separate components thereof, the engine apparatus in its entirety is denoted with the numeral 10, and the components comprising the same include a compressor mechanism or module 11, a storage mechanism or module 12 (see FIG. 4) physically embodied within the compressor mechanism 11 in the form of the apparatus being considered, and a turbine mechanism or module 13.

In the compressor module 11, an admixture of fuel and air is compressed to an elevated pressure which ordinarily implies an elevated temperature unless heat is extracted to force the compression toward an isothermal cycle. In the storage module 12, the compressed admixture of fuel and air is maintained in a captive state for subsequent use with substantially no diminution in pressure, although temperature will decrease with time and at a rate determined by the insulating quality of the storage mechanism. The period of captivity is very brief in the engine apparatus illustrated, and while confined within the storage mechanism, the captive charge is ignited to expand the same. The expanded gases are utilized in the turbine module 13 to energize rotation of certain of the engine components, thereby developing output torque.

Prior to describing the modules 11, 12, and 13 in detail it may be helpful to observe, as shown best in FIG. 2, that the apparatus 10 includes an outer casing 14 constituted of separable sections 15 and 16 each of which has a substantially cylindrical side wall terminating at its inner end in a laterally extending flange, which flanges are respectively denoted with the numerals 17 and 18. The flanges 17 and 18 are axially spaced and sandwich the turbine mechanism 13 therebetween to which the casing sections are rigidly secured by a plurality of fasteners 19 extending therethrough. The fasteners 19 may take any conventional form as, for example, the nut and bolt structures illustrated. The turbine mechanism 13 includes a plurality of fins 20 which are substantially coextensive in radial dimension with flanges 17 and 18, and such fins are used to dissipate heat transmitted to the turbine module as a consequence of the elevated temperature of the combustion gases directed thereinto, as described in detail hereinafter.

The casing sections 15 and 16 are respectively equipped with end closures 20 and 21 so that a substantially closed chamber 22 is defined within the composite casing 14. Extending axially through the chamber 22 and projecting beyond the casing end walls 20 and 21 is an output shaft 23 which, in the particular apparatus being considered, is journaled for rotation relative to the casing upon bearing structures 24 and 25. The bearing structures 24 and 25 are completely conventional and, for example, may be ordinary ball bearing assemblies as illustrated. The bearing structure 24 is seated within a cavity or recess 26 provided for this purpose within a support 27 which has a laterally extending flange rigidly secured to the casing end wall 20 by a plurality of cap screws 28. The support 27 has a central boss or collar 29 that extends inwardly from the casing wall 20 into the interior of the chamber 22 and is coaxially circumjacent the shaft 23 with sufficient clearance therebetween to permit free rotation thereof.

As shown in FIG. 2, the bearing structure 25 seats within a cavity or recess 30 provided therefor in a support 31 having an outwardly extending flange rigidly affixed to the end wall 21 of the casing 14 by a plurality of cap screws 32. Adjacent the end wall 21 of the casing exteriorly of the chamber 22 provided therewithin, the output shaft 23 may be equipped with a flywheel 33 which serves the usual function of maintaining the angular momentum of the output shaft 23 relatively uniform irrespective of the transmission thereto of discontinuous power impulses. The flywheel 33 is constrained on the shaft 23 so as to rotate therewith by wedge-shaped key structure 34 upon which the flywheel is tightened by a nut 35 that engages the threaded end portion of the shaft. It will be appreciated that the output shaft 23 is adapted to be connected to a utilization device which, in the case of an automotive vehicle, will be the running gear thereof via the usual transmission and/or clutch assembly.

The compressor module 11 in the particular form shown constitutes a reciprocal piston-cylinder compressor in which each charge admitted into the cylinder is compressed toward a closed end portion thereof by displacement of a reciprocable piston toward such end of the cylinder. However, other forms of compressors may be used, and multiple compression stages also may be employed should this be desirable. Further, the particular apparatus being considered has two diametrically disposed piston-cylinder structures to provide dynamic balance since the entire compressor module 11 is rotatably driven. As respects the present invention, any number of piston-cylinder structures may be employed, and for purposes of maintaining dynamic balance, it will be apparent that whatever particular number is used, they should be symmetrically disposed relative to the axis of rotation of the module.

The compressor module 11 includes as a part thereof a radially disposed support plate 36 mounted within the casing chamber 22 and also within the interior of the turbine mechanism 13 substantially coincident with one of the radial faces thereof, as is most evident in FIG. 2. The mounting plate 36 is a substantially planar element, and it is constrained upon the shaft 23 so as to rotate therewith. Any suitable and conventional means may be employed to secure the plate 36 to the shaft 23 so as to prevent relative rotation therewith (keying, for example), but in the engine being considered, the plate 36 is fixedly secured by a plurality of cap screws 37 to a mounting annulus 38 that is positioned upon the shaft 23 with a press fit so as to prevent relative rotation therebetween. Accordingly, the mounting plate 36 necessarily rotates in unison with the shaft 23.
Bolted or otherwise rigidly secured to the mounting plate 36 at diametrically spaced locations therealong are a pair of cylinders 39 that are substantially identical and are therefore denoted with the same numeral except that the suffixes "a" and "b" are added for purposes of differentiation therebetween. In this same manner, the various elements functionally and structurally associated with the cylinders 39 will be denoted with the same numerals with differentiation therebetween being provided by use of the letter suffixes "a" and "b" wherever appropriate. Correspondingly, for purposes of simplifying the description only one of the cylinder components will be described in detail, it being understood that such description applies equally to the opposite cylinder arrangement. For purposes of specificity, the cylinder 39a will be described with particular reference being made to FIGS. 3 and 4; however, the letter suffixes will be omitted except where helpful to the description.

The cylinder 39 is seen to be radially disposed with respect to the axis of rotation of the shaft 23, and it projects in an axial direction partly through an opening or cut out portion provided for this purpose in the plate 36 to which it is fixedly secured by any appropriate means such as bolting. The cylinder 39 defines a cylinder space or chamber 40 therewithin closed at its outer end with an end closure or end wall 41. Mounted for reciprocable displacements within the cylinder space 40 is a piston 42 having radially spaced end portions 43 and 44 respectively equipped with sealing rings 45 and 46 that slidably and sealingly engage the circumjacent walls of the cylinder 39. Intermediate the ends 43 and 44, the piston 42 is restricted in diameter so as to define an annulus or annular space 47 with the circumjacent walls of the cylinder 39. Accordingly, as the piston 42 is reciprocated within the cylinder space 40, the annular space 47 moves with the piston 42 between the opposite extreme positions thereof. As will become more apparent hereinafter, the annular space 47 constitutes a part of the storage mechanism which receives a compressed admixture of fuel and air from the compressor mechanism so as to hold or retain such admixture captive for subsequent use.

The variable-volume space defined between the end portion 43 of the piston 42 and end wall 41 of the cylinder 39 constitutes the space within which compression of fuel and air is effected. Accordingly, inlet means are necessarily associated with the closed end of the cylinder space 40 to permit air and fuel to be admitted thereto. In the form of engine apparatus being considered, fuel and air are admitted together having been mixed in a carburetor (not shown) although such arrangement is not necessary and a fuel injection system can be employed in which fuel is directly inserted into the cylinder space independently of the combustion air. Further, it is also quite feasible to inject fuel into a compressed charge of air after the charge has been removed from the compression chamber and is held captive in the storage mechanism. The particular arrangement selected in any embodiment of the engine apparatus will depend upon the type of fuel employed, the environment in which the apparatus is to be used, and other extraneous parameters, all of which may influence and control the particular engine design.

In the engine apparatus 10, a large opening 48 is provided in the wall of the cylinder 39 adjacent the end closure 41 thereof, and such opening serves both as an inlet into the cylinder space and as an exit through which a compressed charge is transferred from the compression space into the annulus 47. In communication with the opening 48 is a flow passage 49 formed in a spacer 50 welded or otherwise rigidly secured to the outer wall of the cylinder 39. Fixedly secured to the spacer 50 by cap screws 51, or other suitable means, is an intake manifold 52 having adjacent each cylinder 39 a flow passage 53 that communicates with the associated passage 49 through an intake port 54. The port 54 is opened and closed by a valve 55 which can be a mechanically actuated valve, but in the form shown is a pressure-responsive valve supported adjacent its inner end for pivotal displacements about a pin or axis 56 ordinarily biased toward the closed position thereof illustrated in FIG. 4 by the centrifugal force operative thereon whenever the engine is in operation.

The intake manifold 52 further includes an annular manifold chamber 58 defined in part by a ring 59 which is somewhat U-shaped in transverse section (as shown best in FIGS. 3 and 4) and in part by a cylindrical surface portion 60 of the aforementioned support structure 27 and 61 and 62 which slidingly engage the surface portion 60. In more particular terms, the ring 59 is welded or otherwise rigidly attached to the portion of the manifold defining the passage 53 therein so that the ring is rigidly related to the cylinder 39 and mounting plate 36 so as to rotate therewith, as described in detail hereinafter. The ring 59 provides a port 63 communicating with the passage 53 so as to permit fuel and air present in the manifold chamber 58 to enter the passage 53. The sealing rings 61 and 62 may take any conventional form such as resilient ring-shaped annuli respectively secured to the side walls of the ring 59 by adhesives. The sealing members 61 and 62 at their inner edges ride upon and sealingly engage the cylindrical surface portion 60 so as to substantially close the manifold chamber 58 and confine the air and fuel admixture therewithin.

In open communication with the manifold chamber 58 so as to supply the same with a fuel and air admixture is an intake passage 64 of L-shaped configuration (see FIG. 3) which is formed in the support structure 27, terminating at one end in the manifold chamber 58 and at its other end in open communication with the discharge or outlet conduit 65 of a conventional carburetor which, as indicated hereinbefore, is not shown. As respects the present invention, any conventional carburetor may be employed which combines fuel and air to form a combustible admixture thereof which is then drawn into the manifold chamber 58 for subsequent compression within the cylinders 39.

Each of the pistons 42 has a conventional hollow configuration, as shown most clearly in FIG. 1, and extending across its skirt at the inner open end thereof is a wrist pin 66 providing a pivotal connection for a crank in the form of a ring or annulus 67 having at one position therealong a lobe 68 establishing the pivotal connection thereof with the wrist pin, The ring 67 is coaxially circumjacent a crank disc 69 which passes the shaft 23 therethrough but is offset or eccentrically disposed.
with respect to the axis of rotation thereof, as is clear in FIG. 1. Sufficient clearance is afforded to provide free rotation of the shaft 23 relative to the crank disc 69, the latter of which is constrained against rotation by being fixedly related to the aforementioned support structure 27 by a plurality of cap screws 70 (see FIG. 3) which respectively pass through openings 71 provided therefor in the crank disc and are threadedly received within aligned openings in the support structure.

The piston-cylinder structures 39, 42 are diametrically disposed with respect to the shaft 23 and axis of rotation thereof for purposes of dynamic balance, and since the mounting plate 36 is fixed to the shaft 23 so as to rotate therewith, it will be apparent that the piston-cylinder structures revolve about the axis of the shaft 23 and also revolve about the axis of the crank disc 69, which axis thereof is offset from the axis of the shaft 23. Accordingly, the rotational displacements of the rings 67 about the crank disc 69 upon which they are mounted for relative rotation with respect thereto causes the pistons 42 to be repetitively reciprocated between the opposite ends of the respectively associated cylinders 39 between the inner most position illustrated by the piston 42a in FIG. 1 and the outer most position shown by the piston 42b in the same figure. Inspection of FIG. 1 makes it evident that complete displacement from one extreme position to the other of the pistons 42 is effected in an arcuate distance of 180° so that one complete reciprocation of each piston is completed for each 360° rotation of the mounting plate 36 and cylinders 39 carried thereby. In order to accommodate the requisite degree of displacement of each cylinder 39 with respect to the ring 67 associated therewith, each cylinder at its inner end is provided with aligned slots 72 and 73 of sufficient radial depth and axial thickness to pass the crank rings therethrough, as shown in FIGS. 1 and 2. In this same reference, the slots 72 and 73 are sufficiently wide to accommodate the composite axial thickness of the rings 67a and 67b because such rings are offset or enlarged throughout the lobes 68 thereof to enable the pistons 42 to be disposed in precise diametral alignment. The slotted configuration of the cylinders 39 is a dimensioned characteristic of the particular engine model being discussed, and need not be present in other models.

Considering FIGS. 4, 5, and 6, it will be noted that each cylinder 39 adjacent the inner end thereof is provided with an outlet or exhaust port 74, and connected therewith is one end of an exhaust tube 75 which at its opposite end communicates with nozzle structure 76 through which gases are discharged into the turbine module 13 so as to energize the engine apparatus. As explained subsequently, a compressed charge of fuel and air is present within the annulus 47 during certain predetermined phases in the cyclic displacement of the piston 42, and means are provided for igniting such charge after which the products of combustion are expelled through the exhaust port 74 and conduit 75 connected therewith. In the engine apparatus 10, combustion is initiated by an ignitor 77 which may be a conventional automobile spark plug extending through an opening provided therefor in the wall of the cylinder 39 so as to communicate with the annulus 47. Accordingly, the ignitor 77 is disposed intermediate the ends of the cylinder 39 and, more particularly, intermediate the opening 48 and exhaust port 74.

In the composition of the engine apparatus 10, the storage module 12 although functionally distinct from the compression module 11 is intimately related thereto in structural terms, thereby making it somewhat difficult to describe the storage module independently thereof. In this sense, it will be clear from the foregoing description that the annulus or annular space 47 and exhaust port 74 actually comprise components of the storage module. Similarly, the ignitor 77 which could be distinct and remote from the storage module 12 is intimately associated therewith so that the controlled quantity of any captured admixture of fuel and air ignited by the ignitor 77 constitutes the entire charge present within the annulus 47. Thus, in the particular embodiment of the apparatus 10 being considered, the ignitor 77 constitutes a functional component of the storage module 12, although such interrelationship therebetween is not essential.

The spark plugs or ignitors 77 are cyclically energized in any conventional manner: in more particular reference, by means of the usual breaker points and autotransformer of the type commonly found in the gasoline engine and, for this reason, not shown. For purposes of delivering the energizing potential to the ignitors 77, wires or electric conductors (not shown) are electrically connected to terminals 78 mounted upon the inner surface of the casing end wall 21, as shown in FIG. 2, and each such terminal 78 is equipped with a contact 79 with which the associated ignitor 77 makes electrical contact through an air gap as it sweeps therepast during its rotational movement relative to the casing structure. In the engine apparatus 10, a combustible charge within the annulus 47 is ignited once during each 360° displacement of the piston-cylinder structure 42, 39 so that the ignition system is timed to provide the appropriate voltage at each terminal 78 at the instant that the ignitor 77 associated therewith traverses the contact 79 and a compressed charge of combustible fluids is present in the annulus 47. The position of each contact 79 can be adjusted angularly to change the timing of the engine.

Considering now the turbine module 13, as indicated hereinbefore the expanding products of combustion expelled through an exhaust port 74 into the associated exhaust tube 75 are directed by the nozzle structure 76 connected therewith toward impingement with the turbine wheel or torque ring comprising a part of the turbine module. This arrangement is illustrated most clearly in FIGS. 5 and 6 and, as previously indicated, the turbine module is clamped to the casing sections 15 and 16 by the fasteners 19 (FIG. 2) so as to prevent relative rotation therebetween. Accordingly, since the casing structure 14 is intended to be constrained against rotation in the particular form of the engine illustrated, impingement of the fluids ejected through the nozzles 76 against the turbine wheel effects rotation of the support plate 36 and piston-cylinder compositions 42, 39 mounted thereon. However, such an arrangement is not necessary, and in other forms of the apparatus the shaft 23 together with the crank disc or eccentric 69 could turn as a unit, while the support plate 36 and piston-cylinder structures mounted thereon could be held stationary. The turbine wheel
would then rotate and would be drivingly connected with the shaft 23 to rotate the same.

As is most evident in FIG. 6, the turbine module 13 is a ring-shaped component or annulus having a large central opening therethrough within which the support plate 36 is positioned. Accordingly, a portion of each of the cylinders 39 projects into the hollow interior of the ring-shaped turbine, and the nozzles 76 also extend through the hollow interior of the turbine and are fixedly secured to the plate 36 so as to rotate therewith. The outer circumferential surface of the turbine module is equipped with the aforementioned fins 20', and along its inner surface, the turbine wheel is equipped with a plurality of angularly spaced reaction pockets 80. The pockets 80 are very close to each other and are quite narrow in an angular sense, having a radially disposed wall 81 at one end against which the gases are ejected, and a curved wall 82 at its opposite end so as to permit a reduced-frictional movement of fluids therealong. These pockets can be changed to adapt the same to the requirements of any embodiment of the turbine wheel.

The nozzle structures 76 have substantial angular length, as illustrated in FIG. 5, so as to simultaneously cover a plurality of successive pockets 80, thereby preventing premature escape of the gases from any pocket after impingement of the gases against the radially disposed end wall 81 thereof. Thus, although for the most part each nozzle 76 has a somewhat wedge-shaped configuration, at the trailing edge thereof it is equipped with a tail 83. In the apparatus under consideration, each nozzle 76 covers approximately five pockets 80 at the same time.

It will be appreciated that a number of turbine stages could be employed as in the ordinary case of turbine structures so as to extract as much kinetic energy as practicable from the combustion gases. In the apparatus 10, however, a single turbine stage is used with the exhaust gases being discharged to atmosphere after expansion thereof in the single turbine stage. The exhaust flow for such gases once any particular pocket 80 has been uncovered by the tail 83 of the nozzle structure 76 through which the exhaust gases have been ejected into such pocket is into the interior of the casing structure 14 and especially into the end portion thereof adjacent the casing end wall 21. It will be observed that the mounting plate 36 together with the adjacent surfaces of the turbine wheel effectively divide the casing chamber 22 into two separate compartments with the expended gases being discharged into the compartment along the end wall 21. An exhaust outlet 84 communicates with the interior of the casing structure 14 through the end wall 21 thereof and permits the expended gases to be discharged from the engine apparatus, usually through a muffler system. It may be noted, however, that the expanded gases discharging through the exhaust 84 contain less energy than the exhaust gases in the usual internal combustion engine, thereby creating less exhaust noise and requiring a less elaborate muffling system.

As shown best in FIG. 6, each pocket 80 as it has gases ejected thereinto through an associated nozzle 76 is substantially closed thereby because the pockets 80 are closed along the axially spaced edges thereof by side walls 86 and 87 that terminate in close adjacency with the facing surface 88 of each nozzle structure. As a result, there is very little space to accommodate leakage of the gases especially where the outlet of the nozzle is oriented to direct the gases toward the inner wall or bottom of each pocket, as indicated by the arrow in FIG. 5. Along the wall or lip 86, each nozzle structure 76 has a laterally projecting flange 89 bordering the lip and further inhibiting the escape of gases therepast.

A cycle of operation of the apparatus 10 will now be described, and in this connection consideration will be given first to the manner in which a combustible admixture of fuel and air is drawn into the cylinder space 40 for compression therewith. For purposes of initiating this discussion, reference may be made to FIG. 4 and it can be assumed that the piston 42 illustrated in this figure is being displaced radially inwardly or toward the left, as illustrated in FIG. 4. With these conditions obtaining, the space 40 is enlarging in volume, thereby tending to reduce the pressure within the space and as a consequence thereof, the superior (essentially atmospheric) pressure within the manifold space 58 and passage 53 causes the valve 55 to open with the result that the admixture of fuel and air within the chamber 58 is drawn into the cylinder space 40. This condition of the apparatus is maintained with fuel and air being drawn into the ever-enlarging cylinder space 40 until the piston 42 reaches the innermost position thereof, whereupon the next phase in the cycle of operation commences.

Such phase is one of compression in which the charge admitted into the space 40 is compressed into the progressively decreasing volumetric capacity of the cylinder space 40 as the piston 42 is displaced radially outwardly toward the end wall 41 of the cylinder 39. The charge within such cylinder space 40 cannot escape therefrom because the rising pressure therein rapidly becomes superior to the atmospheric pressure value within the passage 53, whereupon the valve 55 is closed by operation of such superior pressure together with the biasing force imparted thereto by centrifugal force, thereby preventing escape of the charge. As the piston 42 approaches the end wall 41 of the cylinder, it will eventually have the position shown in FIG. 4 in which the opening 48 is closed by the enlarged head 43 of the position with the result that the charge of fuel and air therein is compressed into the composite space defined between the cylinder wall 41 and facing surface of the piston 42 and by the passage 48. As the piston 42 continues to be displaced toward the cylinder end wall 41, the enlarged piston end 43 passes beyond the lower edge of the opening 48, thereby permitting the compressed charge within the cylinder space and passage 48 to escape therefrom into the annulus 47. Such escape of the compressed charge into the annulus continues until the piston 42 reaches its outermost position and again returns to the position thereof illustrated in FIG. 4 in which the opening 48 is closed. At this time, then, one complete reciprocable displacement of the piston 42 has been described and, as will become apparent hereinafter, during a time interval required for such reciprocable displacement, the cylinder 39 will have been displaced angularly through one 360+ revolution about the axis of the shaft 23.
The cycle of operation so far described constitutes an intake phase in which an admixture of fuel and air is drawn into the cylinder space 40, and the compression phase in which such charge is compressed to an elevated pressure. At the same time, however, that the piston 42 is displaced inwardly through the intake phase, a prior-compressed charge previously admitted into the annulus 47 is held captive therein and remains in this space during a part of the inward displacement of the piston. Although such charge could be removed from the annulus 47 for longer-period retention within a storage space connected therewith, in the particular apparatus 10 being considered, the charge is ignited by application of the requisite high voltage to the ignitor 77 as the piston 42 is displaced inwardly. In more particular terms, as respects timing, ignition of the charge within the annulus 47 will occur at about the moment of time illustrated in FIG. 4 in which the enlarged outer end portion 43 of the piston has closed the opening 48, and the enlarged lower end 44 of the piston is closing the exhaust port 74.

Ignition of the compressed charge within the annulus 47 at this time causes a rapid expansion of the gaseous fluids comprising the charge which causes such fluids to escape at relatively high velocity through the exhaust port 74 and exhaust tube 75 as soon as the exhaust port commences to be opened by inward displacement of the enlarged end 44 of the piston therepast. Since the annulus 47 is relatively long, considerable time is afforded for escape of the gases into the exhaust tube 75 as the piston 42 is displaced inwardly into its innermost position from the location thereof illustrated in FIG. 4 and is thereafter displaced outwardly to return it to the position shown in this figure. Accordingly, although there is no separate scavenging cycle (complete scavenging can be provided, however, either with or without an independent cycle therefor, should it be desirable), the annulus 47 is substantially cleared of the products of one combustion cycle at the time that the next compressed charge is expressed thereto. Thus, during the intake phase of the cycle previously described, a combustion cycle is occurring concurrently therewith in the annulus 47. Therefore, combustion occurs once during each complete cycle of reciprocation of the piston 42 which is also once for each 360° angular rotation of the cylinder 39.

As the combustion gases travel at a relatively high velocity through the exhaust tube 75 and into the nozzle structure 76 for ejection therefrom into impingement with the pockets 80 of the turbine wheel, the energy in the ejected gases effects relative rotation between the turbine wheel and nozzle structure and, therefore, between the turbine wheel and mounting plate 36 to which each nozzle structure 76 is rigidly affixed. As previously explained, in the apparatus 10 under consideration, such relative rotation constitutes rotation of the support plate 36 in the counterclockwise direction illustrated in FIG. 5 as the turbine wheel and casing structure 14 attached thereto remain fixed. In any case, however, as soon as each turbine pocket 80 having gases ejected thereinto is uncovered by movement therepast of the nozzle tail 83, the partially-expended gases enter that portion of the casing chamber 22 intermediate the mounting plate 36 and casing end wall 21 from which such gases are exhausted via the exhaust conduit 84.

As previously explained, the mounting plate 36 is secured to the output shaft 23 in a manner preventing relative rotation therebetween so that the rotational motion imparted to the mounting plate 36 as a consequence of the impingement of the exhaust gases against the turbine wheel rotatable drives the output shaft 23. At the same time, each piston and cylinder structure 42,39 is rotated concurrently with the shaft 23 about the axis of rotation thereof because such piston-cylinder structures are rigidly attached to the mounting plate. Necessarily, then, the cranks defined by the rings 67 and lobes 68 are forced to rotate with the plate 36 and piston-cylinder structures attached thereto. However, because the rings 67 are rotatably supported upon the crank disc 69 which is constrained against rotation because of its attachment to the casing structure 14 via the mounting structure 27, and has its geometric center offset from the axis of rotation of the shaft 23, the rings 67 revolve rather than rotate about the axis of the shaft 23, thereby causing the pistons 42 to reciprocate within the cylinders 39 confining the same therewithin. The described relationship of the shaft 23, crank plate 69, rings 67, and pistons 42 is shown in FIG. 1 which makes it evident that the pistons 42a and 42b are offset by 180° or are in an out-of-phase relationship such that one of the pistons is in its outermost compression position simultaneously with the other piston being in its innermost intake position, and vice versa.

As previously explained, the compression, retention, and utilization mechanisms which are time-related and in structural proximity in the engine apparatus 10 can be separated and made relatively independent of each other, thereby lending great versatility to engine apparatus embodying the invention. For example, the relative angular velocities of the mechanisms comprising the combustion chambers and torque ring need have no direct relationship. In this respect, the output shaft which is driven by the turbine module might have a velocity of say, 2,000 RPM whereas the rate of combustion might be varied over a wide range from zero ignitions per minute during free-wheeling to perhaps 6,000 ignitions per minute when high power outputs are required.

Substantially no high magnitude, impact-pipe shock loads appear anywhere within the engine apparatus since the gaseous discharge from the nozzle structures 76 are tangentially oriented with respect to the torque ring and because combustion occurs within a separate combustion chamber 47 and not in the variable-volume compression space defined between each piston 42 and the end closure 41 of the associated cylinder. As a result, the engine apparatus can be compact and lightweight, and anti-friction ball bearings and roller bearings may be used in the engine rather than the babbitt type bearings now used in conventional engines for the purpose of withstanding the tremendous shock load imposed thereon. Also, mechanism (not shown) may be included in the engine apparatus for changing the direction of the nozzle structures 76 to permit the direction of rotation of the output shaft 23 to be changed at any time even at the instant that the shaft is rotating at maximum angular velocity in one particular direction. Such a change in nozzle direction permits the engine apparatus to assume a negative acceleration at any time desired which facilitates breaking of any au-
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tomotive vehicle having the engine apparatus mounted therein. Such an arrangement also simplifies reversing the direction of propulsion of the vehicle, should this be desired.

The output RPM of the engine apparatus is changed with facility simply by altering the diameter of the turbine wheel or torque ring. Thus, increasing the diameter of the torque ring will increase the torque and reduce the angular velocity, assuming the gaseous discharge from the nozzles to remain the same; and decreasing the diameter of the torque ring brings about the opposite result.

In the particular mechanism being considered, the length of time that each captive charge is stored is related to the length of stroke of the pistons 42 since retention terminates as soon as the exhaust ports 75 are uncovered by the enlarged inner end portions 44 of the pistons. However, both the inlet and exhaust ports could be positively valved to make retention independent of the relative positions of the chamber 47 and associated exhaust port 74. Further, and as previously indicated, the storage and/or combustion chambers need not be associated with the pistons 42 and, for example, may be located at the sides or outer ends of the cylinders 39. Rotary valve mechanism might also be used advantageously in association with any such chamber to control fluid flows respecting the same. Pressure relief devices can be associated with the chambers 47 as a safety precaution, if desired, to prevent development of excessively high pressure values within such chambers.

As previously indicated, the engine apparatus lends itself to both diesel and gasoline cycles, and a great variety of fuels can be used to energize the apparatus. Since the engine is characterized by greater efficiency for the reasons previously explained, less fuel is consumed per output horse power delivered, which results in less exhaust emissions. Further, the improved combustion characterizing the engine also results in less noxious exhaust emissions. It may also be noted that the engine consumes rather low quantities of air which tends to keep the operating temperature of the engine quite low.

While in the foregoing specification an embodiment of the invention has been set forth in considerable detail for purposes of making a complete disclosure thereof, it will be apparent to those skilled in the art that numerous changes may be made in such details without departing from the spirit and principles of the invention.

What is claimed is:

1. Engine apparatus operative to convert the chemical energy of a combustible fuel into mechanical energy, comprising: compressor mechanism having a compression chamber adapted to receive a compressible fluid charge and express the same therefrom in a compressed state; structure defining a combustion chamber adapted to have a combustible charge ignited therein; means for transferring compressed fluid previously compressed in said compressor mechanism into said combustion chamber, utilization mechanism connected with said combustion chamber for receiving combustion gases therefrom and being responsive to the energy contained therein to produce work output, said utilization mechanism including a torque ring supported with respect to said combustion chamber for relative rotation therebetween, nozzle structure connected with said combustion chamber to receive the gaseous discharge therefrom and direct the same toward impingement against said torque ring to produce output torque, and a rotatable output shaft adapted to have such output torque applied thereto to effect rotation thereof, said torque ring being constrained against rotation, and said combustion chamber being connected to said shaft so as to rotate therewith.

2. Engine apparatus operative to convert the chemical energy of a combustible fuel into mechanical energy, comprising: compressor mechanism having a compression chamber adapted to receive a compressible fluid charge and express the same therefrom in a compressed state; structure defining a combustion chamber adapted to have a combustible charge ignited therein; means for transferring compressed fluid previously compressed in said compressor mechanism into said combustion chamber, utilization mechanism connected with said combustion chamber for receiving combustion gases therefrom and being responsive to the energy contained therein to produce work output, said compressor mechanism including a cylinder having a piston reciprocable therein, the variable-volume space defined between said piston and one end of said cylinder constituting the aforesaid compression chamber, and a rotatable output shaft adapted to have such output torque applied thereto to effect rotation thereof.

3. The apparatus of claim 2 and further comprising storage means connected with said compression chamber for receiving compressed fluid charges therefrom for retention prior to combustion thereof.

4. The apparatus of claim 2 in which said utilization mechanism includes a torque ring supported with respect to said combustion chamber for relative rotation therebetween, and nozzle structure connected with said combustion chamber to receive the gaseous discharge therefrom and direct the same toward impingement against said torque ring to produce output torque.

5. The apparatus of claim 4 and further comprising storage means connected with said compression chamber for receiving compressed fluid charges therefrom for retention prior to combustion thereof.

6. The apparatus of claim 5 in which said compression chamber is equipped with intake means adapted to receive fuel and air as such combustible fluid charge, whereby such charge leaves said compression chamber as a compressed combustible mixture, and in which said combustion chamber also defines a retention space within which such fluid charges are retained prior to combustion.

7. Engine apparatus operative to convert the chemical energy of a combustible fuel into mechanical energy, comprising: compressor mechanism having a compression chamber adapted to receive a compressible fluid charge and express the same therefrom in a compressed state; structure defining a combustion chamber adapted to have a combustible charge ignited therein; means for transferring compressed fluid previously compressed in said compressor mechanism into said combustion chamber, utilization mechanism connected with said combustion chamber for receiving combustion gases therefrom and being responsive to the energy contained therein to produce work output, said utilization mechanism including a torque ring supported with respect to said combustion chamber for relative rotation therebetween, nozzle structure connected with said combustion chamber to receive the gaseous discharge therefrom and direct the same toward impingement against said torque ring to produce output torque, and a rotatable output shaft adapted to have such output torque applied thereto to effect rotation thereof, said torque ring being constrained against rotation, and said combustion chamber being connected to said shaft so as to rotate therewith.
energy contained therein to produce work output, said utilization mechanism including a torque ring supported with respect to said combustion chamber for relative rotation therebetween, nozzle structure connected with said combustion chamber to receive the gaseous discharge therefrom and direct the same toward impingement against said torque ring to produce output torque, and a rotatable output shaft adapted to have such output torque applied thereto to effect rotation thereof, one of said torque ring and combustion chamber being constrained against rotation and the other thereof being connected to said shaft so as to rotate therewith.

8. The apparatus of claim 7 and further comprising storage means connected with said compression chamber for receiving compressed fluid charges therefrom for retention prior to combustion thereof.

9. The apparatus of claim 7 in which said compression chamber is equipped with intake means adapted to receive fuel and air as such compressible fluid charge, whereby such charge leaves said compression chamber as a compressed combustible mixture.

10. The apparatus of claim 7 in which said compressor mechanism includes a cylinder having a piston reciprocable therein, the variable-volume space defined between said piston and one end of said cylinder constituting the aforesaid compression chamber, said piston having a restricted intermediate section spaced from the circumjacent wall of said cylinder and defining said combustion chamber therewith, and in which said means for transferring compressed fluid into said combustion chamber includes flow passage means interconnecting said compression and combustion chambers at a certain predetermined position in the reciprocable displacements of said piston.

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