Feb. 20, 1951 E. E. CHRISTOPHER 2,542,628

TURBOJET PROPULSION APPARATUS WITH SEPARATE COMBUSTION DISCHARGE JETS

Filed Oct. 25, 1946 5 Sheets-Sheet 1

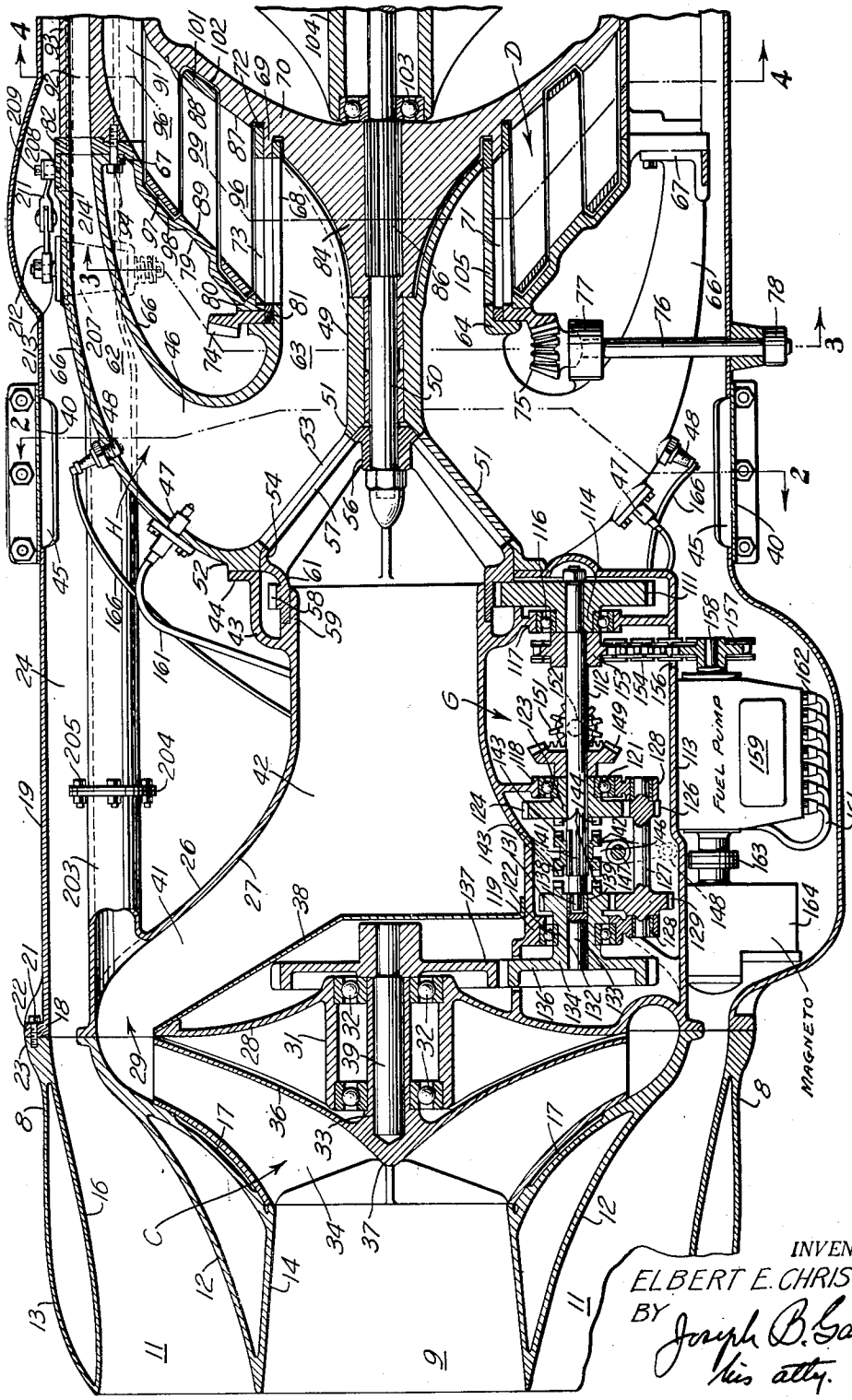


FIG. 1A

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Filed Oct. 25, 1946 5 Sheets-Sheet 2

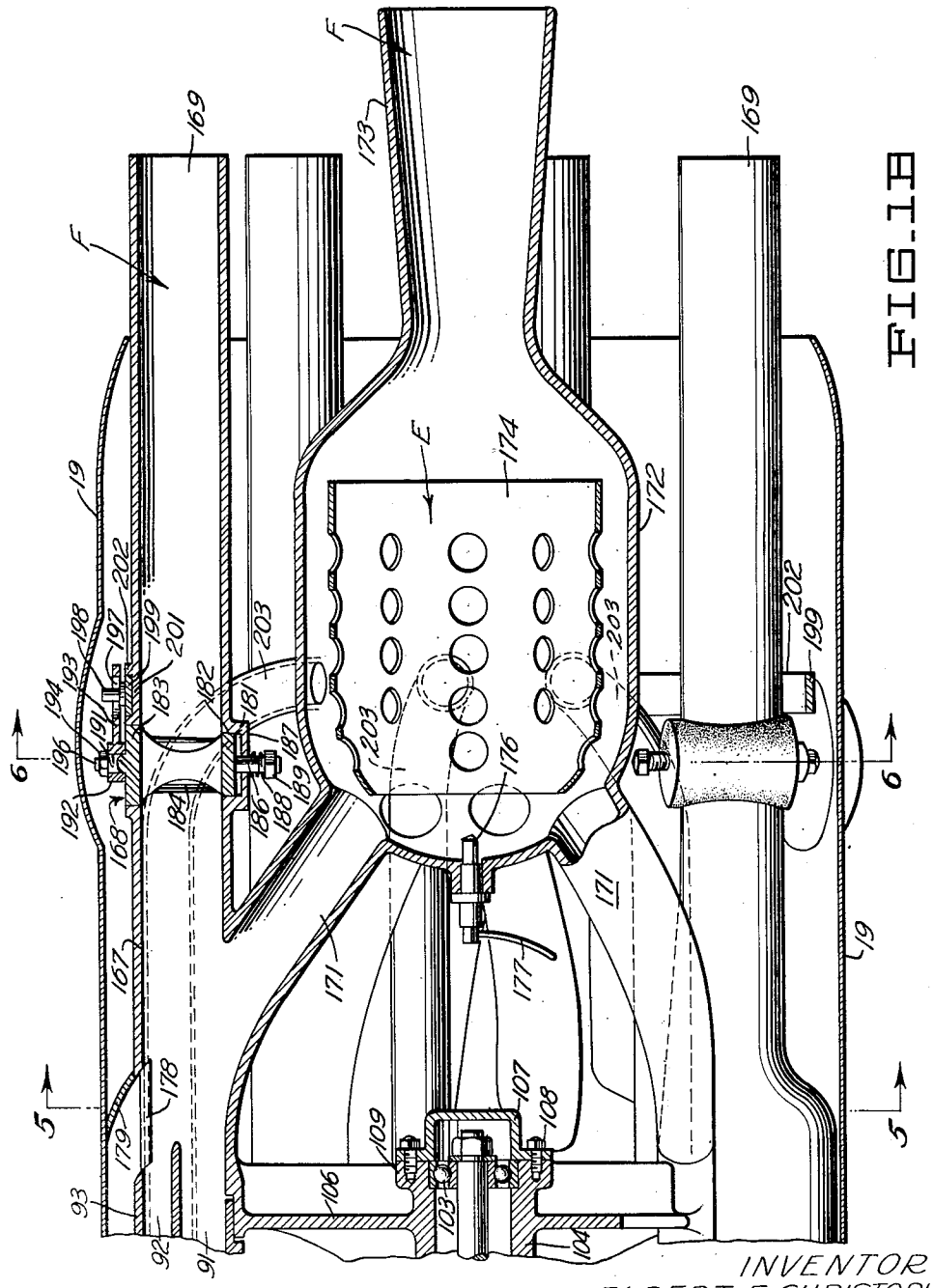


FIG. 1B

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TURBOJET PROPULSION APPARATUS WITH SEPARATE COMBUSTION DISCHARGE JETS

Filed Oct. 25, 1946 5 Sheets-Sheet 3

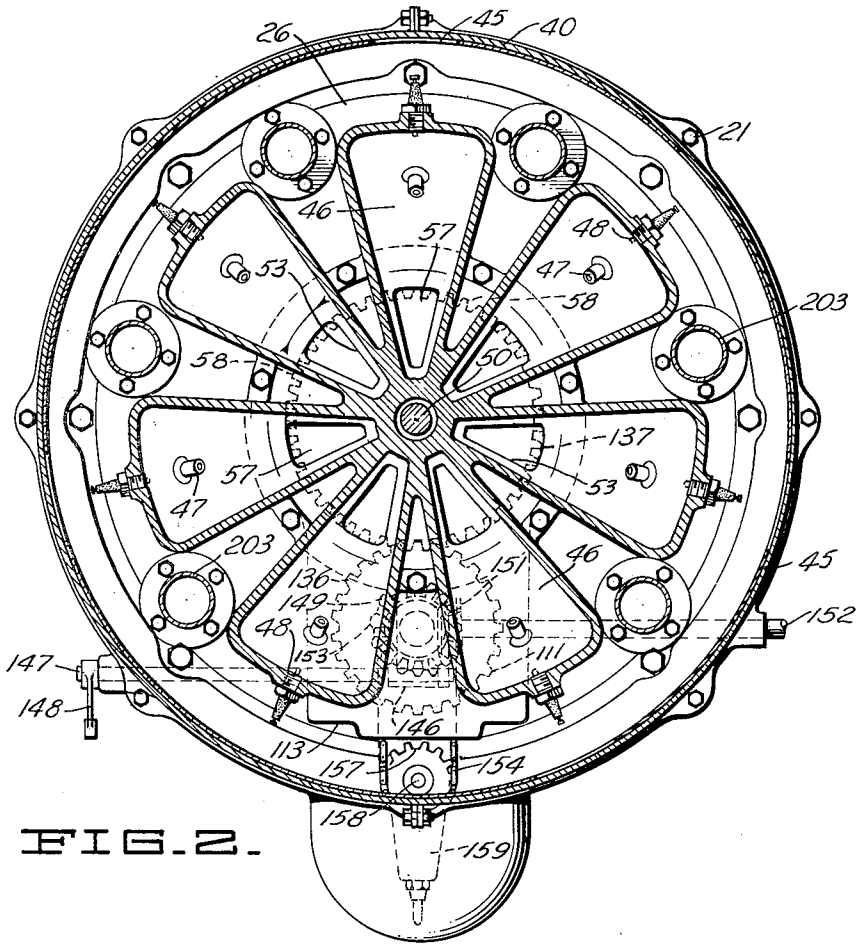


FIG. 2.

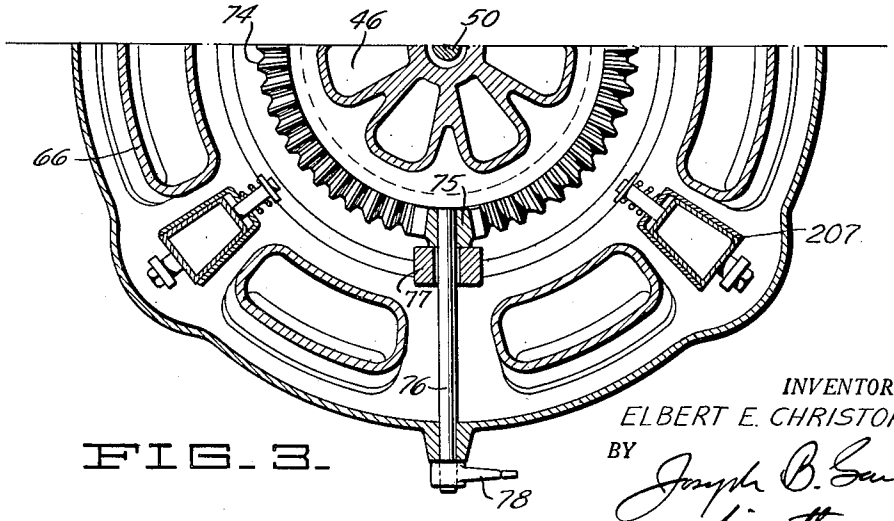


FIG. 3.

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TURBOJET PROPULSION APPARATUS WITH SEPARATE COMBUSTION DISCHARGE JETS

Filed Oct. 25, 1946 5 Sheets-Sheet 4

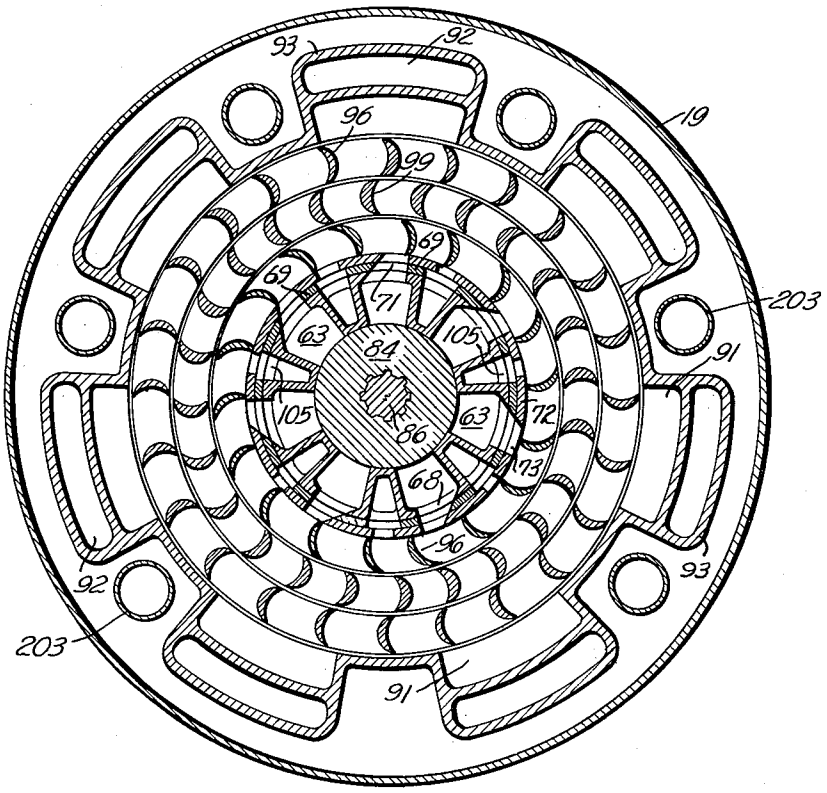


FIG. 4.

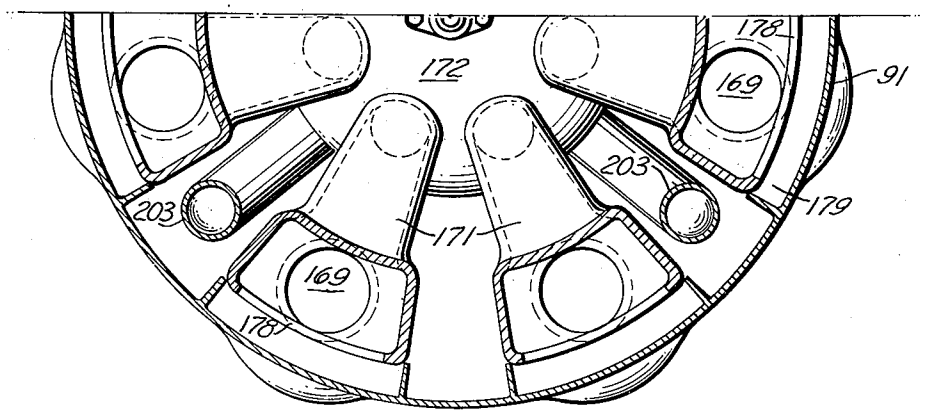


FIG. 5.

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Filed Oct. 25, 1946 5 Sheets-Sheet 5

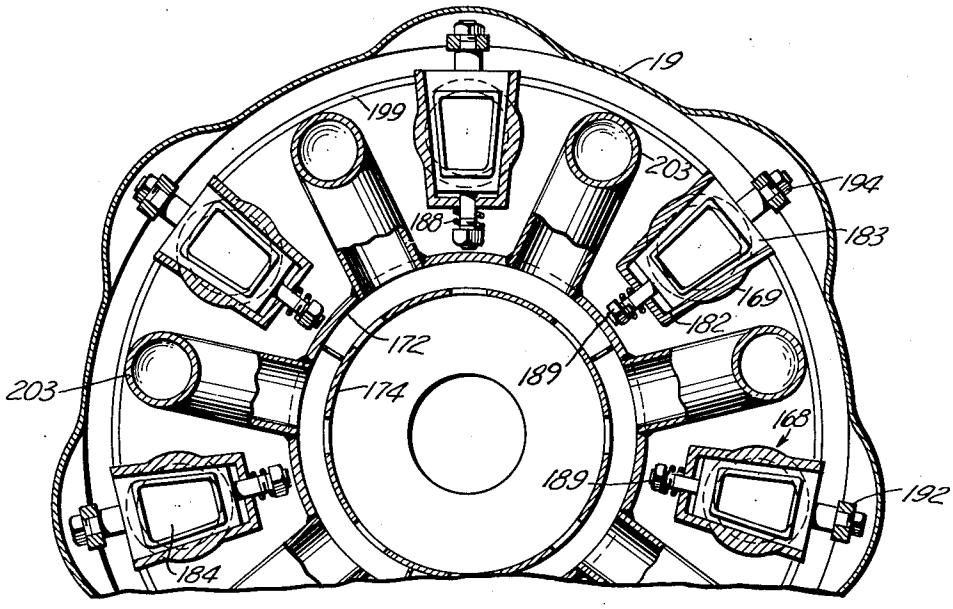


FIG. 6.

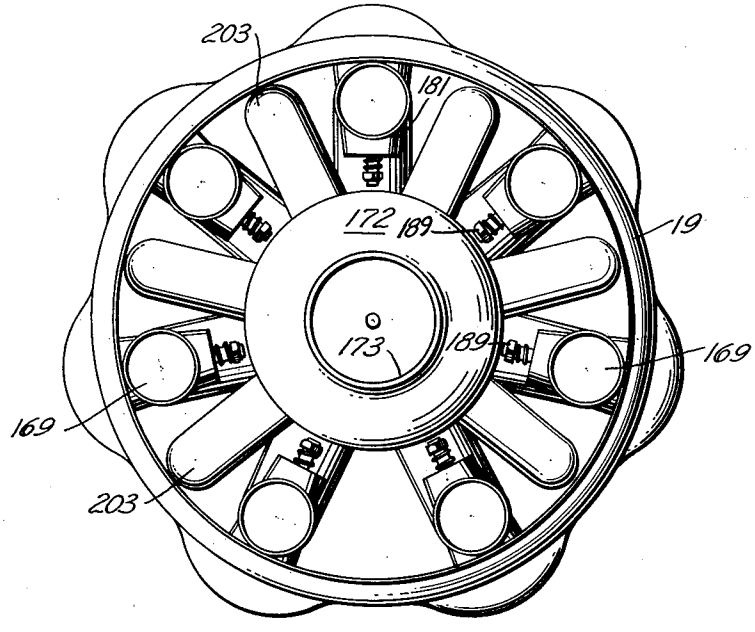


FIG. 7.

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UNITED STATES PATENT OFFICE

2,542,628

TURBOJET PROPULSION APPARATUS WITH SEPARATE COMBUSTION DISCHARGE JETS

Elbert E. Christopher, Oakland, Calif.

Application October 25, 1946, Serial No. 705,777

17 Claims. (Cl. 60—35.6)

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This invention relates to fuel combustion motors capable of generating motive power solely by impact of liberated products of combustion into the atmosphere.

An object of the invention is to provide apparatus of the character described equipped with separate combustion discharge jets which are relatively arranged and capable of selective cooperation so as to vary the effective cross-sectional area of the discharge blast impinging into the atmosphere and thereby vary the thrust effort generated by the apparatus.

Another object of the invention is to provide apparatus of the class referred to in which abrupt changes in, or reversals of, flow of fuel mixtures or combustion gases are avoided as much as possible so as to minimize flow resistance and consequently enhance the thrust characteristics of the apparatus.

A further object of the invention is to provide jet propulsion apparatus capable of utilizing an air stream, primarily employed for cooling purposes, as a combustion sustaining medium so as to take advantage of the absorbed heat contained in the air stream.

Still another object of the invention is to provide jet propulsion apparatus, particularly adapted to powering aircraft in the rarified atmosphere at very high altitudes, in which means is provided for accelerating flow of combustion air to the apparatus to compensate for the diminished supply of oxygen in the air at such altitudes.

A still further object of the invention is to provide jet propulsion apparatus in which a governed proportion of the output of a primary combustion chamber discharging through a first propulsion jet is directed into a secondary combustion chamber discharging through a second propulsion jet so that as complete consumption as possible of the fuel mixture is obtained.

Yet another object of the invention is to provide, in a jet propulsion apparatus using a turbine rotor deriving rotative force from a periodically interrupted flow of combustion gases, means for cooling said rotor by introducing thereto, between interruptions in the flow of said combustion gases, a flow of comparatively cold air.

Still another object of the invention in to provide jet propulsion apparatus in which the various parts are designed to facilitate assembly and are readily accessible for inspection or repair.

It is another object of the invention to provide, in jet propulsion apparatus wherein a turbine rotor powered by the expansion of combustible

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fuel and air is connected with and drives an impeller delivering air under pressure for mixture with said fuel prior to combustion thereof, means for selectively varying the rates of rotation between the turbine rotor and the impeller whereby increased volumes of air in relation to a given speed of rotation of the turbine rotor may be obtained.

It is a further object of the invention to provide, in jet propulsion apparatus, a power turbine combining features of both radial and axial flow designs so as to take advantage of the greater power output of the radial flow type and the lessened resistance to fluid flow of the axial flow type.

It is still another object of the invention to provide apparatus of the character described which may be made very light in weight for a given thrust capacity and of minimum external diameter so as to minimize the frontal resistance to movement of the apparatus at any substantial speed through the air.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of the preferred form of the invention which is illustrated in the drawings accompanying and forming part of the specification. It is to be understood, however, that variations in the showing made by the said drawings and description may be adopted within the scope of the invention as set forth in the claims.

Referring to the drawings:

Figure 1A is a vertical sectional view taken longitudinally through the forward portion of the apparatus of my invention.

Figure 1B is a vertical sectional view of the rear portion of the apparatus of my invention and forming a companion view with Figure 1A.

Figure 2 is a vertical sectional view taken in the plane indicated by the line 2—2 of Figure 1A.

Figure 3 is a vertical sectional view taken in the plane indicated by the line 3—3 of Figure 1A.

Figure 4 is a vertical sectional view taken through the turbine and in the planes indicated by the line 4—4 of Figure 1A.

Figure 5 is a vertical sectional view taken in the plane indicated by the line 5—5 of Figure 1B.

Figure 6 is a vertical sectional view taken in the plane indicated by the line 6—6 of Figure 1B.

Figure 7 is a reduced scale rear elevational view of the apparatus of my invention.

In the form of my invention illustrated in the drawings, I provide a generally cylindrical unit having an air compressor adjacent its forward

end and indicated generally by the letter C, turbine drive mechanism substantially intermediate its ends, connected to drive the compressor and time the fuel charging and indicated generally by the letter D, a secondary combustion chamber near the rear end thereof and indicated generally by the letter E and jet pipes projecting from its rear end carrying the products of combustion from the turbine and secondary combustion chamber and indicated generally by the letter F. Speed change mechanism indicated generally by the letter G is provided for varying the rotational speeds between the compressor and the turbine elements of the apparatus. Primary combustion chambers, generally indicated by the letter H, are provided for receiving charges of ignitable fuel mixture and are arranged to discharge their products of combustion through the turbine D to effect powered rotation of the latter.

The compressor C comprises a casing 8 having a central inlet port 9 and a coaxial annular air scoop 11 surrounding the port 9. The casing is formed with inner and outer ring-shaped walls 12 and 13 respectively, the former having a tapered bore forming the side wall 14 of the inlet port 9 and the former having an outwardly and rearwardly flared wall surface 16 confronting the substantially similarly-shaped wall 12 to form the air scoop 11. A bell-shaped recess 17 is disposed rearwardly of and forms a continuation of the inlet port. The rearward face 18 of the casing 8 abuts against the forward end of a cylindrical shell 19 extending rearwardly over substantially the entire jet apparatus and the casing and shell are secured together in coaxial relation by screws 21 extending through apertured lugs 22 on the shell and threadedly engaged in mating bosses 23 formed on the casing. The shape of the lugs 22 and bosses 23 is streamlined so as to offer as little resistance as possible to air flow thereover. The arrangement of the parts is such that the air scoop passage 11 opens and discharges into the chamber 24 within the shell 19. Disposed within the chamber 24 is a bell-shaped section 26 of the compressor casing which abuts against the face 18 and whose recess 27 forms a continuation of the recess 17. A wall 28 formed as an integral portion of the casing section 26 has an annular opening 29 extending around its periphery, so as to provide communication between the recesses 17 and 27, and is further provided with a central hub 31 concentric with the inlet port and the aforementioned recesses. The hub 31 is bored to receive bearings 32 in which is journaled the center hub 33 of a radially vaned impeller 34 positioned concentrically of the recess 17. The radially-extending disk 36 of the impeller is substantially conical in form and sweeps from an apex 37, coinciding with the axis of the inlet port 9, outwardly and rearwardly to terminate at the periphery of the wall 28 and at the junction of the recesses 17 and 27. A suitably formed baffle plate 38 is positioned rearwardly of and secured in spaced relation to the surface of the recess 27. A shaft 39, suitably secured in the impeller hub 33, is provided for rotating the impeller. When the shaft 39 is rotated, the whirling impeller will draw atmospheric air in through the inlet port 9 whereupon the impeller blades will force the air radially outwardly of the impeller into the annular passage 41 defined by the wall surface of the recess 27 and the confronting surface of the baffle plate 38 wherein the air will be raised to a degree of compression depending upon the speed of rotation of the impeller and the rate at which the compressed air is used, and subsequently delivered into an air chamber 42 formed concentrically with and as an integral extension from the rear of the casing section 26. The air chamber 42 has at the rearward end thereof a bell-shaped enlargement 43 carrying a peripheral flange 44 by means of which is effected connection of the air chamber to the primary combustion chamber unit H.

The primary combustion unit H comprises a plurality in this case seven, of individual combustion chambers 46, each of which is provided with an injector nozzle 47 and with an electrical ignition plug 48. Ports 45 covered by a removable band 40 are provided in the shell 19 in coincidence with the injector nozzles 47 and the ignition plugs 48 and through which the latter may be inspected or serviced. The chambers 46 are arranged in peripherally equidistantly spaced relation about the axis of a central hub 49, through which a shaft 50 extends, which forms a radially inward side wall common to all chambers and which is formed integrally with a conically-shaped wall 51 extending forwardly and outwardly to join an integral flange 52 to which the flange 44 of the air chamber 42 is connected in any suitable manner. Each combustion chamber is provided, in the wall 51 thereof, with a valve port 53 capable of being opened and closed by a conically-shaped valve 54 secured by means of an integral hub 56 with and to be rotated by the shaft 50, ports 57 in the valve being capable of registry with the ports 53 so as to admit compressed air from the chamber 42 into successive of the combustion chambers. The valve 54 is also provided at its larger or forward end with an integral spur gear 58 positioned within the bell-shaped portion 43 of the air chamber 42 and journaled on a cylindrical extension 59 of the chamber housing which projects into the tubular portion 61 of the valve carrying the gear 58. The gear 58 is thus positioned concentrically of the shaft 50 and is rotatable in synchronism therewith. Each of the primary combustion chambers 46 is provided with separate inner and outer discharge ducts 62 and 63 respectively, the latter of which is contained in a rearwardly extending cylindrical hub 64 common to all of the combustion chambers and the former of which is contained in a rearwardly sweeping spout 66, one of which is provided for each separate combustion chamber. The spouts 66 are each provided with integral flanges 67 arranged axially concentrically with the shaft 50. The hub 64 at its distal or rearward end is provided with radially opening ports 68, one being provided for each combustion chamber 46 and being positioned in radial alignment with the corresponding spout 66. The periphery of the hub 64 bounding the ports 68 is machined to provide a cylindrical bearing surface on which is journaled a sleeve valve portion 69 of a turbine rotor 70, the valve having a plurality of openings 71 therein which are complementary with the ports 68. The mounting thus provides for rotational movement of the sleeve valve on the hub 64 so that the openings 71 will open and close successive combustion chambers to control flow therefrom. The duct 63 may be adjusted as to effective area from full open position to any intermediate position wherein a reduced effective discharge area through which flow from the duct 63 may pass is produced. This is accomplished

by providing a tubular valve 72 which is journaled on the sleeve valve portion 69 of the turbine rotor and has therein ports 73 identical in size and number with the ports 68 of the hub 64. Means for imparting rotary movement to the tubular valve 72 so as to effect the aforesaid adjustment of the ports 68 and 73 is provided in a bevel gear 74 formed integrally with the forward end of the tubular valve and meshing with a pinion 75 carried by a shaft 76 journaled in a suitable bearing 77 mounted on a convenient portion of the combustion chamber unit H. The shaft 76 extends radially of and exteriorly of the apparatus and is fitted at its outer end with a lever 788 or other similar device by means of which connection with control mechanism, not shown, may be effected to permit rotation of the shaft 76 in varying degrees and subsequent adjustment and maintenance of the tubular valve 72 in different positions.

Each of the combustion chambers 46 is in communication, through the ports 68, 71 and 73, with the turbine D comprising, in part, a rearwardly dished annular wall member 79 having the hub 80 thereof, which borders the central opening 81, engaging the exterior periphery of the tubular valve 72 and having an outer flange 82 lying in contiguous relationship with the flanges 67. Secured to and for rotation with the shaft 50 is the substantially conically-shaped rotor 70 having a central hub 84 engaging the splines 86 of the aforesaid shaft and having a peripheral face 87 which describes a geometrical figure most aptly termed an ogee-conoid extending from an apex at the hub 84 to a broadened base at the rim 88. The confronting surface 89 of the wall member 79 is curved similarly to the face 87 and cooperates therewith to form the turbine passage extending in an outwardly and rearwardly sweeping curve from a wider dimension adjacent the ports 68, 71 and 73 to a relatively smaller passage 91 adjacent the rim 88. A separate passage 92 paralleling the passage 91 is provided in a cylindrical manifold 93 which also contains the passage 91 and is secured by screws 94 in abutting relationship with the flange 82. The rotor 70 is provided with one or more concentric and radially spaced circular rows of vanes 96 rotatable with the rotor and having the rings 97 bridging their outer ends and disposed in complementary circular recesses 98 formed in the wall surface 89 of the wall member 79. The wall member 79 carries a circular row of fixed vanes 99 extending rearwardly of the turbine, occupying the radial space between the relatively movable vanes 96 and provided with a tie ring 101 disposed in an annular recess 102 formed in the face 87 of the rotor 70. The arrangement of the tie rings 97 and 102 produces a smooth-walled passage through the turbine from the ports 68, 71 and 73 to the passage 91. The shaft 50 carrying the turbine rotor 70 extends rearwardly through suitable axially-spaced bearings 103 carried in a tubular hub 104 integrally connected by a web 106 with the manifold 93. A cap 107 secured by screws 108 to an annular flange 109 of the hub serves to enclose and protect the rear bearing 103. Cooling of the turbine vanes 96 and 99 is effected by providing ports 105 in the hub 64 cooperative with the ports 71 of the rotor and through which air from the chamber 42 may be passed in paths coincident with the flow path therethrough of the combustion gases.

Means is provided for connecting the compressor shaft 39 with and to be driven by the turbine rotor shaft 50. This may be accomplished in any suitable manner but I prefer to provide a gear 111, meshing with the gear 58, which is secured to a shaft 112 paralleling and spaced radially from the common axis of the relatively axially aligned shafts 39 and 50 and which is contained within a housing 113 formed as part of the compressor housing section 26. The hub 114 of the gear 111 is journaled in a bearing 116 carried by an annular mounting 117 forming part of the housing 113 and similar mountings 118 and 119 carrying bearings 121 and 122 respectively are also provided as integral parts of the housing 113 and are disposed in relatively axially spaced and concentric alignment with each other. The bearing 121 carries the hub 123 of a gear 124 through which the shaft 112 extends and in which the latter is journaled. Meshing with the gear 124 is a smaller gear 126 carried by a countershaft 127, which is journaled in suitable bearings 128, forming extensions of the mountings 118 and 119, a relatively larger gear 129 also being carried by the countershaft and meshing with a gear 131 disposed concentrically with the gear 124. The hub 132 of the gear 131 extends into and is secured in the inner ring of the bearing 122 and a shaft 133 fixed in the hub 132 extends through and is secured in the hub 134 of a gear 136 meshing with a drive gear 137 secured to the compressor shaft 39. An end of the shaft 112 is provided with a diametrically reduced stub portion 138 which extends into and is journaled in a pilot bearing 139 provided in the confronting end of the shaft 133. An end portion of the shaft 112 adjacent the stub shaft 138 is also provided with longitudinally extending splines 141 on which is mounted a clutch collar 142 having on the opposite transaxial ends thereof clutch jaws 143 adapted, upon axial shifting of the collar 142 along the splines 141 to be selectively engaged with or disengaged from mating clutch jaws 144 provided on the relatively confronting end faces of the gears 124 and 131. A shifting fork 146 carried by a rocker shaft 147 suitably journaled in the housing 113 is provided for shifting the collar 142 and is connected to be operated by a lever 148 positioned exteriorly of the shell 19. Suitable control apparatus of one form or another for moving the lever 148 may be provided but is not shown since its nature is commonly familiar to those skilled in the mechanical arts. It will be seen that the apparatus just described provides selective speed change means whereby the relative rates of rotation of the shafts 39 and 50 may be varied. When the clutch collar 142 is shifted to the left, as viewed in Figure 1A, so as to interengage the collar and the gear 131, the shafts 112 and 133 will be locked together and will rotate as an integral unit. Consequently the gear 136 will be rotatively interlocked with the gear 111 and the gears 137 and 58 will be correspondingly rotated thus causing simultaneous rotation of the turbine rotor 70 and the compressor impeller 34 at relative speeds which the proportions of the gear train provides. When the clutch collar is shifted to interengage the right-hand set of clutch jaws 144, the shaft 112 will be freed from and may rotate relative to the gear 131. However, under these conditions the shaft 112 will be locked to the gear 124 so that torque from the latter shaft is imparted through the gears 124 and 126 to the countershaft 127 and thence through the gears 129 and 131 to the shaft 133 and finally through the gears 136 and 137 to

the impeller shaft 39. Under these conditions the speed multiplying gears of the countershaft are interposed between the gears 124 and 131 and consequently the impeller 34 will be rotated at a much higher rate of speed than the turbine rotor 70. I have chosen to illustrate a simple form of sliding-clutch speed change transmission incorporating but two speed ratios in order to avoid excessive complication in the drawing and description. However, it will be understood that other forms of speed-change mechanism containing a greater range of ratios may be substituted for the apparatus shown without departing from the spirit of the invention.

Means is provided which may be conveniently associated with the shaft 112 for imparting externally applied rotation to the turbine rotor and compressor impeller for starting the apparatus and rotation of the shaft 112 is further utilized for supplying fuel under pressure to the injector nozzles 47 and for energizing, at proper instances, the ignition plugs 48 so that combustion of fuel charges in the combustion chambers 46 may be instituted and maintained. Secured to and rotatable with the shaft 112 is a bevel gear 149 which meshes with a bevel pinion 151 carried on a shaft 152 suitably journaled in the housing 113 and extending exteriorly of the shell 19. The outer end of the shaft 152 may be arranged to be coupled to a suitable starting mechanism such as a motor or other such prime mover for rotating the shaft. Such power application is necessary in starting the apparatus to bring the compressor impeller up to such speed that the air compressed thereby will be of sufficient volume and velocity as to institute and sustain combustion of the fuel charges. The actual application of rotative power to the impeller and also the turbine rotor is through the gears 149 and 151 and thence through the shaft 112 and the gears 136 and 137 to the impeller and also through the gears 111 and 58 to the shaft 50 and the turbine rotor. Also secured to and for rotation with the shaft 112 is a sprocket 153 meshing with a chain 154 which passes downwardly out of the housing 113 through an aperture 156 in the wall thereof and which meshes with a sprocket 157 secured to the rotatable shaft 158 of a multicylinder fuel pump 159 mounted on and exteriorly of the housing 113. Conduits 161 connect the various outlet couplings 162 of the pump with the respective fuel injector nozzles 47. The shaft 158 is extended and carries a coupling 163 by means of which is connected to and for rotation with the shaft 158, the rotor or equivalent part of a magneto 164 or similar electrical ignition device. Operative connection between the magneto and the various ignition plugs 48 is provided in the conductors 166 running to each of the plugs. The arrangement of the parts is such that, when the apparatus is in operation, both the fuel pump 159 and the magneto 164 will be operated, due to their drive connection with the shaft 112, to deliver metered charges of atomized fuel into the respective chambers 46 in proper sequence and to subsequently ignite the fuel charges in the chambers so as to create flows of the resulting combustion gases from the chambers through the turbine and the ducts 62 and into the passages 91 and 92 as previously explained.

Referring now to Figure 1B it will be seen that the passages 91 and 92 at points rearwardly of the turbine merge into single conduits 167 which are extended through valves 169 into tail pipes or outer jet nozzles 169. Just rearwardly of the confluence of the passages 91 and 92 with the larger common passage of the conduits 167, angularly branching ducts 171 are provided which communicate with and enter the rear of a secondary combustion chamber 172 having a tail pipe or inner jet nozzle 173 enclosed within the encircling ring of outer jet nozzles 169. A perforated cylindrical baffle screen 174 is mounted concentrically within the chamber 172 and a fuel injector nozzle 176 is carried by and is adapted to discharge its fuel spray into the adjacent open end of the baffle screen 174. The injector nozzle is fed through a pipe 177 from the injector pump 159. Ports 178 in the walls of the conduits 167 are positioned adjacent the junction, with the latter conduits, of the ducts 171 and provide communication between the internal chamber of the shell 19 and the adjacent rearward margin of the ports 178 are provided for directing flow from the shell chamber into the latter ports. The valves 168 are shown as the rotary type having a body 181, forming part of the duct 169, in which is provided a tapered bore 182 rectangularly intersecting the axis of the passage of the latter duct and fitted with a complementary tapered plug 183 rotatable in the bore 182 and having an aperture 184 therethrough capable of being brought into and out of registry with the duct passage when the plug 183 is rotated. The smaller end of the plug 183 is provided with a stub shaft 186 which passes rotatably through a suitable aperture formed in the end wall 187 of the body 181 and is exteriorly fitted with a coiled spring 188 interposed between the wall 187 and a nut 189 or its equivalent carried by the stub shaft for the purpose of resiliently urging the plug to tightly seat itself in the bore 182. The larger end of the plug 183 is fitted with an integral stub extension shaft 191, preferably of rectangular cross section for receiving the correspondingly apertured hub 192 of a radially extending control lever 193. A nut 194 threadedly engaged with a correspondingly-threaded stem 196 extending from the stub shaft 191 serves to retain the lever hub 192 in engagement with the latter shaft. The outer end of each lever 193 is provided with an elongated slot 197 in which is engaged a pin 198 secured to and extending radially from a control ring 199 which is journaled on bearing surfaces 201 provided on the outer surface of each duct 167. The ring 199, along one side thereof bears against the periphery of each valve body 181 while the other side thereof bears against buttresses 202 rising from the peripheries of the ducts 167. Air ducts 203 connected with and radially entering the secondary combustion chamber 172 extend forwardly interiorly of the shell 19 and open into the compressor housing 26 at points adjacent the compressed air discharge from the impeller. Suitable flanges 204 secured by bolts 205 provide for attachment of the air ducts 203 to the compressor housing and each of the latter ducts is provided with a rotatable plug valve 207, similar to that previously described, for controlling air flow through the ducts. The valves 207 are controlled in unison by a rotatable control ring 208 carrying radially extending pins 209 which journal one end of links 211, the other end of the links being pivotally connected with the levers 212 associated with the valve stems 213. The control ring 208 is retained against axial movement by a radial extension of the flanges 82 and by lugs 214 provided on the spouts 66.

The jet propulsion apparatus of my invention is designed particularly for use in aerial flight devices such as airplanes and it is in connection with such devices that its operation will be described. In starting the apparatus, a starting motor or other torque-producing mechanism is connected with the starting shaft 152. This causes the compressor impeller, the turbine rotor and the combustion chamber valve to rotate due to their geared interconnection. As the compressor impeller rotates, air will be drawn in thereby through the inlet port 9 and discharged under pressure, depending on the rotational speed of the impeller, into the chamber 42. Quantities of the compressed air in the chamber will pass, under control of the combustion chamber rotary valve 54, as s parate charges into successive of the combustion chambers wherein the charges will be intermixed with injections of vaporized hydrocarbon fuel issuing from the injector nozzles 47 in timed relation to the admittance of the air charges into the combustion chambers. At this point it is best explained that the turbine rotor valve ports 71 are preferably arranged to rotationally lead the air chamber valve ports 57 by a peripheral degree equivalent to the peripheral spacing between a pair of adjacent combustion chambers. Thus, when charges of air and fuel are being admitted to a combustion chamber, the discharge passage through the turbine will be closed. Likewise, when a charge of fuel mixture is ignited in a combustion chamber, the exhaust passage through the turbine will be opening or will be fully open while the compressed air chamber valve ports will be closed or closing. This not only prevents substantial amounts of combustion gases from forcing their way into the compressed air chamber but permits the pressure in the chamber to build up between each ignition of the charges of fuel mixture in the combustion chambers. Upon ignition of a charge of fuel mixture in a combustion chamber, the expanding gases resulting from combustion will rush into the passages 62 and 63, the flow in the latter passages moving radially through the turbine vanes 96 and 99 and into the duct 91 while the flow from the former passage flows into the duct 92. The rotation imparted to the turbine rotor by such gas flow will, of course, furnish power for continued rotation of the air and fuel injection and the subsequent explosion of the fuel mixture may be sustained and repeated in rapidly accelerated sequence as the turbine rotor is driven faster and faster. Rotary adjustment of the tubular valve 72 may be accomplished so that the cooperating ports 68 and 73 will be fully open so as to minimize impedance to flow of combustion gases through the turbine or the cooperating ports may be overlapped so as to reduce as much as desired, the effective port area through which the combustion gases flow. This will produce two effects. First, due to the degree of constriction of the discharge port controlling the gas flow through the turbine, a larger volume of gas may flow out of the combustion chamber through the duct 92, thus effecting operation of the outer propulsion jets 169, as will be presently explained and, secondly, the constricted discharge port will increase the velocity of gas flow through the turbine with the result that a lesser volume of gas is required to sustain a desired rotational speed of the turbine rotor and air compressor impeller and therefore, the larger volume of gas flowing through the propulsion jet will create an increased thrust of the jet discharge on the air and a corresponding reaction thrust on the entire apparatus or the aircraft with which it may be associated.

The rearwardly rushing flows of gas through the ducts 91 and 92 will merge into a single stream upon entering the conduit 167 and will pass rearwardly out of the end of the jet nozzle 169. Some of the combustion gases, however, may be diverted, by partially closing the valve 168, into the branch duct 171 to enter the secondary combustion chamber, 172. The combustion gases issuing from the primary combustion chambers 46 invariably contain an appreciable percentage of unburned fuel which, if permitted to discharge into the atmosphere from the outer jet nozzles 169, would produce no useful power. It is the purpose of the valves 168 to partially block the passages of the outer jet nozzles so as to cause the aforesaid diversion of some of the combustion gases into the secondary combustion chamber. When said diverted flow enters the latter chamber through the branch ducts 171, it will mix with additional fuel injected into the chamber from the nozzle 176 and will also combine with the flow of fresh air entering the chamber, in regulated proportion, through the ducts 203. In addition, air entering the combustion gas streams through the ports 178 will restore the combustion balance of fuel and air in the ducts 171 with the result that when the gas streams reach the secondary combustion chamber, full combustion of the unburned content of the streams will be established and the generated heat will ignite and sustain combustion of the fuel mixture contained within the secondary combustion chamber, the products of combustion of the said mixture in combination with the gas flows from the ducts 171, then passing rearwardly out of the inner jet nozzle 173 as a forcible blast capable of creating powerful reactance thrust in a forward direction on the entire jet propulsion apparatus. It has been found that the utilization of combustion gases in combination with an added mixture of ignitable fuel and air will produce considerably more velocity in the jet blast than would be obtained by combustion of the fuel and air mixture alone. It will be seen that the pattern in which the jet nozzles 169 and 173 are arranged permits a selection in the degree of propulsive thrust which may be expected from the apparatus. If the valves 168 are fully closed, the combustion gas jets from the nozzles 169 will be shut off and the gas streams will issue only from the center nozzle 173. In flight, when the aircraft carrying the jet propulsion apparatus is moving through the air at a speed of several hundred miles an hour, the atmospheric pressure in the compressor inlet port 9 and in the air scoop 11 will be greatly above normal and will be directly proportional to the flight speed of the apparatus and will be augmented or detracted from depending on whether the aircraft is flying with or against the wind. Such ram pressure in the compressor inlet 9 will not only increase the pressure in the air chamber 42 but will also cause a higher velocity flow through the turbine and consequently through the jet nozzles, thus increasing the forward speed of the apparatus and correspondingly increasing the ram pressure. It will thus be evident that, when the apparatus is in flight, considerable back-pressure load is removed from the impeller 34 by the increased

pressure in the port 9 by the atmospheric ram effect. Since this will have a direct bearing on and will increase the rotational speed of the turbine rotor and consequently the forward speed of the apparatus, the ram pressure will continually reduce the suction load on the compressor up to the point where flow resistance through the apparatus passages beyond the compressor inlet will effect a pressure balance. This, however, will occur only at very high speeds since the flow paths have been designed with as few direction changes as possible in order to expedite final clearance of gases from the jet nozzles. The flight speed of the apparatus also creates influx of air at considerable pressure through the air scoop 11 into the shell chamber 24, whence it may flow as a cooling medium rearwardly over the outer surfaces of the various combustion chambers and combustion gas ducts to exhaust through the open rear end of the chamber 24. However, due to the obstruction to flow which is presented by the bulk of the combustion chambers, the turbine housing, the various ducts and the secondary combustion chamber, considerable pressure will be built up in the chamber 24, with the result that the air streams entering the turbine through the ports 105 and entering the ducts 167 through the ports 178 will be at considerable velocity, thus adding to the mass of gas finally issuing from the jet nozzles and directly affecting the thrust effort of the apparatus. In order to take full advantage of the cooling effect produced by the air on the turbine vanes, the flow of air into the secondary combustion chamber through the ducts 203 may be variably controlled by settings of the valves 207 so as to supply combustion air only in the amount needed to augment that entering by way of the ports 105 and 178 in order to produce complete and instant combustion of the fuel mixture in the secondary combustion chamber.

When aircraft propelled by free-flow jet power are flown in the rarified atmosphere at very high altitudes a material drop in the thrust developed by the jet propulsion devices has been noted. This is primarily due to lack of oxygen in the atmosphere sufficient to produce complete combustion of the fuel mixture in order to maintain or exceed the forward speed necessary to produce sufficient air flow through the apparatus to produce satisfactory combustion. Such a condition may be satisfactorily met with the apparatus of my invention by shifting the speed-change gearing so as to cause the compressor impeller to revolve at a much higher rotational speed than the turbine rotor, thereby causing the intake of sufficient excess air into the apparatus to produce the required amount of oxygen to sustain combustion in the combustion chambers which are being fired at a much slower speed than the rate at which the compressor is rotating.

I claim:

1. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a separate turbine passage and said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, said unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced into said air chamber, means for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge and turbine passages of the primary combustion chambers, means for introducing flows of fuel and air into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

2. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a separate turbine passage and said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced into said air chamber, means for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge and turbine passages of the primary combustion chambers, means for introducing flows of fuel and air into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

3. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a separate turbine passage and said secondary combustion chamber having an inlet passage and a

jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, said unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced into said air chamber, means for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge and turbine passages of the primary combustion chambers, means for introducing flows of fuel and air into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber to absorb and carry off radiated heat from said turbine and said primary and secondary combustion chambers, means for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge and turbine passages of the primary combustion chambers, means for introducing flows of fuel and air into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

4. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a separate turbine passage and said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, said unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced into said air chamber, means for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge and turbine passages of the primary combustion chambers, means for introducing flows of fuel and air into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, into said secondary combustion chamber, means for introducing flows of air from said shell chamber and from said compressor respectively into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

5. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a separate turbine passage and said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, said unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced into said air chamber, means for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge and turbine passages of the primary combustion chambers, means for introducing flows of fuel and air into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber, a shell en-

closing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, into said secondary combustion chamber, means for introducing flows of air from said shell chamber directly into said secondary combustion chamber and into said turbine passage, means for introducing a flow of air from said compressor into said secondary combustion chamber, said air flows into the secondary combustion chamber combining with said fuel charges therein to form combustible fuel mixtures, and means for igniting the fuel mixtures in said secondary combustion chamber.

6. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a separate turbine passage and said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, said unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced into said air chamber, means for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge and turbine passages of the primary combustion chambers, means for introducing flows of fuel and air into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, into said secondary combustion chamber, means for introducing flows of air from said shell chamber directly into said secondary combustion chamber and into said turbine passage, means for introducing a flow of air from said compressor into said secondary combustion chamber, means for variably regulating the flow of air from the compressor into the secondary combustion chamber, said air flows into the secondary combustion chamber combining with said fuel charges therein to form combustible fuel mixtures, and means for igniting the fuel mixtures in said secondary combustion chamber.

7. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the combustion chamber discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into the inlet passage of said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

8. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor

unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor unit impeller, said air compressor having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the combustion chamber discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, valve means for opening and closing said combustion chamber discharge ports, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into the inlet passage of said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

9. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor unit impeller, said air compressor having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the combustion chamber discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, valve means for opening and closing said combustion chamber discharge ports, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into the inlet passage of said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

10. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor unit impeller, said air compressor having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the combustion chamber discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, valve

means for opening and closing said combustion chamber discharge ports and connected with and operative by said turbine rotor, said air chamber valve and said discharge port valve being correlated so that when one valve is open the other is closed, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into the inlet passage of said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

11. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said air compressor unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge passages and through the combustion discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, valve means for opening and closing said combustion chamber gases flowing in the jet discharge and turbine passages, valve means for opening and closing said combustion chamber discharge ports and connected with and operative by said turbine rotor, said air chamber valve and said discharge port valve being correlated so that when one valve is open the other is closed, means for introducing flows of cooling air from said cooling air chamber into said turbine passage and past said turbine rotor in timed sequence to the opening and closing of said combustion chamber discharge port valve, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into the inlet passage of said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

12. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said air compressor unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, conduits connecting said compressor and said secondary combustion chamber through which air under pressure may be introduced into said secondary combustion chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge passages and through the combustion chamber discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into the inlet passage of said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

13. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combusition chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said air compressor unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, conduits connecting said compressor and said secondary combustion chamber through which air under pressure may be introduced into said secondary combustion chamber, valves in said conduits and adjustable to regulate the volume of air entering said secondary combustion chamber from said compressor, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge passages and through the combustion chamber discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber to form a combustible fuel mixture therein, and means for diverting a portion of the combustion gases from said primary combustion chambers into the inlet passage of said secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

14. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said air compressor unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge passages and through the combustion discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, valve means for opening and closing said combustion chamber discharge ports and connected with and operative by said turbine rotor, said air chamber valve and said discharge port valve being correlated so that when one valve is open the other is closed, means for introducing flows of cooling air from said cooling air chamber into said turbine passage and past said turbine rotor in timed sequence to the opening and closing of said combustion chamber discharge port valve, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber inlet passage to form in the latter chamber a combustible fuel mixture, means disposed in and for controlling flow of combustion gases through the jet nozzles of the primary combustion chamber, and means connecting the latter jet nozzles with the inlet passage of the secondary combustion chamber for conducting a portion of the combustion gases from the primary combustion chambers into the secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

15. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine

passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said air compressor unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge passages and through the combustion discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, valve means for opening and closing said combustion chamber discharge ports and connected with and operative by said turbine rotor, said air chamber valve and said discharge port valve being correlated so that when one valve is open the other is closed, means for introducing flows of cooling air from said cooling air chamber into said turbine passage and past said turbine rotor in timed sequence to the opening and closing of said combustion chamber discharge port valve, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber inlet passage to form in the latter chamber a combustible fuel mixture, valves in and for regulating flow of combustion gases through the jet nozzles of the primary combustion chamber, and means connecting the latter jet nozzles with the inlet passage of the secondary combustion chamber for conducting a portion of the combustion gases from the primary combustion chambers into the secondary combustion chamber to establish and sustain ignition of the fuel mixture in the latter chamber.

16. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chambers, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said air compressor unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge passages and through the combustion discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, valve means for opening and closing said combustion chamber discharge ports and connected with and operative by said turbine rotor, said air chamber valve and said discharge port valve being correlated so that when one valve is open the other is closed, means for introducing flows of cooling air from said cooling air chamber into said turbine passage and past said turbine rotor in timed sequence to the opening and closing of said combustion chamber discharge port valve, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber inlet passage to form in the latter chamber a combustible fuel mixture, valves in and for regulating the flow of combustion gases through the jet nozzles of the primary combustion chambers, means for operating said nozzle valves in unison to effect diversion of combustion gas from the primary combustion chamber nozzles into said secondary combustion chamber, and means connecting the latter jet nozzles with the inlet passage of the secondary combustion chamber for conducting the diverted combustion gases into the latter chamber to establish and sustain thereon ignition of the fuel mixture.

17. Jet propulsion apparatus comprising a turbine having primary combustion chambers associated therewith and a secondary combustion chamber, said primary combustion chambers each having a jet discharge passage and a discharge port opening into a turbine passage separate from the jet discharge passage, said secondary combustion chamber having an inlet passage and a jet nozzle, said jet discharge and turbine passages of each primary combustion chamber being merged beyond the latter to provide jet nozzles arranged in a pattern about the jet nozzle of the secondary combustion chamber, a turbine rotor associated with the turbine passage

of each primary combustion chamber and rotatably powered by flow of combustion gases resulting from ignition of fuel charges in the latter combustion chamber, an air compressor unit having an impeller operatively connected with and driven by said turbine rotor, speed change means interposed between and for selectively varying the rotational ratios between said turbine rotor and said compressor impeller, said air compressor unit having therein a compressed air chamber and an air inlet port through which atmospheric air may be drawn by said impeller and forced under pressure into said air chamber, a shell enclosing said turbine, secondary combustion chamber and air compressor and defining thereabout a cooling air chamber, said shell having an air scoop concentric with said air inlet port and operative during movement of said apparatus through the air to collect and direct atmospheric air into and through said shell chamber, a valve interposed between and for admitting charges of air from said air chamber into the respective primary combustion chambers, means for injecting charges of combustible liquid fuel into said primary combustion chambers to form fuel mixtures with the air-charges therein, means for igniting said fuel charges to establish said flows of combustion gases through the jet discharge passages and through the combustion discharge ports into the turbine passages, means for variably regulating the effective area of each combustion chamber discharge port to control the relative proportions of combustion gases flowing in the jet discharge and turbine passages, valve means for opening and closing said combustion chamber discharge ports and connected with and operative by said turbine rotor, said air chamber valve and said discharge port valve being correlated so that when one valve is open the other is closed, means for introducing flows

of cooling air from said cooling air chamber into said turbine passage and past said turbine rotor in timed sequence to the opening and closing of said combustion chamber discharge port valve, means for introducing flows of fuel into said secondary combustion chamber, means for introducing charges of air from said air cooling chamber into said secondary combustion chamber inlet passage to form in the latter chamber a combustible fuel mixture, valves in and for regulating the flow of combustion gases through the jet nozzles of the primary combustion chambers, said valves having operating elements thereon, and a movable element associated with each valve operating element for operating said nozzle valves in unison to effect diversion of combustion gas from the primary combustion chamber nozzles into said secondary combustion chamber, and means connecting the latter jet nozzles with the inlet passage of the secondary combustion chamber for conducting the diverted combustion gases into the latter chamber to establish and sustain thereon ignition of the fuel mixture.

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