United States Patent [19]

Sharpe

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[54] **SELF-STARTING AIR FLOW INDUCING REACTION MOTOR**

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[52] **U.S. Cl.** **60/269,** 60/269, 60/39.49, 60/203, 60/261, 60/262, 60/263, 60/267

[51] **Int. Cl.** **F02k 3/00**

[58] **Field of Search** 60/267, 269, 240, 60/258, 39.49, 235, 243, 39.33, 270, 203; 137/15.1, 15.2; 417/184

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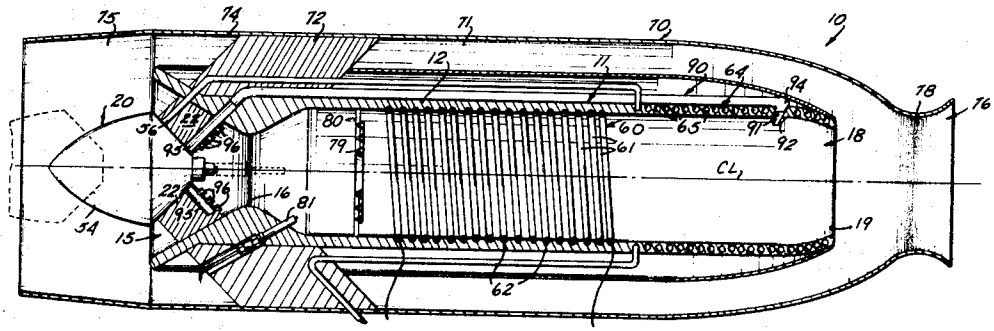
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[57] **ABSTRACT**

An engine including a self-starting engine compressor unit comprising a burner duct defining a converging-diverging inlet at its forward end, a converging exhaust nozzle at its rear end, and a combustion chamber therebetween; a fuel injection device for injecting fuel under pressure axially through the throat of the inlet into the combustion chmaber to draw air therewith into the chamber; and preheater means for heating the chamber to a predetermined temperature. The compressor unit may include a bypass duct encircling the burner duct with an inlet opening forward of the inlet to the burner duct and a converging exhaust opening rearward of the exhuast nozzle so that air will be drawn through the bypass duct by the jet pumping action of the exhaust gases from the burner duct in combination with the exhaust opening in the bypass duct. The fuel injection device may be equipped with pressure responsive means for transferring the point of injection from forward of the throat of the inlet of the burner duct to a point rearward of the throat and within the combustion chamber. The compressor unit may be embodied in a jet engine as a start stage with intermediate and final ram-jet type stages.

6 Claims, 14 Drawing Figures



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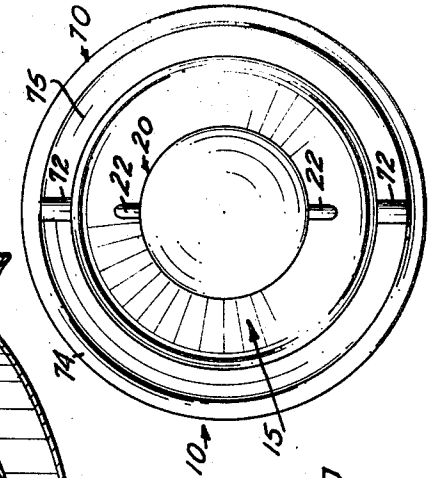


Fig 2

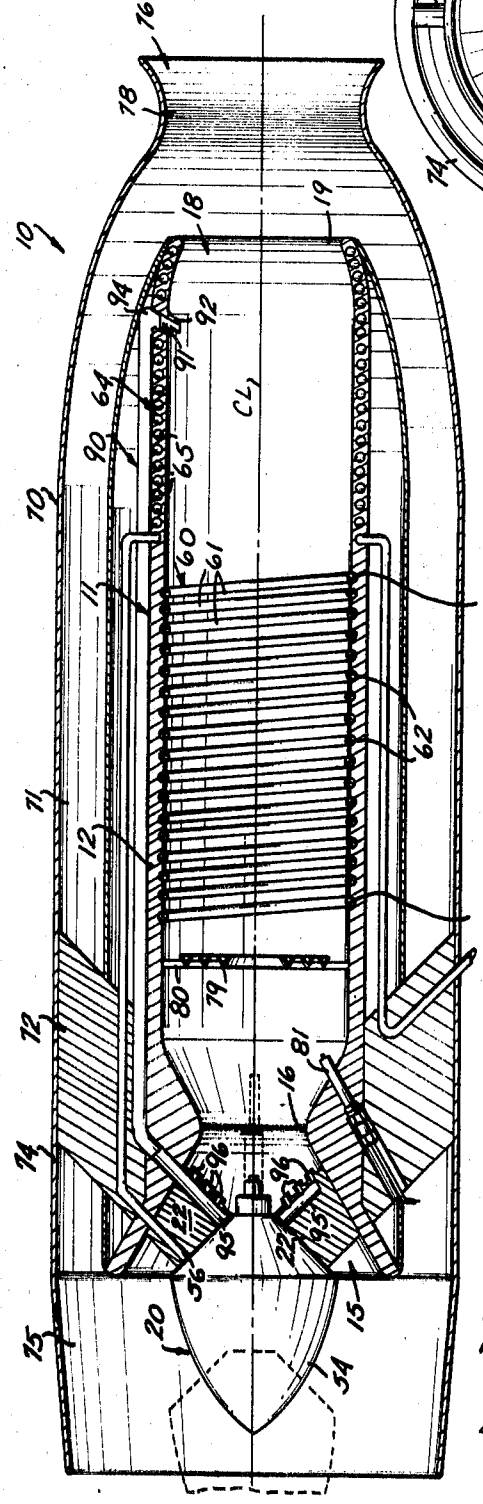


Fig 1

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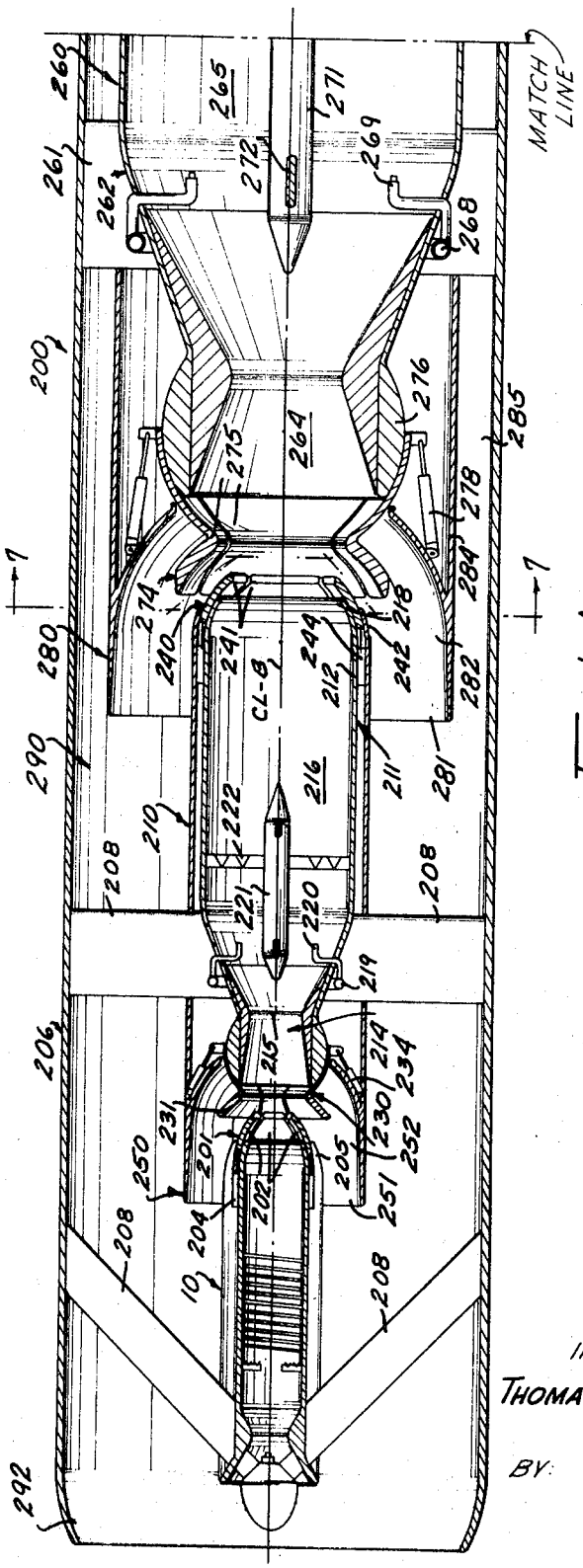


FIG 6A

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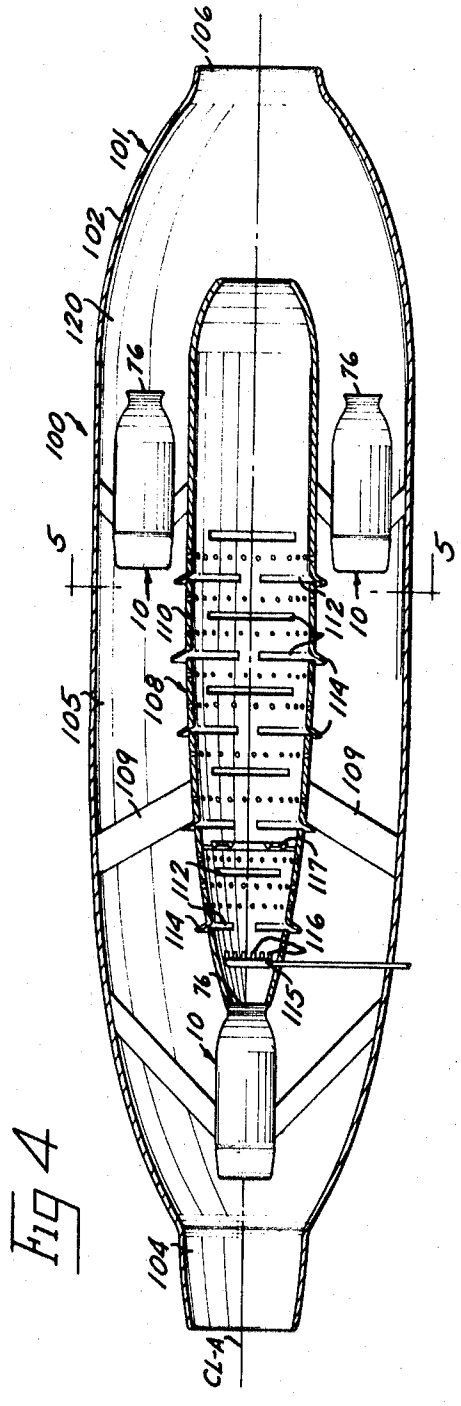


FIG 4

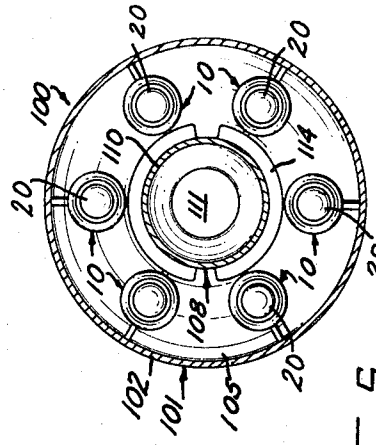


FIG 5

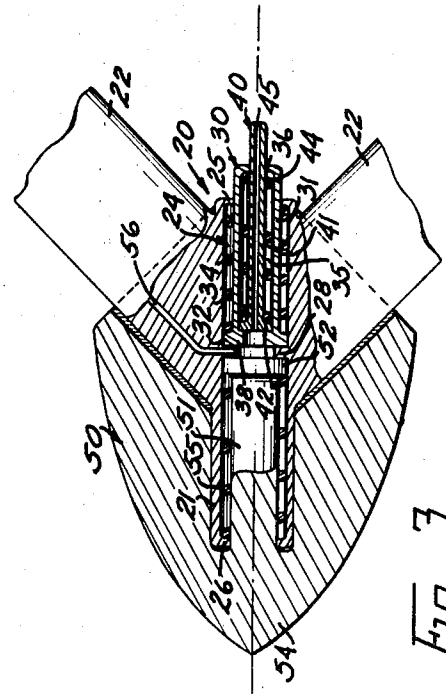


FIG 3

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FIG 7

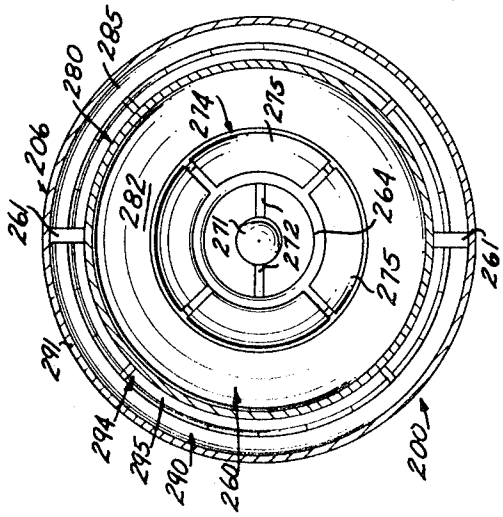
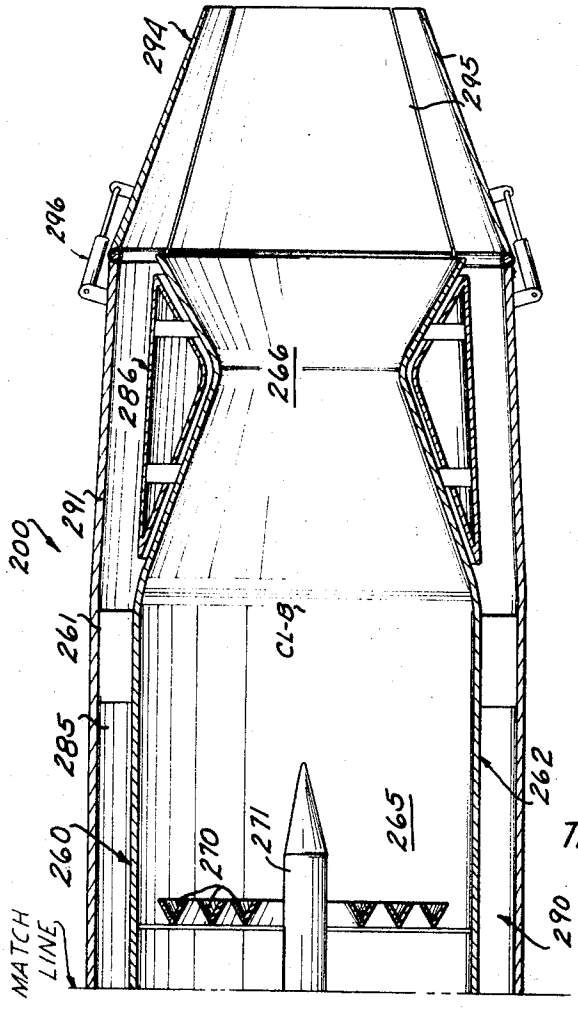


FIG 6B



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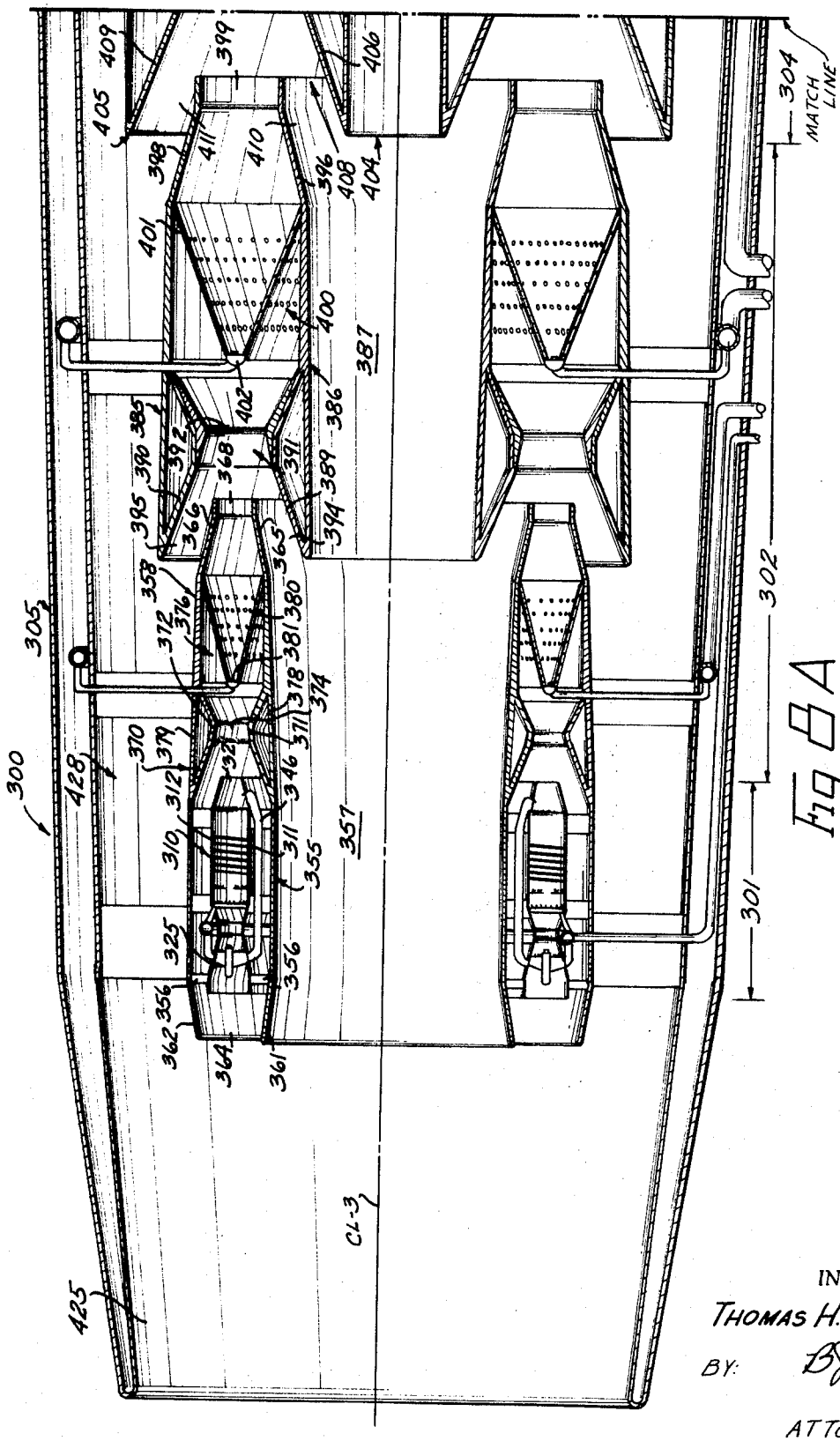


FIG 8A

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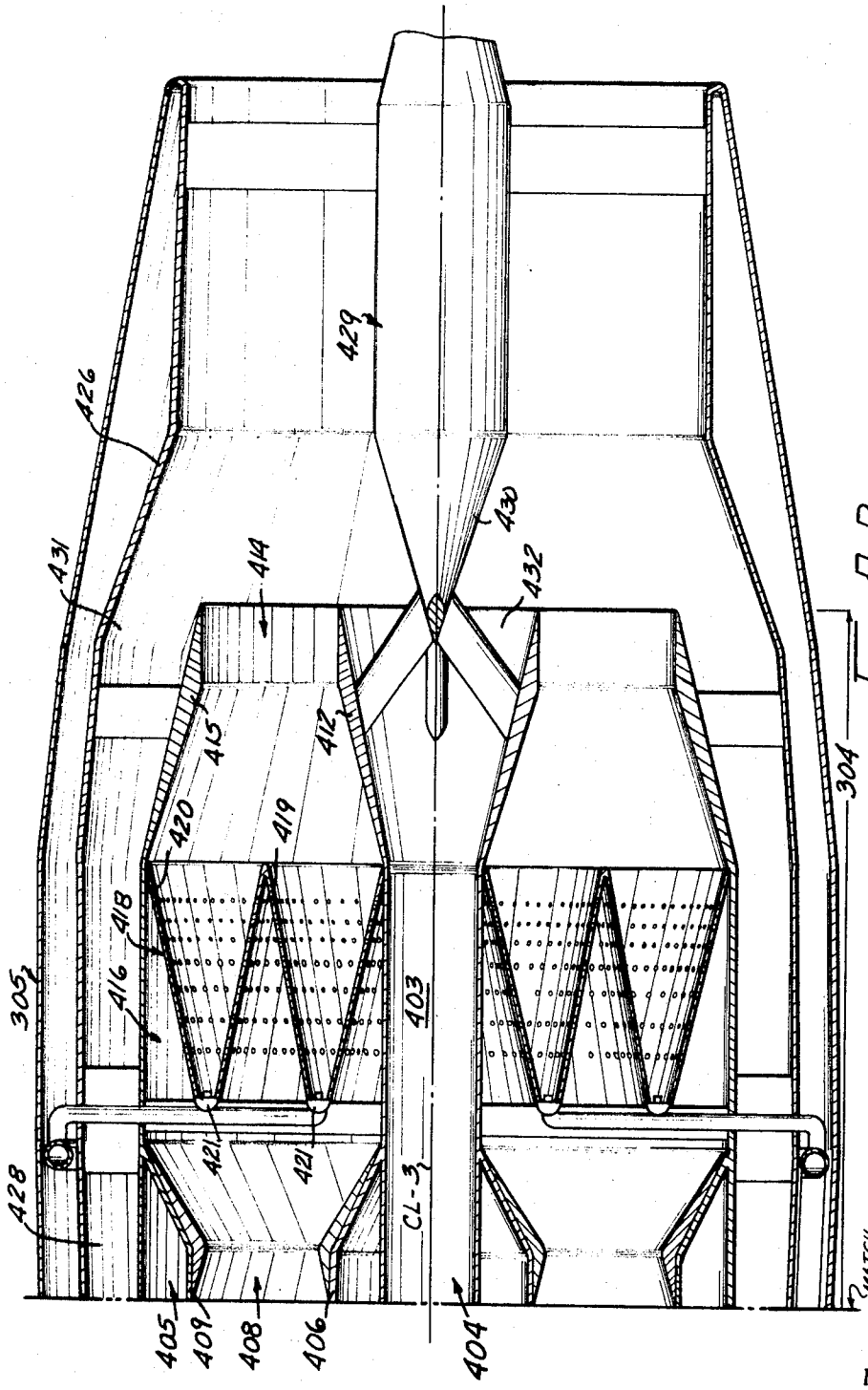


FIG 8B

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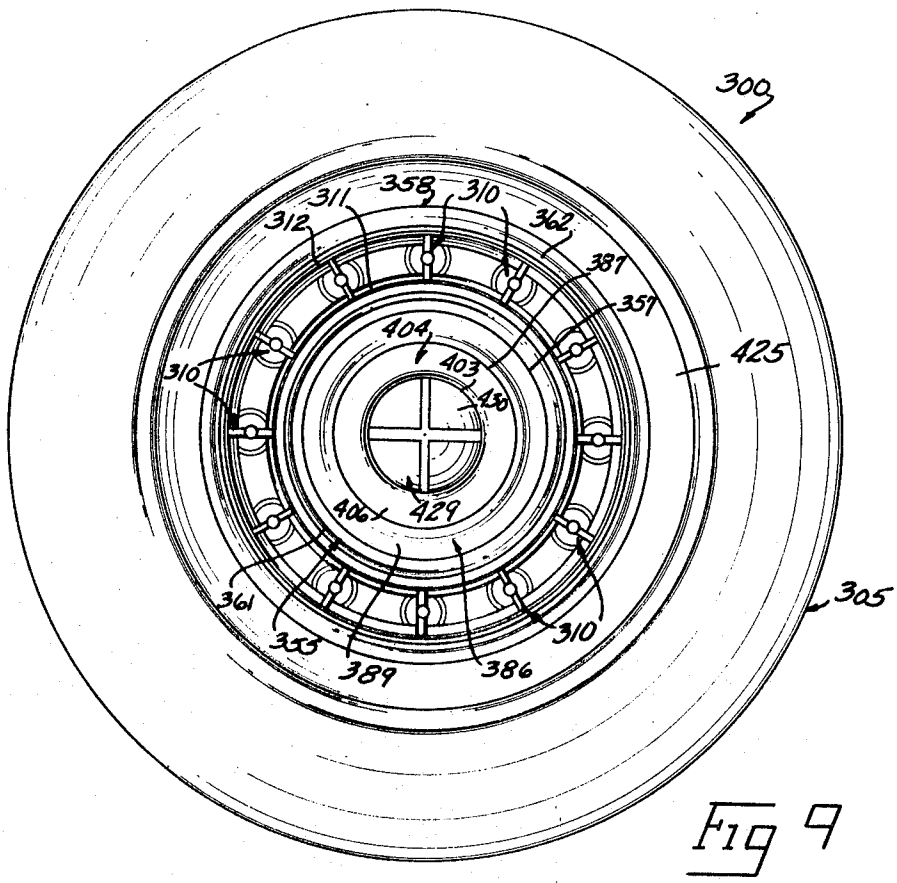
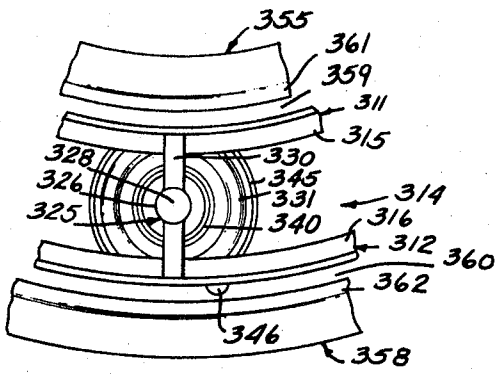


Fig 9

Fig 11



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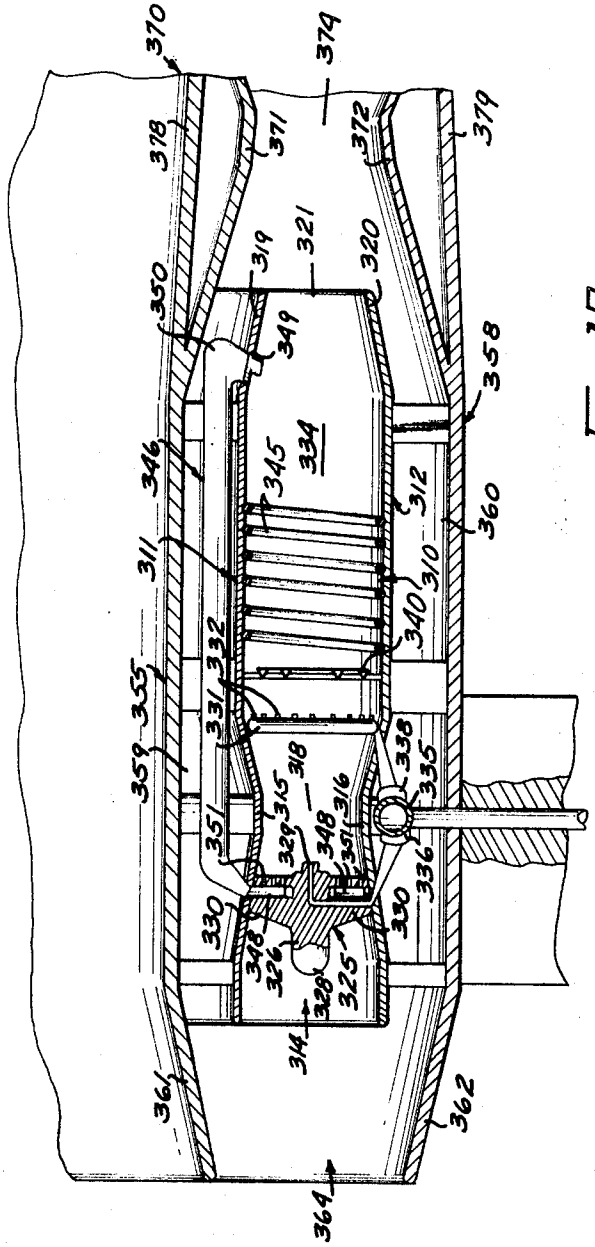


Fig 10

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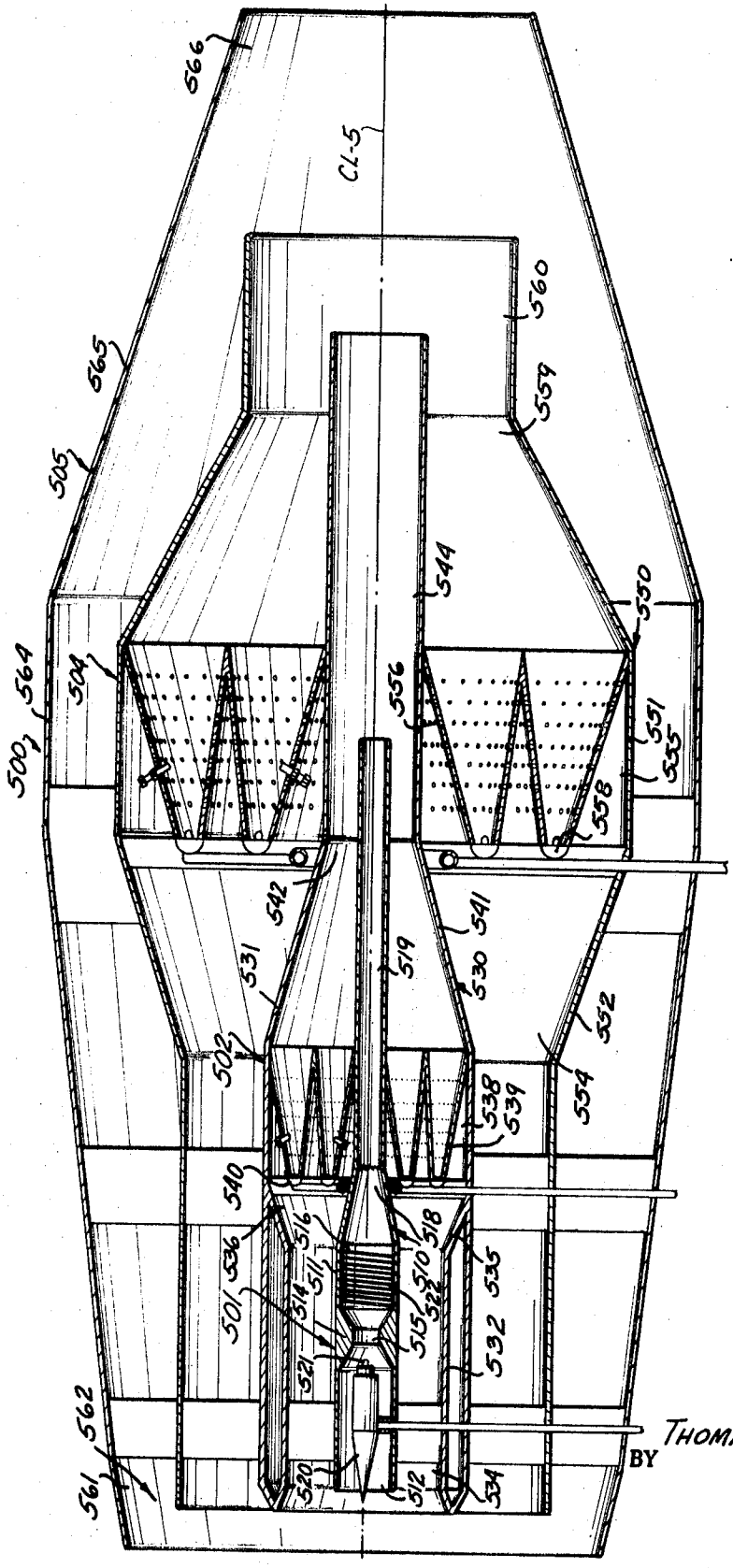


FIG 12

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SELF-STARTING AIR FLOW INDUCING REACTION MOTOR

BACKGROUND OF THE INVENTION

Because jet engines must be capable of operating at low plane speeds, currently used engines require a compressor stage for supplying air under pressure to the burner section thereof and a turbine stage driven by the exhaust gases of the burner section to rotate the compressor stage. This requirement for rotating machinery has increased the weigh of the engine as well as limited the maximum temperatures within the engine. Also, the high rotational speed of the rotating parts has required critical dynamic balancing of the parts and extensive maintenance to keep the engine operating properly.

SUMMARY OF THE INVENTION

These and other problems associated with the prior art are overcome by the invention disclosed herein by providing a means for supplying air to the burner section of the engine which requires no rotating parts in the compressor itself or in the engine after the burner section. The invention maintains operation while the engine is stationery or moving at slow speeds. Because of the lack of moving parts, the temperatures within the engine can be raised to produce a more effective operation.

The apparatus of the invention includes a compressor start stage comprising a burner duct including a burner section and an exhaust nozzle, an inlet duct at that end of the burner duct opposite the exhaust nozzle, a fuel injection device for injecting fuel under pressure axially through the reduced diameter throat of the inlet duct and into the burner duct to draw air into the burner section through the inlet duct, and a pre-heater for heating the burner section. The exhaust from the start stage may be injected through the inlet duct of at least one intermediate stage to achieve a jet pump action therethrough and pressurize the burner section of the intermediate stage. Fuel injected into the intermediate stage supports combustion therein and the exhaust therefrom may be injected into the main engine stage to produce combustion and a final thrust.

These and other features and advantages of the invention will become more fully understood upon consideration of the following specification and accompanying drawings wherein like characters of reference designate corresponding parts throughout the several views and in which:

FIG. 1 is an enlarged longitudinal cross-sectional view of one embodiment of the invention;

FIG. 2 is a front view of the start stage of FIG. 7;

FIG. 3 is an enlarged cross-sectional view of the fuel injection head of the start stage of FIG. 1;

FIG. 4 is a longitudinal cross-sectional view showing the embodiment of FIG. 1 installed in an engine;

FIG. 5 is a transverse cross-sectional view taken along line 5—5 in FIG. 4;

FIG. 6A is a longitudinal cross-sectional view of a portion of another embodiment of the invention;

FIG. 6B is a continuation of FIG. 6A showing the rest of the embodiment;

FIG. 7 is a cross-sectional view taken along line 7—7 in FIG. 6A;

FIG. 8A is a longitudinal cross-sectional view of a portion of a second embodiment of the invention;

FIG. 8B is a continuation of FIG. 8A;

FIG. 9 is an inlet end view of the embodiment of FIG. 8A;

FIG. 10 is an enlarged cross-sectional view of one unit of the start stage of FIG. 8A;

FIG. 11 is an inlet end view of FIG. 10; and,

FIG. 12 is a longitudinal cross-sectional view of still another embodiment of the invention.

These figures and the following detailed description disclose specific embodiments thereof, however, it is to be understood that the inventive concept is not limited thereto since it may be incorporated in other forms.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Referring now to FIGS. 1–3, the first embodiment of the invention includes a self-starting jet pump compressor unit **10**. This unit is capable of sustaining combustion at zero forward speed and to produce an increased pressure at its exhaust or pump end.

The unit **10** includes a generally cylindrical burner duct **11** with an annular duct wall **12** forming a substantially constant diameter burner chamber **14** intermediate its ends, a converging-diverging inlet **15** with a reduced diameter throat **16** smaller than the diameter of the burner camber **14** at the front end of duct **16**, and a converging exhaust nozzle **18** at the rear end of duct **11** with a throat **19** of a diameter smaller than that of chamber **14**.

A fuel injection assembly **20** is positioned just forwardly of inlet **15** for injecting fuel through inlet **15** and into chamber **14** axially along the centerline CL of duct **11**. Referring to FIG. **3**, the assembly **20** includes a cylindrical stationary housing **21** concentrically mounted forwardly of inlet **15** by struts **22** attached to duct wall **12**. Housing **21** defines an axially extending cylindrical passage **24** concentric about centerline CL of duct **11**. An inwardly extending annular retaining lip **25** extends around and projects into passage **24** at its rear end and a similar annular retaining lip **26** extends around and projects into passage **24** at its forward end. An annular abutment **28** extends around passage **24** at its central portion.

An intermediate extension tube **30** is slidably received in passage **24** between lip **25** and abutment **28**. Tube **30** includes a cylindrical body **31** of a constant diameter just sufficient to slidably pass through the opening of lip **25** and an annular projecting flange **32** at the forward end thereof just sufficient to slidably move along passage **24** but be retained between abutment **28** and lip **25**. A compression coil spring **34** is received about the body **31** of tube **30** between flange **32** and lip **25** to constantly urge tube **30** toward abutment **28**. A central support passageway **35** axially extends through tube **30** with an annular inwardly extending lip **36** at its rear end and a similar lip **38** at its forward end.

A fuel nozzle tube **40** is slidably received in passageway **35**, and includes a main body portion **41** of constant diameter just sufficient to pass through the opening of lip **36** with an annular outwardly projecting flange **42** at its forward end sufficient to slidably move in passageway **35** and be retained between lips **36** and **38**. A compression coil spring **44** is received about the main body portion **41** between lip **36** and flange **42** to constantly urge tube **40** forwardly against lip **38** in passageway **35**. An axially extending fuel passage **45** is defined through nozzle tube **40** which communicates with

passage 24 in housing 21 at its forward end and into the burner duct 11 at its rear end.

An inlet spike 50 is slidably mounted about housing 21 and in passage 24 forwardly of abutment 28 and includes a central shaft 51 of a constant diameter just sufficient to slidably pass through the opening defined by lip 26, a disc 52 on the rear end of shaft 51 slidably received in the forward portion of passage 24 and retained between abutment 28 and lip 26, and a conical spike head 54 on the forward end of shaft 51 and extending back over the housing 21. A compression coil spring 55 is received around shaft 51 between disc 52 and lip 26 to constantly urge spike 50 rearwardly toward abutment 28.

A fuel line 56 communicates with passage 24 through abutment 28 and with a pressurized fuel supply source (not shown). In the fully retracted position, the rear end of the intermediate extension tube 30 is substantially flush with the rear end of housing 21 and the discharge end of the nozzle tube 40 is positioned axially within the inlet 15 forward of its throat 19 so that fuel discharged from fuel passage 45 will be injected axially through throat 19 into the burner chamber 14. The spike head 54 is fully retracted rearwardly over housing 21 and about struts 22. The operation of the assembly 20 will be explained in more detail hereinafter.

A preheater assembly 60 is mounted in the burner chamber 14 for preheating same prior to injection of fuel therein in order to start unit 10. Assembly 60 may be any of a number of available preheating means and is shown as a heating coil 61 carried within appropriate recesses 62 around the inside of duct wall 12 at the burner chamber. This allows substantially unrestricted passage of the combustion medium through chamber 14. Coil 61 is connected to an appropriate power source (not shown) to heat same as will be explained.

Fuel line 56 is connected to the pressurized fuel supply source through a heat transfer section 64 located in duct wall 12 at the exhaust nozzle 18 and includes a series of passages 65 in duct wall 12. The fuel passes through the passages 65 on its way to the fuel injection assembly 20 to be heated while at the same time cooling the duct wall 12.

A by-pass duct 70 is concentrically located about the burner duct 11 and defines a central opening 71 therethrough into which the duct 11 is positioned on struts 72. The duct wall 74 defines a diverging inlet 75 just forward of the inlet 15 of duct 11 and a converging-diverging outlet 76 just rearwardly of exhaust nozzle 18. As combustion takes place within burner chamber 14, the discharging exhaust gases from the exhaust nozzle 18 pass through the reduced diameter throat 78 of outlet 76 to cause air to be drawn into inlet 75 by a jet pump effect.

In order to retain the combustion within the burner chamber 14, conventional flame holders 79 are concentrically mounted in burner chamber 41 rearwardly of the throat 16 of inlet 15. The flame holders 79 are carried by mounting bars 80 attached to duct wall 12 of the duct 11. Igniter plugs 81 may be provided to start combustion.

A feedback bleed tube 90 may be fitted to the duct 11 and provided with an inlet 91 at the converging section of exhaust nozzle 18. A forwardly facing scoop 92 is provided within duct wall 12 to direct a small portion of the high velocity exhaust gases into a pressure reservoir 94 in tube 90. The trapped gases pressurize the tube 90 and travel forwardly along tube 90 to a manifold 95 in struts 22 to pressurize same. The gases then pass from manifold 95 back into inlet 15 through nozzles 96 to force more air into chamber 14.

OPERATION

In operation, power is first supplied to the preheater assembly 60 to heat the air within the burner chamber 14 to the approximate ignition temperature of the fuel. This also heats the fuel within the heat transfer section 64 so that it will be substantially completely vaporized when it leaves the passage 45 in fuel nozzle tube 40. When the appropriate temperature is reached, the fuel supply injects the fuel through the passage 24 and out of the fuel passage 45 through the throat 16 of inlet 15 and into the heated air in the burner chamber 14. The igniter plugs 81 are powered in conventional manner so that as the incoming high velocity fuel stream mixes with the air combustion takes place. At the same time, the incoming fuel stream draws more air into burner chamber 14 to pressurize same and supply more air to support combustion. The preheater assembly 60 and igniter plugs 81 are then de-powered and the combustion is self-sustaining. It is to be understood that the preheater assembly 60 may be integrated with the heat transfer section 64 or that the fuel may be preheated before it reaches the section 64 and this heat used to heat chamber 14 without or in combination with the assembly 60.

As the exhaust gases exit through the exhaust nozzle 18 of duct 11, they pass through the throat 78 of outlet 76 to create a suction at the inlet 75 to draw additional air into unit 10 to further pressurize the burner chamber 14.

Since the unit 10 is designed for use as a compressor stage in a jet engine as will be described, the fuel injection assembly 20 is provided with means for moving the point of injection of the fuel from forward of throat 16 to a position behind the throat in burner chamber 14 when the pressure within the burner chamber 14 due to the ram effect from the velocity of the unit is sufficient to support combustion. This is provided by increasing the pressure of the fuel being supplied in response to ram pressure to a point where the intermediate extension tube 30 and fuel nozzle tube 40 are fully extended against the force of springs 34 and 44 as seen by dashed lines in FIG. 1. This converts unit 10 into a ram jet. At the same time, the spike 50 is moved forwardly as shown by dashed lines in FIG. 1 to open up the inlet 15 and allow more air to enter the unit 10. When the incoming air to inlet 15 becomes supersonic, spike head 54 of inlet spike 50 also generates a shock wave ahead of the inlet 15 to increase the static pressure.

The fuel nozzle tube 50 may also be equipped with multiple nozzles, each directing a stream of vaporized fuel substantially axially through the throat 16 of inlet 15 in lieu of the single fuel passage 45. This allows more fuel to be injected into the burner chamber 14 while at the same time generating enough jet pumping effect to force the necessary additional air into chamber 14 to support combustion and provide the necessary mixing of fuel and air.

ENGINE INSTALLATION

As seen in FIGS. 4 and 5, units 10 are installed in an engine 100 to provide sufficient pressure within the en-

gine to operate same even when the engine is stationary. Engine **100** has a main duct tube **101** having an annular side wall **102.** Wall **102** defines a diverging inlet opening **104** with a main burner chamber **105** of increasinG diameter thereafter and terminating in a converging outlet **106.** A tapered burner can **108** is concentrically located within chamber **105** by struts **109** between the side wall **102** of tube **101** and the can wall **110** of burner can **108.** The rear end of can wall **110** forms a converging exhaust nozzle **111** which discharges through the larger diameter outlet **106.** Burner can **108** is provided with dircumferentially extending slots **112** with forwardly facing air scoops **114** along the rear endges of slots **112** as will be explained.

The smaller forwardly facing end of burner can **108** joins with the rear end of a compressor unit **10** so that the exhaust gases and air discharged through the outlet **76** of unit **10** moves axially rearwardly along the centerline CL-A of the engine **100** and burner can **108.** An annular fuel manifold **115** is positioned in burner can **108** behind the outlet **76** of unit **10** and is provided with rearwardly facing nozzles **116** of conventional design for spraying the fuel into can **108.** Flame holders **117** may be provided in cna **108** to retain the flame.

A plurality of units **10** are positioned in the annular passage **120** between the burner can **108** and side wall **102** of duct tube **101** near the rear end of the can **108.** The units **10** are equally spaced circumferentially about can **108** so that the exhaust gases and air discharged from each of their outlets **76** are directed through the converging outlet **106** of duct tube **101** to draw air moving along the annular passage **120** into the burner can **108.**

In operation, the units **10** are ignited as set forth hereinabove to draw air into the inlet opening **104.** The unit **10** in front of the burner can **108** discharges the air-exhaust gas mixture therefrom axially along the burner can **108** while the remaining units **10** discharge the air-exhaust gas mixture through the outlet **106** to draw air along the annular passage **120.** The forwardly facing air scoops **114** direct a portion of the air from passage **120** into the interior of can **108** and the jet pumping action of the discharging air-exhaust gas mixture also draws additional air into the burner can **108.**

After the units **10** are operating, fuel is supplied to manifold **115** and discharged rearwardly by nozzles **116** where it is mixed with the air and exhaust gas mixture within burner can **108** and ignited by the heat of the exhaust gases from the forward unit **10** and combustion is sustained for the engine **100** to produce thrust.

SECOND ENGINE INSTALLATION

Referring to FIGS. **6A–7,** the unit **10** is incorporated in an engine **200** of the axial flow type. The unit **10** has the by-pass duct **70** removed therefrom and is equipped with a variable throat exhaust nozzle assembly **201.** Assembly **201** includes a plurality of arcuate vanes **202** slidably positioned about the nozzle **18** of duct **11** and selectively positioned by a plurality of fluid cylinders **204.** An appropriate guide **205** is provided to cause the vanes **202** to pass along the duct wall **12** to selectively throttle the exhaust gases being discharged from the burner chamber **14** as will be explained.

The unit **10** is concentrically mounted in the forward end of a cowling tube **206** described below by a pair of mounting struts **208.** Mounted rearwardly of the unit **10** concentrically in tube **206** is an intermediate stage **210** carried by struts **208.**

The intermediate stage **210** is aligned with the discharging exhaust gases from unit **10** and receives additional air from the jet pump arrangement at the forward end thereof to support combustion therein. Stage **210** includes a main tube **211** with an annular tube wall **212** concentrically located about the centerline CL–B of engine **200.** Tube **211** defines a converging-diverging inlet **214** at its forward end sPaced rearwardly of the vanes **202** on unit **10.** The diameter of the throat **215** of inlet **214** is larger than the maximum opening provided by vanes **202.**

Rearwardly of inlet **214** wall **212** defines a combustion chamber **216** and the rear end of tube **210** defines a converging exhaust opening **218.** A fuel manifold **219** is positioned around the outside of tube wall **212** at the forward end of combustion chamber **216** with a plurality of fuel nozzles **220** of conventional design protruding through the tube wall **212** into the combustion chamber **216.** An inlet spike **221** may be mounted in the forward end of combustion chamber **216** to act as a diffuser section within chamber **216** especially at supersonic air-exhaust gas mixture flow rates through the throat **215** of inlet **214.** Flame holders **222** may be provided aft of the fuel nozzles **220** to maintain the flame within combustion chamber **216.**

A throttling assembly **230** complimentary to the assembly **201** of unit **10** is provided forward of inlet **214.** Assembly **230** includes a plurality of movable vanes **231** around inlet **214** to define a converging-diverging opening. Vanes **231** are carried by the forward end of tube wall **212** and selectively positioned by a plurality of fluid cylinders **234** so as to vary the annular opening between vanes **202** and the converging walls **235** of vanes **231.** This serves to vary the amount of air pumped through the inlet **214** of stage **210** by the jet pumping action of the exhaust from unit **10.**

A variable throat exhaust nozzle assembly **240** is provided about the exhaust opening **218** of tube **211.** The nozzle assembly **240** is similar in construction to the nozzle assembly **201** with a plurality of arcuate vanes **241** slidably mounted in guide **242** and positioned by cylinders **244** so as to vary the discharge opening of stage **210** and throttle the exhause therefrom.

A generally semi-circular cowling **250** is provided about the throttling assembly **230** with its open mouth **251** extending over the rear end of unit **10** to provide an air metering passage **252** into the inlet **214** of stage **210.**

A main thrust stage **260** is mounted within cowling tube **206** rearwardly of intermediate stage **210** by struts **261** and aligned with the discharging exhaust gases from unit **10.** Additional air is supplied thereto by the jet pump arrangement at the forward end thereof to support combustion therein.

The main thrust stage **260** is similar in construction to the intermediate stage **210** except larger with a main thrust tube **262** having a converging-diverging inlet **264,** combustion chamber **265,** and a converging-diverging exhaust outlet **266.** A fuel manifold **268** encircles the outside of tube **262** and has a plurality of conventional fuel nozzles **269** projecting into combustion chamber **265.** A plurality of flame holder rings **270** are positioned in chamber **265** and an inlet spike **271** is mounted on struts **272** in the forward end of combustion chamber **265** to act as a diffuser section in cham-

ber 265, especially at supersonic air-exhaust gas mixture flow rates through inlet 264.

A throttling assembly 274 similar to assembly 230 and complimentary to the exhaust nozzle assembly 240 at the rear end of intermediate stage 210 is provided on the forward end of tube 262. The assembly 274 cooperates with assembly 240 similarly to the co-operation between assembly 230 and assembly 201 to selectively throttle the amount of air drawn through the inlet 264 of the main thrust stage 260 by the jet pumping action of the exhaust gases discharged by intermediate stage 210. Assembly 274 includes a plurality of movable vanes 275 around inlet 264 to form a converging-diverging opening and slidably mounted on guide 276. A plurality of fluid cylinders 278 control the position of the vanes 275.

A generally semi-circular cowling 280 is provided about the throttling assembly 274 similarly to cowling 250 of intermediate stage 210. The forwardly facing open mouth 281 of cowling 280 extends over the rear end of stage 210 to provide an air metering passage 282 into the inlet 264 of the main thrust stage 260. The cowling 280 includes an cylindrical annular outer wall 284 which extends rearwardly from mouth 281 to join with the thrust tube 262 at its combustion chamber. This provides an annular by-pass duct 285 around the main thrust stage 260 as will be explained.

A cooling ring assembly 286 is positioned around the reduced diameter portion of tube 262 at the exhaust outlet 266 to direct a portion of the air from the by-pass duct 285 along the outer surface of tube 262 and cool same.

The cowling tube 206 defines the outside of the engine and mounts the compressor unit 10, intermediate stage 210 and main thrust stage 260 in its central cavity 290. Tube 206 has an annular cylindrical side wall 291 which projects forwardly of the unit 10 to provide a diverging inlet duct 292 forwardly of unit 10 and terminates substantially in the same plane as the exhause outlet 266 of the main thrust stage 260.

A flap-type augmentated exhaust nozzle assembly 294 is mounted on the rear end of cowling tube 206. Assembly 294 includes a plurality of flaps 295 hinged to the tube 206 and positioned by fluid cylinders 296 in known manner. The varying of the position of flaps 295 serves to control the amount of by-pass air drawn through duct 285 by the jet pumping action of the exhaust from the main thrust stage 260.

OPERATION OF SECOND ENGINE INSTALLATION

In operation, the compressor unit 10 is ignited as set forth hereinabove. Its exhaust gases are injected axially through the inlet 214 of intermediate stage 210 which creates a jet pumping action to draw additional air into stage 210 through the annular metering opening defined between vanes 202 and 231 and also to draw additional air into the inlet 15 of unit 10. The jet pumping action of unit 10 pressurizes the burner chamber 216 of stage 210.

When fuel is sprayed into the chamber 216 by nozzles 220, ignition takes place because of the heat from the exhaust gases of unit 10 and operation of the intermediate stage 210 starts. The discharging exhaust gases from stage 210 are injected through the inlet 264 of the main thrust stage 260. This causes air to be drawn into the stage 260 through the annular opening between vanes 241 and 275 to pressurize the burner chamber 265 thereof. When fuel is supplied via nozzles 269 to chamber 65, ignition takes place from the heat of the exhaust gases of stage 210. The exhaust gases from stage 260 discharging through the nozzle assembly 294 causes additional air to be drawn into the engine via the inlet duct 292 to further pressurize the engine.

Because control systems for controlling the amount of fuel injected into the engine 200 as well as the position of the assemblies 201, 230, 240, 274 and 294 are available, these controls are not described. It will be seen that the jet pumping action of each stage is summed, sufficient operating pressure is maintained within the engine.

THIRD ENGINE INSTALLATION

Referring now to FIGS. 8A–10, the invention is embodied in engine 300 having a compressor stage 301, an intermediate stage 302, and a main thrust stage 304.

Engine 300 includes a main cowling tube 305 which mounts the various engine stages therein. The compressor stage 301 includes a plurality of compressor units 310 positioned within the forward portion of tube 305 and equally spaced concentrically about the centerline CL–3 of engine 300. The compressor units 310 are mounted between an inner tube ring 311 and an outer tube ring 312 concentrically located with respect to each other and to the centerline CL–3 to form a compressor annulus 314 therebetween. An outwardly projecting bend 315 is formed in inner ring 311 just inwardly of its forward end and, in conjunction with a complementary inwardly projecting bend 316 formed in outer ring 312, forms an annular throat 318 between the rings 311 and 312. The rear end of inner ring 311 is angled outwardly to form a nozzle flange 319 and in conjunction with the inwardly angled complementary flange 320 of outer ring 312, forms an annular exhaust nozzle 321 between rings 311 and 312. The rings 311 and 312 are arranged so that the throat 318 is axially aligned with exhaust nozzle 321.

Each unit 310 as best seen in FIGS. 10 and 11 includes a primary fuel metering assembly 325 positioned in the converging portion of annulus 314 forwardly of the throat 318 thereof. Assembly 325 has a cylindrical body 326 with a forwardly facing projection 328 extending toward the inlet of annulus 314 and a rearwardly facing low pressure fuel nozzle 329 for injecting fuel axially through the throat 318 as will be explained. Unit 310 is mounted by struts 330 connected to rings 311 and 312. Positioned rearwardly of throat 318 in alignment with assembly 325 is a ring manifold 331 having a plurality of rearwardly facing fuel nOzzles 332 in the forwared end of the annular combustion chamber 334 defined by rings 311 and 312.

Each nozzle 329 and ring manifold 331 is supplied fuel from a distribution manifold 335 extending around the outside of the ring 312 within bend 316. Each nozzle 329 is connected to manifold 335 through a low pressure bypass valve 336 that restricts fuel flow to the nozzle inversely to the fuel pressure to allow the fuel to flow to nozzle 329 at lower pressure and decrease the flow as pressure increases until the fuel flow is cut off at nozzle 329 when a predetermined fuel pressure is reached. Each ring manifold 331 is connected to manifold 335 through a high pressure bypass valve 338 which allows fuel to flow to ring manifold 331 when the fuel pressure reaches the predetermined pressure at

which the fuel flow is cut off to nozzle 329. Flame holders 340 may be positioned in the combustion chamber 334 behind each fuel metering assembly 325 and ring manifold 331 to retain the flame in combustion chamber 334.

A heating coil 345 is placed in the combustion chamber 334 rearwardly of flame holders 340 behind each fuel metering assembly 325 so that preheating as described for unit 10 can take place. This insures starting of each unit 310.

An air bleed tube 346 similar to tube 90 for unit 20 connects the rear end of combustion chamber 334 with a chamber 348 in struts 330. Each tube 346 has a forwardly facing scoop 349 projecting into chamber 334 to direct the gases into a reservoir 350 in tube 346. A plurality of rearwardly facing ports 351 in struts 330 inject the gases from chamber 348 through throat 318 to assist in pressurizing combustion chamber 334.

An inner tubular section 355 is positioned inside of ring 311 and concentrically therewith by struts 356 to define an inner bypass 359 between section 355 and ring 311. An outer tubular section 358 is positioned outside of ring 312 and concentrically therewith to define an outer bypass 360 between section 358 and ring 312. An outwardly angled flange 361 is provided at the forward end of section 355 and, in conjunction with an inwardly angled flange 362 on the forward end of section 358, defines a diverging inlet 364 forward of the inlet of the compressor stage 301. The rearmost end of tubular section 355 is provided with an outwardly angled flange 365, which, in conjunction with an inwardly angled flange 366, forms an annular exhaust nozzle 368 for the first power unit 370 of intermediate stage 302.

Just rearwardly of the exhaust nozzle 321 of compressor stage 301, the inner tubular section 355 is provided with an outwardly projecting bend 371, which, in conjunction with a complementary inwardly projecting bend 372 in the outer tubular section 358, forms the inlet 374 of power unit 370 with throat 375 having a slightly larger opening than that of the exhaust nozzle 321 of compressor stage 301 and axially aligned therewith. This forms an annular combustion chamber 376 between inlet 374 and exhaust nozzle 368. A ring 378 covers the depression of bend 371 and a ring 379 covers the depression of bend 372 to provide a smooth inner surface along section 355 and a smooth outer surface along section 358.

An annular cone shaped burner shroud liner 380 is positioned in combustion chamber 376 with a plurality of fuel nozzles 381 positioned in the forward end of the liner 380 to supply fuel thereto in conventional manner. The liner 380 serves as a flame holder to retain the combustion flame within chamber 376.

The second power unit 385 of intermediate stage 302 includes an inner tubular section 386 and an outer tubular section 388. The forward ends of sections 386 and 388 project just forwardly of exhaust nozzle 368 of the first power unit and are provided with outwardly and inwardly directed projections 389 and 390 respectively to form an annular converging-diverging inlet 391 with throat 392 axially aligned with the exhaust opening in nozzle 368. Inlet passages 394 and 395 are defined between projection 389 and flange 365 and between projection 390 and flange 366. The rearmost ends of tubular sections 386 and 388 are provided respectively with an outwardly flaring flange 396 and an inwardly flaring flange 398 to form a converging exhaust nozzle 399.

An annular combustion chamber 400 is defined between inlet 391 and exhaust nozzle 399. An annular cone shaped burner shroud liner 401 is positioned in chamber 400 with a plurality of fuel nozzles 402 in the forward ends thereof to supply fuel thereto in conventional manner.

The main thrust stage 304 is positioned rearwardly of the second power unit 385 of intermediate stage 302 and includes an inner tubular section 404 projecting within the flange 396 of unit 385 and an outer tubular section 405 projecting around flange 398 of unit 385. The forward end of section 404 has an inwardly extending projection 406 to form an annular converging-diverging inlet 408 with an inwardly extending projection 409 on the forward end of tubular section 405. An annular inner inlet duct 410 to stage 304 is defined between flange 396 of unit 385 and projection 406 and an annular outer inlet duct 411 is defined between flange 398 of unit 385 and projection 409.

The rearmost end of tubular section 404 has an outwardly flaring flange 412 which forms a diverging exhaust nozzle 414 with an inwardly flaring flange 415 at the rearmost end of tubular section 405. This defines an annular combustion chamber 416 between inlet 408 and exhaust nozzle 414.

A compound burner can assembly 418 is positioned in combustion chamber 416. Can assembly 418 includes an annular cone shaped inner shroud liner 419 and outer shroud liner 420. The forward ends of liners 419 and 420 are provided with fuel nozzles 421 of conventional design to provide fuel to chamber 416.

The main cowling tube 305 defines a diverging inlet duct 425 forwardly of compressor stage 301 and a converging exhaust opening 426 rearwardly of the exhaust nozzle 414 of the main thrust stage 304. Since the cowling tube 305 is larger in diameter than any of stages 301, 302 or 304, a bypass duct 428 is provided along the length of engine 300 outside of stages 301, 302 and 304. A cone member 429 is positioned in the exhaust opening 426 with its forwardly facing tapered end 430 projecting within flange 412. The converging portiOn of tube 305 at exhaust opening 426 defines a bypass air inlet duct 431 with flange 415 and member 429 defines an inner air inlet duct 432 with flange 412.

OPERATION OF THIRD ENGINE INSTALLATION

Engine 300 is started similarly to engine 200. First, the heating coils 345 are supplied with electricity to heat same. This also heats the air within the annular combustion chamber 334 in the vicinity of each unit 310 to a temperature sufficient to ignite the fuel as with unit 10. It is also to be understood that coils 345 may extend completely around the rings 311 and 312 to achieve the same result.

When the desired temperature is reached, fuel under pressure is supplied to the low pressure fuel nozzle 329 of each unit 310. The fuel pressure is sufficiently low to not open valves 338 so that no fuel is supplied to chamber 334 from the nozzles 332 of ring manifold 331. The fuel is ejected from the low pressure nozzles 329 small streams at high velocity axially through the throat 318 of annulus 314 and into combustion chamber 334. This causes air to be drawn into chamber 334 with the fuel through throat 318 by the jet pumping influence of the fuel. When the fuel reaches the heated

air in chamber 334, it ignites to start combustion. The additional fuel and air entering chamber 334 sustains the combustion once it has started and the heat of combustion maintains the proper operating temperature in the chamber 334 thus allowing the coils 345 to be shut off.

The exiting exhaust gases from the exhaust nozzle 321 pumps additional air into the combustion chamber 376 of the first power unit 370 via the inlet 364, bypasses 359 and 360, and throat 375 of inlet 374 because of the jet pumping action of the gases in combination with the throat 375 of unit 370. This also draws additional air into the throat 318 of the compressor stage 301. A portion of the exhaust gases is trapped by the scoops 349 of the units 310 to pressurize the bleed tubes 346 and force these gases rearwardly out of ports 351 in struts 330. The jet pumping action of the exiting gases from the ports 351 forces additional air into the combustion chamber 334 to pressurize same and support combustion.

The exhaust gases from the compressor stage 301 passing into the chamber 376 of the first power unit 370 heats same to fuel ignition temperature whereupon fuel is sprayed from nozzles 381 into chamber 376 to start combustion within this unit. The exiting exhaust gases from the nozzle 368 of power unit 370 creates a jet pump effect as it passes through the throat 392 of the second power unit 385 to draw air into the combustion chamber 400 from the central passage 357 of the tubular section 355 and from the bypass duct 428 through the inlet passages 394 and 395 to support combustion. This also draws additional air into the front of engine 300 to further pressurize the inlet to units 310. Once combustion chamber 400 is pressurized, the fuel is sprayed therein by fuel nozzles 402 to start combustion.

The exhaust gases from the second power unit 385 are injected axially through the inlet 408 of the main thrust stage 304 to pressurize same from the jet pump action drawing air through inlet ducts 410 and 411 from the central passage 387 of inner tubular section 386 and from the bypass duct 428. Once the combustion chamber 416 is pressurized, fuel is sprayed therein from fuel nozzles 421 to start combustion.

As the exhaust gases from the main thrust stage 304 passes through the exhaust opening 426 in the cowling tube 305, they exert a jet pumping action drawing air through the bypass duct 428 and the central passage 403 of the tubular section 404 thus drawing more air into the inlet duct 425 and further pressurizing the stages 301, 302 and 304.

When the velocity of the engine 300 with respect to the ambient air is sufficient to sustain combustion pressure from the ram effect, control means (not shown) causes the fuel pressure to the metering assemblies 325 of compressor units 310 to be increased sufficiently to cause the valves 336 to shut off fuel flow to nozzles 329 and to open valves 338 to supply fuel to nozzles 332 since the jet pumping action of units 310 is no longer needed.

FOURTH ENGINE INSTALLATION

Referring now to FIG. 12, the fourth embodiment of the invention is an engine 500 which has a jet pumping action directed from the center of the engine outwardly. Engine 500 includes a compressor stage 501, an intermediate stage 502 and a main thrust stage 504 concentrically mounted about the centerline CL-5 of the main cowling tube 505.

The compressor unit 501 has an open duct 510 centrally located in cowling tube 505 at the forward end thereof. Duct 510 has a tubular wall 511 defining a cylindrical inlet passage 512 and with an annular projection 514 at the rear end of passage 512 defining a throat 515 and a combustion chamber 516 therebehind. Combustion chamber 516 is terminated by the wall 511 converging to form an exhaust nozzle 518 with an elongated cylindrical exhaust duct 519 extending through the intermediate stage 502.

A fuel injection assembly 520 similar to assembly 20 of unit 10 is positioned in inlet passage 512 so that the fuel nozzle 521, in its forward retracted position, is positioned ahead of throat 515 so that the fuel is sprayed axially therefrom through throat 515 into combustion chamber 516 and draws air into the chamber 516 similarly to that described hereinabove. The nozzle 521 may be made to extend through throat 515 similar to the assembly 20 for unit 10.

A preheater coil 522 is positioned in combustion chamber 516 similarly to coil 61 in unit 10. This heats the air in chamber 516 to start combustion.

The intermediate stage 502 includes an open ended duct 530 with a tubular wall 531 positioned concentrically about duct 510 of stage 501. Wall 531 has an inwardly projecting annular section 532 forming a reduced diameter inlet passage 534 around the duct 510 of stage 501 with an outwardly flaring rear end portion 535 in the vicinity of the converging wall 511 at exhaust nozzle 518 to form a diverging inlet 536 to combustion chamber 538. Chamber 538 is provided with a compound annular burner can assembly 539 with fuel nozzles 540 similar to assembly 418 in engine 300.

The duct wall 531 has an inwardly tapering section 541 behind the combustion chamber 538 to form a converging exhaust nozzle 542 with a cylindrical exhaust duct 544 extending through the main thrust stage 504 and concentrically about the duct 519 of stage 501. Duct 519 terminates within duct 544.

The main thrust stage 504 includes a duct tube 550 with a tubular wall 551 extending forwardly to the inlet ends of the stages 501 and 502 and concentrically about the duct tube 530 of stage 502. Wall 551 forms a reduced diameter cylindrical inlet passage about stage 502 with an outwardly flaring section 552 in the vicinity of the tapering section 541 of wall 531 in stage 502 to form a diverging inlet 554 to the combustion chamber 555. This chamber, like chamber 538 of stage 502, is provided with a compound burner can assembly 556 and fuel nozzles 558.

Duct wall 551 tapers inwardly after chamber 555 to form a converging exhaust nozzle 559 and a cylindrical exhaust duct 560 concentric about duct 544. It will be noted that duct 544 terminates within duct 560.

The cowling tube 505 has an outwardly flaring inlet wall section 561 extending from the vicinity of the forward end of combustion chamber 555 of stage 504 forward of the inlets to stages 501, 502 and 504 to define a diverging inlet 562. A cylindrical wall section 564 encircles the combustion chamber 555 of stage 504 and an inwardly tapered wall section 565 joins with the rear end of section 564 to extend past the end of duct 560 of stage 504 and form a converging discharge 566.

This engine is started similarly to the previous embodiments. The primary jet pumping action is per-

formed by the escaping exhaust gases from the stages **501, 502** and **504** and air is drawn into the engine starting from the inside and moving outwardly.

It is to be further understood that each compressor stage **301** of engine **300** or compressor stage **501** of engine **500** may be equipped with heat transfer means similar to the section **64** for unit **10** to preheat the fuel prior to injection into the engine. Further, it is to be understood that the fuel injection assembly **20** may be interchanged with the assembly **335** without departing from the scope of the inventive concept. Moreover, it is to be understood that any of the engines may be equipped with bypass air throttling means as illustrated for engine **200** and that those engines not having air bleed tubes in the compressor stage may be so equipped. A plurality of bleed tubes may be used in lieu of the tube **90** for unit **10.**

While specific embodiments of the invention have been disclosed herein, it is to be understood that full use of modifications, substitutions, and equivalents may be made without departing from the scope of the inventive concept.

I claim:

1. A self-starting engine unit including:

a burner duct including a combustion chamber and an exhaust nozzle;

a converging-diverging inlet at that end of said combustion chamber opposite said exhaust nozzle and defining a reduced diameter throat;

a fuel injection device for injecting fuel under pressure axially through said throat of said inlet and into said combustion chamber to draw air into said burner duct through said inlet, said fuel injection device including an injection nozzle having a discharge end, said nozzle having a first position so that its discharge end is located forwardly of said throat of said inlet and a second position so that its discharge end is located within said combustion chamber rearwardly of said throat; and,

preheater means in said combustion chamber for heating the air in said combustion chamber to a predetermined temperature.

2. The engine unit of claim **1** further including a bypass duct encircling said burner duct concentrically therewith, and defining an inlet forward of said inlet of said burner duct and a converging exhaust opening rearward of said exhaust nozzle so that, when the exhaust gases from said exhaust nozzle pass through said exhaust opening, air will be drawn through said bypass duct by the jet pumping action of the exhaust gases in combination with said exhaust opening.

3. The engine unit of claim **1** further including igniter means and flame holder means within said combustion chamber.

4. The engine unit of claim **2** further including throttling means for selectively varying the opening in said exhaust nozzle and the size of said exhaust opening.

5. A engine unit including:

a burner duct including a combustion chamber and an exhaust nozzle;

a converging-diverging inlet at that end of said combustion chamber opposite said exhaust nozzle and defining a reduced diameter throat;

a fuel injection device for injecting fuel into said combustion chamber, said fuel injection device including a housing; a plurality of struts mounting said housing concentrically in said inlet forward of said throat, said housing defining a central longitudinally extending primary passage therethrough and including a forward inwardly directed lip extending into said central passage about the forward end of said housing, an annular abuttment extending into said central passage intermediate the ends of said housing, and a rear inwardly directed lip extending into said central passage at the rear end of said housing, said forward and rear lips and said abuttment defining passages therethrough smaller in diameter than said primary passage; a spike member defining a recess in the rear end thereof receivable over the front end of said housing, said spike member including a central shaft concentrically located within said recess and slidably receivable through said passage in said forward lip and a disc on the rear end of said shaft slidably movable along said primary passage and retained between said forward lip and said abuttment; a first compression coil spring received around said shaft between said forward lip and said disc for constantly urging said disc rearwardly toward said abuttment and said spike member over the forward end of said housing; a nozzle assembly slidably received through said passage in said rear lip and defining a fuel discharge passage therethrough and including a flange on the forward end thereof slidably movable along said primary passage and retained between said rear lip and said abuttment; a second compression coil spring received around said assembly between said rear lip and said flange for constantly urging said nozzle assembly into said housing and said flange toward said abuttment, said housing defining a fuel passage communicating with said passage through said abuttment so that fuel supplied through said fuel passage will be discharged rearwardly through said fuel discharge, said injection device located so that the rearmost end of said nozzle assembly is forward of said throat of said inlet when said nozzle assembly is in its forwardmost retracted position and is rearward of said throat when said nozzle assembly is in its rearwardmost extended position, said spike member located in the converging portion of said inlet forward of said throat and defining an inwardly tapering surface that increases the effective opening between said spike member and said converging portion as said spike member moves from its rearwardmost position to its forwardmost position;

an electrical heating coil mounted within said combustion chamber and extending concentrically around the inside of said burner duct adjacent thereto for selectively heating the air in said combustion chamber;

a flame holder assembly mounted on said burner duct within said combustion chamber forwardly of said heating coil and rearwardly of said throat of said inlet;

a bleed tube communicating at one end with said combustion chamber at said exhaust nozzle, said struts carrying said fuel injection device defining rearwardly facing nozzles forwardly of said throat, said tube communicating with said rearwardly facing nozzles, said bleed tube including a forwardly facing scoop member projecting into said combustion chamber for directing a portion of the gases passing from said combustion chamber through

said bleed tube and rearwardly through said throat from said rearwardly facing nozzles; and,

a by-pass duct of a diameter larger than said burner duct concentrically located about said burner duct, said by-pass duct including a diverging inlet forward of said converging-diverging inlet and a converging-diverging outlet rearwardly of said exhaust nozzle.

6. A self-starting engine unit including:

an annular burner duct comprising an inner wall and an outer wall concentric with each other, said inner and outer walls defining an annular converging-diverging inlet at the forward end thereof having a reduced diameter throat, an annular combustion chamber rearwardly of said inlet and communicating therewith, and an annular converging exhaust nozzle at the rear end of said combustion chamber and communicating therewith;

a plurality of fuel injection assemblies circumferently spaced about said duct between said inner and outer walls, each of said fuel injection assemblies including a secondary fuel injection nozzle having a secondary discharge end positioned forwardly of said throat; a primary set of fuel injection nozzles located in the forward end of said combustion chamber and concentrically arranged about the discharge path of said secondary nozzle, said primary nozzles each having a primary discharge end located in the front end of said combustion chamber; a fuel line; and pressure responsive fuel valve means connecting said primary and secondary nozzles to said fuel line to selectively transfer the fuel flow from said secondary nozzle to said primary nozzles; and,

a plurality of heating coils circumferentially spaced about said burner duct between said inner and outer walls, one of said heating coils axially aligned with each of said fuel injection assemblies rearwardly thereof within said combustion chamber for heating the air within the combustion chamber prior to ignition.

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