Dec. 21, 1965 B. R. WALSH 3,224,195

GAS TURBINE FIRED WITH AN ASPIRATING BURNER NOZZLE

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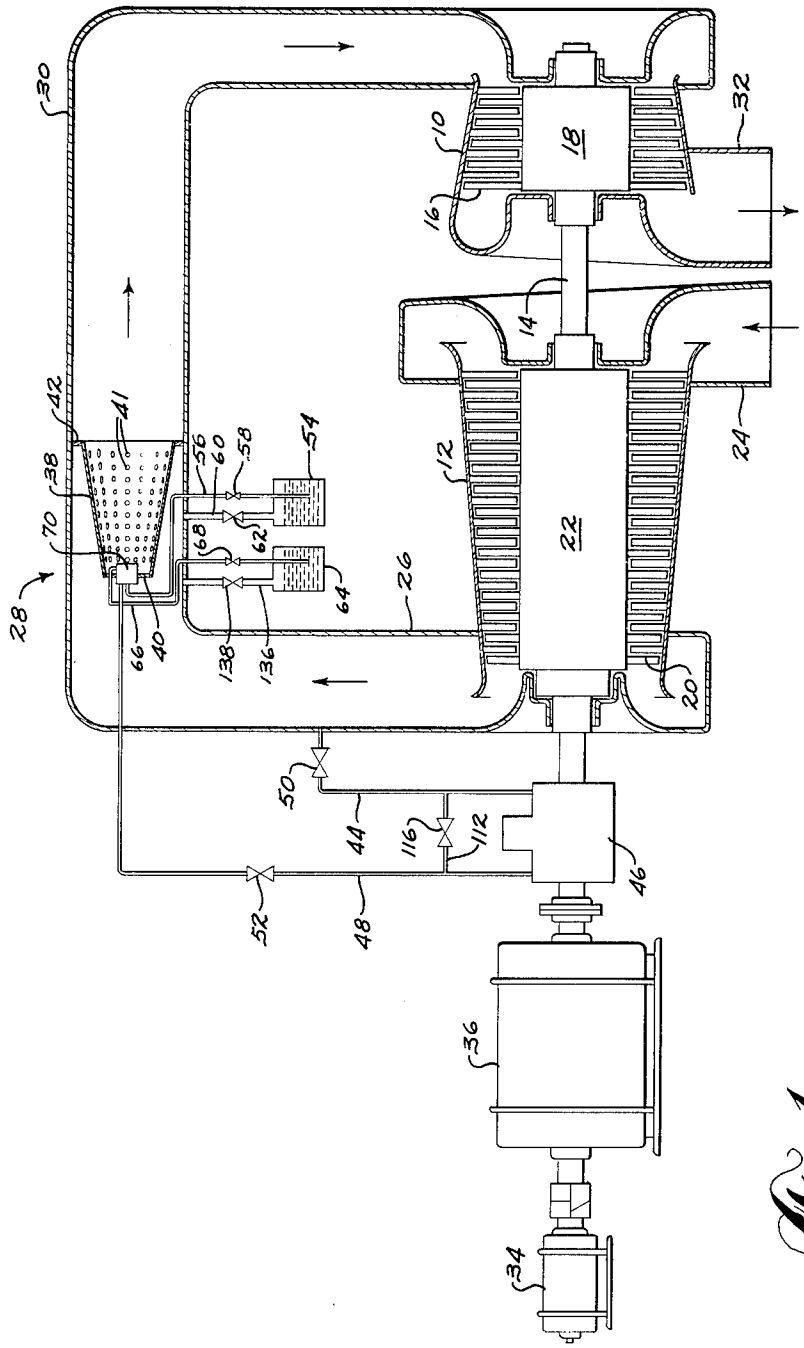


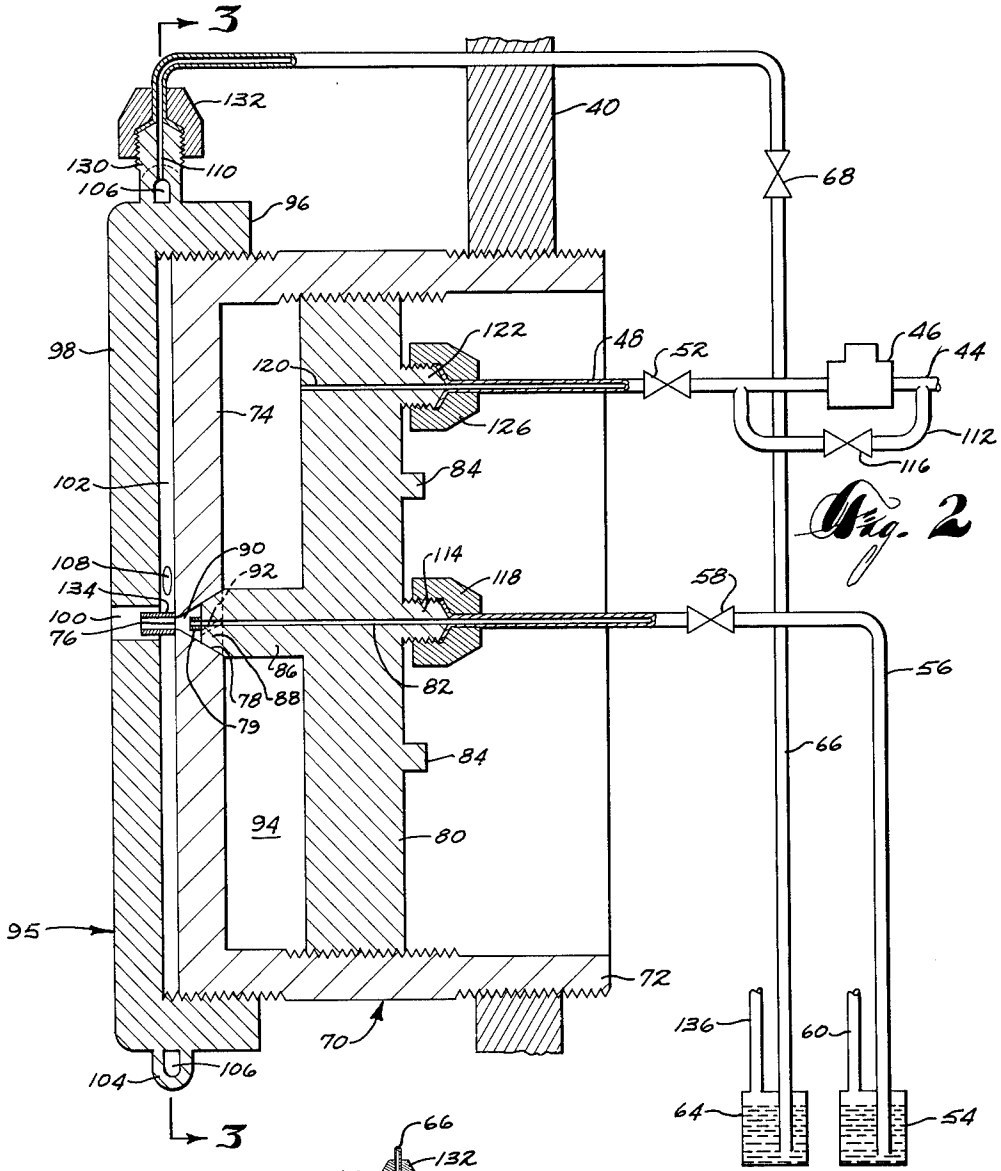
Fig. 1

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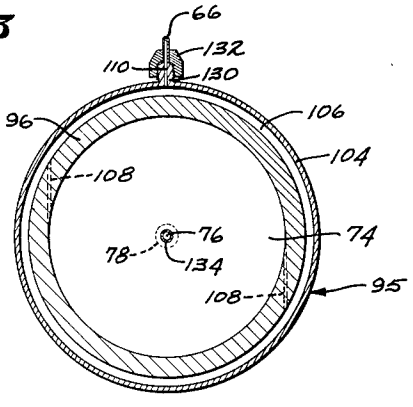


Fig. 3

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GAS TURBINE FIRED WITH AN ASPIRATING BURNER NOZZLE

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This invention relates to improvements in gas turbines. More particularly, this invention relates to a gas turbine apparatus fired by means of an aspirating burner nozzle and to a process relating thereto.

The nozzle employed in the combustor of a gas turbine employing liquid fuel is generally of the pressure type adapted to receive liquid fuel under a pressure substantially greater than combustor pressure and to spray therefrom a jet of atomized fuel for combustion. In accordance with this invention the nozzle employed in the combustor is of the aspirating type adapted to receive and spray fuel oil existing at combustor pressure by drawing the oil into the nozzle by means of a stream of aspirating air passing through the nozzle at a pressure slightly above that of the combustor. The use of an aspirating nozzle in the combustor of a turbine utilizing liquid fuel results in many advantages including substantially reduced combustion product deposit formation. Combustion product deposit formation tends to be greater in a pressurized system such as a turbine power plant as compared to a combustion chamber operating under atmospheric pressure, such as a heating furnace. Reduction of combustion product deposit formation is a highly advantageous feature in turbine operation since deposit formation upon gas turbine blades induces erosion and abrasion thereon resulting in reduced turbine efficiency. Attempted removal of deposit formation from turbine blades results in further abrasion of blade surfaces and turbine efficiency thereafter is unlikely to return to its original level.

This invention is best understood by reference to the accompanying drawings in which FIGURE 1 illustrates the combination gas turbine apparatus of the invention and FIGURES 2 and 3 show details of a preferred aspirating nozzle structure to be utilized in the combination of FIGURE 1.

FIGURE 1 shows reaction-type gas turbine **10** axially connected by means of shaft **14** to multistage axial flow combustor air compressor **12**. Gas turbine **10** is equipped with a plurality of blades **16** mounted on rotor **18** while combustor air compressor **12** is equipped with a plurality of blades **20** mounted on rotor **22**. Combustor air compressor **12** is provided with atmospheric air inlet duct **24** and pressurized air discharge duct **26**. Air discharge duct **26** leads into combustor chamber **28**. Products of combustion exit from combustor chamber **28** into duct **30** which leads them to turbine **10**. Turbine **10** is provided with combustion gas exit duct **32**. Starter motor **34**, generator **36** and aspirating air compressor **46** are all axially connected to combustor air compressor **12** and turbine **10** by means of common shaft means.

Combustor chamber **28** is comprised of aspirating nozzle **70** axially disposed at one end of flame tube **38** having perforations **41** uniformly distributed over its surface. Aspirating nozzle **70** is positioned to direct a spray to the opposite end of perforated tube **38**. The nozzle end of perforated tube **38** is enclosed by circular plate **40** through which nozzle **70** extends. The downstream end of combustor **28** is enclosed by circular plate **42** having a concentric opening to receive the open discharge end of perforated flame tube **38**.

Aspirating nozzle **70** is provided with air to accomplish aspiration at a pressure of about 2 to 10 and preferably

about 3 pounds per square inch gauge above the pressure within combustor chamber **28** by means of tube **44** extending from combustor compressed air duct **26** to aspirating nozzle air compressor **46**. A second tube **48** extends from aspirating nozzle air compressor **46** to nozzle **70**. Tube **44** is equipped with valve **50** and tube **48** is equipped with valve **52**. Tubes **44** and **48** are connected by means of bypass line **112** having valve **116**.

Oil is supplied to aspirating nozzle **70** from oil reservoir **54** which is disposed at about nozzle level through tube **56** equipped with valve **58**. Oil reservoir **54** is exposed to combustor pressure by means of tube **60** equipped with vaive **62**. Water is also supplied to nozzle **70** from reservoir **64** which is disposed at about nozzle level through tube **66** having valve **68**. Reservoir **64** is exposed to combustor pressure by means of tube **136** equipped with valve **138**.

Although nozzle **70** is a preferred aspirating nozzle to be employed with the apparatus of this invention, a variety of aspirating nozzles are suitable such as are shown in copending application Serial Number 111,821, filed May 22, 1961, now abandoned. FIGURE 2 shows an elevational view of a longitudinal section through the axis of nozzle **70**. Nozzle **70** has a tubular body portion **72** which is internally and externally threaded as shown. The forward end of body portion **72** terminates with a substantially flat integral enclosure **74** which is on a plane transverse to the axis of tubular body **72**. Enclosure **74** has an orifice opening **76** which is the apex of an axial conical bore **78**.

A plug **80** having external threads and an axial bore **82** is equipped with two or more prongs **84** on its rear face so that it can be screwed into the interior of tubular body **72** as shown. Plug **80** has a central forwardly projecting stud **86** terminating with a frusto-conical swirl stem **88** which abuts firmly against the complementary interior surface of the base portion of conical bore **78** leaving unoccupied the apex of conical bore **78**, said unoccupied apex constituting a swirl chamber **90**. Swirl stem **88** has one or more peripheral slots **92** extending the lengh of the stem and providing passage between air chamber **94** and swirl chamber **90**. Axial bore **82** constitutes a connecting passageway into swirl chamber **90** for the suction of fuel oil from oil reservoir **54**. Axial bore **82** protrudes a portion of the distance into swirl chamber **90** by means of cylindrical tube **79**.

A cap designated generally as **95** encloses the forward outer portion of tubular body **72** and the end enclosure **74** of tubular body **72**. FIGURE 3 is a view facing the cross section taken on plane **3—3** of FIGURE 2. Cap **95** has a side portion **96**, a top portion **98** and an orifice opening **100** in the center of the top portion which opening is larger than orifice opening **76**. Cap **95** is screwed in sealing engagement with tubular body **72** and the top portion **98** is spaced apart from enclosure **74** to form a second swirl chamber **102**. A hollow rib **104** which is integral with side **96** of cap **95** has an interior chamber **106** from which one or more passageways **108** approach chamber **102**. Passageways **108** can approach chamber **102** radially but preferably approach chamber **102** tangentially as shown in FIGURE 3. An inlet passage **110** to space **106** is provided through the interior of boss **130**.

A cylindrical duct **134** extends from orifice **76** axially into cylindrical orifice **100**. Duct **134** can extend a portion of the distance to orifice **100** but it preferably extends into orifice **100**, as shown. The outer diameter of duct **134** is less than the diameter of orifice **100**.

After the plug **80** is screwed tightly in the interior of tubular body **72** and the cap **95** is screwed onto the exterior of tubular body **72** as shown the resulting nozzle assembly is secured into position for use by screwing tubular body **72** into circular end plate **40** of perforated

tube 38. Oil reservoir 54 which is exposed to combustor pressure is connected to the nozzle at externally threaded boss 114 extending rearwardly from the center of plug 80 and coaxial with oil passageway 82. The flared end of tubing 56 is attached in sealing connection to boss 114 by means of nut 118. Aspirating air flows to chamber 94 from aspirating air compressor 46 through tube 48, valve 52 and passageway 120 in plug 80 terminating with rearwardly extending externally threaded boss 122 to which the flared end of tubing 48 is attached in sealing connection by means of internally threaded nut 126. The aspirating air is preferably at a pressure slightly above the pressure within combustor chamber 28, for example, at a pressure of 2 to 10 pounds per square inch gauge above the pressure within the combustor. Whatever the pressure of the aspirating air it must be at a pressure higher than both the combustor and the liquid under aspiration. Water is aspirated into chamber 106 through passageway 110 from reservoir 64, which is exposed to combustor pressure, by attaching the flared end of tubing 66 in sealing connection with boss 130 by means of nut 132.

During start-up of the apparatus of FIGURE 1, starting motor 34 causes rotation of shaft 14 thereby setting into operation combustor air compressor 12. Air from the atmosphere is drawn through conduit 24 into combustor air compressor 12 and discharged therefrom under pressure into conduit 26 which leads into combustor chamber 28. Starting motor 34 also drives aspirating air compressor 46 which withdraws a small portion of the combustor compressed air stream, for example, about 5 percent of the combustor compressed air stream, from duct 26 through tube 44 and delivers aspirating air at a pressure about 3 pounds per square inch gauge greater than combustor air pressure to nozzle 70 through tube 48. Aspirating air traveling through nozzle 70 aspirates oil through the nozzle from reservoir 54 through tube 56 and also aspirates water, after completion of start-up operations, from reservoir 64 through tube 66. Any suitable ignitor, not shown, ignites the spray from nozzle 70. After starting motor 34 brings the unit to about 25 percent of normal running speed, turbine 10 becomes capable of driving combustor air compressor 12 and thereupon becomes the motive force in the system.

During operation of the aspirating nozzle shown in FIGURES 2 and 3 to aspirate fuel oil from reservoir 54 and water from reservoir 64, air at a pressure about 3 pounds per square inch gauge above combustor pressure is charged through air passageway 120 to air chamber 94 from which it is passed through slot 92 and approaches swirl chamber 90 in a substantially tangential manner. The air swirls in swirl chamber 90 creating an evacuated axial vortex which causes fuel oil from reservoir 54 to be drawn through tube 56, axial passageway 82 and duct 79 into swirl chamber 90 to form a first mixture of air and oil. The cylindrical configuration of the outer surface of duct 79 prevents transverse motion of air across its open end, thereby preventing air back pressure against the oil in reservoir 54. In the absence of duct 79 insufficient aspiration of oil from reservoir 54 to support combustion would occur. The mixture passes through orifice opening 76 and duct 134 into second orifice 100 where it aspirates into itself water from reservoir 64 which enters chamber 102 through tube 66, having open valve 68, bore 110, annulus 106 and tangential slots 108 to form a mixture of air, oil and water which mixture is then emitted through orifice 100. The quantity of water aspirated from reservoir 64 depends upon the differential diameter between duct 134 and orifice 100. Also, the quantities of oil and water aspirated by nozzle 70 and their ratio to each other can be adjusted externally by regulation of valves 58 and 68, respectively. Operation of the nozzle can be terminated merely by closure of air valve 52 without ensuing emission of oil and water from the nozzle by virtue of reservoirs 54 and 64 being at combustor pressure.

The mixture of aspirating air, fuel oil and water is sprayed from nozzle 70 into flame tube 38 and ignited by any suitable means such as a spark plug to produce a jet-like flame within perforated flame tube 38. The total stream of combustor compressed air is forced into flame tube 38 through perforations 41. Products of combustion, unburned excess compressed air and steam are passed through conduit 30 to turbine 10. The unburned excess compressed air and steam are not only utilized as expandable gas for the turbine 10 but also advantageously serve to cool the products of combustion to a suitable turbine inlet temperature. Expansion of the combustor product gas at turbine 10 and discharge through conduit 32 produces more power than that required to operate combustor air compressor 12 and aspirating air compressor 46 and the excess power is supplied to generator 36. The turbine apparatus of this invention can be adapted for automotive, aircraft or industrial usage. If the turbine is utilized as an aircraft engine, the expanded gases leaving the turbine may be discharged through a reaction tube to impart a thrust to the aircraft, or the exhaust gases can be utilized to further assist in rotation of the aircraft propeller.

During turbine operation, turbine speed is changed by changing the pressure of the aspirating air. This can be accomplished by changing the speed of aspirating air compressor 46 or by adjustment of valve 116 in bypass line 112. A change in the pressure of the aspirating air results in a corresponding change in aspiration rate of fuel and water causing a change in speed of turbine 10 and combustor compressor 12. A change of aspirating air pressure, therefore, results in a corresponding change in combustor air pressure. The fuel-air-water ratio before and after a change in aspirating air pressure remains substantially constant since aspirating air compressor suction line 44, oil reservoir 54 and water reservoir 64 are all exposed to the pressure of the combustor air.

When a conventional nonaspirating, pressure type nozzle is utilized as the burner of a turbine power plant of the type shown in FIGURE 1, conditions often arise which render it extremely difficult to maintain stable operation of the burner or to maintain proper flame propagation. For example, if it is desired to reduce turbine speed the change is accomplished with a conventional pressure type nozzle by means of a reduction in fuel pressure to the nozzle. However, the momentum of the engine may momentarily maintain a high air flow tending to blow out the flame, possibly requiring reignition under adverse conditions. Such an occurrence is substantially avoided with the aspirating nozzle burner arrangement shown in FIGURE 1. With the apparatus of FIGURE 1, a reduction in turbine speed is accomplished solely by reducing the pressure of the aspirating air supply to the nozzle by any suitable means, such as the opening of bypass valve 116, but the rate of fuel aspiration does not decline to the full extent corresponding to the reduction in aspirating air pressure as long as the momentum of the combustor air compressor continues to produce a high combustor air pressure. The reason is that the pressure of the oil supplied to the nozzle is determined only by the pressure in the combustor since oil reservoir 54 is directly exposed to the pressure within the combustor and therefore high combustor air pressure continues to be exerted upon oil reservoir 54, tending to prevent decrease of the rate of oil aspiration until the combustor air compressor loses momentum and slows to a lower rotational velocity.

Still another advantage is realized by the use of an aspirating nozzle with a turbine apparatus as compared to a conventional pressure burner nozzle. When employing a conventional burner nozzle in a combination turbine apparatus of the type shown in FIGURE 1, water is commonly introduced into the perforated flame tube as an independent pressurized stream downstream from the nozzle. This mode of water addition is likely to produce relatively uneven cooling due to localized zones of maximum

water vaporization. However, with an aspirating nozzle as shown in FIGURE 2 the water is aspirated into the nozzle in the form of very small droplets which are intimately admixed with oil and air even prior to leaving the nozzle. These water droplets are uniformly dispersed throughout the nozzle spray so that upon reaching the flame vaporization and cooling is even and uniform throughout the flame, thereby avoiding the possibility of alternate surges of hot and cold gas to the turbine. Localized surges of excessively hot gas can cause burning and deformation of turbine parts, thereby reducing turbine efficiency. In contrast, the uniform dispersion of water accomplished by aspiration produces turbine gases highly uniform in temperature thereby tending to maintain high turbine efficiency.

A series of tests was conducted which shows the reduced formation of combustion deposits occurring when utilizing an aspirating nozzle as compared to a pressure type nozzle. The conditions of each test were uniform and are shown in Table I. The test conditions approximate cruise operation of a moderate pressure ratio aircraft gas turbine engine at about 25,000 feet altitude or represent part load operation of a moderate pressure ratio industrial gas turbine engine. ASTM number 2 grade fuel oil was utilized in each test. The combustor apparatus utilized in each test was similar to that shown in FIGURE 1. The combustor was 2 inches in diameter and the flame tube was 1 5/16 inches in diameter at the nozzle end and 1¾ inches in diameter at the opposite end.

Table I

Combustor inlet air pressure, pounds per square inch absolute	24.5
Combustor inlet air temperature, ° F.	300
Combustor air flow, lb. air/hour	375
Fuel-air ratio, lb. fuel/lb. air	0.014
Test duration, minutes	60

The results of the tests are shown in Table II.

Table II

Fuel nozzle	Nozzle air aspirating pressure, p.s.i.g.	Combustor deposit weight, grams	Average smoke rating (0 is clean, 10 is dirty)	Combustion efficiency, percent	Combustor pressure drop, inches of water	Flame	
						Color	Length, inches
Aspirating	16.5	−0.020	1.0	73	13.2	Blue	6.0
Do	17.0	0.010	1.0	82	13.2	do	6.5
Pressure atomizing (0.015" discharge orifice).		0.210	0.9	71	9.7	Yellow	6.5
Pressure atomizing (0.009" discharge orifice).		0.180	1.0	77	10.2	do	6.5

I claim:

1. In an apparatus comprising a gas turbine, a combustor having inlet means, discharge means and a burner nozzle, a combustor air compressor, first conduit means connecting said combustor air compressor and said combustor inlet means, second conduit means connecting the discharge means of said combustor and said gas turbine, said apparatus adapted so that gases from said combustor drive both said turbine and said combustor air compressor, the improvement comprising said burner nozzle being of the aspirating type, aspirating nozzle air compressor means having suction connecting means extending to the pressurized combustor air and discharge connecting means extending to said nozzle and adapted to supply to said nozzle aspirating air at a pressure slightly above the pressure within said combustor, liquid oil reservoir means exposed to the pressure of said combustor, said nozzle adapted so that the movement of said aspirating air therethrough aspirates liquid oil from said reservoir to said combustor, and means for adjusting the pressure of the aspirating air supply to said nozzle whereby turbine speed is adjusted.

2. In an apparatus comprising a gas turbine, a combustor having inlet means, discharge means and a burner nozzle, said burner nozzle disposed axially at one end of a perforated flame tube, a combustor air compressor, first conduit means connecting said combustor air compressor and said combustor inlet means, second conduit means connecting the discharge means of said combustor and said gas turbine, common shaft means connecting said gas turbine and said combustor air compressor, the improvement comprising said burner nozzle being of the aspirating type, aspirating nozzle air compressor means having suction connecting means extending to the pressurized combustor air and discharge connecting means extending to said nozzle and adapted to supply to said nozzle aspirating air at a pressure slightly above the pressure within said combustor, liquid oil reservoir means exposed to the pressure within said combustor, means connecting said liquid oil reservoir and said nozzle, water reservoir means exposed to the pressure within said combustor, means connecting said water reservoir and said nozzle, said nozzle adapted so that the movement of said aspirating air therethrough aspirates both oil and water from said reservoirs through said nozzle and into said combustor.

3. In an apparatus comprising a gas turbine, a combustor having inlet means, discharge means and a burner nozzle, a combustor air compressor, first conduit means connecting said combustor air compressor and said combustor inlet means, second conduit means connecting the discharge means of said combustor and said gas turbine, common shaft means connecting said gas turbine and said combustor air compressor, said apparatus adapted so that gases from said combustor drive both said turbine and said combustor air compressor, the improvement comprising said burner nozzle being of the aspirating type, aspirating nozzle air compressor means having suction connecting means extending to the pressurized combustor air and discharge connecting means extending to said nozzle and adapted to supply to said nozzle aspirating air at a pressure slightly above the pressure within said combustor, liquid oil reservoir means at substantially the pressure of said combustor, said nozzle adapted so that the movement of said aspirating air therethrough aspirates liquid oil from said reservoir to said combustor, means for adjusting the pressure of the aspirating air supply to said nozzle whereby turbine speed is adjusted, the pressure of the liquid oil supply to said nozzle being determined only by the pressure in said combustor.

4. In an apparatus comprising in series a combustor air compressor, a combustor chamber having a burner nozzle therein, and a turbine, the improvement comprising said burner nozzle being of the aspirating type, aspirating air compressor means associated with said nozzle and adapted to supply to said nozzle aspirating air at a pressure slightly above the pressure within said combustor, liquid oil reservoir means at substantially the pressure of said combustor associated with said nozzle, said nozzle adapted so that the movement of aspirating air therethrough aspirates liquid oil from said reservoir means into said combustor, and means for adjusting the pressure of the aspirating air supply to said nozzle whereby turbine speed is adjusted.

5. In an apparatus comprising in series a combustor air compressor, a combustor chamber having a burner

nozzle therein, and a turbine, the improvement comprising said burner nozzle being of the aspirating type and having aspirating air swirling means, aspirating air compressor means associated with said nozzle and adapted to supply to said nozzle aspirating air at a pressure slightly above the pressure within said combustor, liquid oil reservoir means at substantially the pressure of said combustor associated with said nozzle, said nozzle adapted so that the swirling motion of aspirating air passing therethrough aspirates liquid oil from said reservoir means into said combustor, and means for adjusting the pressure of the aspirating air supply to said nozzle whereby turbine speed is adjusted.

6. In a process for controlling the speed of a turbine comprising charging compressed air to a combustion chamber, spraying fuel oil into said combustion chamber, and passing the products of combustion from said combustion chamber through a turbine to drive said turbine, the improvement comprising spraying said fuel oil by providing to said combustion chamber fuel oil maintained at substantially the pressure of said combustion chamber, aspirating said fuel oil into said combustion chamber by means of an aspirating gas which is at a pressure slightly above the pressure of said combustion chamber, and adjusting the pressure of said aspirating gas whereby turbine speed is adjusted.

7. In a process comprising charging compressed air to a combustion chamber, spraying fuel oil and water into

said combustion chamber, and passing the products of combustion and steam from said combustion chamber through a turbine to drive said turbine, the improvement comprising syraying said fuel oil and water by providing to said combustion chamber fuel oil and water maintained at substantially the pressure of said combustion chamber, and aspirating said fuel oil and water into said combustion chamber by means of an aspirating gas which is at a pressure slightly above the pressure of said combustion chamber.

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