Sept. 20, 1960 | DE CARR C. BRADDY | 2,952,975

VAPOR GENERATING AND SUPERHEATING UNIT

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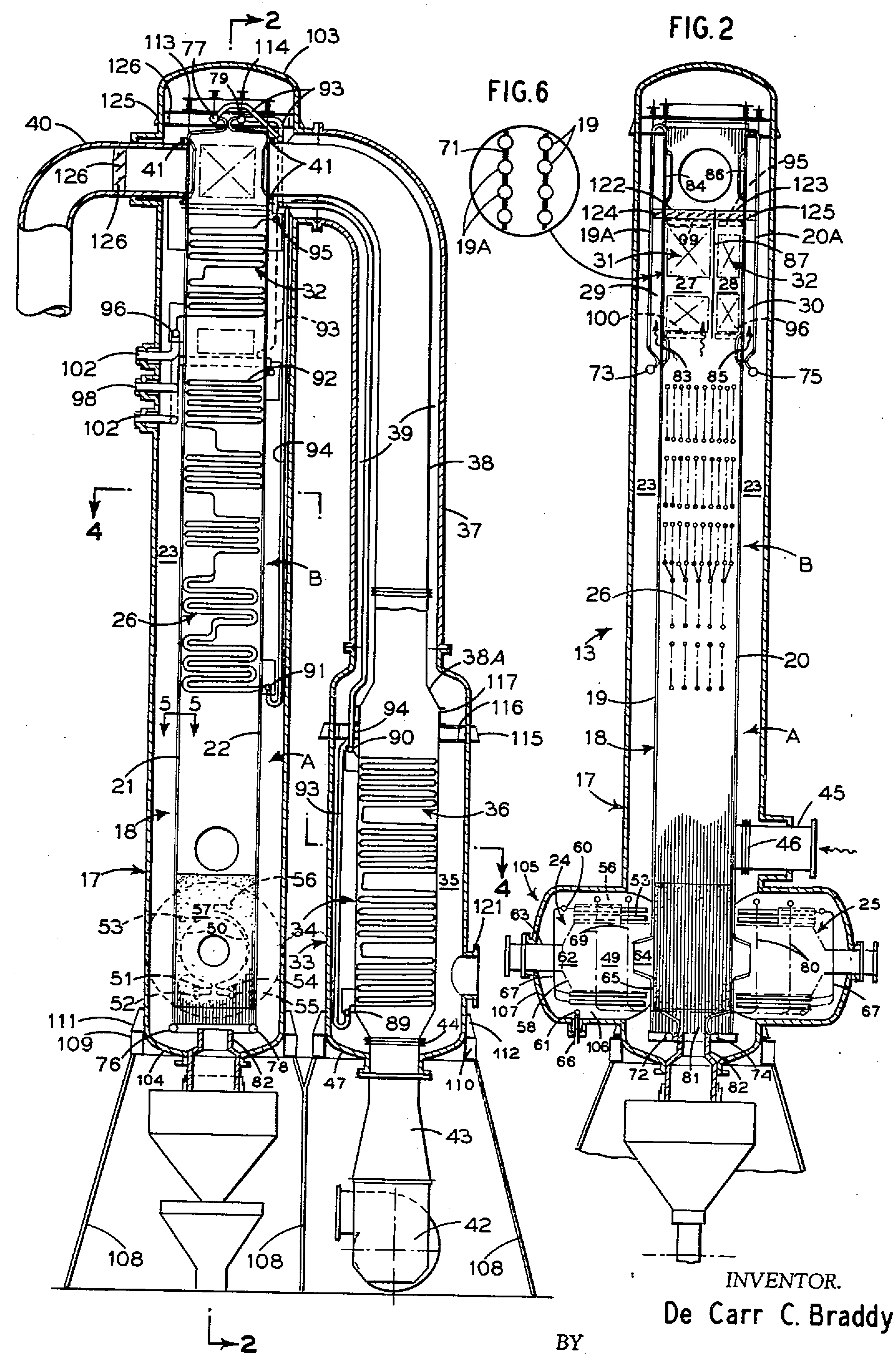
FIG. 1 | FIG. 6 | FIG. 2



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VAPOR GENERATING AND SUPERHEATING UNIT

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FIG. 3

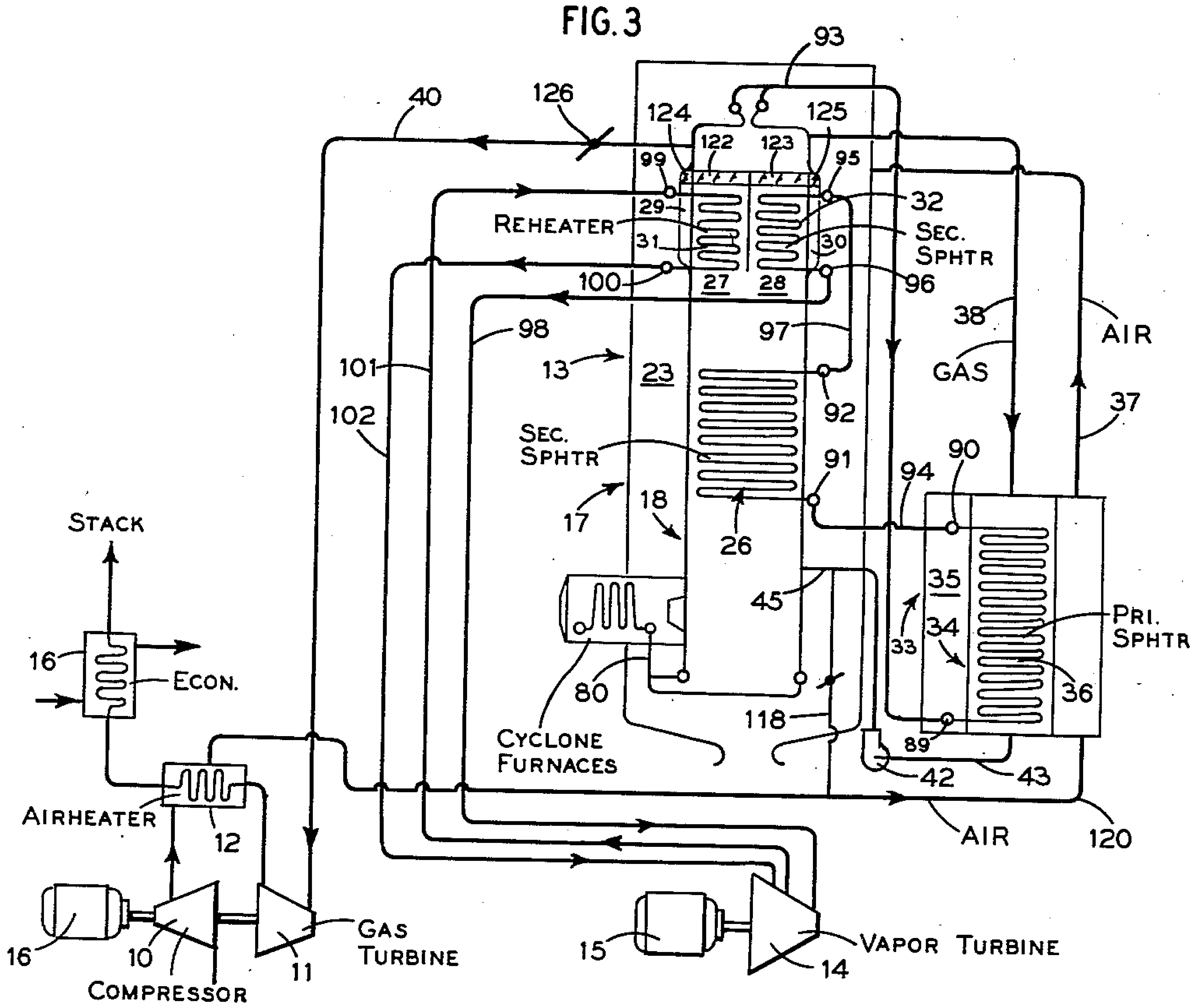

FIG. 9

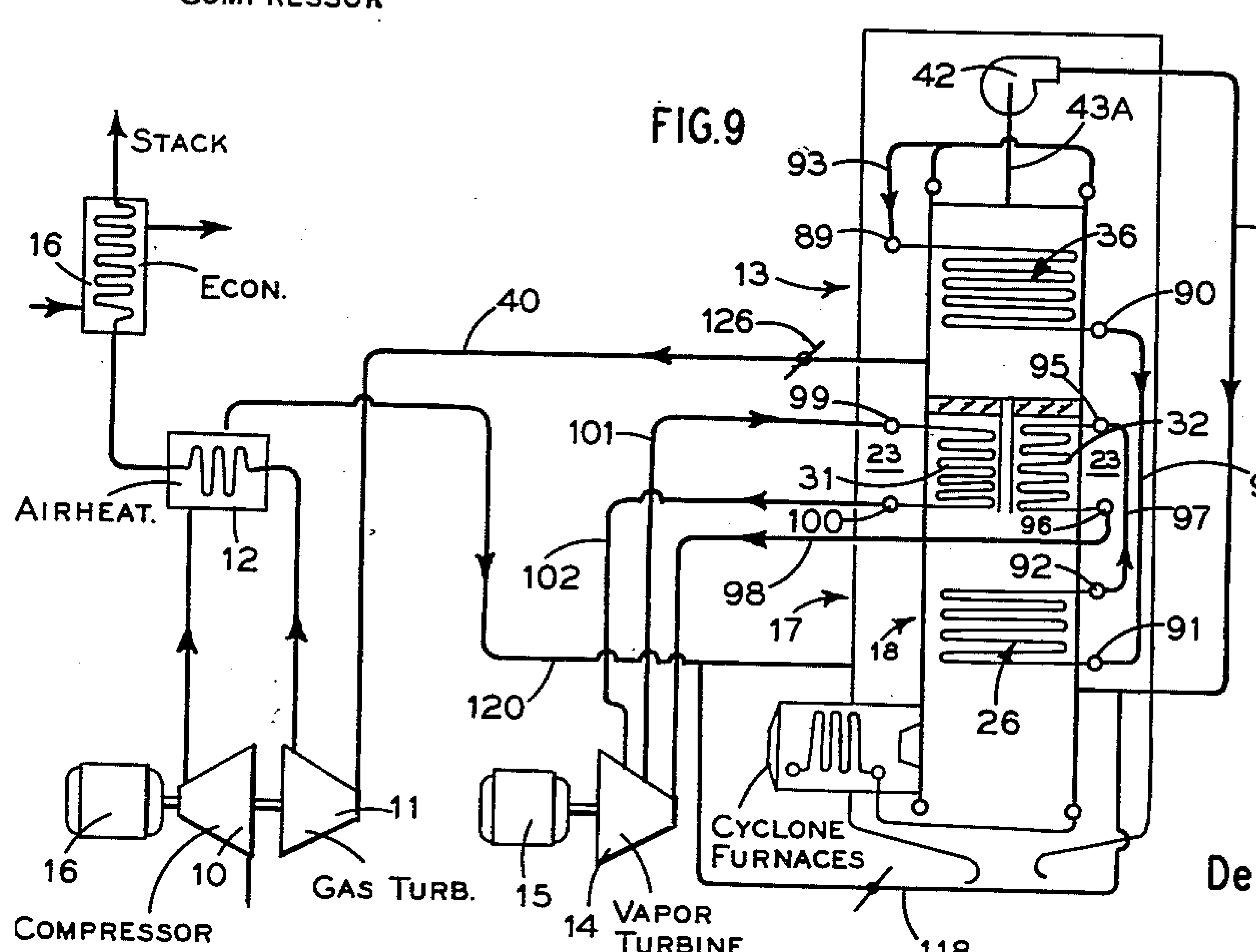

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FIG. 4

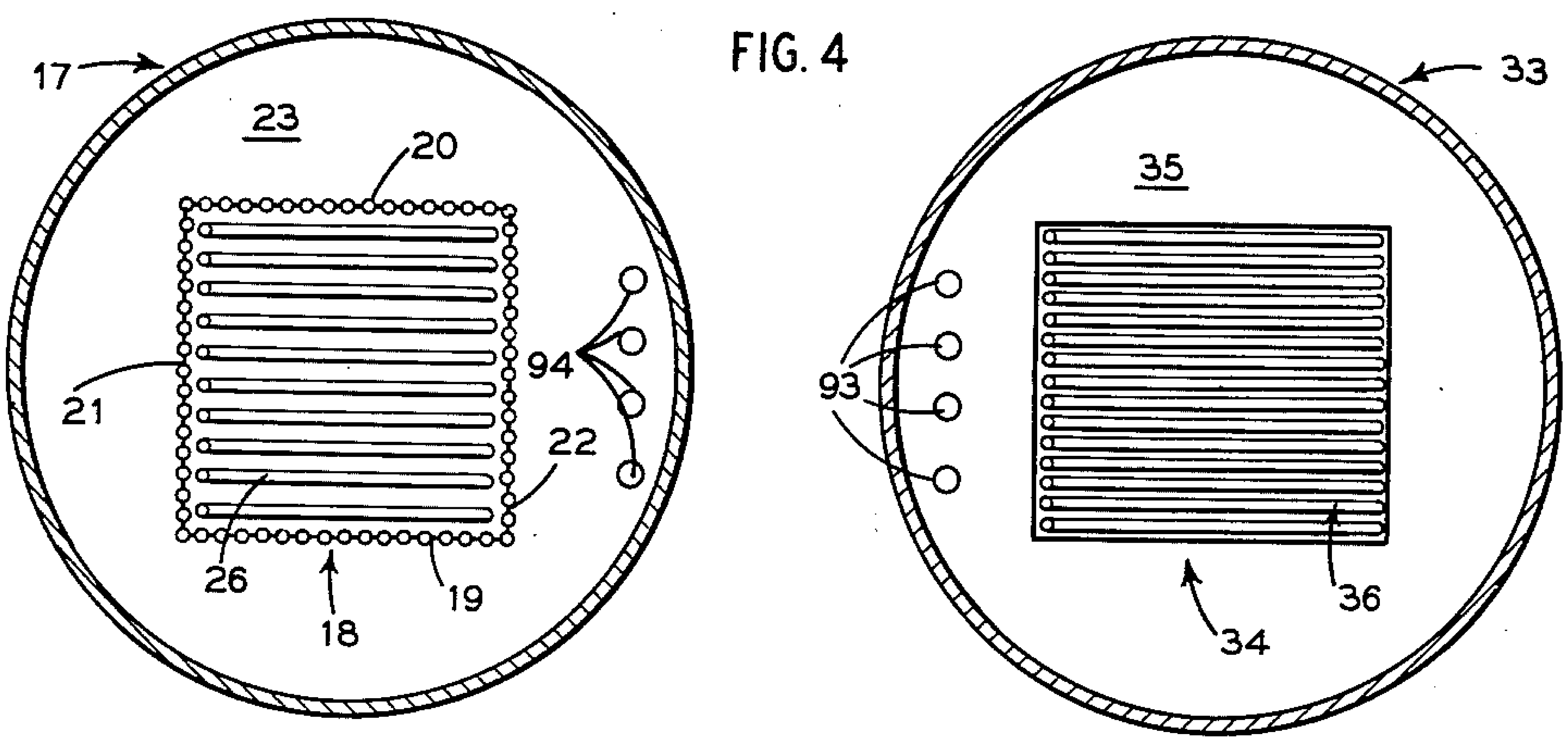


FIG. 5

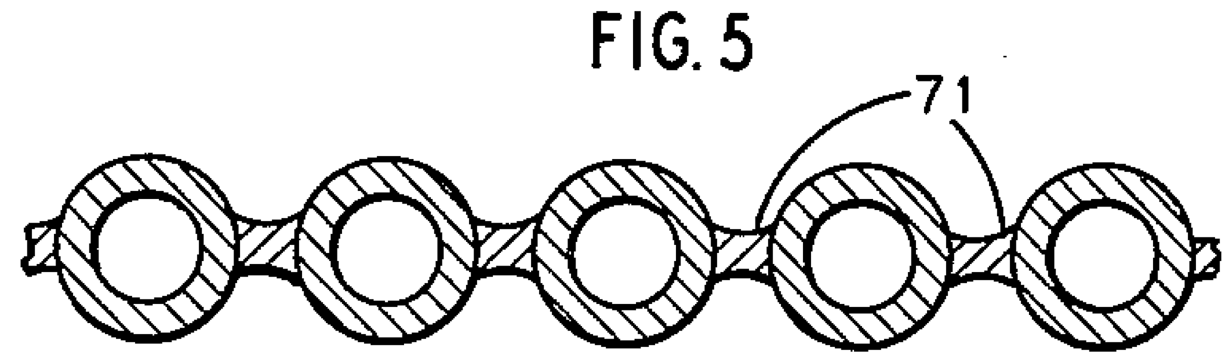
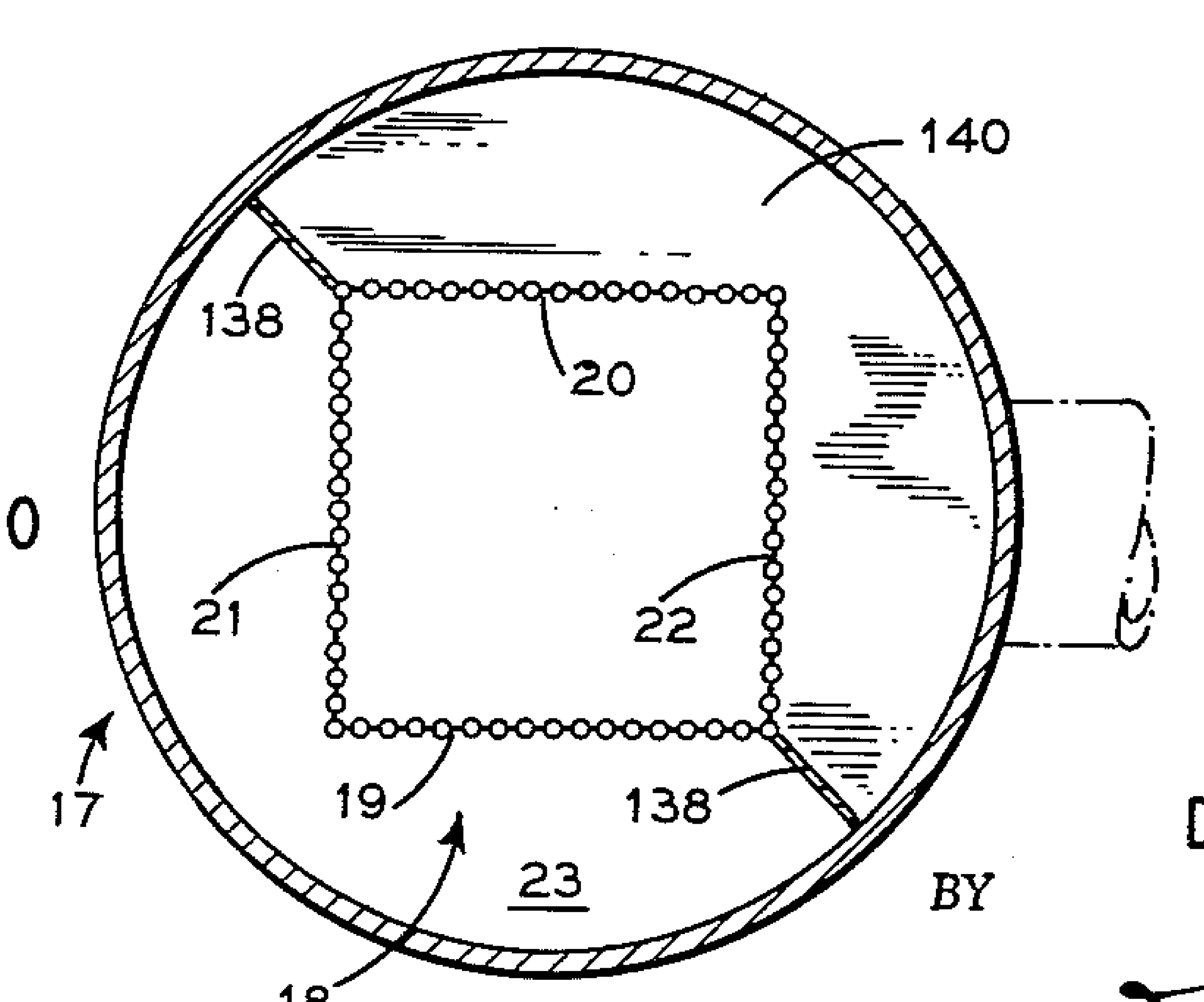


FIG. 10



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VAPOR GENERATING AND SUPERHEATING UNIT

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FIG. 7

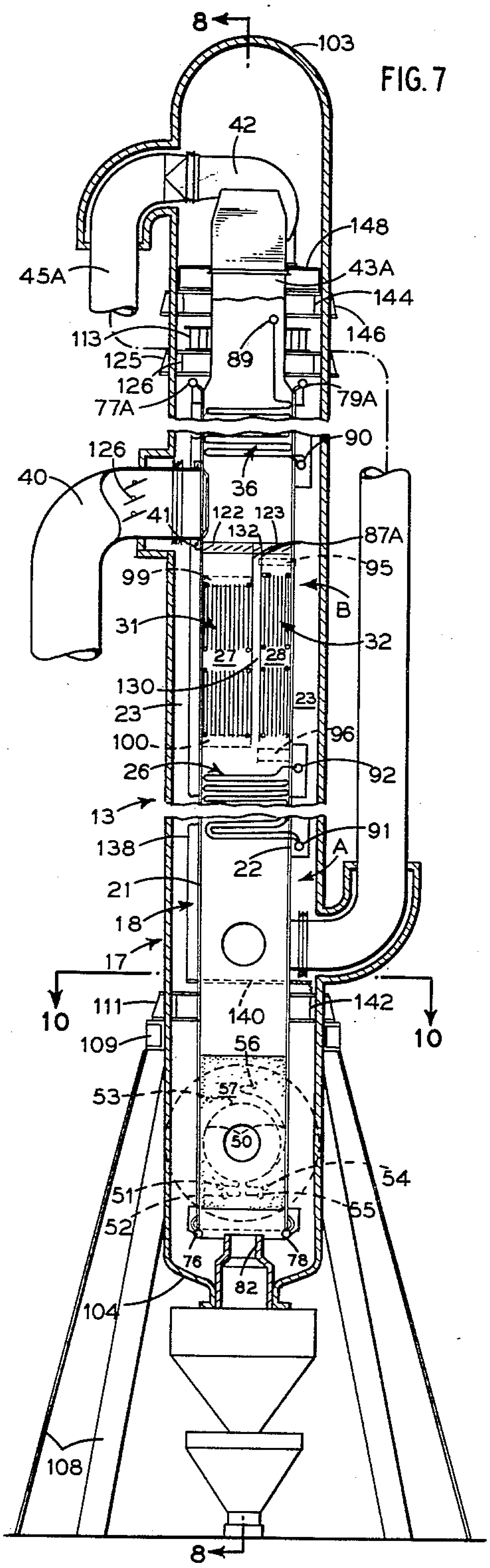
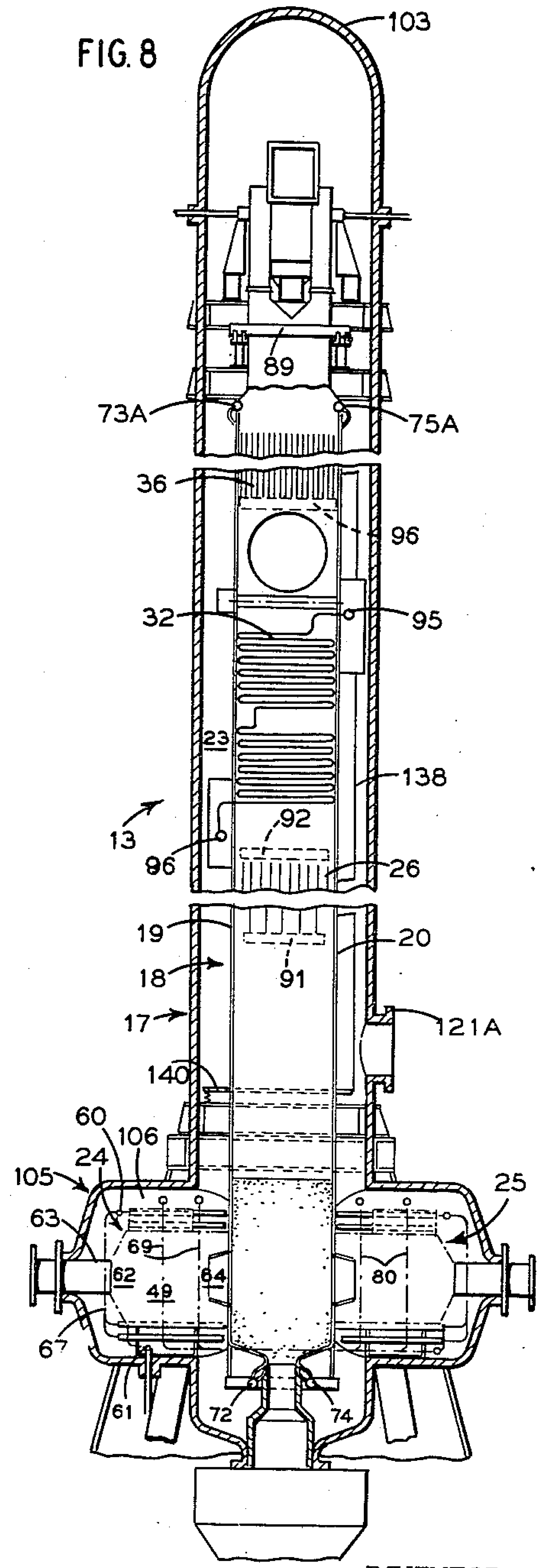


FIG. 8



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VAPOR GENERATING AND SUPERHEATING UNIT

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Filed Nov. 15, 1957, Ser. No. 696,721

17 Claims. (Cl. 60—39.18)

This invention relates to the construction and operation of binary elastic fluid power plants and more particularly to improvements in the construction and operation of a fluid heating unit especially adapted for the simultaneous generation of highly superheated high pressure vapor and high temperature high pressure gases for use in the production of power by a binary elastic fluid power plant.

In accordance with the invention, the fluid heating unit is of the supercharged forced circulation type and is associated with a power plant including a vapor turbine, a gas turbine and an air compressor driven by the gas turbine. The term "supercharged" as used herein means a combustion process wherein the pressure of the gases generated in the fluid heating or vapor generating unit is of such a magnitude that useful work may be done by these gases after leaving the fluid heating unit through expansion in a gas turbine to essentially atmospheric pressure. The invention provides for a supercharged fluid heating unit wherein the fuel firing equipment is supplied with high pressure air from the air compressor and the vapor generating and superheating surfaces are specially proportioned and arranged to maintain a substantially constant vapor temperature to the vapor turbine over a relatively wide range of vapor generation rates, while a substantially constant portion of the high pressure heating gases at a substantially constant temperature are delivered to the gas turbine from a particular position in the gas flow path in the fluid heating unit and the remainder of the gases generated in the unit are recirculated for mixing with the freshly generated gases. In addition, the construction and arrangement of the fluid heating unit of the invention provides a higher efficiency when incorporated in a combined gas turbine-steam turbine power plant than the base steam or gas-turbine plants individually; eliminates the need for the forced and induced draft fans customarily associated with a vapor generating unit; and provides a compact installation of reduced size and weight as compared to a conventional unit due to higher heat transfer rates resulting from high gas density in the unit.

The invention also provides for a fluid heating unit comprising an upright vessel of substantially circular horizontal cross-section, an upright gas flow chamber of substantially rectangular horizontal cross-section containing superheating surface in the form of horizontally extending return bend tubes and disposed within and cooperating with the upright vessel to define an air flow space therebetween, with the air flow space supplied with air from the gas turbine-driven compressor at a pressure at least equal to the gas pressure in the upright chamber to counter-balance the outward thrust of the heating gases exerted on the inside of the boundary walls of the upright chamber. This arrangement minimizes the need for lateral steel supports for the boundary walls of the upright gas flow chamber, prevents blasting or leakage of the heating gases through the boundary walls of the upright chamber, provides an optimum quantity

of space in the upright chamber for accommodation of vapor generating and superheating surface, and permits use of uncomplicated superheater tube arrangements.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred form of my invention.

Of the drawings:

Fig. 1 is a partly diagrammatic sectional elevation of a supercharged once-through forced circulation steam generating unit constructed and operable in accordance with the invention;

Fig. 2 is a sectional elevation taken along line **2—2** of Fig. 1;

Fig. 3 is a diagrammatic representation of the flow paths of the vaporizable fluid, the heating gases and the air in the binary fluid power plant with which the fluid heating unit of Figs. 1 and 2 is associated;

Fig. 4 is a plan view taken along the line **4—4** of Fig. 1;

Fig. 5 is a fragmentary plan view taken along the line **5—5** of Fig. 1;

Fig. 6 is a fragmentary plan section view of one of the gas by-passes of Fig. 2;

Fig. 7 is a partly diagrammatic sectional elevation of a modified fluid heating unit construction;

Fig. 8 is a sectional elevation taken along the line **8—8** of Fig. 7;

Fig. 9 is a diagrammatic representation of the flow paths of the vaporizable fluid, heating gases and air in the binary elastic fluid power plant with which the fluid heating unit of Figs. 7 annd 8 is associated; and

Fig. 10 is a plan view taken along the line **10—10** of Fig. 7.

In the drawings the invention has been illustrated as embodied in a binary elastic fluid power plant intended for central station use. The particular power plant illustrated in Figs. 1–6 has a net combined output of 144,000 kw., with the steam turbine supplying 126,000 kw. and the gas turbine 18,000 kw., which represents 12.5% of the plant rating. The bottom-supported supercharged forced flow once-through steam generating unit is designed on coal firing for a maximum continuous steam output of 800,000 lbs. of steam per hr. at a pressure of 3550 p.s.i. and a total temperature of 1050° F. at the superheater outlet, a maximum continuous steam output of 685,000 lbs. of steam per hr. at a pressure of 530 p.s.i. and a total temperature of 1000° F. at the reheater outlet, and a maximum continuous gas discharge from the steam generating unit to the gas turbine of 1,075,000 lbs. of gas per hr. at a temperature of 1450° F. and a pressure of 83 p.s.i.a. While the fluid heating unit constructions illustrated and hereinafter described are specifically designed and particularly adapted for burning coarsely pulverized or "granulated" bituminous or semibituminous coal in a cyclone type furnace, it will be understood that the fluid heating units illustrated may also be fired by other types of solid fuel burners or by various types of liquid or gaseous fuel burners.

In the binary elastic fluid power plant illustrated in Figs. 1–6, a compressor **10**, driven by a gas turbine **11**, discharges air at a pressure of about 88 p.s.i.a. through an airheater **12** to a supercharged forced flow once through fluid heating or steam generating unit **13**. All combustion takes place in the fluid heating unit **13**, and steam is generated at supercritical pressures and temperatures. It will be understood, however, that the fluid heating units illustrated and hereinafter described may also be advantageously used for steam generation at subcritical pressures and temperatures. The fluid heating unit is constructed and arranged to deliver steam to the high and low pressure stages of a vapor or steam turbine **14**, while passing high pressure high temperature gases to the gas turbine **11**. To maintain high plant efficiency at low steam generation rates, the gas turbine power is kept near maximum over a wide range of steam generation rates on the fluid heating unit by maintaining a substantially constant gas flow to the turbine **11**, while varying the fuel rate to the fluid heating unit, and maintaining the gas temperature to the gas turbine and the steam temperatures to the steam turbine at substantially constant values. The vapor turbine **14** drives an electric generator **15** and the gas turbine **11** drives an electric generator **16**, as well as the compressor **10**. Heat from the gas turbine exhaust is recovered by passing the gases over the airheater **12** to preheat the compressor discharge air before flowing to the fluid heating unit **13**; and over an economizer **16** to partially heat the feedwater for the fluid heating unit **13**.

In accordance with the invention, and with particular reference to the embodiment of Figs. 1–6, the fluid heating unit comprises an upright insulation covered metallic vessel **17** of substantially circular horizontal cross-section; an upright chamber **18** of substantially rectangular horizontal cross-section having a lower furnace chamber portion A and an upper convection gas cooling chamber portion B defined by a front wall **19**, a rear wall **20**, and opposing side walls **21**, **22** and disposed within and cooperating with the vessel **17** to define an air flow space **23** therebetween; and a fuel firing section consisting of a pair of independently operable horizontally extending cyclone type furnaces **24**, **25** of relatively small volume and boundary wall area disposed at the same level on opposite walls **19** and **20** at the lower portion of the chamber A, arranged to burn a solid fuel at high rates of heat release, and separately discharging high temperature gaseous products of combustion and separated ash residue as a molten slag into the lower portion of the chamber A. A secondary superheater **26** occupies the lower and central portions of the chamber B. Parallel gas passes **27**, **28** and **29**, **30** are provided in the upper portion of the chamber B and the vessel **17**, respectively, the passes **27** and **28** being occupied by a reheater **31** and another secondary superheater **32**, respectively, and the passes **29** and **30** being gas by-passed around the reheater **31** and superheater **32**. A vertically elongated insulation covered metallic vessel **33** of substantially circular horizontal cross-section is disposed laterally adjacent the vessel **17**. An upright gas pass **34** of substantially rectangular horizontal cross-section is disposed within and cooperates with the vessel **33** to define an air flow space **35** therebetween. A primary superheater **36** occupies the upright gas pass **34**. An upwardly extending insulation covered metallic conduit **37** of substantially circular horizontal cross-section is connected at one end and opens to the upper portion of the vessel **17** and is connected at its opposite end to the upper end of the vessel **33**. An upwardly extending metallic conduit **38** of substantially circular cross-section is concentrically disposed within and cooperates with the conduit **37** to define an annular air flow space **39** therebetween communicating at one end with the air flow space **23** and at its opposite end with the air flow space **35**. The conduit **38** is connected at its upper or gas inlet end and opens to the upper portion of the chamber B through the side wall **22** thereof at a position downstream gas-wise of the parallel gas passes **27**, **28** and is connected at its lower or gas discharge end to the upper or gas inlet end of the upright gas pass **34** by a transition conduit **38A**. The intake to the gas turbine **11** is connected to the chamber B by an insulation covered metallic conduit **40** of substantially circular cross-section extending through the vessel **17** in sealing relation therewith and opening to the chamber B through the side wall **21** thereof at the same level as the gas inlet to the conduit **38**. The connections of the conduits **38** and **40** to the walls **22** and **21**, respectively, are provided by slip type expansion joints **41** to allow for differential vertical expansion between the vessel **17** and the chamber **18** and intermediate portions of the conduits **38** and **40** are provided with bellows type expansion joints to permit vertical expansion thereof. A gas recirculation fan **42** has its intake connected to the lower end of the upright gas pass **34** by a conduit **43** having a bellows type expansion joint **44** and its discharge connected to the chamber A by an insulation covered conduit **45** of circular cross-section extending through the vessel **17** in sealing relation therewith and opening to the chamber A through the rear wall **20** thereof at a position superjacent the cyclone furnaces and between the cyclone furnaces and the secondary superheater **26**. The conduit **45** is provided with a pair of spaced bellows type expansion joints **46** adjacent its discharge end. The lower end of the vessel **33** is formed with a dished wall **47** having an opening therein through which the conduit **43** extends in sealing relation therewith.

Each cyclone furnace **24**, **25** comprises a horizontally elongated combustion chamber **49** of substantially circular cross-section, the circular boundary wall being formed by oppositely arranged groups of refractory covered closely spaced studded tubes **50**, the tubes **50** along one side having their lower ends alternately connected to lower headers **51** and **52** and their upper ends connected to a header **53** and the tubes **50** along the opposite side having their lower ends alternately connected to lower headers **54** and **55** and their upper ends connected to a header **56**. The upper and lower ends of each tube **50** are reversely bent, and opposite tubes at the top of each combustion chamber spaced apart to form a tangentially arranged secondary combustion air inlet **57** extending over a major portion of the length of the chamber. The front or outer end of each combustion chamber **49** is closed by a frusto-conical wall section **58** including refractory covered closely spaced studded tubes extending between horizontally arranged top and bottom headers **60** and **61**, respectively, and having their intermediate portions curved to define a circular fuel inlet port **62**. A fuel inlet conduit **63** registers with the port **62** and is arranged to discharge a whirling stream of primary combustion air and crushed coal through the port **62**. The rear or inner end of each combustion chamber is partially closed by fluid heating tubes of the front and rear walls **19** and **20**, respectively, intermediate portions of some of these tubes being bent to form an inwardly projecting gas outlet throat **64** and a slag outlet **65** for each combustion chamber.

In cyclone furnace **24** the header **61** is supplied with feedwater by tubes **66**, the headers **51**, **52** and **54**, **55** are connected for flow of fluid from the header **60** by tubes **67**, and the headers **53** and **56** are connected for flow of fluid to the inlet header **61** of cyclone furnace **25** by tubes **69**. In cyclone furnace **25** header **60** is connected for fluid flow to the headers **51**, **52** and **54**, **55** by tubes **67**.

Each boundary wall of the upright chamber **18** is formed by fluid heating tubes having their intertube spaces closed by metallic webs **71**, as shown in Figs. 5 and 6, welded to the tubes along the lengths thereof to provide a gas-tight enclosure, the tubes of the front wall **19** having their opposite ends connected to headers **72** and **73**, the tubes of the rear wall **20** having their opposite ends connected to headers **74** and **75**, the tubes of side wall **21** having their opposite ends connected to headers **76** and **77**, and the tubes of side wall **22** having their opposite ends connected to headers **78** and **79**. The tubes of each boundary wall of the upright chamber **18** are arranged for parallel flow of fluid relative to the other boundary walls thereof and are supplied with fluid by tubes 80 extending from the headers 53 and 56 of the cyclone furnace 25 to the supply headers 72, 74, 76 and 78. The tubes of the front and rear walls 19 and 20 have their lower portions bent inwardly and downwardly to define in conjunction with the side walls 21, 22 a rectangular throat passage 81 for discharging molten slag into a slag tank 82. The tubes of the side walls 21, 22 have their upper portions bent inwardly and upwardly in converging relation, with the space at the point of convergence sealed with suitable refractory material. Alternate tubes of the front and rear walls 19 and 20 are bent laterally and inwardly at positions subjacent and superjacent the gas passes 27, 28 to provide gas inlets and outlets 83, 84 and 85, 86 to the gas by-passes 29 and 30, respectively. Gases passing through the outlets 84 and 86 discharge into the portion of chamber B from which gases flow to the conduits 38 and 40. At the top of the chamber B the tubes of the front and rear walls 19 and 20 are formed with return bends from which tubes 19A and 20A having their intertube spaces closed by metallic webs extend downwardly in the air flow space 23 in spaced relation and parallel to the front and rear walls 19 and 20 to define in conjunction with the front and rear boundary walls the gas by-passes 29 and 30, respectively. An upright gas-tight metallic baffle 87 cooperates with the enclosure walls of the chamber B to define the gas passes 27 and 28. Intermediate portions of some of the boundary wall tubes of the chamber 18 are bent to form the openings with which the gas outlet of the conduit 45 and the gas inlets of the conduits 38 and 40 register.

Substantially all of the space available in the chamber B and the upright gas pass 34 is effectively employed for heat transfer, this space being occupied by steam superheating and reheating surface in the form of banks of horizontally arranged serially connected return bend tubes disposed across the path of the heating gases. The upright gas pass 34 is occupied by the primary superheater 36 which comprises banks of top-supported multi-looped horizontally extending tubes arranged in laterally spaced panels and having their opposite ends connected to horizontally extending inlet and outlet headers 89 and 90 disposed in the air flow space 35, with corresponding panels serially connected to define parallel paths for fluid flow between the headers 89 and 90 in counter flow heat transfer relation with the gases. The space from the gas inlet of the chamber B to a position subjacent the gas inlets 83, 85 is occupied by the secondary superheater 26, the tubes of which are arranged similar to those of the primary superheater, except that the lateral spacing of the tube panels in th two lower banks thereof is double that of the upper banks and the tubes are arranged in parallel flow heat transfer relation with the gases, and have their opposite ends connected to horizontally extending inlet and outlet headers 91 and 92, respectively, situated in the air flow space 23.

The primary superheater 36 is connected for series flow of fluid from the boundary walls of the chamber 18 by tubes 93 extending between the inlet header 89 and the headers 73, 75, 77, and 79 and for series flow of fluid to the secondary superheater 26 by tubes 94 extending between the outlet header 90 and the inlet header 91. The tubes of the secondary superheater 32 occupy the gas pass 28, are arranged similar to those of the primary superheater 34 and for fluid flow in counter flow heat transfer relation with the gases, and have their opposite ends connected to horizontally extending inlet and outlet headers 95 and 96, respectively, disposed in the air flow space 23. The secondary superheater 32 is connected for series flow of fluid from the secondary superheater 26 by tubes 97 extending between the outlet header 92 and the inlet header 95. Fluid discharging from the outlet header 96 passes to the vapor turbine 14 by way of a conduit 98.

The gas pass 27 is occupield by the reheater 31, the tubes of which are arranged similar to those of the superheater 32 and for fluid flow in counter flow heat transfer relation with the gases and have their opposite ends connected to horizontally extending inlet and outlet headers 99 and 100, respectively, disposed in the air flow space 23. The reheater 31 is connected for series flow of fluid from the vapor turbine 14 by a conduit 101 and to the low pressure stage of the turbine 14 by way of conduits 102 leading from the outlet header 100. Suitable seals are provided between the vessel 17 and the conduits 101, 102 at their points of passage through the vessel 17.

The upper end of the vessel 17 is closed by an inverted dished wall 103 and the lower end is formed with a dished wall 104 having an opening therein through which the upper portion of the slag tank 82 extends in sealing relation therewith. A horizontally extending insulation covered metallic cylindrical vessel 105 is concentrically arranged about each cyclone furnace and opens at one end to the vessel 17 to define in cooperation with the cyclone furnace an annular space 106 communicating with the air flow space 23 in the vessel 17. The opposite or outer end of each vessel 105 is formed with a dished wall 107 having an opening therein through which the fuel inlet conduit 63 extends in sealing relation therewith.

The fluid heating unit 13 is bottom-supported by structural steel members including upright members 108, ribbed annular skirts 109 and 110 secured to the upper ends of the upright members 108, and ribbed annular skirts 111 and 112 adjacent the bottom of the vessels 17 and 33, respectively, snugly-fitted and welded to the outer sides thereof and suitably secured to the annular skirts 109 and 110, respectively. These structural members are of sufficient size and strength to bottom support the entire load of the fluid heating unit. All of the boundary walls of the upright chamber 18, as well as the superheating and reheating surfaces therein, are pendently supported from horizontally disposed steelwork including ribbed annular skirts 125 and 126 at the top portion of the vessel 17 welded and snugly-fitted to the inner and outer sides thereof and cross members such as 113 and 114 carried by the skirt 126. Steel-work for pendently supporting the gas pass 34 and the primary superheater disposed therein includes annular ribbed skirts 115 and 116 at the top portion of the vessel 33 welded to the inner and outer sides thereof and cross beams 117 carried by the skirt 116 and from which suitable hangers support the primary superheater. Thus the described support arrangement provides for upward expansion of the vessels 17 and 33, while the boundary walls of the chamber 18 and the gas pass 34 and the superheating and reheating surfaces expand downwardly.

For the sake of clarity, Fig. 3 diagrammatically shows the flow paths of the vaporizable fluid, the air for combustion, and the heating gases for the embodiment of the invention illustrated in Figs. 1 and 2. Feedwater at a pressure of 4500 p.s.i. is supplied by a feed pump, not shown, through feedwater heaters, not shown, using steam bled from the turbine 14 at appropriate stages in the turbine. The partially heated feedwater then passes through the economizer 16 and tubes 66 to the inlet header 61 of cyclone furnace 24. While Fig. 3 diagrammatically illustrates that the water then passes successively through the wall-cooling tubes of the cyclone furnaces 24 and 25 to the boundary wall supply headers of the chamber 18, the particular path of the water through the cyclone furnaces is best seen in Figs. 1 and 2. With reference to cyclone furnace 24, water discharging from the header 61 flows through the tubes lining the frustoconical section 58 to the header 60, then passes through tubes 67 to the headers 51, 52, 54, 55 for flow through wall tubes 50. Headers 53 and 56 receive water from the wall tubes 50 and discharge to the inlet header 61 of the cyclone furnace 25 by way of tubes 69. Circulation in cyclone furnace 25 is the same as in cyclone furnace 24, the water successively passing through the tubes lining the frustoconical section 58, header 60, tubes 67, headers 51, 52, 54, 55, walls tubes 50, headers 53, 56 and tubes 80 to the inlet headers 72, 74, 76 and 78 of the boundary walls of the upright chamber 18. The water then flows in parallel through the tubes of the side walls 21, 22 and the front and rear walls 19 and 20, including the tube portions 19A and 20A, respectively, to the boundary wall outlet headers 73, 75, 77 and 79, from which the water passes to the inlet header 89 of the primary superheater 36 by way of tubes 93. The fluid heating surfaces in the cyclone furnaces and the boundary walls of the upright chamber 18 are proportioned and arranged so that the portion of the heated fluid circuit in which the transition of the water from a liquid to a vapor condition occurs will be located in the relatively low temperature primary superheater 36 throughout the operating range of the fluid heating unit. Steam discharges from the tubes of the primary superheater into the outlet header 90, then passes through tubes 94 to the inlet header 91 of the secondary superheater 26. The tubes of the secondary superheater 26 discharge to the header 92, from which steam passes through tubes 97 to the inlet header 95 of the finishing or secondary superheater 32. The steam receives its final superheating in the tubes of the super heater 32 and is discharged to the outlet header 96, from which it passes through conduit 98 to the turbine 14 for partial expansion therein. Steam passes from the turbine 14 through conduit 101 to the inlet header 99 of the reheater 31, then flows through the tubes of the reheater to the header 100, from which it returns to the turbine 14 through the conduits 102 for final expansion.

Combustion air is supplied by the compressor 10 at a pressure of about 88 p.s.i.a. and temperature of 460° F. through the air heater 12, which is preferably of the tubular type, to the air flow space 35 at about 600° F. by way of a conduit 120 having its discharge end registering with a circular flanged opening 121 in the vessel 33. The air flows upwardly through the spaces 35 and 39 in counter flow relation to the gases passing through the conduit 38 and the gas pass 34, then enters the air flow space 23 for flow downwardly therethrough to the secondary air inlet 57 of each cyclone furnace in counter flow relation to the gasses passing through the chamber 18. Thus the air is further heated in passing through the spaces 35, 39 and 23, since it cools the boundary surfaces of the upright gas pass 34, the conduit 38 and the chamber 18 before entering the secondary air inlets 57 at a temperature of around 620° F. The air flow spaces 35, 39 and 23 are normally under an air pressure about 2–3 p.s.i. higher than the heating gas pressure at any point along its flow path, largely due to the pressure drop of the gases in flowing through the cyclone furnaces, so that any leakage through the boundary walls of the chamber 18, the conduit 38 or the gas pass 34 is inward toward the gas flow path rather than outward to avoid the blasting of hot gases on the walls of the vessels 17 and 33 and the conduit 37. Thus, the outward thrust of the heating gases on the inside of the boundary walls of the upright gas pass 34, the conduit 38 and the chamber 18 is counter balanced by the thrust of the air acting on the outside of the same boundary walls, resulting in a differential thrust of only a few pounds and minimizing the need for lateral steel supports or horizontal buckstay members on these boundary walls to prevent warping or buckling thereof. In addition, the counter balancing effect of the air on the outward thrust of the gases permits the chamber 18 and the gas pass 34 to be of substantially rectangular cross-section, as shown in Fig. 4, thereby making available optimum space for accommodation of heating surfaces and permitting use of superheater and reheater tube arrangements free from complexity. The vessels 17 and 33 and the conduit 37 are advantageously of circular form in horizontal cross-section to best withstand the outward thrust of the air on the inner surface thereof with a minimum of lateral supports, while providing a compact installation.

Since the gas turbine power is maintained substantially constant over a wide range of steam generation rates, the compressor air flow will also be constant over this range. Thus at steam loads less than full load the compressor air flow rate will be in excess of that required for complete combustion of the fuel. While the entire air flow from the compressor at steam loads less than the full load may be passed to the cyclone furnaces, alternatively the air in excess of that needed for complete combustion of the fuel may be regulably withdrawn from the conduit 120 through a dampered conduit 118 and discharged into the conduit 45 at the outlet portion thereof for flow into the chamber A with the recirculated gases.

In the normal operation of the fluid heating unit described at pressures and temperatures above the critical values, primary air and a relatively coarse crushed fuel in suspension is supplied to the cyclone furnaces through the fuel inlets 63 from independently controllable sources and the fuel burned in the cyclone furnaces at high rates of heat release sufficient to maintain a normal mean temperature therein above the fuel ash fusion temperature. The secondary combustion air is supplied in quantities insuring substantially complete combustion of the fuel in the cyclone furnaces. The ash separates as a molten slag which flows through the outlet 65 of each cyclone furnace into the chamber A and is discharged through the outlet 81 into the slag tank 82, while gases with a relatively small amount of slag particles in suspension discharge through the throats 64 into the lower portion of the chamber A. The gases then flow upwardly through the chamber A to the inlet of the chamber B. The inside of the lower portion of the enclosure walls of the chamber A is covered with refractory to reduce the heat input thereto, to maintain temperatures in this chamber portion above the ash fusion temperature so that slag will continuously pass through the throat 81 in a molten condition, and to withstand the high temperature conditions in this chamber portion.

The temperature of the heating gases flowing through the chamber portion A is regulated to provide a gas temperature at the entrance of the chamber portion B of a degree which will insure any slag particles in suspension in the gases being in a solidified or "dry" condition, avoid overheating and plugging of the tubes in the secondary superheater 26, and yet provide a heat content of the heating gases sufficient to attain the desired final superheat and reheat temperatures. For this purpose, gases withdrawn by the recirculating fan 42 from the gas outlet of the gas pass 34 by way of the conduit 43 are passed through the conduit 45 into the chamber A. At steam loads less than full steam load, air in excess of that required for complete combustion of the fuel may be delivered to the cyclone furnaces or regulably by-passed in whole or in part through the conduit 118 to the conduit 45 for discharge into the chamber A with the recirculated gases. The recirculated gases and by-passed air enter at sufficient velocity to insure an intimate mixing with the fresh combustion gases passing upwardly through the chamber A. The gas temperature leaving the chamber A is controlled by variations in the rate of fuel firing and by the quantity of gaseous fluids introduced into the chamber A by way of the conduit 45. The flow of recirculated gases is at a maximum at full steam load and progressively decreases as the steam load decreases. If all the air in excess of the burner requirements is by-passed through the conduit 118 to the conduit 45, the quantity thereof is at a minimum at full steam load and progressively increases as the steam load decreases.

The tempered heating gases at the desired temperature flow vertically over and between the tubes of the secondary superheater 26 and then enter the parallel gas passes 27, 28, 29 and 30, the proportioning of the gas flow to these passes being regulated by dampers 122, 123, 124 and 125, respectively, to control the final steam temperature leaving the reheater 31 and the superheater 32 and the temperature of the gases passing to the gas turbine 11. The superheating and reheating surfaces are proportioned and arranged to provide the required final or outlet steam temperatures at full steam load with no gas flow through the passes 29 and 30. Gas flow through the passes 29 and 30 is increased as the rate of steam generation decreases to hold the reheater 31 and superheater 32 outlet steam temperatures constant over a wide range of steam loads, while maintaining the temperature of the combined gases leaving the passes 27, 28, 29 and 30 at a substantially constant value of 1450° F.

Gases flowing through the parallel gas passes merge in the upper part of the chamber B, from which a portion of the gases discharge through the conduit 40 to the gas turbine 11 at a pressure of about 83 p.s.i.a. and temperature of approximately 1450° F. and the remainder of the gases pass to the inlet of the gas pass 34 by way of the conduit 38. The proportion of gases passing to the gas turbine 11 and the gas pass 34 is controlled by dampers 126 in the conduit 40, the quantity of gases at constant temperature passing to the turbine 11 being maintained constant over a wide range of steam generation rates, this range extending from about one third to full steam load, while the quantity of gases passing to the gas pass 34 and thence to the chamber A progressively decreases with decreasing steam load from a maximum at the full rate of steam generation.

The portion of the gases passing to the gas turbine 11 discharge therefrom at a temperature of about 928° F., then flow over the airheater 12 and the economizer 16 to the stack at a temperature of about 325° F. The portion of the gases discharging through the conduit 38 to the gas pass 34 flow over and between the tubes of the primary superheater 36 and then are withdrawn by the gas recirculation fan 42 for return to the chamber A at a temperature of approximately 850° F., as previously described.

In the embodiment of the invention illustrated in Figs. 7–10, the construction and arrangement of the fluid heating unit is generally the same as that shown in Figs. 1–6, except in the particulars hereinafter described, and accordingly for convenience and clarity the same reference characters are utilized to identify identical or closely similar parts. In the modified form, the chamber B is extended vertically upwardly to accommodate the primary superheater 36 and the upright vessel 17 is extended vertically upwardly to define with the chamber B an extension of the air flow space 23 and to accommodate the gas recirculation fan 42 and its associated supporting steelwork. With the chamber B so extended, the reheater 31 and the superheater 32 occupy the central portion thereof. Upright gas-tight baffles 87A cooperate with the enclosure walls of the chamber B to define three parallel gas passes 27, 28 and 130, pass 27 being occupied by the reheater 31, pass 28 by the superheater 32, and the pass 130 being a gas by-pass around the reheater 31 and superheater 32. Dampers 122, 123 and 132 control gas flow through the gas passes 27, 28 and 130, respectively. The banks of superheater and reheater tubes are of the same construction and form as those of the first embodiment, except that the tube panels of the reheater 31 and superheater 32 are arranged in planes normal to the planes of the corresponding tube panels illustrated in Figs. 1 and 2. The upper ends of the front, rear and side walls 19, 20, 21 and 22 are connected to horizontally arranged headers 73A, 75A, 77A and 79A, respectively, disposed at the same elevation.

The conduit 40 connecting the gas turbine 11 to the chamber B opens to the chamber B at a position intermediate the primary superheater 36 and the parallel gas passes 27, 28, 130. The gas recirculation fan 42 has its intakes connected to the upper end of the chamber B by a conduit 43A and its discharge connected to the chamber A by an insulation covered conduit 45A of circular cross-section extending through the vessel 17 in sealing relation therewith and opening to the chamber A through the side wall 22 thereof at a position between the cyclone furnaces and the secondary superheater 26. Thus the conduits 40 and 43A receive gases from the same relative positions in the heating gas flow path as the corresponding conduits in the first embodiment.

The vessel 17 includes a circular flanged opening 121A which registers with the discharge end of the air supply conduit 120. As shown in Fig. 10, the air flow space 23 is divided into two halves along the centerline of the fluid heating unit by vertical baffles 138 disposed and closing the space between the vessel 17 and the chamber 18 from a position subjacent the opening 121A to the upper end of the chamber 18 and secured along their lengths to diagonally opposite corners of the chamber 18. The lower ends of the baffles 138 are connected to a horizontal baffle 140 disposed and closing the space between the vessel and the chamber 18 and secured to the rear wall 20 and the side wall 22. The baffles 138 and 140 cooperate to direct incoming air upwardly through one half of the air flow space 23, then downwardly through the remaining half of the space 23 to the secondary air inlet 57 of each cyclone furnace.

The fluid heating unit is bottom-supported by structural steel members including upright members 108, skirt 109, and ribbed annular skirts 111 and 142 snugly-fitted and welded to the inner and outer sides of the vessel 17 at a position intermediate the baffle 140 and the cyclone furnaces, with the skirt 111 being suitably secured to the skirt 109. The general arrangement of the structural supports for the upright chamber 18 and the heating surfaces contained therein is the same as in the first embodiment. Steelwork for supporting the fan 42 includes ribbed annular skirts 144, 146 welded to the inner and outer sides of the vessel 17 and cross beams 148 carried by the skirt 144.

As illustrated in Fig. 9, the tubes of the cyclone furnaces, the boundary walls of the chamber 18 and the superheaters and reheater are connected for serial flow of the vaporizable fluid therethrough in the same order as that of Fig. 3; and the superheaters and the reheater occupy the same relative positions in the heating gas flow path and are arranged for fluid flow in the same heat transfer relations with the heating gases as the corresponding apparatus in the first embodiment.

While in accordance with the provisions of the statutes, I have illustrated and described herein a specific form of the invention now known to me, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by my claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of the other features.

What is claimed is:

1. A fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine, comprising walls including fluid heating tubes defining an upright chamber, means for supplying a vaporizable fluid to said fluid heating tubes, burner means for supplying heating gases to said chamber for flow therethrough, means for supplying air from said compressor to said burner means, means forming at least a pair of parallel passes for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the vapor turbine, another of said parallel passes being a gas by-pass around the superheater in said one pass, and means for

maintaining a predetermined vapor temperature to the vapor turbine over a wide range of vapor turbine power output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine including gas turbine supply means for conducting heating gases from a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from a position downstream gas-wise of said parallel gas passes to said upright chamber at a position upstream gas-wise of said superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

2. A supercharged fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed at least in part within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases to said chamber for flow therethrough, means conducting air from said compressor to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming at least a pair of parallel passes for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the vapor turbine, another of said parallel pases being a gas by-pass around the superheater in said one pass, and means for maintaining a predetermined vapor temperature to the vapor turbine over a wide range of vapor turbine power output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine including gas turbine supply means for conducting heating gases from a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from a position downstream gas-wise of said parallel gas passes to said upright chamber at a position upstream gas-wise of said superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

3. A supercharged once-through forced flow fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compresser driven by the gas turbine and a vapor turbine, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases at superatmospheric pressure to the lower part of said chamber for flow therethrough, means for conducting air from said compressor to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming at least a pair of parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the vapor turbine, another of said parallel passes being a gas by-pass around the superheater in said one pass, and means for maintaining a predetermined vapor temperature to the vapor turbine over a wide range of vapor turbine power output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine including gas turbine supply means for conducting heating gases from said upright chamber from a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from a position downstream gas-wise of said parallel gas passes to said upright chamber as tempering gases at a position between the burner means and said superheater for mixing with the freshly generated heating gases, and damper means for proportioning the total gas flow between said parallel gas passes.

4. A fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine, comprising walls including fluid heating tubes defining an upright chamber, means for supplying a vaporizable fluid to said fluid heating tubes, burner means for supplying heating gases to said chamber for flow therethrough, means for supplying air from said compressor to said burner means, means forming at least a pair of parallel passes for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the vapor turbine, another of said parallel passes being a gas by-pass around the superheater in said one pass, gas turbine supply means for conducting heating gases from a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from a position downstream gas-wise of said parallel gas passes to said upright chamber at a position up-stream gas-wise of said superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

5. A supercharged fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed at least in part within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases to said chamber for flow therethrough, means for conducting air from said compressor to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming at least a pair of parallel passes for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the vapor turbine, another of said parallel passes being a gas by-pass around the superheater in said one pass, gas turbine supply means for conducting heating gases from a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from a position downstream gas-wise of said parallel gas passes to said upright chamber at a position upstream gas-wise of said superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

6. A supercharged once-through forced flow fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed at least in part within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supply-

ing heating gases at superatmospheric pressure to the lower part of said chamber for flow therethrough, means for conducting air from said compressor to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming at least a pair of parallel passes downstream gas-wise of said burner means for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the vapor turbine, another of said parallel passes being a gas by-pass around the superheater in said one pass, gas turbine supply means for conducting heating gases from a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from a position downstream gas-wise of said parallel gas passes to said upright chamber at a position upstream gas-wise of said superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

7. A fluid heating unit comprising walls defining an upright vessel of substantially circular horizontal cross-section, walls including fluid heating tubes defining an upright chamber of substantially rectangular horizontal cross-section disposed at least in part within said vessel and cooperating with said vessel to define a space therebetween for air under pressure, means for supplying a vaporizable fluid to said fluid heating tubes, burner means for suplying heating gases to said chamber at a pressure at least as great as a plurality of atmospheres for flow therethrough, means for supplying air to said space at a pressure at least equal to the gas pressure in said upright chamber, and a superheater including horizontally extending return band tubes disposed in said upright chamber at a position downstream gas-wise of said burner means and transversely of gas flow through said chamber, said superheater being connected for series flow of fluid from said fluid heating tubes.

8. A fluid heating unit comprising walls defining an upright vessel of substantially circular horizontal cross-section, walls including fluid heating tubes defining an upright chamber of substantially rectangular horizontal cross-section disposed at least in part within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases to said chamber at a pressure at least as great as a plurality of atmospheres for flow therethrough, means for supplying air to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming at least a pair of parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes and including horizontally extending return bend tubes, said superheater being connected for series flow of fluid from said fluid heating tubes, another of said parallel passes being a gas by-pass around the superheater in said one pass, and means for proportioning the total gas flow between said parallel gas passes.

9. A supercharged once-through forced flow fluid heating unit comprising walls defining an upright vessel of substantially circular horizontal cross-section, walls including fluid heating tubes defining an upright chamber of substantially rectangular horizontal cross-section disposed within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases at superatmospheric pressure to the lower part of said chamber for flow therethrough, means for supplying air to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming at least a pair of parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes and including horizontally extending return bend tubes, said superheater being connected for series flow of fluid from said fluid heating tubes, another of said parallel passes being a gas by-pass around the superheater in said one pass, and means for proportioning the total gas flow between said parallel gas passes.

10. A supercharged forced flow fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed at least in part within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases at superatmoshperic pressure to said chamber for flow therethrough, means for conducting air from said compressor to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming at least a pair of parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes and the remainder upstream gas-wise of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the vapor turbine, another of said parallel passes being a gas by-pass around the superheater in said one pass, and means for maintaining a predetermined vapor temperature to the vapor turbine over a wide range of vapor turbine power output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine including gas turbine supply means for conducting a portion of the heating gases from said upright chamber at a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct the remainder of the heating gases from a position downstream gas-wise of said parallel gas passes to said upright chamber at a position upstream gas-wise of said superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

11. A supercharged once-through forced flow fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases at superatmospheric pressure to said chamber for flow therethrough, means for conducting air from said compressor to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming at least a pair of parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a first superheater in said upright chamber disposed downstream gas-wise of said parallel gas passes, a second superheater having at least a portion thereof in one of said parallel passes, said fluid heating tubes and said superheaters being connected for series flow of fluid to said vapor turbine, another of said parallel passes being a gas by-pass around the superheater in said one

pass, and means for maintaining a predetermined vapor temperature to the vapor turbine over a wide range of vapor turbine power output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine including gas turbine supply means for conducting a portion of the heating gases from said upright chamber at a position between the parallel gas passes and the first superheater to said gas turbine, gas recycling means constructed and arranged to conduct the remainder of the heating gases from said upright chamber at a position downstream gas-wise of said first superheater to said upright chamber at a position between the burner means and said second superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

12. A supercharged once-through forced flow fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with one end of said air flow space for supplying heating gases at superatmospheric pressure to said chamber for flow therethrough, means forming at least a pair of parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a vertically elongated vessel disposed laterally adjacent said upright vessel, an upright gas pass disposed within said vertically elongated vessel, said upright gas pass having its inlet end communicating with said upright chamber at a position downstream gas-wise of said parallel gas passes and cooperating with said vertically elongated vessel to define an air flow zone communicating at one end with the opposite end of said air flow space, means for conducting air from said compressor to the opposite end of said air flow zone for flow therethrough to said air flow space and thence to said burner means at a pressure at least equal to the gas pressure in said upright chamber, a first superheater in said upright gas pass, a second superheater having at least a portion thereof in one of said parallel passes, said fluid heating tubes and said superheaters being connected for series flow of fluid to the vapor turbine, another of said parallel passes being a gas by-pass around the superheater in said one pass, and means for maintaining a predetermined vapor temperature to the vapor turbine over a wide range of vapor turbine power output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine including gas turbine supply means for conducting a portion of the heating gases from said upright chamber at a position between the parallel gas passes and the first superheater to said gas turbine, the remainder of the heating gases discharging to said upright gas pass, gas recycling means constructed and arranged to conduct the remainder of the heating gases from said upright gas pass at a position downstream gas-wise of said first superheater to said upright chamber at a position between the burner means and said second superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

13. A supercharged forced flow fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine having high and low pressure stages, comprising walls including fluid heating tubes defining an upright chamber, means for supplying a vaporizable fluid to said fluid heating tubes, burner means for supplying heating gases at superatmospheric pressure to said chamber for flow therethrough, means forming three parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the high pressure stage of said turbine, a reheater in another of said passes and connected for series flow of fluid from the high pressure stage of said vapor turbine and to the low pressure stage of said vapor turbine, the third pass being a gas bypass around the superheater in said one pass and the reheater, and means for maintaining predetermined vapor temperatures to the high and low pressure stages of said vapor turbine over a wide range of vapor turbine power output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine including gas turbine supply means for conducting heating gases from a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from a position down-stream gas-wise of said parallel gas passes to said upright chamber at a position upstream gas-wise of said superheater for mixing with the freshly generated heating gases, and means for proportioning the total gas flow between said parallel gas passes.

14. A supercharged forced flow fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine having high and low pressure stages, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed at least in part within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases at superatmospheric pressure to said chamber for flow therethrough, means for conducting air from said compressor to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming three parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a superheater having at least a portion thereof in one of said parallel passes, said superheater being connected for series flow of fluid from said fluid heating tubes and to the high pressure stage of said turbine, a reheater in another of said passes and connected for series flow of fluid from the high pressure stage of said vapor turbine and to the low pressure stage of said vapor turbine, the third pass being a gas by-pass around the superheater in said one pass and the reheater, gas turbine supply means for conducting heating gases from a position downstream gas-wise of said parallel gas passes to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from a position downstream gas-wise of said parallel gas passes to said upright chamber at a position upstream gas-wise of said superheater for mixing with the freshly generated heating gases, and damper means for proportioning the total gas flow between said parallel gas passes.

15. A supercharged once-through forced flow-fluid heating unit for use in a binary elastic fluid power plant including a gas turbine, an air compressor driven by the gas turbine and a vapor turbine having high and low pressure stages, comprising walls defining an upright vessel, walls including fluid heating tubes defining an upright chamber disposed within said vessel and cooperating with said vessel to define an air flow space therebetween, means for supplying a vaporizable fluid to said fluid heating tubes, burner means communicating with said air flow space for supplying heating gases at superatmospheric pressure to said chamber for flow therethrough, means for conducting air from said compressor

to said air flow space for flow therethrough to said burner means at a pressure at least equal to the gas pressure in said upright chamber, means forming three parallel passes at a position downstream gas-wise of said burner means for the gases flowing through said chamber, a first superheater in said upright chamber disposed downstream gas-wise of said parallel gas passes, a second superheater having a portion thereof in one of said parallel passes and the remainder upstream gas-wise of said parallel passes, said fluid heating tubes and said superheaters being connected for series flow of fluid to the high pressure stage of said vapor turbine, a reheater in another of said passes and connected for series flow of fluid from the high pressure stage of said vapor turbine and to the low pressure stage of said vapor turbine, the third pass being a gas bypass around the superheater in said one pass and the reheater, and means for maintaining predetermined vapor temperatures to the high and low pressure stages of said vapor turbine over a wide range of vapor turbine power output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine including gas turbine supply means for conducting heating gases from said upright chamber at a position between the parallel gas passes and the reheater to said gas turbine, gas recycling means constructed and arranged to conduct heating gases from said upright chamber at a position downstream gas-wise of said first superheater to said upright chamber as tempering gases at a position between the burner means and said second superheater for mixing with the freshly generated heating gases, and damper means for proportioning the total gas flow between said parallel gas passes.

16. The method of operating a binary elastic fluid power plant comprising a gas turbine, an air compressor driven by the gas turbine, and a vapor generating and superheating unit having a fluid cooled heating gas receiving zone, means supplying freshly generated high pressure heating gases to the gas receiving zone, a pair of parallel gas passes beyond said gas receiving zone, and a superheater having at least a portion thereof in one of said parallel gas passes and subject to the heating gas flow after loss of heat therefrom in vapor generation, the other of said parallel gas passes being a gas bypass around the superheater in said one gas pass, said method comprising the steps of passing the superheated vapor from the superheater to the vapor turbine, maintaining a predetermined vapor temperature to the vapor turbine over a wide range of vapor turbine output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine by withdrawing heating gases from a position downstream gas-wise of said parallel gas passes and discharging the withdrawn gases into said gas receiving zone at a position upstream gas-wise of said parallel gas passes for mixing with the freshly generated heating gases, proportioning the flow of gases thus mixed between said parallel gas passes, conducting heating gases from a position downstream gas-wise of said parallel gas passes to said gas turbine, decreasing the rate of supply of freshly generated gases as the rate of vapor turbine power output decreases, and passing high pressure air from said compressor to said high pressure heating gas supply means.

17. The method of operating a binary elastic fluid power plant comprising a gas turbine, an air compressor driven by the gas turbine, and a vapor generating and superheating unit having a fluid cooled heating gas receiving zone, means supplying freshly generated high pressure heating gases to the gas receiving zone, a pair of parallel gas passes beyond said gas receiving zone, and a superheater having at least a portion thereof in one of said parallel gas passes and subject to the heating gas flow after loss of heat therefrom in vapor generation, the other of said parallel gas passes being a gas bypass around the superheater in said one gas pass, said method comprising the steps of passing the superheated vapor from the superheater to the vapor turbine, maintaining a predetermined vapor temperature to the vapor turbine over a wide range of vapor turbine output, while maintaining a substantially constant rate of gas flow at a substantially constant gas temperature to said gas turbine by withdrawing heating gases from a position downstream gas-wise of said parallel gas passes and discharging the withdrawn gases into said gas receiving zone at a position upstream gas-wise of said parallel gas passes for mixing with the freshly generated heating gases, decreasing the rate of flow of the gases so withdrawn as the rate of vapor turbine power output decreases, conducting the gases thus mixed through said parallel gas passes to a common gas mixing zone therebeyond and proportioning the flow of gases through the parallel gas passes so that the temperature thereof upon mixing in the common gas mixing zone remains substantially constant as the rate of vapor turbine power output decreases, supplying the gas turbine with heating gases from said common gas mixing zone at a substantially constant rate as the rate of vapor turbine power output decreases, decreasing the rate of supply of freshly generated gases as the rate of vapor turbine power output decreases, and passing high pressure air from said compressor to said high pressure heating gas supply means at a substantially constant rate as the rate of vapor turbine power output decreases.

References Cited in the file of this patent

UNITED STATES PATENTS

1,948,538	Noack	Feb. 27, 1934
2,184,845	Noack	Dec. 26, 1939
2,361,812	Barnes	Oct. 31, 1944
2,628,598	Van Brunt	Feb. 17, 1953
2,776,647	Hawley	Jan. 8, 1957