Aug. 21, 1934. K. HAMM ET AL 1,970,747

POWER PLANT

Filed Feb. 21, 1930 4 Sheets-Sheet 1

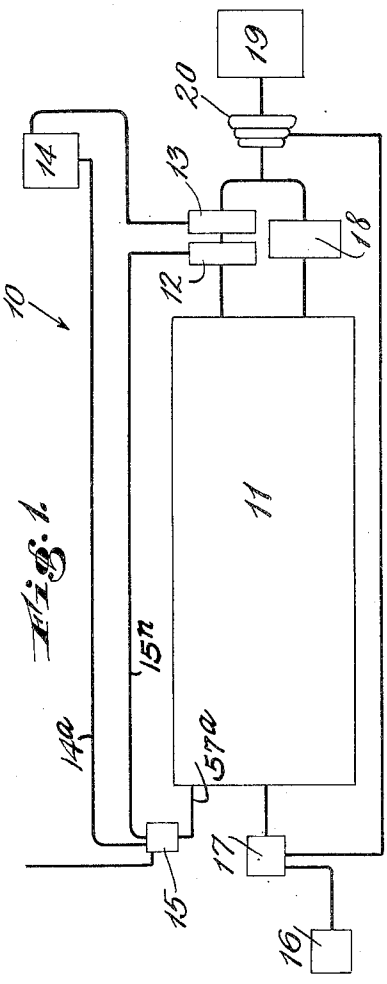

Fig. 1.

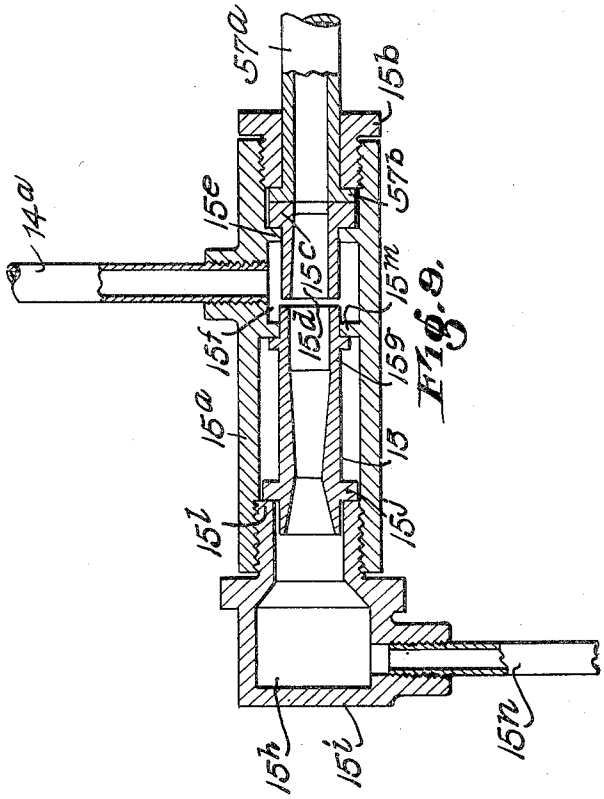

Fig. 2.

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POWER PLANT

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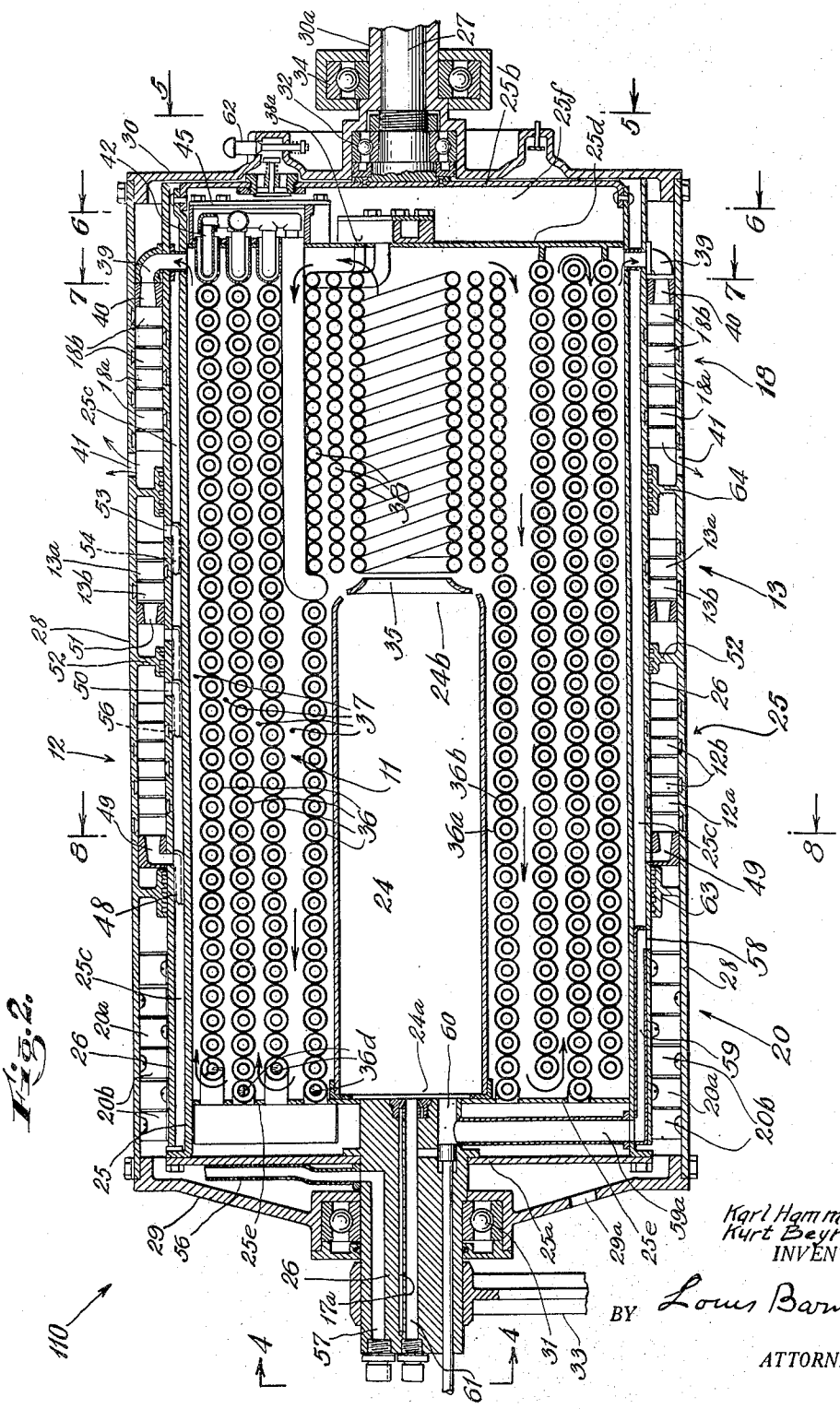

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Fig. 5.

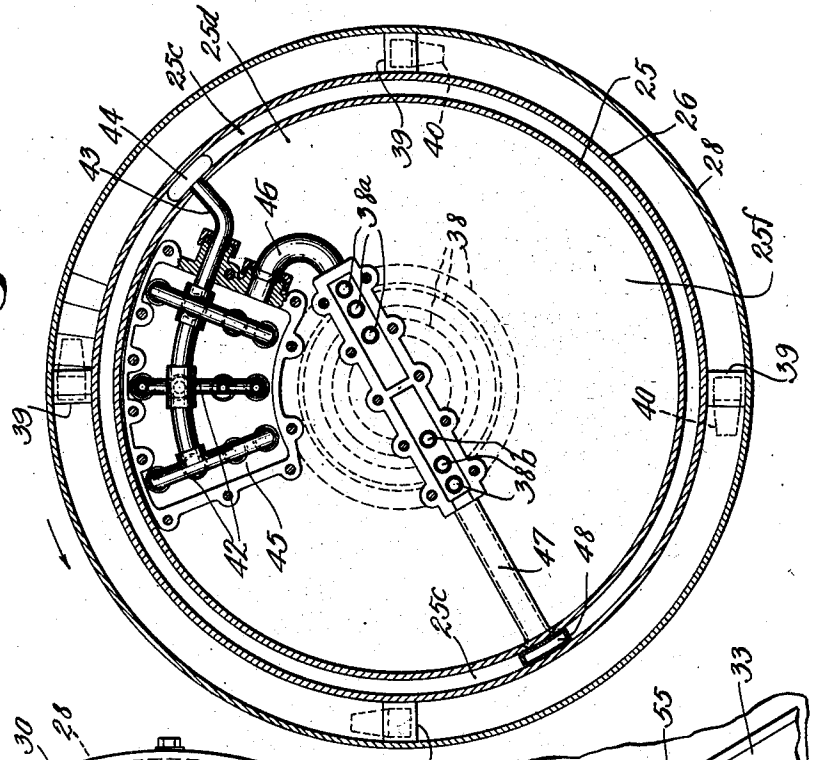

Fig. 4.

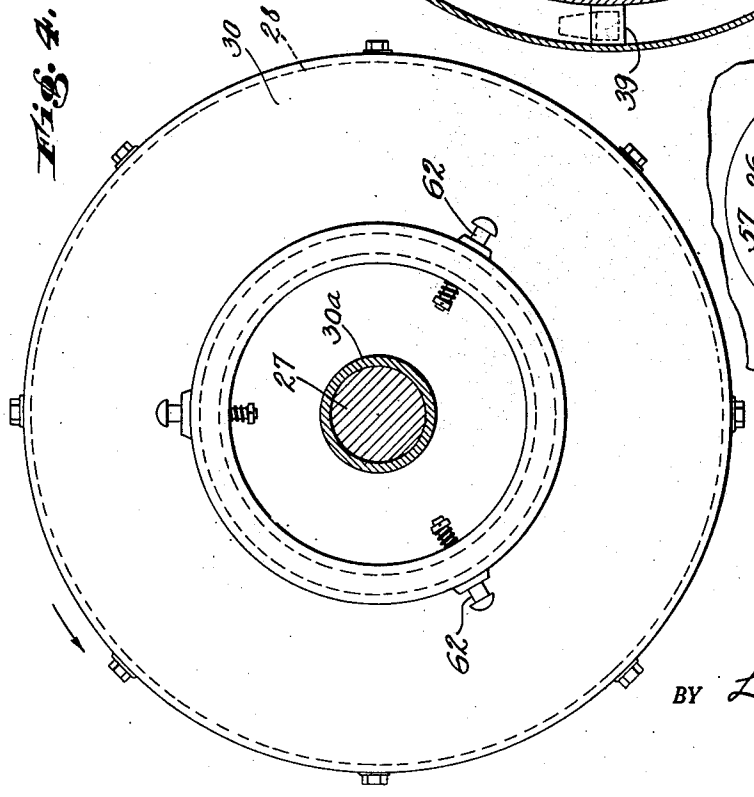

Fig. 3.

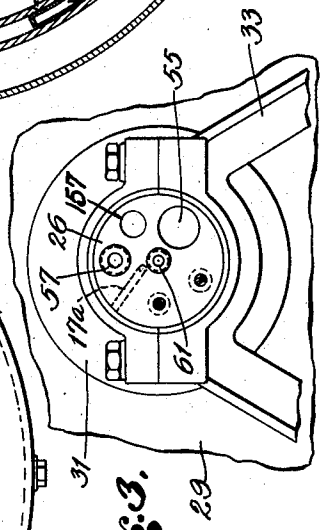

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Fig. 7.

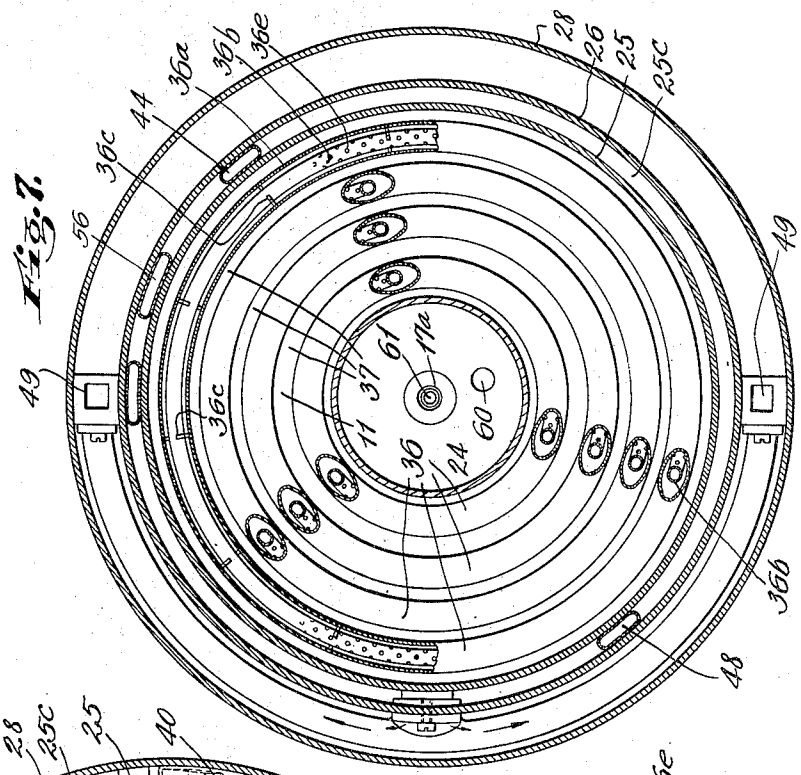
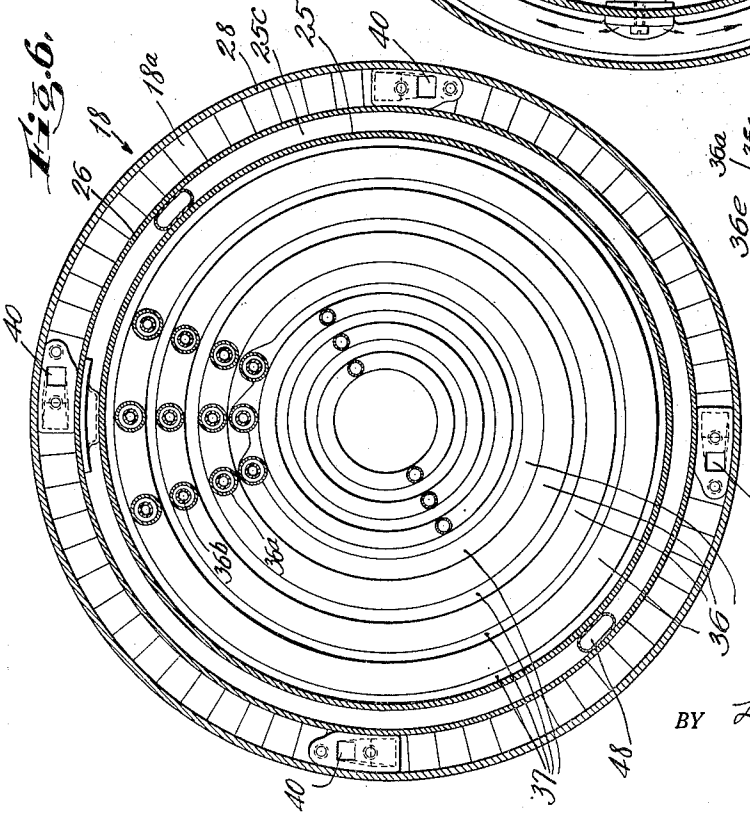


Fig. 6.



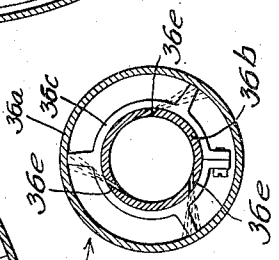


Fig. 8.

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Patented Aug. 21, 1934 1,970,747

UNITED STATES PATENT OFFICE

1,970,747

POWER PLANT

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Application February 21, 1930, Serial No. 430,170

8 Claims. (Cl. 60—49)

This invention relates to power plants of the continuous combustion type, and more particularly is directed to an improved method for converting the energy of continuously burning fuel into mechanical energy and to novel apparatus for practising the improved method, said apparatus and method herein described being particularly adapted to furnish motive power for transportation equipment.

It is contemplated in practising this invention to use power plant units arranged and operated in a novel manner in which fuel is continuously burnt to generate a steam supply for a turbine, the gases of combustion after generating the steam supply being further utilized by a gas turbine. In the method of operation here described an oil burner may be used to atomize and burn crude oil in a chamber under pressure greater than atmospheric. The heat extracted from the gases of combustion in passing through a boiler cools the gases sufficiently for practical use in the gas turbine, thus eliminating difficulty heretofore experienced with turbine parts exposed to combustion gases of high temperatures. One object of the invention is to provide and operate an improved power plant of the character described utilizing fuel combustion apparatus, boilers, gas and steam turbines, and condensers in novel combination whereby said power plant is made suitable to furnish motive power for vehicles, aeroplanes, dirigibles and the like.

Another object of the invention is to provide an improved method of the character described for converting the energy of continuously burning fuel into mechanical energy which is simple to carry out, the combustion of the fuel and conversion of the energy derived therefrom being carried out within limits most practical and efficient for utilization by the unit forming the power plant.

One feature of the invention is to bleed, that is, abstract steam from a comparatively high pressure stage of the steam turbine and utilize this bleed steam to operate means for forcing the said water into the boiler. Steam turbine operation with a bleeder system increases the internal efficiency and permits decreasing the size of the cooling condenser equipment since said equipment need only be of sufficient size to handle the steam passing from the steam turbine. Heretofore the tremendous weight of apparatus using a steam plant, and particularly those including a condenser were not to be thought of as motor power for aeroplanes. It is still another object of the invention to provide a practical improved steam condenser type of power plant adapted to be used for aeroplane propulsion.

A further object of the invention is to provide an improved power plant of the character comprising simple and novel arrangement of parts which shall form a compact, relatively lightweight apparatus, shall operate with very little attention requiring practically no skilled or expert supervision in operation, which shall reduce the vibratory stresses to a minimum, which shall be readily installed as a unitary structure, which shall be relatively inexpensive to manufacture and install, and practical and efficient to a high degree in use.

Other objects of this invention will in part be obvious and in part hereinafter pointed out.

The invention accordingly consists in the features of construction, combinations of elements and arrangement of parts which will be exemplified in the constructions hereinafter described and of which the scope of application will be indicated in the following claims.

In the accompanying drawings, in which are shown various possible illustrative embodiments of this invention:

Fig. 1 is a diagrammatic view showing the general layout of the power plant units interconnected for practising the method embodying the invention.

Fig. 2 is a cross-sectional view showing a novel compact arrangement of the rotary apparatus parts of the units, concentrically positioned about the fuel combustion unit and boiler, and exposing the interior construction of said units.

Fig. 3 is an end view as seen along lines 4—4 in Fig. 2.

Figs. 4, 5, 6, and 7 are cross-sectional views taken on lines 5—5, 6—6, 7—7 and 8—8, respectively, in Fig. 2.

Fig. 8 is a detailed cross-sectional view showing the means for supporting the inner feed water supply tube within the outer steam tube and also showing the nozzle construction for spraying the feed water against the inner surface of the outer tube, and

Fig. 9 is a detailed cross-sectional view showing the construction of an injector adapted to be used in the power plant embodying the invention.

A novel power plant embodying this invention now to be described in detail includes in combination a gas turbine and a bleeder or extraction type of steam turbine, the unit being so arranged as to form an efficient power plant for aeroplanes, automobiles, and other purposes where an excep-

tionally light weight prime mover is desired. The principal idea of operating the improved power plant is as follows:

A reduction of the temperature of the gases to be used as medium for converting heat energy into mechanical energy in the gas turbine is obtained by extracting a certain amount of heat per unit volume of the gas in the combustion chamber and converting this heat by means of a steam boiler and a bleeder type of steam turbine into available mechanical energy. This reduction of temperature of the gases is essential and vital to the efficient and practical operation of the gas turbine since the material forming the parts of the gas turbine is not capable of satisfactorily withstanding the excessive initial temperature of the gases in the combustion chamber. The method here used of reducing the temperature of the combustion gases for operating the gas turbine departs from the usual methods now employed in the arts, since heretofore the reduction of the temperature has been obtained by introducing excess air, steam or water to the combustion chamber. Under this usual method of reducing the temperature a gas turbine operates at a very low thermal efficiency, whereas the power plant in the present invention which requires no excess air, steam or water, permits reduction of size and weight of apparatus yet operates efficiently.

The use of the bleeder or extraction type of turbine reduces considerably the weight of condenser necessary to condense the steam, the latter being bled off from the turbine at one of the high pressure stages. The extracted steam is used to operate an injector for feeding the condensed water back into the boiler.

The improved power plant may be adapted to burn crude oil in a combustion chamber which is set within a helical tube boiler of the plate or flash type. The gas turbine receives the gases passing from the boiler, and the steam turbine is connected to the boiler. A turbine type of air compressor supplies air to the combustion chamber and the injector receives steam bled from the steam turbine for feeding condensed water passing from the condenser. The power generated by the turbines may be delivered to a propeller through a gear transmission. It is to be understood that mechanisms for automatically controlling the steam, air, oil and water supply of any standard, well understood construction may be provided on the power plant units.

Now referring to the drawings, Fig. 1, 10 denotes an improved layout of interconnected power-plant units in which the novel method for converting the energy of continuously burning fuel into mechanical energy embodying the invention, may be carried out. The power plant units 10 here shown comprise a suitable fluid pressure generator, such as a steam boiler 11, preferably of the flash or hot plate type, a multistage turbine having a high pressure stage 12 and a lower suitable condenser 14 taking the exhaust steam from the lower pressure turbine stage 13. The condensed water from the condenser 14 is fed back to the boiler 11 through an injector 15, the latter being operated by steam fed from the high pressure stage 12.

For heating the boiler, liquid fuel, such as crude oil, may be used and supplied from a convenient source 16 to a suitable burner 17 of any conventional make.

The partially cooled gases of combustion leaving the boiler are passed through a gas turbine 18 which supplements the available power or mechanical energy generated by the steam turbine portions 12 and 13, the power generated is utilized through a suitable transmission 19. Connected to turn with the rotary parts of the units there is a blower or compressor 20 which supplied air to the oil burner 17 and to a combustion chamber (shown in Fig. 3) within the boiler.

Referring now to Figs. 2 to 8, inclusive, a novel compact combination apparatus 110 is shown constructed to embody the invention. Said apparatus 110 has the rotary parts of the units, concentrically arranged about the fuel combustion chamber 24 and boiler 11 which form an internal stator structure for the equipment shown. Said stator structure is enclosed in a horizontally disposed cylindrical casing 25 which has its flat and circular shaped ends 25*a* and 25*b* axially supported on spaced and aligned fixed shafts 26 and 27, respectively. The outer surface of the cylinder 25 has fixed thereto an annular shell 26 which carries along one end portion, radially outward extending stationary blades 18*a* of the gas-turbine unit 18; along the midportion thereof, the radially outward extending stationary blades 12*a* and 13*a* of the high and low pressure steam turbine stages 12 and 13, respectively; and at the other end portion of said shell 26, the radially outward extending stationary blades 20*a* of the air compressor 20. The channel 25*c* between the casing 25 and shell 26 forms a passage for air, steam and water conduits arranged in the manner hereinafter described.

An external rotor structure is seen to form an enclosure, surrounds the stator structure of the improved combustion apparatus 110, said enclosure comprising a horizontally disposed cylindrical shell casing 28, supported at its opposite ends by disc plates 29 and 30. The shell casing 28 is concentrically positioned with respect to the annular shell 26 and carries gas turbine, high and lower pressure steam turbine and air blower runners or blades 18*b*, 12*b*, 13*b* and 20*b*, respectively, complementary to said stationary blades 18*a*, 12*a*, 13*a* and 20*a*, respectively.

The discs 29 and 30 are mounted for revolving the shell casings 28 on the shafts 26 and 27 respectively, through suitable bearings, which preferably are of the antifriction type, such as ball-bearings 31 and 32, respectively. The shaft 26 is fixedly supported on a stanchion 33 and the shaft 27 is supported within a sleeve 30*a* extending axially outward from the disc 30. The sleeve 30*a* may be supported upon a suitable fixed base (not shown) through a bearing, also preferably of the anti-friction type, such as ball-bearing 34.

The fuel combustion chamber 24 which extends axially partially the length of the stator structure has one end 24*a* connected with the oil burner equipment through a passage 17*a*, said passage being formed in the shaft 26 as shown in Figs. 3 and 4. The opposite end 24*b* of said chamber is provided with a constricting baffle 35. Surrounding the chamber 24*a* and extending throughout the length of the stator structure, there are provided closely wound sets of concentrically arranged boiler tubes 36 spaced to provide communicating passages or flues 37 between each set of tubes. There is also provided a group of closely wound boiler tubes 38 between the end 24*b* of the chamber and a partition 25*d* spaced inwardly from the end 25*b*. Said tubes 38 connect with the tubes 36 and serve as a superheater for the steam generator in the tubes 36. The passages 37 through which the gases of combustion

pass from the chamber 24 extends through the superheater tube 38 and to and fro lengthwise the stator between the sets of tubes 36 as indicated by the arrows shown in Fig. 3. Said passages 37 terminate in inlets 39 at the gas turbine nozzles 40 for supplying the gases of combustion passing to the gas turbine 18, said gases after passing through the turbine blades 18*a* and 18*b* being exhausted at outlets 41. Thus the continuous burning fuel in the chamber 24 provides a heating medium for the superheater tubes 38 and the boiler tubes 36, and the gases of combustion passing said tubes after being greatly reduced in temperature are delivered to the turbine blades 18*a* and 18*b* for generating power.

The boiler 11 comprising the tubes 36 and 38 is preferably of the flash or hot plate type, and may be constructed as shown in Figs. 2, 7 and 8. The boiler tubes 36 are seen to comprise an outer helically wound pipe 36*a* and a perforated inner helically wound pipe 36*b* extends centrally through said pipe 36*a*. The inner pipes 36*b* are supported within the pipes 36*a* in a substantially concentric position by any suitable means, as for example by spaced spiders 36*c*, the latter being made slightly smaller than the internal diameter of the pipes 36*a* to facilitate the assembly or removal of the pipes 36*b*.

The ends of the pipes 36*b* are end capped at 36*d*, adjacent the partition 25*e*, inwardly from the casing end 25*a* as shown in Fig. 3. The other ends of the pipes 36*b* of each set of tubes 36 may be interconnected by a manifold 42 which through a pipe 43 communicates with the feed water conduit 44, the latter extending through the channel 25*c* between casing 25 and shell 26. This manifold connection is located in the space 25*f* between the partition 25*d* and the casing end 25*b* as is clearly shown in Figs. 2 and 5.

The water fed through the inner pipe 36*b* passes through spaced perforations 36*e* provided in the inner pipe 36*b*, said perforations being preferably tangentially extending see Fig. 9 for spraying the water against the inner heated surface of the outer surrounding pipes 36*a*. Thus the feed water will be flashed into steam which will pass through the pipes 36*a* into a header 45 and through pipe 46 into the inlet ends 38*a* of superheater tubes 38. From the outlet ends 38*b* of the superheater tubes 38, the steam passes through a pipe 47 to a live steam conduit 48, in the channel 25*c*. The conduit 48 communicates with nozzles 49 at the inlets of the high pressure turbine stage 12, see Figs. 3 and 8. After acting on the blades 12*a* and 12*b*, the steam will pass through the outlet 50, and hence into the inlet 51 of the low pressure turbine 13. A ring gland packed bearing 52 is provided to extend inwardly from the rotor shell casing 28 to the shell 26 adjacent the high pressure turbine stage inlet 51 as is clearly shown in Fig. 3. The steam passing from the outlet 53 of the steam turbine enters the exhaust conduit 54 and passes through the passage 55 formed in the shaft 26 to the condenser 14.

A steam bleeder conduit communicates with the outlet end 50 of the high pressure steam turbine 12. Said conduit 56 through a passage 57 extending through the shaft 26 connects with the injector 15. The steam bled from the high pressure turbine is used by the injector to force the condensed water coming from the condenser 14 into the boiler 11 in the well understood manner. As shown in Fig. 9, the injector 15 which connects with the passage 57 through a fitting 57*a*, comprises a hollow body portion 15*a*, said fitting 57*a* connecting with one end of said body portion 15*a* through a suitable gland ring 15*b*.

Said fitting 57*a* has a flange 57*b* which abuts against the inlet end 15*c* of a steam nozzle 15*d*. Said end 15*c* may be provided with an outwardly extending flange for bearing on a stop-ledge 15*e* projecting within the body portion 15*a*, so that when the gland ring 15*b* is screwed into the end of the body portion 15*a* it securely retains the steam nozzle 15*d* in axial alignment within said portion 15*a*. The nozzle 15*d* terminates within a condensed-water receiving chamber 15*f*, the latter communicating through a pipe 14*a* with the condenser 14.

Aligning with the steam nozzle 15*d* and also supported within the body portion 15*a* there is a mixing and delivering tube 15*g*. The mixing end of the tube 15*g* is positioned to project into the receiving chamber 15*f* and is spaced from the end of the steam nozzle 15*d* so that the water from the condenser 14 delivered by the pipe 14*a* to the chamber 15*f* may enter the mixing end of the tube 15*g* for combining the steam from the nozzle 15*d* with the water from the condenser 14. The mixture is delivered to an end fitting 15*i* which is secured to the end of the body portion 15*a* opposite the gland ring 15*b*. The mixing and delivering tube 15*g* may be rigidly retained within the body portion 15*a* by providing spaced projecting flanges 15*j* and 15*k* for abutting against the leading end 15*l* of the fitting 15*i* and a stop-ledge 15*m* on the body portions 15*a*, said ledges 15*m* and 15*e* forming walls for the chamber 15*f*.

The fitting 15*i* has a pipe which connects with a passage 157 provided in the shaft 26. See Fig. 3. Said passage 157 communicates with the boiler to receive the feed water supply. The injector 15 operates in the conventional manner to feed a mixture of steam from the bleeder conduit and water from the condenser therethrough to the boiler.

The blower or air compressor 20 has inlet openings 29*a* formed in the rotor end plates 29. The air after being compressed passes through the outlet 58 into a channel conduit 59 and then through a pipe 59*a* is conducted into the combustion chamber 24 by means of a passage 60. Another passage 61 extends through the shaft 26 for supplying air to the oil burner 17 for vaporizing the liquid fuel sprayed through passage 17 into the combustion chamber 24.

A suitable ring packed bearing 63 may be provided to extend from the rotor casing 28 for separating the steam turbine 12 from the air compressor 20. A ring gland packed bearing 64 may also be provided for separating the steam turbine 13 from the gas turbine 18. It should be noted that the turbines are positioned relative each other so that the outlet 52 of the steam turbine 13 is adjacent to the outlet 41 of the gas turbine 18, thus the ring gland bearing 64 is subjected to a minimum difference of pressure. In a like manner, the gland bearing 63 of the high pressure steam inlet is positioned adjacent the outlet end 58 of the air compressor, so as to subject packed bearing 62 to a minimum difference of pressure.

Suitable centrifugal operated valves 62 may be provided which are adapted to automatically open the interior of the apparatus 110 to the atmosphere when the latter is at rest and during the starting period.

The operation of the apparatus 110 will now be apparent. From a conveniently positioned source corresponding to 16 shown in Fig. 1, crude oil is supplied to the burner 17. Said oil may be conditioned for efficient combustion by mixing same with air supplied through passage 61. The oil is sprayed into the combustion chamber 24 and burnt under in the air supplied through passage 60 from the compressor 20. The gases of combustion leaving the chamber 24 pass through the superheater and flues 37 between the boiler tubes 36 in the direction indicated by arrows in Fig. 3. The superheater and boiler extract heat from said gases so that the temperature of the latter is dropped from about 1800° C. to approximately 1100° C. While much difficulty is experienced in building gas turbines to satisfactorily withstand operation with gases at 1800° C., at 1100° C., as in the apparatus here provided, such difficulties can be practically eliminated. The combustion gases at reduced temperature pass next to the turbine nozzle 40 and through the blades 18*a* and 18*b* converting much of the heat energy in the gases into available mechanical energy in turning the rotor. The temperature of the gases exhausted at the turbine outlets 41 will be lowered to approximately 200° C.

The steam generated in the boiler tubes 36 is superheated in tubes 38 and passes to and through the high pressure stage 12, to the outlet 50. Next the steam passes to the low pressure turbine stage inlet 51, through the low pressure stage 13 to the outlet 53. Before the steam passes to the low pressure stage, about 80% of the steam flowing is bled off into conduit 56, through passage 57 in the shaft 26 to the injector 15.

If the boiler is operated at 800 lbs. pressure per square inch, the steam bled from the turbine will be about 200 lbs. pressure per square inch. This bled steam is expanded in the injector 15 to force the condenser water back into the boiler.

The exhaust steam passes from the low stage turbine outlet 53, through channel conduit 54 and the passage 55 in the shaft 26 to the condenser 14. Said condenser may be of relatively small size since in the present arrangement it is required to handle only about 20% of the steam generated, the remainder being bled off as described above and returned to the boiler by the injector 15. The energy extracted from the steam is transmitted to the rotor and together with that produced by the gas turbine 18 is made available through the extension sleeve 30*a* which is connected with the propeller 23 through the transmission 19 and gears 22. It is contemplated with the power plant herein described to operate the units so that the gas turbine 18 normally provides at least 40% of the total power generated.

The air supply is furnished by the turbine type air compressor 20 having an inlet at 29*a* and outlets through passages 60 and 61 to the combustion chamber 24 and oil burner 15, respectively, as has been described above, the air pressure in said chamber 24 being preferably maintained to correspond to several atmospheres.

It will thus be seen that there is provided devices in which the several objects of this invention are achieved and which are well adapted to meet the conditions of practical use.

As various possible embodiments might be made of the above invention, and as various changes might be made in the embodiment above set forth, it is to be understood that all matters herein set forth are to be interpreted as illustrative and not in a limiting sense.

Having thus described our invention we claim as new and desire to secure by Letters Patent:

1. A combination interconnected boiler and turbine, the turbine having a rotor surrounding a stator, said turbine stator forming a housing for enclosing the boiler.

2. In a power plant of the character described, the combination of a boiler having a combustion chamber, a gas turbine having a rotor and a stator, and a steam turbine having a rotor and a stator, said gas and steam turbines being connected with said chamber and boiler respectively, the gas and steam turbine rotors forming a unitary power output source, the boiler being stationary and forming the stator of the steam and gas turbines.

3. In a power plant of the character described, a boiler forming an internal stator structure of a steam turbine, an external rotor structure for said turbine surrounding the stator structure, co-operating means carried by and extending between the stator and rotor structure, and means for connecting the boiler with said turbine.

4. In a power plant of the character described, a fuel combustion unit and boiler forming an internal stator structure, an external rotor structure surrounding the stator structure, a plurality of sets of co-operating means carried by and extending between the stator and rotor structures forming a gas and a steam turbine, means connecting the boiler to the steam turbine, and means connecting the unit through the boiler to the gas turbine.

5. In a power plant of the character described, a fuel combustion unit and boiler forming an internal stator structure, an external rotor structure surrounding the stator structure, a plurality of sets of co-operating means carried by and extending between the stator and rotor structures forming a gas and a steam turbine, an air-compressor, means connecting the boiler to the steam turbine, means connecting the unit through the boiler to the gas turbine, and means connecting the air-compressor to said unit.

6. A power plant comprising a rotor in the form of a cylindrical rotary shell, means disposed within the shell for supplying rotary power to said shell, said means comprising a steam turbine and a gas-turbine, a stationary fuel combustion chamber and a steam boiler disposed within the shell, means for supplying a combustible fluid mixture to said chamber, and means for conducting hot gases generated in said chamber, and steam generated in said boiler to said gas and steam turbines respectively.

7. A power plant of the character set forth in claim 6 in which the rotor also comprises an air compressor, and means for supplying the air compressed therein to said combustion chamber.

8. In a power plant of the character described, the combination of a boiler having a combustion chamber and forming an internal stator structure, an external rotor structure surrounding the stator structure, cooperating means carried by and extending between the rotor and stator structures forming a gas and a steam turbine, and means for connecting the chamber and boiler with the gas and steam turbines respectively.

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