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GAS TURBINE DRIVE

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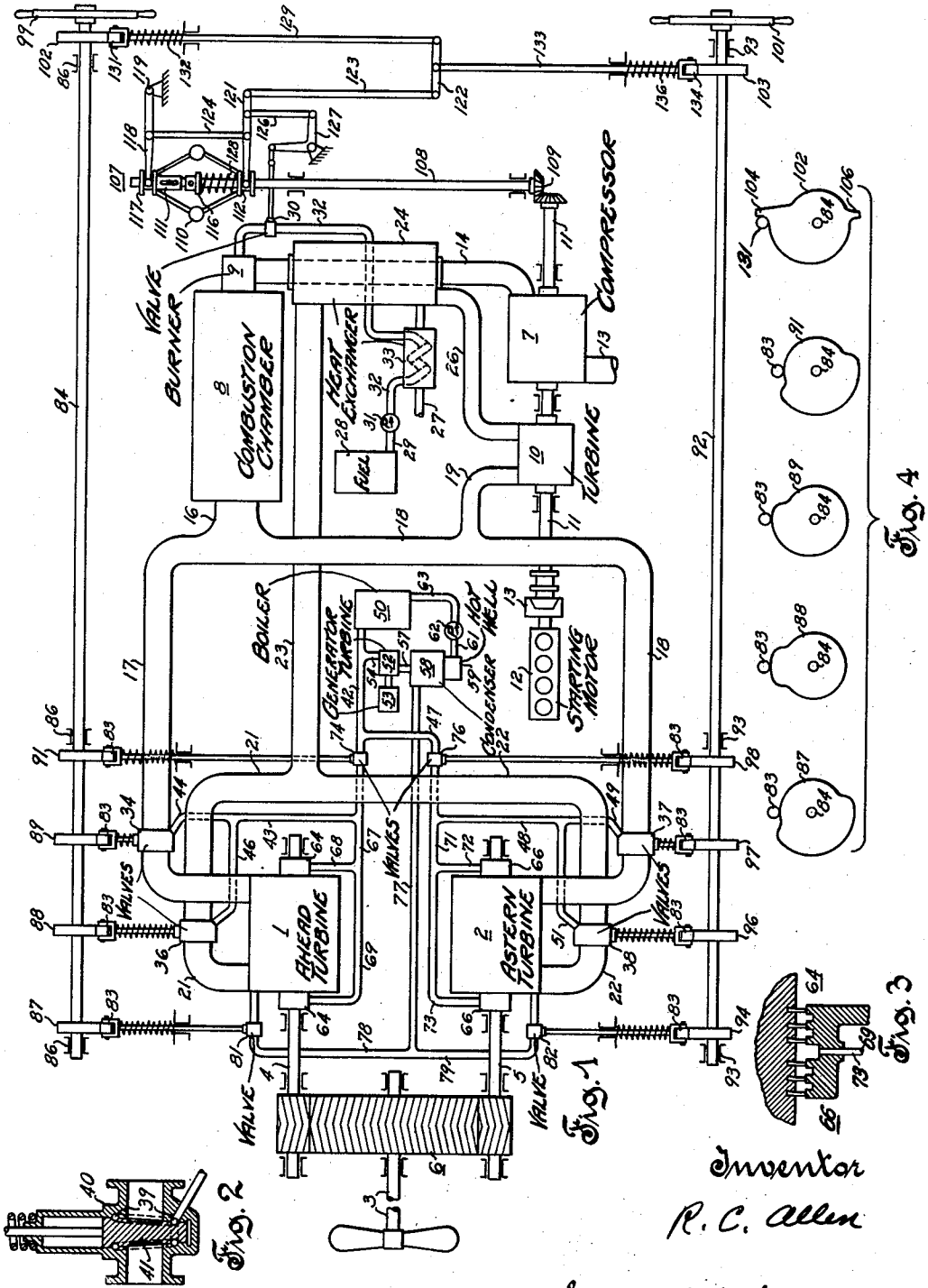


Fig. 1

Fig. 2

Fig. 3

Fig. 4

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GAS TURBINE DRIVE

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This invention relates generally to prime movers driven by combustion gases or other non-condensable gases and more particularly to an arrangement including two or more of such prime movers or prime mover sections operatively connected with a driven element so that when one of said prime movers or prime mover sections is operating to drive said element, another one of said prime movers or prime mover sections is inoperative and running idle.

The propulsion of ships by means of continuous combustion gas turbines is one illustration of the form of apparatus to which the invention is particularly applicable, since in this connection it is generally desirable to employ at least two independently operable turbines, one for ahead operation and one for astern operation, which are operatively connected with the propeller shaft so that when one of said turbines is operating to propel the ship, the other is running idle. Gas turbines operate at relatively high speeds and prior to this invention the power required to drive the idle turbine has reduced the overall efficiency to a degree sufficient to render the use of gas turbine drives of this nature highly impractical.

Consequently, the primary object of this invention is to provide an improved drive embodying a novel correlation of elements including two or more prime movers or prime mover sections driven by non-condensable gases and operatively connected with a driven element so that when one of said prime movers or prime mover sections is operating to drive said element, another prime mover or prime mover section can run idle without materially decreasing overall efficiency.

Another object of this invention is to provide an improved and novel gas turbine drive combination including two or more turbines or turbine sections, a sealing means and a vacuum producing means arranged so that the turbines or turbine sections always run idle in a high degree of vacuum, thereby materially reducing the losses inherent in the known gas turbine drives.

The invention accordingly consists of the various features of construction, combinations of elements and arrangements of parts as more fully pointed out in the appended claims and in the detailed description, in which:

Fig. 1 is a schematic illustration of a combustion gas turbine system embodying the invention;

Fig. 2 is a partial sectional view illustrating the form of fluid sealed valves employed in the system shown in Fig. 1;

Fig. 3 is a partial sectional view illustrating the general form of labyrinth shaft seals employed; and

Fig. 4 diagrammatically illustrates the form and arrangement of the control cams shown in Fig. 1.

Referring to Fig. 1, it is seen that the illustrated marine drive arrangement comprises an ahead turbine 1, an astern turbine 2, and a propeller shaft 3 which is continuously connected with the ahead turbine shaft 4 and with the astern turbine shaft 5 by means of reduction gearing 6. The arrangement is such that when the ahead turbine 1 is operating to drive the propeller shaft 3, the astern turbine 2 is running idle at a commensurate speed.

Motive fluid for operating the ahead and astern turbines 1 and 2, respectively, is produced by a continuous combustion gas generating unit comprising a compressor 7, a combustion chamber 8 provided with a fluid fuel burner 9, and a gas turbine 10. The compressor 7 and the turbine 10 are preferably mounted on a common shaft 11 adapted for connection with an internal combustion starting engine 12 by means of a clutch 13. Air, which enters the compressor 7 through an inlet conduit 13, is compressed and discharged into the combustion chamber 8 through a pipe 14. The combustion gases produced in the combustion chamber 8 discharge into a conduit 16 which in turn is connected with the inlet or admission ends of the turbines 1, 2 and 10 by means of pipes 17, 18 and 19, respectively. Turbines 1 and 2 exhaust into the pipes 21 and 22, respectively, which merge into a common exhaust conduit 23 connected with a heat exchanger 24 operatively associated with the air conduit 14 connecting the compressor 7 with the combustion chamber 8. The turbine 10 also exhausts into the heat exchanger 24 through a pipe 26. The exhaust gases entering the heat exchanger 23 are discharged to atmosphere through a conduit 27. Fluid fuel from a suitable source 28 is delivered under pressure to the burner 9 by means of pipe 29, pump 31 and pipe 32. A portion of the pipe 32 passes through a heat exchanger 33 operatively associated with the conduit 27. The flow of fuel to the burner 9 is varied by a suitable regulating valve 30 disposed in the pipe 32.

The inlet and exhaust conduits of the ahead turbine 1 are provided with spring biased control valves 34 and 36, respectively. The inlet and exhaust conduits of the astern turbine 2 are also provided with spring biased control valves 37

and 38, respectively. The valves 34, 36, 37 and 38 are similarly constructed to embody a pair of annular sealing grooves 39 formed between the valve casing 40 and the gate member 41 on the inlet and discharge sides of the valve and adapted for connection with a suitable source of sealing fluid, as best shown in Fig. 2. In this illustration, the sealing fluid, which consists of low pressure steam generated in a boiler 50, is conducted to the sealing grooves in the valves 34 and 36 through pipe 42, pipe 43 and branch pipes 44 and 46, respectively. Sealing fluid is also conducted to the sealing grooves in the valves 37 and 38 through pipe 42, pipe 47, pipe 48 and branch pipes 49 and 51, respectively. The arrangement is such that when the valves 34, 36, 37 and 38 are closed, the admission of sealing fluid to the pairs of annular grooves 39 prevents the motive fluid and/or air from entering the interiors of the turbines 1 and 2. A portion of the steam generated in the boiler 50 is used to drive a steam turbine 52 which in turn drives a generator 53 for supplying power to the ship's auxiliaries (not shown). The steam, which is conducted to the turbine 52 through pipes 42 and 54, exhausts through a conduit 57 into a condenser 58 having its hot well 59 connected with the lower portion of boiler 50 by means of pipe 61, pump 62 and pipe 63.

The opposite ends of each of the turbines 1 and 2 are provided with similar labyrinth shaft seals 64 and 66, respectively, which are preferably constructed to permit the introduction of a suitable sealing fluid at a point intermediate the ends of the seals, as best shown in Fig. 3. Low pressure steam from the boiler 50 is introduced into each of the seals 64 through the pipe 42, pipe 67 and branch pipes 68 and 69, and into each of the seals 66 through pipe 42, pipe 47, pipe 71 and branch pipes 72 and 73. The flow of sealing fluid to the valves 34 and 36 and the seals 64 and to the valves 37 and 38 and the seals 66 is controlled by the spring biased valves 74 and 76, respectively. The interior of each of the turbines 1 and 2 is operatively connected with the interior of the condenser 58 by means of the common pipe 77 and the branch pipes 78 and 79, respectively. Communication between the interiors of the turbines 1 and 2 and the condenser 58 is controlled by spring biased valves 81 and 82 disposed in pipes 78 and 79, respectively.

The valves 34, 36, 37, 38, 74, 76, 81 and 82 are urged by their respective biasing springs toward their fully open positions and the stem portion of each valve is similarly provided with an identical cam engaging roller 83. A cam shaft 84 is mounted for angular movement in bearings 86 and is provided with cams 87, 88, 89 and 91 arranged for continuous engagement with the rollers 83 carried by the stem portions of valves 81, 36, 34 and 74, respectively. Another cam shaft 92 is mounted for angular movements in bearings 93 and is provided with cams 94, 96, 97 and 98 which are similar to cams 87, 88, 89 and 91, respectively, and which are arranged for continuous engagement with the rollers 83 carried by the stem portions of valves 82, 38, 37 and 76, respectively. The cam shafts 84 and 92 are also provided with hand wheels 99 and 101 and with cams 102 and 103, respectively. Cams 102 and 103 are each provided with spaced projections 104 and 106, as shown in Fig. 4 to limit the angular movements of their respective shafts.

The arrangement is such that when the turbines 1 and 2 are both idle the cam shafts 84 and 92 are in the positions shown in Fig. 1, the rollers 83 on the stem portions of valves 81, 36, 34 and 74 and on the stem portions of valves 82, 38, 37 and 76 engage their respective cams in the manner shown in Fig. 4. That is, the rollers 83 on the stem portions of valves 81 and 82 engage the low portions of cams 87 and 94, respectively; the rollers 83 on the stem portions of valves 36 and 38 engage the high portions of cams 88 and 96, respectively; the rollers 83 on the stem portions of valves 34 and 37 engage the high portions of cams 89 and 97, respectively; and the rollers 83 on the stem portions of valves 74 and 76 engage the low portions of cams 91 and 98, respectively.

The cams 94, 96, 97 and 98 on shaft 92 are identical in construction and arrangement to cams 87, 88, 89 and 91, respectively, on shaft 84. Consequently, since the cams on the shaft 92 are also constructed and arranged as shown in Fig. 4, it should be obvious that when the shafts 84 and 92 are positioned as shown in Fig. 1 the valves 81, 82, 74 and 76 are in their fully opened position. Moreover, it should also be obvious that the inlet and exhaust conduits 17 and 21, respectively, of turbine 1, and 18 and 22, respectively, of turbine 2, are closed, that the sealing fluid conduits are open which permits sealing fluid to flow to the valves 34 and 36 and the shaft seals 64 associated with turbine 1 and to the valves 37 and 38 and the shaft seals 66 associated with turbine 2, and that the conduits connecting the interiors of the turbines 1 and 2 with the interior of the condenser 58 are open which evacuates the turbines. Referring particularly to Fig. 4, it should also be noted that the configuration of the cams 87, 88, 89 and 91 is such that a movement of shaft 84 in a clockwise direction through an angle of approximately forty degrees from the position shown (stop 104 on cam 102 prevents a movement of the shaft in a counterclockwise direction) effects a rapid closure of valves 81 and 74, a rapid opening of the exhaust valve 36, and a gradual partial opening of the admission valve 34 and that if this movement of the shaft is continued until further movement is prevented by the stop 106 on cam 102, during such movement the valves 81 and 74 remain fully closed, valve exhaust 36 remains fully open, and admission valve 34 is gradually moved to its fully open position. With the parts in this position, a movement of the shaft 84 in a counterclockwise direction to the position shown in Fig. 4 first effects a gradual closing of admission valve 34 and when the admission valve 34 actually closes, a sudden closure of exhaust valve 36 and a sudden opening of valves 74 and 81. The valves 82, 38, 37 and 76 associated with the turbine 2 are sequentially actuated by means of the shaft 92 and cams 94, 96, 97 and 98, respectively, in the identical manner just described with respect to the valves 81, 36, 34 and 74 associated with the turbine 1.

The quantity and the energy content of the combustion gases produced in the combustion chamber 8 for operating the turbine 10 and either turbine 1 or 2 is varied in accordance with load requirements by regulating the fuel supply to the burner 9 and the speed of the turbine 10 and the compressor 7. This regulation is accomplished in the illustrated arrangement by a speed responsive governor including a flyball mechanism 107 operatively connected with the shaft 11, which is common to the turbine 10 and the compressor 7, by means of the shaft 108 and the gearing

109. The flyball mechanism 107 includes a pair of weights 110 and upper and lower sleeve members 111 and 112, respectively, which are slidably mounted on the upper portion of shaft 108 and which are operatively connected with the weights 110. The upper sleeve member 111 when in its lowermost position engages the adjacent end of the member 116 formed on or secured to the shaft 108, and is provided at its upper end with a collar portion 117 operatively connected with one end of a lever 118 which has its other end pivotally connected with a fixed fulcrum 119. The lower sleeve member 112 is also operatively connected with one end of a lever 121 having its other end pivotally connected with one end of a lever 122 by means of a link 123. An intermediate portion of lever 121 is pivotally connected with an intermediate portion of lever 118 by means of a link 124 and another intermediate portion of lever 121 is operatively connected with the stem portion of the fuel regulating valve 30 by means of a link 126 and the bell crank lever 127. A compression spring 128 is disposed in abutting relation between the member 116 on the shaft 108 and the upper end of the lower sleeve member 112. The other end of lever 122 is pivotally connected with one end of a link 129 which carries at its other end a cam engaging roller 131 and which has associated therewith a biasing spring 132 operative to maintain the roller 131 on the end thereof in continuous engagement with the cam 102 on shaft 84. An intermediate portion of lever 122 is pivotally connected with one end of a link 133 which carries at its other end a cam engaging roller 134 and which has associated therewith a biasing spring 136 operative to maintain the roller 134 on the end thereof in continuous engagement with the cam 103 on the shaft 92.

With the parts in the various positions shown, the turbines 1 and 2 are both idle, since their respective admission and exhaust valves 34, 36 and 37, 38 are all closed and the combustion gas generating unit comprising the compressor 7, the combustion chamber 8 and the turbine 10, assuming operation of the unit has been initiated in the usual manner by employing the internal combustion starting engine 12, is operating under no load or idling conditions and the fuel regulating valve 30 is in its minimum closed position and the speed governor is set to maintain the speed of said unit substantially constant at a predetermined minimum. When it is desired to propel the vessel in the ahead direction, all that has to be done is to move the hand wheel 99 secured to cam shaft 84 in a clockwise direction until the admission valve 34 opens. This movement of hand wheel 99 effects a complete closure of valves 74 and 81 and a complete opening of exhaust valve 36 before admission valve 34 actually begins to open and in addition permits the biasing spring 132 associated with the link 129 to effect a gradual upward movement of the link (note that the configuration of the cam 102 is similar to cam 89 as shown in Fig. 4), which in turn causes lever 122 to move in a counterclockwise direction about its point of pivotal connection with link 133. This movement of lever 122, which preferably slightly precedes the actual opening of admission valve 34, effects a downward movement of link 123 and a clockwise movement of lever 121 about its point of pivotal connection with link 124, which in turn moves the link 126 and bell crank lever 127 in a direction to effect an opening movement of the fuel valve 30. This movement of lever 121 also moves the lower sleeve member 112 upward which compresses the spring 128. However, since the upper and lower sleeve members 111 and 112 are interconnected through the flyballs 110, the upward movement of the lower sleeve member 112 also effects a corresponding upward movement of the upper sleeve member 111 and as a result lever 118 pivots about its fixed fulcrum 119 in a clockwise direction and by means of the link 124 effects a corresponding pivotal movement of lever 121 about its point of pivotal connection with link 123. This results in the link 126 being moved upward, which in turn effects a counterclockwise movement of bell crank lever 127 and a closing movement of the fuel regulating valve 30. In this connection, the lever and link arrangement is such that the opening movement of valve 30 effected by the pivotal movement of lever 121 about its point of pivotal connection with link 124 is greater than the closing movement thereof effected by the interconnection between the levers 121 and 118 and the resultant pivotal movement of lever 121 about its point of pivotal connection with link 123. In other words, a sufficient movement of the hand wheel 99, which is secured to shaft 84, in a direction to effect an opening movement of the admission valve 34 simultaneously moves the valve 30 towards its fully opened position and increases the fuel supply to the burner 9 which in turn increases the energy content of the combustion gases and thereby the speed of the turbine 10 and compressor 7. The net result is that the quantity and the energy content of the combustion gases are simultaneously increased as the valve 34, which controls the admission of motive fluid to the turbine 1, is moved toward its fully open position. Conversely, when the turbine 1 is operating and the admission valve 34 is moved toward its fully closed position, the quantity and the energy content of the combustion gases are correspondingly decreased by moving the valve 30 towards its closed position which in turn decreases the energy content of the combustion gas and thereby the speed of the turbine 10 and compressor 7.

When the combustion gas turbine unit comprising the compressor 7, the combustion chamber 8, which includes the burner 9, and the turbine 10 is operating (operation of this unit is terminated either by closing a fuel shut-off valve, not shown, or by stopping the pump 31), the position of the fuel regulating valve 30 can be varied either by moving cam 102 or 103 on the control shafts 84 and 92, respectively, or by the governor flyball mechanism 107 in response to variations in the speed of the turbine 10. Variations in the speed of the turbine 10 may occur due to appreciable changes in the temperature of the air which is being compressed and to unequal distribution of the gases between the turbine 10 and the power turbines 1 or 2. When a change in speed does occur, for example, a decrease in speed, the spring 128 causes the collar 112 to move downward, thereby effecting a counterclockwise movement of lever 121 about its point of pivotal connection with link 123, which in turn moves the link 126 and bell crank lever 127 in a direction to more fully open the valve 30. The downward movement of collar 112 effects a corresponding movement of collar 111 and connected lever 118 and link 124. Obviously, as the speed increases the sleeve 112 and the mechanism operatively connected there-

with are moved in opposite directions from that just described to effect a closing movement of the valve 30.

When the turbine 1 is operating in the manner just described, the cam shaft 92 and the associated valves 82, 38, 37 and 76 are in the positions shown; i. e., the valves 82 and 76 are fully open and the valves 38 and 37 are fully closed. Consequently, the inlet and exhaust conduits 18 and 22, respectively, of the turbine 2 are closed, the sealing fluid (low pressure steam) flows from the boiler 50 into the sealing grooves 39 in the valves 37 and 38, the interior of the turbine 2 is connected with the interior of the condenser 58, and the rotor of the turbine 2 is running in a vacuum which materially decreases the losses normally experienced with this type of prime mover.

When the vessel is being propelled in the ahead direction, by the turbine 1 and it is desired to propel the vessel in the astern direction, the hand wheel 99 on shaft 84 is moved in a direction to effect a closure of admission valve 34 and, as soon as the admission valve actually closes, the exhaust valve 36 closes and the valves 74 and 81 are fully opened. The opening of valve 74 admits sealing fluid to the sealing grooves in the valves 34 and 36 (note the construction shown in Fig. 2) and into the shaft seals 64 (see Fig. 3). The opening of valve 81 connects the interior of the turbine with the interior of the condenser 58 and since both the inlet and exhaust conduits are fully closed by the valves 34 and 36, respectively, the rotor of the turbine is running in a vacuum; i. e., the interior of the turbine is being evacuated by the condenser 58. All that now remains to be done to effect an operation of the turbine 2 is to move the hand wheel 101, secured to cam shaft 92, in a direction to effect an opening movement of the inlet valve 37 associated with turbine 2.

The movement of hand wheel 101 actuates the valves 76, 37, 38 and 82, which are associated with turbine 2, varies the setting of the governor, and varies the position of the fuel regulating valve 30 in exactly the same manner as described in connection with the movements of the hand wheel 99. Consequently, a repetition of the operation in this respect should not be necessary for a complete understanding of the invention. However, it should be particularly noted in this connection that whenever the flow of motive fluid to either turbine 1 or turbine 2 is terminated by the closure of its inlet valve, its exhaust valve is also closed, a condensable sealing fluid is admitted to the sealing grooves in its inlet and exhaust valves and into its shaft seals, and the interior of the turbine is connected with the interior of a condenser.

The invention is applicable generally to prime mover arrangements in which the prime movers are driven by non-condensable gases and in which two or more of such prime movers or prime mover sections are operatively connected with a driven element so that when one of said prime movers or prime mover sections is operating to drive said element, another of said prime mover or prime mover sections is inoperative and running idle and it should be understood that although the invention has been illustrated in connection with a continuous combustion gas turbine marine drive arrangement, it it not intended to limit the invention to the exact mode of operation and to the exact details of construction herein shown and described, as various modifications within the scope of the appended claims may occur to persons skilled in the art.

It is claimed and desired to secure by Letters Patent:

1. In combination, a power plant including a power developing rotor element enclosed in a casing, a source of non-condensable gas for operating said rotor element, an evacuating means connected with the interior of said casing, means controlling the flow of non-condensable gas to said rotor element, means controlling the connection between said evacuating means and the interior of said casing, and control mechanism operatively associated with said non-condensable gas flow control means and with said connection control means so as to connect said evacuating means with the interior of said casing whenever the flow of non-condensable gas to the rotor element in said casing is terminated.

2. In combination, a power plant including two encased power developing rotor elements operatively connected together for simultaneous rotation, a source of non-condensable gas for operating said rotor elements, an evacuating means connected with the interior of the casing of each rotor element, means for selectively controlling the flow of non-condensable gas to said rotor elements, means selectively controlling the connection between said evacuating means and the interior of each of said casings, and control mechanism operatively associated with said non-condensable gas flow control means and with said connection control means so as to connect said evacuating means with the interior of the casing of the operating one of said elements whenever the flow of non-condensable gas to the said one of the rotor elements is terminated.

3. In combination, a power plant including a power developing rotor element enclosed in a casing, a source of non-condensable gas for operating said rotor element, a first means controlling the flow of non-condensable gas to said rotor element, means on said element and casing coacting to provide labyrinth seals adjacent the ends thereof, an evacuating means, a second means for connecting said evacuating means with the interior of said casing, a source of sealing fluid, a third means for connecting said labyrinth seals with said source, and control mechanism operatively associated with said first, second and third means to terminate the flow of non-condensable gas to said rotor element, to connect the interior of its casing with said evacuating means, and to connect said seals with the said source of sealing fluid.

4. In combination, a power plant including a power developing rotor element enclosed in a casing having gas inlet and exhaust connections, a source of non-condensable gas for operating said element, a first means operative to control the flow of non-condensable gas through said inlet and exhaust connections, an evacuating means connected with the interior of said casing, a second means controlling the connection between said evacuating means and the interior of said casing, and control mechanism operatively associated with said first and second means so as to connect said evacuating means with the interior of said casing whenever the flow of non-condensable gas through said inlet and exhaust connections is terminated.

5. In combination, a power plant including a power developing rotor element enclosed in a

casing having gas inlet and exhaust connections, a source of non-condensable gas for operating said element, means on said element and casing coacting to provide labyrinth seals adjacent the ends thereof, a first means operative to control the flow of non-condensable gas through said inlet and exhaust connections, an evacuating means, means operative to connect said evacuating means with the interior of said casing, a source of sealing fluid, a second means operative to connect said labyrinth seals with said source of sealing fluid, a control mechanism operatively associated with said first and second means and with said evacuating connecting means to terminate the flow of non-condensable gas through said inlet and exhaust connections, to connect said labyrinth seals with said source of sealing fluid, and to connect said evacuating means with the interior of said casing.

6. In combination, a power plant including a power developing rotor element enclosed in a casing having gas inlet and exhaust connections, a source of non-condensable gas for operating said element, means on said element and casing coacting to provide labyrinth seals adjacent the ends thereof, a first means operative to control the flow of gases through said inlet and exhaust connections, a source of condensable gas, a condenser operatively connected with said source of condensable gas, a second means operative to connect said labyrinth seals with said source of condensable gas, a third means operative to connect said condenser with the interior of said casing, and control mechanism operatively associated with said first, second and third means to terminate the flow of non-condensable gas through said inlet and exhaust connections, to connect said labyrinth seals with the said source of condensable gas, and to connect said condenser with the interior of said casing.

7. In combination, a power plant including a combustion gas turbine, a first means controlling the flow of combustion gases to said turbine, an evacuating means connected with the interior of said turbine, a second means controlling the connection between said evacuating means and the interior of said turbine, and control mechanism operatively associated with said first and second means so as to connect said evacuating means with the interior of said turbine casing whenever the flow of combustion gases to said turbine is terminated.

8. In combination, a combustion gas turbine system including ahead and reverse turbine elements operatively connected together, a first means for selectively controlling the flow of combustion gases to said turbine elements, an evacuating means connected with the interior of each turbine element, a second means for selectively controlling the connection between said evacuating means and the interior of each turbine element, and control mechanism operatively associated with said first and second means so as to connect said evacuating means with the interior of the operating one of said turbine elements whenever the flow of combustion gases through the said one turbine element is terminated.

9. In combination, a combustion gas turbine system including ahead and reverse turbine elements operatively connected together and capable of developing power independently of each other, said turbine elements each including labyrinth seals operative to prevent motive fluid from escaping along the shaft portion of the turbine element, a source of condensable gas, a first means operative to connect said labyrinth seals with the said source of condensable gas, a condenser, a second means operative to connect the interior of the casings enclosing said turbine elements with said condenser, and control mechanism operatively associated with said first and second means to terminate the flow of motive fluid to the operating one of said turbine elements and to connect the interior of its casing with said condenser and its labyrinth seals with the said source of condensable gas.

10. In combination, a combustion gas turbine system including ahead and reverse turbine elements enclosed in casings each having inlet and exhaust connections, means on each of said elements and its associated casing providing labyrinth seals adjacent the ends thereof, a first means operative to control said inlet and exhaust connections, a source of condensable gas, a second means operative to connect said labyrinth seals with said source of condensable gas, a condenser, a third means operative to connect said condenser with the interior of said casings, and control mechanism operatively associated with said first, second and third means so as to close the inlet and exhaust connections to one of said casings and so as to then connect its labyrinth seals with the said source of condensable gas and the interior of its casing with the said condenser.

11. In combination, two encased prime mover rotor elements, a source of non-condensable gas for operating said elements, a first means for selectively connecting said source with said elements to effect an independent operation thereof, a device to be driven by said elements, means operatively connecting said elements with said device so that when one of said elements is driving said device the other of said elements is also rotating at a commensurate speed, an evacuating means connected with the interior of the casing of each element, a second means for selectively controlling the connection between said evacuating means and the interior of each of said casings, and a control operatively associated with said first and second means so as to connect said evacuating means with the interior of the casing of one of said elements whenever the flow of gas to the said one of said elements is terminated.

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