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GAS TURBINE APPARATUS

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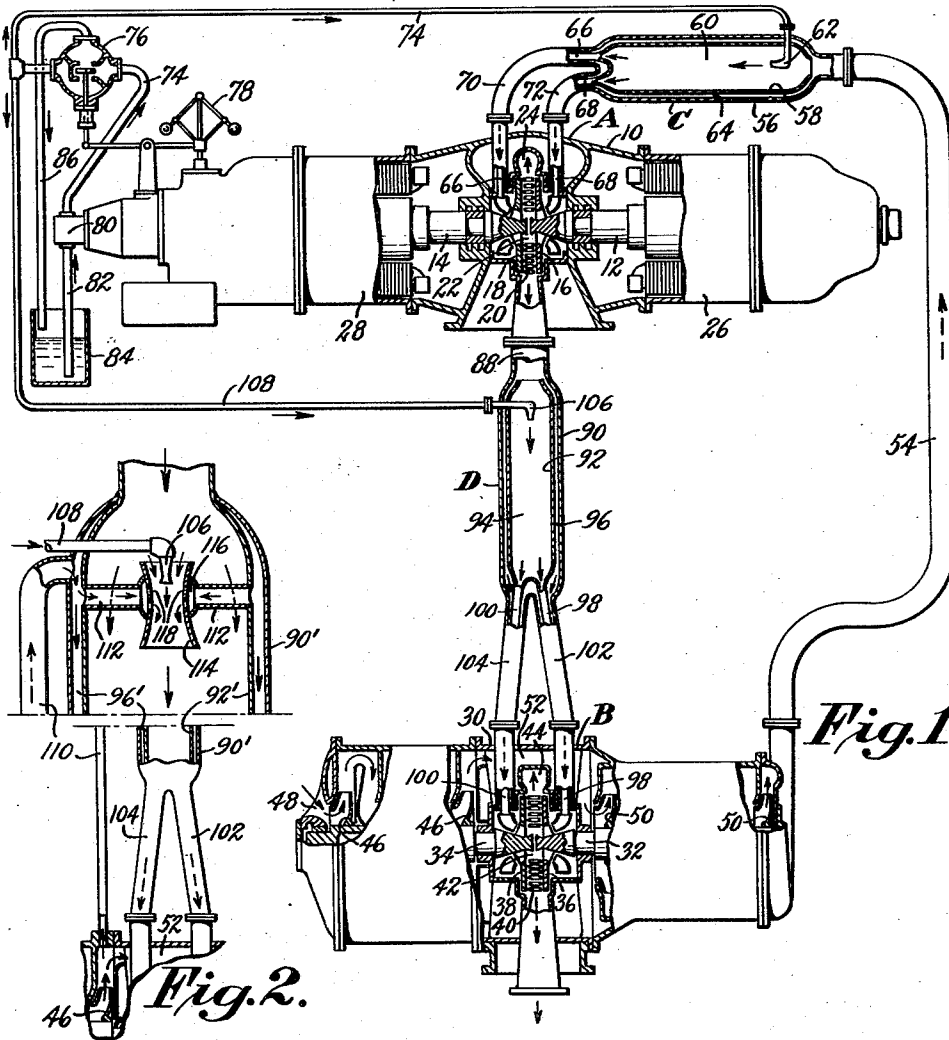


Fig. 2.

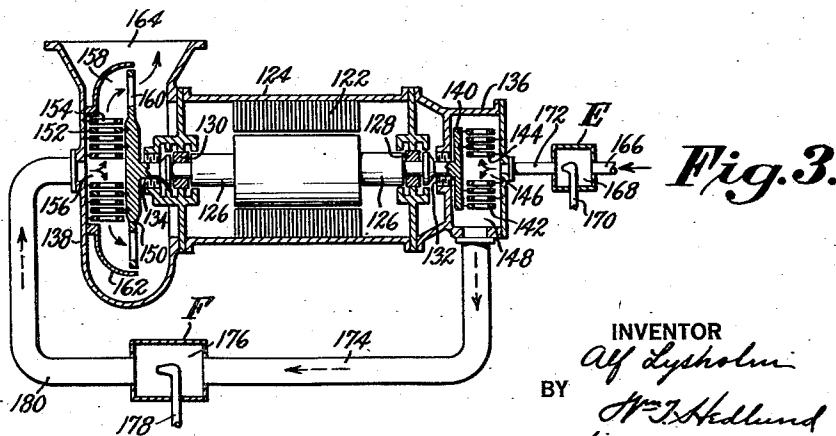


Fig. 3.

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GAS TURBINE APPARATUS

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Application July 22, 1933, Serial No. 681,697
In Germany March 24, 1930

6 Claims. (Cl. 60—41)

This application is a continuation in part replacing my application Serial No. 523,505 filed March 18, 1931, and relates back to said application Serial No. 523,505, so far as herein continued for all dates and rights incident to the filing thereof and to the filing in foreign countries of applications corresponding thereto.

This invention relates to gas turbine apparatus of the type comprising a plurality of gas turbines adapted to be operated by a compressed gaseous motive fluid supplied to the turbines at high temperature. Still more particularly the invention relates to such apparatus in which the motive fluid is formed by continuous combustion of fuel with air compressed in compressor apparatus driven by one or more of the turbines.

A general object of the invention is to improve upon prior forms of apparatus of the above general kind by the provision of apparatus in which heating and reheating of the gaseous motive fluid is effected in combustion chamber apparatus separated from the turbines and in which the hot motive fluid comprising combustion gases is conducted to and expanded in each turbine in a manner permitting the potential energy of the motive fluid to be utilized with high efficiency in each of the turbines of the apparatus.

The manner in which the above general and further and more detailed objects of the invention are attained in accordance with the present invention may best be understood from the ensuing description taken in conjunction with the accompanying drawing forming a part of this specification, in which:

Fig. 1 is a more or less diagrammatic view partly in section of gas turbine apparatus embodying the invention;

Fig. 2 is a more or less diagrammatic view partly on enlarged scale, of a different form of part of the apparatus shown in Fig. 1; and

Fig. 3 is a more or less diagrammatic view of another form of gas turbine apparatus embodying the invention.

In order for gas turbine apparatus of the character under discussion to be sufficiently efficient to be commercially practical, the initial temperature of the gaseous motive fluid must be above a certain temperature in order to secure a sufficiently high temperature drop in the turbine system and, while this has heretofore been recognized and the fact that reheating between turbines, has also been heretofore recognized, the arrangements previously proposed have not provided practical means for the production and utilization of high temperature gaseous motive fluids, as will hereinafter more fully appear.

In accordance with the present invention, I provide apparatus whereby a sufficiently high initial temperature of motive fluid may be obtained and such motive fluid may be efficiently

utilized while at the same time avoiding the necessity, in order to secure the desired over-all turbine efficiency, of having to resort to an initial temperature of motive fluid so high that it is impractical to use the motive fluid efficiently at its initial temperature. This I accomplish by the combination, with separate turbines having certain characteristics to be hereinafter more fully explained, of separate heating and reheating devices for the motive fluid, the whole apparatus being arranged so that accurate and reliable control of the temperatures of the motive fluid at the place of admission to the different turbines may be obtained.

Turning now to the embodiment of the invention shown by way of illustration in Fig. 1, the apparatus comprises a first turbine designated generally at A and a second turbine designated generally at B. Turbine A is of the double rotation radial flow type and comprises an outer casing 10 in which are rotatably mounted the shafts 12 and 14. Shafts 12 and 14 are adapted to rotate in opposite directions and at their adjacent inner ends have overhung thereon the turbine rotors 16 and 18 respectively. Each of rotors 16 and 18 carries a plurality of rings of turbine blades 20, the rings of the blades on the two rotors being interleaved and together forming a blade system for radial flow of motive fluid from the central admission chamber 22 to the exhaust casing 24. The details of design of the blade system are not germane to the present invention but in accordance with the invention the blading is of the reaction type as distinguished from impulse blading and full admission of motive fluid to the blade system is employed.

In the embodiment illustrated, shafts 12 and 14 have mounted thereon the rotor parts of electric generators indicated generally at 26 and 28.

Turbine B is similar in form to turbine A and comprises an outer casing 30 in which are rotatably mounted the oppositely rotating shafts 32 and 34 having rotors 36 and 38 overhung on the inner ends of the shafts. Rotors 36 and 38 carry a plurality of interleaved rings of turbine blades 40 forming a second radial flow blade system for flow of motive fluid from the central admission chamber 42 to the exhaust casing 44.

Shaft 34 has mounted thereon the rotor 46 of a low pressure compressor which in the embodiment illustrated comprises a plurality of axially side by side stages for centrifugal compression of air admitted to the compressor through the inlet 48. Shaft 32 carries the rotor 50 of a high pressure compressor, the form of which is in general similar to that of the low pressure compressor. Air discharged from the low pressure compressor passes through the space 52 between the outer turbine casing 30 and the exhaust casing 44 to the inlet end of the high pressure com-

pressor and is delivered from the latter compressor through the conduit 54. Air is delivered by conduit 54 to the inlet end of a heating device indicated generally at C. In the embodiment shown, the heating device C comprises an outer casing 56 and an inner casing 58, the inner casing forming a combustion chamber 60 to which fuel is admitted through the nozzle 62. Air is admitted from conduit 54 both to the combustion chamber 60 and to the jacketed space 64 between the outer casing 56 and the inner casing 58. Combustion chamber 60 is connected to the central admission chamber 22 of turbine A by means of pipes 66 and 68 which are surrounded respectively by outer pipes 70 and 72. The spaces between inner pipes 66 and 68 and outer pipes 70 and 72 are in communication with the jacketed space 64 around the combustion chamber 60 so that motive fluid is delivered to the central admission chamber of the turbine in the form of streams of high temperature gas surrounded by annular envelopes of a cooler gaseous medium. All of the gaseous medium conducted through the several pipes 66, 68, 70 and 72 is delivered to the inlet of the blade system and at this point the cooler and hotter mediums are mixed. The air supply to the combustion chamber 60 is preferably unthrottled and control of the temperature of the motive fluid delivered to the turbine is preferably effected wholly by regulation of the amount of fuel supplied. In order to secure the benefits of the invention, the motive fluid is supplied to turbine A for initial expansion from a temperature within a range of which the lower limit is approximately 800° C. absolute and the upper limit is such as will permit the continuous full admission of the motive fluid to the turbine blading without the destruction of the moving blades due to excessive temperature of motive fluid. Ordinarily, I prefer to supply motive fluid within a temperature range of which the lower limit is approximately 800° C. absolute and the upper limit of which is approximately 1000° C. absolute.

It will be noted from the figures of the drawing that pipes 66, 68, 70, 72 provide conduits of substantial length connecting the combustion chamber 60 with the admission chamber 22 of the turbine. The reasons for providing this construction will be explained later.

Fuel is supplied to nozzle 62 through the pipe 74 and the amount of fuel passing through pipe 74 is advantageously controlled by means of a suitable valve 76 controlled by governor 78 driven from the shaft 14. Fuel may be conveniently supplied to pipes 74 by pump 80 driven from the generator shaft 14 and drawing fuel through pipe 82 from the fuel supply reservoir indicated at 84. Excess fuel is returned through pipe 86 to the fuel reservoir.

Motive fluid, expanded in the blade system formed by the blades 20 to a temperature and pressure lower than the initial temperature and pressure, is conducted through the exhaust pipe 88 to a reheating device indicated generally at D. The reheating device D comprises an outer casing 90 and an inner casing 92. A reheating combustion chamber 94 is formed within the inner casing 92 and annular space 96 is formed between the casings 90 and 92. Both chamber 94 and space 96 are in communication with the outlet of the exhaust pipe 88. Combustion chamber 94 is connected by means of inner pipes 98 and 100 with the admission chamber 42 of turbine B, and pipes 98 and 100 are surrounded respectively by

outer pipes 102 and 104, the latter being in communication with space 96. These pipes provide conduits of substantial length connecting the combustion chamber 94 with the admission chamber 42 of the compressor turbine. Fuel is supplied to the reheating combustion chamber 94 through nozzle 106 to which fuel is supplied from pipe 108 which communicates with pipe 74 on the discharge side of the control valve 76.

Air compressed in the compressor rotors 40 and 50 is delivered through conduit 54 to the combustion chamber 60 and a suitably regulated quantity of fuel, supplied through nozzle 62, is burned with the air at constant pressure to provide the heated and compressed motive fluid for the turbines. The quantity of fuel supplied to combustion chamber 60 is regulated so that the desired temperature of the motive fluid is obtained with a fluid which contains a considerable amount of excess air. In the embodiment shown, wherein some of the air is conducted to the turbine separately from the products of combustion, this separately conducted air may comprise all or the major portion of the excess air. The initially heated and compressed motive fluid is expanded by passage through the blade system comprising blades 20 and is discharged to the exhaust pipe 88 at reduced pressure and temperature. Some of this motive fluid at relatively low temperature is delivered to the combustion chamber 94 of the reheating device, and a certain amount of it passes through the outer space 96. Additional fuel is supplied to the combustion chamber 94 through pipe 108 and nozzle 106. This fuel is burned with the excess air contained in the motive fluid as exhausted through pipe 88 and is regulated so that the motive fluid is reheated to a temperature preferably substantially the same as that of the initial temperature. The reheated motive fluid, at a pressure lower than the initial pressure but at substantially the same temperature as the initial temperature, is then expanded by passage through the blade system comprising blades 40 and the energy of the reheated motive fluid employed to drive the compressors which supply the compressed air to the initial heating device C.

The arrangement shown by way of illustrative example is that for a stationary gas turbine plant designed primarily for substantially constant load operation and shows to scale the relative sizes of the several parts of the plant in a plant of from 7000 to 10,000 kw. capacity. It is to be noted that both the heating device C and the reheating device D are made separate from the turbines and that the motive fluid discharged from these devices is conducted to the respective turbines through pipes of substantial length. By making the heating and reheating devices separate from the turbines and connecting them to the turbines in the manner indicated, I am enabled to effect a control of the temperature of the motive fluid to a degree which is not possible in constructions in which it is attempted to heat or reheat motive fluid in combustion chambers directly associated with the turbine structure. This relatively close control of temperature which I obtain should be employed if operation of apparatus of the character described with the desired efficiency is to be obtained, since such operation involves the use of an initial temperature substantially as high as can be successfully employed in the type of turbine used. As hereinbefore pointed out, the heating and reheating devices are separated from the turbines and con-

nected thereto by conduits of substantial length.

An important reason for this construction is to insure delivery to the admission chambers of the turbines of motive fluid having substantially homogeneous temperature characteristics. Even the minimum temperatures required at the place or places of initial expansion in the turbine or turbines of a system of this kind where heating and reheating is employed, is such that any possibility of localized strata of gases at a much higher temperature than the designed temperature must be prevented from reaching the turbine blading if the life of the latter is to be maintained for a reasonably satisfactory length of time. Consequently, by the term substantial length as herein used, I intend to define connections, the length and character of which are such in any given installation as to provide high temperature motive fluid having substantially homogeneous temperature characteristics as admitted to the turbines.

While I prefer to employ, and have shown, jacketed combustion chambers and double pipe means for conducting motive fluid to the turbines in separated streams comprising inner streams of relatively high temperature fluid surrounded by streams of fluid of lower temperature, this arrangement is not essential to the practice of the present invention and constitutes the subject matter of my copending application Serial No. 619,093 filed June 24, 1932.

Within the scope of the present invention the heating and reheating chambers may be connected to the inlets of the respective turbines by single pipes which conduct all of the motive fluid supplied to the turbines.

In order to secure high over-all thermal efficiency of the apparatus, it is necessary to have a relatively high over-all temperature drop of the motive fluid. In previous forms of apparatus this high temperature drop has been attempted to be secured by employing an excessively high initial temperature, but arrangements for carrying this method of heat utilization into effect have proved to be impractical because of the inability of turbine materials to sustain the stresses imposed thereon at the temperatures resulting from the employment of excessively high initial temperatures of motive fluid. By the arrangement according to the present invention I am enabled to obtain high efficiency without employing an initial temperature of the motive fluid which exceeds that which known turbine blading can sustain without resort to water cooling or the like and this is primarily due to two principal factors in my construction.

The first of these factors is the arrangement of the apparatus so that practicable reheating of the motive fluid to substantially its initial temperature may be obtained, thus making it possible to obtain a high over-all heat drop with a maximum temperature of the motive fluid which is within practicable limits.

The second of the factors is the utilization of the motive fluid in turbine blading of the reaction type with full admission of the motive fluid to blading in each turbine which is so constructed that the motive fluid, considered in the direction of flow through the turbine, has a component of flow in radially outward direction of substantial value. With such construction of the blading, the first row or rows of blades in each turbine, through which motive fluid flows at or near the initial temperature, are of relatively small diameter and consequently are sub-

jected to relatively small mechanical stresses. The radial flow type of turbine is an excellent example of the turbine in which full admission to initial blade rows of relatively small diameter may be effected and I have chosen this type of turbine for illustration in the present application. The invention, however, is not necessarily limited in its application to radial flow turbines but may also be employed in conjunction with axial flow turbines having the characteristics of full admission of motive fluid to initial blade rows of substantially smaller mean diameter than that of the rows at the exhaust end of the blade system, and, as herein employed, the term "central admission" is to be considered as applicable both to radial flow turbines and axial flow turbines in which admission of motive fluid is to initial blade rows of small diameter as compared with subsequent blade rows. A suitable form of axial flow turbine for use with high temperature gaseous motive fluid is disclosed and claimed in my German application Serial No. 46 f. A. 51/30 filed March 24, 1930.

By employing the motive fluid with full central admission in each of the turbines, the high efficiency of reaction blading can be taken advantage of. Also, full admission of motive fluid at an initial temperature which is relatively high as compared with the temperature possible with the usual form of axial flow turbine where the fluid is admitted to a turbine stage of comparatively large diameter, may be safely employed because of the relatively small mechanical stresses imposed on the blades which must sustain the high initial temperatures.

The present invention is not restricted in its scope of application to gas turbine apparatus of the type shown in Fig. 1, in which fuel in the initial heating device is burned in an excess of air so as to provide oxygen for further combustion in the gases exhausted from the first turbine. It is equally well applicable to systems wherein reheating is accomplished by adding to the exhaust gases from one turbine additional air for combustion as well as fuel.

In Fig. 2 I have shown more or less diagrammatically an arrangement for reheating which contemplates the addition of air as well as fuel to the combustion gases in the reheating combustion chamber.

In the arrangement illustrated, the reheating device comprises an outer shell 90' and an inner shell 92' and the space 96' between these shells is placed in communication with a supply of fresh air at suitable pressure by means of pipe 110. In the present instance pipe 110 is placed in communication with the discharge side of the low pressure compressor from which compressor air is delivered at a pressure slightly above the pressure to which the motive fluid is exhausted from the turbine A. Obviously, the necessary supply of air can be obtained from a zone of higher pressure such, for example, as the conduit 54, in which case it is suitably throttled to the desired pressure approximately corresponding to the pressure of the motive fluid as exhausted from turbine A. Generally speaking, however, arrangements involving throttling of the air, with its accompanying losses, should be avoided.

The inner shell 92' carries, by means of suitable webs or the like 112, a tube 114 preferably of Venturi form through which the nozzle 106 discharges fuel. Around tube 114 there is provided the annular channel 116 which is in com-

munication with the interior of the tube by means of a number of ports or openings 118. Channel 116 may advantageously be placed in communication with the space 96' to which air is supplied by means of webs 112, which may, as shown, be hollow.

It will be evident that arrangements differing in details of construction from that more or less diagrammatically illustrated may be employed, and it will also be evident that, if desired, the space 96' can be utilized to conduct gases exhausted from the turbine in the manner of the apparatus shown in Fig. 1. In this case air from the pipe 110 would be conveyed only to the part of the apparatus supplying air to support combustion of fuel introduced through nozzle 106.

With apparatus of the kind just described, the quantity of fuel admitted to the heating device C is regulated so as to provide comparatively little, if any, excess air in the combustion gases.

When regulation is accomplished so as to provide comparatively little excess air, the temperature of the combustion gases produced will be comparatively high and under such conditions it may be desirable to inject water into the combustion chamber for the purpose of reducing the temperature level of the motive fluid as delivered to the turbines. Such injection of water is known per se and need not be described herein for purposes of understanding of the present invention.

In case, however, water injection is employed, the volume of the combustion chambers and piping will be considerably greater than in the type of apparatus indicated in Fig. 1, since with water injection the water is converted into steam and the volume of motive fluid obtained through the combustion of given amounts of air and fuel will be greater than when water injection is not resorted to.

In Fig. 3 I have illustrated more or less diagrammatically another form of part of the apparatus of a gas turbine plant. In the apparatus illustrated the generator 122 is housed in a casing 124 which supports the bearings for the rotor shaft 126. Shaft 126, or parts rigidly secured thereto, project past the bearings 128 and 130 and pass through suitable stuffing boxes or packings 132 and 134. The projecting ends of the shaft extend respectively into turbine casings 136 and 138. The portion of the shaft extending into casing 138 is provided with a disc-like rotor 140 carrying a plurality of rings of turbine blades 142 which cooperate with a plurality of interleaved rings of stationary turbine blades 144 carried by the stationary portion of casing 138 to form a radial flow blade system of the single rotation type through which motive fluid flows from the central admission chamber 146 to the exhaust space 148.

Similarly, the end of the shaft 126 projecting into the casing 136 carries a rotor disc 150 having rings of turbine blades 152 cooperating with rings of stationary turbine blades 154 to form a radial flow blade system of the single rotation type for flow of motive fluid from the central admission chamber 156 to the exhaust space 158. The rotor 134 of this turbine also carries a row of radially extending turbine blades 160 through which the motive fluid discharged into space 158 and guided by the stationary guide 162 flows in axial direction to the exhaust passage 164 of the turbine.

Air for combustion purposes is supplied through

conduit 166 from any suitable source to the heating device E which provides a combustion chamber 168 to which fuel is supplied through pipe 170. The heating device C is connected by means of pipe 172 with the central admission chamber 146 of the first turbine and the exhaust space 148 of this turbine is connected by means of conduit 174 to the reheating device F which provides a combustion chamber 176 to which fuel is supplied through pipe 178. The reheating device F is connected by means of pipe 180 to the central admission chamber 156 of the second turbine.

The mode of operation of this turbine will be readily understood from a description of the apparatus shown in Fig. 1. The present embodiment illustrates the possibility of utilizing types of turbines other than those shown in Fig. 1 and further illustrates the use of single conduit means for conveying the products of combustion forming the motive fluid from the combustion chamber to the turbines. It will be observed that in this apparatus as well as that shown in Fig. 1 the admission of motive fluid to the turbines is central and full admission is employed. While the axial flow blades 160 are, in the apparatus shown, at a relatively great radius, and not suitable for initial admission of motive fluid, they may be employed in the manner indicated since the motive fluid entering these blades from space 158 is at relatively low temperature due to expansion through the blade system provided by blades 152 and 154.

While for purposes of clarity I have illustrated the present invention as applied to gas turbine plants of substantially the most simple arrangement possible with the minimum number of turbines, it is to be understood that the number and arrangement of turbines both for driving compressors and generators or the like for producing net useful power may be varied widely within the scope of the invention, and for plants adapted to operate at relatively high pressures and employing a relatively large number of turbines, the reheating as hereinbefore described may be employed between a plurality of expansion stages of the motive fluid.

Also, in the interests of simplicity and clarity of the disclosure, I have not shown the means employed for starting operation of the plant, since various means, such as suitably valved reservoirs for compressed air or auxiliary starting motors for starting the compressor turbine or turbines of the plant from an independent source of power, are well known in the art and a description of such apparatus is not deemed to be necessary for an understanding of the present invention.

Likewise, the invention has been illustrated and described only with reference to the normal operating conditions which the system is designed and expected to meet, and it will be understood that the invention does not exclude the employment of emergency or like control apparatus, for protecting the system against damage or destruction owing to abnormal operating conditions, the operation of which emergency apparatus may interrupt or otherwise affect the continuous free flow of fluids characteristic of the normal operation of the system.

The specific manner of producing the combustion gases at the desired temperature, that is, for example, by use of large quantities of excess air to maintain the temperature at a value sufficiently low to enable the gases to be expanded

directly with high efficiency in a reaction turbine having full admission or by the use of water injection for the avoidance of excessive initial gas temperatures, is optional within the scope of the invention, and it will be apparent to one skilled in the art that many modifications and variations in the fuel control system may be employed without departing from the invention.

The number and arrangement of the turbines with respect to flow of motive fluid in a given plant and the specific manner of producing and controlling the motive fluid will be dictated largely by the character of the load for which the plant is intended, and the present invention is therefore not to be considered as limited in its application to any specific plant arrangement but is to be considered as including all forms of gas turbine apparatus falling within the scope of the appended claims when construed as broadly as is consistent with the state of the prior art.

The hereinbefore described gas turbine system falls within the scope of the broad subject matter claimed in my copending application Serial No. 715,267, filed March 13, 1934, and the disposition of the separate compressor and useful power turbines in the system, with reference to the flow of compressed air and motive fluid through the system, shown in Fig. 1 hereof but not herein claimed, is included in the subject matter claimed in my copending application Serial No. 51,230, filed November 23, 1935.

What I claim is:

1. In a gas turbine system of the continuous combustion type, a plurality of gas turbines including a power turbine producing power for external use, each of said plurality of turbines having a blade system including a plurality of stages of high efficiency reaction blading providing a path for flow of motive fluid therethrough with a substantial component of flow in radially outward direction from an inlet of relatively small diameter to an outlet of relatively large diameter and having full admission of motive fluid to the inlet, means for supplying heated gaseous motive fluid to said turbines including compressor means for compressing a gaseous combustion supporting medium driven by at least one of said turbines operating independently of said power turbine with respect to speed of operation, a heating device providing a combustion chamber for heating said compressed medium to produce motive fluid comprising products of combustion, said heating device being located externally of the casings of said turbines, conduit means of substantial length for delivering said motive fluid to at least one of said turbines for expansion therein, a reheating device providing a combustion chamber for reheating motive fluid exhausted from at least one of said turbines, said reheating device being located externally of the casings of said turbines, conduit means of substantial length for delivering reheated motive fluid to at least one of said turbines not receiving motive fluid from said heating device, both of said conduit means being arranged for continuous free flow of motive fluid therethrough, and means for controlling the temperature of the heated motive fluid delivered from said heating device to provide for initial expansion thereof from a temperature within a range of which the lower limit is approximately 800° C. absolute and the upper limit permits continuous full admission of the motive fluid to the turbine blading without destruction of the moving blading thereof due to excessive temperature.

2. In a gas turbine system of the continuous combustion type, a plurality of gas turbines including a power turbine producing power for external use, each of said plurality of turbines having a blade system including a plurality of stages of high efficiency reaction blading providing a path for flow of motive fluid therethrough with a substantial component of flow in radially outward direction from an inlet of relatively small diameter to an outlet of relatively large diameter and having full admission of motive fluid to the inlet, means for supplying heated gaseous motive fluid to said turbines including compressor means for compressing a gaseous combustion supporting medium driven by at least one of said turbines operating independently of said power turbine with respect to speed of operation, a heating device providing a combustion chamber for heating said compressed medium to produce motive fluid comprising products of combustion, said heating device being located externally of the casings of said turbines, conduit means of substantial length for delivering said motive fluid to at least one of said turbines for expansion therein, a reheating device providing a combustion chamber for reheating motive fluid exhausted from at least one of said turbines, said reheating device being located externally of the casings of said turbines, conduit means of substantial length for delivering reheated motive fluid to at least one of said turbines not receiving motive fluid from said heating device, both of said conduit means being arranged for continuous free flow of motive fluid therethrough, and means for controlling the temperature of the heated motive fluid delivered from said heating device to provide for initial expansion thereof from a temperature within a range of which the lower limit is approximately 800° C. absolute and the upper limit is approximately 1000° C. absolute.

3. In a gas turbine system of the continuous combustion type, a plurality of gas turbines including a power turbine producing power for external use, each of said plurality of turbines having a blade system including a plurality of stages of high efficiency reaction blading providing a path for flow of motive fluid therethrough with a substantial component of flow in radially outward direction from an inlet of relatively small diameter to an outlet of relatively large diameter and having full admission of motive fluid to the inlet, means for supplying heated gaseous motive fluid to said turbines including compressor means for compressing a gaseous combustion supporting medium driven by at least one of said turbines operating independently of said power turbine with respect to speed of operation, a heating device providing a combustion chamber for heating said compressed medium to produce motive fluid comprising products of combustion, said heating device being located externally of the casings of said turbines, conduit means of substantial length for delivering said motive fluid to at least one of said turbines for expansion therein, a reheating device providing a combustion chamber for reheating motive fluid exhausted from at least one of said turbines, said reheating device being located externally of the casings of said turbines, conduit means of substantial length for delivering reheated motive fluid to at least one of said turbines not receiving motive fluid from said heating device, both of said conduit means being arranged for continuous free flow of motive fluid therethrough,

and means for controlling the temperatures of the heated motive fluid and of the reheated motive fluid delivered respectively from said heating device and from said reheating device to provide for initial expansion of the heated motive fluid from a temperature within a range of which the lower limit is approximately 800° C. absolute and the upper limit permits continuous full admission of the motive fluid to the turbine blading without destruction of the moving blading thereof due to excessive temperature and to provide for initial expansion of the reheated motive fluid from an initial temperature approximating the initial temperature of said heated motive fluid.

4. In a gas turbine system of the continuous combustion type, a first gas turbine constituting a power turbine producing power for external use, a second gas turbine operating independently of said power turbine with respect to speed of operation, each of said turbines having a blade system including a plurality of stages of high efficiency reaction blading providing a path for flow of motive fluid therethrough with a substantial component of flow in radially outward direction from an inlet of relatively small diameter to an outlet of relatively large diameter and having full admission of motive fluid to the inlet, means for supplying heated gaseous motive fluid to said turbines including compressor means driven by said second turbine for compressing a gaseous combustion supporting medium, a heating device providing a combustion chamber for heating said compressed medium to produce motive fluid comprising products of combustion, said heating device being located externally of the casings of said turbines, conduit means of substantial length for delivering motive fluid from said heating device to one of said turbines for expansion therein, a reheating device providing a combustion chamber for reheating motive fluid exhausted from said one of said turbines, said reheating device being located externally of the casings of said turbines, conduit means of substantial length for delivering reheated motive fluid from said reheating device to the other of said turbines, both of said conduit means being arranged for continuous free flow of motive fluid therethrough, and means for controlling the temperature of the heated motive fluid delivered from said heating device to provide for initial expansion thereof from a temperature within a range of which the lower limit is approximately 800° C. absolute and the upper limit permits continuous full admission of the motive fluid to the turbine blading without destruction of the moving blading thereof due to excessive temperatures.

5. In a gas turbine system of the continuous combustion type, a first gas turbine constituting a power turbine producing power for external use, a second gas turbine operating independently of said power turbine with respect to speed of operation, each of said turbines having a blade system including a plurality of stages of motive fluid therethrough with a substantial component of flow in radially outward direction from an inlet of relatively small diameter to an outlet of relatively large diameter and having full admission of motive fluid to the inlet, means for supplying heated gaseous motive fluid to said turbines including compressor means driven by said second turbine for compressing a gaseous combustion supporting medium, a heating device providing a

combustion chamber for heating said compressed medium to produce motive fluid comprising products of combustion, said heating device being located externally of the casings of said turbines, conduit means of substantial length for delivering motive fluid from said heating device to said first turbine for expansion therein, a reheating device providing a combustion chamber for reheating motive fluid exhausted from said first turbine, said reheating device being located externally of the casings of said turbines, conduit means of substantial length for delivering reheated motive fluid from said reheating device to said second turbine, both of said conduit means being arranged for continuous free flow of motive fluid therethrough, and means for controlling the temperatures of the heated motive fluid and of the reheated motive fluid delivered respectively from said heating device and from said reheating device to provide for initial expansion of the heated motive fluid from a temperature within a range of which the lower limit is approximately 800° C. absolute and the upper limit permits continuous full admission of the motive fluid to the turbine blading without destruction of the moving blading thereof due to excessive temperature and to provide for initial expansion of the reheated motive fluid from an initial temperature approximating the initial temperature of said heated motive fluid.

6. In a gas turbine system of the continuous combustion type, a first gas turbine constituting a power turbine producing power for external use, a second gas turbine operating independently of said power turbine with respect to speed of operation, each of said turbines having a blade system including a plurality of stages of high efficiency reaction blading providing a path for flow of motive fluid therethrough with a substantial component of flow in radially outward direction from an inlet of relatively small diameter to an outlet of relatively large diameter and having full admission of motive fluid to the inlet, means for supplying heated gaseous motive fluid to said turbines including compressor means driven by said second turbine for compressing a gaseous combustion supporting medium, a heating device providing a combustion chamber for heating said compressed medium to produce motive fluid comprising products of combustion, said heating device being located externally of the casings of said turbines, conduit means of substantial length for delivering motive fluid from said heating device to said first turbine for expansion therein, a reheating device providing a combustion chamber for reheating motive fluid exhausted from said first turbine, said reheating device being located externally of the casings of said turbines, conduit means of substantial length for delivering reheated motive fluid from said reheating device to said second turbine, both of said conduit means being arranged for continuous free flow of motive fluid therethrough, and means for controlling the temperatures of the heated motive fluid delivered from said heating device and of the reheated motive fluid delivered from said reheating device to provide for initial expansion thereof in the respective turbines from temperatures within a range of which the lower limit is approximately 800° C. absolute and the upper limit is approximately 1000° C. absolute.

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