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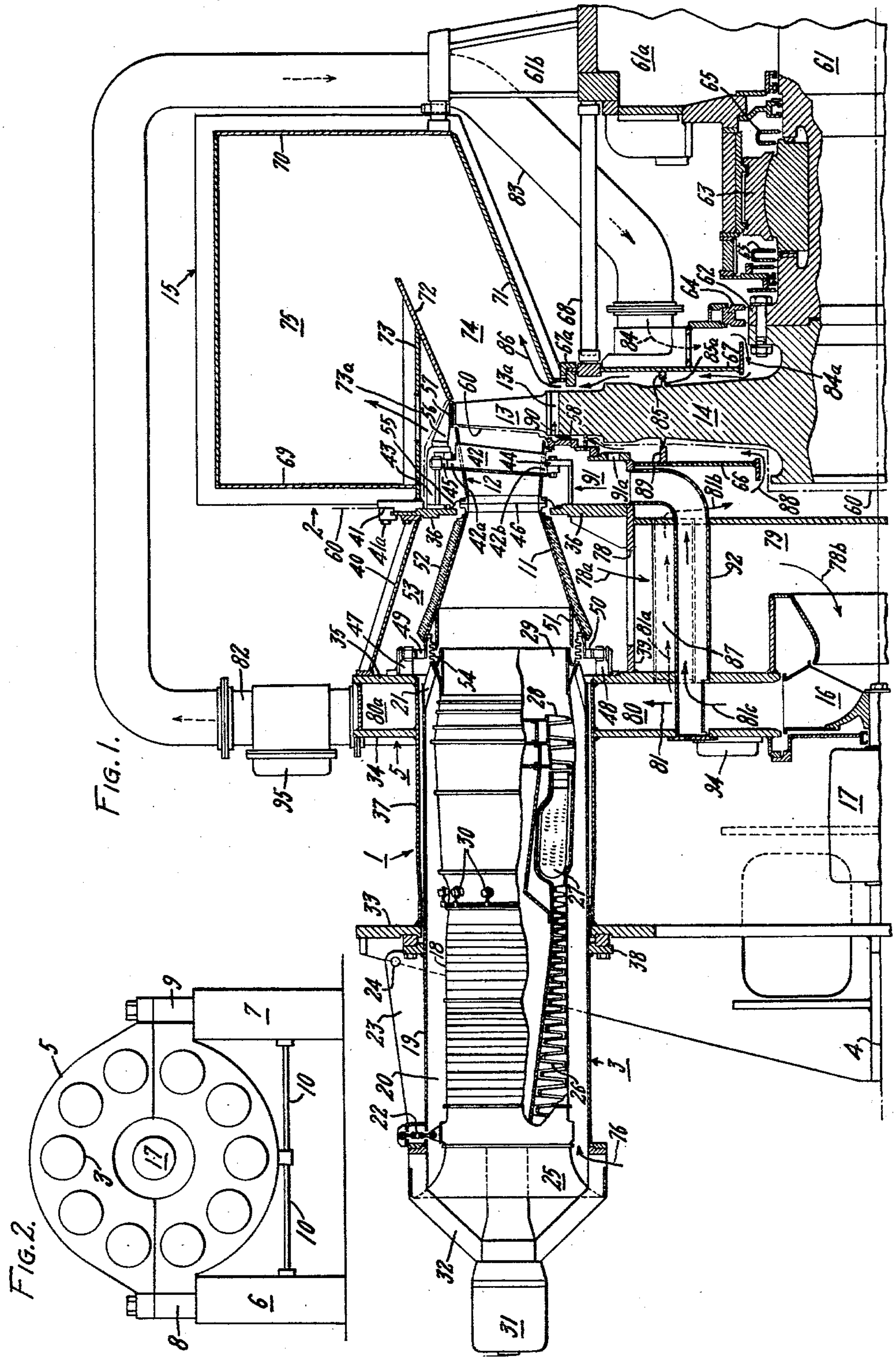
MULTIPLE GAS GENERATOR TURBINE

Filed March 25, 1963 2 Sheets-Sheet 1



MULTIPLE GAS GENERATOR TURBINE

Filed March 25, 1963 2 Sheets-Sheet 2

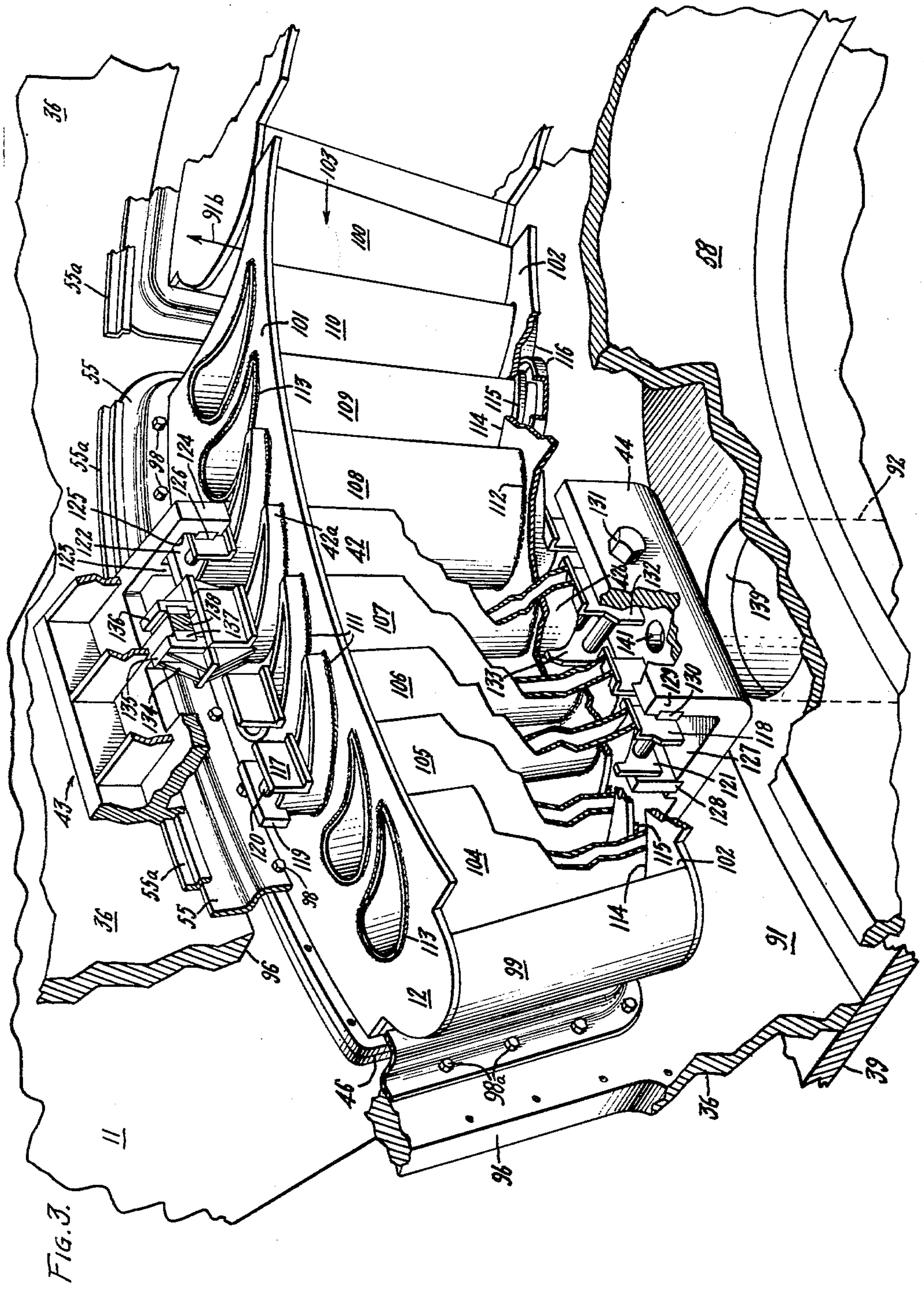


FIG. 3.

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MULTIPLE GAS GENERATOR TURBINE

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13 Claims. (Cl. 60—39.37)

This invention relates to an improved turbo-machine which employs a number of individually operative gas generators supplying motive fluid through separate nozzle boxes to a single turbine rotor. More particularly, the invention relates to an arrangement for a gas turbine prime mover, wherein a group of quick-starting gas generators having low-inertia rotating elements supply motive fluid to separate sectors of a relatively large load turbine wheel, which arrangement includes provisions for cooling the hot gas generators, their supporting structure, and the turbine wheel.

The conventional gas turbine, of a size suitable for utility or industrial applications, generates its own motive fluid by means of a number of rotating stages of blades compressing air in which fuel is then burned. The hot motive fluid is then passed through one or more stages of turbine buckets some of which furnish power to drive the compressor and the remainder of which serve to drive the load. The compressor turbine stages and load turbine stages may be on a single shaft, or the load turbine may be on a separate rotor shaft so that its speed need not be the same as that of the compressor. However, one design philosophy has been to include the hot gas generating portion, i.e., a compressor and the turbine stages driving the compressor, along with the load turbine stages in a single casing on coaxial shafts. Since the gas generating portion must furnish sufficient motive fluid for driving the whole powerplant, its rotating elements and casing have heretofore been massive, requiring a "prewarming period" upon starting to allow the parts to come to normal operating temperature evenly. The full circumferential flow annulus of motive fluid from the gas generator has commonly been discharged through nozzle partitions into the full circumferential flow annulus of the load turbine buckets.

Large steam turbines have also required slow startup cycles due to the massive casings and rotors used, and the necessity to prewarm or take on load slowly. Contrary to gas turbine practice, it is common in stream turbines to admit the steam through individual arcuate nozzle boxes disposed around the circumference of the entrance to the first stage bucket wheel, the flow through each nozzle arc being controlled by separate control valves. This is done to reduce throttling losses due to a partially-open control valve. The steam flowing to the control valve chests and the separate nozzle boxes is, however, supplied from a common steam generator, rather than from multiple sources. Hence trouble in the steam generator or boiler may require that the turbine be shut down completely.

The separate nozzle box constructions employed in steam turbine practice are generally unsuitable for the temperatures and rapid changes of temperature found in gas turbines. Steam turbine nozzle boxes are generally cast with heavy walls and operate at a maximum of perhaps 1050° F. The temperature of the gas passing through gas turbine nozzles, on the other hand, may reach peaks on the order of 1,600° F., and it is desirable to employ special cooling means. This calls for thin-walled fabricated constructions. Also provision must be made for thermal expansion of the parts relative to each other.

It has been previously suggested that two or more aircraft type gas turbine powerplants might be employed as hot gas generators to drive a common load turbine, and that the powerplant might continue to operate with one of the gas generators out of action. This suggestion has been made with regard to a moving vehicle, specifically an aircraft where "ram air" will continue to flow through the inoperative gas generator. In this previously suggested construction, therefore, there is no substantial probability of flow of hot motive fluid from the outlet of an active gas generator back through the inoperative gas generator, as may tend to occur in a stationary powerplant.

Another concern in the operation of a large gas turbine or steam turbine is the necessity for periodic routine examination of seals, buckets, shrouds and other elements subject to deterioration. Large turbine prime movers often have a horizontally split casing, and the top half must be removed to examine and service the critical parts. A powerplant for "peaking" service, required to operate only intermittently, must always be in a state of instant readiness. Hence an arrangement providing for quick inspection and maintenance is highly desirable.

It is desirable to have a quick-starting "peaking" prime mover able to furnish sufficient power for large industrial and utility generating plant applications which provides the utmost reliability and lends itself to unattended operation by remote control.

Accordingly, an object of the present invention is to provide an improved high temperature turbine powerplant which can start up and take on load on very short notice.

Another object is to provide a turbine prime mover with improved reliability through having a substantial number of motive fluid sources in parallel and capable of operating independently of each other.

Still another object is to provide a quick-starting gas turbine prime mover with a number of individually operative hot gas generators having low-inertia rotating elements and thin, quick-heating walls defining the motive fluid flow path.

Another object is to provide an improved thin-walled load turbine nozzle box construction, and support system therefor.

Another object is to provide a stationary multiple gas generator turbine which can operate with one or more hot gas generators inoperative, without backflow through the inoperative gas generators.

Yet another object is to provide an improved cooling arrangement for a multiple gas generator turbine powerplant of the type described.

Another object of the invention is to provide an improved multiple gas generator turbine which can be easily and quickly inspected and serviced so as to keep it in a constant state of readiness to assume load.

Briefly stated, the invention is practiced by providing a frame or cage supporting a cylindrical array of parallel, individually operative hot gas generators, for instance of the axial flow aircraft turbine type, arranged to deliver hot gas through separate transition ducts and nozzle boxes to arcuate sectors of a single load turbine bucket wheel mounted in overhung relation on the shaft of an adjacent coaxial generator or other load machine. Cooling air is drawn over the casings of the gas generators, in parallel, to a blower at the axis of the cylindrical array and is used to cool the frame and the load turbine wheel. Each gas generator is mounted in a separate cylindrical container or can readily withdrawable from the frame and arranged for quick replacement and routine maintenance on a continuing basis. The nozzle boxes are of thin-walled construction and supported for relative expansion by the nozzle partitions themselves. A shroud assembly for the load turbine buckets is also supported by and withdrawable with the common frame supporting the gas generators.

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of practice, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in connection with the accompanying drawings in which:

FIG. 1 is a longitudinal sectional view of the upper half of the complete powerplant,

FIG. 2 is a simplified view, looking in an axial direction, showing the basic arrangement, and

FIG. 3 is an enlarged perspective view of one of the special nozzle boxes, showing its construction and preferred manner of support.

General arrangement

Referring now to FIG. 1, the gas generating portion is shown generally at 1 on the left, while the turbine and its exhaust hood are shown generally at 2 on the right. There are ten self-contained individually-operative gas generators in the present embodiment, one of these being shown generally at 3. The gas generators are disposed in a cylindrical array about a horizontal centerline 4 and are parallel to one another. Gas generators 3 are supported in common frame or "cage" structure, shown generally at 5, which is axially withdrawable to the left for servicing and maintenance of the thereby exposed load turbine wheel and nozzle boxes.

Referring briefly to the simplified end view in FIG. 2 of the drawing, it will be seen that cage 5 is supported at either side thereof on foundation members 6, 7 by means of supporting brackets 8, 9 attached to the cage. Tie rods 10 assist in holding the cage centered. To withdraw cage 5 from the load turbine wheel, it is lifted slightly and rollers are placed beneath support brackets 8, 9, whereupon the cage can be rolled back on the foundation 6, 7. The gas generator 3 shown in full in FIG. 1 is indicated at 3 in FIG. 2.

Returning to FIG. 1 of the drawing, each gas generator 3 discharges into a separate transition duct 11 with an attached arcuate nozzle box 12. From nozzle box 12, the hot gas flows through the buckets 13 of the common load turbine wheel 14, and from there through exhaust hood 15 to the atmosphere, through a horizontal outlet, not shown.

In order to provide cooling of the gas generators, the various hot gas ducts, frame members, and the load turbine wheel, a centrifugal blower 16 is disposed on the centerline 4 and separately driven by an electric motor 17, both being supported in cage 5.

Having briefly described the basic components of the powerplant, the components will now be described in more detail.

Gas generators

Each gas generator 3 is a modified aircraft gas turbine engine, of the type commonly known as a "jet engine," with its usual casing indicated at 18. The modification here consists in supporting the aircraft gas turbine casing 18 coaxially within an outer casing or can 19 with a substantial annular space 20 therebetween. At its right end or outlet end, casing 18 is held in a substantially fixed support from outer casing 19, by means of circumferentially spaced struts 21. At its left or intake end, casing 18 is supported by means of two pivotable turnbuckles. One of these is shown in the drawing at 22 and the other (not shown) is located 90 degrees therefrom. Thus casing 18 is free to expand along horizontal and vertical diameters at the location of the turnbuckle supports 22.

Furthermore, as casing 18 gets hot, it lengthens, expanding to the left from the fixed struts 21, this being allowed by pivoting of the turnbuckle supports 22.

A strengthening rib 23, with a hole 24 above the approximate center of gravity or "balance point" of the gas generator 3, is attached to outer casing 19 and allows the gas generator to be supported from a hoist as it is axially withdrawn from cage 5 for servicing or replacement. Each of the gas generators 3 is self-contained and individually-operative and is completely piped, wired, and aligned within outer casing 19 at assembly. As explained later, one or more of the gas generators 3 is thus allowed to be inoperative without shutting down the entire powerplant. Also, by having available a "spare" gas generator, at least one active gas generator may always be made available for overhauling on a continuous rotating schedule.

The engine in inner casing 18 is substantially the same as the "jet engine" used in aircraft. One such suitable engine is the Type C–J–805 commercial aircraft gas turbine as manufactured by the General Electric Company, assignee of the present application. It consists of an air intake cone 25, a seventeen-stage axial-flow compressor section 26, a circumferentially spaced group of combustion chambers 27, and a three-stage axial-flow turbine section 28, all co-operating to discharge hot gas through outlet 29. Fuel is fed to the combustion chambers 27 by fuel pipes 30 from a central fuel supply and control system (not shown). An electric starting motor 31 is supported by struts 32 from the outer casing 19.

Cage structure

The gas generators 3 are held in the cage structure 5 now to be described in detail. Cage 5 basically comprises four vertical transverse plates 33, 34, 35, and 36. These are circular in shape, split on a horizontal centerline, and bolted together as indicated diagrammatically in FIG. 2. Plates 33, 34, 35 are connected together and spaced as shown by means of circumferentially spaced cylindrical tubes 37 welded into circular holes in the three plates, there being one tube 37 for each gas generator. Gas generators 3 are held within tubes 37 by means of a radial flange 38 welded to can 19 and bolted to the first plate 33. Plates 35 and 36 are attached together by means of an inner drum 39 and an outer conical drum 40 welded between the plates 35, 36 and coaxial with axis 4. Cage 5 is detachable by unbolting it from the walls of exhaust hood 15 at the location 41 by removing bolts 41*a*.

Flow-directing ducts

Also supported by and withdrawable along with cage 5 are the transition ducts 11 and nozzle boxes 12. Each nozzle box 12 contains a group of radially extending hollow nozzle partitions, one of which is shown at 42. Nozzle partition 42 is slightly different from the other nozzle partitions in nozzle box 12, in that its ends extend through the box as indicated at 42*a*, 42*b* and are held in an upper bracket 43 and a lower bracket 44 attached to plate 36. Inner end 42*b* of the nozzle partition is pivotally fixed to bracket 44, while the outer end 42*a* is free to expand radially in bracket 43 by means of the connection shown at 45. The details of this nozzle box support will be discussed more fully in connection with FIG. 3, but it should be noted that axial movement of nozzle box 12 is thereby prevented at its outlet, so that clearances can be maintained substantially constant between the arcuate mouth of nozzle box 12 and the closely adjacent rotating blades 13.

The transition duct 11 and the nozzle box 12 are bolted together at flange 46. The lefthand or inlet end of transition duct 11 is axially slidable to the left and is supported by brackets 47, 48 having sliding ways and attached to plate 35. Sliding mountings 49, 50 support the inlet end of transition duct 11 and slide axially on the ways of brackets **47**, **48** respectively. A ring **51** attached to the transition duct **11** provides an inlet lip coaxial with the outlet **29** of the gas generator, and is slightly larger in diameter so as to move to the left over the fixed outlet **29** when the transition duct and nozzle box expand. The outer walls of the transition duct **11** are covered with insulation indicated as **52** around that portion of the duct which is disposed inside an annular chamber **53**. Chamber **53** is formed between the two coaxial drums **39**, **40** and the case plates **35**, **36**. Insulation **52** serves to reduce heating of the cooling air as it flows radially inward to blower **16**.

Seals and shrouds

A gas seal is provided between the outer casing **18** of the gas generator and the transition duct **11**, by means of a bellows **54** which allows relative axial movement as described above. An additional seal plate **55** is provided between the flange **46** and cage plate **36**. Seal **54** isolates chamber **53** from the hot gas flowing through transition duct **11**. Seal **55** prevents flow into chamber **53** of higher pressure cooling air in chamber **91**.

Another feature of the invention is that the shroud for the turbine buckets **13** is also attached to and withdrawable with the cage structure, thereby completely exposing turbine wheel **14**, buckets **13**, and nozzle boxes **12**, for servicing. The shroud bracket, shown as **56**, is attached to the outer nozzle box bracket **43**, so as to extend over the tips of buckets **13**. Shroud **57** is held by brackets **56**, so as to form close clearances with the tips of buckets **13**.

It remains to note that an additional sealing assembly **58**, which is also secured to and removable along with the cage, forms close axial clearances with the shanks of buckets **13** and is indicated generally at **58**. This sealing assembly meters the flow of cooling air and also distributes a portion to the axial holes **13*a*** in the bucket shanks.

With exception of the description of the cooling assembly in the cage, the foregoing completes a detailed description of the gas generator portion **1**, which is withdrawable as a unit from the turbine and hood assembly **2**. The dot-dash line **60** indicates the irreglar "dividing plane" between portions **1** and **2** when cage **5** is rolled to the left.

Load turbine wheel

Referring now to the turbine wheel and hood assembly **2**, turbine wheel **14** is of the "overhung" type, being attached to the end of a shaft **61** by means of bolted flanges **62**. Shaft **61** may be the extending end of the shaft of the load device, such as a generator, a portion of the generator housing being shown at **61*a***. Hence the load turbine and its driven device may employ only two main bearings, one of which is seen at **63**. The left side of turbine wheel **14** therefore is unsupported and accessible after cage **5** is withdrawn. A shaft seal for preventing escape of the cooling fluid is indicated at **64**, while seals **65** help to prevent oil loss from bearing **63**.

The load turbine wheel **14** is enclosed between parallel walls, one of which, shown at **66**, is a portion of the cage structure. The other wall, shown at **67**, is supported from the housing **61*a*** by means of struts **68**.

Exhaust hood

The hood **15** consists of spaced transverse vertical walls **69**, **70**, carrying the motive fluid to a horizontal discharge exhaust duct (not shown). The gas path from buckets **13** is formed by an inner conical wall **71**, connecting the vertical walls **67**, **70**, and an outer conical wall **72** supported from the vertical hood wall **69** by means of a cylinder **73**. The conical walls **71**, **72** diverge slightly to form an annular diffusing passage **74** leading to a main discharge chamber **75**. The circumferential inner edge of wall **71** is sealed to the outer periphery of plate **67** by a simple slip joint indicated at **67*a***, thus permitting differential thermal expansion of hood **15** relative to plate **67**. Support for the exhaust hood is represented by bracket **61*b*** on generator housing **61*a***.

Cooling system

The cooling system for the hot gas ducts and the turbine wheel will now be described. Generally speaking, the centrifugal blower **16** draws air over the gas generator casings **18** in parallel flow relationship and then distributes it to selected areas to be cooled. Cooling air enters at the inlet end of the gas generators as indicated by arrow **76** and passes along the annular passage **20** between inner and outer casings **18**, **19**. This air flows past the supporting struts **21** holding the outlet end of the gas generator and into the annular chamber **53** defined between drums **39**, **40**. Cooling air flow into the motive fluid stream is prevented by means of bellows **54**, and seal **55** prevents ingress of air from chamber **91**. Cooling air flows radially inward, as indicated by the arrows **78*a***, **78*b***, through holes **78** in the inner drum **39** to an inlet chamber **79** for blower **16**. The air required for cooling the gas generators **3** is greatly in excess of that needed elsewhere and approximately 70% of this air is then discharged from blower **16** in a downward direction through a duct (not shown) into the exhaust hood.

The remainder of the cooling air is discharged radially outward into an annular chamber **80** defined between the spaced vertical walls **34**, **35** of the cage. Here it divides into three portions. The first portion, indicated by arrow **81** continues flowing radially outward around tubes **37** to the outer portion **80*a*** of chamber **80**, where it enters two U-shaped cooling pipes, only one of which is shown at **82**. Cooling pipe **82** passes over the hood **15** and in toward the wheel again on the other side, as shown at **83**, so as to discharge air against the radially inner part of wheel **14** on the far side, as shown by arrows **84**, **84*a***. This air flows radially outward across the turbine wheel to cool it, the rate of flow being controlled by means of the circumferential seal **85** forming a restricted clearance space with lip **85*a*** on the wheel. From there it joins the hot motive fluid going to the exhaust hood as shown by arrow **86**.

The second portion of cooling air **81*a*** in chamber **80** passes axially through short pipe sections **87** connected between plates **35**, **36** and thence radially inward again at **81*b*** to discharge against a radially inner portion on the near side of turbine wheel **14** as indicated by arrow **88**. From there it flows radially outward along the wheel, restricted somewhat by means of a seal **89** and by portions of the sealing assembly **58**. A part of this air bleeds into the axial holes **13*a*** in the bucket platforms as shown by arrow **90**, while the remainder enters an annular chamber **91** under nozzle boxes **12** through openings **91*a***, and flows around the nozzle boxes, and into hood **15** through holes **73*a***, by way of openings defined between the ends of adjacent nozzle boxes (FIG. 3) per flow arrow **91*b***.

The third portion **81*c*** of the cooling gas from blower **16** passes into L-shaped pipes **92** which lead directly to the nozzle box chamber **91**. This air also serves to cool the nozzle boxes and is discharged through holes **73*a*** into hood **15**.

It remains to note that, inasmuch as the prime mover is intended to be used intermittently as a "peaking" plant, it may be desirable to keep the massive turbine wheel **14** at a somewhat elevated temperature, so that the only elements required to be brought up to operating temperature will be the thin-walled flow ducts and gas generators **3**. For this reason, electric heaters **94** and **95** are disposed in blower outlet chamber **80** and also in the cross-over pipes **82** so that if desired, the blower **16** and heaters **94**, **95** may be operated to prewarm wheel **14** before starting the gas generators, or to maintain wheel **14** at a suitable elevated temperature when at "no load" operating condition. These may also serve to warm the cooling air somewhat, when ambient temperature is very low, to avoid "chilling" the turbine wheel with excessively cold air.

Nozzle box construction

Referring now to FIG. 3 of the drawing, the nozzle box **12** and its associated structure will be described in detail. The juncture between the transition pieces **11** and nozzle boxes **12** take place at the vertical cage wall **36** inside circumferentially spaced arcuate apertures **96**. Each aperture is large enough to accommodate the flanges **46** of the transition piece **11** and the nozzle box **12**, and to provide space around the flange for circumferential, radial, and axial movement. To provide a gas seal between the flange and opening **96**, a seal plate **55** is bolted as shown at **98** to the flanged joint **46** and held to wall **36** by means of a slip joint formed by a Z-shaped strip *55a* welded adjacent the outer periphery of opening **96** in wall **36**. The remaining three sides of seal **55** are secured by bolts *98a* to wall **36**. Nozzle box **12** is of relatively thin-walled construction and has end walls **99**, **100** which are curved so as to cooperate with adjacent like nozzle box end walls to form the radial cooling air passages for the flow *91b*. To the end walls are welded upper and lower arcuate walls **101**, **102** respectively. The downstream edges of walls **99**, **100**, **101**, **102** define an arcuate mouth **103** which is closely spaced and aligned so as to discharge into an arcuate sector of turbine buckets (see FIG. 1).

In the embodiment shown, there are eight airfoil-shaped hollow nozzle partitions extending radially between arcuate walls **101**, **102**. The centrally located partition **42** is the primary load-bearing partition, while the other partitions are designated with numerals **104–110**. The four center partitions **106**, **107**, **42**, **108** form a group of thrust-sustaining partitions and extend through walls **101**, **102**. They are securely and sealingly welded thereto all around at top and bottom, as indicated by arrows **111**, **112** respectively. The two partitions on each end, **104**, **105**, **109**, **110** form a group of "floating" partitions and are welded all around but only to the top wall **101** as indicated by arrow **113**. The lower ends, as indicated on partition **109**, extend through a closely fitting hole **114** in the bottom wall **102** and provide partial support for the bottom wall by means of a flange **115** welded to the partitions. In order to prevent leakage through holes **114** along the "floating" partitions, four cover boxes such as the one indicated at **116** are placed over the open ends at the bottom of the four floating partitions and are welded to the bottom of arcuate wall **102**. These boxes accommodate radial movement of the partitions in holes **114**. Thus the hot gas cannot escape downwardly from the nozzle boxes.

In order to carry the downstream axial thrust exerted on nozzle box **12** by the hot gas passing through the transition duct **11**, each of the four center partitions **106**, **107**, **42**, **108** are provided with thrust plates in the form of angles welded into cutouts in the top and bottom partition walls. One set of these angle thrust plates for the partition **106** are indicated at **117** and **118** at the top and bottom of the partition. These eight thrust plates carry the axial thrust of the entire nozzle box **12**.

In case one of the gas generators becomes inoperative, there is a possibility of reverse axial thrust on nozzle box **12**. To prevent this, reverse thrust plates are provided at the top and bottom of intermediate partitions **106**, **108**. These are formed by employing additional plates, such as **119** shown at the top of partition **106**, spaced from angle thrust plate **117** by a tubular spacer **120**. Other reverse thrust plates may be seen, such as **121** at the bottom of partition **106** and **122** at the top of partition **108**. The reverse thrust plates also keep the nozzle box aligned and prevent it from "wobbling" about the primary supporting partition **42**.

Upper bracket **43** and lower bracket **44** carry the thrust at the top and bottom of the nozzle box respectively. Bracket **43** is welded or otherwise suitably secured to wall **36** and has two transversely spaced radially extending lips, only one being shown at **124**, and also has other spaced lip portions **123** forming an opening **125**. Lip **124** carries a specially hardened shoe **126**, which resists wear caused by relative movement of upper thrust plates **117**. The nozzle box is free to move radially outward and tangentially toward either side within opening **125**.

Bracket **44** at the bottom is similarly constructed to provide a channel-shaped opening **127** between axially spaced vertical lip portions **128**, **129**. A hardened thrust bearing shoe similar to **126** above, may be seen at **130**. Bracket **44** takes the axial downstream thrust of the nozzle box while yet allowing the individual nozzle partitions to move radially or tangentially within the channel opening **127**.

The entire weight of nozzle box **12** is carried on a single bolt **131** which passes through the lip **129** of bracket **44**, through the enlarged lower portion **132** of the angle member welded to the bottom of partition **42**, through an additional plate **133**, and is attached to the rear of bracket **44** by a nut (not shown). The position of the nozzle box is thus fixed at its center and at the radially inner wall. The weight of the nozzle box **12** is transmitted to partition **42** through the welds between the partitions and the top and bottom walls **101**, **102**.

It will be observed that unless provision were made, the tangential force on the nozzle box due to the fluid-directing action of the nozzle partitions, would tend to rotate the nozzle box **12** counterclockwise about the bolt **131**. To resist this tangential reaction force, and yet allow nozzle box **12** to expand radially outward as it is heated, a special welded assembly **134** is attached to the top of partition **42**. Assembly **134** has two spaced vertical walls **135**, **136**, each carrying hardened inserts such as **137**. Bracket **43** is provided with an axially extending leg **138** fitting between legs **135**, **136**. This arrangement serves to resist the tangential reaction force exerted by the nozzle box, while still allowing legs **135**, **136** and partition **42** to move radially outward as the nozzle box expands.

The L-shaped pipes **92** furnishing cooling air to the annular chamber **91** may be seen at the bottom. These open through a hole **139** into the annular chamber **91**. A hole **141** allows access of cooling air to the portions of the nozzle box covered by bracket **44**.

Thus it will be seen that this special nozzle box construction includes inner and outer main brackets, with a single supporting pivot **131** carrying the inner end of a central partition, this and certain adjacent partitions being seal welded at both ends to the inner and outer walls **101**, **102** and carrying thrust bearing and guide means cooperating with the brackets to prevent "wobbling" of the nozzle box about the single pivot, the end partitions being seal welded at their outer ends to wall **101** and projecting freely inwardly through capped openings in wall **102**.

It is to be noted that when one gas generator is inactive, the high velocity flow of hot gas at the downstream side of the adjacent active nozzle boxes has a tendency to aspirate a flow of cooling air through the compressor, combustion system, and turbine of the inactive generator. This aspirating action is aided by the "pumping action" of the load turbine buckets passing the inactive nozzle box.

These effects combine to prevent reverse flow of hot gas from the discharge side of active nozzle boxes back into the downstream side of the inactive nozzle box. Thus it becomes possible in a stationary powerplant to operate the gas turbine with one or several gas generators inactive, without "blow-back" of hot gas, which would damage the compressor of the inactive generator.

Conclusion

The invention provides an improved multiple gas generator turbine plant having a common load turbine wheel overhung on the shaft of an adjacent coaxial load machine. The common frame structure for the array of gas generators permits ready access to the load turbine wheel by simply uncoupling the frame from the exhaust casing and rolling back the frame to expose the load turbine and nozzle boxes.

A separate motor-driven ventilating fan draws cooling air over the gas generators and supplies coolant to the load turbine, transition ducts, and nozzle boxes, with heaters arranged to prewarm or maintain turbine operating temperatures at the no-load condition. The separate hot gas generators are self-contained and readily withdrawn from the frame structure for overhauling. The special nozzle box arrangement prevents reverse flow through an inactive gas generator, while providing ready means for removal of a box for servicing.

The result is an improved gas turbine power plant well suited for intermittent operation, with short start-up time, maximum availability and reliability, capable of operating with some of the gas generators inactive, and suitable for unattended operation by remote control.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A multiple gas generator turbine powerplant comprising:
a turbine wheel including a circumferential row of radially extending buckets,
a cylindrical array of individually-operaitve gas generators disposed parallel to one another, said array being coaxial with said turbine wheel, each of said gas generators including combustion chambers and rotating compressor and turbine stages discharging hot motive fluid axially from a substantially cylindrical outlet,
a plurality of flow-directing ducts each shaped to receive fluid from one of said gas generator outlets and to discharge it from an arcuate mouth into a portion of said turbine buckets,
a plurality of radially extending nozzle partitions sealed within the arcuate mouth portion of each of said flow-directing ducts, a selected number of said nozzle partitions in each of said ducts being constructed to extend through opposite arcuate walls thereof and to support the arcuate end of the duct against axial and tangential thrust of the fluid, the remainder of the nozzle partitions in the duct being supported by the arcuate walls thereof, all of said nozzle partitions directing the motive fluid into an arcuate sector of said turbine buckets, whereby each of said gas generators supplies an arcuate sector of buckets through a group of both supporting and supported nozzle partitions separately from each of the other gas generators.

2. A multiple gas generator turbine comprising:
a turbine wheel including a circumferential row of radially extending buckets,
a cylindrical array of individually operative gas generators disposed parallel with one another, said array being arranged coaxially with said turbine wheel, each of said gas generators having inner and outer coaxial casings defining an annular passage therebetween for the passage of cooling air and also arranged to discharge hot motive fluid axially from an inner casing outlet,
a plurality of flow-directing ducts each shaped to receive fluid from said inner casing outlet and to discharge it from an arcuate mouth into a portion of said turbine buckets, whereby each of said gas generators supplies an arcuate sector of buckets separately from each of the other gas generators,
blower means disposed within said cylindrical array of gas generators,
first conduit means interconecting the gas generator annular passages in parallel flow relationship to the inlet of said blower means,
second conduit means connected to the outlet of said blower means and conducting a portion of the cooling air from the blower around portions of said flow-directing ducts, and
third conduit means connected to the outlet of said blower means and conducting another portion of the cooling air from the blower to a radially inner portion of said turbine wheel.

3. A multiple gas generator turbine comprising:
a turbine wheel including a circumferential row of radially extending buckets,
a cylindrical array of individually operative gas generators disposed parallel to one another, said array being arranged coaxially with said turbine wheel, each of said gas generators including a substantially cylindrical outer casing and a coaxial inner casing containing combustion chambers and rotating compressor and turbine stages discharging hot motive fluid axially from a substantially cylindrical inner casing outlet, said casings defining an annular passage therebetween for the flow of cooling air,
a plurality of flow-directing ducts each including a transition portion with a cylindrical inlet shaped to receive fluid from said gas generator inner casing and connected to an arcuate nozzle box with an arcuate mouth disposed adjacent an arcuate sector of said turbine buckets, said nozzle box having radially extending nozzle partitions sealed within said mouth,
a blower disposed substantially coaxial with the turbine wheel and within said array of gas generators,
first conduit means connecting the gas generator annular passages to a common chamber at the inlet of said blower and passing cooling gas over the transition portions of said flow-directing ducts, and
second conduit means connected to the outlet of said blower and discharging cooling air against radially inner portions of the turbine wheel on either side thereof and over the nozzle boxes of said flow directing ducts.

4. A nozzle box assembly for directing hot motive fluid into an arcuate sector of turbine blades comprising:
a thin-walled box open at either end and having sidewalls and arcuate top and bottom walls,
a plurality of spaced nozzle partitions extending between said top and bottom walls,
upper and lower fixed support brackets disposed above and below the top and bottom walls respectively,
a first group of said nozzle partitions having end portions extending through the top and bottom walls and constructed to support the nozzle box assembly within said brackets for thermal expansion with respect thereto, and
a second group of said nozzle partitions being supported by one of said arcuate walls and arranged to expand thermally with respect to the other of the arcuate walls.

5. A nozzle box assembly for directing hot motive fluid into an arcuate section of turbine blades comprising:
a thin-walled box open at either end and having side walls and arcuate top and bottom walls,
a plurality of spaced nozzle partitions extending between said top and bottom walls,
upper and lower fixed support brackets disposed above and below the top and bottom walls respectively and each including a lip extending toward said arcuate walls over a central portion thereof,
a first group of said nozzle partitions having end portions extending through the top and bottom walls and having thrust plates attached thereto bearing against said bracket lips to resist the reaction force on the nozzle box assembly by the hot motive fluid passing therethrough,
a central one of said nozzle partitions being constructed to support the nozzle box assembly within said brackets for thermal expansion in a direction normal to said arcuate walls, and
a second group of nozzle partitions being supported by one of said arcuate walls and arranged to expand

thermally with respect to the other of the arcuate walls.

6. The combination according to claim 5 wherein said central nozzle partition is pivotably attached to one of said support brackets and wherein the other of said support brackets cooperates with the other end of said central nozzle partition to resist the sideways reaction force on the nozzle box assembly caused by the motive fluid passing through the nozzle box while allowing the central nozzle partition to slide relative thereto for thermal expansion.

7. A nozzle box assembly for directing hot motive fluid into an arcuate sector of turbine blades comprising:

a thin-walled box open at either end and having sidewalls and arcuate top and bottom walls,

a plurality of spaced hollow airfoil-shaped nozzle partitions extending between said top and bottom walls,

upper and lower fixed support brackets disposed above and below the top and bottom walls respectively, each having a front lip portion and a spaced rear lip portion extending toward the adjacent arcuate wall,

a first group of said nozzle partitions extending through and sealingly attached to the top and bottom walls over a central portion thereof and having thrust plates bearing against said front lip portions of the support brackets,

selected ones of the first group of nozzle partitions also having reverse thrust plates bearing against the rear lip portions of the support brackets,

a central one of said first group of nozzle partitions being attached at its lower end to the lower bracket by a pivotable connection to support the weight of the nozzle box assembly, the other end of said central nozzle partition having an extending portion bearing transversely against a portion of the upper support bracket to prevent sideways movement, while allowing thermal expansion away from said pivotable connection,

a second group of nozzle partitions disposed on either side of said first group being sealingly attached to and supported by one of said arcuate walls and free to expand through holes defined in the other of said arcuate walls,

and a plurality of gas-tight boxes covering said holes and sealingly attached to said other arcuate wall so as to accommodate the movements of the second group of nozzle partitions while preventing leakage through said holes.

8. A multiple gas generator turbine comprising:

an overhung turbine wheel with an unsupported end and having a plurality of radially extending buckets adapted to discharge fluid into an exhaust hood,

a cage assembly coaxial with said turbine wheel and constructed for axial withdrawal from the unsupported end of the wheel,

a plurality of individually-operative gas generators supported in a cylindrical array within said cage assembly and each discharging hot motive fluid from an outlet,

a plurality of flow-directing ducts each shaped to receive motive fluid at an inlet end from one of said gas generator outlets and to discharge it from an arcuate mouth into a portion of said turbine buckets,

each of said ducts having radially extending nozzle partitions disposed within said mouth and constructed to support one end of the duct from the cage assembly, whereby the gas generators and the flow-directing ducts can be axially withdrawn together with the cage assembly to expose the turbine wheel.

9. The combination according to claim 8 including a shroud assembly forming close clearances with the tips of said turbine buckets and also supported by the cage assembly, whereby said shroud assembly is axially withdrawable along with the cage assembly to expose the turbine buckets.

10. The combination according to claim 8 wherein said arcuate mouths of the flow-directing ducts are held fixed against axial movement with respect to the cage assembly by the nozzle partitions, and wherein the inlet ends of said flow-directing ducts are supported by the cage to effect axial movement thereof relative to the gas generator outlets, whereby axial clearances between said turbine buckets and said arcuate flow-directing duct mouths are held substantially constant.

11. A multiple gas generator turbine comprising:

an overhung turbine wheel with an unsupported end and having a plurality of radially extending buckets adapted to discharge fluid into an exhaust hood,

a cage assembly coaxial with said turbine wheel and constructed for axial withdrawal from the unsupported end of the wheel,

a plurality of individually-operative gas generators supported in a cylindrical array by said cage assembly, each generator including combustion chambers and rotating compressor and turbine stages discharging hot motive fluid axially from an outlet and having spaced coaxial casings defining an annular passage therebetween open at either end for passage of cooling air,

a plurality of flow-directing ducts each shaped to receive motive fluid from one of said gas generator outlets and to discharge it from an arcuate mouth into a portion of said turbine buckets,

each of said ducts having radially extending nozzle partitions disposed within said mouth and constructed to support one end of the duct from the cage assembly,

a blower supported by said cage and drawing air in parallel flow relation through said annular passages between the gas generator casings, and

conduit means directing portions of the cooling air over portions of said flow directing ducts and against said turbine wheel, whereby the gas generators, the flow-directing ducts, and the blower and the conduit means can all be withdrawn axially with the cage assembly to expose the turbine wheel.

12. A multiple gas generator turbine powerplant comprising:

bearing means supporting a load turbine bucket wheel in overhung relation to the bearing,

foundation means disposed at the side of the load turbine wheel remote from the bearing means,

common frame means supported on said foundation means for axial sliding movement away from the load turbine wheel,

a cylindrical array of parallel individually operable hot gas generators carried by said frame means and disposed in circumferentially spaced relation about the axis of the load turbine wheel,

each hot gas generator having a first substantially cylindrical casing containing a compressor, combustion system, and turbine driving the compressor, and a second outer cylindrical casing disposed around the first casing to define an annular cooling passage,

a circumferential row of arcuate nozzle boxes carried by said common frame means and cooperating to discharge hot motive fluid into the buckets of the load turbine wheel,

a plurality of separate transition duct means, each communicating hot gas from the outlet of one of the hot gas generators to a corresponding one of said nozzle boxes,

motor-driven fan means carried by said common frame means adjacent the axis of said cylindrical array of gas generators,

walls defining passages supplying air to the inlet of said fan means from said annular cooling passages of the gas generators whereby the fan draws cooling air over each of the gas generator casings, and walls defining passages supplying air discharged from the fan for controlling the temperature of the load turbine wheel,

the common frame means being axially retractible from the load turbine wheel for exposing said wheel and nozzle boxes.

13. A gas turbine powerplant in accordance with claim 12 and including heater means for controlling the temperature of the cooling air supplied to the load turbine wheel.

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