June 3, 1941. A. LYSHOLM 2,244,467

TURBINE

Original Filed Feb. 9, 1934 2 Sheets-Sheet 1

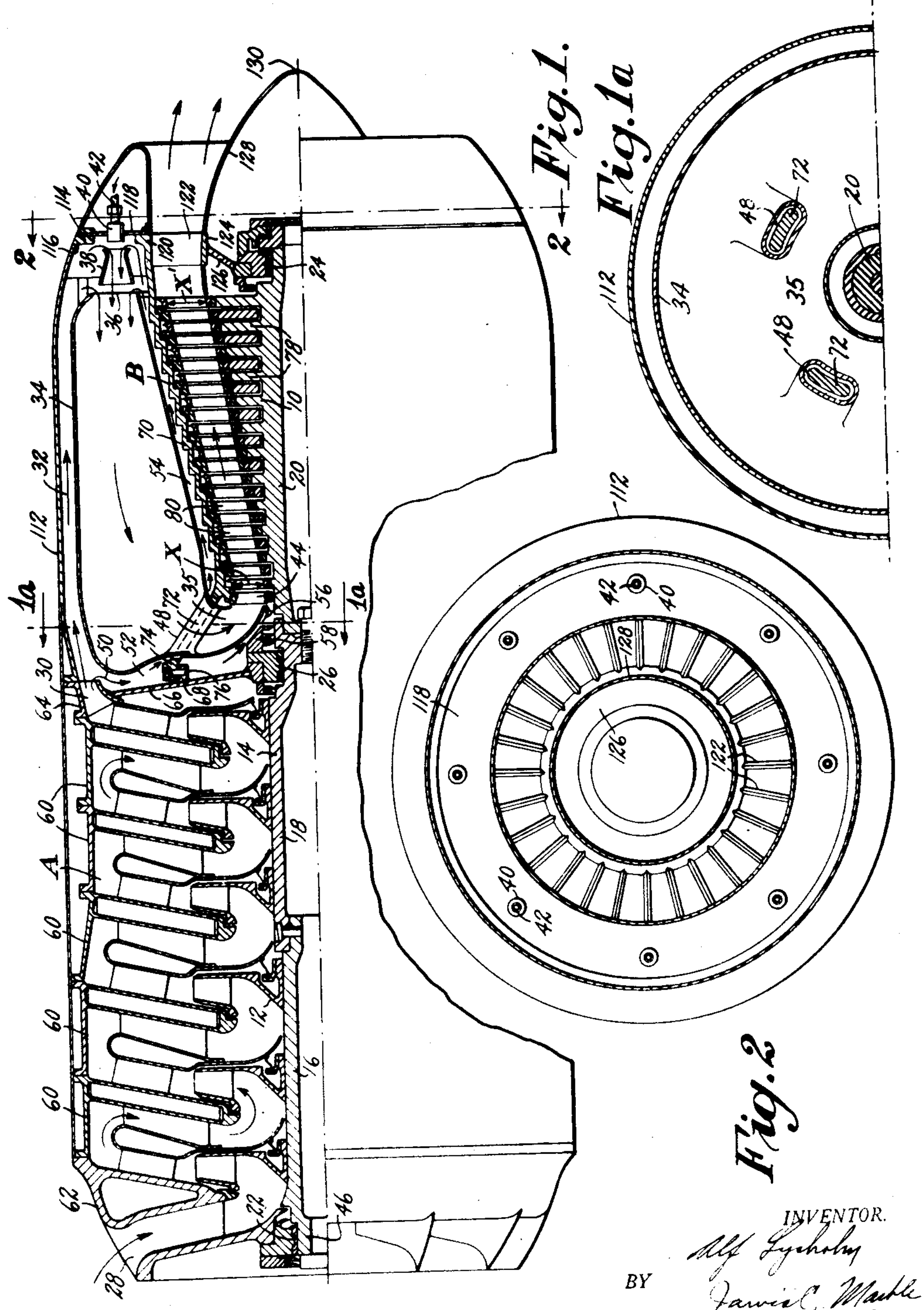

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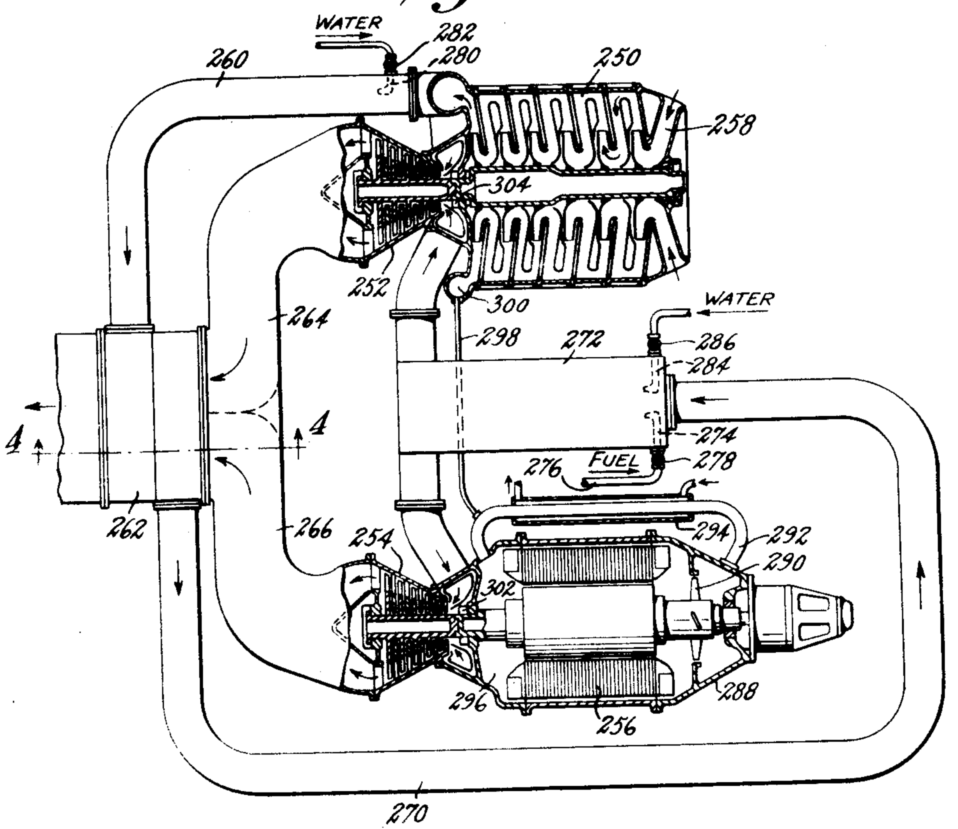
Fig. 3



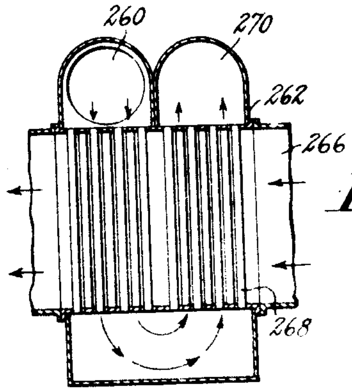


Fig. 4

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TURBINE

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Original application February 9, 1934, Serial No. 710,465, now Patent No. 2,080,425, dated May 18, 1937. Divided and this application May 4, 1937, Serial No. 140,639. In Germany February 10, 1933

13 Claims. (Cl. 60—41)

This application is a division of my copending application Serial No. 710,465, filed February 9, 1934, which has matured into Patent No. 2,080,425, granted May 18, 1937.

The present invention relates to gas turbine systems of the continuous combustion type, as distinguished from such systems of the explosion type, and has particular reference to such systems embodying axial flow turbines directly connected to compressors or generators as may be required.

In one of its phases the invention has for a general object the provision of a novel power unit for gas turbine systems in which the arrangement of turbine, compressor and combustion chamber provides certain advantages to be hereinafter more fully explained.

In another of its aspects the invention has for a general object the provision of a novel arrangement of turbine, compressor and power producing parts in a system of the kind under consideration, which among other advantages, provides capacity for readily carrying overloads with simple and relatively inexpensive equipment.

The detailed nature of the above noted general objects and of further and more detailed objects of the invention, together with the manner in which the several objects are attained, will appear more clearly in the ensuing description of the apparatus illustrated in the accompanying drawings forming a part of this specification, in which:

Fig. 1 is a longitudinal sectional view of a power unit embodying the invention.

Fig. 1a is a section taken on the line 1a—1a of Fig. 1.

Fig. 2 is a section taken on the line 2—2 of Fig. 1.

Fig. 3 is a more or less diagrammatic view of a gas turbine system embodying the invention; and

Fig. 4 is a section taken on the line 4—4 of Fig. 3.

Turning now to Fig. 1, the power unit illustrated comprises a compressor designated generally at A and an axial flow turbine designated generally at B. The turbine rotor, indicated generally at 10, and the compressor rotor, designated generally at 12, are mounted on a common shaft designated generally at 14. Shaft 14, in the illustrated embodiment, is built up on a plurality of hollow sections 16, 18 and 20, and is supported at its ends in the journal bearings 22 and 24. An intermediate shaft bearing 26 is also provided.

The compressor A draws in air through a plurality of inlet openings, one of which is shown at 28, and discharges the compressed air through the annular discharge passage 30. The compressed air flows in the direction of the arrow 32 past the outside of a combustion chamber 34 and enters the chamber from the rear through a plurality of inlet openings 36 distributed around the perimeter of the rear end of the chamber. Air also flows through a plurality of air inlet cones 38, each discharging through an opening 36, and in the current of air passing through each of these cones, which may be considered as primary air, fuel, for example, crude oil, is injected by means of nozzles 40. Ignition of the fuel is effected in known manner, and through suitable regulating apparatus, which also may be of known form and which need not be described herein, the quantity of fuel passed to the nozzles 40 through the fuel supply pipes 42, is suitably regulated so that the air is heated to the temperature desired for the motive fluid for the turbine. Motive fluid is discharged from the combustion chamber 34 through the annular discharge passage, which is advantageously provided with stationary guide vanes 44 for guiding the motive fluid into the first row of moving turbine blades. The motive fluid, before it enters the turbine proper, is not passed through nozzles which serve to increase the velocity and reduce the temperature, and because of the resulting high temperature of the motive fluid entering the first row of moving turbine blades, this row and the adjacent rows at the inlet end of the turbine are subjected to very high temperatures, and accordingly the diameter of the first row of blades, and the adjacent rows, is kept as small as possible. In a turbine of the kind illustrated, this diameter may be, for example, 200 mm.

The turbine of the kind illustrated in Fig. 1 may be employed either to extract all the useful energy possible from the motive fluid and convert it into mechanical energy, in which case power over and above that required to operate the compressor will be obtained, which power may be conveniently taken off from a shaft attached to the forward end 46 of the shaft 14, or less than the total available energy of the motive fluid may be converted into mechanical energy in the turbine and the resulting exhaust gases of high velocity as discharged from the turbine may be employed to produce propulsion by reactive or rocket effect. In the embodiment illustrated, the latter form of turbine is shown, the blade length x' at the exhaust end of the turbine being little, if any, longer than the blade length x, at the inlet end of the turbine. As a consequence, the ratio of the blade lengths to the mean diameters of the rows of blades decreases from the inlet to the outlet end of the turbine rather than remaining substantially constant, as is the case where it is desired to convert the maximum available energy in the motive fluid to mechanical work. In the illustrated embodiment, the combustion chamber **34** is in the form of a hollow annular shell which surrounds the turbine casing. At the end of the combustion chamber adjacent to the compressor a number of angularly disposed conduits **48** are provided, which permit air flowing in the direction of the arrow **50** to the space **52** to pass to the space **54** between the turbine casing and the inner wall of the combustion chamber **34**. A part of the air which flows to space **52** passes along the path indicated by the arrow **56** and enters the turbine blading in the form of a thin annular stream between the stream of hot gas from the outet of the chamber **35** and the turbine shaft. This thin stream of relatively cool air serves to protect the intermediate shaft bearing **26** and packing **58** from heat radiated from the combustion chamber.

The compressor casing is preferably built up of a number of similar sections **60** suitably bolted or welded together, the forward end of the casing being provided by an end section **62** and the rearward end of the casing being provided by an end section **64**. Section **62** provides the air inlet openings **28** and also serves to support the front end bearing **22**. A conical plate **66** secured to section **64**, preferably by welding, serves to support the intermediate shaft bearing **26**. Plate **66** carries a circular flange **68** which serves to support the forward end of the turbine casing in a manner to be described.

It will be noted that the high pressure end of the compressor is immediately adjacent to the plate **66** so that the space to the left of this plate as well as the space to the right thereof is under the pressure of the compressed air. This, combined with the stream of cool air flowing as indicated at **56**, not only protects the bearing **26** but also acts to prevent leakage of hot motive fluid past the packing **58** and the bearing **26**, without requiring elaborate and expensive packing means at this point.

The turbine casing **70** terminates at its forward end in a flaring portion seen at **72** terminating in an annular flange **74**. Flange **74** is connected to the flange **68** by means of a plurality of radially extending pins or bolts **76** which permit relative movement between the two flanges in radial direction to compensate for expansion and contraction of the parts at different rates. The flaring part **72** of the turbine casing is provided with a number of openings through which the main part of the combustion chamber **34** is connected with the outlet part **35** which forms in effect an admission chamber for the turbine. The spaces between these openings provide for the conduits **48** through which air flows to the spaces **54**.

The turbine rotor consists of the hollow shaft part **20** which in the present embodiment has integral therewith the discs **78** carrying the rows of moving turbine blades **80**. The blades **80** may be secured to the discs **78** by one of a number of different forms of mechanical conection such, for example, as dove-tail and bolt connections, but such connections, regardless of their specific forms, are further advantageously secured by welding.

An outer shell **112** is secured to the compressor casing part **64**, and to the rearward end of this shell is secured a flange **114** which may be advantageously welded as at **116**. An annular plate **118** is secured to the flange **114** in any suitable manner, and the exhaust end **120** of the turbine casing **70** is secured to this plate. Extending radially inwardly from the part **120** of the turbine casing is a plurality of ribs **122** which are preferably stream-lined in cross section and the inner ends of these ribs are joined by a ring part **124**. A conical plate **126** is secured to ring **124** and serves to carry the turbine shaft bearing **24**. The bearing **24** and the turbine parts associated therewith are protected against hot exhaust gases by means of a shield **128** of generally conical form, which extends from the outlet of the turbine blade system to a rounded point indicated at **130** at the rearward end of the apparatus.

In accordance with one aspect of the invention, the plate **118** is made relatively thin and flexible in order to compensate for relative axial expansion between the turbine casing **70** and the outer shell **112**. The arrangement whereby the rear shaft bearing **24** is carried by the exhaust end of the casing and the arrangement of the bearing within the annular exhaust passage insures minimum relative axial movement between the bearing and the shaft under the influence of expansion and contraction, and the nature of the bearing permits the shaft to expand freely when heated.

The general organization of the major component elements shown in Fig. 1 provides numerous advantages, particularly for a unit intended for the propulsion of aircraft or other vehicles. As will be observed from the figure, all of the major units required to produce power for propulsion purposes, whether such power be in the form of high velocity exhaust gases or of a propeller attached to the turbine shaft may be housed within an outer casing providing a substantially cylindrical nacelle of compact form and having minimum wind resistance.

By mounting the compressor immediately adjacent to the turbine, and discharging the air into the turbine end of the outer casing, the minimum in the way of flow resistance to the air is attained. The conical form of the turbine, with the inlet end thereof adjacent to the compressor, provides a space in which the necessary combustion chamber may be most advantageously situated. The arrangement of the combustion chamber with the surrounding air space within the outer casing enables the parts to be closely and compactly arranged while at the same time avoiding difficulties owing to the high temperature of the combustion chamber walls. The heat radiated from these walls is carried away by the enveloping air stream which enters the blade system of the turbine. This enveloping air stream not only prevents heating certain parts of the assembly to undesirable temperatures, but also accomplishes this without involving material heat losses, because of the fact that the heat imparted to the enveloping air is returned to the stream of motive fluid passing through the blade system of the turbine. The enveloping air stream also acts as an insulating medium to diminish radiation losses to the atmosphere surrounding the unit and such losses can be maintained at a relatively low figure without the necessity for heavy external insulation. This contributes to lightness of the unit, and the desirable characteristic of lightness is further aided by the arrangement of the component parts which eliminates the necessity for separate conduits of substantial length with their attendant weight, while at the same time providing for a sufficiently long path of flow for the air and motive fluid to insure the admission to the turbine of gaseous motive fluid having adequately homogeneous temperature characteristics at the inlet of the turbine.

In Figs. 3 and 4 a gas turbine system is shown, in which the system is employed to produce useful power in the form of electrical energy. In this arrangement a compressor 250 is shown as connected to an axial flow turbine 252 in the manner previously described in connection with Figs. 1 and 2, and a second similar turbine 254 is connected to the casing of an electric generator 256. Air entering the compressor 250 through the inlet 258 is delivered through conduit 260 to a regenerator 262, where it is heated by gases exhausted from turbines 252 and 254 through exhaust conduits 264 and 266. As shown in Fig. 4, regenerator 262 is a heat exchange device of the surface type comprising a plurality of tubes 268 around which the hot gases flow, and through which air delivered from conduit 260 flows to the conduit 270. Conduit 270 connects the regenerator with the inlet of a heater 272, where the air is heated by internal combustion of fuel admitted through nozzle 274 from the fuel supply pipe 276. A control valve 278, which may be controlled in any suitable manner, provides for the injection of an amount of fuel suitable to produce motive fluid at the desired temperature. Between the compressor 250 and the regenerator 262 the air, heated by compression, is cooled by the injection of a suitable cooling fluid so that the temperature of the air entering the regenerator is relatively low, and as a consequence substantial heat recovery may be obtained from exhaust gases which have been expanded in the turbines to a relatively low temperature. In the illustrated embodiment water is injected into the conduit 260 through a nozzle 280, the amount of water injected being under the control of a valve 282. Regulation of the amount of water supplied to cool the air to the desired temperature may be effected in any suitable manner. In order to increase the volume of motive fluid produced in the heater 272, to take care of over-loads on the system, water is injected through nozzle 284 under the control of valve 286. The water injected into the combustion chamber of the heater is converted into steam, and the volume and the energy of the motive fluid is increased, although this increase is obtained at some sacrifice in thermal efficiency, since the heat of vaporization of the water is lost in the exhaust. Consequently, the injection of water into the combustion chamber is advantageously employed to take care of over-loads when plant capacity is of greater importance than thermal efficiency. The introduction of water into the air before the air passes through the regenerator also produces steam, and some thermal loss is caused by the production of this steam, but this loss is more than compensated for by the increased heat recovery obtainable by admitting the air to the regenerator at relatively low temperature.

The casing 288 of the electric generator 256 provides a closure for this part of the apparatus, and on the rotor shaft of the regenerator is provided a fan 290 for circulating air around the parts within the casing. The two ends of the casing are connected by means of a conduit 292, part of which is surrounded by the cooling jacket 294, through which suitable cooling fluid may be circulated. The space 296 within the generator casing is maintained under pressure by means of a connection 298 leading from the outlet chamber 300 of the compressor. Circulation of compressed air through the generator is highly advantageous since the cooling effect of the air passing through the generator parts is much greater than when the air is at normal pressure. Also, the maintenance of air within the generator casing at high pressure is of particular advantage in an arrangement of the kind shown, since the substantial equalization of pressures on the two sides of the shaft packing, indicated generally at 302, makes unnecessary the provision of expensive packing means at this point for preventing leakage of motive fluid from the inlet end of the turbine into the generator casing. Similarly, the arrangement whereby the inlet end of the compressor turbine is placed adjacent to the outlet of the compressor eliminates the necessity for an expensive shaft packing at 304 between the turbine and the compressor, in order to avoid leakage of motive fluid at the inlet end of the turbine.

The gas turbine system illustrated in Figs. 3 and 4 provides a particularly advantageous arrangement for a system which is periodically subjected to no-load operation. Under no-load operation the heat drop of the motive fluid flowing through the turbines is relatively high as compared with the heat drop when the turbines are operating under normal load, and axial flow turbines of the hereinbefore described type are particularly well adapted to withstand variations in temperature and mechanical stress in the various parts of the turbine incident to the changes in operating temperatures resulting from substantial changes in the value of the load on the system. Furthermore, the arrangements illustrated are particularly well adapted for taking care of no-load operation of the system merely by controlling the amount of fuel supplied to the system and without resorting to any change in the character of the flow of air or motive fluid through the units of the system.

What I claim is:

1. In a gas turbine system, a power unit including an axial flow turbine, an outer casing structure spaced from the turbine, means providing a combustion chamber located in the space around the turbine and spaced from the walls of said space, a compressor driven by the turbine, said compressor discharging compressed air into the space within said casing structure surrounding said combustion chamber and said combustion chamber having an inlet in communication with said space and an outlet in communication with the inlet of said turbine.

2. In a gas turbine system, a power unit comprising outer casing structure, partitioning means for dividing the unit into a compressor section and a turbine section, an axial flow turbine located in said turbine section, a compressor located in said compressor section, means passing through said partitioning means for transmitting drive from the turbine to the compressor, and means providing a combustion chamber located in said turbine section outside of said turbine, there being space for compressed air in said turbine section adjacent to said combustion chamber means, said compressor delivering compressed air to said space in the turbine section

and said combustion chamber having an inlet in communication with said compressed air space in the turbine section and an outlet for delivering motive fluid to the turbine.

3. In a gas turbine system, a power unit including an axial flow turbine having an inlet for motive fluid, an outer casing structure spaced from said turbine, means providing a combustion chamber disposed in the space between said turbine and said outer casing and spaced from the walls of said space, and means for supplying compressed air to the interior of said combustion chamber and to the space surrounding the combustion chamber, said combustion chamber having an outlet for delivering motive fluid to the inlet of the turbine and the space surrounding the combustion chamber being in communication with the inlet of the turbine for flow of compressed air from the last mentioned space into the turbine.

4. In a gas turbine system, an axial flow turbine comprising a rotor and a turbine casing enclosing said rotor, an outer housing spaced from and surrounding said casing and fixed axially with respect to the casing adjacent to the inlet end of the turbine, a flexible member connecting said outer housing and the outlet end of said turbine casing to permit expansion of the outer housing axially with respect to the turbine casing, and means providing a combustion chamber for producing gaseous motive fluid located in the space between said casing and said outer housing, space being provided around said combustion chamber for flow of gaseous fluid past the same and said combustion chamber having an inlet adjacent to the outlet end of the turbine for admission to said chamber of fluid supplied to the last mentioned space.

5. In a gas turbine system, a multiple stage axial flow gas turbine comprising a rotor and a casing surrounding said rotor, said casing being of generally conical form and being open at the inlet end to provide for full admission of motive fluid to the blade system of the turbine, means providing an annular combustion chamber surrounding said casing and spaced therefrom, said combustion chamber having an inlet for a compressed gaseous medium to be utilized in producing motive fluid for the turbine and an outlet delivering motive fluid through the open inlet end of said casing, the inlet of the combustion chamber being located adjacent to the outlet end of the turbine, an outer housing surrounding said combustion chamber and spaced therefrom, means connecting the outlet end of said turbine casing with said outer housing, a nozzle for supplying fuel to said combustion chamber through said inlet, said nozzle being carried by said connecting means, and a channel for admitting said compressed gaseous medium to the space around said combustion chamber adjacent to the inlet end of the turbine.

6. A gas turbine unit comprising an axial flow turbine having a shaft and a casing, said casing being generally conical and being of relatively small diameter at the inlet of the turbine, a device located on the inlet side of the turbine and having a rotor driven from said shaft and a casing, and means including a part extending axially beyond the turbine inlet and flaring outwardly therefrom for connecting said casings and an axially rigid and radially movable connection between said part and one of said casings.

7. A gas turbine unit comprising an axial flow turbine having a shaft and a casing, said casing being generally conical and being of relatively small diameter at the inlet of the turbine, a device located on the inlet side of the turbine and having a rotor driven from said shaft and a casing, and means including a part extending axially beyond the turbine inlet and flaring outwardly therefrom for connecting said casings and a plurality of radially extending pins for securing said part to one of said casings to permit relative radial expansion of the two members engaged by said pins.

8. A gas turbine unit comprising an axial flow turbine having a shaft and a casing, said casing being generally conical and being of relatively small diameter at the inlet of the turbine, a device located on the inlet side of the turbine and having a rotor driven from said shaft and a casing, and means including a part extending axially beyond the turbine inlet and flaring outwardly therefrom for connecting said casings and an axially rigid and radially movable connection between said part and the casing of said device.

9. A gas turbine unit comprising a generally conical casing part increasing in diameter from the inlet to the outlet end of the turbine and a flaring part rigid with the first mentioned part and extending axially beyond said inlet, a turbine shaft extending through said flaring part, a device having stationary casing structure and a rotor driven from said shaft, and means providing an axially rigid and radially movable connection between said flaring part and said stationary casing structure.

10. A unit for gas turbine systems comprising an axial flow gas turbine having a casing providing an inlet and an annular apertured flaring part extending axially from said inlet, a turbine shaft projecting axially through said part, a compressor having stationary casing structure and a rotor driven by said shaft, said annular part being secured to said casing structure to connect the turbine and the compressor together as a unit, and means for conducting motive fluid having air from said compressor as a constituent thereof through the apertures in said flaring part to the turbine inlet.

11. A gas turbine unit, comprising a shaft, an axial flow turbine having a rotor on said shaft and a device adapted to be driven by said turbine having a rotor connected to said shaft, said device having an end wall extending inwardly to adjacent the shafts between said rotors, said turbine having a conical casing and said casing having an inlet for motive fluid adjacent to said end wall, an annular part extending axially beyond said inlet for connecting the turbine casing to said end wall, and means providing an annular admission chamber for hot gaseous motive fluid in the space between said end wall and said inlet, said chamber having an outlet in communication with the turbine inlet and being spaced from said end wall and said annular part for flow of a relatively cool gaseous medium around said admission chamber.

12. A gas turbine unit comprising a shaft, an axial flow turbine having a rotor on said shaft and a device adapted to be driven by said turbine having a rotor connected to said shaft, said device having an end wall extending inwardly to adjacent the shaft between said rotors, said turbine having a conical casing and said casing having an inlet for motive fluid adjacent to but spaced from said end wall, an annular part extending axially beyond said inlet for connecting the tur-

bine casing to said end wall, means providing an annular admission chamber for motive fluid in the space between said end wall and said inlet, said chamber having an outlet in communication with the turbine inlet and being spaced from said end wall and said annular part for flow of a relatively cool gaseous medium around said admission chamber, an outer housing surrounding and spaced from the turbine casing, means providing an annular combustion chamber in the space between the turbine casing and the outer housing, said annular part having an opening therein, and means providing a connection passing through said opening for flow of motive fluid from the combustion chamber to the admission chamber.

13. A turbine compressor unit for gas turbine systems comprising a shaft, an axial flow turbine having a rotor on said shaft, a compressor having a rotor connected to said shaft, said compressor comprising a casing having an end wall extending inwardly between said rotors, a bearing for the shaft carried by said end wall, said turbine comprising a conical casing having an inlet end of relatively small diameter adjacent to the compressor but spaced axially from said end wall, a perforated annular part for connecting the turbine and compressor casings, an outer housing connected to the compressor casing and extending around the turbine casing and spaced therefrom, flexible means for connecting said outer housing with the outlet end of the turbine casing, means providing an admission chamber for motive fluid in the space between said end wall and said annular part, means providing a combustion chamber in the space between said outer housing and the turbine casing, said combustion chamber having an inlet adjacent to the outlet end of the turbine and having an outlet communicating with said admission chamber, the walls of said chambers being spaced from adjacent parts and the spaces around said chambers communicating with the outlet of the compressor.

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