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APPARATUS FOR TURBINE TEMPERATURE ANALYSIS

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Fig. 1.

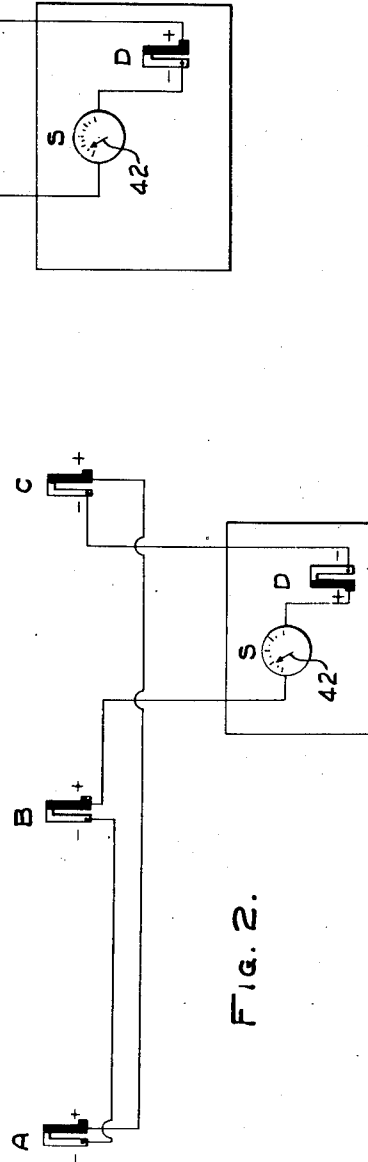
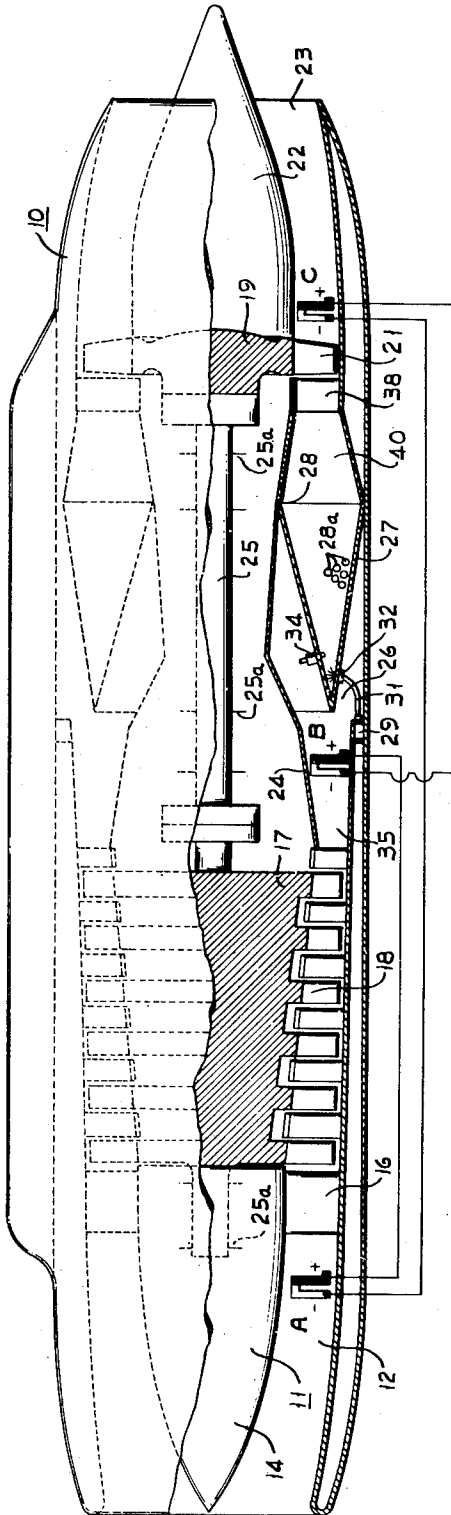


Fig. 2.

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APPARATUS FOR TURBINE TEMPERATURE ANALYSIS

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2 Claims. (Cl. 73-341)

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This invention relates to power plants, more particularly to those of the gas turbine type, and has for an object to provide improved means for determining the temperature of the gases entering the turbine.

The present invention, while not limited thereto, is particularly adapted to be used with a gas turbine power plant like that disclosed in the copending application of Stewart Way, Serial No. 482,533, filed April 10, 1943, resulting in Patent No. 2,405,723, and assigned to the assignee of the present invention. A power plant of the type disclosed in the mentioned Way application includes an air compressor, an air heating apparatus, a turbine, and a propulsion jet nozzle all housed with a streamlined tubular casing. A plant of this character is particularly suitable for propelling aircraft at high speeds and operates generally as follows: Air enters the forward end of the tubular casing and is compressed in the compressor, the compressed air is then heated in the heating apparatus by combustion of fuel supported by the compressed air. The resulting motive fluid comprising the products of combustion and the excess compressed air drives the turbine and is then discharged through the propulsion nozzle as a jet, the reaction of which serves to propel the aircraft. The turbine extracts at least sufficient power from the motive fluid to drive the compressor and auxiliaries. The fuel is supplied to the air heating apparatus, under the control of a throttle valve, by means of a positive displacement pump which is preferably driven by the turbine.

The air heating apparatus includes an annular combustion chamber, located between the compressor and the turbine, and the maximum temperature in the power plant is found at this location. To prevent heat injury to the turbine blading and to other parts of the apparatus, it is necessary that the temperature of the gases leaving the combustion chamber shall not exceed a predetermined safe value. When the gas temperature exceeds such predetermined value, it may be suitably reduced by reduction in the rate of delivery of fuel to the combustion chamber.

However, a serious problem is encountered in determining the actual temperature of the gases just prior to their entry into the turbine. This problem is primarily due to non-uniformity of temperature conditions at various points circumferentially of the annular combustion chamber.

Where a single annular burner of conical section is provided, as herein illustrated, and as

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more fully disclosed in the copending application of Way et al, Serial No. 511,468, filed November 23, 1943, hot spots may occur at unpredictable locations about the annular chamber, and where the combustion apparatus comprises an annular series of separate combustion "cans" or "burners," which construction also is disclosed in said Way et al. application, some burners may operate at higher temperatures than others, with consequent uneven temperature distribution.

As a result of these conditions, the use of a temperature measuring device at any single point in the annular flow path of hot gases to the turbine is very likely to give a highly inaccurate and misleading picture of the overall temperature conditions. Nor is it feasible to take temperature readings at numerous locations about the annular flow path and attempt to average them.

The present invention provides a simple method and apparatus for accurately determining indirectly the true temperature conditions existing in the annular flow path of hot gases to the turbine.

In power plants of the type herein illustrated and more fully described in the aforementioned Way and Way et al. applications, the turbine drives the compressor and various auxiliaries, such as fuel and lubricating oil pumps and a governor. Actually, the portion of the turbine output used to drive the auxiliaries is so small relative to that used by the compressor (for example, 25 H. P. against 4620 H. P.), that the power consumption of the auxiliaries may be ignored. Assuming then that the total output of the turbine is used to drive the compressor, the temperature drop across the turbine will be equal to the temperature rise across the compressor. Hence, if the temperature of the exhaust gases is known, and the compressor inlet and outlet temperatures are known, the turbine inlet temperature can be determined simply by adding to the turbine exhaust temperature the difference between the compressor inlet and outlet temperatures. The temperatures at these through points can be accurately determined as the gases at these points are well mixed, with no stratification or "hot spots." The present invention provides a simple single thermocouple hook-up involving thermocouples disposed at the three locations where the temperatures are to be read, the thermocouples being so connected to each other and to an indicating instrument that the latter indicates the sum of the temperature at the turbine exhaust plus the differ-

ence between the compressor inlet and outlet temperatures, this sum being the temperature of the gases at the turbine inlet, (the power consumption of the auxiliaries being ignored as it amounts to less than .06 of one per cent of the total power of the turbine).

Accordingly, it is a further object of the invention to provide means for determining indirectly the turbine inlet temperature of a power plant.

Another object of the invention is to provide a novel method of determining indirectly the turbine inlet temperature of a power plant.

Yet another object of the invention is to provide an arrangement of thermocouples for determining indirectly the turbine inlet temperature of a power plant including a turbine and a compressor driven thereby.

These and other objects are effected by the invention as will be apparent from the following description and claims taken in connection with the accompanying drawings, forming a part of this application, in which:

Fig. 1 is a side elevational view of a gas turbine power plant in which the present invention is incorporated, portions of the outer casing structure being broken away to show certain details of construction; and

Fig. 2 is a diagrammatic view of an alternative hookup of the thermocouples.

The power plant shown comprises in general an outer casing structure 10, open from end to end, and having a central core structure 11 providing an annular flow passage 12, which extends fore and aft with respect to the aircraft in which it is mounted. The central core structure 11 is supported by the casing structure along its longitudinal axis and includes a hollow fairing cone 14 defining with the forward, or left end, as viewed in Fig. 1 of the casing 10, the inlet portion of the flow passage 12. The fairing cone houses a fuel pump and other auxiliary apparatus (not shown) and is supported from the casing by hollow compressor guide vanes 16. The core structure also includes a rotor 17 of an axial flow compressor 18 (the fixed blades of which are carried by the casing 10), a rotor 19 of a turbine 21 and a conical tailpiece 22 which defines, with the rear end of the casing structure, a propulsion nozzle 23. The intermediate portion of the core structure between the compressor and the turbine comprises an inner wall structure 24 which houses a shaft 25 connecting the turbine rotor 19 and compressor rotor 17, and defines with the casing 10 an annular combustion chamber 26. The shaft 25 is journaled in suitable bearings 25a carried by the outer casing.

The combustion chamber 26 is provided with a suitable burner or burners, such as disclosed in the Way et al application, for heating the air compressed by the compressor 18. In the embodiment herein illustrated, a single annular burner 27 of conical longitudinal section is disposed in the annular combustion chamber 26 with its apex upstream and its base, or open end 28; downstream. Preferably, the open end 28 completely fills the annular flow passage, extending from the inner wall 24 to the outer casing 10, so that all air from the compressor must pass through the burner. For this purpose, both the inner and outer annular walls of the burner are perforated, as at 28a. Fuel under pressure is supplied to the burner at a plurality of points from a fuel manifold 29, connected to a fuel supply (not shown), and is fed through pipes 31 to atomizing nozzles

32, spaced circumferentially about the burner near the apex thereof. Suitable means, such as spark plugs 34, are provided for igniting the air-fuel mixture.

The present invention is not concerned with the specific design of the apparatus thus far referred to, although it is preferably constructed in accordance with the disclosure of the mentioned Way and Way et al. applications.

The power plant operates substantially as follows: Air enters the casing 10 at the inlet of the flow passage 12, is compressed by the compressor, and flows into a diffuser or divergent portion 35 of the flow passage which effects a further compression of the air. The compressed air then passes through the openings provided in the walls of the burner 27. The compressed air mixes with the fuel atomized in the burner by the nozzles 32. The air and fuel mixture is ignited by the spark plugs and burns steadily thereafter. The hot gases or motive fluid comprising the products of combustion, and the excess air heated by the combustion, on leaving the burner 27 is directed by fixed guide vanes or nozzles 38 of the turbine 21 into the blade passage of the turbine rotor 19. The turbine extracts at least sufficient energy from the motive fluid to drive the compressor 18, the pump and other auxiliary apparatus that may be housed in the fairing cone 14. The spent gases leaving the turbine are discharged through the propulsion nozzle 23 at a high velocity so that the remaining energy in the motive fluid is available to propel the aircraft. The tailpiece 22 is preferably axially movable with respect to the casing structure so that the back pressure on the turbine and the jet effect produced by the nozzle may be varied.

As indicated previously, temperature conditions in the space 40 between the open end 28 of the burner 27 and the blading of the turbine 21, are unstable due to the occurrence of "hot spots," or to non-uniformity of the products of combustion of the various nozzles 32. For these reasons, it is impractical to attempt to obtain a satisfactory reading of the temperature in the space 40 by the aid of a single temperature responsive member inserted into space 40 at any particular point therein.

The present invention provides for determining the temperature in the space 40 at the inlet side of the turbine 21, which means comprises the provision of three thermocouples, A, B and C. The thermocouple A is disposed in the annular flow passage 12 adjacent the inlet side of the compressor 18, the thermocouple B is disposed in the space 35 at the discharge side of the compressor and the thermocouple C is disposed in the annular flow path at the exhaust side of the turbine 21.

As previously indicated, the turbine 21 drives the compressor 18 and also auxiliaries such as fuel and lubricating oil pumps, governor mechanism, etc. However, the auxiliaries constitute such a small portion of the total load on the turbine that their power requirements may be ignored. Actually, they generally consume less than .06 of one per cent of the total power generated by the turbine. Therefore, for the purposes of this invention, it may be considered that the compressor 18 absorbs all of the power generated by the turbine 21. Consequently, the heat loss through the turbine will be equal to the heat rise through the compressor. Knowing the temperature at the exhaust side of the turbine, as indicated by the thermocouple C, and knowing the temperature

rise through the compressor, which will equal the difference between the temperatures recorded by the thermocouples A and B the temperature at the inlet side of the turbine, in the space 40, may be determined by adding to the temperature indicated by the thermocouple C, the temperature rise through the compressor, indicated by the temperature difference between the thermocouples A and B.

Only one each of the thermocouples A, B and C is necessary in this arrangement, inasmuch as the temperature at each of these points is substantially uniform all of the way around the annular flow passage 12.

While it is possible to determine the temperature at the inlet side of the turbine by taking separate readings of the thermocouples A, B and C and performing the necessary calculations, as indicated above, it is preferred to connect the three thermocouples with an indicating instrument S, in the manner illustrated in the drawing.

Preferably, the thermocouples are constructed with their positive elements made of Chromel and their negative elements made of Alumel, although it will be obvious that other suitable and well-known materials may be used, if desired.

The thermocouples A, B and C are connected in series in a circuit so that the sum of the voltages of the thermocouples B and C is opposed by that of the thermocouple A. The circuit voltage or E. M. F., which is a function of the gas temperature at the turbine inlet, is used to operate any suitable instrument indicated at S. Preferably, the instrument, at S, includes a thermocouple, at D, arranged contiguously to the voltage-responsive means 42 and subject to ambient or atmospheric temperature conditions at the instrument, the thermocouple D being connected in circuit so that the sum of the voltages of the thermocouples B and C is opposed by the sum of the voltages of the thermocouples A and D, the voltage-responsive means 42 being operated in response to the E. M. F. or voltage of the circuit. These voltage relations may be secured by having the thermocouples connected in either of the ways shown in Figs. 1 and 2.

The instrument S may be of any well-known type and, in itself, forms no part of the present invention except in regard to the specific manner in which its thermocouple D is connected to the circuit including the three thermocouples A, B and C.

It will be apparent that the method of determining indirectly the turbine inlet temperature of the power plant, as herein disclosed, and the apparatus for performing that method, may have various uses, and such method and apparatus will be particularly useful during shop testing of a gas turbine power plant of the character de-

scribed. However, the usefulness of the herein disclosed method and apparatus is not limited to testing, but may be found desirable when used as a permanent part of the installation, either by itself or in combination with temperature control means for preventing the temperature at the inlet side of the turbine from exceeding a predetermined safe value.

While the invention has been shown in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications without departing from the spirit thereof.

What is claimed is:

1. In apparatus whose operation depends upon the temperature of gases delivered to a turbine by combustion apparatus to which air is furnished by a compressor driven by the turbine so as to use substantially the entire mechanical output of the turbine, first, second and third thermocouples exposed to gas temperatures at the compressor inlet, at the compressor outlet, and the turbine outlet, respectively, and a fourth thermocouple exposed to external atmospheric temperature; means for connecting the thermocouples in circuit so that the sum of the voltages of the second and third thermocouples is opposed by the sum of the voltages of the first and fourth thermocouples; and means operated in response to voltage of said circuit.

2. Apparatus for determining the turbine inlet temperature of a power plant including a turbine, a compressor driven by said turbine for compressing the turbine motive fluid, and combustion apparatus for heating the compressed motive fluid prior to its entry into the turbine; said temperature-determining apparatus comprising an electrical circuit including first, second and third thermocouples adapted to be disposed in the path of the turbine motive fluid at the inlet to the compressor, at the outlet of the compressor, and at the outlet of the turbine, respectively; and an electrical measuring instrument in said circuit and adapted to indicate the sum of the temperature at the turbine outlet plus the difference between the temperature at the compressor inlet and the temperature at the compressor outlet.

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