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DEVICE FOR REDUCING OR PREVENTING ICE FORMATION
ON COMPRESSORS OF GAS-TURBINE ENGINES

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3 Sheets-Sheet 1

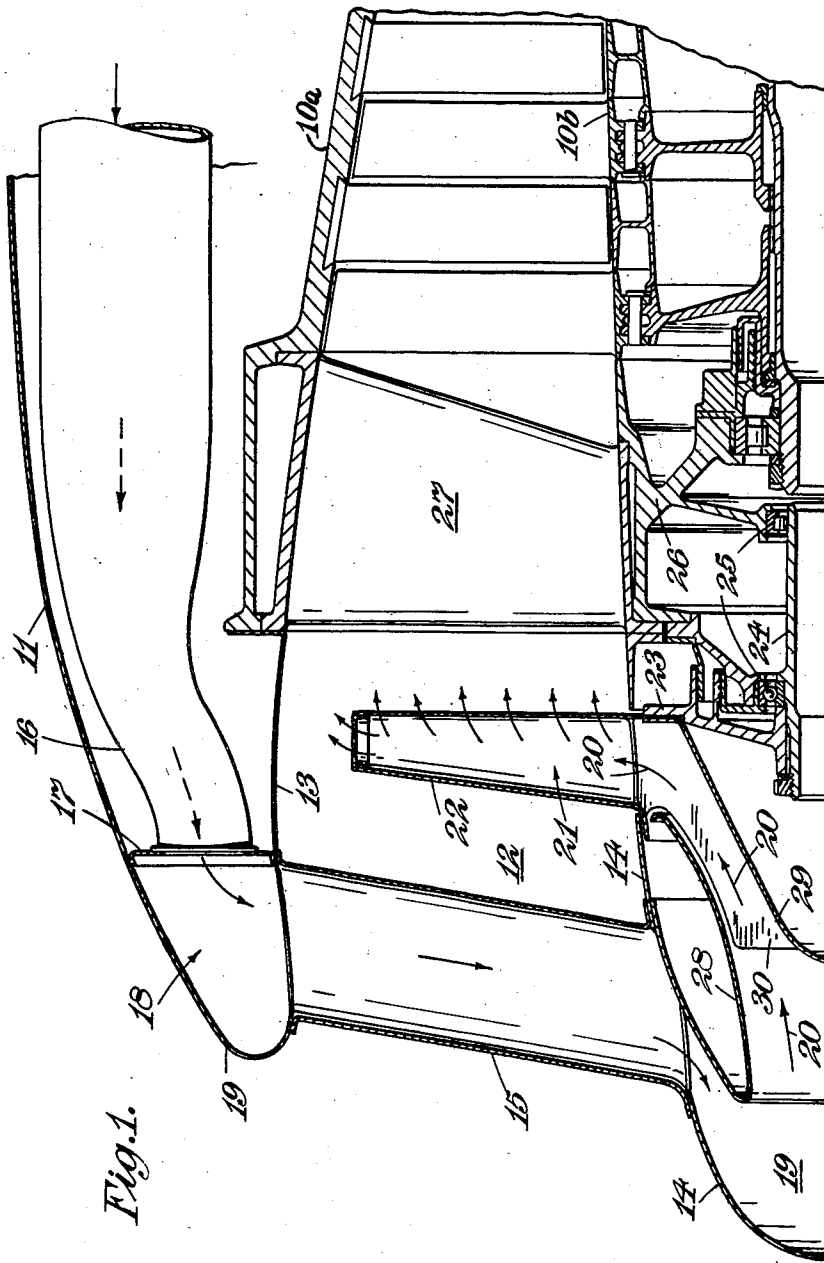


Fig. 1.

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3 Sheets-Sheet 2

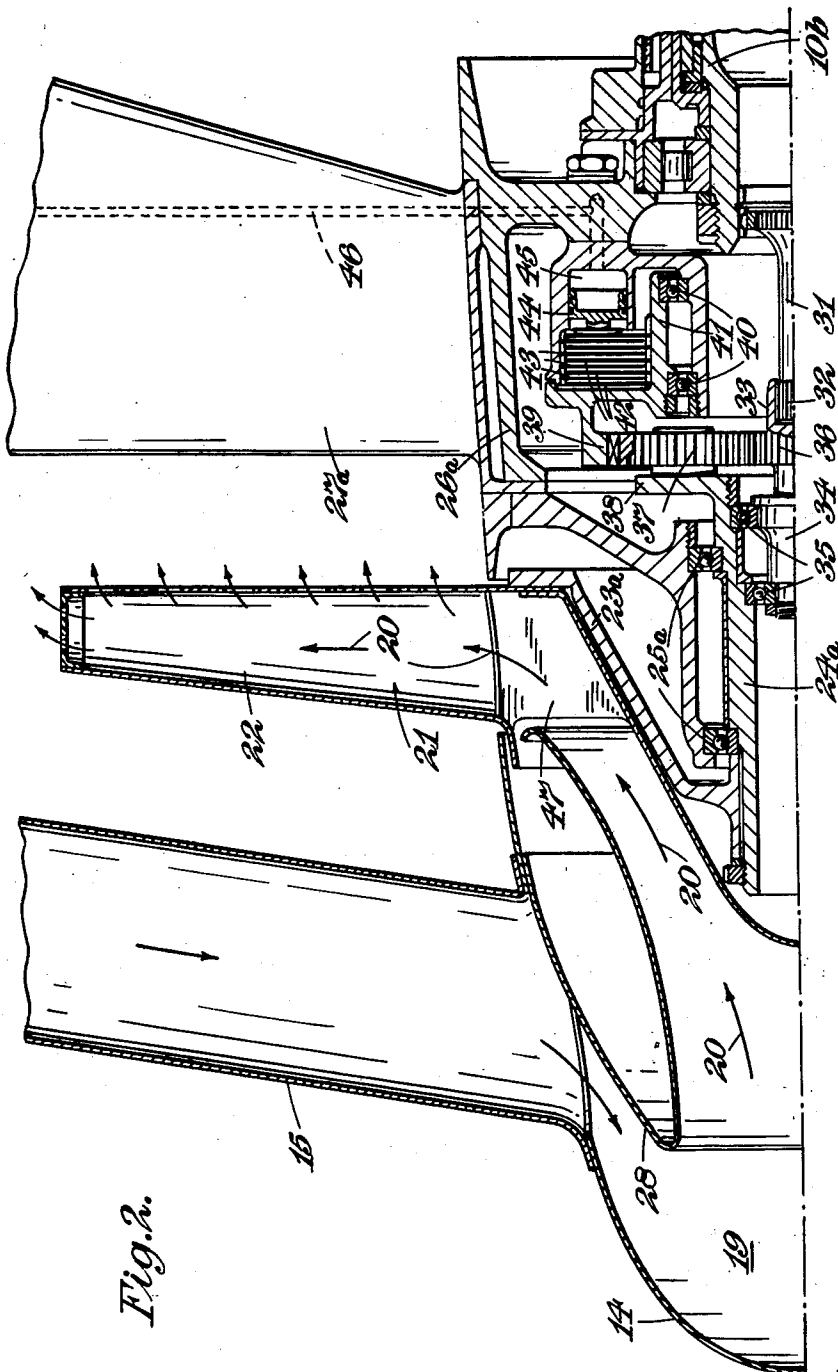


Fig. 2.

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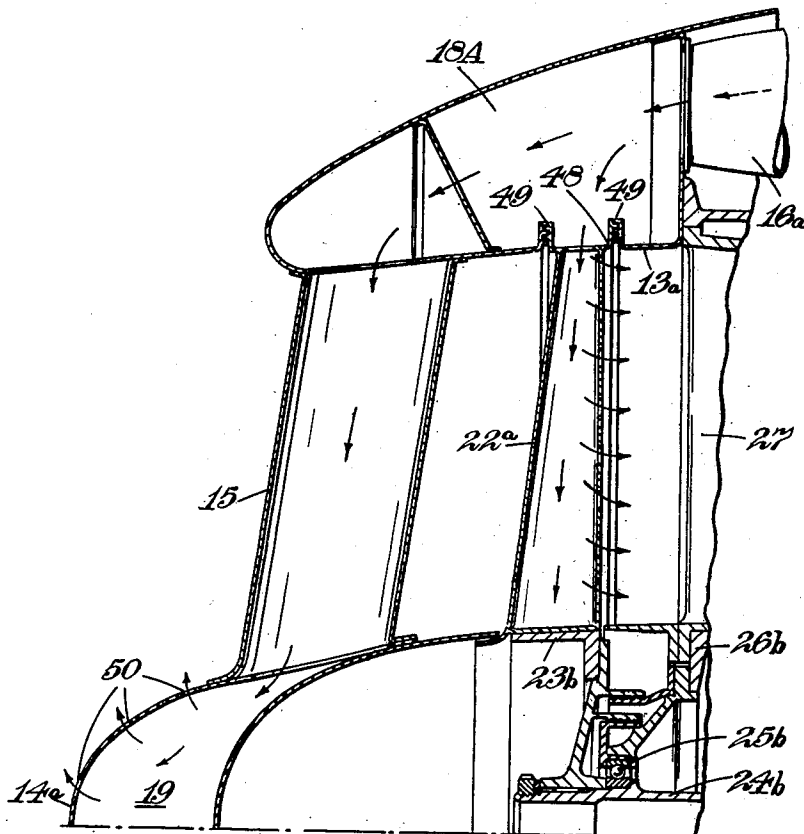
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Fig. 3.



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UNITED STATES PATENT OFFICE

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DEVICE FOR REDUCING OR PREVENTING
ICE FORMATION ON COMPRESSORS OF
GAS-TURBINE ENGINES

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15 Claims. (Cl. 230—122)

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This invention relates to gas turbine engines. The invention is concerned with an improved means for preventing the formation (or ensuring the removal) of ice on compressor parts under atmospheric conditions favourable to ice formation.

We are aware that proposals have been made to provide means for this purpose, in which hot gas is tapped off upstream or downstream of the turbine, such gas being injected to mix with, and heat the air entering the compressor; this heated air then heats the compressor parts. It is necessary to ensure that all the air is at least hot enough to heat the compressor parts to a temperature above which ice formation will not occur. The efficiency of such a system is dependent upon the intimacy of mixing of the hot gas and cold air, and the above requirements can usually only be fulfilled by using a larger quantity of hot gas than is theoretically required and/or at the expense of a large pressure drop of the air entering the compressor due to turbulence and/or an excessive length of the air-intake. It will be appreciated that the use of hot gas in the manner indicated and the pressure drop in the air-intake both reduce the overall efficiency of the engine and it is desirable to reduce both the quantity of hot gas injected and the pressure drop of the air entering the compressor to a minimum. The primary object of our invention is to provide means for injecting hot gases into the air-intake in a manner whereby an economy is obtainable in the use of hot gas and the pressure drop in the air-intake is not unduly increased.

According to the present invention there is provided in combination with a compressor of a gas-turbine engine a distributor arranged to deliver hot gas successively over substantially the whole area of the air intake to the compressor. Each part of the compressor is therefore heated in turn by the hot gas and cooled by the air, so that it remains at a mean temperature sufficiently high to prevent ice formation.

Such a distributor may be of the rotary type scanning in rotation substantially the whole cross-sectional area of the intake, and may comprise a plurality of hollow members carried on a hub rotatably mounted in the intake opening of the compressor. These pipes will be fed internally with hot gas and conveniently are provided with outlets along their length, for example each pipe may have a longitudinal slit in its wall.

In one preferred construction, the hot gases are delivered to the radially inner ends of the

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hollow members and for this purpose the hot gases are delivered to an annular chamber forming the leading edge of the outer wall of the air-intake and conveyed from this chamber through fixed ducts extending across the air-intake to a chamber formed within the inner wall of the air-intake. The hot gases pass from the second chamber into the hub portion of the distributor and thus into the hollow members.

In another preferred construction, hot gases after delivery into an annular chamber forming the leading edge of the outer wall of the air intake, enters the blades of a rotating distributor through the blade tips, the latter supporting a shroud ring rotating with the distributor and having gas seals with respect to the adjacent stationary walls of the annular chamber.

The distributor may be rotated either by the wind-milling effect on it of the air flowing through the air-intake or it may be power driven for instance by being connected through gearing to the compressor rotor.

There will now be described by way of example of this invention three arrangements for delivering hot gas into the inlet of the compressor of a gas-turbine engine. The description makes reference to the accompanying drawings in which:

Figure 1 is a diagrammatic sectional view through a portion of the inlet of an axial compressor, and

Figure 2 is a modification of the arrangement of Figure 1.

Figure 3 is a further modification of the arrangement of Figure 1, in which the hot gas is delivered into the tips of the rotating distributor.

Referring to Figure 1, the compressor comprises a stator 10a and a rotor 10b and is located within a nacelle 11 the leading portion 13 of which is shaped to form the outer wall of the annular air-inlet 12 to the compressor. The inner wall of the annular air-inlet is provided by a substantially conical fairing 14 which is supported from the outer wall 13 by means of a plurality of hollow, streamlined struts 15.

In order to reduce or to prevent the formation of ice on the parts of the compressor air inlet or on the parts of the compressor itself hot gases are supplied to the air inlet and are discharged into the airstream by means of a rotating distributor. The hot gas may be obtained from any suitable point in the gas-turbine engine of which the compressor forms a part and the hot gases are conveniently abstracted from the exhaust gases from the turbine and con-

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veyed forwardly through conduits 16 disposed within the nacelle 11 to the leading edge of the nacelle. Suitable means will be provided to enable the supply of hot gases to be controlled.

At their forward ends, the conduits 16 are arranged to deliver the hot gases through a transverse wall 17 into an annular chamber 18 formed between the wall and the nose portion of the nacelle. The leading edge of the nacelle is thus heated and ice-formation thereon will be prevented or reduced.

The hot gases then flow through the hollow struts, thus heating them, into a chamber 19 formed within the conical fairing 14 which is thus also heated to prevent or reduce ice-formation thereon.

The hot gases then flow rearwardly as indicated by arrows 20 and are delivered into the airstream by means of a rotating distributor indicated generally by reference numeral 21.

The rotary distributor 21 comprises a series of hollow blade members 22 of aerofoil section radiating from a hub member 23 which is carried by a shaft 24 mounted in bearings 25 in the front bearing housing 26 of the compressor rotor. The bearing housing is supported from the compressor stator casing 10a by inlet guide vanes 27. The hot gases leave the blades through perforations which, in this embodiment, are distributed along the trailing edges thereof.

The hot gases are guided into the inlet ends of the blade members by a fixed fairing 28 carried by conical fairing 14 and a dished fairing 29 carried by the hub 23. The fairings 28, 29 form between them an annular channel leading from the chamber 19 to the blades 22. Swirl vanes 30 may be provided on the fairing 29 to give the hot gases a swirl in the direction of rotation of the distributor.

In this construction, there is no positive drive for the distributor and the windmilling effect of the air entering the compressor is relied upon to rotate it.

It will be seen that with the construction above described the hot gases are distributed uniformly over the air-inlet so that the air flowing to the compressor is uniformly heated and stratification of the hot gases and air is avoided. The hot gases warm the air and thus prevent or reduce ice formation in the entry to and on the parts of the compressor.

Referring now to Figure 2, there is illustrated an alternative construction in which the distributor 21 is positively driven from the compressor rotor 10b.

In this construction, a stub shaft 31 is secured on the end of the rotor 10b and is formed at its forward end with splines 32. The splines 32 engage within an internally splined portion 33 of a second stub shaft 34 which is mounted in bearings 35 within the shaft 24a. The stub-shaft 34 is formed with a toothed portion 36 to constitute a sun wheel which meshes with planet wheels 37 carried on a flange 38 on the end of shaft 24a. The planet wheels 37 also mesh with an annular gear 39 mounted to rotate in bearings 40 carried by the bearing housing 26a. This double stub-shaft arrangement facilitates assembly of the distributor on the front end of the compressor.

The bearings 40 engage with a sleeve-like portion 41 of the annular gear 39 and this sleeve-like portion has splined engagement with a series of clutch plates 42, the co-operating plates 43 of which are engaged with an annular flange 75

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formed in one piece with the bearing housing 26a. The plates 42, 43 are arranged to be pressed into contact by means of piston members 44 which are received in cylinders 45 formed in the bearing housing 26a. A pressure fluid is supplied to the cylinders 45 through a duct 46 formed in the guide vanes 27a.

With this arrangement, when it is desired to supply hot gases to the compressor inlet, pressure fluid is admitted to the cylinders 45 so that the clutch plates are pressed into contact and the annular gear 39 is locked to the bearing housing 26a. The shaft 24a and the distributor 21 will then be driven through the epicyclic gear, constituted by the elements 36, 37 from the rotor 10b.

As in the previous construction above described, swirl vanes 47 are provided to give the hot gases a swirl in the direction of rotation of the distributor.

In Figure 3 a modification of the arrangement in Figure 1 is illustrated, like reference numerals being used where applicable. In this arrangement the hot gases are supplied through the pipe 16a into the annular chamber 18A. These gases do not as in the case of Figure 1 enter the chamber 19 through the hollow struts, prior to distribution by the blade members 22, but enter the latter through their ends at outer radius. These ends carry a portion 48 of the inner wall 13a of the annular chamber 18A, constituting a shroud ring rotating with the distributor. This shroud ring has seals 49 relative to the adjacent wall parts to prevent undue gas leakage from the chamber 18A directly into the air inlet duct. The blades are blanked at their hub ends, and are perforated along the trailing and leading edges. A limited flow of hot gases may be permitted through the hollow struts 15 for the purpose of heating the conical fairing 14 and the bearing support of the rotary distributor, such flow may pass into the air intake flow through apertures 50.

We claim:

1. In a gas-turbine engine; a compressor having rotor and stator blading; an air intake for said compressor; a distributor mounted independently of the compressor and positioned upstream of said blading and having a hub and a plurality of hollow arms radiating from said hub and extending across said air intake, said hub being mounted for rotation co-axially with said air intake; ports from the interiors of said arms to said air intake; and means connected to the interiors of said arms to supply hot gas thereto.

2. A combination according to claim 1 wherein said means is connected to supply hot gas to the inner ends of said arms.

3. In a gas-turbine engine; an axial compressor; an annular air intake for said compressor having an inner wall and an outer wall; a first chamber formed in said outer wall; means communicating with a source of hot gas and with said chamber to supply hot gas to said chamber; a second chamber inside said inner wall; fixed ducts extending from said first chamber to said second chamber; a distributor having a hub and a plurality of hollow arms radiating from said hub and extending across said air intake, said hub being mounted for rotation coaxially with said air intake; ports from the interiors of said arms to said air intake; and inlets from said second chamber to the interiors of said arms.

4. A combination according to claim 3 where-

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in said first chamber is annular and constitutes the edge of said outer wall remote from said compressor; wherein said inner wall is constituted by a substantially conical fairing; wherein said second chamber is constituted by the space within said conical fairing; and wherein said distributor is located between said conical fairing and said compressor.

5. In a gas-turbine engine; a compressor; an air intake for said compressor; a rotatable shroud ring comprising part of the wall of said air intake; a chamber comprising said rotating shroud ring as part of its wall and located to surround said air intake; a plurality of hollow arms extending inwardly across said air intake from said shroud ring; means connected to said chamber to supply hot gas to said chamber; inlets through said shroud ring from said chamber to the interiors of said hollow arms; and ports from the interiors of said hollow arms to said air intake.

6. In a gas-turbine engine; a compressor; an air intake for said compressor; a distributor having a hub mounted for free rotation coaxially with said air intake, and having a plurality of hollow aerofoil-section arms radiating from said hub and extending across said air intake, so that said distributor is rotated by the passage of air through said air intake; ports from the interiors of said arms to said air intake; and means connected to the interiors of said arms to supply hot gas thereto.

7. In a gas-turbine engine; a compressor having a rotor; an air intake for said compressor; a bearing for said compressor rotor adjacent said air intake; a housing for said bearing; further bearings in said housing; a shaft mounted for free rotation in said further bearings and coaxial with said air intake; a distributor having a hub mounted on said shaft, and having a plurality of hollow aerofoil-section arms radiating from said hub and extending across said air intake, so that said distributor is rotated by the passage of air through said air intake; ports from the interiors of said arms to said air intake; and means connected to the interiors of said arms to supply hot gas thereto.

8. In a gas-turbine engine; a compressor; an air intake for said compressor; a distributor having a hub and a plurality of hollow arms radiating from said hub and extending across said air intake, said hub being mounted for rotation coaxially with said air intake; ports from the interiors of said arms to said air intake; means connected to the interiors of said arms to supply hot gas thereto; and a positive drive for said distributor.

9. In a gas-turbine engine; a compressor having a rotor; an air intake for said compressor; a bearing for said compressor rotor adjacent said air intake; a housing for said bearing; further bearings in said housing; a shaft mounted in said further bearings and coaxial with said air intake; gearing between said shaft and said rotor; a distributor having a hub mounted on said shaft for rotation therewith and having a plurality of hollow arms radiating from said hub and extending across said air intake; ports from the interiors of said arms to said air intake; and means connected to the interiors of said hollow arms to supply hot gas thereto.

10. In a gas-turbine engine; a compressor having a rotor; an air intake for said compressor; a bearing for said compressor rotor adjacent said air intake; a housing for said bearing; further

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bearings in said housing; a shaft mounted in said further bearings and coaxial with said air intake and with said rotor; a sun wheel driven by said rotor; planet wheels meshing with said sun wheel and carried by said shaft; a further gear member meshing with said planet wheels; means to lock said further gear member at will against rotation; a distributor having a hub mounted on said shaft for rotation therewith and having a plurality of hollow arms radiating from said hub and extending across said air intake; ports from the interiors of said arms to said air intake; and means connected to the interiors of said hollow arms to supply hot gas thereto.

11. In a gas-turbine engine; a compressor having a rotor; an air intake for said compressor; a bearing for said compressor rotor adjacent said air intake; a housing for said bearing; further bearings in said housing; a shaft mounted in said further bearings and coaxial with said air intake and with said rotor; a sun wheel driven by said rotor; planet wheels meshing with said sun wheel and carried by said shaft; an annular gear meshing with said planet wheels and supported within said housing; clutch means to lock said annular gear to said housing at will, a distributor having a hub mounted on said shaft for rotation therewith and having a plurality of hollow arms radiating from said hub and extending across said air intake; ports from the interiors of said arms to said air intake; and means connected to the interiors of said hollow arms to supply hot gas thereto.

12. In a gas-turbine engine; a compressor having a rotor; an air intake for said compressor; a bearing for said compressor rotor adjacent said air intake; a housing for said bearing; further bearings in said housing; a shaft mounted in said further bearings and coaxial with said air intake and with said rotor; a sun wheel driven by said rotor; planet wheels meshing with said sun wheel and carried by said shaft; an annular gear meshing with said planet wheels and supported within said housing; clutch plates carried by said annular gear; co-operating clutch plates carried by said housing; a fluid-operated piston device to press said clutch plates and said co-operating clutch plates into contact with one another at will; a distributor having a hub mounted on said shaft for rotation therewith and having a plurality of hollow arms radiating from said hub and extending across said air intake; ports from the interiors of said arms to said air intake; and means connected to the interiors of said hollow arms to supply hot gas thereto.

13. In a gas-turbine engine; a compressor having a rotor; an air intake for said compressor; a bearing for said compressor rotor adjacent said air intake; a housing for said bearing; further bearings in said housing; a shaft mounted in said further bearings and coaxial with said air intake and with said rotor; a first stub-shaft on said compressor rotor; a second stub-shaft mounted for rotation in said shaft and having splined engagement with said first stub-shaft; a sun wheel carried by and rotatable with said second stub-shaft; planet wheels meshing with said sun wheel and carried by said shaft; a further gear member meshing with said planet wheels and mounted for rotation relative to said housing; means to lock said further gear member at will against rotation relative to said housing; a distributor having a hub mounted

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on said shaft for rotation therewith and having a plurality of hollow arms radiating from said hub and extending across said air intake; ports from the interiors of said arms to said air intake; and means connected to the interiors of said hollow arms to supply hot gas thereto.

14. In a gas-turbine engine; a compressor, an air intake for said compressor; a distributor having a hub and a plurality of hollow arms radiating from said hub and extending across said air intake, said hub being mounted for rotation coaxially with said air intake; ports from the interiors of said arms to said air intake; a chamber communicating with said hub; means connected to the interior of said chamber to supply hot gas thereto; inlets from said chamber to the interiors of said hollow arms through said hub; and swirl vanes in said chamber and carried by said hub to give swirl to gas passing through said inlets in the direction of rotation.

15. In a gas-turbine engine, a compressor having rotor and stator blading, an air intake for said compressor, a distributor mounted independently of the compressor and positioned upstream of said blading and having a hub and

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a plurality of hollow arms radiating from said hub and extending across said air intake, said hub being mounted for rotation coaxially with said air intake, ports from interior of said arms to said air intake and means connected to the interiors of the radially outer ends of said arms to supply hot gas thereto.

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