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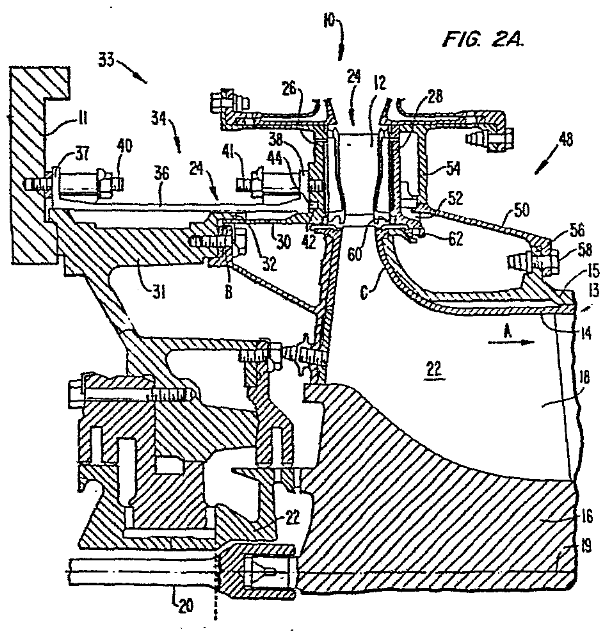
(54) **Apparatus for controlling the axial component of running clearance in radial gas turbine engines.**

(57) An apparatus for controlling the axial component of the running clearance between a radial inflow turbine and a cooperating turbine shroud. The turbine is fixed to a shaft which is rotatably supported at one end by a frame assembly (11, 31). The shaft and the turbine change in position in the axial direction relative to the shroud with changes in turbine operating temperature. The apparatus comprises a shroud mounting assembly (13), in which the shroud is attached to the mounting assembly, a turbine nozzle assembly (24), which is connected to the shroud mounting assembly, a slidable connection (29) between the turbine nozzle assembly and the frame, providing axial sliding movement, and struts (36) for controlling the axial position of the turbine nozzle assembly relative to the frame. The struts compensate for changes in the turbine axial position and control the relative axial displacement of the shroud. The struts fixedly connect the turbine nozzle assembly to the frame. The struts are positioned to be subjected to temperature changes corresponding to the turbine temperature changes and have a preselected axial length. The struts are also formed from a material having a preselected thermal expansion coefficient.

FIG. 2A.



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BACKGROUND OF THE INVENTION

The present invention relates to an apparatus for controlling the axial component of the running clearance between a radial-inflow gas turbine and a cooperating turbine shroud.

In most types of turbine machinery, turbine blades are rotated on a shaft and the radially outward edge of the blades is enveloped by a casing, referred to hereinafter as a turbine shroud. The gap between the edge of the blades and the inner surface of the shroud is known as running clearance. In general, an increase in the running clearance causes a corresponding decrease in turbine efficiency. Increases in running clearance develop primarily in response to the engine growth resulting from the thermal effects of turbine operation.

The effect of an increase in running clearance is related to turbine size and design. A small, high performance and high efficiency turbine is more sensitive to variations in running clearance than a large, low or medium performance engine. For example, in some high performance, high efficiency engines, a 1% increase in turbine running clearance can cause a 0.38% reduction in both power output and thermal efficiency.

Conventional apparatus for mounting the turbine shroud to the turbine are shown in Figure 1A. Figure 1A, discloses a shroud which is fixedly attached to a turbine nozzle assembly 3 which, in turn is attached to frame 1 by nozzle assembly extension 2. For such configurations, the axial movement of the turbine shroud directly dependent on the thermal-induced displacement of the turbine frame and nozzle assembly caused by turbine operation. Expansion vectors 1 through 5 in the turbine growth diagram of Figure 1B depict the response to turbine operation by the principal rotating and static parts of turbine machinery. The expansion vectors correspond to materials capable of

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withstanding excessive turbine temperature and commonly used in turbine construction at the noted positions. The thermal expansion-induced growth in actual running clearance of the turbine depicted in Figure 1A is about 1.2 mm when measured from about room temperature to steady state operation with a turbine inlet temperature of about 1100°C.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the problems and disadvantages of the prior art by controlling the increase in running clearance during engine operation and, in particular, by reducing the axial component of thermal expansion-induced increase in the running clearance.

It is another object of the present invention to provide a turbine shroud mounting apparatus capable of minimizing the axial displacement imparted by the turbine frame and nozzle assembly.

It is also an object of the present invention to reduce substantially the net growth in actual turbine running clearance from room temperature to steady state running temperature.

Additional objects and advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the structure and methods particularly pointed out in the appended claims.

To achieve the objects and in accordance with the purpose of the invention as embodied and broadly described herein, the apparatus for controlling the axial component of the running clearance between a radial-inflow turbine and the corresponding turbine shroud, the turbine of the type being fixed to a shaft and the shaft being rotatably supported at one end by a frame assembly, the shaft and the turbine changing in position in the axial direction relative to the frame with changes in turbine operating temperature, the apparatus comprising a shroud mounting assembly including the shroud, a turbine nozzle assembly, the nozzle assembly being connected to the shroud mounting assembly, means for slidably connecting the turbine nozzle assembly to the frame for axial sliding movement therewith, and means for adjusting the axial position of the shroud relative to the frame to compensate for changes in the turbine axial position and for controlling the relative axial displacement of the shroud, the adjusting means including axial spacer means fixedly connecting the turbine nozzle assembly to the frame, the spacer means being positioned to be subjected to temperature changes corresponding to the turbine temperature changes and having a preselected axial length and being formed from a material having a preselected thermal expansion coefficient.

The accompanying drawings, which are incorporated in and constitute part of this specification, illustrate one embodiment of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a cross-section of a partial elevational view depicting a prior art turbine blade and shroud assembly;

Figure 1B is a schematic vector diagram of the thermal expansion-induced increase in the running clearance of the apparatus in Figure 1A;

Figure 2A is cross-section of a partial elevational view depicting a turbine apparatus constructed in accordance with the present invention; and

Figure 2B is a schematic vector diagram of the thermal expansion-induced increase in the running clearance of the apparatus in Figure 2A.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made in detail to the presently preferred embodiment of the invention, an example of which is illustrated in Figure 2A.

A portion of a gas turbine generally designated 10 is shown including frame 11, turbine inlet nozzle assembly 24, and a shroud mounting assembly generally designated by the numeral 13 and which will be discussed in more detail hereinafter. Gas turbine 10 also comprises rotor hub 16 and turbine blades 18 mounted on hub 16 for rotation about turbine axis 19. A tie bolt 20 is connected to hub 16 and is enveloped by a rotor coupling 21.

As depicted, gas turbine 10 is of the radial-inflow, axial-outflow type. That is, hot combustion gases are fed through turbine inlet nozzle 12 of nozzle assembly 24 essentially in a radial direction. Thereafter, the hot gases flow into a region 22 swept by rotating blades 18 and are expanded to produce power. The expanded gases leave turbine 10 in an axial direction as indicated by an arrow designated "A". This flow of hot combustion gases creates a substantial rise in temperature throughout turbine 10 and corresponding axial and radial expansion of the components therein.

Further, turbine nozzle assembly 24 is positioned axially between frame 11 and shroud 14. The forward portion of nozzle assembly 24 is connected to frame 11. The nozzle assembly includes inlet 12, and nozzle wall members 26 and 28. Walls 26 and 28 form the outer surface of turbine nozzle assembly 24.

In accordance with the present invention, the gas turbine also includes means for slidably connecting the turbine nozzle assembly to the turbine frame to allow axial sliding movement therewith. As embodied herein, slidably connecting means 29 includes an individual cylindrically-shaped axial extension 30 at the base of the wall member 26 that is directed away from inlet nozzle 12. Slidably connecting means 29 further includes a frame support member 31 having flange 32, which is rigidly affixed to frame 11. Axial extension 30 engages flange 32 to allow continuous sliding contact therebetween at a point B, in response to changes in turbine operating temperature. In Figure 2A, axial extension 30 is shown to be positioned radially inward of flange 32 of frame support member 31 at point B. The relative positions of flange 32 and axial extension 30 may be reversed while not departing from the scope of the invention.

In accordance with the invention, the turbine further includes means for controlling the axial position of the turbine nozzle assembly relative to the frame to compensate for changes in the turbine axial position and for controlling the relative axial displacement of the shroud. As embodied herein, controlling means 33 include axial spacer means 34 fixedly connecting turbine nozzle assembly 24, and specifically nozzle wall member 26, to frame 11. Axial spacer means 34 preferably include a plurality of individual struts 36 positioned radially outward of slidably connecting means 29 and spaced discontinuously in the circumferential direction around turbine 10. As embodied herein, fourteen struts of about 16cm in length are distributed circumferentially around turbine 10. Struts 36 take the shape of a longitudinal bar having L-shaped facing edges 37 and 38 at opposite ends. Bolts 40, 41 or equivalent means, are used to connect edge 37 with frame 11, and edge 38 with wall member 26, respectively. The radial inward surface of strut 36 is supported at the forward end by frame support member 31 and at the rear end by portion of axial extension 30.

Importantly, struts 36 are continuously subjected to various temperature changes during turbine operation and should be formed from a material having an extremely low coefficient of thermal expansion relative to the coefficient correponding the other turbine components, such as shroud 14 and turbine nozzle assembly 22. Preferably, struts 36 are composed of a material having a coefficient of thermal expansion of about $5x10^{-6}{}^{\circ}C^{-1}$ or less, which is, characteristic of a material such as NILO 42.

In accordance with the present invention, the controlling means further includes means for attaching the shroud mounting assembly to the turbine nozzle assembly. As embodied herein, the attaching means includes second axial spacer means 48 positioned radially outward of shroud mounting assembly 13. Second spacer means are intended to be sensitive to temperature changes within turbine 10, and provide relative axial movement between shroud 14 and turbine nozzle assembly 24. As further embodied herein, second spacer means 48 generally consist of an axially extending cone-shaped member 50 surrounding turbine 10 having an axial length of about 10.4cm are used. Cone 50 is typically formed of a material having a low level of thermal expansion with respect to other turbine components such as shroud 14. Preferably, cone 50 has a coefficient of thermal expansion of about $8x10^{-6}{}^{\circ}C^{-1}$ or less, as can be obtained with material such as INCO 907.

As embodied herein, shroud assembly 13 includes shroud 14 in the form of a flared annular member, which is positioned adjacent turbine nozzle assembly 24 and substantially corresponds to an axially outer surface of revolution traced by blades 18. The shroud extends from a point adjacent turbine nozzle assembly 24, to a point beyond turbine blades 18 and essentially parallel to turbine axis 19. As embodied herein, shroud assembly 13 includes shroud suport member 15 having a form which substantially corresponds to the radially outer surface of shroud 14 and also having a space therebetween to provide a passage for coolant gas flow. A conduit 51 admits coolant gas which flows between shroud 14 and shroud support member 15. Shroud 14 is formed of a material having a high coefficient of thermal expansion relative to other turbine components such as struts 36 and cone 50. A material, such as IN 718, having a coefficient of thermal expansion of about $15x10^{-6}$°C, is preferably used.

Cone 50 is rigidly attached between turbine nozzle assembly 24 and a rear portion of support member 15. Mounting pad 52 with integral flow passages and a clamping ring 54 rigidly attaches the forward end of cone-shaped member 50 to turbine nozzle assembly 24. Upwardly extending flange 56 on shroud support member 15 radially distant from turbine nozzle assembly 24 is rigidly attached to the rear end of cone-shaped member 50 by bolts 58.

As further embodied herein, shroud mounting assembly 13 includes ring 60, which clamps shroud 14 to shroud support 15. Ring 60 seals the forward ends of shroud 14 and shroud support member 15 against the escape of cooling air admitted through conduit 51. Ring 60 further provided sealing contact with the radially inner edge of nozzle assembly 24 to prevent ingestion of combustion gases into the flow of coolant gas while allowing relative axial movement. Flexible seal 64 is positioned between shroud support 15 and inward base projection 62 of nozzle wall 28 and also facilitates relative axial movement of shroud mounting assembly 13.

The operation of a radial gas turbine according to the present invention will now be described in detail with reference to Figures 2A and 2B. Gases of combustion are transferred through turbine inlet 12 impinging against turbine blades 18, thus rotating hub 16 about turbine axis 19. Operation of turbine 10 results in a substantial increase in temperature within the turbine and a corresponding axial expansion of frame 11 and turbine nozzle assembly 24. The net effect is to tend to cause the turbine running clearance at point C to grow. However, the extremely low thermal expansion characteristic of struts 36 limits the axial displacement transferred to turbine nozzle assembly 24 from frame 11. In addition, cone 50, which is attached to the rear of shroud support member 15 and have a low thermal expansion coefficient, and thereby grow slightly, force shroud 14 to expand in the forward direction. Consequently, shroud 14 and support member 15 having a high coefficient of expansion, expand axially to reduce the gap at point C.

Figure 2B displays a net growth of .2mm in actual turbine clearance at point C for the depicted turbine, measured from room temperature assembly to steady state running temperature. The line of reference, characterized by the phantom line between Figures 2A and 2B is established at the only point of zero relative axial movement between the rotating and static turbine elements. The expansion vectors correspond to materials capable of in turbine construction at the noted positions. For example, the noted turbine elements may be formed from materials, such as frame support member 31 - AISI 410, nozzle wall members 26 and 28 - IN 718, and inlet nozzle 12 - X 40. In this respect, rotor coupling 21 should be formed of material other than stainless steel, such as SS 2240.

It will be apparent to those skilled in the art that various modifications and variations can be made in the apparatus for controlling turbine running clearance of the present invention. As an example, there can be different types of clamps 58 for connecting the forward end of shroud mounting assembly 13 to turbine nozzle assembly 11. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

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WHAT IS CLAIMED IS:

1. Apparatus for controlling the axial component of the running clearance between a radial-inflow turbine and a cooperating turbine shroud, the turbine of the type being fixed to a shaft and the shaft being rotatably supported at one end by a frame assembly, the shaft and the turbine changing in position in the axial direction relative to the shroud with changes in turbine operating temperature, the apparatus comprising:

a) a shroud mounting assembly, said shroud being attached to said mounting assembly;

b) a turbine nozzle assembly, the nozzle assembly being connected to said shroud mounting assembly;

c) means for slidably connecting said turbine nozzle assembly to the frame for axial sliding movement therewith; and

d) means for controlling the axial position of said turbine nozzle assembly relative to the frame to compensate for changes in the turbine axial position and for controlling the relative axial displacement of said shroud, said controlling means including axial spacer means fixedly connecting said turbine nozzle assembly to the frame, said spacer means being positioned to be subjected to temperature changes corresponding to the turbine temperature changes and having a preselected axial length and being formed from a material having a preselected thermal expansion coefficient.

2. Apparatus as recited in claim 1, wherein said turbine nozzle assembly is positioned axially between said spacer means and said shroud mounting assembly.

3. Apparatus as recited in claim 1, wherein said slidably connecting means comprises a cylindrically-shaped axial extension on said turbine nozzle assembly and a cylindrical support member rigidly affixed to said frame, said axial extension cooperatively engaging said frame support member to allow continuous sliding contact between said extension and said frame support member in response to changes in turbine operating temperature.

4. Apparatus as recited in claim 1, wherein said axial spacer means is formed of a material having an extremely low coefficient of thermal expansion relative to the coefficient of said shroud.

5. Apparatus as recited in claim 4, wherein said axial spacer means has a coefficient of thermal expansion of about $5x10^{-6}$°C or less, and said shroud bar has a coefficient of about $15.0x10^{-6}$°C.

6. Apparatus as recited in claim 4 wherein said axial spacer means comprises a plurality of individual axial-extending struts distributed around said turbine in the circumferential direction and positioned radially outward of said slidably connecting means.

7. Apparatus as recited in claim 6 including 14 of said struts each about 16cm in length.

8. Apparatus as recited in claim 7 wherein each of said struts comprises a longitudinal bar having an L-shaped facing edge at each end, said struts being fixedly connected at one end to said frame and at the opposite end to said turbine nozzle assembly.

9. Apparatus for controlling the axial component of the running clearance between a radial-inflow turbine and a cooperating turbine shroud, the turbine of the type being fixed to a shaft and the shaft being rotatably supported at one end by a frame assembly, the shaft and the turbine changing in position in the axial direction relative to the shroud with changes in turbine operating temperature, the apparatus comprising:

a) a shroud mounting assembly including said shroud;

b) a turbine nozzle assembly, the nozzle assembly being connected to said shroud mounting assembly;

c) means for slidably connecting said turbine nozzle assembly to the frame for axial sliding movement therewith; and

d) means for controlling the axial position of said turbine nozzle assembly relative to the frame to compensate for changes in the turbine axial position, and for controlling the relative axial displacement of said shroud, said controlling means including first axial spacer means fixedly connecting said turbine nozzle assembly to the frame, said first spacer means being positioned to be subjected to temperature changes corresponding to the turbine temperature changes and having a preselected axial length and being formed from a material having a preselected thermal expansion coefficient.

said controlling means further including means for attaching the shroud mounting assembly to said turbine nozzle assembly for providing relative axial movement between the shroud and said turbine nozzle assembly, said attaching means being sensitive to temperature changes corresponding to the turbine temperature changes.

10. Apparatus as in claim 9 wherein said attaching means includes second axial spacer means for attaching the shroud mounting assembly to said turbine nozzle assembly, said second spacer means being positioned radially outward of said shroud mounting assembly, said second spacer means also being positioned to be subject to temperature changes corresponding to the turbine temperature changes and having a preselected axial length and being formed from a material having a preselected thermal expansion coefficient.

11. Apparatus as recited in claim 9, wherein said shroud mounting assembly also includes a shroud support member, said shroud support member having a form substantially corresponding to the radially outer surface of said shroud, said shroud being clamped to said support member at both shroud axial ends, said shroud and said shroud support member being spaced apart between said axial ends for providing a passage for coolant gas flow, and wherein said shroud mounting assembly also includes a flexible seal providing relative axial movement at one shroud axial end.

12. Apparatus as recited in claim 9 wherein the part of said shroud mounting assembly axially proximate said turbine nozzle assembly is sealingly connected to said turbine nozzle assembly and the part of said shroud mounting assembly axially distant from said turbine nozzle assembly is rigidly connected to said attaching means, said sealing connection preventing the escape of cooling air while allowing relative axial movement between said shroud and said nozzle assembly.

13. Apparatus as recited in claim 10 wherein the part of said shroud mounting assembly axially proximate said turbine nozzle assembly is sealingly connected to said turbine nozzle assembly and the part of said shroud mounting assembly axially distant from said turbine nozzle assembly is rigidly connected to said second spacer means, said sealing connection preventing the escape of combustion gas while allowing relative axial movement between said shroud and said shroud support member.

14. Apparatus as recited in claim 15 wherein said second spacer means has a low thermal expansion coefficient relative to the coefficient of thermal expansion of said shroud.

15. Apparatus as recited in claim 16 wherein said second spacer means has a coefficient of thermal expansion of about $8x10^{-6}$°C or less.

16. Apparatus as recited in claim 13 wherein said second spacer means comprise a cone-shaped member positioned around said turbine in the circumferential direction, said cone-shaped member being connected at one end to said turbine nozzle assembly and at the other end to said shroud mounting assembly.

17. Apparatus as recited in claim 14, including cone-shaped member each of about 10.4cm in length.

FIG. 1A.

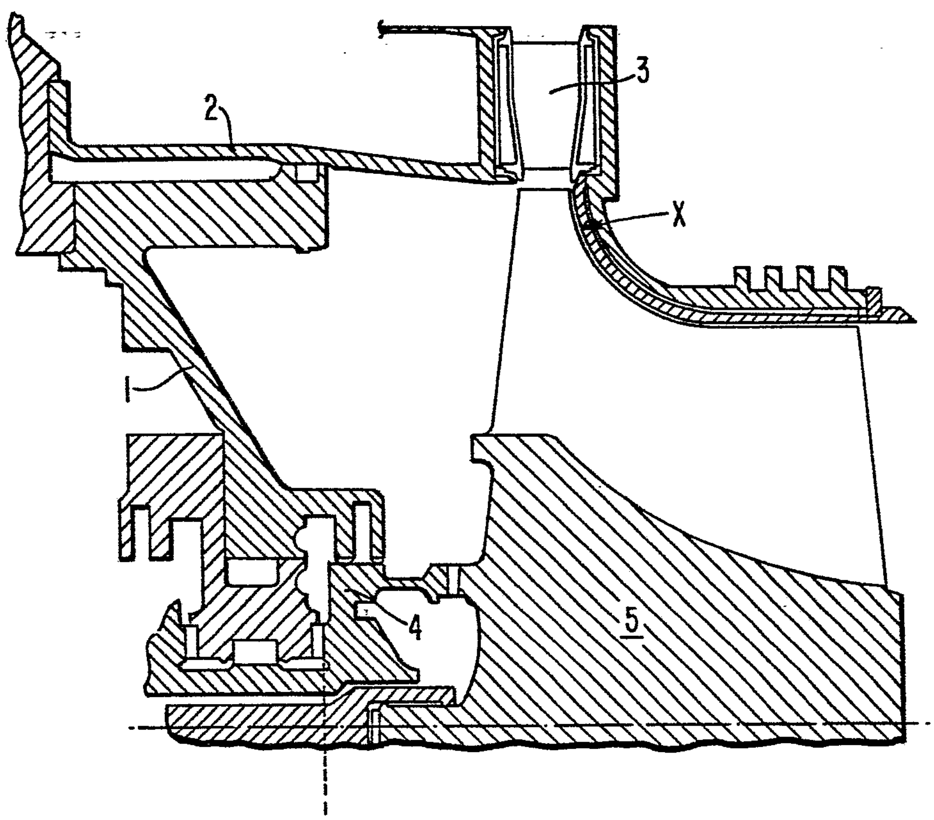
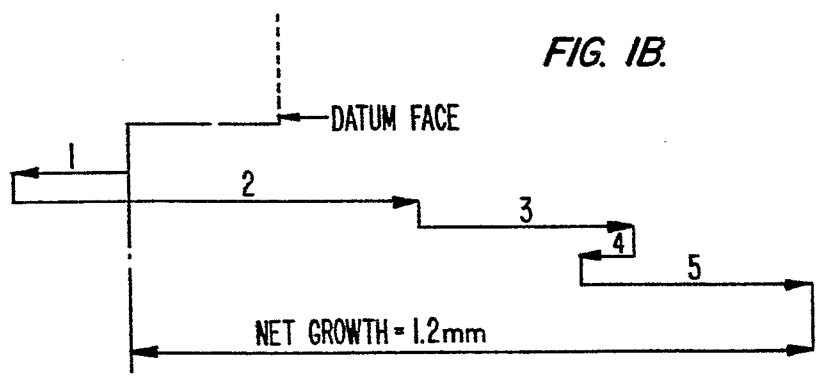


FIG. 1B.



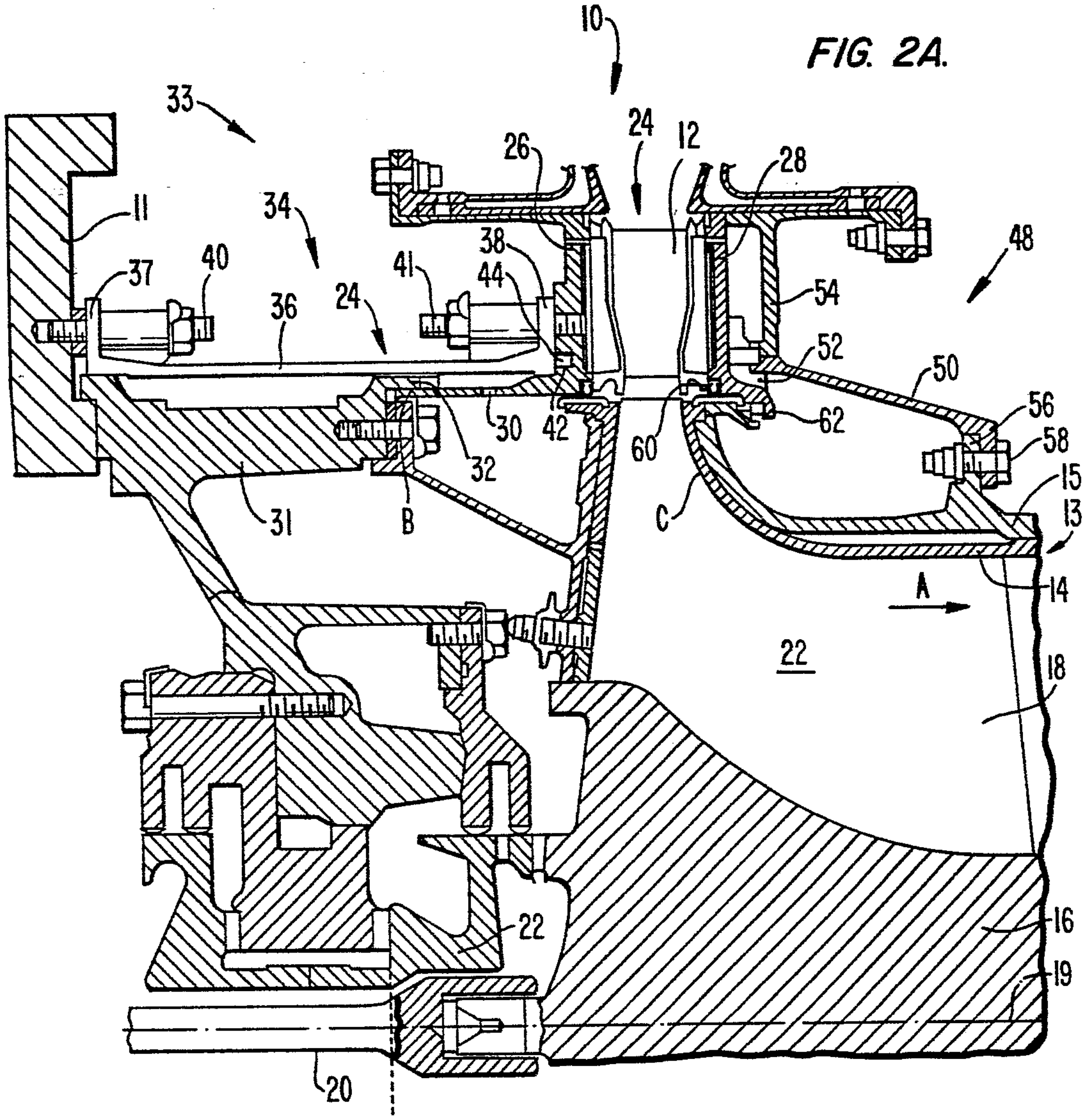

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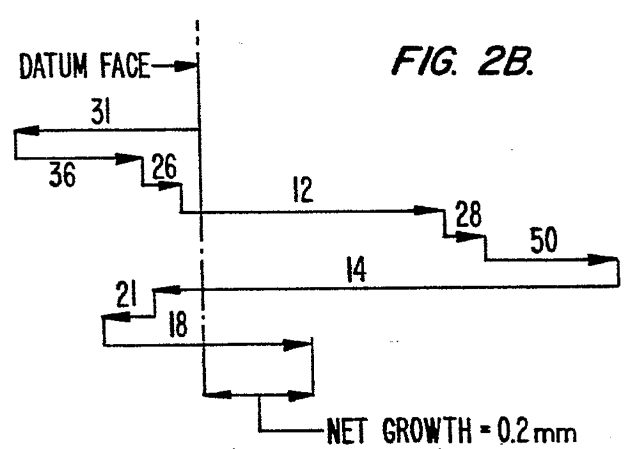
FIG. 2A.


DATUM FACE
31
36
26
12
28
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14
21
18
NET GROWTH = 0.2 mm

FIG. 2B.

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EUROPEAN SEARCH REPORT

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Application number

EP 85 10 5154

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	GB-A- 842 093 (POWER JETS) * Page 1, lines 21-38; figure * ---	1,9	F 01 D 11/00 F 01 D 25/24
A	US-A-2 383 948 (ALFORD) * Page 2, left-hand column, lines 11-46; figures 1-3 * ---	1,3,6, 8,9	
A	US-A-2 283 176 (BIRMANN) * Figures 1,5 * ---	1,2,6, 9	
A	US-A-2 429 936 (KENNEY et al.) * Column 2, line 6 - column 3, line 3; figures 1-3 * ---	1-3,6, 9	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
A	US-A-1 889 554 (KENNEDY) * Page 2, lines 11-31,47-63; figures 1-3 * ---	1,2,9, 10	F 01 D
A	DE-C-1 220 671 (ESCHER WYSS) * Column 3, lines 55-61; column 4, lines 17-32; figure 1 * ---	1,9	
A	CH-A- 268 647 (ARMSTRONG SIDDELEY) * Page 1, lines 40-49; figures 1-3 * --- -/-	8	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24-07-1985	ATTASIO R.M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

0162340
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-3 384 345 (NEATH et al.) * Figure 1 * -----		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

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THE HAGUE	24-07-1985	ATTASIO R.M.

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