

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
1 December 2005 (01.12.2005)

PCT

(10) International Publication Number
WO 2005/114013 A1

(51) International Patent Classification⁷: **F16J 15/43**,
15/40, F01D 11/04

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(21) International Application Number:
PCT/GB2005/001402

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(22) International Filing Date: 12 April 2005 (12.04.2005)

(81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,
GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,
KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA,
MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM,
PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY,
TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU,
ZA, ZM, ZW.

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0411178.7 20 May 2004 (20.05.2004) GB

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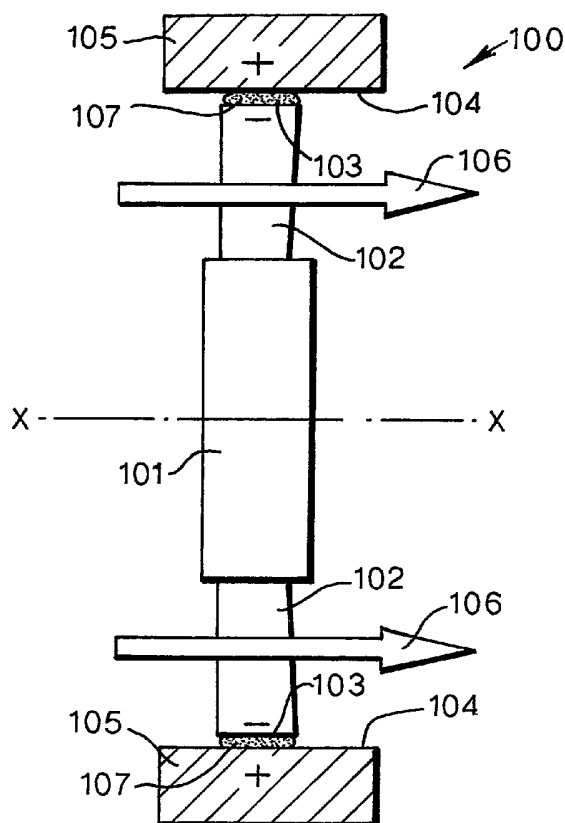
(84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),

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(54) Title: SEALING ARRANGEMENT



(57) Abstract: A seal arrangement (100) is provided in which opposed surfaces such as a blade tip (103) and an opposed surface (104) of a casing (105) have an electrical potential which sustains and retains an electrical plasma with sufficient force in the electrical field to achieve a seal barrier. The plasma (107) will be generated by appropriate ionisation at least one charge site and this plasma is then entrained by the electrical potential between the opposing surfaces (103, 104) along with any rotational flow factors. In such circumstances a high efficiency gas seal is created by the retained plasma without the necessity of elaborate labyrinth seals.



European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

— *with international search report*

SEALING ARRANGEMENT

The present invention relates to sealing arrangements and more particularly to such arrangements utilised for
5 blade tip sealing in turbine engines.

Operation of gas turbine engines is relatively well known. For example, referring to Fig. 1, an aero turbo fan engine is generally indicated at 10 and comprises, in axial flow series, an air intake 11, a propulsive fan 12, an
10 intermediate pressure compressor 13, a high pressure compressor 14, a combustor 15, a turbine arrangement comprising a high pressure turbine 16, an intermediate pressure turbine 17 and a low pressure turbine 18, and an exhaust nozzle 19.

15 The turbo fan gas turbine engine 10 operates in a conventional manner so that air entering the intake 11 is accelerated by the fan 12 which produces two air flows: a first air flow into the intermediate pressure compressor 13 and a second air flow which provides propulsive thrust. The
20 intermediate pressure compressor compresses the air flow directed into it before delivering that air to the high pressure compressor 14 where further compression takes place. Gas turbines other than turbo fans have different compression arrangements.

25 The compressed air exhausted from the high pressure compressor 14 is directed into the combustor 15 where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive, the high, intermediate and low pressure turbines 16,
30 17 and 18 before being exhausted through the nozzle 19 to provide additional propulsive thrust. The high, intermediate and low pressure turbines 16, 17 and 18 respectively drive the high and intermediate pressure compressors 14 and 13 and the fan 12 by suitable
35 interconnecting shafts.

It will be understood that flow leakage across the blade tips in either the compressor or turbine stages of an engine leads to loss of efficiency. In such circumstances it is common to incorporate relatively complex grooves and

surface structures as shrouds between the opposing blade tips and inner casing surface in order to attempt to minimise that leakage through labyrinthine sealing effects. Clearly provision of such sealing can be difficult and add
5 to assembly/manufacturing costs. The structural features may comprise a shroud overhanging the blade tips and also require a relatively narrow gap between those tips and the inner casing surface again to limit available leakage cross-sectional area.

10 In accordance with the present invention there is provided a seal arrangement comprising a rotor assembly and a stator assembly, at least one charge site arranged to ionise gas between the rotor assembly and the stator assembly to form a plasma, means to produce an electrical
15 potential between the rotor assembly and the stator assembly in order to sustain a seal barrier formed by the plasma in a gap between the rotor assembly and the stator assembly.

The at least one charge site comprises means to produce spark ionisation of the gas to produce the plasma or a laser
20 to produce laser induced breakdown of the gas to produce a plasma.

Preferably, electrical ionisation is achieved between the charge site and rotor assembly. Alternatively, ionisation is achieved between the charge site and a
25 specific electrode.

Normally, the gap is in the order of one millimetre.

Advantageously, there is more than one charge site in the arrangement.

Advantageously, a radio frequency electromagnetic
30 radiation source is coupled to the plasma and so to sustain the plasma.

Preferably the radio frequency electromagnetic source has a frequency of 300GHz.

Preferably the radio frequency electromagnetic source
35 comprises a solid state device.

Preferably the solid state device comprises a IMPATT diode.

Preferably a hollow waveguide guides the radio frequency electromagnetic radiation.

Preferably there are means to measure the speed of rotation of the rotor assembly and means to adjust the electrical potential between the rotor assembly and the stator assembly.

5 Preferably there are means to measure the clearance between the rotor assembly and the stator assembly and means to adjust the electrical potential between the rotor assembly and the stator assembly.

10 Preferably there are means to measure the pressure differential across the seal arrangement and means to adjust the electrical potential between the rotor assembly and the stator assembly.

15 Preferably the rotor assembly comprises a rotor blade assembly including a rotor disc and rotor blades, the stator assembly comprises a casing, the at least one charge site being arranged to ionise gas between tips of the rotor blades and an opposed surface of the casing in order to sustain the barrier formed by the plasma in the gap between the tips of the rotor blades and the casing.

20 Possibly, the tips of the rotor blades and/or the opposed surface of the casing are electrically isolated from associated structures.

25 Preferably portions at the tips of the rotor blades are electrically isolated from the remainder of the rotor blades by insulating layers.

Preferably a portion of the casing is electrically isolated from the remainder of the casing by insulating layer.

30 Preferably the insulating layer is a dielectric insulating layer.

Possibly, the tips of the rotor blades and/or the opposed surface of the casing are shaped to sustain the seal barrier.

Preferably the tips of the rotor blades have channels.

35 Preferably the opposed surface of the casing has a trench.

Possibly, the tips of the rotor blades and/or the opposed surfaces of the casing are made from different materials to the remainder of the associated structures.

The rotor blade assembly may comprise a fan stage, a compressor stage or a turbine stage.

The seal may be provided between the radially inner ends of stator vanes extending radially inwards and the
5 rotor.

Also, in accordance with the present invention there is provided a turbine engine including a seal arrangement as described above.

An embodiment of the present invention will now be
10 described by way of example and with reference to the accompanying drawings:-

Fig. 2 illustrating a schematic side cross-section of a seal arrangement in accordance with the present invention;

Fig. 3 illustrating a schematic front view of a seal
15 arrangement in accordance with the present invention; and

Fig. 4 provides a further illustration of the side cross-section shown in Fig. 2 providing greater detail as to plasma generation and distribution.

In accordance with the present invention, ionised gas
20 between blade tips of a rotor and its casing, arranged concentrically around the rotor and the blades, blocks gas flow over the blade tip without obstructing gas flow through the inter-blade passages. Ionisation of the gas without affecting the blade or casing material is initiated at one
25 or more locations around the rotor casing using a spark or laser-induced breakdown. Radio frequency electromagnetic energy may then be coupled into the breakdown spark to maintain the plasma. If the casing is positively charged and the rotor is electrically isolated from the casing, a
30 negative charge will be induced in the blade tips. Electrons, which are highly mobile, are attracted to the positively charged opposing surface of the casing and the remaining plasma is dragged around with the negatively charged rotating blades. The electric field between the
35 casing and blade tips prevents the plasma being swept downstream with a gas leakage and so blocks the flow over the blade tips.

By sustaining a plasma between the tips of a blade assembly and an opposed surface in a casing, it is possible

to achieve a sustained seal barrier in the gap between those blade tips and the opposed surface. In such circumstances greater blade assembly flow efficiency is achieved.

Referring to Fig. 2 providing a schematic cross-section of a sealing arrangement 100 in accordance with the present invention. The arrangement 100 comprises a rotor blade assembly 101 incorporating rotor blades 102. The rotor blade assembly 101 generally rotates about an axis X-X such that there is a gap between the tips 103 of the rotor blades 102 and an opposed surface 104 of a casing 105. The rotor blade assembly 101 essentially comprises a central rotor disc 99 from which the rotor blades 102 extend. Thus, the rotor blades 102 generate a gas flow in the direction of arrowheads 106 in a compressor stage or a fan stage of a gas turbine engine or alternatively in a turbine stage the gas flow 106, heated in the combustor, expands through the rotor blades 102 causing them to rotate. In either event, leakage in a gap left between the tips 103 and opposed surface 104 will cause inefficiencies. It will be understood a gap is required in order to take account of component and assembly tolerances as well as for structural/operational variation in rotor blade 102 and casing 105 dimensions, for example due to thermal expansion, aerodynamic loading or creep. Normally this gap will be in the order of one millimetre.

In accordance with the present invention the gap has a seal barrier formed by a sustained plasma 107. This plasma 107 is sustained as a result of establishing an electrical potential between the blade tips 103 and the opposed surface 104 along with rotation of the rotor blades 102 about the axis X-X.

The plasma 107 can be formed by a number of plasma generation processes. Although plasmas with comparable density to welding arcs are required for sealing, the intention is not to heat the surrounding metal. What is required is a uniform plasma rather than an arc running between two metal components, that is to say the blade tips and opposed surface. There are various ways of generating plasma in a gas without involving the surrounding metal.

The most common, and most efficient, way of generating plasma is to bombard neutral gas with high energy electrons. However, this method is probably not practical within a gas turbine engine. Any electron beam would have to be generated in vacuo, which would require an electron transmitting window capable of withstanding high pressures between the electron beam source and the main gas flow through the rotor blade assembly. The electron beam would be absorbed to some extent by the gas to form the ionised plasma, but the majority of its energy would be dumped on the component where the electron beam terminates. Also, electron impact generated plasmas undergo Joule heating to very high temperatures, which tends to cause transition from plasma to filamented arcs.

Other ways of generating plasma less likely to lead to arc formation are 'associative ionisation', ionisation by repeated short electrical pulses, laser induced breakdown, and photo-ionisation.

Associative ionisation involves 'pumping' a molecular species to a high vibrational state. When two excited molecules collide and their total energy exceeds the ionisation potential then ions can be formed as a plasma. Vibrational excitation of CO has been demonstrated using a CO laser, but it should be possible to excite nitrogen to the required levels using a microwave discharge.

Repeated spark ionisation uses nanosecond electrical excitation pulses. This is much more efficient and causes less bulk heating of the gas than a DC or low frequency AC discharge. Pulses with peak voltages 1-10 KV at repetition rates -1MHz have been used to ionise atmospheric air.

Laser induced breakdown involves tightly focusing a pulsed laser (~10 ns) to generate a plasma. This method has the additional complication that a laser is involved, but a highly localised plasma can be generated which has great benefits for creating a blade tip seal arrangement.

Photo-ionisation uses high energy UV photons to detach electrons from molecules. These photons are at vacuum UV wavelengths and do not penetrate far in air. However, it

may be possible to generate photons close to the region where ionisation is required.

Once a localised plasma 'spark' has been generated high (radio) frequency electromagnetic radiation can be coupled to it to increase the volume and electron density. The blade/casing gap may form a resonant cavity. Frequencies ~300 GHz match the dimensions. These high frequencies can be generated by solid state devices, e.g. IMPATT diodes and can be guided in hollow waveguides.

Irrespective of the manner in which the plasma is generated, as indicated previously, the electrons are relatively fast moving and so will pass between a charge site and either the tips 103 of the rotor blades 102 or a particular electrode provided to create the ionisation between the plasma and electrodes. Essentially, the electrons are more mobile than the ions within the plasma such that the ions have a longer life and so, dependent on temperature and pressure, the plasma may be sustained throughout the rotational circumference of the rotor blade assembly 101. The plasma is entrained by a retained electrical potential between the blade tips 103 and opposed surface 104 in order to create the seal barrier as described previously. The plasma is retained and lingers between the blade tips 103 and opposing surface 104 as a result of that electrical field created between the surface 104 and the tips 103. Clearly, the stronger the electrical field the stronger the retention of the plasma in the gap between the surface 104 and the blade tips 103 and therefore strength of seal created.

Possibly, a single source of electrical plasma is provided such that the plasma is sustained and entrained throughout the circumference of rotation of the rotor blade assembly 101 in order to create the desired seal. However, as indicated, although ions are less mobile than electrons, it will be appreciated that they still have a definite life dependent upon temperature and pressure and so it may be necessary to refresh the plasma created by each charge site by providing a number of such charge sites about the rotational circumference of the rotor blade assembly 101.

In such circumstances each charge site will create its own plasma which then travels or propagates with rotor blade assembly 101 rotation and the electrical potential between the rotor blades 102 and opposing surface 104 in the direction of rotation in order to create the seal barrier. In terms of creating this seal barrier it will be appreciate that by providing an entrained and retained plasma flow between the tips 103 and opposed surface 104 it is not possible for there to be air flow across the tips 103 in the form of air/gas leakage about each tip 103 of the rotor blades 102.

Fig. 3 is a schematic illustration of a front view of a seal arrangement for a blade assembly 201 in accordance with the present invention. As can be seen, the rotor blade assembly 201 rotates in the direction of arrowheads A such that there is a gap 202 between the tip extremities of the rotor blade assembly 201 and an opposed surface 203. In accordance with the present invention, as described above, a charge site 204 is located such that an ionised plasma 205 is created between that charge site 204 and an opposed electrode or tips of the rotor blade assembly 201. This plasma 206 is entrained by the airflow of the rotor blade assembly 201, but more importantly is retained in the gap 202 by an electrical potential between the rotor blade assembly 201 and the opposed surface 203. As indicated previously, the value of this electrical potential will depend upon operational requirements. In order to sustain and achieve linger throughout the circumference of the gap 202 and the electrical potential will be chosen to meet requirements in terms of acceptable leakage, but in any event generally additional energy will be provided through radio frequency electromagnetic energy which provides further excitation to the charged particles of the plasma. Nevertheless, it will be appreciated a single charge site such as site 204 may be insufficient or inefficient with respect to creating a necessary ionised plasma which can be sustained throughout the circumference of the gap 202 in order to create a desired seal barrier. In such circumstances further charge sites may be provided at 90

degree or 120 degree or 180 degree spacings as required. Furthermore, as indicated above, in addition to varying the electrical potential between the opposing surfaces in order to sustain and retain the plasma for creation of a desired seal barrier, it may be possible to monitor the plasma and then activate charge sites as required in order to supplement the plasma ionisation density as required dependent upon expected pressure differentials, etc.

Gas turbine engine efficiency is important, and as indicated above, segregation of gaseous flows in order to improve efficiency is an ongoing objective. Clearly, in order to form the plasma which in turn through entrainment creates the barrier seal in accordance with the present invention requires significant electrical energy. Gas turbine engines are used in a wide range of situations including with respect to generation of electricity as well as power plant for marine and aeronautical applications. Nevertheless, it is submitted that the present invention will have particular application with regard to electrical power generation gas turbines.

Since these machines are being used to generate electricity, electrical power will always be available. Plasma generation could give rise to electromagnetic radiation, which might interfere with aircraft systems. Power generation control systems are designed to operate in an environment where there is likely to be electromagnetic interference.

For aero applications, the most likely advantage of the present seal arrangement is that an ionised gas sealed compressor could be controlled to allow operation well beyond current surge margins.

It will also be understood that in addition to use with respect to rotor blade assemblies, the present invention could be utilised in other situations such as

- a) Seals between rotor/stator discs in order to eliminate the necessity for labyrinthine bush seals.

- b) Relatively fast acting fail safe valves to control secondary air flows for cooling systems, etc.
- c) Fine tuning control of combustion gas flows.
- 5 d) Altitude relight.
- e) Exhaust gas directioning.

In such circumstances to a greater or lesser extent the entrainment effects of rotary flow about blade tips or other rotating structures is utilised or not in addition to the maintained electrical potential between surfaces, tips to casing, in which the plasma is retained.

Clearly, in accordance with the present invention, provision of the plasma through an electrical process is of paramount importance. Nitrogen is the most difficult species to ionise in air. The energy requirement to produce ionising of one nitrogen molecule to the higher energy state of N_2^+ is 2.49×10^{-18} J. Even at welding arc densities, the internal energy of 1 cm³ of nitrogen plasma is only ~0.25 J above ambient air. However, the ionisation process is inefficient and much higher energies have to be applied to the gas to achieve plasma formation.

It will also be understood that consideration must be made as to whether an absolute or complete seal is required or achievement of a seal arrangement in accordance with the present invention which has a similar efficiency to conventional seals. It will be understood that if an absolute seal is required then far greater electrical power will be needed, but provision of that electrical power in itself may through a law of diminishing returns render the achievement of an absolute seal itself inefficient through energy wastage in other ways. It can be shown for an unshrouded high pressure turbine with a blade cord of 30mm, a thickness of 5mm and a clearance gap of 1mm and gap volume of 0.15mm cubic centimetres along with a pressure ratio of 5 to 1 and an initial static pressure of 500 KPa that the force on the gas in the gap is in the order of 960 Newtons. A high plasma density will be required to provide a force in the order of 960 Newtons at reasonable voltages. It can be

shown that this voltage will be in the order of 400 volts to create the 960 Newton force in a 1mm gap.

It will be understood that a requirement of the present invention is creating the plasma by appropriate choice of charge site opposed by a blade tip or electrode in order to create the plasma. Subsequently, this plasma is drawn by the electrical potential between the opposing surfaces, in the example a rotor blade assembly and opposed surface 104 of the casing 105 in order to create the desired seal barrier. It will also be understood that it is the opposed surfaces which are important in order to create the electrical field for retention of the plasma as a seal barrier. In such circumstances these opposed surfaces may be electrically isolated through a dielectric layer from other associated structures. In such circumstances, with respect to the rotor blades 102, the tips 103 may be formed such that they are electrically isolated by an insulating dielectric layer from the remainder of the rotor blades. Similarly, with respect to the opposed surface 104 of the casing 105, it will be understood that this surface may take the form of a ring isolated from the remainder of the casing 105 through an intermediate dielectric layer or ring of material. In such circumstances, creation of the electrical potential between the opposing surfaces in order to create the necessary electrical field for retention of the plasma as a seal barrier will be made easier.

Fig. 4 provides greater detail of plasma generation and distribution in accordance with the present invention. The portion 108 at the tip 103 of a rotor blade 102 and the dielectric insulating layer 109 and portion 110 of the casing 105 and the dielectric insulating layer 111 are shown in Fig. 4. It also shows the trench 112 in the casing 105. It also shows the power supply 113 and leads 114 and 115 to the portion 108 of the tip 103 of the rotor blade 102 and the portion 110 of the opposed surface 104. In addition it shows a pressure sensor 116 at the upstream end of the rotor blades 102 and a pressure sensor 118 at the downstream end of the rotor blades 102 and leads 117 and 119 to a processor 120. Also there is a clearance sensor 121 and lead 122 to

the processor 120. Finally there is the speed sensor 123 and lead 124 to the processor 120. The processor 120 then may use the signals described below to adjust the power supplied from the power supply 113.

5 Thus, the processor 120 analyses the signals from the speed sensor 123, the clearance sensor 121 and the pressure sensors 116 and 188. If the processor 120 determines that the speed of rotation of the rotor blades 102 has increased then the processor 120 increases the electric potential
10 supplied by power supply 113 between the tips 103 of the rotor blades 102 and the casing 105. If the processor 120 determines that the speed of the rotation of the rotor blades 102 has decreased then the processor 120 decreases the electric potential supplied by the power supply 113
15 between the tips 103 of the rotor blades 102 and the casing 105. Similarly, if the processor 120 determines that the gap, or clearance, between the tips 103 of the rotor blades 102 and the casing 105 has increased then the processor 120 increases the electric potential supplied by the power
20 supply 113 between the tips 103 of the rotor blades 102 and the casing 105. If the processor 120 determines that the gap, or clearance, between tips 103 of the rotor blades 102 and the casing 105 has decreased then the processor 120 decreases the electric potential supplied by the power
25 supply 113 between the tips 103 of the rotor blades 102 and the casing 105. If the processor 120 determines the pressure difference between the pressure sensors 116 and 118 has increased then the processor 120 increases the electric potential supplied by the power supply 113 between the tips
30 103 of the rotor blades 102 and the casing 105. If the processor 120 determines that the pressure difference between the pressure sensors 116 and 118 has decreased then the processor 120 decreases the electric potential supplied by the power supply 113 between the tips 103 of the rotor
35 blades 102 and the casing 105. If two, or more, of the speed of rotation gap and pressure difference have changed the electric potential is increased or decreased accordingly.

In most respects the electrical plasma created in accordance with the present invention will act as a gas. In such circumstances, the opposing surfaces, in the blade tips 103 and/or opposing surface 104 may be shaped to facilitate retention of the plasma as a seal barrier. For example, the blade tips may incorporate a channel which causes vortexes and so the plasma may linger. Furthermore, the opposed surface 104 may incorporate a groove trench in which the tips 103 enter in order to create an effective shroud which again will facilitate retention of the electrical plasma through the electrical potential between the tips 103 and the opposing surface 104.

It will be understood that the tips 103 and opposing surface 104 in the example embodiment of the present invention will not be generally subject to erosion. Nevertheless, care must be taken with respect to the particular materials utilised for these tips 103 and opposing surface 104 to ensure such erosion if it occurs is minimised. Potentially tungsten electrodes may be used, but normally the materials utilised in order to initially create the plasma and then subsequently retain the plasma will be metals. Again in accordance with the present invention, the particular materials utilised in the tips 103 and opposed surface 104 may be idealised for the particular seal barrier of the present invention in terms of sustaining and retaining the plasma in order to create the seal barrier. However, these materials may not be those best suited to the particular operation or requirements for rotor blade 102 operation or otherwise. In such circumstances, particular segments may be incorporated in the rotor blade assembly 101 at the tips 103 of the rotor blades 102 for creation of the desired seal arrangement in accordance with the present invention whilst the remainder of the rotor blade assembly 101 is formed from other materials more suitable to operational requirements. Similarly, the casing 105 may incorporate particular materials in the opposed surface 104 most suited to retention and/or creation of the plasma in order to achieve the seal barrier in accordance with the present invention.

As indicated above the electrical potential between the opposed surfaces in order to at least sustain the plasma to form the seal barrier in accordance with the present invention may be determined in order to achieve the desired seal efficiency up to a substantially absolute seal barrier with limited leakage. In such circumstances, the electrical potential in order to create the electrical field for plasma retention may be adjusted dependent upon operational factors such as rotational speed of the rotor blade assembly 101 and/or operational variation in dimensions of the rotor blade assembly 101 due to temperature and/or structural deformation such as creep. It will also be understood that the electrical potential and therefore electrical field to retain the plasma may be increased or decreased dependent upon the expected or detected pressure differential across the seal arrangement in order to achieve the desired operational efficiency with least electrical power supply in order to create the necessary electrical field.

Alternative embodiments of the present invention will be readily understood by those skilled in the technology. Thus, it is possible to provide a seal between a surface of the rotor and the radially inner ends of the stator vanes or shrouds/platforms at the radially inner ends on the stator vanes.

Similarly, the electric potential in order to create the electric field for plasma retention may be adjusted dependent upon operational factors such as rotational speed of the rotor, pressure differential across the seal arrangement and dimension of the gap between the rotor and radially inner ends of the stator vanes.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

CLAIMS

1. A seal arrangement (100,200) comprising a rotor assembly (101,102,201) and a stator assembly (105),
5 characterised by at least one charge site (204) arranged, to ionise gas between the rotor assembly (101,102,201) and the stator assembly (105) to form a plasma (107,205), means (113) to produce an electrical potential between the rotor assembly (101,102,201) and the stator assembly (105) in
10 order to sustain a seal barrier formed by the plasma (107,205) in a gap (202) between the rotor assembly (101,102,201) and the stator assembly (105).
2. An arrangement as claimed in claim 1 wherein the at least one charge site (204) comprises means to produce spark
15 ionisation of the gas to produce the plasma.
3. An arrangement as claimed in claim 1 wherein the at least one charge site (204) comprises a laser to produce laser induced breakdown of the gas to produce the plasma.
4. An arrangement as claimed in any of claims 1, 2 or 3
20 wherein ionisation is achieved between the at least one charge site (204) and the rotor assembly (101,102,201).
5. An arrangement as claimed in any of claims 1, 2 or 3 wherein ionisation is achieved between the at least one charge site (204) and a specific electrode.
- 25 6. An arrangement as claimed in any preceding claim wherein the gap (202) is in the order of one millimetre.
7. An arrangement as claimed in any preceding claim wherein there is more than one charge site (204) in the arrangement.
- 30 8. An arrangement as claimed in any preceding claim wherein a radio frequency electromagnetic radiation source is coupled to the plasma (107,205) to sustain the plasma (107,205) and so the barrier.
9. An arrangement as claimed in claim 8 wherein the radio
35 frequency electromagnetic source has a frequency of 300 GHz.
10. An arrangement as claimed in claim 8 or claim 9 wherein the radio frequency electromagnetic source comprises a solid state device.

11. An arrangement as claimed in claim 10 wherein the solid state device comprises a IMPATT diode.

12. An arrangement as claimed in any of claims 8 to 10 wherein a hollow waveguide guides the radio frequency
5 electromagnetic radiation.

13. An arrangement as claimed in any preceding claim wherein there are means (12) to measure the speed of rotation of the rotor assembly (101,102,201) and means (120) to adjust the electrical potential between the rotor
10 assembly (101,102,201) and the stator assembly (105).

14. An arrangement as claimed in any preceding claim wherein there are means (121) to measure the clearance between the rotor assembly (101,102,201) and the stator assembly (105) and means (120) to adjust the electrical
15 potential between the rotor assembly (101,102,201) and the stator assembly (105).

15. An arrangement as claimed in any preceding claim wherein there are means (116,118) to measure the pressure differential across the seal arrangement and means (120) to
20 adjust the electrical potential between the rotor assembly (101,102,201) and the stator assembly (105).

16. A seal arrangement as claimed in any preceding claim wherein the rotor assembly (101,102,201) comprises a rotor blade assembly (101) including a rotor disc and rotor blades
25 (102), the stator assembly (105) comprises a casing (105), the at least one charge site (204) being arranged to ionise gas between tips (103) of the rotor blades (102) and an opposed surface (104) of the casing (105) in order to sustain the barrier formed by the plasma (107,205) in the
30 gap (202) between the tips (103) of the rotor blades (102) and the casing (105).

17. An arrangement as claimed in claim 16 wherein the tips (103) of the rotor blades (102) and/or the opposed surface (104) of the casing (105) are electrically isolated from
35 associated structures.

18. An arrangement as claimed in claim 17 wherein portions (108) at the tips (103) of the rotor blades (102) are electrically isolated from the remainder of the rotor blades (102) by insulating layers (109).

19. An arrangement as claimed in claim 17 or claim 18 wherein a portion (110) of the casing (105) is electrically isolated from the remainder of the casing (105) by insulating layer (111).

5 20. An arrangement as claimed in claim 18 or claim 19 wherein the insulating layer (109,111) is a dielectric insulating layer.

21. An arrangement as claimed in any preceding claim wherein the tips (103) of the rotor blades (102) and/or the
10 opposed surface (104) of the casing (105) are shaped to sustain the seal barrier.

22. An arrangement as claimed in claim 21 wherein the tips (103) of the rotor blades (102) have channels.

23. An arrangement as claimed in claim 21 or claim 22
15 wherein the opposed surface (104) of the casing (105) has a trench (112).

24. An arrangement as claimed in any of claims 16 to 23 wherein the tips (103) of the rotor blades (102) and/or opposed surfaces (104) of the casing (105) are made from
20 different materials to the remainder of the associated structures.

25. An arrangement as claimed in any of claims 15 to 24 wherein the rotor blade assembly (101,102,201) comprises a fan stage, a compressor stage or a turbine stage.

25 26. A seal arrangement as claimed in any of claims 1 to 15 wherein the rotor assembly comprises a rotor disc and the stator assembly comprises a stator disc.

27. A seal arrangement as claimed in any of claims 1 to 15 wherein the rotor assembly comprises a rotor and the stator
30 assembly comprises stator vanes.

28. An arrangement as claimed in claim 27 wherein the seal is provided between the radially inner ends of stator vanes extending radially inwards and the rotor.

29. A turbine engine incorporating a seal arrangement as
35 claimed in any preceding claim.

Fig.1.

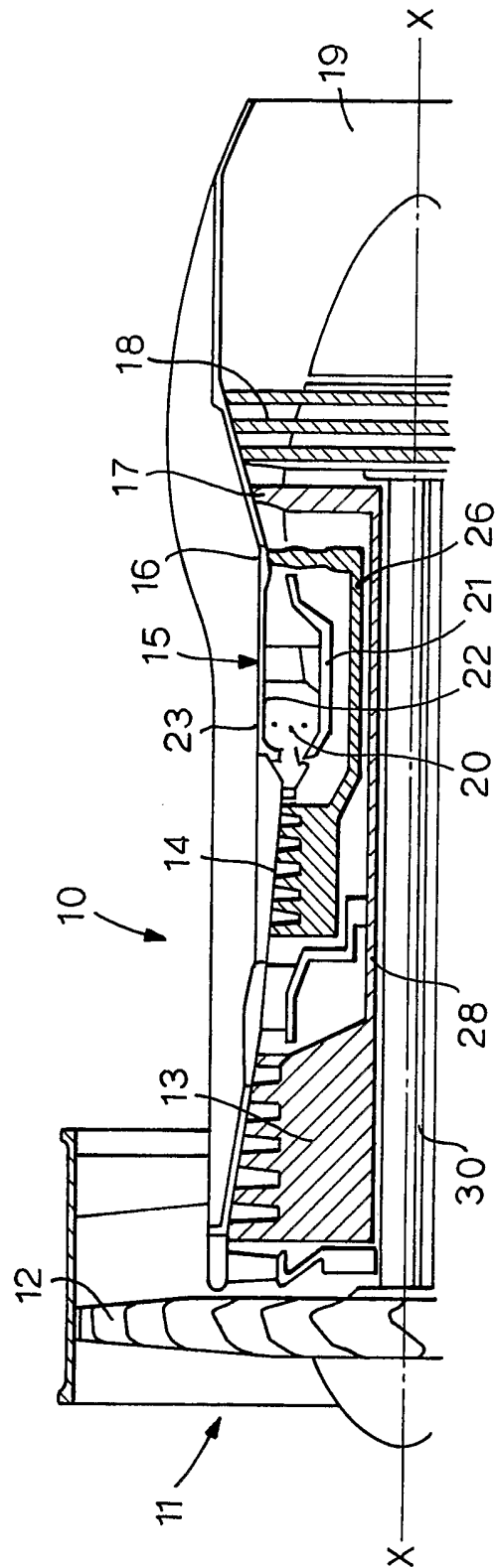


Fig.2.

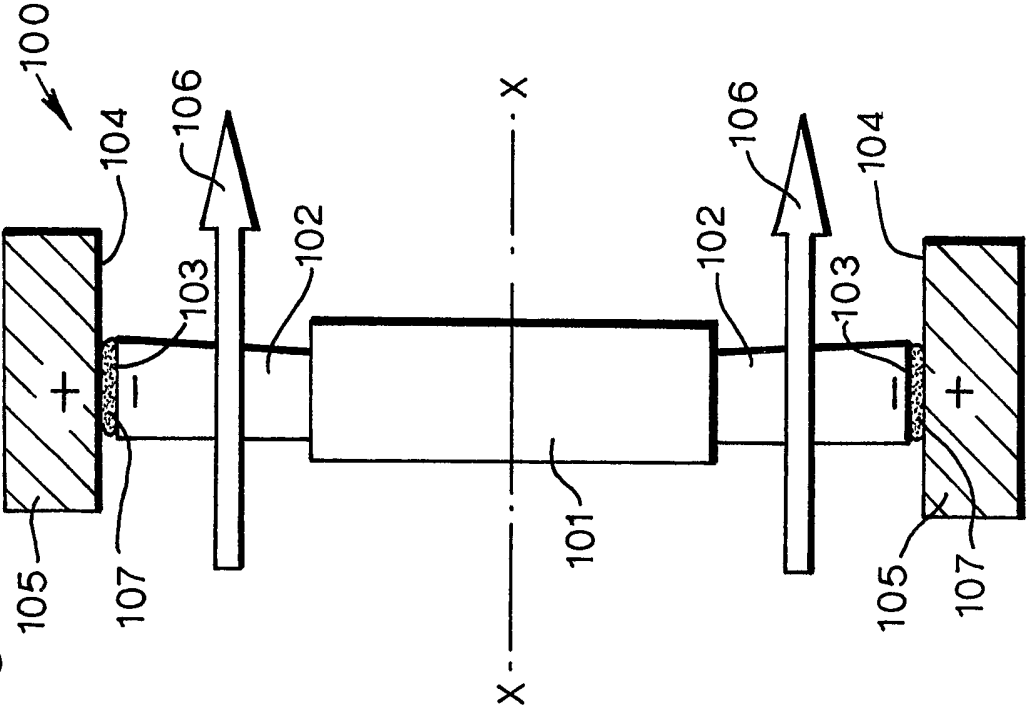


Fig.3.

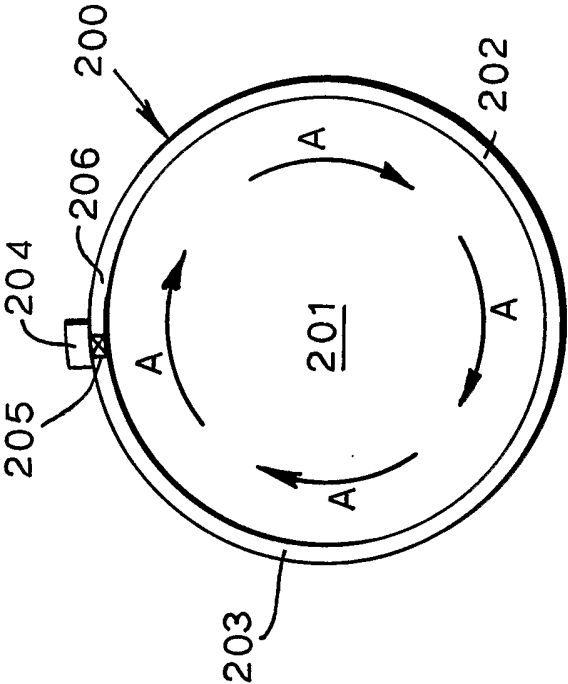
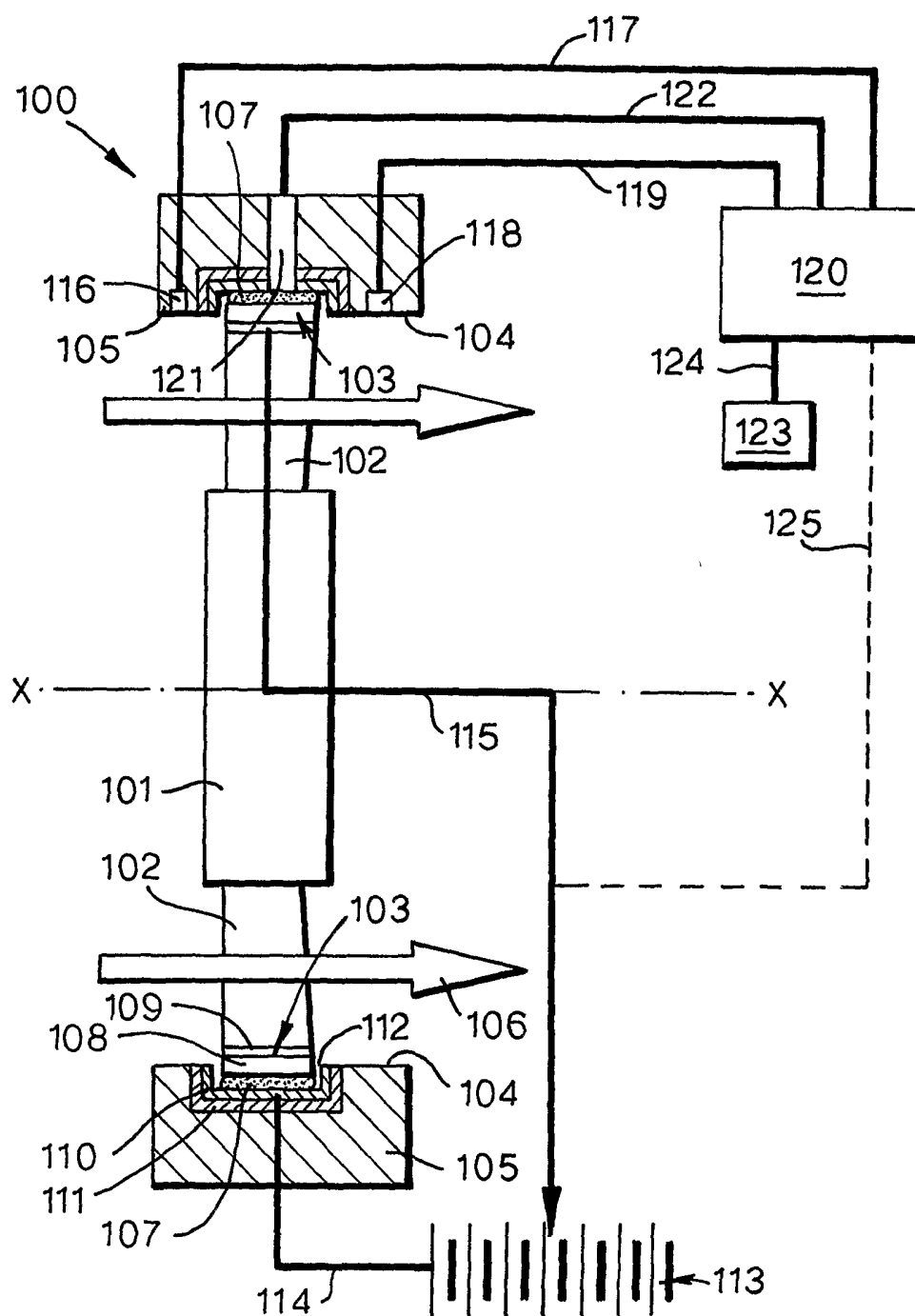


Fig.4.



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2005/001402

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16J15/43 F16J15/40 F01D11/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16J F01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 209 389 A (ROLLS-ROYCE PLC) 29 May 2002 (2002-05-29) figures -----	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search

22 June 2005

Date of mailing of the international search report

30/06/2005

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Internal Application No.

PCT/GB2005/001402

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1209389 A	29-05-2002	EP 1209389 A2	29-05-2002
		US 2002060432 A1	23-05-2002