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(54) **RADIAL SEAL ARRANGEMENT BETWEEN ADJACENT BLADES OF A GAS TURBINE**

(57) A blade row assembly for a gas turbine having an axis (34), the blade row assembly (31) comprising:
- a plurality of blades (32) adjacent arranged along a circumferential direction (33) centered in the gas turbine axis (34); each blade (32) along a radial direction (35) comprising a root (36) configured for coupling the blade (32) to a rotor (37), a platform (39) and an airfoil (40); each blade (32) being provided with a shank cavity (41) supplied with cooling air and delimited outwardly by the platform (39) and downstream by a rear wall (42);
- a plurality of platform sealing devices (43) for sealing the gaps between two adjacent platforms (39);
- a plurality of radial sealing devices (44) for sealing the gaps between two adjacent rear walls (42);
wherein the radial sealing devices (44) comprise a plurality of radial sealing strips arranged between the adjacent rear walls (42).

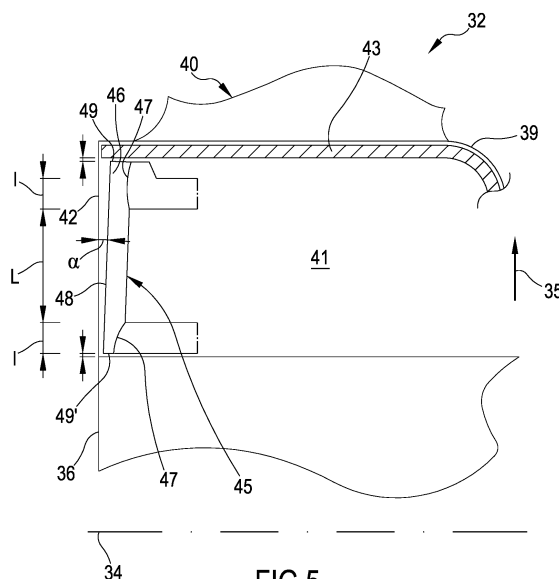


FIG.5

EP 3 342 988 A1

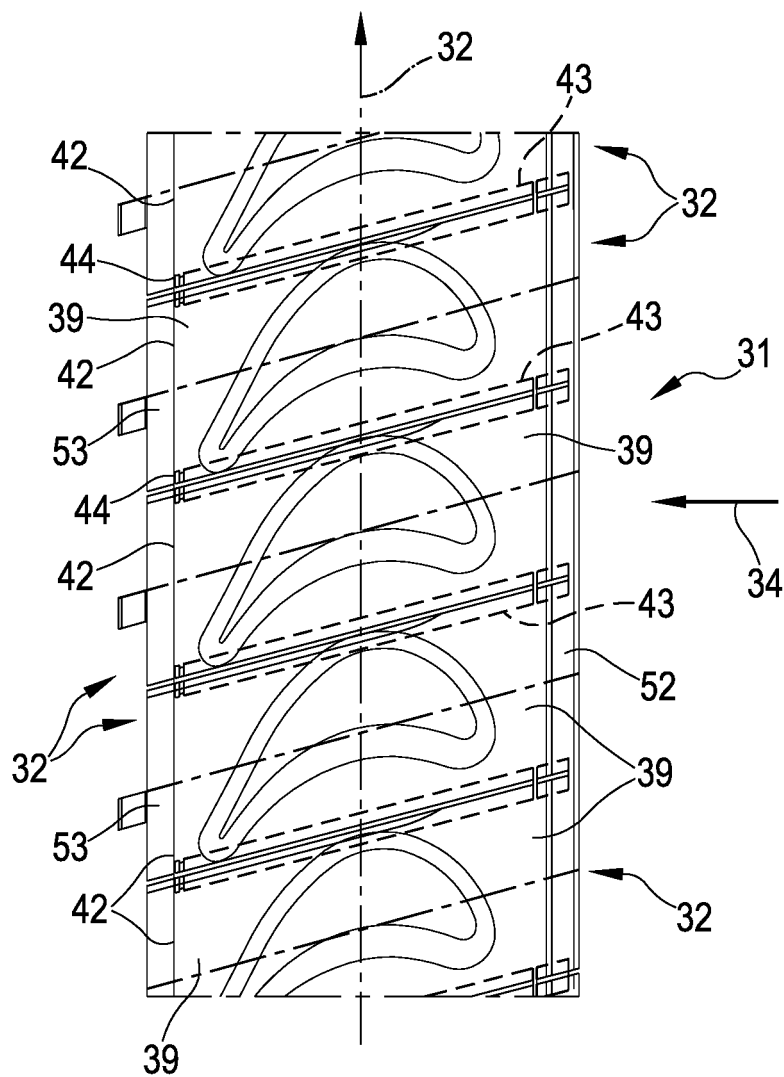


FIG.6

Description

Field of the Invention

[0001] The present invention relates to a radial seal arrangement between adjacent blades of a row of blades in a gas turbine. In particular, the present invention refers to a radial seal arrangement between adjacent blade shank cavities. Moreover, the present invention relates to a gas turbine provided with such radial seal arrangement.

Description of prior art

[0002] As known, a gas turbine power plant (in the following only gas turbine) comprises a rotor provided with an upstream compressor, at least a combustion chamber and at least a downstream turbine. The terms "downstream" and "upstream" refer to the direction of the main gas flow passing through the gas turbine from the compressor to the turbine. In particular, the compressor comprises an inlet supplied with air and a plurality of blades and vanes configured for compressing the air entering the compressor. The compressed air leaving the compressor flows into a plenum and from there into a burner. Inside the burner, the compressed air is mixed with at least one fuel. The mixture of such fuel and the compressed air flows into a combustion chamber where this mixture is combusted. The resulting hot gas leaves the combustor chamber and expands in the turbine performing work on the rotor.

[0003] In order to achieve a high efficiency, a high turbine inlet temperature is required. However, due to this high temperature, high NO_x emission levels are generated.

[0004] In order to reduce these emissions and to increase operational flexibility, today is known a particular kind of gas turbines called "sequential" gas turbine.

[0005] In general, a sequential gas turbine comprises two combustion chambers in series. According to a first kind of sequential gas turbines, the two combustion chambers are physically separated by a stage of turbine blades, called high pressure turbine.

[0006] Today is known a second kind of sequential gas turbines not provided with the high pressure turbine. According to this kind of gas turbine, the two combustion chambers are integrated in a single casing, for instance a can-shaped combustor. Of course, this kind of gas turbine is provided with a plurality of can combustors arranged as a ring around the turbine axis.

[0007] In these kinds of gas turbines, as in other kinds not mentioned, the turbine comprises a plurality of alternated rows of blades and vanes wherein in each row the blades are adjacent arranged along a circumferential direction centered at the turbine axis. As known, each blade has a radial development with respect to the turbine axis and comprises in series a root configured for coupling the blade to the rotor, a shank, a platform and an airfoil.

[0008] Gas turbine blades are exposed to high temperature combustion gases and, consequently, are subject to high thermal stresses. Methods are known in the art for cooling the blades and reducing these thermal stresses. Typically, high pressure air discharged from the compressor is introduced inside the blade from the blade root, i.e. the inner blade portion configured for coupling the blade to the rotor. The terms "inner/inward" and "outer/outward" refer to the direction of the turbine axis in the meaning that an inner portion is closer to the turbine axis than an outer portion. The high pressure air is therefore supplied in the blade shank cavity inwardly arranged below the blade platform and from the shank cavity the air enters in a plurality of cooling ducts. At the end of these cooling ducts, the cooling air flows out from fine holes provided at a blade airfoil and/or at a blade tip. Thus, the high pressure air cools the metal temperature of the blades exposed to the hot gas.

[0009] In order to maximize the above described cooling effect, the cooling air flow is to be effected with the lowest losses possible. It is therefore known to provide the gas turbine with seals configured for sealing two adjacent blade shank cavities. In particular, the gas turbine comprises horizontal seal arrangements, configured for sealing the horizontal gap between the platforms of adjacent blades and avoiding the radial leakage from below to above the platforms. Moreover, the gas turbine comprises also radial seal arrangements configured for sealing the radial gap between adjacent blades and avoiding the axial leakage from the blade shank cavity along the downstream direction.

[0010] According to the prior art practice, today the horizontal seal arrangements are realized in form of a plurality of seal strips, for instance made of a metal sheet, arranged as bridges between the platforms of adjacent blades.

[0011] According the prior art practice, the foregoing mentioned radial seal arrangements are realized in form of overlapping portions of the adjacent blades. In particular, the trailing edge side of the blade root comprises a projecting portion that extends along the circumferential direction into the direction of the adjacent blade that comprises a corresponding stepped seat for receiving the projecting portion of the adjacent blade. This particular kind of radial seal arrangement is known as "ship-lap" seal.

[0012] Along a blade row, for mounting reason a single blade or a limited number of blades do not have the above mentioned projecting portion. This blade is known as "closing" blade because this blade is the last blade to mounted in the row or in a group of blades.

[0013] This prior art solution will be described in detail with reference to figure 3 that discloses a portion of a blade row provided with horizontal seals and radial ship-lap portions.

[0014] Unfortunately, the ship-lap seal arrangement is not able to fully seal the corresponding radial gap and a significant amount of cooling air can escape from the

stepped overlapping region. Moreover, the ship-lap seal arrangement requires the presence of the closing blade, that causes additional manufacturing costs being such blade different with respect to the other blades. Additionally, the ship-lap seal arrangement does not allow an individual blade replacement due to the required predetermined assembly/disassembly sequence.

[0015] Accordingly, a primary object of the present invention is to provide a radial seal arrangement between adjacent blades of a row of blade in a gas turbine suitable for overcoming the prior art drawbacks above mentioned.

[0016] In order to achieve the scope mentioned above, the present invention provides a blade row comprising a plurality of blades adjacent arranged along a circumferential direction centered in the gas turbine axis. Along a radial direction from inside to outside the turbine, each blade comprises a root configured for coupling the blade to a rotor; a shank; a platform and an airfoil. In particular, the shank is configured for defining a shank cavity to be supplied with cooling air. The shank cavity is at least in part upstream opened, or closed by a removable wall, and delimited outwardly by the platform and downstream by a rear radial wall, preferably made integral with the platform. The platform is substantially horizontal and parallel to the turbine axis while the rear wall is substantially vertical and parallel to the radial direction of the gas turbine.

[0017] In order to avoid a radial leakage from below (i.e. inside the shank cavity) to above the platform, the blade row comprises a plurality of platform or horizontal sealing devices configured for sealing the horizontal gaps between adjacent platforms.

[0018] In order to avoid an axial leakage from upstream (i.e. inside the shank cavity) to downstream the rear wall, the blade row comprises a plurality of radial seal devices configured for sealing the radial gaps between adjacent rear walls.

[0019] According to the prior art, the above mentioned radial seal devices are realized in form of mutual overlapping portion of adjacent rear walls (the so called ship-lap seal portions). On the contrary, according to the invention, the radial seal devices comprise a single or a plurality of radial sealing strips each of which is arranged along the radial direction between two adjacent rear walls.

[0020] Advantageously, in this way the so called "closing blade", i.e. a blade having a different shape with respect to the other blades, is not necessary. Consequently, the assembly/disassembly sequence of the blade row is not predetermined and therefore the invention allows to replace any individual blade in an easy and quick manner.

[0021] In particular, each rear wall comprises two opposite radial seats facing corresponding radial seats of the adjacent rear walls wherein each radial seat has a radial development and is accessible from the shank cavity for placing the radial sealing strip. In other words, the seats are closed downstream but open upstream within

the shank cavity. Therefore, a radial sealing strip comprises a first radial edge housed in a radial seat of a blade and a second radial edge housed in the radial seat of the adjacent blade.

[0022] Advantageously, in this way in case of seal loss the seal is trapped inside the shank cavity and therefore the lost seal can be easily removed or placed again in position.

[0023] According to an embodiment of the invention, also the platform sealing devices are realized in form of a single or a plurality of horizontal sealing strips arranged between two adjacent platforms. In this case, the radial sealing strips and the horizontal sealing strips can have the same width or length measured along the circumferential direction.

[0024] Advantageously, in this way the radial sealing strips and the horizontal sealing strips can be derived by a common sheet material.

[0025] According to an embodiment of the invention, the radial seat comprises a radial groove, i.e. a groove having a radial development, provided with a downstream radial surface, facing the shank cavity and an inward and outward surface orthogonal to the radial surface respectively close to the blade root and to the blade platform. The radial groove also comprises two lip portions connected to the inward and outward surface, wherein such lip portions are configured for partially overhanging the groove radial surface.

[0026] Advantageously, in this way the overhanging lip portions allow to keep in position the radial sealing strips inside the groove avoiding seal losses.

[0027] According to an embodiment of the invention, the lip portions are projecting towards the shank cavity and are curved shaped in order to help the positioning of the radial sealing strips inside the radial groove.

[0028] Preferably, the radial sealing strips are pre-shaped, for instance curved pre-shaped, so that can be easily enter the groove passing through the lip portions.

[0029] According to one embodiment, the radial seat is inclined with respect to the radial direction so that the outer lip portion is inclined toward the shank cavity.

[0030] Advantageously, in this way the centrifugal force acting on the radial sealing strips improves the sealing effect by enhancing the contact forces against the downstream rear wall of the seat.

[0031] According to one embodiment, the radial sealing strip comprises at least an opening.

[0032] Advantageously, in this way the invention allows to realize a controlled purge flow passing through the radial sealing strips.

[0033] It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed. Other advantages and features of the invention will be apparent from the following description, drawings and claims.

Brief description of drawings

[0034] Further benefits and advantages of the present invention will become apparent after a careful reading of the detailed description with appropriate reference to the accompanying drawings.

[0035] The invention itself, however, may be best understood by reference to the following detailed description of the invention, which describes an exemplary embodiment of the invention, taken in conjunction with the accompanying drawings, in which:

- figures 1 and 2 are schematic sectional views of two different examples of gas turbines, in particular sequential gas turbines, which can be provided with the radial sealing arrangement of the invention;
- figure 3 is a schematic view along the radial direction of an example of a turbine blade;
- figures 4 and 5 are schematic views along the circumferential direction of a portion of a row of blades; in figure 4 the seal arrangements between adjacent blades are realized according to the prior art practice, in figure 5 the seal arrangements between adjacent blades are realized according to the invention;
- figure 6 is a schematic view along the radial direction of a blade shank provided with an example of a groove for housing the radial seals of figure 5 according to the invention;
- figures 7-9 are schematic views of the assembly/disassembly sequence of a radial seal arrangement according to the invention.

Detailed description of preferred embodiments of the invention

[0036] In cooperation with attached drawings, the technical contents and detailed description of the present invention are described thereafter according to preferred embodiments, being not used to limit its executing scope. Any equivalent variation and modification made according to appended claims is all covered by the claims claimed by the present invention.

[0037] Reference will now be made to the drawing figures to describe the present invention in detail.

[0038] Reference is now made to Fig. 1 that is a schematic view of a first example of a sequential gas turbine 1 that can be provided with a supply assembly according to the invention. In particular, figure 1 discloses a sequential gas turbine with a high pressure and a low pressure turbine.

[0039] Following the main gas flow 2, the gas turbine 1 comprises a compressor 3, a first combustion chamber 4, a high-pressure turbine 5, a second combustion chamber 6 and a low-pressure turbine 7. The compressor 3 and the two turbines 5, 7 are part of a common rotor 8 rotating around an axis 9 and surrounded by a concentric casing 10.

[0040] The compressor 3 is supplied with air and is

provided with rotating blades 18 and stator vanes 19 configured for compressing the air entering the compressor 3. The compressed air flows into a plenum 11 and from there into a premix burner 12 where this compressed air is mixed with at least one fuel introduced via a first fuel injector supplied by a first fuel supply 13. The fuel/compressed air mixture flows into the first combustion chamber 4 where this mixture are combusted.

[0041] The resulting hot gas leaves the first combustor chamber 4 and is partially expanded in the high-pressure turbine 5 performing work on the rotor 8.

[0042] Downstream of the high-pressure turbine 5 the gas partially expanded flows into the second burner where fuel is injected via second fuel injector (not shown) supplied by a fuel lance 14.

[0043] The partially expanded gas has a high temperature and contains sufficient oxygen for a further combustion that, based on a self-ignition, takes place in the second combustion chamber 6 arranged downstream the second burner. The reheated gas leaves the second combustion chamber 6 and flows in the low-pressure turbine 7 where is expanded performing work on the rotor 8.

[0044] The turbine component 7 comprises a plurality of stages, or rows, of rotor blades 15 arranged in series in the main flow direction. Such stages of blades 15 are interposed by stages of stator vanes 16. The rotor blades 15 are connected to the rotor 8 whereas the stator vanes 16 are connected to a vane carrier 17 that is a concentric casing surrounding the low-pressure turbine 7.

[0045] Reference is now made to Fig. 2 that is a schematic view of a second example of a sequential gas turbine 1 that can be provided with a supply assembly according to the invention. In particular, figure 2 discloses a sequential gas turbine 20 provided with a compressor 29, an only a turbine 21 and a sequential combustor arrangement 22. The sequential combustor arrangement 22 of figure 2 comprises a first burner 24, a first combustion chamber 25, a second burner 26, and a second combustion chamber 27. The first burner 24, the first combustion chamber 25, the second burner 26 and the second combustion chamber 27 are arranged sequentially in a fluid flow connection. The sequential combustor arrangement 22 can be annular shaped housed in a combustor casing 28 or can be realized in form of a plurality of cans arranged as a ring around the turbine axis. A first fuel is introduced via a first fuel injector (not shown) into the first burner 24 wherein the fuel is mixed with the compressed gas supplied by the compressor 29. A second fuel is introduced into the second burner 26 via a second fuel injector (not shown) and mixed with hot gas leaving the first combustion chamber 25. The hot gas leaving the second combustion chamber 27 expands in the turbine 21 performing work on a rotor 30.

[0046] The gas turbine of figures 1 and 2 are only two examples of gas turbine that can be provided with the radial seal arrangement according the invention. Of course, also other kinds of gas turbines, or turbo machines in general having shank cavities to be sealed, can

be provided with the seal arrangement according the invention.

[0047] Reference is now made to Fig. 3 that is a schematic view along the radial direction of an example of a turbine blade. In particular, in figure 3 the gas turbine axis, the radial direction and the main hot gas flow have respectively represented by the reference 34, 35 and M. Along the radial direction 35, and from inside to outside the gas turbine axis 34, the blade 32 comprises a root 36 configured for coupling the blade 32 to a rotor 37 (only schematically represented), a shank cavity 41, a rear-wall 42, a platform 39 and an airfoil 40. The airfoil 40 comprises a leading edge 48, a trailing edge 49, a pressure side 50 and a suction side 51 (not shown in figure 3). The shank cavity 41 is configured to be supplied with cooling air. This shank cavity 41 is at least in part upstream opened and delimited inwardly by the blade root 36, outwardly by the platform 39 and downstream by a rear wall 42.

[0048] A plurality of blades 32 as represented in figure 3 as adjacent arranged along the circumferential direction 33 centered the gas turbine axis 34 in order to realize a row of blades 31.

[0049] For mounting reasons, and in view of the thermal deformation of the blade 32, once the blades 32 are adjacent arranged two different gaps are to be sealed in order to avoid leakages of cooling air from the shank cavity.

[0050] The first kind of gap is present between adjacent platforms and therefore is substantially a horizontal gap parallel to the axial direction 34. The second gap is present between adjacent rear walls 42 and therefore is substantially a radial gap parallel to the radial direction 35. In figure 3, the horizontal and radial zones of such gaps have been schematically represented by the reference I and II.

[0051] Figure 4 is a schematic view long the circumferential direction of a portion of a row of blades. In particular, figure 4 discloses the seals according to the prior art practice of foregoing mentioned gaps between two adjacent blades. In figure 4, the circumferential direction has been represented by the reference 33.

[0052] The airfoil 40 comprises a leading edge 48, a trailing edge 49, a pressure side 50 and a suction side 51. The corresponding sides of the platform are a leading edge side 52, a trailing edge side 53, a platform pressure side 54 and a platform suction side 55. The platform pressure side 54 and the platform suction side 55 of the platforms 39 of adjacent blades 32 are facing straight parallel lines. In order to close the gap between the platform pressure side 54 and the platform suction side 55 of adjacent platforms 39, the embodiment of figure 4 discloses the presence of a plurality of horizontal sealing strips 43.

[0053] At the trailing edge side 53 of the platform 39, the rear wall 42 comprises a projecting portion that extends along the circumferential direction towards the adjacent blade. The corresponding neighboring blade comprises a seat configured for receiving the foregoing men-

tioned projecting portion and for realizing a radial overlapping portion. This overlapping portion, schematically represented in figure 4 by the reference IV, is known as "ship lap" portion. For mounting reason, only one blade 32 or a limited number of blades of the row 31, called closing blade(s), do not have a shiplap portion. The local absence of this overlapping portion has been represented in figure 4 by the reference III.

[0054] Figure 5 is a schematic view long the circumferential direction of a portion of a row of blades. In particular, figure 5 discloses an example of the radial seal arrangement according to the invention. In particular, according to the invention the foregoing described ship lap portions are replaced by a plurality of radial sealing strips 44 each of which is radial arranged between two adjacent rear walls 42.

[0055] As represented in figure 5, according to the invention all blade 32 of the row 31 have the same shape. Moreover, in figure 5 the horizontal sealing strips 43 and the radial sealing strips 44 can have the same width or length measured along the circumferential direction 33. Advantageously, in this way the radial sealing strips 44 and the horizontal sealing strips 43 can be derived by a common sealing strip sheet material.

[0056] The radial sealing strips 44 and/or the horizontal sealing strips 43 can consist of a single layer of material or can comprise multiple layers of seal material or different seal materials having, for instance, different thicknesses and material strengths.

[0057] Figure 6 is a schematic view along the radial direction 35 of a blade shank 41 provided with an example of a radial groove for housing a portion of a radial sealing strip according to the invention.

[0058] Each blade 32, in particular each rear wall 42, is provided with two opposite radial grooves, one at the suction side and one at the pressure side, for housing two corresponding radial sealing strips. The radial groove 46 of figure 6 is substantially C-shaped with an inlet opening facing the shank cavity 41. In particular, the radial groove 46 comprises a radial downstream surface 48, an inward 49' and outward surface 49, and radial lip portions 47 connected to the inward and outward surface 49 for partially overhanging the radial surface 48. The inward 49' and outward surface 49 can be substantially orthogonal to the radial surface 48 or respectively parallel to the blade root/fir tree 36 and to the blade platform 39. In figure 6, the length along the radial direction 35 of the lip portions 47 has been represented by the reference I. As shown, in view of the lip portions 47, the radial groove opening has a radial length L that is less than the length of the downstream surface 48.

[0059] According to the example of figure 6, the lip portions 47 are projecting toward the inside of the shank cavity 41 and are at least in part curved-shaped. The radial seat 45 of figure 6 is inclined with respect to the radial direction 35.

[0060] The angle of this inclination α of figure 5 is about 3°. The distances between the inward 49' and outward

surface 49 and respectively the blade root 36 and the platform 39 have been minimized as possible.

[0061] Figures 7-9 are schematic views along the circumferential direction 33 of an assembly sequence of the radial seal of the present invention.

[0062] Preferably, the radial seal strip 44 is pre-shaped, e.g. curved C pre-shaped, so that it can be freely arranged inside the groove 46. According to figure 7, the inner and outer end of the radial seal strip 44 can reach the surface 48 passing through the groove opening limited by the lip portions 47.

[0063] Once the radial seal strip 44 is arranged inside the groove 46, the curved radial seal strip 44 can be made straight by pushing the radial seal strip 44 against the surface 48 of the groove 16. This pushing action has been schematically represented in figure 8 by the arrow P. According to the invention, this pushing action can be easily performed by an assembly aid tool, for instance a rod, passing to the upstream opening of the shank cavity 41.

[0064] Once the radial seal strip 44 has been pushed inside the groove 26, such curved seal strip 44 is intended to become straight and substantially parallel to the radial direction 35.

[0065] Although the invention has been explained in relation to its preferred embodiment(s) as mentioned above, it is to be understood that many other possible modifications and variations can be made without departing from the scope of the present invention. It is, therefore, contemplated that the appended claim or claims will cover such modifications and variations that fall within the true scope of the invention.

Claims

1. A blade row assembly for a gas turbine having an axis (34), the blade row assembly (31) comprising:

- a plurality of blades (32) adjacent arranged along a circumferential direction (33) centered in the gas turbine axis (34); each blade (32) along a radial direction (35) comprising a root (36) configured for coupling the blade (32) to a rotor (37), a platform (39) and an airfoil (40); each blade (32) being provided with a shank cavity (41) supplied with cooling air and delimited outwardly by the platform (39) and downstream by a rear wall (42);
- a plurality of platform sealing devices (43) for sealing the gaps between two adjacent platforms (39);
- a plurality of radial sealing devices (44) for sealing the gaps between two adjacent rear walls (42);

wherein the radial sealing devices (44) comprise a plurality of radial sealing strips arranged between

the adjacent rear walls (42).

2. Blade row assembly as claimed in claim 1, wherein each rear wall (42) comprises a radial seat (45) for housing a portion of a radial sealing strip (44).
3. Blade row assembly as claimed in claim 1 or 2, wherein the platform sealing devices (43) comprises a plurality of horizontal sealing strips arranged between adjacent platforms (39).
4. Blade row assembly as claimed in claim 3, wherein along the circumferential direction (33) the radial sealing strips (44) and the horizontal sealing strips (43) have same or different length.
5. Blade row assembly as claimed in claim 3 or 2 or 4, wherein the radial seat (45) comprises a radial groove (46) provided with a radial downstream surface (48), an inward (49') and outward surface (49) orthogonal to the downstream surface (48), and radial lip portions (47) connected to the inward and outward surface (49) for partially overhanging the downstream surface (48).
6. Blade row assembly as claimed in claim 5, wherein the lip portions (47) are projecting from the shank cavity (41).
7. Blade row assembly as claimed in claim 5, wherein at least a lip portion (47) is curved.
8. Blade row assembly as claimed in one of the foregoing claims, wherein the radial sealing strips (44) are straight or pre-shaped.
9. Blade row assembly as claimed in claim 8, wherein the radial sealing strips (44) are curved pre-shaped.
10. Blade row assembly as claimed in one of the foregoing claims, wherein the radial seat (45) is inclined with respect to the radial direction (35).
11. Blade row assembly as claimed in one of the foregoing claims, wherein the radial sealing strips (44) comprise at least an opening.

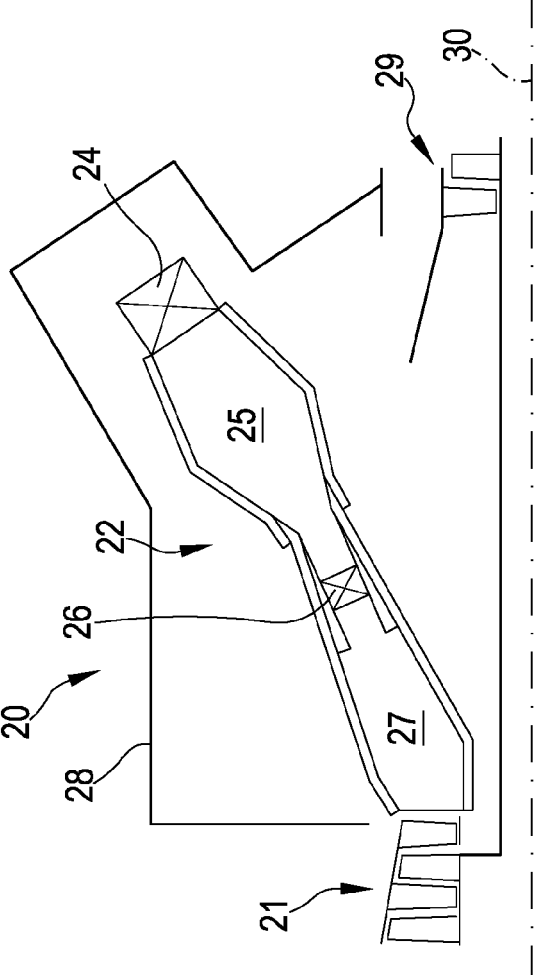
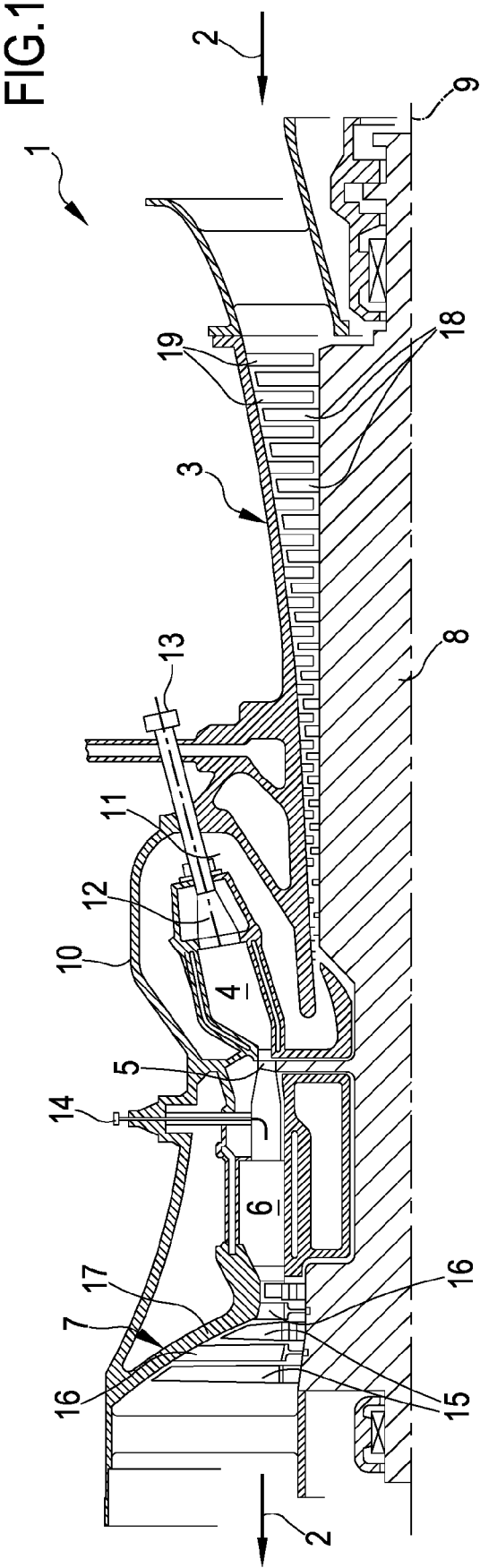


FIG.3

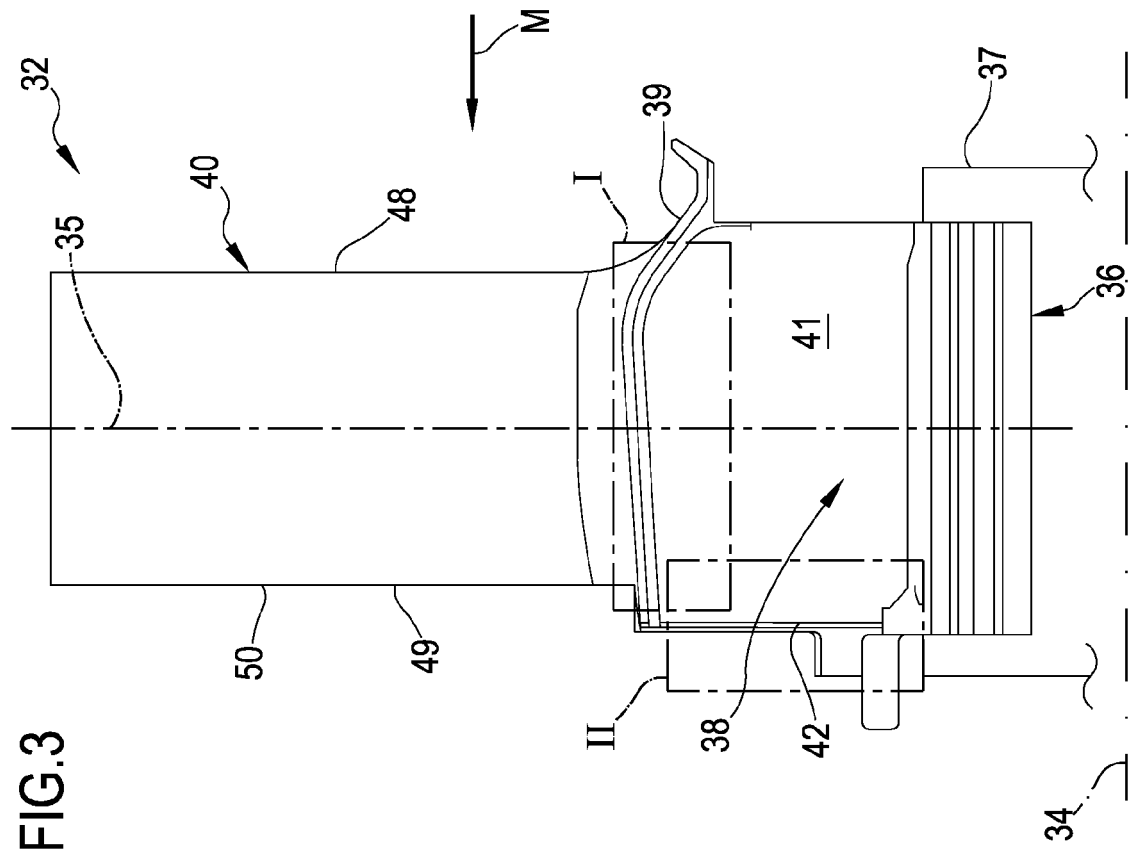
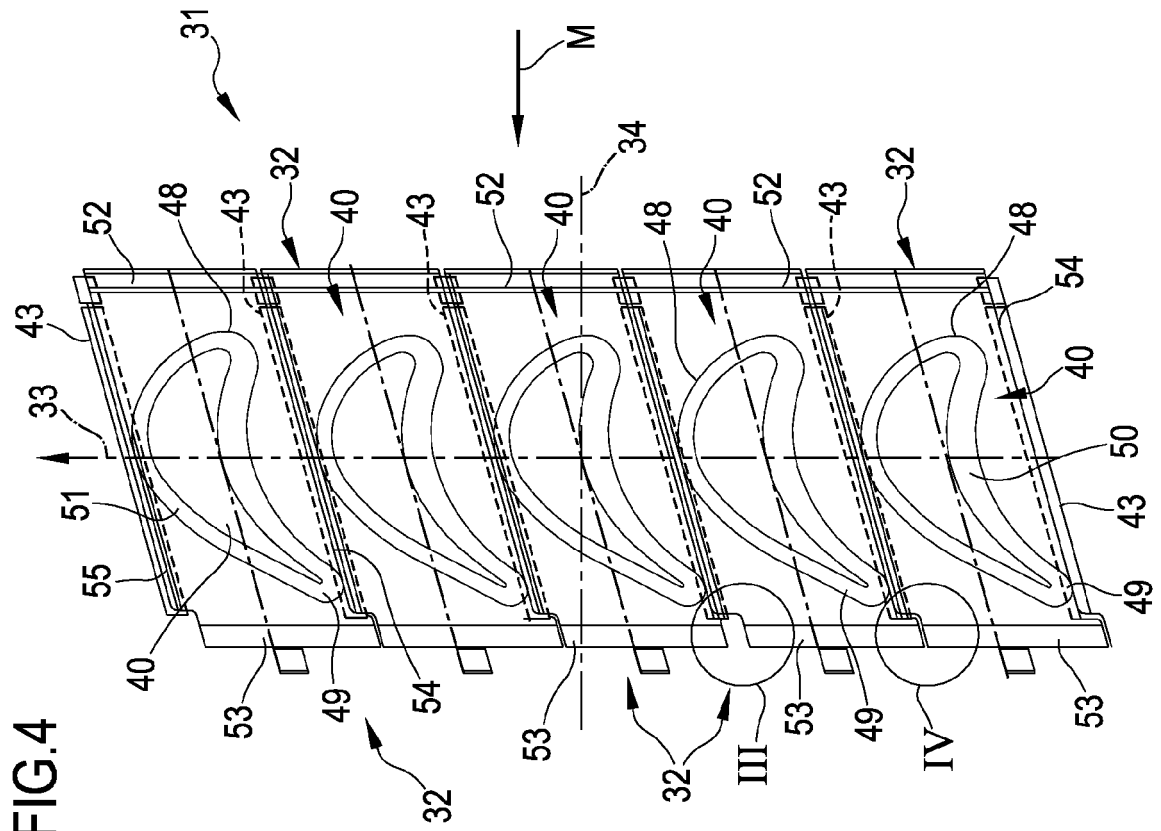
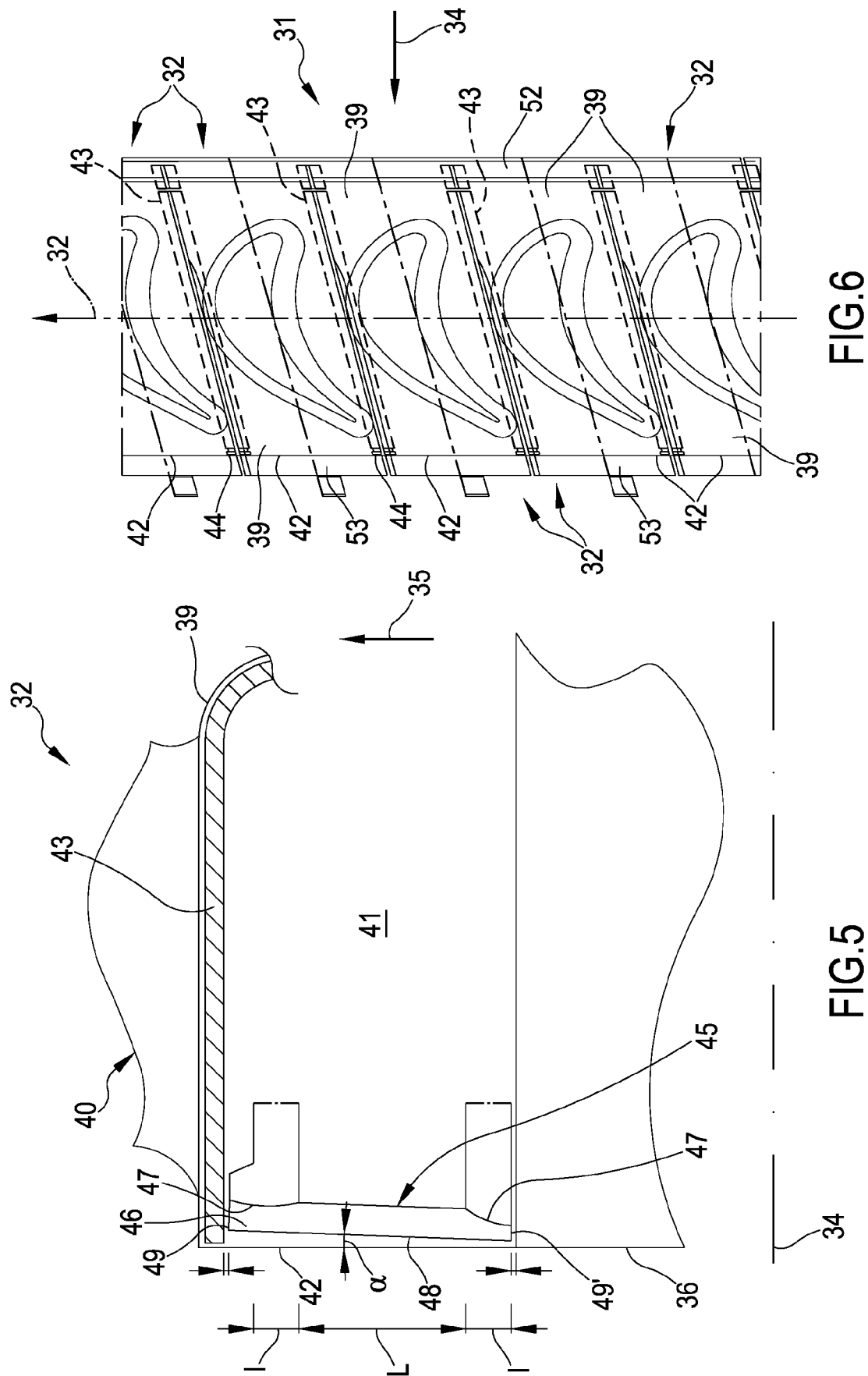


FIG.4





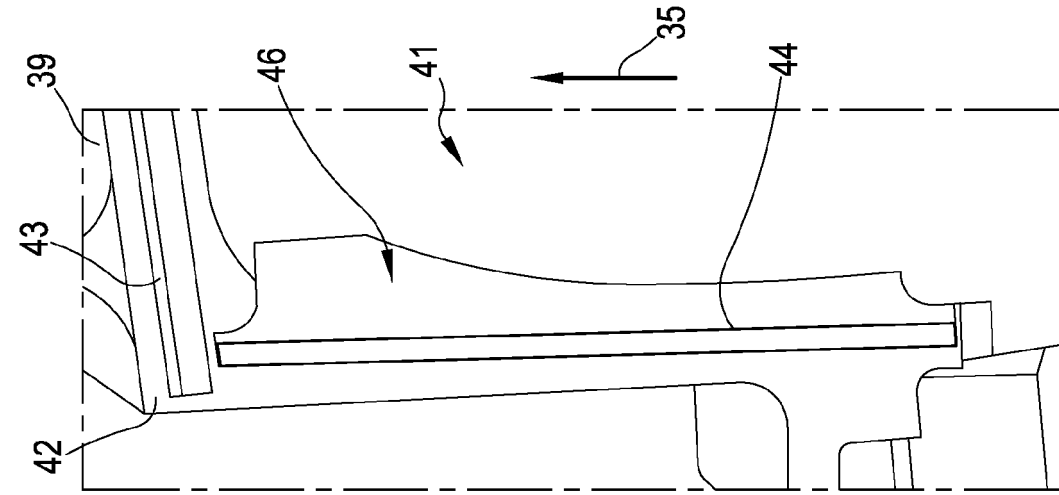


FIG.9

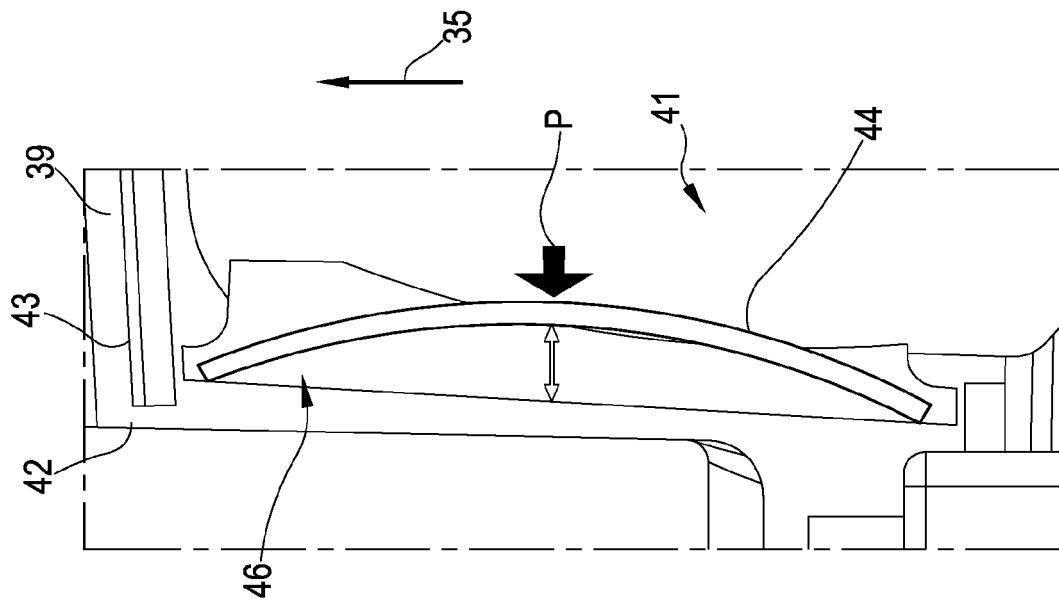


FIG.8

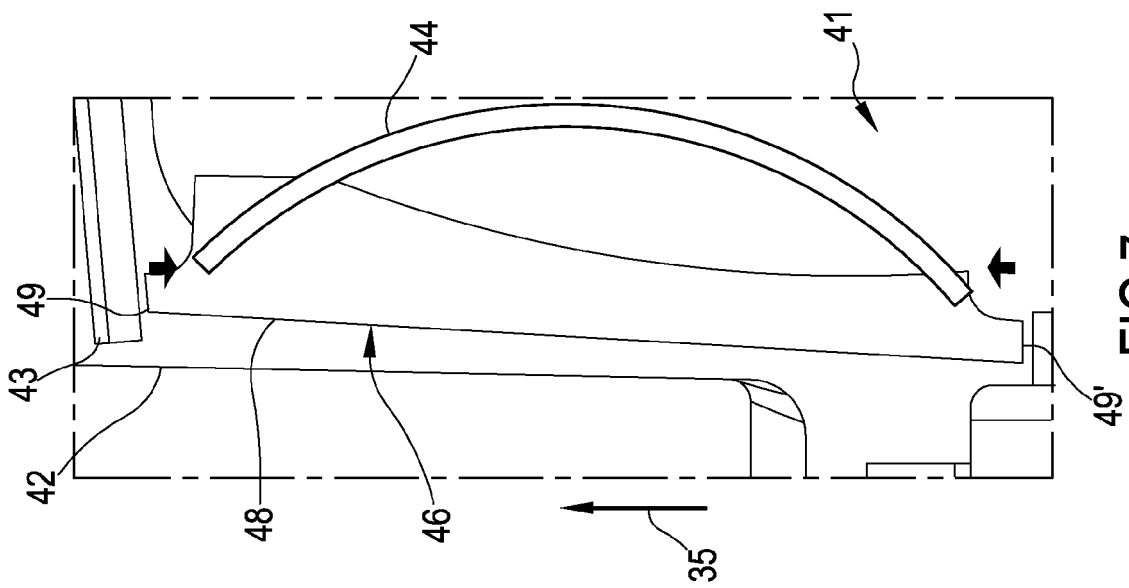


FIG.7



EUROPEAN SEARCH REPORT

Application Number
EP 16 20 7638

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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X	EP 2 843 197 A2 (ALSTOM TECHNOLOGY LTD [CH]) 4 March 2015 (2015-03-04)	1-4,8-10	INV. F01D11/00
Y	* paragraph [0024] - paragraph [0045]; figures 1, 2, 3, 5 *	5-7,11	
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Place of search Munich		Date of completion of the search 2 June 2017	Examiner Georgi, Jan
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EPO FORM 1503 03/02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 16 20 7638

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