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(54) **Axial flow turbine**

(57) The invention relates to an axial flow turbine having a shroud cavity (10) formed in the stator (4), rotor (3) or both, that circumscribes the shroud (6) of an airfoil (5). A fin (20) is disposed in an end cavity formed within the cavity downstream of the shroud (6). It is arranged within the end cavity so as to reduce secondary losses as leakage flow passing between the shroud (6) and either the stator (4) or rotor (3), depending on the orientation of the airfoil, rejoins the main flow in the flow passage (2).

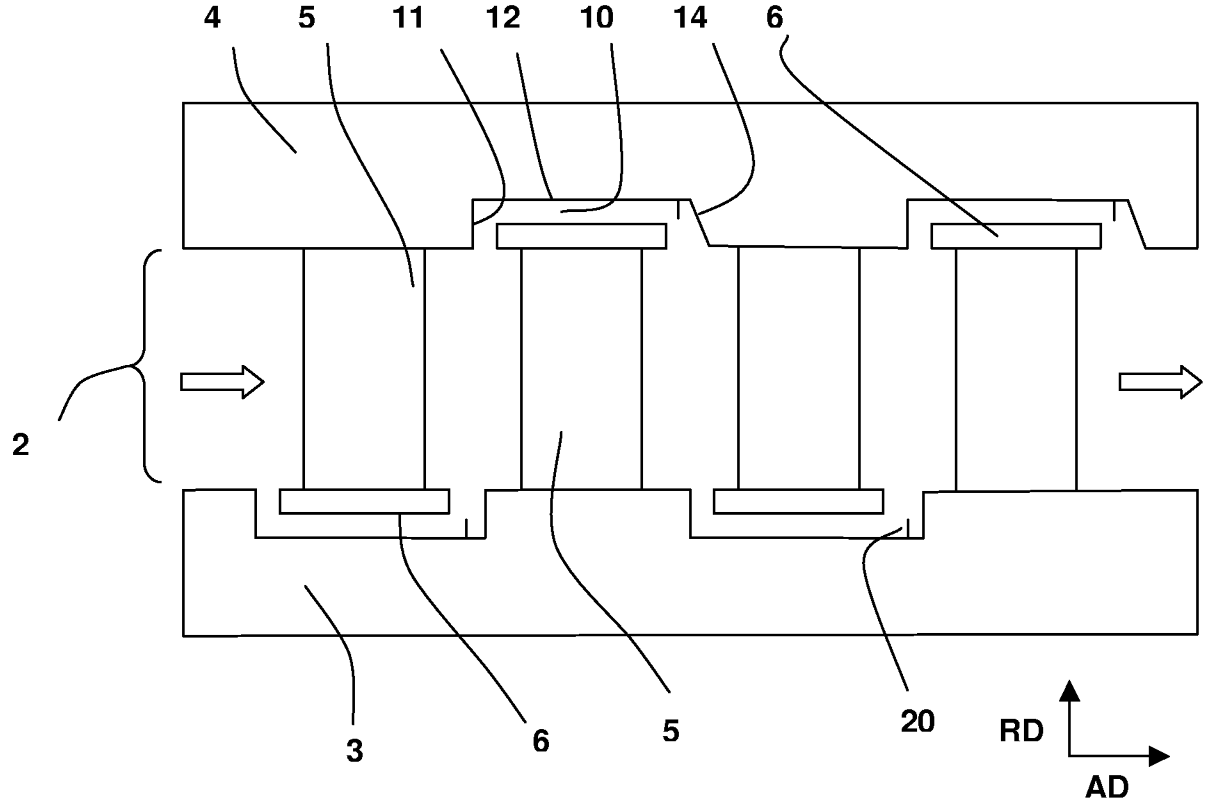

FIG. 1

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Description

TECHNICAL FIELD

[0001] The disclosure relates generally to axial flow turbines of the type that use a compressible working fluid, such as steam and gas turbines and specifically to the aerodynamic environment within shroud cavities in which airfoil shrouds are circumscribed.

BACKGROUND INFORMATION

[0002] An axial flow steam or gas turbine typically comprises rotating airfoils attached to a rotor wherein a cavity in the casing of the stator circumscribes the outer periphery of the rotating airfoils. Between the periphery of the rotating airfoils and the stator there typically is a gap through which a working fluid can leak. The leakage represents a loss in turbine efficiency. In many turbines, the leakage over the rotating airfoils is minimised by the fitting of a shroud and the further circumscribing of the shroud by a casing cavity. To further minimise leakage a seal may be provided between the casing cavity and shroud.

[0003] Fixed non-rotating airfoils are typically provided in steam and gas turbines. These non-rotating airfoils are fixed at one end to the stator and may have a shroud at another radially distant end, which, like rotating airfoils may also be circumscribed within a cavity. Unlike rotating airfoils, the cavity for a non-rotating airfoil is typically formed in the rotor. The gap formed between the shroud and hub suffers similar leakage losses to that of rotating airfoils and so is typically also provided with a seal.

[0004] Despite the differences between rotating and non-rotating airfoils, both types of airfoils when fitted with shrouds share the same problem of leakage flow flowing across their shrouds resulting in secondary flow as the leakage flow rejoins the main flow. This loss is exacerbated by the size and shape of an end cavity through which the leakage flow flows in order to reach the main flow. The end cavity, which is part of the cavity formed by the downstream end of the cavity and the shroud, is sized to accommodate axial expansion of the rotor during operation.

[0005] One method of reducing the turbulence created by this end cavity is to angle the end wall of the cavity from the radial direction towards the downstream flow direction. While such an arrangement can have a positive influence on turbulence such angulation requires additional axial space that can negatively impact the axial machine length, and/or axial distance between axially neighbouring airfoils.

[0006] Another solution is to place inserts or block in the end cavity. The effect of this is similar to that of contouring the end wall with the same disadvantage that the axial length of the end cavity must also be increased in order to avoid possible contact between the insert or block and the shroud.

SUMMARY

[0007] A means is provided to reduce secondary flow losses caused by shroud leakage flow as it re-enters the main flow stream via an end cavity that forms part of a shroud cavity circumscribing the shroud. This is achieved without increasing overall turbine length.

[0008] The disclosure attempts to address this problem by means of the subject matters of the independent claims. Advantageous embodiments are given in the dependent claims.

[0009] An aspect provides an axial flow turbine comprising a rotor, a row of circumferentially distributed airfoils, a shroud and a stator. The airfoils extend radially from the rotor across a flow passage end and have, at a radial distal end, a shroud having a downstream end. The stator has a shroud cavity, circumscribing the shroud that is defined by an upstream radial wall, an axially extending base wall and a downstream radial wall. The shroud cavity further comprises an end cavity that opens out into the flow passage. The downstream end of the shroud, a portion of the base wall and the downstream radial wall define this end cavity. Located in the end cavity and disposed on the portion of the base wall is a radial fin. The fin extends circumferentially around the stator and is adapted to deflect, in the direction of the flow passage, leakage flow entering the end cavity from a gap between the shroud and the base wall.

[0010] An aspect provides an axial flow turbine comprising a rotor, a row of circumferentially distributed airfoils, a shroud and a stator. The airfoils extend radially from the stator across a flow passage end and have, at a radial distal end, a shroud having a downstream end. The rotor has a shroud cavity, circumscribing the shroud that is defined by an upstream radial wall, an axially extending base wall and a downstream radial wall. The shroud cavity further comprises an end cavity that opens out into the flow passage. The downstream end of the shroud, a portion of the base wall and the downstream radial wall define this end cavity. Located in the end cavity and disposed on the portion of the base wall is a radial fin. The fin extends circumferentially around the rotor and is adapted to deflect, in the direction of the flow passage, leakage flow entering the end cavity from a gap between the shroud and the base wall.

[0011] While highly dependent on the exact dimensional arrangement and operating conditions, by calculations, it has been estimated that the placement of a fin in the end cavity may increase turbine efficiency by up to 0.4 % by deflecting the leakage flow so as to reduce secondary flow losses.

[0012] As compared to an insert a fin is more cost effective as it has less metal and further is does not restrict axial movement. That is if the shroud where to axially expand over the fin, damage would be limited to the bending of the fin and as a result would not require the shutting down of the machine for repair. As a result the end cavity axially length can be shortened as its sizing does not

need to consider the fin, thus achieving the combined benefit of a shorter length and efficiency gain.

[0013] Other aspects and advantages of the present invention will become apparent from the following description, taken in connection with the accompanying drawings wherein by way of illustration and example, exemplary embodiments of the invention are disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] By way of examples embodiments of the present disclosure are described more fully hereinafter with reference to the accompanying drawings, in which:

Figure 1 is a side cut view of a portion of a steam turbine with features of an exemplary embodiment of the disclosure; and

Figure 2 is an expanded view of an end cavity of Fig. 1.

DETAILED DESCRIPTION

[0015] Preferred embodiments of the present disclosure are now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosure. It may be evident, however, that the disclosure may be practiced without these specific details.

[0016] In this specification, lengths may be referred to in terms of the radial or axial dimensions whose direction is measured relative to the rotational axis of the rotor. Further, within this specification these terms are also taken to mean the radial or axial vector component of the length as measured from the end points of the referenced feature, as such, the radial or axial length maybe different to the actual length. For example, the length of a surface, which is curved but has end points that lie in the radial plain has a shorter radial length that actual length. Likewise were angles are described, the reference the angle of a feature is defined by a vector line drawn between the end points of the feature and not the discrete angles along portions of the feature.

[0017] An exemplary embodiment provides an axial flow steam turbine as shown in FIG. 1 that comprises a rotor 3 on which a row of circumferentially distributed rotating airfoils 5 extend radially into the main steam flow passage 2 of a steam turbine. The direction of flow, represented by arrows, defines the relative up and downstream location designations. At a radial distal end of the airfoils 5, that is at a point distal from the rotor 3, is a shroud 6 circumscribed by a shroud cavity 10. The shroud cavity 10 is formed in the stator 4 by an upstream radial wall 11, an axially extending base wall 12 and a downstream radial wall 14. The downstream end of the shroud 7 with a portion of the base wall 12 and the downstream radial wall 14 forms an end cavity within the shroud cavity 10. The purpose of this end cavity is to provide space for the typical axial expansion of the rotor 3 that results in the axial movement of the shroud 6. The end cavity opens out in the flow passage thus enabling leakage flow to pass through the gap between the shroud 6 and base wall 12 and rejoin the main steam flow.

[0018] An alternate exemplary embodiment provides an axial flow steam turbine as shown in FIG. 1 that comprises a stator 4 on which a row of circumferentially distributed fixed airfoils 5 extend radially into the main steam flow passage of the steam turbine. The direction of flow, represented by arrows, defines the relative up and downstream location designations. At a radial distal end of the airfoils 5, that is at a point distal from the stator 4, is a shroud 6 which is circumscribed by a shroud cavity 10 formed in the rotor 3 by an upstream radial wall 11, an axially extending base wall 12 and a downstream radial wall 14. The downstream end of the shroud 7, a portion of the base wall 12 and the downstream radial wall 14 form an end cavity within the shroud cavity 10. The purpose of this end cavity is to provide space for the typical axial expansion of the rotor 3 that results in the axial movement of the shroud 6. The end cavity opens out in the flow passage thus enabling leakage flow to pass through the gap between the shroud 6 and base wall 12 to reunite with the main steam flow.

[0019] Both these exemplary embodiments provide a circumferentially extending radial fin 20 in the end cavity that is disposed on a downstream portion of the base wall 12. The purpose of the fin 20 is to direction leakage flow that enters the end cavity from a gap between the shroud 6 and the base wall 12 back into the main passage flow in a way that secondary flow losses are reduced. This can be achieved by adapting the axial length of the fin 20.

[0020] A fin 20 is differentiated from a block or insert by having only one point of contact with the end cavity i.e. the base wall 12 and further by a large length to width ratio. As a result, a fin 20, depending on the materials it is made of, is inherently flexible. Therefore, if for example, a shroud 6 was to come in contact with a fin 20 for a short period of time, the fin 20 may flex or blend and as a result damage to both the shroud and fin 20 will be minimised. As a result, when designing the end cavity for axial expansion, the size of the end cavity does not need to consider the fin 20 unlike the case were inherently inflexible blocks and inserts are used in the end cavity for the purpose of reducing secondary losses. As a result, a fin 20 can be retrofitted to existing designs more easily than blocks and inserts and further due to their lower material weight are cheaper to manufacture.

[0021] Although a fin 20 is inherently flexible, by adapting the radial length of the fin 21, contact between the shroud 6 and the fin 20 can be avoided in all circumstances, eliminating the risk of even slight damage to the fin 20.

[0022] The shape of the base wall 12, shroud 6 and the gap is typically non-uniform throughout its length. Therefore the radial length of the fin 21, to avoid contact with the shroud 6, must be adapted taking in account of individual turbine configuration. In one exemplary embodiment, this is achieved by configuring the fin 20 to have a radial length 21 less than the radial width 16 of the gap between the downstream end of the shroud 7 and the base wall 12. The gap, in this specification, is defined as the radial gap at the downstream end of the shroud not including fins or other seal elements that are typically mounted on the shroud 6 and/or the corresponding base wall 12.

[0023] In order to reduce second losses from the deflection of the leakage flow by the fin 20, the fin 20 may be angled α from the radial in the downstream axial direction by greater than 0°. If the fin 20 is angled too far the negative benefit of turbulence created by the fin 20 may be greater than the benefit of the flow deflection. Therefore, in an exemplary embodiment, the fin 20 is angled no more than about 30°.

[0024] If the fin 20 is located too close to the downstream end of the shroud 7 the chances of contact with the shroud 6 increases. Therefore, in an exemplary embodiment, the fin 20 extends from a point located more than 30% along the axial length of the end cavity base wall portion 13, as taken in the flow direction.

[0025] If the fin 20 is located too far from the downstream end of the shroud 7, the radial end wall's 14 influence on flow deflection increases therefore reducing the effectiveness of the fin 20. Therefore, in an exemplary embodiment, the fin 20 extends from a point located less than 60% along the axial length of the end cavity base wall portion 13 as taken in the flow direction.

[0026] In a further exemplary embodiment the fin 20 is provided in an end cavity in which the radial length of the downstream radial wall 14 is between 0.5 and 3 times the axial length of the end cavity base wall portion 13. In another exemplary embodiment the downstream radial wall 14 is angled θ in the downstream direction by less than 10° from the radial. These arrangements provide suitable dimensional constraints for the end cavity that enable flow deflection by the fin 20 to be optimised. Beyond these limits aerodynamic efficiency may be lost.

[0027] Although the disclosure has been herein shown and described in what is conceived to be the most practical exemplary embodiment, it will be appreciated that the present invention can be embodied in other specific forms. For example although the exemplary embodiments provide relate to steam turbine the invention may be applied to gas turbines The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restrictive. The scope of the invention is indicated by the appended claims rather that the foregoing description and all changes that come within the meaning and range and equivalences thereof are intended to be embraced therein.

REFERENCE NUMBERS

[0028]

2	Flow passage
3	Rotor
4	Stator
5	One of a row of airfoils
6	Shroud
7	Downstream end of the shroud
10	Shroud cavity
11	Upstream radial wall
12	Base wall
13	Axial length of the end cavity portion of the base wall
14	Downstream radial wall
16	Shroud/Base wall radial gap
20	Fin
21	Radial length of fin
RD	Radial Direction
AD	Axial Direction
θ	Radial downstream wall angle
α	Fin angle

Claims

1. An axial flow turbine comprising:

a rotor (3);
a row of circumferentially distributed airfoils (5) extending radially from the rotor (3) into a flow passage;
a shroud (6), at a radial distal end of the row of the airfoils (5), having a downstream end (7);
a stator (4) with a shroud cavity (10) circumscribing the shroud (6), the shroud cavity (10) defined by:

an upstream radial wall (11);
an axially extending base wall (12); and
a downstream radial wall (14),

the shroud cavity (10) comprising an end cavity opening out into the flow passage that is formed by, the downstream end of the shroud (7), a portion of the base wall (12) and the downstream radial wall (14),
the turbine **characterised by** a radial fin (20) in the end cavity, disposed on the portion of the base wall (12),extending circumferentially around the stator (4) and adapted to deflect, in the direction of the flow passage, leakage flow entering the end cavity from a gap between the shroud (6) and the base wall (12).

2. An axial flow turbine comprising:

a stator (4);
a row of circumferentially distributed airfoils (5) extending radially from the stator (4) into a flow passage;

a shroud (6), at a radial distal end of the row of the airfoils (5), having a downstream end (7);
a rotor (3) with a shroud cavity (10) circumscribing the shroud (6), the shroud cavity (10) defined by:

an upstream radial wall (11);
an axially extending base wall (12); and
a downstream radial wall (14),

the shroud cavity (10) comprising an end cavity opening out into the flow passage that is formed by the downstream end of the shroud (7), a portion of the base wall (12) and the downstream radial wall (14),
the turbine **characterised by** a radial fin (20) in the end cavity, disposed on the portion of the base wall (12), extending circumferentially around the rotor (3) and adapted to deflect, in the direction of the flow passage, leakage flow entering the end cavity from a gap between the shroud (6) and the base wall (12).

3. The turbine of claim 1 or 2 wherein the radial length of the fin (21) is configured to preventing contact between the shroud (6) and the fin (20) caused by axial movement of the shroud (6).

4. The turbine of claim 3 wherein the radial length of the fin (21) is less than the radial width (16) of the gap between the downstream end of the shroud (7) and the base wall (12) so by preventing the contact between the shroud (6) and the fin (20) resulting from axial movement of the shroud (6).

5. The turbine of any one of claims 1 to 3 wherein the fin (20) is adapted to deflect leakage flow by angulation (α) of the fin (20) from the radial in the downstream axial direction by greater than 0° and less than about 30°.

6. The turbine of any one of claims 1 to 4 wherein the fin (20) extends from a point between 30% and 60% of the axial length of the end cavity base wall portion (13).

7. The turbine of any one of claims 1 to 5 wherein the radial length of the downstream radial wall (14) is between 0.5 and 3 times the axial length of the end cavity base wall portion (13).

8. The turbine of any one of claims 1 to 7 wherein the downstream radial wall (14) is angled (θ) from the radial in the downstream axial direction by less than 10°.

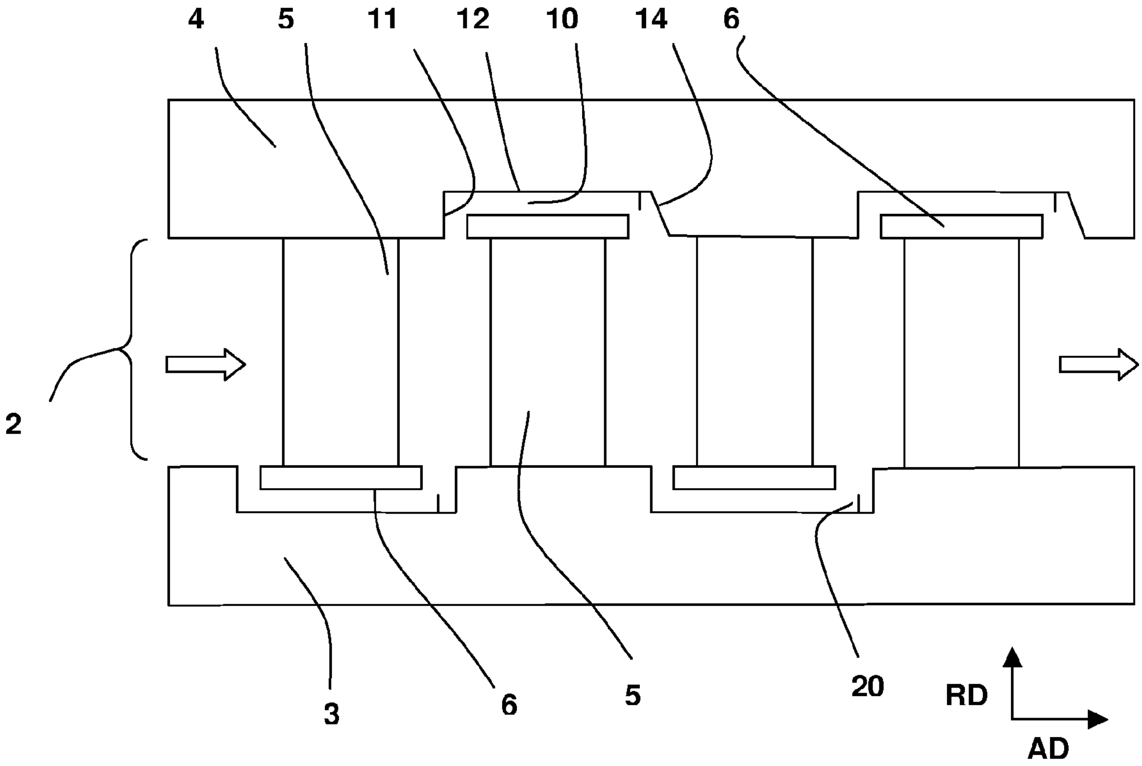

FIG. 1

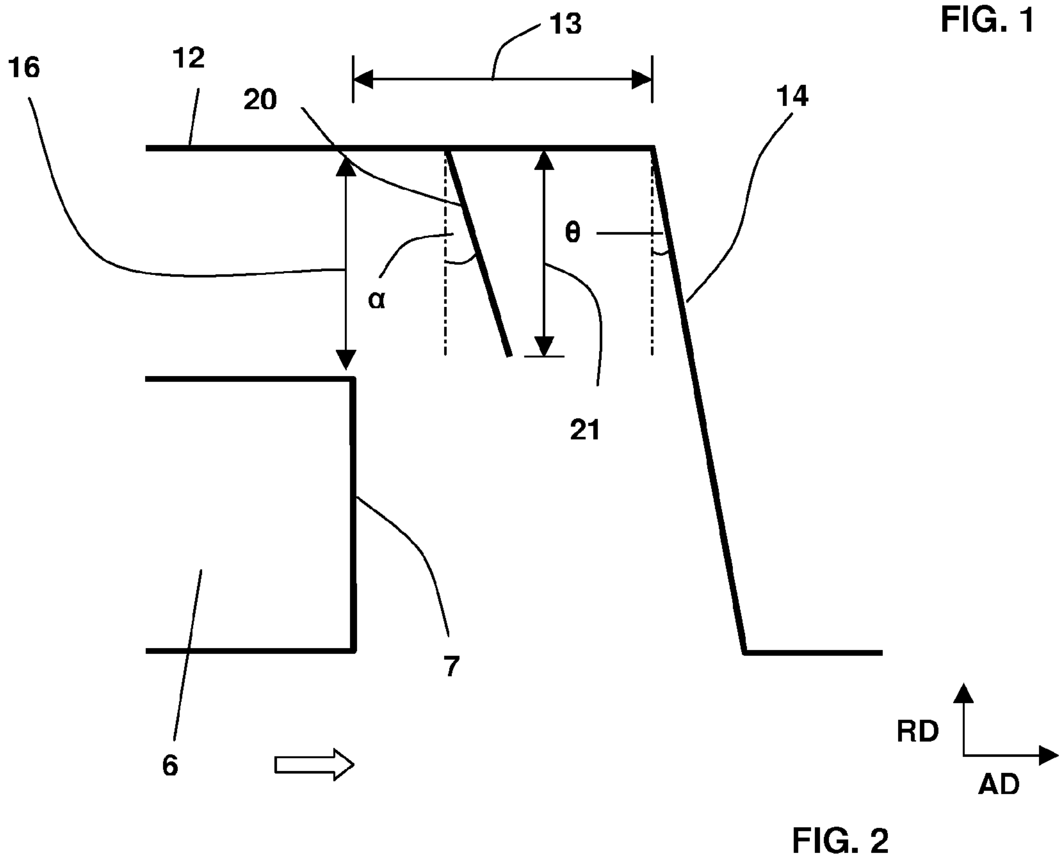

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 09 16 9234

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	12 March 2010	Rini, Pietro

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 16 9234

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82