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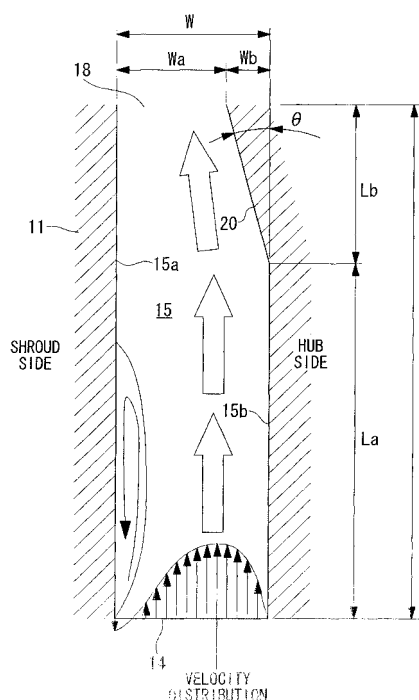
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(54) **CENTRIFUGAL COMPRESSOR**

(57) There is provided a centrifugal compressor having a diffuser structure in which airflow is unlikely to separate from a hub side wall surface on a hub side wall surface downstream side within a diffuser passage. In a centrifugal compressor provided with a diffuser passage 15 for recovering static pressure by slowing down discharged air from an outer circumferential end of an impeller that rotates within a housing 11, a hub side wall surface 15b of the diffuser passage 15 is provided with an inclined plane 20 that approaches toward a shroud side, in a position on a downstream side of a portion parallel with a normal line direction of a section surface of an impeller exit.

FIG. 1



Description

Technical Field

[0001] The present invention relates to a centrifugal compressor of a turbo charger or the like.

Background Art

[0002] Conventionally, a centrifugal compressor of a turbo charger or the like to be used for an internal combustion engine of a motor vehicle for example, is commonly known.

[0003] FIG. 5A is a sectional view showing a relevant section of a conventional centrifugal compressor. A centrifugal compressor 10 shown in the drawing compresses fluid such as gas and air introduced from outside a housing 11, by rotating an impeller 13 having a large number of blades 12, within the housing 11. The fluid flow (airflow) formed in this way travels through an impeller exit (Hereunder, also referred to as "diffuser entry") 14, being an outer circumferential end of the impeller 13, then through a diffuser passage 15 and a scroll 16, and is then delivered to the outside. Reference symbol 17 in the drawing denotes a shaft axis about which the impeller 13 rotates.

[0004] The diffuser passage 15 mentioned above is provided between the impeller exit 14 and the scroll 16, being a passage for recovering static pressure by slowing down the airflow discharged from the impeller 14. The diffuser passage 15 is normally formed from a pair of opposing wall surfaces. In the description below, one of the opposing wall surfaces is called a shroud side wall surface 15a and the other is called a hub side wall surface 15b.

[0005] In a turbo charger of a motor vehicle to be used in combination with an internal combustion engine, since a wide compressor operation range is required, a type of diffuser that does not have vanes (vaneless diffuser) is normally employed.

[0006] Incidentally, in recent years, in response to an increase in flow amount and pressure ratio of the centrifugal compressor 10, distortion of the airflow flowing into the diffuser passage 15 has become greater. It is thought that a flow with a large distortion flowing into the diffuser passage 15 results in the occurrence of a phenomenon known as surging, which determines the operation limit on the small flow amount side in the diffuser passage 15.

[0007] In the mechanism that gives rise to surging it is thought that surging occurs when a backflow area of the airflow reaches an exit side end section of the diffuser passage 15. Moreover, since the occurrence of the backflow area mentioned above is thought to be caused by a flow on the compressor shroud side within the diffuser passage 15, that is, distortion of the flow along the shroud side wall surface 15a, a diffuser structure for reducing such distortion in the flow is proposed.

[0008] The distortion in the flow mentioned above refers to the flow velocity distribution or pressure distribu-

tion being in a non-uniform state. Conventional techniques for making this uniform employ a structure or method that changes a flow passage sectional area of the diffuser passage 15, or that utilizes a circulation passage or the like. Each of such conventional techniques has a focus on reducing distortion that occurs on the entry side (impeller exit 14 side) of the diffuser passage 15.

[0009] As a conventional technique for reducing the distortion mentioned above, for example, provision of a convex section or a concave section for changing the flow passage sectional area on the wall surface of the diffuser passage 15 has been proposed. Such a convex section or concave section regularize the airflow along the circumferential direction by changing the passage shape in the circumferential direction, thereby enabling an improvement in compression efficiency. (for example, refer to Patent Document 1).

[0010] Patent Document 1: Japanese Unexamined Patent Application, Publication No. Hei 10-176699

Disclosure of Invention

[0011] However, in a small centrifugal compressor such as a turbo charger for a motor vehicle in particular, it is difficult to measure the internal flow of the airflow flowing within the diffuser passage. Therefore, since distortion in actual internal flow has yet to be sufficiently understood and furthermore since the phenomena up to the point of surging have not been explained, it is necessary to understand these and develop an effective surging prevention method to widen the operation range of the centrifugal compressor.

[0012] As shown in FIG. 5B, the conventional diffuser passage 15 generally has a shape in which a pair of opposing wall surfaces, namely a shroud side wall surface 15a and a hub side wall surface 15b, are in a parallel form, so that an axial direction flow passage width W of the diffuser passage 15 is constant in the circumferential direction. Having examined a flow pattern of up to surging, by carrying out internal flow measurement using a model for the conventional diffuser passage 15 configured in this way, it was revealed that before the backflow area (shown with an arrow A in the drawing) forms a flow area that reaches the diffuser exit 18 side end section of the diffuser passage 15, the airflow separates from the hub side wall surface 15b in the vicinity of the diffuser exit 18, forming another backflow area (shown with an arrow B in the drawing). That is to say, it is thought that it is not a shroud side backflow area A, but a hub side backflow area B which causes surging to occur.

[0013] It is thought that such a flow separation from the hub side wall surface 15b occurring in the vicinity of the diffuser exit 18 cannot be suppressed by a conventional technique, as disclosed in Patent Document 1 for example, in which airflow is regularized along the circumferential direction by changing the passage shape in the circumferential direction.

[0014] In consideration of the above circumstances,

an object of the present invention is to provide a centrifugal compressor having a diffuser structure in which airflow is unlikely to separate from a hub side wall surface on the hub side wall surface downstream side within the diffuser passage (in the vicinity of the diffuser exit).

[0015] The present invention employs the following means to solve the above problems.

[0016] A centrifugal compressor according to the present invention is a centrifugal compressor provided with a diffuser passage for recovering static pressure by slowing down discharged air from an outer circumferential end of an impeller that rotates within a housing, wherein a hub side wall surface of the diffuser passage is provided with an inclined area that approaches toward a shroud side, in a position on a downstream side of a portion parallel with a normal line direction of a section area of an impeller exit.

[0017] According to such a centrifugal compressor, since the hub side wall surface of the diffuser passage is provided with the inclined area that approaches the shroud side, in the position on the downstream side of the portion parallel with the normal line direction of the section area of the impeller exit, the radial direction velocity of the low velocity area that occurs on the hub side wall surface increases in the inclined area, and the radial direction velocity distribution within the diffuser passage is made uniform.

[0018] The inclined area in this case is a portion of an inclined plane, a curved surface, or a stepped plane, formed on the hub side wall surface for example, and must be such that, in this inclined area, the axial direction flow passage width of the diffuser passage narrows down from the upstream side toward the downstream side by inclining the hub side wall surface so as to approach the opposed shroud side wall surface as it approaches the downstream side.

[0019] In the above aspect of the invention, a preferable longitudinal position of the inclined area in the diffuser passage, on a proportional scale of 0 (the base point) as the diffuser entry to 1 as the diffuser exit, is in the area of the downstream side with respect to the position between 0.3 and 0.7.

[0020] Moreover, in the above aspect of the invention, it is preferable that the inclined area provided in the diffuser passage be such that the maximum value of an amount of projection of the inclined area from the hub side wall surface toward the shroud side wall surface is set to approximately 1/3 to 1/5 of the passage width, being equivalent to the size of the measured backflow area.

[0021] Furthermore, in the above aspect of the invention, the preferable inclination angle is less than or equal to 20 degrees based on the normal line of the impeller exit section when the inclined area is taken as a plane. However, a more preferable inclination angle is between 2 degrees and 10 degrees, inclusive, based on the normal line of the impeller exit section. An excessively large inclination angle is not preferable, as the airflow is re-accelerated due to the reduction in the passage area in

this case.

[0022] According to the present invention described above, since on the hub side wall surface of the diffuser passage there is provided the inclined area that approaches the shroud side in the position on the downstream side of the portion parallel to the normal line of the impeller exit section, the radial direction velocity of a low velocity area that occurs on the hub side wall surface increases in this inclined area. Therefore, the radial direction velocity distribution within the diffuser passage is made uniform, and separation of the airflow is unlikely to occur locally, so that the surge flow rate can be reduced and the compressor operation range can be widened.

[0023] Moreover, the present invention described above is suited for widening the operation range of a small centrifugal compressor provided with a vaneless diffuser, such as a turbo charger for a motor vehicle, which requires a particularly wide compressor operation range.

Brief Description of Drawings

[0024]

[FIG. 1] is a sectional view of a diffuser passage showing a first embodiment of a centrifugal compressor according to the present invention.

[FIG. 2] is a sectional view showing a first modified example of FIG. 1.

[FIG. 3] is a sectional view showing a second modified example of FIG. 1.

[FIG. 4] is a sectional view of a diffuser passage showing a second embodiment of a centrifugal compressor according to the present invention.

[FIG. 5A] is a sectional view showing a relevant section of the centrifugal compressor.

[FIG. 5B] is a sectional view showing a conventional structure of a diffuser passage.

Explanation of Reference Signs:

[0025]

10:	Centrifugal compressor
11:	Housing
12:	Impeller
14:	Impeller exit (diffuser entry)
15, 30:	Diffuser passage
15a, 30a:	Shroud side wall surface
15b, 30b:	Hub side wall surface
16:	Scroll
18:	Diffuser exit
20:	Inclined plane (inclined area)
21:	Inclined curved surface (inclined area)
22:	Inclined inflected line (inclined area)
33:	Shroud side inclined section (inclined area)

Best Mode for Carrying Out the Invention

[0026] Hereunder an embodiment of a centrifugal compressor according to the present invention is described, based on the drawings.

[0027] As shown in FIG. 5A, a centrifugal compressor 10 is provided with a diffuser passage 15 that recovers static pressure by reducing the velocity of a discharged air from an outer circumferential end of an impeller 13 that rotates within a housing 11. The diffuser passage 15 is provided so as to connect between an impeller exit (diffuser entry) 14 and a scroll 16, and is formed between a pair of opposing wall surfaces that comprise a shroud side wall surface 15a and a hub side wall surface 15b.

[0028] FIG 1 is a sectional view of the diffuser passage 15 showing a first embodiment. Discharged air (indicated with white arrows in the drawing) coming from the outer circumferential end of the impeller 13 is introduced in the diffuser passage 15 through the diffuser entry 14, is guided through the passage between the shroud side wall surface 15a and the hub side wall surface 15b, and flows out from a diffuser exit 18 into the scroll 16.

[0029] In the embodiment shown in the drawing, the hub side wall surface 15b of the diffuser passage 15 is provided with an inclined plane 20 that approaches the direction of the shroud side wall surface 15a in a position on the downstream side in a portion parallel with a normal line of the area of the impeller exit. This inclined plane 20 is an inclined area, formed on the hub side wall surface 15b of the diffuser passage 15, that becomes closer to the shroud side wall surface 15a as the distance from the diffuser entry 14 increases, approaching the diffuser exit 18 and narrowing an axial direction flow passage width W , which is a distance between the opposing wall surfaces, down to W_a .

[0030] That is to say, in the diffuser passage 15 that has a flow passage length L as measured along the normal line direction, the inclined area formed by the inclined wall surface 20 is inclined toward the shroud side wall surface. This inclined area forms a downstream portion having a flow passage length L_b and begins at the end of the upstream portion of the passage that has a flow passage length L_a and has its sides parallel to the normal line direction. Here, taking 1 as the flow passage length L , the preferred length of the downstream portion L_b , which becomes the inclined area, is a portion remaining on the downstream side where the length L_a of the upstream portion parallel with normal line direction is 0.3 to 0.7. In other words, the preferred position for providing the inclined area in the lengthwise direction of the diffuser passage 15 may be set so that, where the flow passage length from the diffuser entry 14 which is taken as a base point (0), to the diffuser exit 18, which is taken as an end point (1), is taken as L ($L=1$), the length L_a of the upstream portion is set at a ratio of 0.3 to 0.7, and the length L_b of the downstream portion is set at a ratio of 0.7 to 0.3. Therefore, since the flow passage length L is the total length of the length L_a of the upstream portion and the

length L_b of the downstream portion ($L = L_a + L_b$), the total length L of the upstream portion length L_a and the downstream portion length L_b is always "1".

[0031] Moreover, it is preferable that the inclined area provided in the diffuser passage 15 be such that a projection amount of the inclined wall surface from the hub side wall surface 15b to the shroud side wall surface 15a is set to be approximately 1/3 to 1/5 of the passage width at the diffuser exit 18, where the projection amount of the inclined wall surface 20 reaches its maximum value W_b . That is to say, since the maximum value W_b of the projection amount is 1/3 to 1/5 W ($W_b \approx 1/3$ to $1/5W$), the axial direction flow passage width W_a narrowed by the inclined wall surface 20 is set to be approximately 2/3 to 4/5 of the axial direction flow passage width W ($W_a \approx 2/3$ to $4/5W$).

[0032] Moreover, as is the case with the inclined wall surface 20 mentioned above, the angle of inclination θ formed between a plane surface of the inclined area and the normal line of the impeller exit section, is preferably set less than or equal to 20 degrees. However, a further preferable angle of inclination θ is greater than or equal to 2 degrees and less than or equal to 10 degrees based on the normal line of the impeller exit section.

[0033] The normal line and normal line direction of the impeller exit section mentioned above refers to a straight line or direction that extends radially outward from an axial center line 17 of rotation of the impeller 13 and passes the impeller exit section, and it practically approximates the airflow direction.

[0034] As described above, the diffuser passage 15 provided with the inclined area formed by the inclined wall surface 20 is provided with: an upstream side area where the shroud side wall surface 15a and the hub side wall surface 15b are both parallel with the normal line direction and the axial direction flow passage width W is constant; and an inclined area on the downstream side where the axial direction flow passage width W to the diffuser exit 18 side is narrowed by the inclined wall surface 20, in which the hub side wall surface 15b inclines toward the shroud side wall surface 15a.

[0035] Therefore the airflow introduced from the diffuser entry 14 is slowed down by flowing through the diffuser passage 15, and recovers its static pressure. However, at this time, on the downstream side closer to the diffuser exit 18, the airflow in a low velocity area, which occurs in the vicinity of the wall surface and is thought to cause the airflow to separate from the hub side wall surface 15b, is guided to the inclined wall surface 20 so that it gradually flows toward the shroud side wall surface 15a.

[0036] The low velocity area in this case is an area where a velocity component in the radial direction from the diffuser entry 14 toward the diffuser exit 18 is low. In the example shown in the drawing, the radial direction corresponds to the normal line direction.

[0037] As a result, the airflow in the low velocity area that has occurred in the vicinity of the wall surface of the

hub side wall surface 15b increases its velocity component in the radial direction. Therefore, in the diffuser passage 15, the velocity distribution in the radial direction becomes uniform and flow separation is unlikely to occur locally.

[0038] As described above, if flow separation is unlikely to occur locally in the diffuser passage 15, the surge flow rate can be reduced, enabling the operation range of the centrifugal compressor to be widened. In particular, if the invention is applied in the case where a wide range of compressor operation is required in a small sized centrifugal compressor such as a turbo charger provided with a vaneless diffuser, widening of the range can be easily achieved.

[0039] Incidentally, considering the case of providing a similar inclined area on the shroud side wall surface 15a, the axial direction flow passage width W becomes narrower in the opposite direction as it approaches the diffuser exit 18. However, since there is no low velocity area, which is thought to be a cause of flow separation, present in close proximity to the wall surface of the shroud side wall surface 15a in the vicinity of the diffuser exit 18, the airflow guided to the inclined wall surface 20 is accelerated by gradually flowing toward the hub side wall surface 15b. Therefore, a difference between the accelerated velocity on the shroud side wall surface 15 and the velocity on the hub side wall surface 15b, in which the low velocity area is present, increases, and hence non-uniformity of the velocity distribution in the radial direction increases.

[0040] Next, a first modified example of the inclined area mentioned above is described, based on FIG. 2. The same reference symbols are given to parts that are the same as in the above embodiment, and detailed descriptions thereof are omitted.

[0041] In this first modified example, in place of the inclined plane 20 in FIG. 1, an inclined curved surface 21 forms an inclined area. This inclined curved surface 21 is the same as the inclined plane 20 with respect to the preferred position along the diffuser passage length direction in which the inclined area is to be provided (ratio of length Lb), and with respect to the maximum value Wb of the projection amount from the hub side wall surface 15b toward the shroud side wall surface 15a, and the curvature may be appropriately set to satisfy these conditions. The curved surface in this case may be either a concave curved surface or convex curved surface when seen from inside the diffuser passage 15.

[0042] Since the radial direction velocity component of the low velocity area airflow that has occurred in the vicinity of the wall surface of the hub side wall surface 15b also increases even when the inclined curved surface 21 provided is formed by such an inclined area, the velocity distribution in the radial direction is made uniform so that flow separation becomes unlikely to occur locally.

[0043] Therefore, the surge flow rate can be reduced, and hence the operation range of the centrifugal compressor can be widened and, in particular, if the invention

is applied in a case where a wide range of compressor operation is required in a small size centrifugal compressor provided with a vaneless diffuser, the compressor operation range can be easily widened.

5 **[0044]** Next, a second modified example of the inclined area mentioned above is described, based on FIG. 3. The same reference symbols are given to parts that are the same as in the above embodiment, and detailed descriptions thereof are omitted.

10 **[0045]** In this second modified example, in place of the inclined plane 20 in FIG. 1, an inclined inflected line 22 forms an inclined area. This inclined inflected line 22 is formed from a plane inclined section 22a and a parallel section 22b on the diffuser exit 18 side, the parallel section 22b in this case being parallel to the shroud side wall surface 15a and the hub side wall surface 15b.

15 **[0046]** Moreover, this inclined inflected line 22 is the same as the inclined plane 20 with respect to the preferred position along the diffuser passage length direction in which the inclined area is to be provided (ratio of length Lb), and with respect to the maximum value Wb of the projection amount from the hub side wall surface 15b toward the shroud side wall surface 15a.

20 **[0047]** Since the radial direction velocity component of the low velocity area airflow that has occurred in the vicinity of the wall surface of the hub side wall surface 15b also increases even when the inclined inflected line 22 provided is formed by such an inclined area, the velocity distribution in the radial direction is made uniform so that flow separation becomes unlikely to occur locally.

25 **[0048]** Therefore, the surge flow rate can be reduced, and hence the operation range of the centrifugal compressor can be widened and, in particular, if the invention is applied in a case where a wide range of compressor operation is required in a small size centrifugal compressor provided with a vaneless diffuser, the compressor operation range can be easily widened.

30 **[0049]** The inclined inflected line 22 shown in the drawing is a combination of the inclined section 22a and the parallel section 22b. However, an inclined section 22a of two or more steps may be combined, and furthermore, a curved surface may also be combined.

35 **[0050]** FIG. 4 is a sectional view showing a second embodiment of the centrifugal compressor according to the present invention. The same reference symbols are given to parts that are the same as in the first embodiment, and detailed descriptions thereof are omitted.

40 **[0051]** In the present embodiment, a diffuser passage 30 is divided into three areas. Specifically, from the upstream side, a hub side inclined section 31, a parallel section 32 parallel with the normal line direction of the impeller exit section, and a shroud side inclined section 33 are integrally connected. Therefore, compared to the first embodiment shown in FIG. 1, the hub side inclined section 31 is added on the most upstream side, and, in the shroud side inclined section 33, the shroud side wall surface 30a and the hub side wall surface 30b are arranged parallel with each other so as to be inclined toward

the shroud side at the same inclination angle.

[0052] When employing this kind of configuration also, in the shroud side inclined section 33 of the diffuser passage 30, the hub side wall surface 30b is provided with an inclined area that approaches the shroud side in a position on the downstream side of the parallel section 32, which is a portion parallel with the normal line of the impeller exit section. That is to say, by having the hub side wall surface 30b of the shroud side inclined section 33 approach the shroud side, an inclined area having the same effect as that of the inclined plane 20 mentioned above is formed.

[0053] As a result, since radial direction velocity component of the low velocity area airflow that has occurred in the vicinity of the wall surface of the hub side wall surface 30b is increased by the hub side wall surface 30b that serves as an inclined plane similar to the inclined plane 20, the velocity distribution in the radial direction is made uniform so that flow separation becomes unlikely to occur locally in the diffuser passage 30.

[0054] Therefore, the surge flow rate can be reduced, and hence the operation range of the centrifugal compressor can be widened and, in particular, if the invention is applied in a case where a wide range of compressor operation is required in a small size centrifugal compressor provided with a vaneless diffuser, the compressor operation range can be easily widened.

[0055] As described above, on the hub side wall surface 15a of the diffuser passage 15, since the inclined area that approaches the shroud side is provided in a position on the downstream side of the portion parallel with the normal line direction of the impeller exit section, the radial direction velocity of the low velocity area that occurs on the hub side wall surface 15a increases, and the radial direction velocity distribution within the diffuser passage 15 is made uniform. Therefore, airflow is unlikely to separate locally from the wall surface in the vicinity of the diffuser exit 18 of the diffuser passage 15, and hence the surge flow rate can be reduced and the compressor operation range can be widened.

[0056] The present invention is not limited to the above embodiments and can be appropriately modified without departing from the scope of the present invention.

Claims

1. A centrifugal compressor provided with a diffuser passage for recovering static pressure by slowing down discharged air from an outer circumferential end of an impeller that rotates within a housing, wherein a hub side wall surface of said diffuser passage is provided with an inclined area that approaches toward a shroud side, in a position on a downstream side of a portion parallel with a normal line direction of a section area of an impeller exit.

FIG. 1

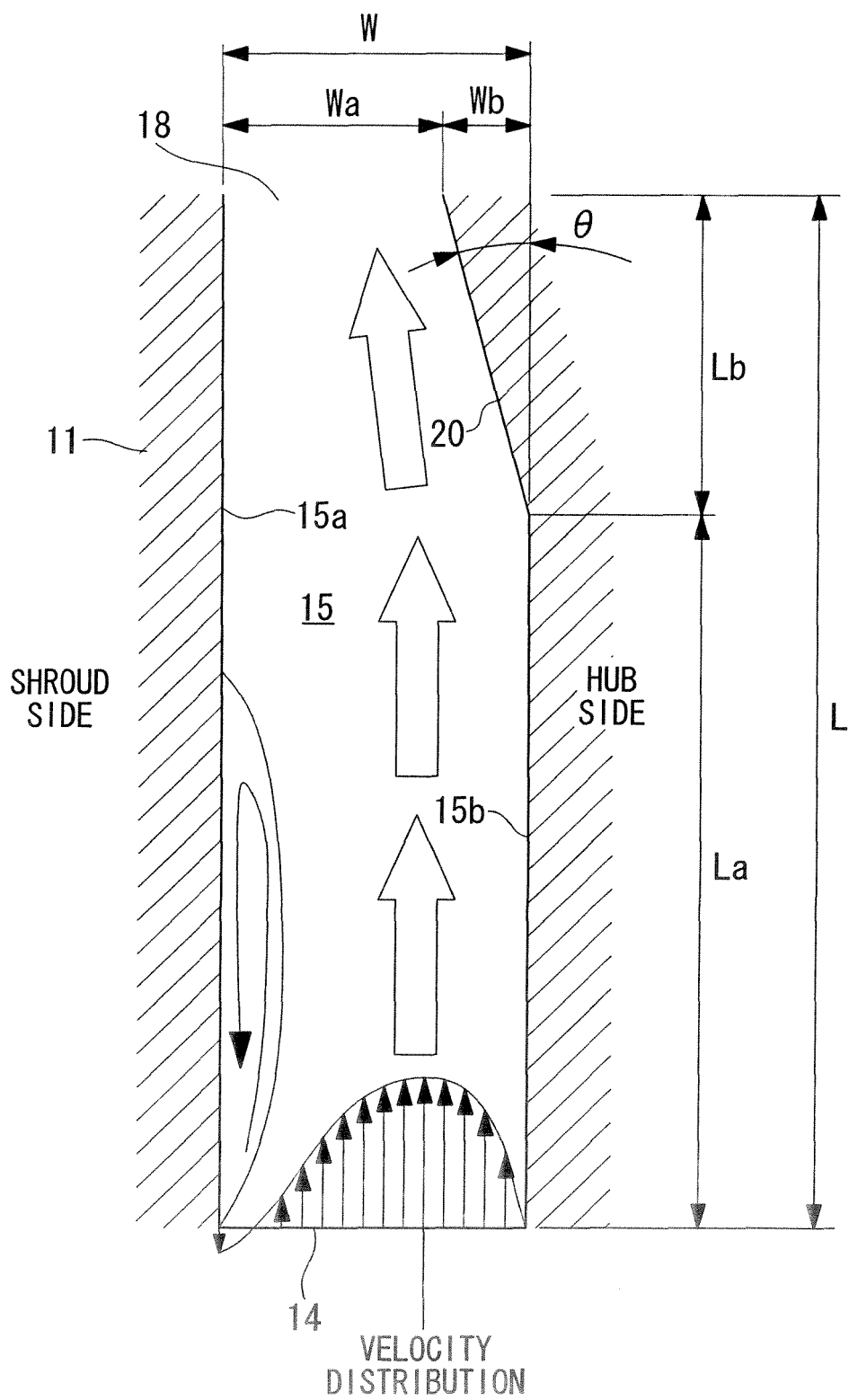


FIG. 2

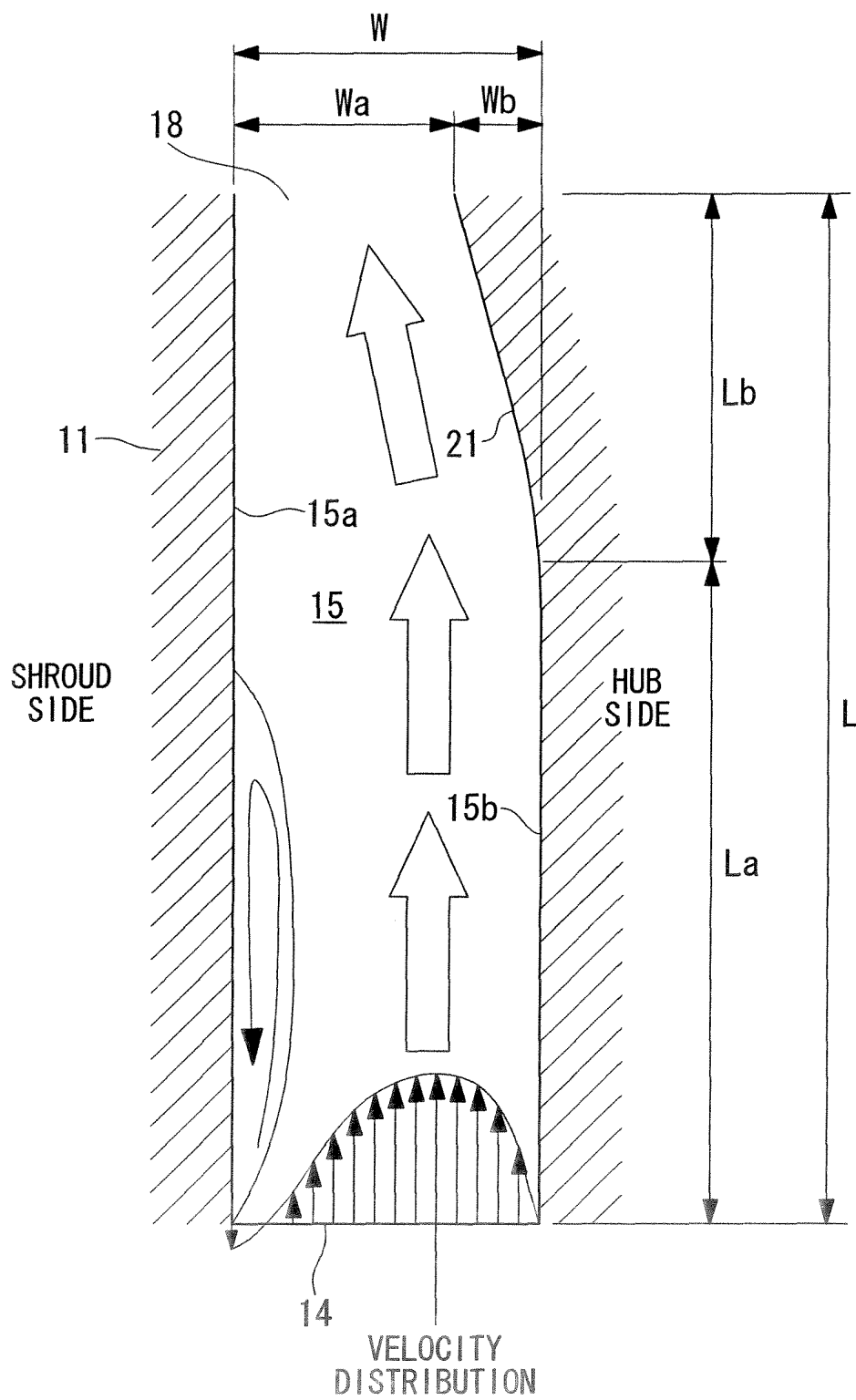


FIG. 3

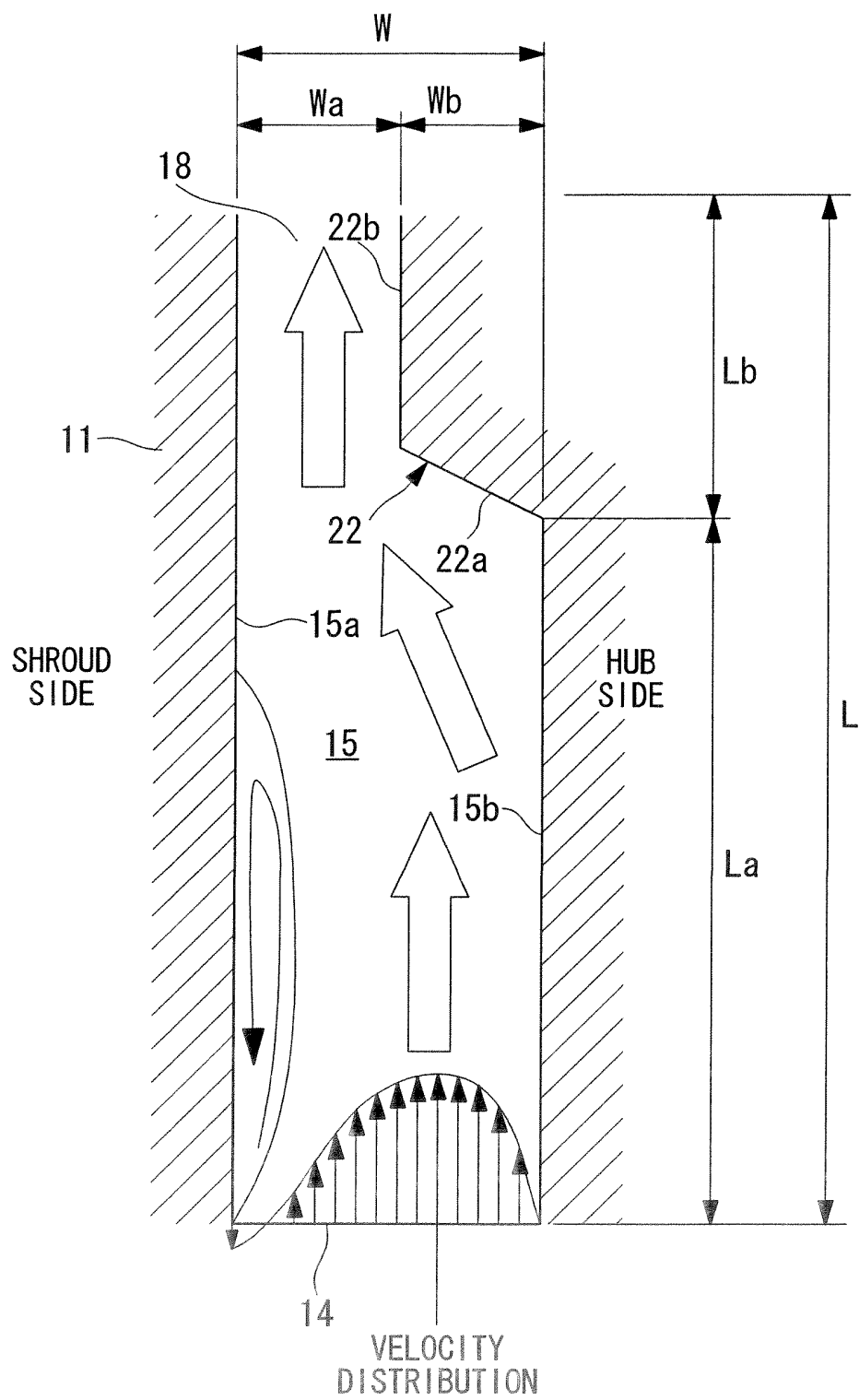


FIG. 4

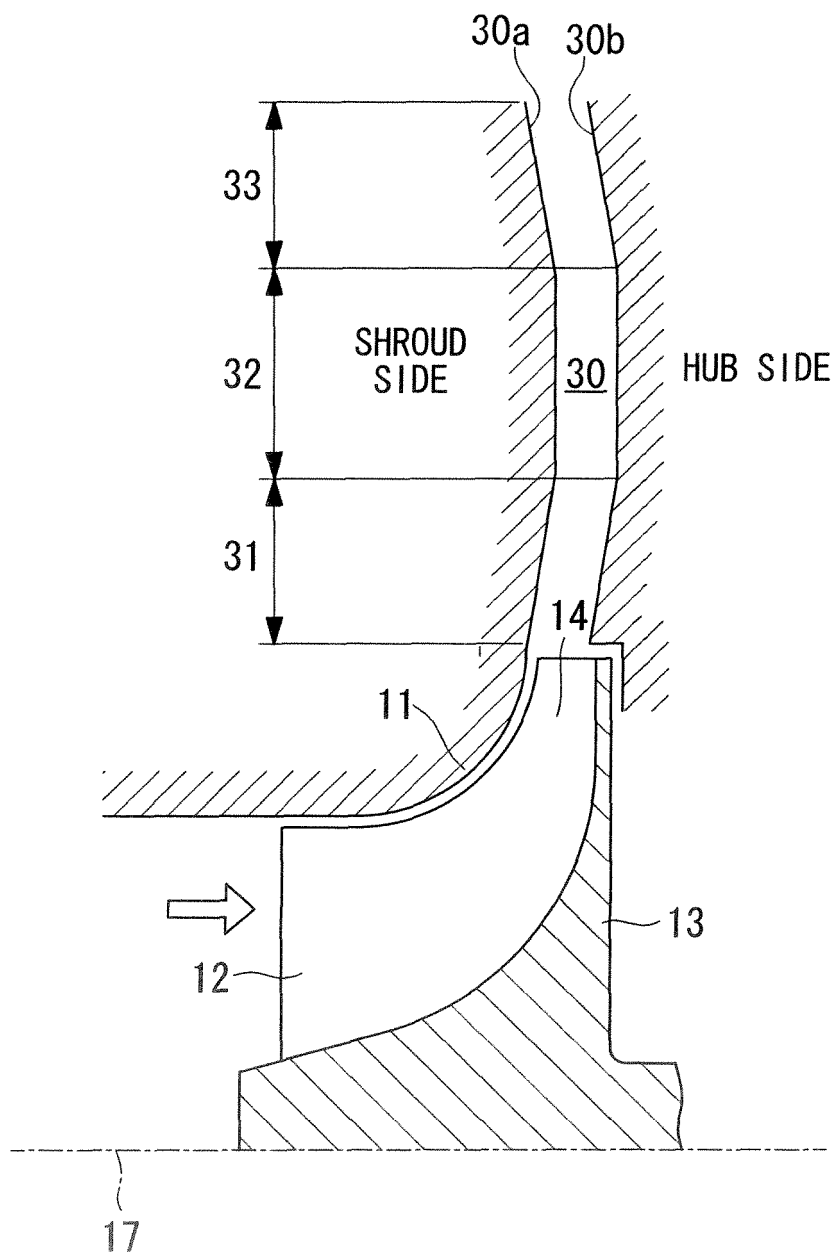


FIG. 5A

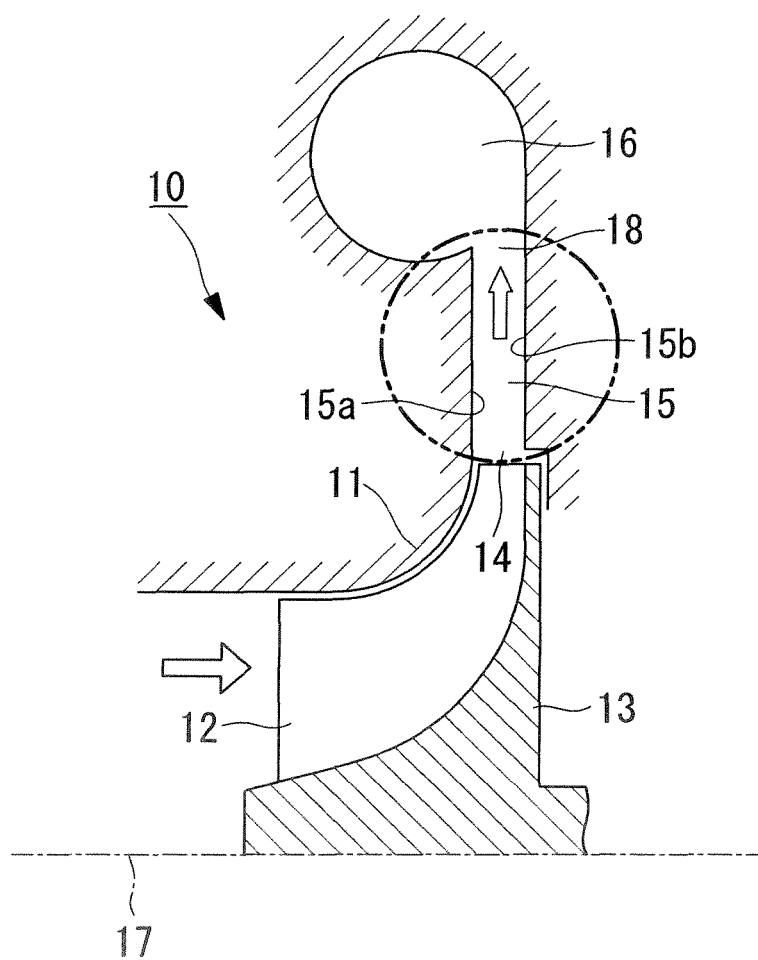
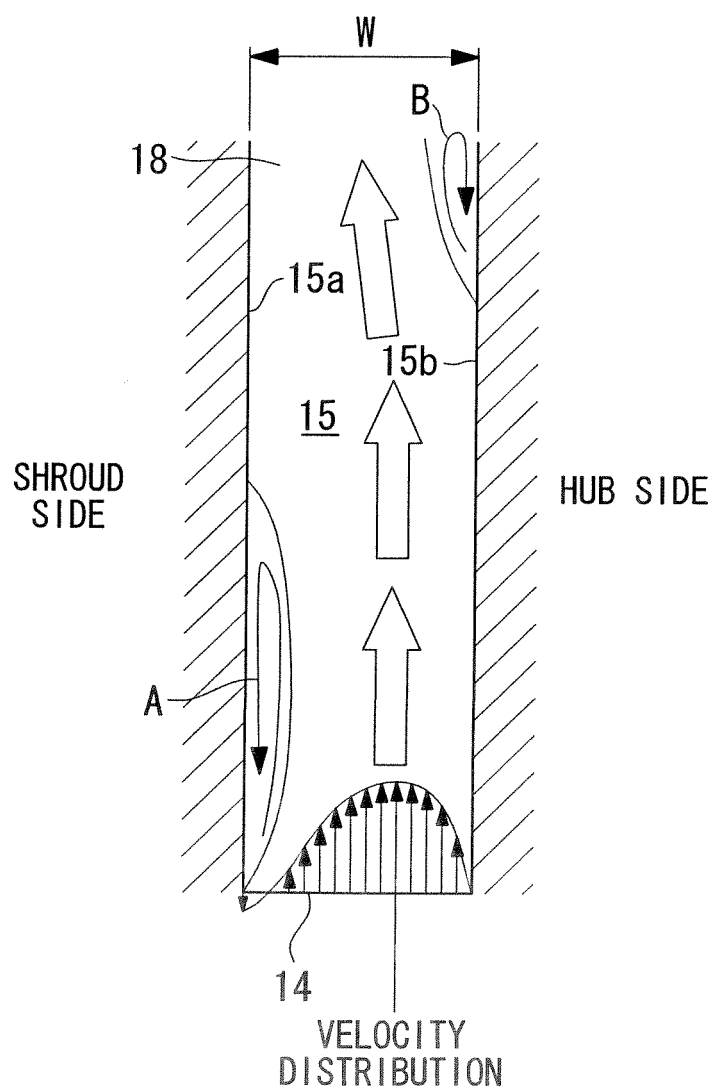


FIG. 5B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/052391

A. CLASSIFICATION OF SUBJECT MATTER

F04D29/44 (2006.01) i

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)

F04D29/44

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 69737/1988 (Laid-open No. 173426/1989) (Nissan Motor Co., Ltd.), 08 December, 1989 (08.12.89), Description, page 4, line 17 to page 5, line 8; Fig. 1 (Family: none)	1
X	JP 11-257291 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 21 September, 1999 (21.09.99), Par. Nos. [0014] to [0015]; Fig. 1 (Family: none)	1

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search
15 March, 2007 (15.03.07)Date of mailing of the international search report
27 March, 2007 (27.03.07)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/052391

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 58918/1978 (Laid-open No. 161007/1979) (Mitsubishi Heavy Industries, Ltd.), 10 November, 1979 (10.11.79), Description, page 3, line 20 to page 5, line 10; Fig. 6 (Family: none)	1
X	WO 1997/033092 A1 (Hitachi, Ltd.), 12 September, 1997 (12.09.97), Description, page 10, lines 15 to 21; Fig. 5 & EP 0886070 A1 & US 6203275 B1 & DE 69628462 T2	1

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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