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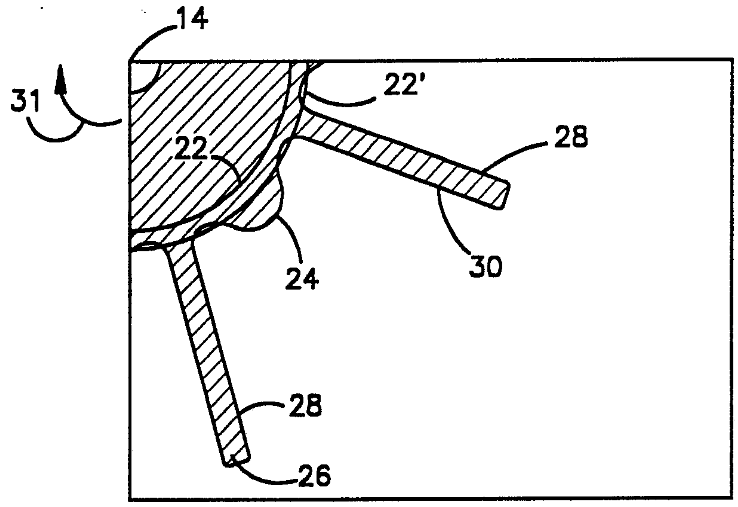
(54) Title: ARBITRARY HUB FOR CENTRIFUGAL IMPELLERS



(57) Abstract

A centrifugal impeller includes a hub formed about an axis of rotation (14) with a plurality of substantially radially extending blades (26) affixed to the hub. The blades have a height measured in a radial direction from the hub. An imaginary plane extending in a direction normal to the axis of rotation is used to define a cross-sectional view of the impeller. A first (22) and a second (22') concentric circle are formed in the plane with the center of the concentric circle being the axis of rotation. The first circle passes through a point on the hub located closest to the axis of rotation. The second circle has a radius greater than the first circle by an amount equal to five percent of the blade height, wherein a portion (24) of the hub extends outside of the second circle.

ARBITRARY HUB FOR CENTRIFUGAL IMPELLERS

BACKGROUND OF THE INVENTION

This invention relates generally to centrifugal impellers and more particularly to arbitrary hub designs for centrifugal impellers.

In the prior art centrifugal impellers, each point on the hub which is located in the same plane normal to the axis of rotation is approximately the same distance from the axis of rotation. This configuration is referred to as concentric or non arbitrary hub design or contour.

The non arbitrary hub designs often are not the optimal design considering the compressibility of fluids, nonuniform flow across the passage between the impeller blades, resistance of the impeller to loads placed thereupon and the fact that the impeller rotates in one direction. For these reasons, among others, the impeller with a non arbitrary hub configuration often will not be the most efficient, or will limit the range of rotational speeds at which the impeller may operate.

The foregoing illustrates limitations known to exist in present centrifugal impeller designs. Thus, it is apparent that it would be advantageous to provide an alternative directed to overcoming one or more of the limitations set forth above. Accordingly, a suitable alternative is provided including features more fully disclosed hereinafter.

SUMMARY OF THE INVENTION

In one aspect of the present invention, this is accomplished by providing a centrifugal impeller comprising a hub formed about an axis of rotation with a plurality of substantially radially extending blades are affixed to the hub, each blade having a suction surface, a pressure surface is formed on the adjacent blade facing the suction surface. The blades have a height being measured in a radial direction from the hub. A portion of the hub, having a hub configuration, extends between the pressure surface and the suction surface. An imaginary plane extending in a direction normal to the axis of rotation is used to define a cross-sectional view of the impeller. A first and a second concentric circle are formed in the plane with the center of the concentric circle being the axis of rotation. The first circle passes through a point on the hub located closest to the axis of rotation. The second circle has a radius greater than the first circle by an amount equal to five percent of said blade height, wherein a portion of the hub extends outside of the second circle.

The foregoing and other aspects will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

Fig. 1 is a perspective top and side view illustrating a prior art embodiment of a centrifugal impeller, showing a plane which is normal to the axis of rotation of the impeller that identifies a cross-sectional view of the impeller;

Fig. 2 is the cross-sectional view of one quadrant of the impeller, identified by the plane in Fig. 1;

Fig 3 is a cross-sectional view, similar to Fig. 2, of one embodiment of an arbitrary hub of the instant invention;

Fig. 4 is a cross-sectional view, similar to Fig. 2, of an alternate embodiment of an arbitrary hub of the instant invention;

Fig. 5 is a cross-sectional view taken along sectional line 5-5 of Fig. 4 during the milling of the impeller;

Fig. 6 is a cross-sectional view, similar to Fig. 5, after milling, showing a stationary (i.e., nonrotating) shroud in its proper location;

Fig. 7 is a diagram illustrating fluid flow velocities along line A-A of Fig. 2 for an ideal centrifugal impeller with no surface friction;

Fig. 8 is a view similar to Fig. 7 for the actual prior art centrifugal impeller of Figs. 1 and 2 when surface friction is taken into account;

Fig. 9 is a view similar to Fig. 7 for the impeller of the present invention as illustrated in Fig. 3;

Fig. 10 is a cross-sectional view, similar to Fig 2, of a non reflexive arbitrary hub of the instant invention; and

Fig. 11 is an elevational view of the centrifugal impeller of the instant invention with the blades removed illustrating the two imaginary surfaces used to determine whether a particular hub surface is arbitrary, the first imaginary surface being the imaginary plane 20 and the second imaginary surface being the imaginary frusto-conical surface 86.

DETAILED DESCRIPTION

In this specification, identical elements in different embodiments are given identical reference characters.

This invention relates to the contour of a hub 10 for a centrifugal impeller 12. The hub and the impeller are concentrically formed and rotate about an axis of rotation 14.

A plurality of substantially radially extending blades 26 are affixed to the hub 10 of the centrifugal impeller 12. Each blade has a first or suction side 28 and a second or pressure side 30 with a distinct portion of the hub being located between the first side 28 and the second side 30. The impeller rotates about the axis of rotation in the direction of rotation 31. A transition fillet 32 may be located between hub 10 and the sides 28, 30.

For a given point on the axis of rotation 14, only a single plane 20 can be generated which is normal to the axis of rotation. Two concentric circles 22 and 22′ can be generated, in the plane, about the axis of rotation. In prior art centrifugal impellers (see Fig. 2), the hub contour 23 closely corresponds to a concentric circle 22.

Whether a hub profile is arbitrary can be determined as follows. For each plane, the concentric circle 22 (Fig. 2 and 3) is drawn to intersect a point 33′on the hub 10 which is closest to the axis of rotation 14. The second concentric circle 22′ is drawn with a radius being greater than the first concentric circle 22 by a distance equal to five percent of the height 25 of a blade 26 taken in the radial direction.

If a portion of the hub does not extend outside of the second concentric circle 22′, then the hub is concentric or non arbitrary (as illustrated in Fig. 2). If a portion of the hub 24 extends outside of the second concentric circle 22′ (as in Fig. 3), then the hub is considered arbitrary or non concentric.

An alternate method to determine an arbitrary hub profile for a given plane 20 follows (see Fig. 4). A first ray 33 extends from the axis of rotation 14 to a first point 33', which is the point on the hub which is closest to the axis of rotation. A second ray 35 extends from the axis of rotation 14 to a second point 35', which is the point on the hub 10 which is furthest from the axis of rotation.

For a hub profile to be considered arbitrary, the difference in length between the first ray 33 and the second ray 35 must exceed 5 percent of the total height 36 (measured radially) of the blade 26. No point located within the transition fillets 32, or sides of the blades 28, 30 are to be considered in determining whether a surface is arbitrary.

A certain impeller with an arbitrary hub design may have a series of planes having arbitrary hub profiles while another series of planes in the same impeller do not have an arbitrary profile. Alternately, the specific profile of the arbitrariness, or the purpose for the arbitrariness, may be altered from plane to plane within the impeller 12.

The arbitrariness of a hub surface may be similarly defined by an imaginary plane normal to the primary flow direction, as it has been defined above by an imaginary plane normal to the axis of rotation.

Even though the sides 28, 30 are curved surfaces, often they can be generated with a flank 42 of a miller 34 since the curve which forms the sides may be formed from a series of straight lines (as described in U.S. Patent No. 5,014,421, issued May 14, 1991 incorporated herein by reference).

When a flank 42 of the miller 34 is shaping the sides 28, 30, a point 44 of the miller 34 is forming a portion of the hub 10 as shown in Fig. 5. Often the entire hub 10 is formed by point milling. In the prior art the hub has scalloped surfaces 23 after machining (see Fig. 2). An arbitrary surface pertains to a much greater surface irregularity than that of a scalloped surface.

Since a curved surface takes approximately the same time to machine by point milling as a flat surface, an arbitrary hub surfaces (being curved as desired by the impeller designer) as illustrated in Figs. 3 and 4 may be machined with a point miller nearly as efficiently as a concentric surface.

While the above discussion about the arbitrary hub profile pertains to machining the impeller by milling techniques, it is also understood that there are equally significant advantages to a cast impeller having an arbitrary hub surface. Further, impellers with arbitrary hub surfaces may be cast as easily as the prior art impellers.

Arbitrary hub profiles have improved flow characteristics in centrifugal impellers as follows. A specific arbitrary hub surface may have different effects on impeller efficiencies based upon the RPM of the impeller, the specific characteristics of the fluid being pumped or compressed, and the specific blade geometry of the impeller.

There are only four surfaces in the centrifugal impeller 12 which are in direct contact with the working fluid, and which therefore may affect fluid flow characteristics. These surfaces are the suction side 28 of the blade, the pressure side 30 of the blade, the hub 10 and the shroud 45. These four surfaces 28, 30, 10 and 45 form a passage 52 through which fluid passes as it traverses the impeller.

The shroud 45 forms the fourth side of the passage which restricts fluid flow within the passage along with the two blades and the hub 10. The shroud may be stationary and separate from the impeller or may be attached to and rotate with the impeller. The shroud 45, if it is attached, may be formed in an arbitrary design to produce results similar to that of the hub.

There are several reasons why arbitrary hub profiles may be desired over concentric hub profiles. The ideal flow characteristics for the centrifugal impeller, as taken along line A-A of Fig. 2 (into the paper) where flow velocities adjacent the wall 28 are identical to the flow velocities in the center of the passage 52.

The actual flow characteristics produced by centrifugal impellers 12 having concentric hub surfaces, are illustrated in Fig. 8 in which the velocities near the center of the passage 52 exceed the velocities of the fluid near the blades due to skin friction and turbulence. These flow irregularities make the impeller less efficient and restrict the operating range at which the impeller exhibits stable flow characteristics.

To equalize the flow velocities across the width of the passage, an arbitrary hub profile 24 illustrated in Fig. 3 is contoured wherein fluid entering the center of passage 52 will tend to be diverted to either wall. The resultant velocity profile of fluid passing through this passage is illustrated in Fig. 9 which is closer to the ideal velocity profile than the prior art centrifugal impellers.

As illustrated in Fig. 4, an alternate arbitrary hub configuration involves channels 65 which extend in a meridional direction (into the page). These channels resist the tendency of fluid passing through passage 52 to flow across the passage. Cross flow tends to create turbulence which will decrease the efficiency of the impeller as well as limit the range at which the impeller will operate stably.

A third reason for forming an arbitrary hub involves structural considerations as illustrated in Fig. 10. When the impellers are exposed to high rotational velocities about the axis of rotation 14, an unacceptable stress may be placed upon the blades or the hub. This stress may be increased in those designs where the shroud 45 rotates with the impeller. To reduce this stress, the hub may be built up by an arbitrary contour at a location where the flow characteristics is not critical.

For whatever reason the hub surface is being formed in an arbitrary manner, since the hub is usually produced using either point milling or casting, the time required to produce the parts should not be increased considerably.

In each of the above descriptions, an imaginary plane 20 is used to determine whether a surface is arbitrary. An alternate device which may be used to determine whether a surface is arbitrary is an imaginary frusto-conical surface 86 which is generated as a series of rays 88 which extends from the axis of rotation 14, and is perpendicular to a general fluid flow direction 90 adjacent each hub point 92.

An arbitrary hub 10 configuration results in the possibility that the hub will not be reflexive, which may be determined as follows (see Fig. 10). A suction intersection 70 is the point, in the surface 20, where the suction plane 28 intersects the hub 10. A pressure intersection 72 is the point where the pressure surface 30, of an adjacent blade, intersects the hub 10. Fillets are not considered in determining the intersection points.

A first ray 74 is constructed from the axis of rotation 14 to the suction intersection 70. A second ray 76 is constructed from the axis of rotation to the pressure intersection 72. A third ray 78 is constructed to bisect the angle between the first ray and the second ray.

A mirror image 80 of the hub between the third ray and the first ray is produced between the third ray and the second ray. If the hub is reflexive or concentric, the mirror image will approximate the hub between the third ray and the second ray.

If, however, the hub is non reflexive and arbitrary as indicated in the figure 10, the hub 10 between the third and the second ray will not match the mirror image. This configuration demonstrate the freedom which a designer has in alternate arbitrary hub configurations.

While the above describe reasons for arbitrary hub configuration, it is within the intended scope of the present invention to provide arbitrary surfaces, for whatever reason.

Having described the invention, what is claimed is:

1. A centrifugal impeller comprising:

a hub formed about an axis of rotation;

a plurality of substantially radially extending blades which are affixed to the hub, each blade having a suction surface, a pressure surface formed on the adjacent blade facing the suction surface, the blades having a height being measured in a radial direction from the hub, a portion of the hub, having a hub configuration, extending between the pressure surface and the suction surface;

an imaginary plane extending in a direction normal to the axis of rotation, a first and a second concentric circle formed in the plane with the center of the concentric circle being the axis of rotation;

the first circle passing through a point on the hub located closest to the axis of rotation; and

the second circle having a radius greater than the first circle by an amount equal to five percent of said height, wherein a portion of the hub extends outside of the second circle.

2. The centrifugal impeller as described in claim 1, further comprising:

transition fillets located between a blade suction surface and the hub, and between a blade pressure surface and the hub.

3. The centrifugal impeller as described in claim 1, wherein the hub configuration equalizes the flow velocities across a width of a passage formed between the suction surface and the pressure surface.

4. The centrifugal impeller as described in claim 1, wherein the hub configuration reduces flow across a passage formed between the suction surface and the pressure surface.

5. The centrifugal impeller as described in claim 1, wherein the hub configuration increases the strength of the impeller.

6. A centrifugal impeller comprising:

a hub having a hub configuration formed about an axis of rotation; a plurality of substantially radially extending blades which are affixed to the hub, the blades having a height being measured in a radial direction from the hub;

an imaginary plane extending in a direction normal to the axis of rotation;

a first ray, coincident with the plane, extending from the axis of rotation to a first point, being the point closest to the axis of rotation in the hub;

a second ray, coincident with the plane, extending from the axis of rotation to a second point, being the point furthest from the axis of rotation in the hub, wherein the difference in length between the first ray and the second ray is greater than 5 percent of the height of the blades;

7. The centrifugal impeller as described in claim 6, further comprising:

transition fillets located between a blade suction surface and the hub and a blade pressure surface and the hub.

8. The centrifugal impeller as described in claim 6, wherein the hub configuration equalizes the flow velocities across a width of a passage formed between any two adjacent blades.

9. The centrifugal impeller as described in claim 6, wherein the hub configuration reduces flow across a passage formed between any two adjacent blades.

10. The centrifugal impeller as described in claim 6, wherein the hub configuration increases the strength of the impeller.

11. A centrifugal impeller comprising:

a hub formed about an axis of rotation;

a plurality of substantially radially extending blades which are affixed to the hub, each blades having a suction surface, and a pressure surface is formed on the adjacent blade facing the suction surface, the blades having a height being measured in a radial direction from the hub, a portion of the hub having a hub configuration extending between the pressure surface and the suction surface;

a suction intersection and a pressure intersection is formed at the intersection of the hub and the suction surface and the pressure surface, respectively;

an imaginary plane extending in a direction normal to the axis of rotation; a first ray and a second ray extends from the axis of rotation, within the plane, to the suction intersection and the pressure intersection, respectively;

a third ray extends from the axis of rotation, and bisects an angle between the first ray and the second ray;

a mirror image of the hub between the third ray and the first ray being produced between the third ray and the second ray;

the distance between any two points, taken in the radial direction, between the mirror image and the hub located between the third ray and the second ray exceeds five percent of said height.

12. The centrifugal impeller as described in claim 11, further comprising:

transition fillets located between a blade suction surface and the hub, and between a blade pressure surface and hub.

13. The centrifugal impeller as described in claim 11, wherein the hub configuration equalizes the flow velocities across a width of a passage formed between the suction surface and the pressure surface.

14. The centrifugal impeller as described in claim 11, wherein the hub configuration reduces flow across a passage formed between the suction surface and the pressure surface.

15. The centrifugal impeller as described in claim 11, wherein the hub configuration increases the strength of the impeller.

16. A centrifugal impeller comprising:

a hub having opposite ends, a peripheral surface and an axis of rotation extending through the opposite ends;

blades connected to the surface of the hub and extending substantially radially outwardly from the axis of rotation, said blades being spaced apart to define a fluid flow passage having a width between adjacent ones of the blades; and

means formed on the surface for maintaining velocity of the fluid flow at a point along the passage width substantially equal with the velocity of the fluid flow at any other point along the passage width.

17. A centrifugal pump impeller comprising:

a hub formed about an axis of rotation, an imaginary frusto-conical surface being generated by a set of rays originating at the axis of rotation and extending in a direction perpendicular to a general flow direction of the fluid adjacent the hub;

a plurality of substantially radially extending blades which are affixed to the hub, each blade having a suction surface, a pressure surface is formed on the adjacent blade facing the suction surface, the blades having a height being measured within the frusto-conical surface from the hub, a portion of the hub, having a hub configuration, extending between the pressure surface and the suction surfaces;

the first circle, within the frusto-conical surface, passing through a point on the hub located closest to the axis of rotation; and

the second circle having a radius greater than the first circle by a distance equal to five percent of the height, wherein a portion of the hub extends outside of the second circle.

18. A centrifugal impeller comprising:

a hub having a hub configuration formed about the axis of rotation, an imaginary frusto-conical surface being generated by a set of rays originating at the axis of rotation and extending in a direction perpendicular to a general flow direction of the fluid adjacent the hub;

a plurality of substantially radially extending blades which are affixed to the hub, the blades having a height being measure within the frusto-conical surface from the hub;

a first ray, coincident with the frusto-conical surface, extending from the axis of rotation to a first point being the point closest to the axis of rotation of the hub; and

a second ray, coincident with the frusto-conical surface, extending from the axis of rotation in the hub, wherein the difference in length between the first ray and the second ray is greater than 5 percent of the height of the blades.

AMENDED CLAIMS

[received by the International Bureau on 02 July 1992 (02.07.92); original claims 2,5,7,10,11-15,16-18 cancelled; original claims amended; new claims 4-7,10 and 11 added; claim 1 amended and renumbered as claims 1 and 3; claims 3 and 8 replaced by amended claim 8, claims 4 and 9 replaced by amended claim 9 and claim 6 replaced by amended claim 2 (4 pages)]

1. A centrifugal impeller comprising:

a hub having an axis of rotation;

a plurality of substantially radial extending blades affixed to the hub, each blade having a height being measured in a radial direction from the hub, each blade having a suction surface, a pressure surface being formed on an adjacent blade facing the suction surface;

a blade suction surface, the adjacent blade pressure surface and the hub forming a flow passage; and

the hub having an arbitrary configuration defined by first and second concentric circles formed in an imaginary plane, the imaginary plane extending in a direction normal to the axis of rotation, the centers of the concentric circles being the axis of rotation, the first circle passing through a point on the hub located closest to the axis of rotation, the second circle having a radius greater than the first circle by an amount equal to five percent of said blade height, at least a portion of the hub extending outside the second circle.

2. A centrifugal radial flow impeller comprising:

a hub having a configuration formed about an axis of rotation;

a plurality of substantially radially extending blades which are affixed to the hub, the blades having a height being measured in a radial direction from the hub;

the hub configuration having an arbitrary surface defined by a first ray coincident with an imaginary plane, the imaginary plane extending in a direction normal to the axis of rotation, the first ray extending from the axis of rotation to a first point, the first point being a point on the hub configuration closest to the axis of rotation; a second ray, coincident with the imaginary plane, extending from the axis of rotation to the second point, the second point being a point on the hub configuration furthest from the axis of rotation, the difference in length between the first ray and the second ray being greater than five percent of the blade height.

3. A centrifugal radial flow impeller comprising:

a hub having an axis of rotation;

a plurality of substantially radially extending blades affixed to the hub, each blade having a height being measured in a radial direction from the hub, each blade having a suction surface, a pressure surface being formed on an adjacent blade facing the suction surface;

a blade suction surface, the adjacent blade pressure surface and the hub forming a flow passage; and

the hub having an arbitrary surface defined by first and second concentric circles formed in an imaginary plane, the imaginary plane extending in a direction normal to the axis of rotation, the centers of the concentric circles being the axis of rotation, the first circle passing through a point on the hub located closest to the axis of rotation, the second circle having a radius greater than the first circle by an amount equal to five percent of said blade height, at least a portion of the hub extending outside of the second circle.

4. The centrifugal radial flow impeller of claim 3 wherein the portion of the hub extending outside of the second circle does not divide the flow passage formed by the blade suction surface, the adjacent blade pressure surface and the hub into additional flow passages.

5. The centrifugal impeller according to either claims 1 or 3 wherein the portion of the hub surface between a pair of adjacent blades is asymmetric relative to a point located midway between the pair of blades.

6. The centrifugal impeller of claim 5 wherein the hub extends outside the second circle between the midpoint and one blade and does not extend outside the second circle between the midpoint and the other blade.

7. The centrifugal impeller according to either claims 1 or 2 wherein the arbitrary hub configuration maintains the flow passage formed by the blade suction surface, the adjacent blade pressure surface and the hub as a single flow passage.

8. The centrifugal impeller of the claims according to any of the claims 1, 2, 3, 4 or 7 wherein the arbitrary hub configuration equalizes the flow of velocities across a width of the flow passage.

9. The centrifugal impeller according to any of the claims 1, 2, 3, 4 or 7 wherein the arbitrary hub configuration reduces flow across the flow passage.

10. The centrifugal impeller according to any of claims 1, 2, 3, 4 or 7 wherein the hub surface between a pair of adjacent blades is non-reflexive.

11. A centrifugal radial flow impeller comprising:

a hub having an axis of rotation;

a plurality of substantially radially extending blades affixed to the hub, each blade having a height being measured in a radial direction from the hub, each blade suction surface, a pressure surface being formed on an adjacent blade facing the suction surface;

a blade suction surface, the adjacent blade pressure surface and the hub forming a flow passage; and

the hub having an arbitrary surface defined by first and second concentric circles formed in an imaginary plane, the imaginary plane extending in a direction normal to the axis of rotation, the centers of the concentric circles being the axis of rotation, the first circle passing through a point on the hub located closest to the axis of rotation, the second circle having a radius greater than the first circle by an amount equal to five percent of said blade height, at least a portion of the hub extending outside of the second circle; the portion of the hub extending outside of the second circle does not divide the flow passage formed by the blade suction surface, the adjacent blade pressure surface and the hub into additional flow passages; and the hub surface between a pair of adjacent blades is non-reflexive.

STATEMENT UNDER ARTICLE 19

Applicant's Attorney wishes to amend the originally filed claims. Applicant submitted 18 claims in the initial application. Following amendments to these claims, a total of eleven claims will remain pending in this application.

Claim 1 has been replaced by amended claims 1 and 3;
Claim 2 has been cancelled;
Claims 3 and 8 have been replaced by amended claim 8;
Claims 4 and 9 have been replaced by amended claim 9;
Claim 5 has been cancelled;
Claim 6 has been replaced by amended claim 2; and
Claims 7, 10, 11-15 and 16-18 have been cancelled.

Amended claims 4-7, 10 and 11 have been added to the present application.

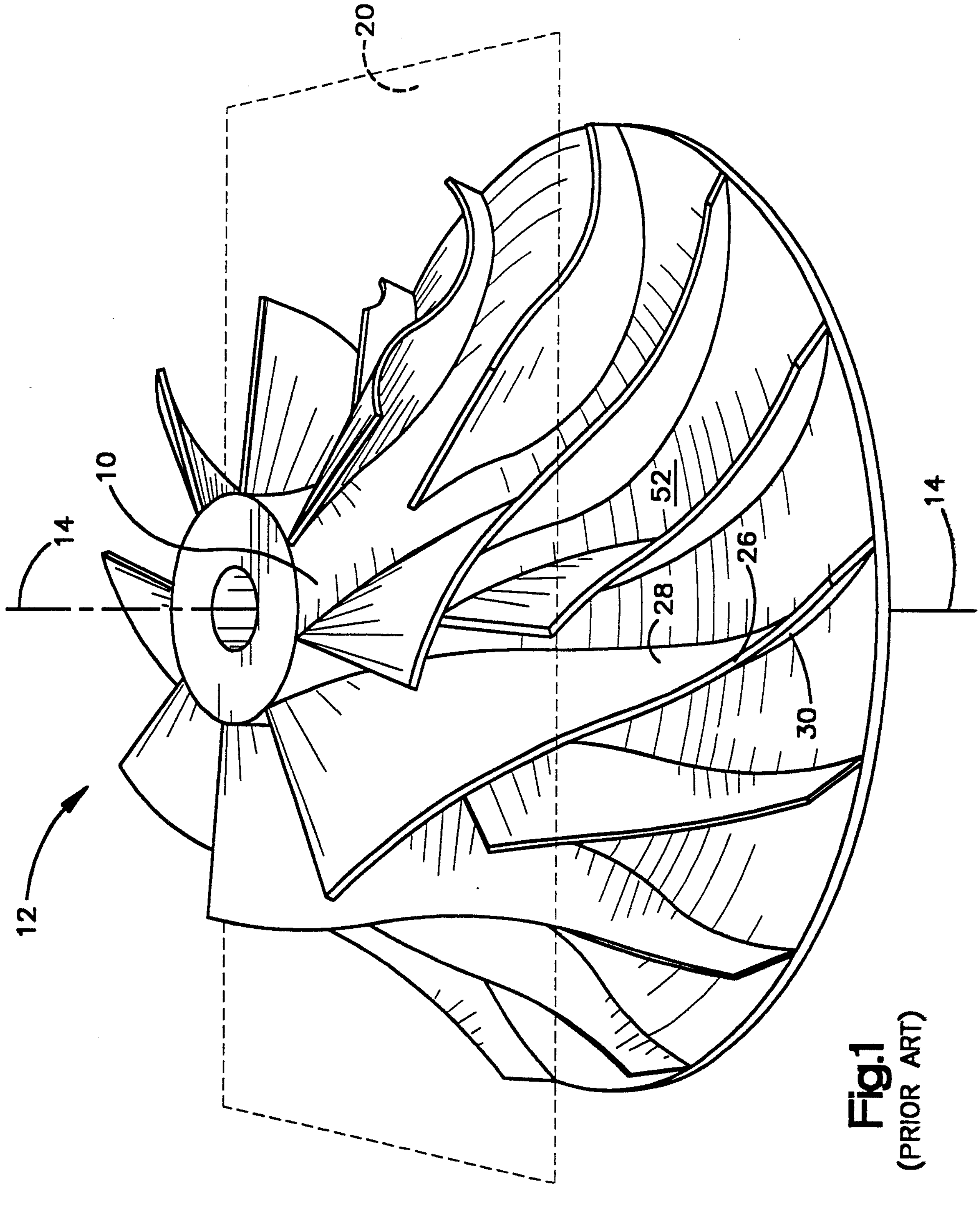


Fig.1
(PRIOR ART)

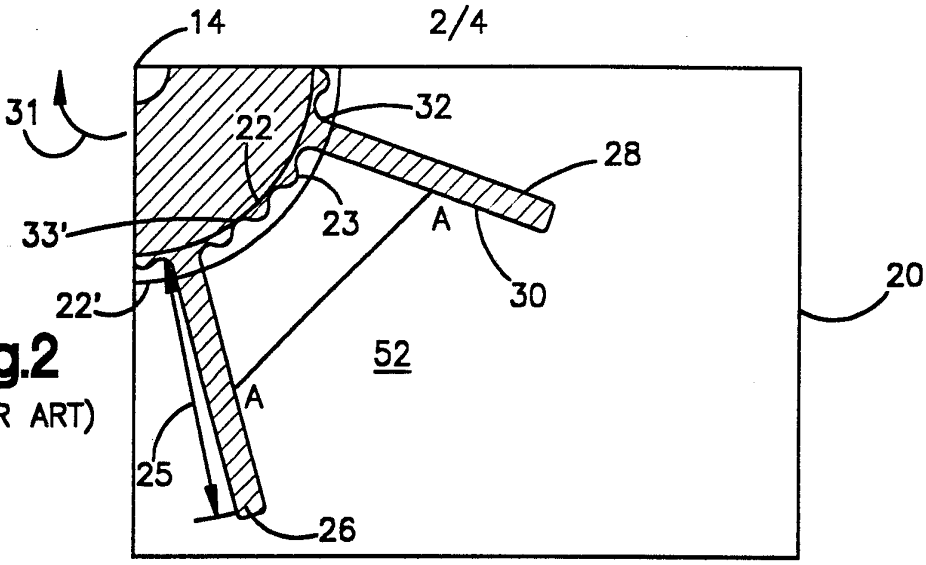


Fig.2
(PRIOR ART)

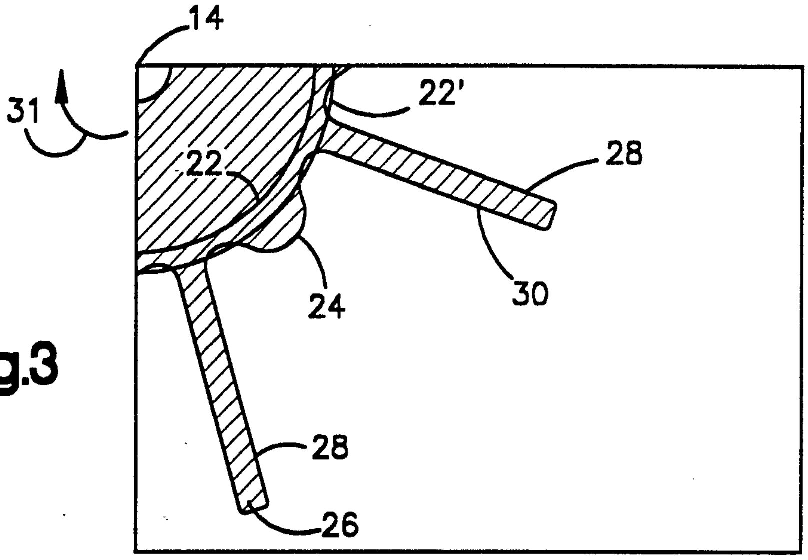


Fig.3

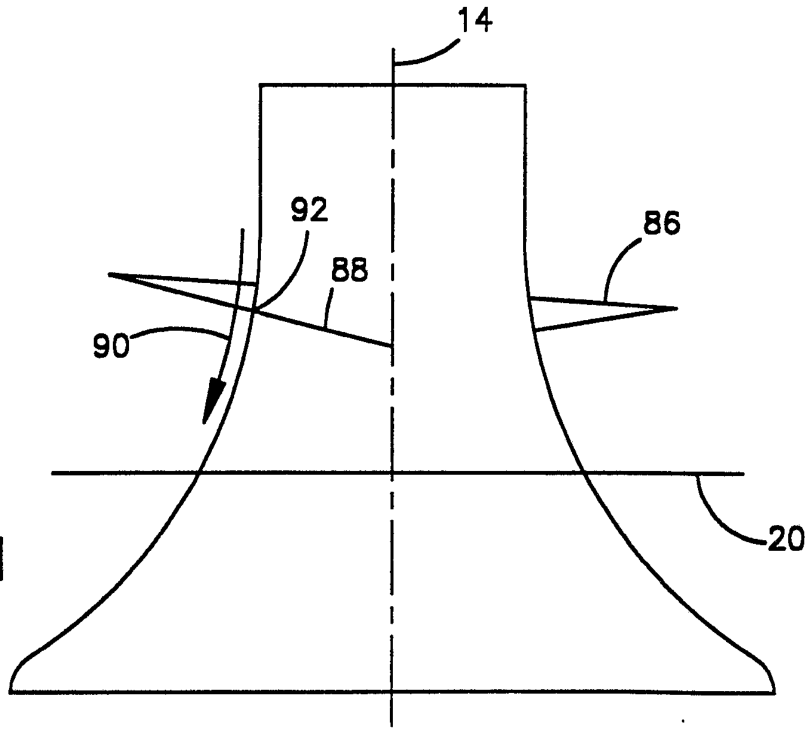


Fig.11

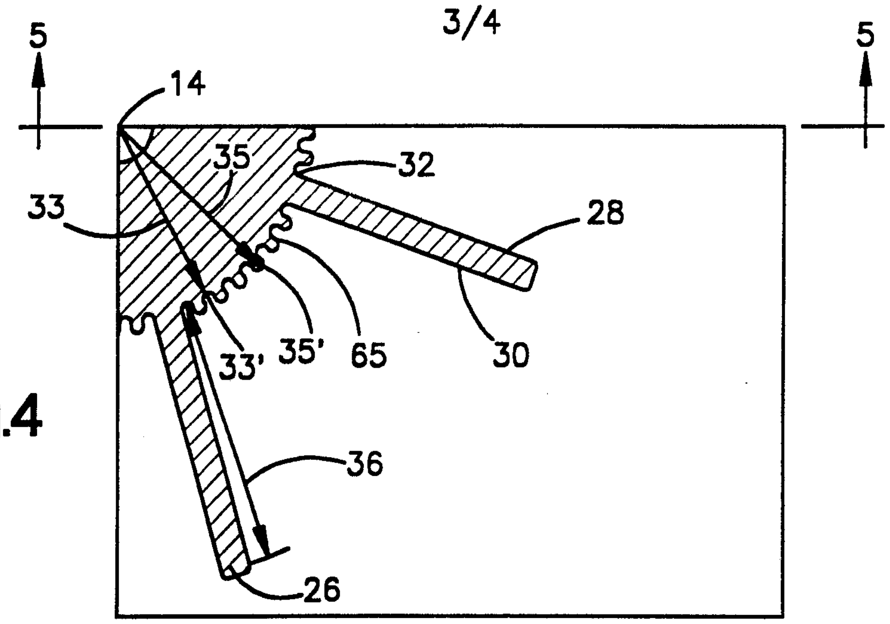


Fig.4

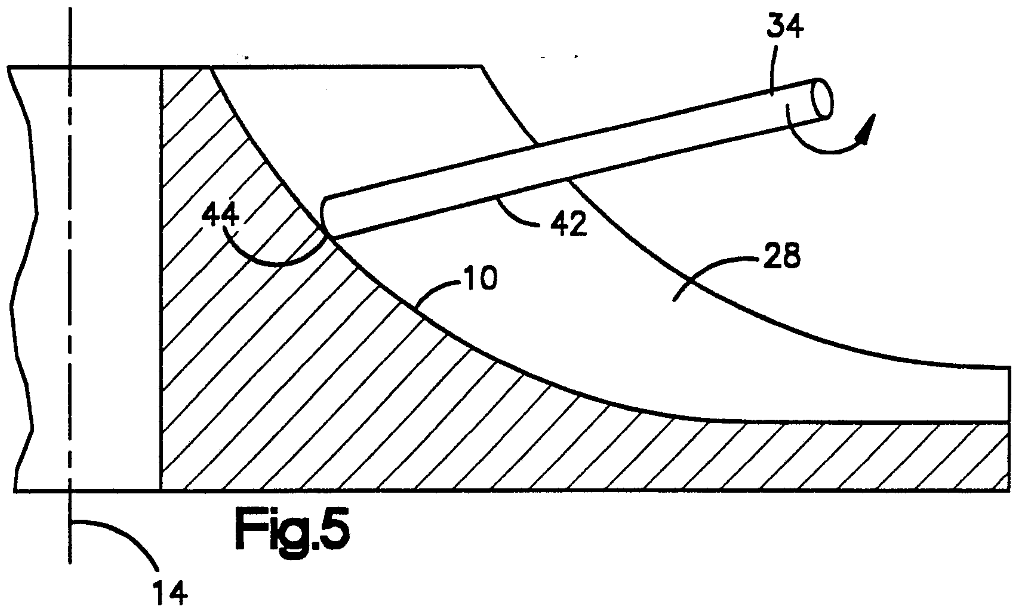


Fig.5

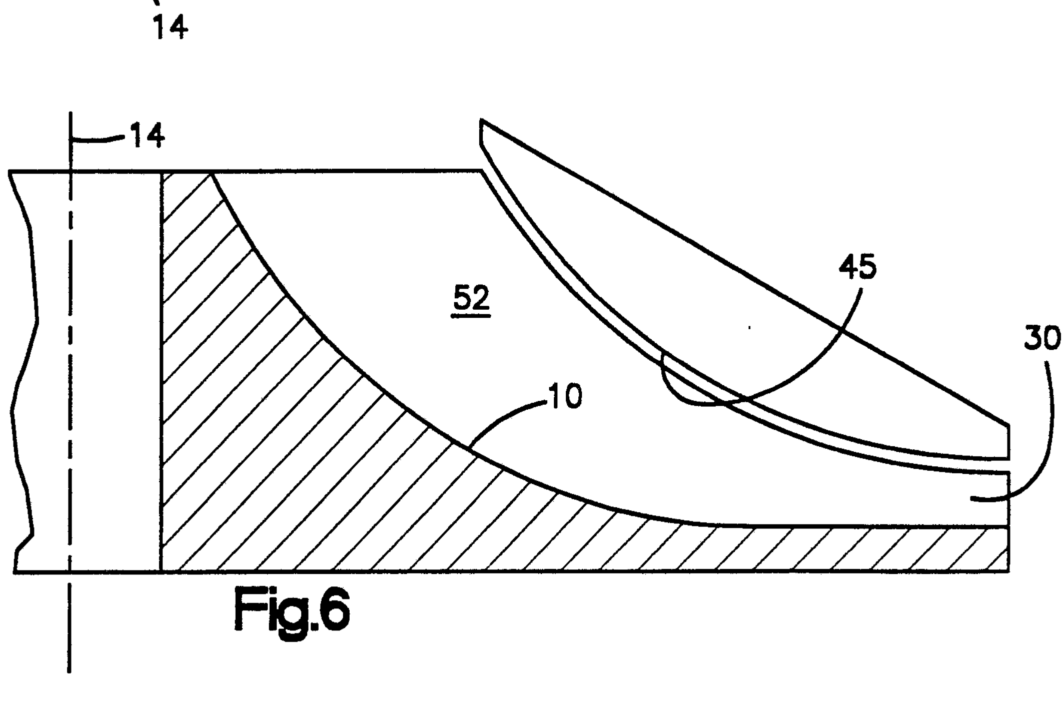


Fig.6

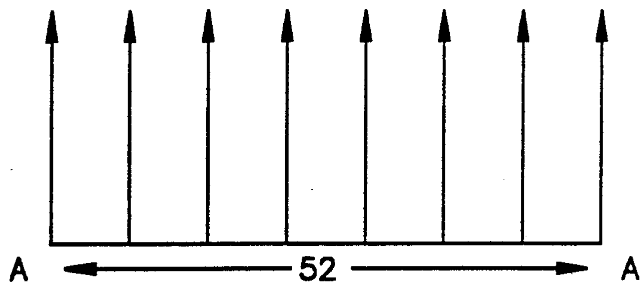


Fig.7

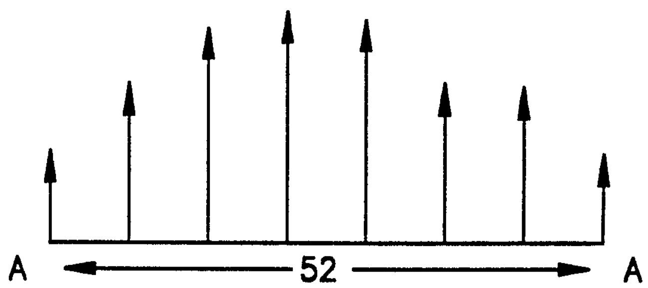


Fig.8 (PRIOR ART)

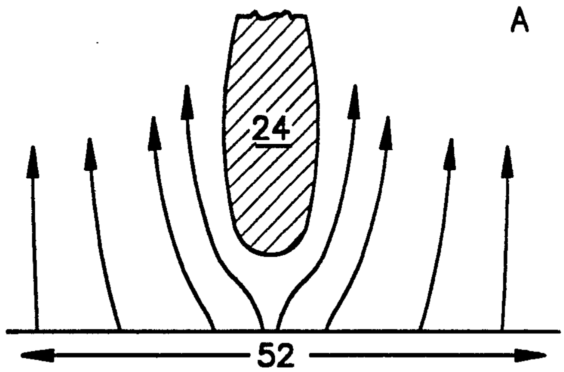


Fig.9

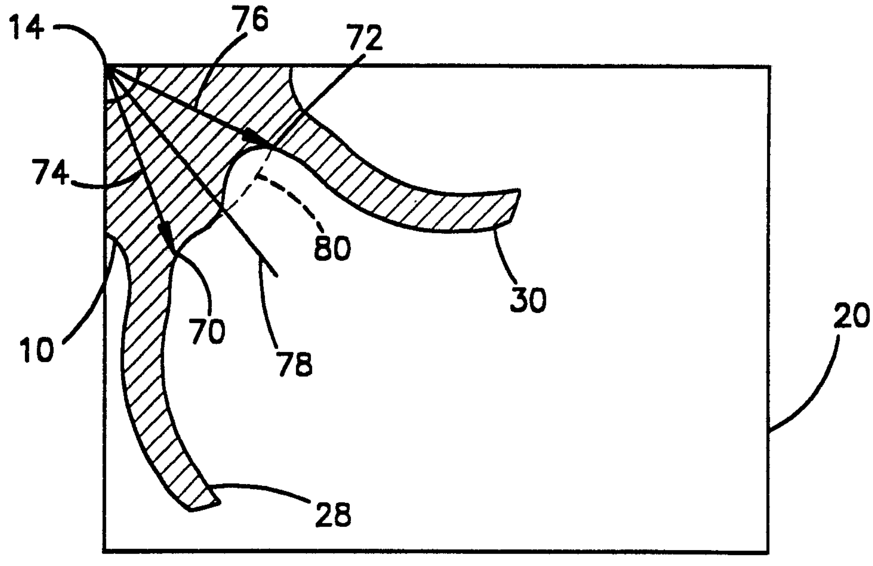


Fig.10

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US92/00319

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): F04D 17/10, 29/28
US CL : 416/183, 188, 235, 236R

II. FIELDS SEARCHED

Minimum Documentation Searched[4]

Classification System	Classification Symbols
U.S.	416/179, 182, 183, 185, 186, 188, 223B, 235, 236R 415/914

Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched[5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[14]

Category*	Citation of Document,[16] with indication, where appropriate, of the relevant passages[17]	Relevant to Claim No.[18]
X Y	WO,A, WO90/02265 (DRESSER-RAND CO.) 08 MARCH 1990 SEE ENTIRE DOCUMENT	1,3,6,8,16-18 2,4-5,7,9-15
Y	US,A, 2,918,254 (HAWSAMMANN) 22 DECEMBER 1959 SEE FIGURES 1 and 2	5,10-15
Y	US,A, 3,481,531 (MacARTHUR et al.) 02 DECEMBER 1969 SEE FIGURES 3 and 5; column 2, lines 1-4)	2,4,7,9,12,14
A	US,A, 2,735,612 (HAUSMANN) 21 FEBRUARY 1956 SEE FIGURES 2-3)	5,10,11,15
A	US,A, 4,420,288 (BISCHOFF) 13 DECEMBER 1983 SEE FIGURES 2-3	1-18
A	US,A, 4,465,433 (BIRSCHOFF) 14 AUGUST 1984 SEE FIGURE 2	5,10,11,15
A	FR,A, 999,826 (SOCIETE RATEAU) 10 OCTOBER 1951 SEE FIGURES 6-7	1-18
A	GB,A, 944,166 (HAUSMMANN et al.) 11 DECEMBER 1963 SEE FIGURES 11-14	5,10-15
A	SU,A, 1,059,217 (DAVYDOU) 07 DECEMBER 1983 SEE FIGURES 1-3	1-18

* Special categories of cited documents:[15]

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search[2]	Date of Mailing of this International Search Report[2]
19 MARCH 1992	26 MAY 1992
International Searching Authority[1] ISA/US	Signature of Authorized Officer[20] JAMES LARSON

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	JP,A, 60-69211 (MITSIBISHI JUKOGY K.K.) 19 APRIL 1985 SEE FIGURES 4,6	1-18

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE[1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers _, because they relate to subject matter (1) not required to be searched by this Authority, namely:

2. ☐ Claim numbers _, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out (1), specifically:

3. ☐ Claim numbers _, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING[2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Search Authority did not invite payment of any additional fee.

Remark on protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.