

⑫

EUROPEAN PATENT APPLICATION

⑰ Application number: 86106851.8

⑸ Int. Cl.⁴: **F 04 D 29/28**

⑱ Date of filing: 20.05.86

⑳ Priority: 24.05.85 US 737659

㉓ Date of publication of application:
17.12.86 Bulletin 86/51

㉔ Designated Contracting States:
DE FR GB SE

⑴ Applicant: **A. S. Kongsberg Våpenfabrikk**
Post Office Box 25
N-3601 Kongsberg(NO)

⑵ Inventor: **Skoe, Ivar Helge**
Raadyrveien 7
N-3600 Kongsberg(NO)

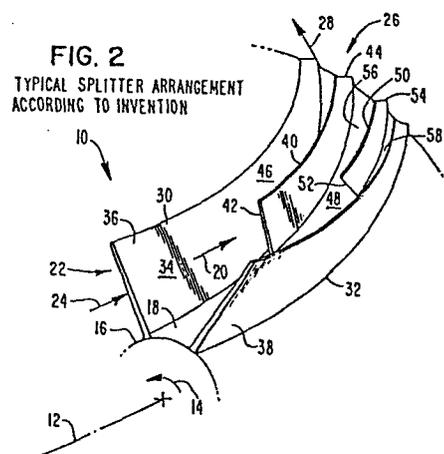
⑵ Inventor: **Oeverland, Geir**
Erik Brofossvei 41
N-3600 Kongsberg(NO)

⑵ Inventor: **Stroem, Sigmunn**
Mosekollen 6
N-3600 Kongsberg(NO)

⑴ Representative: **Patentanwält Grünecker, Kinkeldey,**
Stockmair & Partner
Maximilianstrasse 58
D-8000 München 22(DE)

⑸ **Splitter blade arrangement for centrifugal compressors.**

⑸ A centrifugal compressor impeller has a first set of splitter blades (40) positioned in the flow channels between the full length blades (30,32) such that about 1/3 of the channel flow is directed between each first splitter blade and the adjacent full length blade having its suction side facing the first splitter blade. Each blade of a second, shorter set of splitter blades (50), is positioned between the first splitter blade (40) and the adjacent full length blade (32) having its pressure side facing the first splitter blade to divide about in half the other 2/3 of the channel flow.



BACKGROUND OF THE INVENTIONField of The Invention:

This invention relates to centrifugal compressor impellers and, specifically, to the arrangement of the blades and splitter blades on the impeller.

Description of the Prior Art:

The performance of a centrifugal compressor stage is limited by the fluid (e.g. air/gas) pressure differences between blade surfaces. If the pressure difference from suction to pressure side of a compressor blade is larger than a critical value (as a percent of the average dynamic pressure at that position), the flow will separate from the suction side and create large losses in the impeller as well as in the downstream diffuser.

Towards the exit of the compressor where the impeller perimeter is large, the distance between the blades increases and the blade pressure loading is increased to an extent that flow-separation takes place. This flow-separation is well known to exist all compressors and is often referred to as the "jet-wake" flow.

To reduce the high blade loading the impeller exit, it is customary to put a set of shorter length blades, called "1/2 blades" or "splitter blades," between the full length blades at the exit portion of the impeller. A typical "single entry" compressor impeller with one set of splitter blades is shown in Fig. 1. In Fig. 1, the full length blades are designated by the letter A and extend from the inlet region B to the exit region C.

The splitter blades D are shown spaced in alternating relation with full length blades A.

Compressors with double set of splitters are also known. The second set of splitters, which are generally shorter in length than the first splitter set, have been positioned symmetrically in the middle of the channels formed between the full blades and the first splitter blades. Such a configuration results in a total of $N + N + 2N = 4N$ blades spaced about the periphery of the impeller at the compressor exit, where N is the number of full length blades. The stresses caused by the extra impeller mass at the periphery during high rotational speed can limit performance of the compressor.

SUMMARY OF THE INVENTION

In accordance with the present invention, as embodied and broadly described herein, the impeller for a centrifugal compressor comprises a hub having a surface defining in part the flow passage past the impeller, the surface being contoured to form a substantially axial flow passage inlet and a substantially radial flow passage exit. A plurality of impeller blades are spaced symmetrically about the hub on the surface, each extending the full length of the flow passage from the inlet to the outlet, and each of the full length blades having a suction side and a pressure side. The full length blades divide the flow into a plurality of flow channels equal in number to the plurality of full

length blades. Also, a plurality of first splitter blades equal in number to the plurality of full length blades are provided spaced symmetrically about the hub in alternating relation with the full length blades, each of the first splitter blades being shorter in length than the full length blades and having a leading edge and a trailing edge. The leading edge of each one of the first splitter blades is located in the respective flow channel downstream of the inlet, and the trailing edge of the one splitter blade is located at the flow passage exit. Each first splitter blade is spaced tangentially relative to the two of the full length blades disposed on either side of the first splitter blade such that about 1/3 of the flow in the channel defined by the two disposed full length blades passes between the one first splitter blade and that one of the two disposed full length blades, the suction side of which faces the one first splitter blade.

Preferably, the centrifugal compressor impeller further includes a plurality of second splitter blades equal in number to the plurality of full length blades and spaced about the hub surface each between a respective first splitter blade and the adjacent full length blade having its pressure side facing the respective first splitter blade.

It is also preferred that each of said second splitter blades is shorter in length than said respective first splitter

blade, and divides about in two the flow between the respective first splitter blade and the adjacent pressure-side-facing full length blade, whereby the flow, as a fraction of the channel flow, in the sub-channels formed by each first splitter blade and the adjacent second splitter blade is about 1/3:1/3:1/3 at the compressor exit.

It is still further preferred that the respective flow splits are determined on the basis of the ^{30-04-85 60. SS #S} qV distribution at the first splitter blade leading edge location and the second splitter blade leading edge location, respectively.

And it is still further preferred that a double entry centrifugal compressor impeller unit comprise the centrifugal compressor impeller as defined above and a second centrifugal compressor impeller which is the mirror image of the defined impeller with respect to a plane perpendicular to the defined impeller axis at the impeller axial end corresponding to the compressor exit portion.

The accompanying drawings which are incorporated in, and constitutes a part of this specification, illustrate two embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of a single entry centrifugal compressor impeller made in accordance with the prior art;

5

Fig. 2 is a schematic plan view of a portion of a single entry centrifugal compressor impeller made in accordance with the present invention;

Fig. 3 is a top view of a detail of the impeller shown in Fig. 2; and

Fig. 4 is a schematic side view of a dual entry centrifugal compressor impeller made in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made to the preferred embodiments shown in Figure 2-4 of the drawings which, together with the description, serve to explain the principles of the invention.

With initial reference to Figure 2, there is shown a centrifugal compressor impeller made in accordance with the present invention and designated generally by the numeral 10. Impeller 10 is intended to rotate about axis 12 in the direction shown by arrow 14. Impeller 10 is used in conjunction with the close fitting housing (not shown) in the same fashion as the prior art impeller shown in Figure 1, but with improved performance characteristics stemming from the features of the invention to be described henceforth.

In accordance with the present invention, the centrifugal compressor impeller includes a hub having a surface defining in part the flow passage past the impeller. The surface is

contoured to form a substantially axial flow passage inlet and a substantially radial flow passage exit for the compressor. As embodied herein, impeller 10 includes hub 16 with surface 18 for guiding the fluid flow through the compressor. Surface 18 is contoured to form, in conjunction with the housing (not shown), a flow passage designated generally by the arrow 20 past hub 16. Flow passage 20 includes a generally axial inlet portion 22 for the entering flow (designated by arrow 24) and an exit portion 26 for the discharge flow (arrow 28). The actual orientation of the flow exiting the centrifugal compressor is combined radial/tangential as a result of rotational motion imparted to the fluid by impeller 10.

Further in accordance with the present invention, the centrifugal compressor impeller includes a plurality of impeller blades spaced symmetrically about the hub on the surface and each extending the full length of the flow passage from the compressor inlet to the compressor outlet. Each of the full length blades has a suction side and a pressure side, with the full length blades dividing the flow past the impeller hub into a plurality of flow channels equal in number to the plurality of full length blades. As embodied herein, full length impeller blades 30, 32 are mounted on surface 18 of hub 16 extending from compressor inlet portion 22 to the compressor exit 26. It will be understood that the full length blades are evenly distributed about

the circumference of hub 16 and act to create a series of flow channels equal in number to the full length blades. Generally, the number of full length blades will range between about 7 and 15. For clarity, only two full length blades 30, 32 are shown in Figure 2, with the blades 30, 32 acting to create flow channel 34.

As would be understood by one skilled in the art, each of blades 30, 32 has a pressure side which is the leading side with respect to the direction of rotation 14 as well as a trailing, suction side. In the Figure 2 schematic, suction sides 36, 38 of blades 30, 32, respectively, can be seen.

Further in accordance with the present invention, the centrifugal compressor impeller includes a plurality of first splitter blades equal in number to the plurality of full length blades and spaced symmetrically about the hub periphery in alternating relation with the full length blades. Each of the first splitter blades are shorter in length than the full length blades, and each has a characteristic leading edge and a trailing edge. As embodied herein, first splitter blade 40 is disposed between full length blades 30, 32, and it is understood that other first splitter blade will be disposed in a similar fashion between the other full length blades, which are not shown for clarity. Blade 40 has leading edge 42, with respect to the flow direction, positioned downstream of compressor inlet 22.

Trailing edge 44 of blade 40 is positioned at the compressor exit 26 at the same radial distance as trailing edges of the full length blades 30, 32.

As can best be seen in Figure 3, first splitter blade 40 is positioned between full length blades 30, 32 such that about 1/3 of the flow in channel 34 is diverted to subchannel 46 between first splitter blade 40 and blade 30 (i.e. between blade 40 and the blade having suction side 36 facing first splitter blade 40). Approximately the remaining 2/3 of the channel 34 flow would travel in subchannel 48 between blade 40 and the full length blade 32.

Preferably, the positioning to achieve the desired flow split will be determined by considering the ρV (density times velocity) distribution at the axial position corresponding to the leading edge 42 (designated by x_1 in Figure 3). As schematically shown in Figure 3, the ρV distribution is skewed significantly toward the suction side of blade 30 and, therefore, blade 40 will not be positioned precisely 1/3 the circumferential distance between blades 30 and 32.

It is also preferred that the impeller according to the present invention include a plurality of second splitter blades positioned between each first splitter blade and the full length blade having the pressure side facing the first splitter blade. As embodied herein, and with continued reference to Figures 2 and

3, second splitter blade 50 is shown mounted on surface 18 of hub 16 positioned between first splitter blade 40 and full length blade 32. Second splitter blade 50 has leading edge 52 and trailing edge 54, both with respect to the flow direction. Leading edge 52 is located downstream of leading edge 42 of first splitter blade 40 and trailing edge 54 is coterminus with trailing edge 44 of first splitter blade 40 and with the trailing edges of the full length blades 30, 32. Consequently, second splitter blade 50 is shorter in length than the first splitter blade 40.

Importantly, the circumferential position of second splitter blade 50 is such as to divide the flow in subchannel 48 evenly in two parts, preferably based on the ρv distribution in subchannel 48 at the axial location x_2 of leading edge 52. Thus, at the compressor exit 26, a more even flow distribution exists around the periphery of impeller 10, with approximately 1/3 of the channel 34 flow in each of the subchannels 46, 56 and 58.

The benefits of the present invention stem not only from the improved flow distribution which results from the decreased tendency for flow separation at the impeller exit, but also from reduction of the amount of material located at the periphery of impeller 10. Centrifugal impellers are run at high speeds which can be limited by the mass at the impeller periphery. Lower tip mass means higher margin-to-structural-failure or higher

operating speeds. Compared to prior art impellers, impeller 10 of the present invention achieves an even flow distribution with one less set of second splitter blades. Thus, a prior art impeller with N full length blades and N first splitter blades would have $2N$ second splitter blades for a total of $4N$ blades, as described previously. However, an impeller constructed in accordance with the present invention would have N full length blades, N first splitter blades, and N second splitter blades for a total of $3N$ blades. The reduction in the overall impeller mass which results from the present invention also would enable quicker acceleration to operating speed due to the lower impeller inertia.

The reduction in the total number of blades at the compressor exit may also provide for an improved aspect ratio for the exits of each of subchannels 46, 56, and 58. Ideally, the cross-sectional geometry of the individual subchannel exits for the impellers of the present type should approach a square to minimize the hydraulic diameter.

Another embodiment in accordance with the present invention is shown in Figure 4 in the form of a "double entry" centrifugal compressor impeller. In general, the same numerical designations used for similar parts in the embodiment shown in Figures 2 and 3 will be used, but with a 100 series prefix.

AA

As embodied herein, the double entry compressor impeller unit in accordance with the present invention, and designated generally by the numeral 110 as shown in Figure 4, has a left hand impeller portion essentially the same as depicted in Figures 2-3, including hub portion 116, full length blades 130, first splitter blades 140, and second splitter blades 150 (only one blade of each shown). Right hand impeller portion is a mirror image of the left hand portion taken about plane 160 located at the axial end of impeller hub portion 116 proximate the compressor exit 162. Thus, right hand impeller portion 116' has full length blades 130', first splitter blades 140', and second splitter blades 150' (only one blade of each shown). Impeller unit 110 thus has a pair of opposed, substantially axial entrances 122, 122' with a common, single exit 162. Impeller unit 110 rotates in an angular direction 114 such that point P would be going into the paper in the Figure 4 representation.

Preferably, hub portions 116, 116' are integrally formed. As taught in copending application S.N. 577,359, the radially outer parts of hub portions 116, 116' at plane 160 can be relieved between the blades to facilitate mixing of the flow streams from the left and right hand impeller portions. Also, the trailing edges of the full length blades from the left portion can be made to terminate at exit 162 with either the first splitter blades or the second splitter blades from the right hand

impeller portion to further even out the flow stream, as explained in S.N. 577,359. In this case, the right hand portion would still be a mirror image but shifted angularly about axis 112.

It will be apparent to those skilled in the art that various modifications and variations can be made in the centrifugal compressor impellers of the present invention without departing from the scope or spirit of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. An impeller for a centrifugal compressor comprising:
a hub having a surface defining in part the flow passage past the impeller, said surface being contoured to form a substantially axial flow passage inlet and a substantially radial flow passage exit;

a plurality of impeller blades spaced symmetrically about said hub on said surface and each extending the full length of the flow passage from said inlet to said outlet, each of said full length blades having a suction side and a pressure side, said full length blades dividing the flow into a plurality of flow channels equal in number to said plurality of full length blades;

a plurality of first splitter blades equal in number to said plurality of full length blades and spaced symmetrically about said hub in alternating relation with said full length blades, each of said first splitter blades being shorter in length than said full length blades and having a leading edge and a trailing edge;

wherein the leading edge of each one of said first splitter blades is located in the respective flow channel downstream of said inlet and the trailing edge of said one splitter blade is located at the flow passage exit; and

wherein said one first splitter blade is spaced

tangentially relative to the two of said full length blades disposed on either side of said one first splitter blade such that about 1/3 of the flow in the channel defined by said two disposed full length blades passes between said one first splitter blade and the one of said two disposed full length blades, the suction side of which faces said one first splitter blade.

2. The centrifugal compressor impeller as in claim 1 further including a plurality of second splitter blades equal in number to said plurality of full length blades and spaced about said hub surface each between a respective first splitter blade and the adjacent full length blade having its pressure side facing said respective first splitter blade.

3. The centrifugal compressor impeller as in claim 2 wherein each of said second splitter blades is shorter in length than said respective first splitter blade.

4. The centrifugal compressor impeller as in claim 2 wherein each of said second splitter blades divides about in two the flow between said respective first splitter blade and said adjacent pressure-side-facing full length blade, whereby the flow, as a fraction of the channel flow, in the sub-channels formed by each first splitter blade and the adjacent second splitter blade is about 1/3:1/3:1/3 at said impeller exit.

5. The centrifugal compressor impeller as in claim 2 wherein each one of said second splitter blades has a leading edge and a trailing edge, and wherein said one second splitter blade trailing edge is located downstream of said respective first splitter blade leading edge and said one second splitter blade trailing edge is located at said impeller exit.

6. The centrifugal compressor impeller as in claim 1 wherein the number of said full length blades ranges from 7 to 15.

7. The centrifugal compressor impeller as in claim 1 wherein the desired flow split is determined based on the gV distribution at the first splitter blade leading edge location. ^{30-04-85 of S: H.}

8. The centrifugal compressor impeller as in claim 4 wherein the respective flow splits are determined on the basis of the gV distribution at the first splitter blade leading edge location and the second splitter blade leading edge location, respectively. ^{30-04-85 GP.}

9. A centrifugal compressor impeller comprising:
a hub having an axis of rotation;
a number of full length blades mounted on said hub;
an equal number of first splitter blades mounted on
said hub in alternating relation with said full length blades;
and

an equal number of second splitter blades mounted on
said hub, each of said second splitter blades being positioned
between one of said first splitter blades and the one of said
adjacent full length blades trailing with respect to the intended
direction of rotation of the impeller, said second splitter
blades being shorter in length than said first splitter blades.

10. The centrifugal compressor as in claim 9 wherein the
flow in the three sub-channels formed in the channel between
adjacent full length blades by the respective first and second
splitter blades is about 1/3:1/3:1/3 of the channel flow.

11. A double entry centrifugal compressor impeller unit
comprising the centrifugal compressor impeller defined by claim 1
and a second centrifugal compressor impeller which is the mirror
image of the defined impeller with respect to a plane perpendicu-
lar to the defined impeller axis at the impeller axial end corre-
sponding to the impeller exit portion.

12. The double entry centrifugal compressor unit as in claim 11 wherein said defined impeller and said mirror image impeller are integrally formed.

13. An impeller for a centrifugal compressor comprising:
a hub;
N full length blades distributed about said hub; and
Y splitter blades distributed about said hub and disposed between said full length blades,
wherein N and Y are integer numbers and Y is equal to 3N.

FIG. 1
PRIOR ART

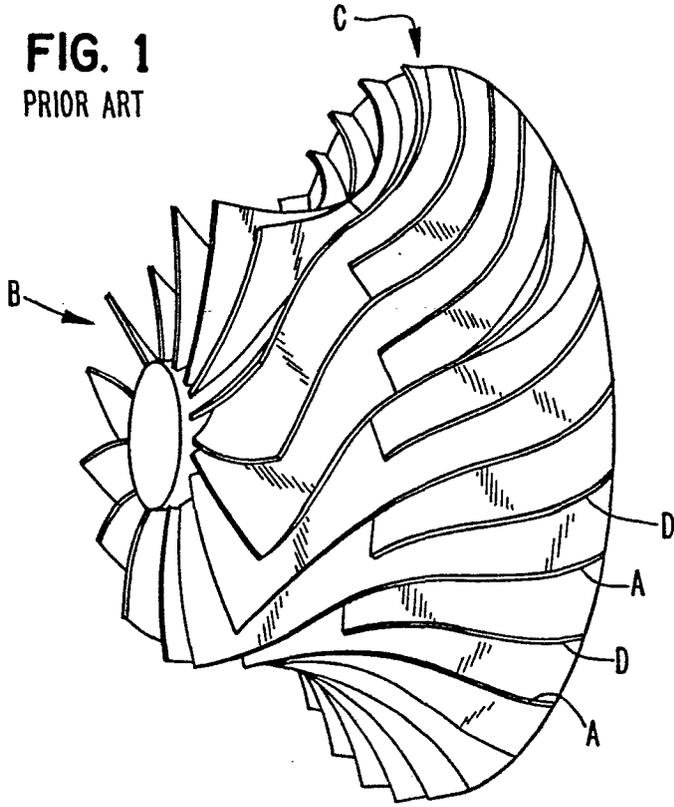


FIG. 2
TYPICAL SPLITTER ARRANGEMENT
ACCORDING TO INVENTION

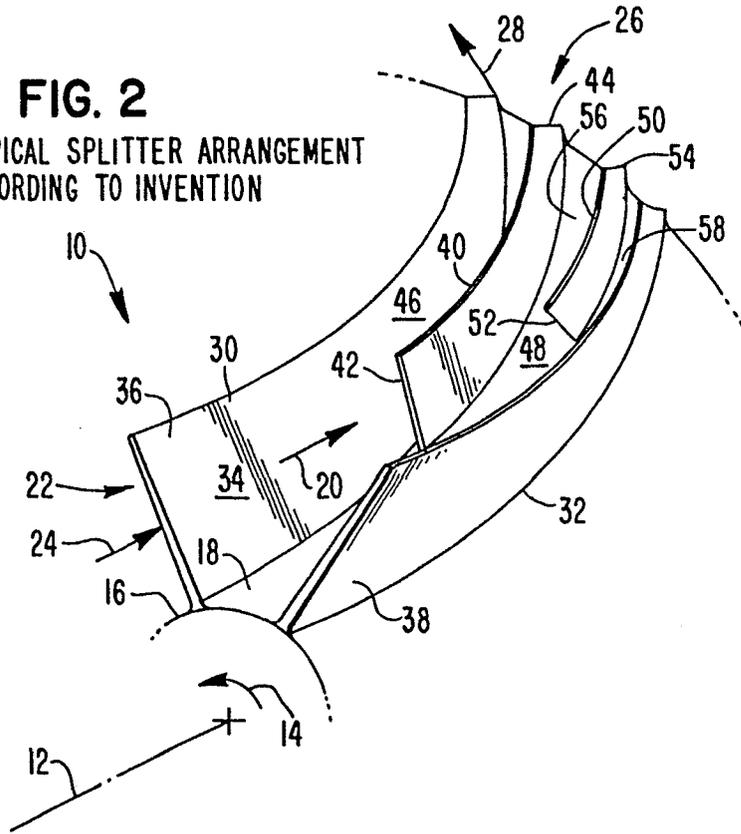


FIG. 3

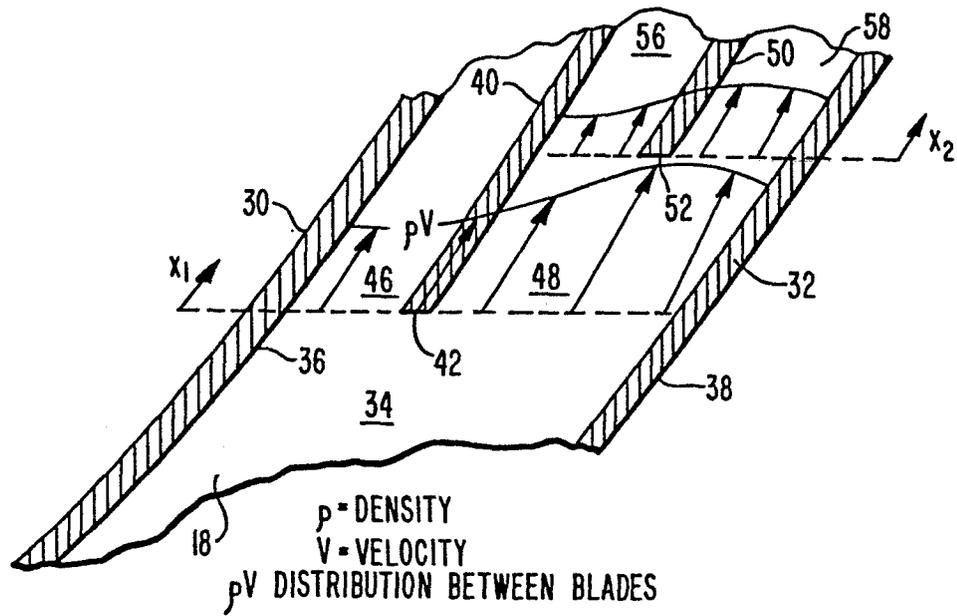
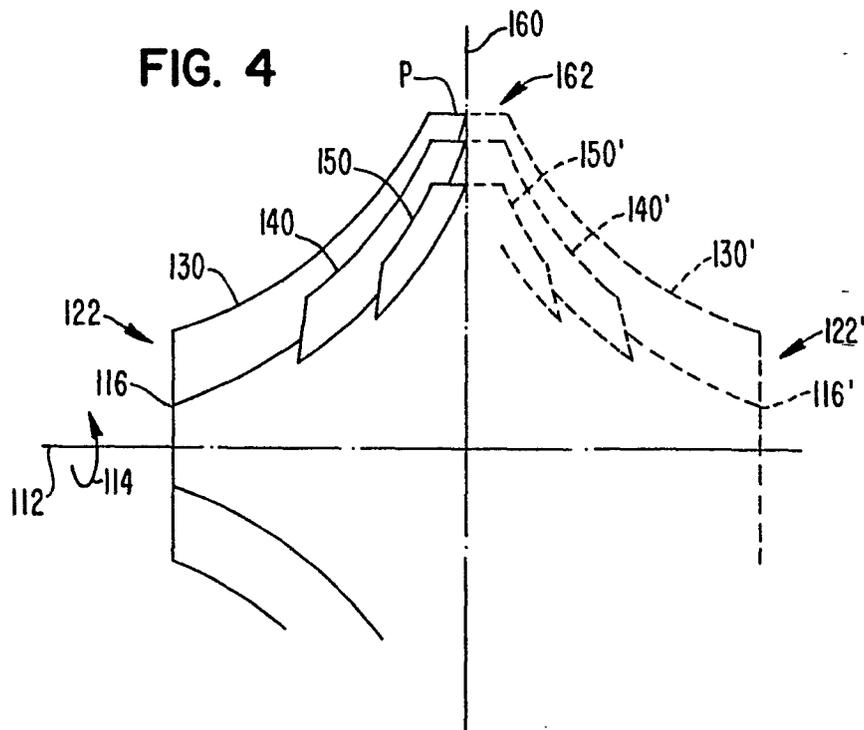


FIG. 4





DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
1	X FR-A-2 550 585 (FOUEILLASSAR) * Page 1, line 7 - end of page; page 2, lines 1-26; figures; page 3, lines 1-9 *	1-5,9, 10	F 04 D 29/28
	A	7,8,13	
3	X DE-C- 174 855 (WITTIG) * Page 1, lines 1-57; figures *	1-3,5, 9,13	
	A	4,7,8, 10	
3	X GB-A- 161 464 (REID) * Page 1, line 58 - page 2, line 27; figures 1-4,7,8 *	1-3,5, 9,11, 12	TECHNICAL FIELDS SEARCHED (Int. Cl.4) F 04 D 29/00 F 01 D 5/00
	A	4,10	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05-09-1986	Examiner KAPOULAS T.
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			