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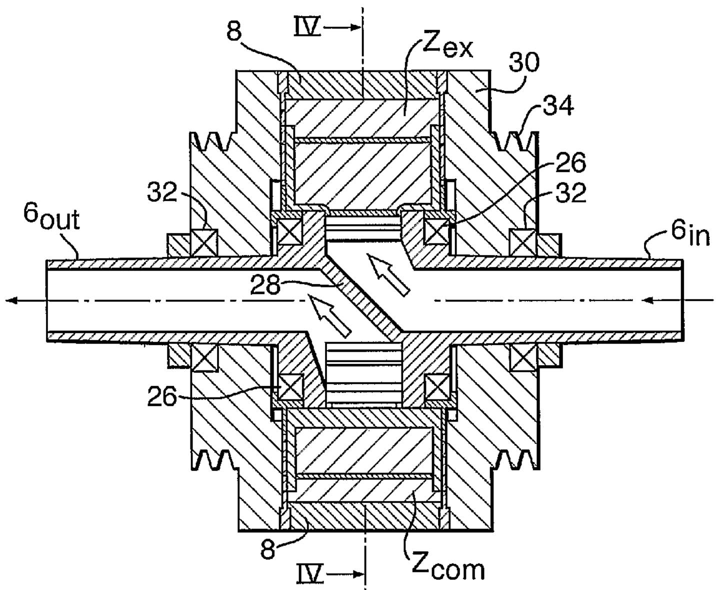
(54) Title: LIQUID RING COMPRESSOR



(57) Abstract: There is provided a liquid ring rotating casing compressor (LRRCC), including a shaft, an impeller having a core and a plurality of radially extending vanes rotatably coupled to the shaft, a tubular casing having an inner surface and an outer surface eccentrically rotatably disposed with the impeller and disc-shaped portions laterally coupled to the vanes and/or to the core. The casing defines with the impeller a compression zone, wherein edges of the vanes rotate in increasing proximity to an inner surface of the casing and an expansion zone and edges of the vanes rotate in increasing spaced-apart relationship along an inner surface of the casing. An inlet port communicates with the expansion zone, an outlet port communicates with the compression zone, and there is also provided a drive for rotating motion to the casing.

WO 2006/134590 A1

LIQUID RING COMPRESSOR

Field of the Invention

The present invention relates to Liquid Ring Compressors (LRC's) and more specifically to an LRC with a rotating casing.

Background of the Invention

U.S. Patent 5,636,523 discloses an LRC and expander having a rotating jacket, the teaching of which is incorporated herein by reference.

This known LRC, however, has several disadvantages: while the jacket is free to rotate by the liquid ring which is driven by the rotor, the velocity of the rotating casing lags behind the rotor's tips, rendering the flow unstable namely, causing inertial instability, especially when the angular momentum becomes smaller with large radiuses (the angular momentum of a liquid element located at a radius r is defined as the produces $u \cdot r$, where u is the tangential velocity). As the liquid velocity near the jacket follows the jacket's velocity, when the jacket's velocity lags behind the rotor's velocity, the friction, which is formed between the liquid and the jacket and the liquids between the liquid ring and the rotor vanes, will cause instability in the compressor.

Furthermore, in the prior art LRC, the lateral disc-shaped walls of the compressor are stationary. Thus, the liquid ring which rotates around the wet stationary walls, will also generate friction, detracting from the overall efficiency of the compressor.

Disclosure of the Invention

It is therefore a broad object of the present invention to overcome the above-described disadvantages and to provide a Liquid Ring Rotating Casing Compressor (LRRCC) in which the friction between the liquid ring and rotating casing is minimal.

It is a further object of the present invention to provide an LRRCC in which the lateral walls are not stationary, so as to reduce friction.

It is still a further object of the invention to provide an LRRCC in which the casing is driven at a velocity which is greater than 70% of the velocity of the impeller.

Another object of the present invention is to provide an LRRCC having a casing controllably driven by external means.

In accordance with the invention, there is therefore provided a liquid ring rotating casing compressor (LRRCC), comprising a shaft; an impeller having a core and a plurality of radially extending vanes rotatably coupled to said shaft, a tubular casing having an inner surface and an outer surface eccentrically rotatably disposed with said impeller, disc-shaped portions laterally coupled to said vanes and/or to said core; said casing defining with said impeller a compression zone wherein edges of said vanes rotate in increasing proximity to an inner surface of the casing and an expansion zone wherein edges of said vanes rotate in increasing spaced-apart relationship along an inner surface of the casing, an inlet port communicating with said expansion zone, an outlet port communicating with said compression zone, and a drive for imparting rotating motion to said casing.

Brief Description of the Drawings

The invention will now be described in connection with certain preferred embodiments with reference to the following illustrative figures, so that it may be more fully understood.

With specific reference now to the figures in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

In the drawings:

Fig. 1 is an isometric, partly exposed view, of the LRRCC, according to the present invention;

Fig. 2 is an isometric view of an impeller for the LRRCC, according to the present invention;

Fig. 3 is a cross-sectional view of the LRRCC along line III-III of Fig. 1, according to the present invention, and

Fig. 4 is a cross-sectional view along line IV-IV of Fig. 3.

Detailed Description of Preferred Embodiments

An isometric, partly exposed view of the LRRCC 2 according to the present invention is shown in Fig. 1. The compressor 2 having a general cylindrical shape, is composed of three major parts: an inner impeller 4 mounted on a shaft 6 and a casing 8, configured as a curved surface of a cylinder. The shaft 6 is stationary and advantageously hollow, and the impeller 4 is rotatably coupled thereon, as seen in detail in Fig. 3. The impeller 4 shown in Fig. 2 consists of a plurality of radially extending vanes 10 mounted about a core 14, and of ring-shaped side walls 12, having concentric inner edges 16 and outer edges 16'. Advantageously, as seen in the Figure, the vanes 10 terminate shorter than the outer edges 16 for reasons that will be discussed hereinafter. Further seen in Fig. 1 is the casing 8 eccentrically rotatably coupled with the impeller 4 and extending across the outer edges of the vanes 10 between the side walls 12. Optionally, the casing 8 is mechanically coupled to the impeller 4. For this purpose it is fitted with lateral rings 18 having internal teeth 20, configured to mesh with outer teeth 22 made on rings 24, which are attached to the outer sides of the side walls 12. Hence, when teeth 20 and 22 are meshed, the impeller 4 will rotate about the shaft 6 at a constant velocity with respect to the velocity of the casing 8. Preferably, the velocity of the casing 8 should be greater than 70% of the velocity of the impeller 4.

The eccentricity ecr of the casing 8 with respect to the impeller 4 is given by the formula:

$$ecr < (1 - c)/3,$$

wherein $ecr = e/R$,

where e is the distance between the impeller and casing axis and c is the ratio between the radius C of the shaft 6 and the radius R of the casing 8.

Referring now also to Figs. 3 and 4, it can be seen that once the shaft mounted impeller and casing are assembled, there will be formed inside the casing 8 two distinct zones defined by the inner surface of the casing 8 and the impeller 4: a compression zone Z_{com} where the edges of the vanes 10 are disposed and rotate in increasing proximity to the inner surface of the casing 8 and an expansion zone Z_{ex} where the edges of the vanes 10 are disposed and rotate in increasing spaced-apart relationship along an inner surface of the casing 8. Also seen in Fig. 3 are bearings 26 coupling the impeller 4 on the shaft 6, the hollow shaft inlet portion 6_{in} and an outlet portion 6_{out} separated from the inlet portion 6_{in} by a partition 28.

According to the present invention, the casing 8 is driven by an outside drive means such as a motor (not shown), coupled to the casing by any suitable means such as belts, gears, or the like. In Fig. 3 there is shown a casing, drive coupling means 30 mounted on the shaft 6 via bearings 32. The drive coupling means 30 may be provided on any lateral side of the casing 8, on both sides (as shown), or alternatively, the casing 8 may be driven by means provided on its outer surface. The ribs 34 are provided for guiding driving belts (not shown) leading to a motor.

The radial liquid flow near the border between the compression zone Z_{com} and expansion zone Z_{ex} is associated with high liquid velocity variations between the vanes 10 and the casing 8. This tangential velocity variation is dissipative. To reduce the dissipative velocity, in the present invention the ends of the vanes 10 are shorter as compared with the impeller's side walls 12. In this way, the distance between the ends of the vanes 10 and the casing 8 increases, the dissipative velocity is reduced and the efficiency increases.

In the compression zone Z_{com} shaft work is converted to heat. In accordance with another feature of the present invention cold fluid can be introduced into the compression zone Z_{com}, thus heat will be extracted from the compression zone by the cold liquid. In this way, the compressed gas will be colder, further increasing the compressor's efficiency, as less shaft work is required to compress cold gas than hot gas.

In the preferred embodiment, the fluid (usually cold water) should be atomized and sprayed directly into the compression zone Z_{com}. To be effective, the droplet average diameter by volume should advantageously be smaller than 200 microns. In order to extract most of the generated heat and keep the air temperature at low levels, the liquid mass flow ml (kg/s) should be comparable to the air mass flow, say ml>ma/3.

In Fig. 4, there are illustrated spray nozzles 36 formed in the core 14 about which the vanes 10 are mounted. As can be seen, the spray nozzles 36 may be formed on the partition 28, so as to direct atomized fluid in two directions.

In the compression zone Z_{com} near the border or interface between the two zones liquid waves are developed. The waves are associated with leakage of compressed air to the expanding zone Z_{ex}, which is dissipative in nature. The wave's amplitude and with it, the leakage, increases with distance between two neighboring vanes. To reduce the leakage, the vane numbers should be larger than 10. Furthermore, it is required that the leakage air will expand at the expanding zone Z_{ex}. For this reason, the vanes 10 should be close to the central shaft 6, so that the interval between the vanes and the duct will be small and the angle α between the narrow point Tec and the opening to the low pressure inlet Te exceeds ½ radian.

It will be evident to those skilled in the art that the invention is not limited to the details of the foregoing illustrated embodiments and that the present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

WHAT IS CLAIMED IS:

1. A liquid ring rotating casing compressor (LRRCC), comprising:

a shaft;

an impeller having a core and a plurality of radially extending vanes rotatably coupled to said shaft;

a tubular casing having an inner surface and an outer surface eccentrically rotatably disposed with said impeller;

disc-shaped portions laterally coupled to said vanes and/or to said core;

said casing defining with said impeller a compression zone wherein edges of said vanes rotate in increasing proximity to an inner surface of the casing and an expansion zone wherein edges of said vanes rotate in increasing spaced-apart relationship along an inner surface of the casing;

an inlet port communicating with said expansion zone;

an outlet port communicating with said compression zone, and

a drive for imparting rotating motion to said casing.

2. The LRRCC as claimed in claim 1, wherein said shaft is hollow.

3. The LRRCC as claimed in claim 1, wherein the eccentricity ecr of the casing relative to the impeller is given by:

$$ecr < (1 - c)/3$$

wherein $ecr = e/R$,

where e is the distance between the impeller and casing axis and c is the ratio between the radius C of the shaft and the radius R of the casing.

4. The LRRCC as claimed in claim 1, wherein the number of vanes of the impeller is at least ten.

5. The LRRCC as claimed in claim 1, wherein the vanes of said impeller are connected to disc-shaped portions having inner and outer edges and said vanes terminate shorter than said outer edges.

6. The LRRCC as claimed in claim 1, wherein said impeller and casing are mechanically coupled.

7. The LRRCC as claimed in claim 6, wherein said mechanical coupling is effected by gear means.

8. The LRRCC further comprising means for rotating said casing.

9. The LRRCC as claimed in claim 1, further comprising spray nozzles located at, or adjacent to, said compression zone for introducing cold fluid in the compression zone.

10. The LRRCC as claimed in claim 9, wherein said cold fluid are droplets of liquid having an average diameter by volume $d < 200$ microns.

Fig.1.

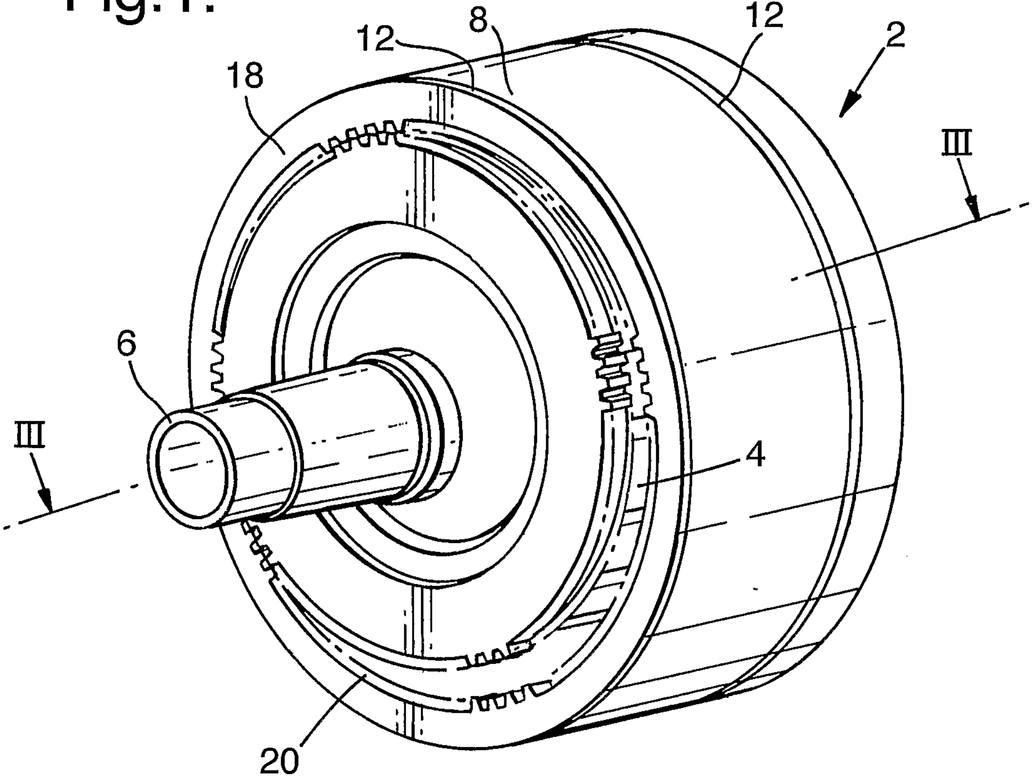


Fig.2.

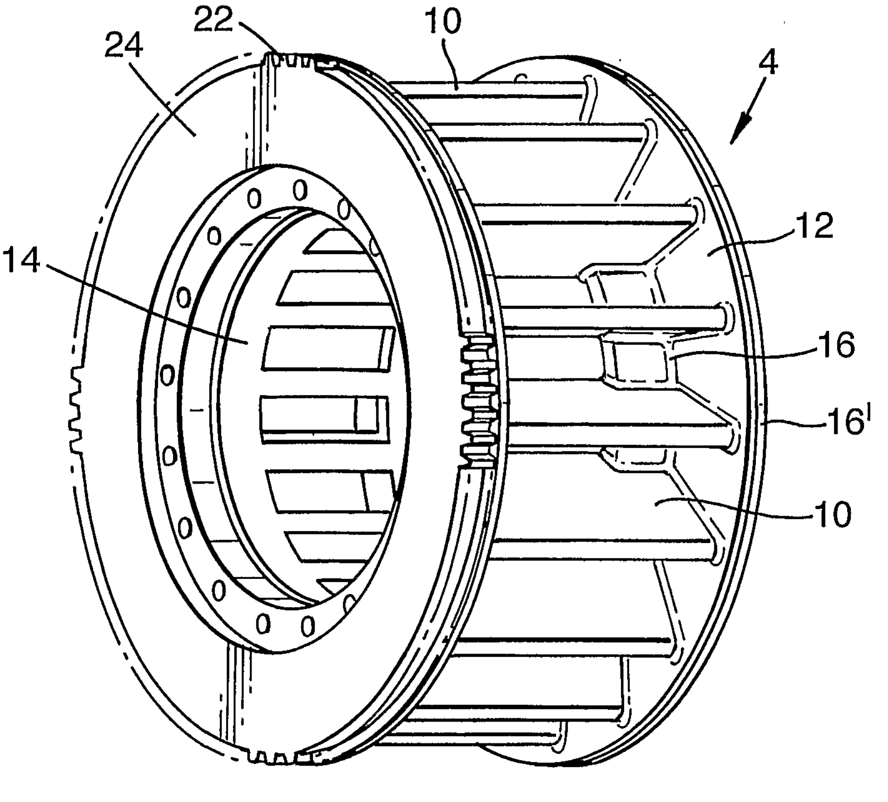


Fig.3.

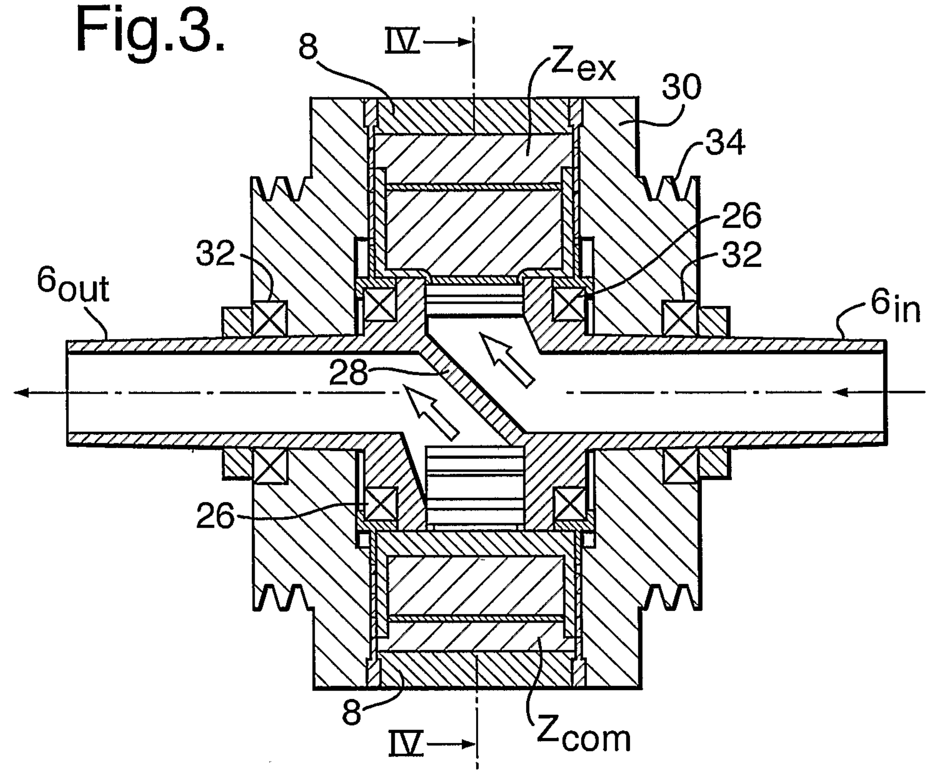
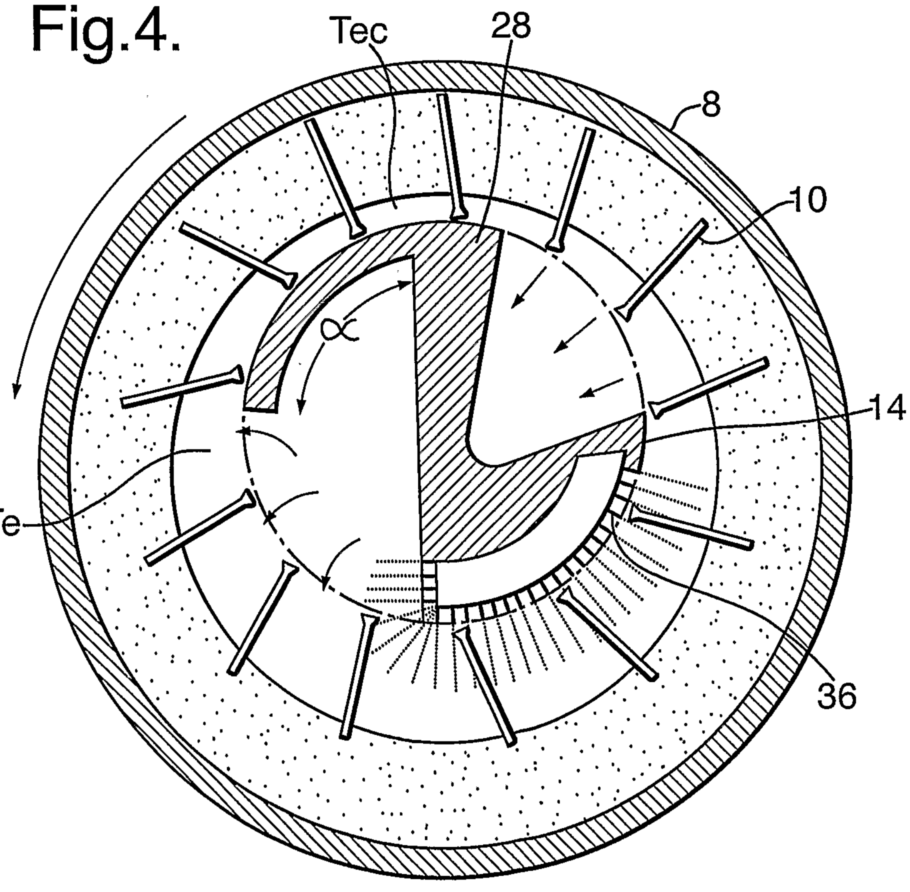


Fig.4.



INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2006/000680

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04C19/00 F01C21/08 F01C17/02
ADD. F04C29/04

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)
F04C F01C

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	FR 865 434 A (MARCEL RENAUD) 23 May 1941 (1941-05-23) figures 1,2 page 1, line 33 - line 60	1,2,4, 6-8 3
X	US 4 112 688 A (SHAW ET AL) 12 September 1978 (1978-09-12) figures 1-7 column 4, line 36 - column 5, line 44	1,2,4, 6-8
X	US 953 222 A (LEWIS HALLOCK NASH) 29 March 1910 (1910-03-29) figures 3-7 page 2, line 106 - line 130	1,2,4-6, 8

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
7 September 2006	15/09/2006

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2006/000680

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 201 575 A (CORNEIL ERNEST R ET AL) 21 May 1940 (1940-05-21) figures 3-6 page 1, column 2, line 35 - line 48 page 2, column 1, lines 25-30 page 2, column 2, line 56 - page 3, column 1, line 16	1,2,4, 6-8
X	US 5 122 035 A (JUHOLA ET AL) 16 June 1992 (1992-06-16) figures 3a-b column 3, line 11 - line 49	1,4,8-10
A	FR 999 464 A (SOCIETE CIVILE D'ETUDES ET DE RECHERCHES MECANIQUES ET THERMIQUES) 31 January 1952 (1952-01-31) figures 1,2	5
Y	US 5 636 523 A (ASSAF ET AL) 10 June 1997 (1997-06-10) cited in the application	3
A	figures 3-5 column 1, line 49 - line 66 column 2, line 40 - line 60	2,4

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IL2006/000680

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
FR 865434	A	23-05-1941	NONE			
US 4112688	A	12-09-1978	NONE			
US 953222	A		NONE			
US 2201575	A	21-05-1940	NONE			
US 5122035	A	16-06-1992	DE	68918446	D1	27-10-1994
			DE	68918446	T2	19-01-1995
			EP	0420886	A1	10-04-1991
			FI	882712	A	09-12-1989
			WO	8912168	A1	14-12-1989
			JP	3505901	T	19-12-1991
FR 999464	A	31-01-1952	NONE			
US 5636523	A	10-06-1997	NONE			