(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 September 2015 (24.09.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/140669 A1

(51) International Patent Classification:
F04D 13/02 (2006.01) *F03B 11/00* (2006.01)
F04D 13/06 (2006.01) *F03B 13/10* (2006.01)
F04D 13/08 (2006.01) *B04C 1/00* (2006.01)
F04D 29/10 (2006.01) *B01D 45/12* (2006.01)

(21) International Application Number:
PCT/IB2015/051744

(22) International Filing Date:
10 March 2015 (10.03.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
14/218,640 18 March 2014 (18.03.2014) US

(71) Applicant: **FUGLESANGS SUBSEA AS** [NO/NO]; Nedre Skoyen vei 11, N-0276 Oslo (NO).

(72) Inventor: **SINNERUD, Arve**; Gustav vigelands vei 7b, N-0274 Oslo (NO).

(74) Agents: **BUSH, Gary** et al.; ANDREWS KURTH LLP, 600 Travis St., Suite 4200, Houston, Texas 77002 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: ROTARY MACHINE WITH SEALED MAGNETIC DRIVE

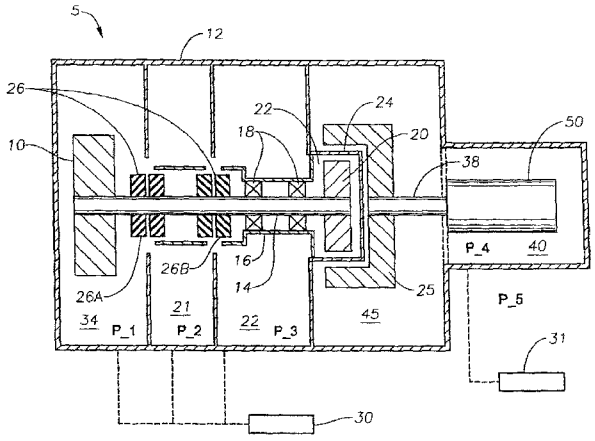

FIG. 1

(57) Abstract: A rotary machine is disclosed which is coupled to a motor by a magnetic coupling. An outer magnet drives an inner magnet which is fixed to a rotary shaft which turns a rotor of the machine. The inner magnet is in an enclosure filled with pressurized fluid. The outer magnet is driven by a motor, both the outer magnet and motor being placed in a pressurized cavity outside of the enclosure for the inner magnet. Such arrangement enables the machine, including the motor to be submerged in the sea or chemical liquid while preventing seawater or liquid chemical contamination of the motor and the rotating machine.

WO 2015/140669 A1

ROTARY MACHINE WITH SEALED MAGNETIC DRIVE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns a rotary machine coupled to a drive source by a magnetic coupling. In particular, the invention concerns a sealing arrangement for such a machine which is submerged in liquid, which may be water or a chemical liquid in a tank.

2. Description of the Prior Art

Machines are well known for compressing or expanding a fluid for the chemical industry or for oil and gas processing. The machines have included a rotor mounted on a stator to rotate in a fluid chamber, a rotary shaft on which the rotor is fixed, and which extends outside the stator through a shaft passage thereof. Bearings are mounted in the shaft passage for guiding and supporting the shaft. Outside the stator, the rotary shaft is connected to a drive shaft from a drive source such as a motor or a turbine or the like.

U.S. Patent 5,334,004 to Lefevre et al. shows a compressor or turbine where the drive shaft is magnetically coupled to an external drive source but with the internal drive shaft enclosed in a bell filled with a liquid under pressure. A closed enclosure is formed around the shaft passage which receives the shaft which drives the rotor. The Lefevre arrangement prevents leakage of dangerous gas from the inside to the outside of the rotary machine.

3. Identification of the Objects of the Invention

A primary object of the invention is to provide a sealing arrangement for a magnetically coupled rotating machine.

Another object of the invention is to provide system reliability for a rotary machine which is installed in a submerged environment such as water or a liquid chemical.

SUMMARY OF THE INVENTION

The machine of the invention includes a housing with a rotor mounted on a shaft supported by bearings which are separated, according to a first embodiment, from the fluid being processed by the rotor by means of high pressure, heavy duty mechanical seals. A barrier fluid between the mechanical seals and a rear magnetic housing, or "bell," is provided under high pressure. According to a second embodiment, the seals of the first embodiment are eliminated such that the rotor pressure is applied directly to the shaft bearings. In both embodiments, a cavity on the outside of the housing surrounds one magnet of the magnetic coupling and is filled with another liquid under pressure that enables the entire arrangement to be submerged in a deep sea environment or in a tank containing liquid chemicals while providing a barrier from seawater or chemicals entry into the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic illustration of the rotating machine of the invention which has a rotor magnetically coupled to an external power source and with an external magnet of the coupling placed in a liquid pressurized cavity; and

Figure 2 is an alternative embodiment of the invention where the magnetic elements of the magnetic coupling of Figure 1 are reversed and with seals between the driven rotor and bearings removed from the embodiment of Figure 1.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Figure 1 shows the invention of a rotating machine 5 with a rotor 10 disposed in a housing 12. The rotor is driven by a rotary shaft 14 which is positioned within a shaft passage 16 disposed within housing 12. Bearings 18 provide rotational support for the shaft 14 within shaft passage 16.

An internal magnet 20 is fixed to an interior end of rotary shaft 14. A first enclosure 22 surrounds the internal magnet 20 and is formed by the bell shaped member 24 and the

shaft passage 16. The first enclosure extends to a seal structure 26 which may be a dual or single mechanical seal. A dual seal 26 is illustrated in Figure 1, but a single seal can be provided.

As illustrated in Figure 1, the first enclosure 22 can be pressurized to a pressure P3 by Pressure Source/Compensator 30. Enclosure 22 serves as a barrier cavity. Another barrier cavity may be provided between dual seals 26 (if provided) and can be pressurized to a pressure P2 by the Pressure Source/Compensator 30. Dual or single seals may be eliminated from the embodiment of Figure 1 such that bearings 18 are exposed to process fluid in cavity 34. Such an arrangement is shown in Figure 2.

The rotary shaft 14 is driven by magnetic coupling between internal magnet 20, inside bell 24, and external magnet 25 which is rotated via motor shaft 38 by a motor 50 disposed in a motor cavity 40. Pressurized liquid is provided in the motor cavity 40 and a second enclosure 45 which surrounds the external magnet and motor shaft 38. The motor cavity 40 and second enclosure 45 are pressurized to a pressure P4 by a pressure source/compensator 31. The pressure P4 may be slightly higher than the ambient pressure P5 for subsea conditions (or chemical tank conditions) which could typically be from 0 to 300 bar.

Figure 2 illustrates an alternative arrangement of the rotating machine where the seals 26 of Figure 1 have been eliminated and the magnetic elements between shafts 14 and 38 have been reversed. In other words, magnet 20 is attached to shaft 38, and magnet 25 is attached to shaft 14.

The entire machine of Figure 1 or Figure 2 may be immersed in water or in chemical liquids of a tank under ambient pressure condition P5.

The arrangement described above provides a sealing mechanism for rotating machines such as a pump, cyclone, separator, or turbine for either water, hydrocarbons, chemicals or slurry applications. The arrangement is especially designed for such rotating machines which

are submerged in the sea. The arrangement provides sealing of components to achieve system reliability. It also enables separation of the process fluid, which may contain sand particles, from other vital components such as bearings and the magnetic coupling.

As illustrated in Figure 1, pressurized liquids or barrier fluids between the mechanical seals 26 and the bell 24 are pressurized to high differential pressures. A second enclosure 45 outside the bell 24 has another pressure compensated liquid provided by pressure source/compensator 31 that enables the entire rotating machine 5 to be submerged deeply in the ocean while providing two barriers against seawater contamination in case of a mechanical seal 26 failure.

The dual mechanical seals 26A, 26B, one 26A facing the process cavity 34, the other 26B facing the barrier cavity 22, provide added security against failure. If sand particles or the like were to penetrate the seal 26A facing the process cavity 34, a second seal barrier 26B exists to inhibit particle intrusion into the cavity 22 in which the bearings are positioned.

It is preferred to provide seals 26 which are capable of handling "reverse" pressure. Such a condition would exist where pressure P1 in process cavity 34 is larger than pressure P2 or P3 in barrier cavities 21, 22. Seals 26A, 26B are preferably hard surface seals so as to be able to withstand operation with sand particles in the liquid.

Although dual mechanical seals are preferred, a single mechanical seal can be provided, whereby a single pressure is provided rather than the two pressure P2 and P3 as illustrated in Figure 1.

As indicated above, Figure 2 shows an arrangement where no seals are provided at all between rotor 10 and bearings 18 where the pressure P3 in enclosures 22 and 45 is maintained at the same pressure P1 of fluid in enclosure 34.

The arrangements of Figures 1 and 2 eliminate the need for a motor 50 with a pressure containing shell, since the pressure P4 is not the same as the barrier fluid pressure P3, due to

the pressure containing capability of the bell 24 in Figure 1 and the surround 28 of Figure 2. As a result, the motor pressure P4 is equal to or slightly higher than ambient pressure condition P5 in a submerged condition in the sea or in a chemical tank. This feature allows the material thickness of the motor shell to be reduced which provides advantages such as less cooling requirements and weight reduction. Furthermore, the arrangement of Figure 1 allows "dry running," (without process fluid) in the process cavity 34, without compromising system reliability, because the bearings 18 are lubricated by the barrier fluids applied to the barrier cavities 21, 22.

As illustrated in Figure 1, two mechanical seals 26A, 26B each mounted on the rotary shaft 14 provide a dual barrier between the process cavity 34 and the bearings 18. The barrier cavity is pressurized by the same pressure source/compensator 30 that generates overpressure P2 or P3 > P1. This arrangement provides significant amounts of barrier fluid leakage from seals 26A, 26B so as to inhibit possible intrusion on the hard surfaces of the mechanical seals 26 while ultimately protecting the load carrying bearings 18 from contaminates in the process fluid of process cavity 34.

The motor 50 and motor cavity 40 can be pressurized by a liquid, shared with the liquid in the second enclosure 45. The liquid is supplied and pressure compensated by source/compensator 31. The pressure P4 is compensated toward the ambient pressure condition P5 of the subsea environment or chemical liquid in a chemical tank. The pressure P4 of the second enclosure 45 of Figure 1 may or may not be lower than the barrier fluid pressure P3 or P2.

WHAT IS CLAIMED

1. A rotary machine for treating fluids under pressure, comprising,

a housing (12) in which an annular fluid flow process cavity (34) is formed and having a shaft passage (16) formed in the housing,

a rotor (10) mounted in said process cavity (34),

a rotary shaft (14) to which the rotor (10) is fixed, said shaft extending outside said process cavity (34) through said shaft passage (16),

bearings (18) mounted between said rotary shaft (14) and said shaft passage (16), said bearings arranged and designed for guiding and supporting the shaft in the shaft passage,

a bell (24) sealingly placed around said shaft passage (16), said bell forming a first barrier cavity (22) which is separated from said annular fluid flow process cavity (34),

a rotation mechanism including an inner permanent magnet (20) fixed to said rotary shaft (14) inside said first barrier cavity (22) and an external magnet (25) fixed to a motor shaft (38) outside said first barrier cavity (22), whereby rotation of said motor shaft (38) transfers rotation to said rotary shaft (14) by magnetic coupling between the external magnet (25) to the internal magnet (20),

said machine having a second enclosure (45) filled with a pressurized fluid, said second enclosure (45) placed around and outside of said bell and around said motor shaft (38).

2. The improved rotary machine of claim 1 further comprising,

a motor (50) in said second enclosure (45) which turns said motor shaft (38).

3. The improved machine of claim 1 wherein,

said rotor (10) is arranged and designed in said fluid flow process cavity (34) as a pump.

4. The improved machine of claim 1 wherein,

said rotor (10) is arranged and designed in said fluid flow process cavity (34) as a cyclone or separator.

5. The improved machine of claim 1 wherein,

said rotor (10) is arranged and designed in said fluid flow process (34) as a turbine for power production or compression.

6. The improved machine of claim 1 wherein,

said bearings (18) in said barrier cavity (22) are exposed directly to said process cavity (34).

7. The improved rotary machine of claim 1 further comprising,

a first seal (26A) mounted on said rotary shaft (14) which faces said fluid flow process cavity (34), and

a second seal (26B) mounted on said rotary shaft (14) which faces said barrier cavity 22.

8. The improved rotary machine of claim 1 further comprising,

a seal structure (26) mounted on said rotary shaft (14) and positioned between said fluid flow process cavity (34) and said first barrier cavity (22).

9. The machine of claim 8 of which said seal structure (26) includes,

a first seal (26A) mounted on said rotary shaft (34) facing said fluid flow process cavity (34), and

a second seal (26B) mounted on said rotary shaft (34) facing said sealed barrier cavity (21),

wherein said first and second seals (26A, 26B) are spread apart from each other, with a space between said first and second seals defining an additional barrier cavity (21).

10. The machine of claim 9 wherein,

a first pressure P1 is established in said fluid flow process cavity (34),

a second pressure P2 is established in said additional barrier cavity (21), and

a third pressure P3 is established in said sealed barrier cavity (22).

11. The machine of claim 10 wherein,

said seals (26A, 26B) are arranged and designed to inhibit particle intrusion into said first sealed barrier cavity (22).

12. The machine of claim 9 wherein,

said third pressure P3 is greater than said second pressure P2, and

said second pressure P2 is greater than said first pressure P1.

13. The machine of claim 11 wherein,

said seal structure (26) is designed and arranged to handle reverse pressure where said first pressure P1 is greater than said second pressure P2 and said second pressure P2 is greater than said third pressure P3.

14. The rotary machine of claim 2 wherein pressure in said second enclosure (45) is pressurized to a level P4 toward the ambient pressure condition P5 of the subsea environment or chemical liquid in which said machine is immersed.

15. A rotary machine (5) for treating fluids while being submerged in a liquid,

a rotor (10) disposed in a process cavity (34),

a rotary shaft (14) connected to said rotor (10),

said rotary shaft (14) rotated by a mechanism that includes a first magnet (20, 25) coupled to said shaft (14) and a second magnet (25, 20) arranged to turn the first magnet (20, 25) by magnetic coupling,

and a motor (50) for rotating said second magnet (25, 20),

said second magnet (25, 20) and said motor (50) being disposed in a housing (40) which is under pressure (P4) that is equal to or greater than the pressure of water or chemical liquid (P5) in which said machine (5) is submerged.

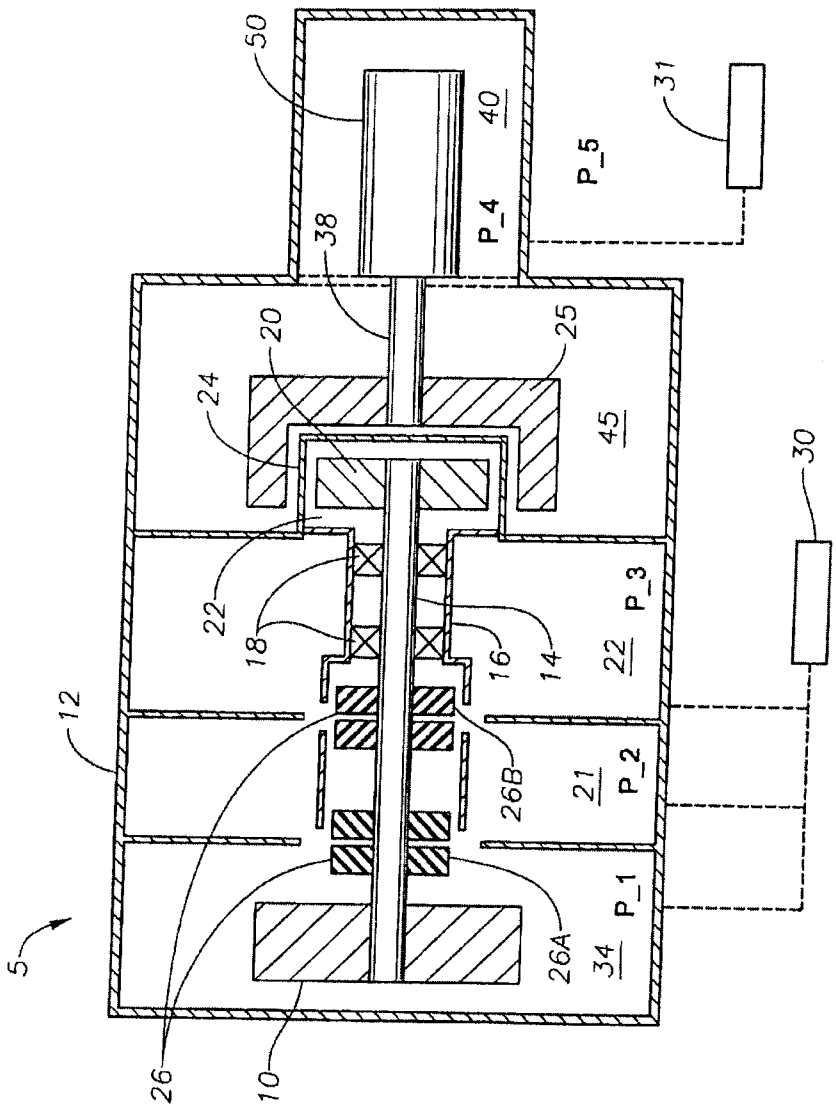
50
40
P_4
P_5
31
38
20
25
24
45
30
22
18
16
14
P_3
22
12
26B
21
P_2
P_1
26A
34
5
26
10

FIG. 1

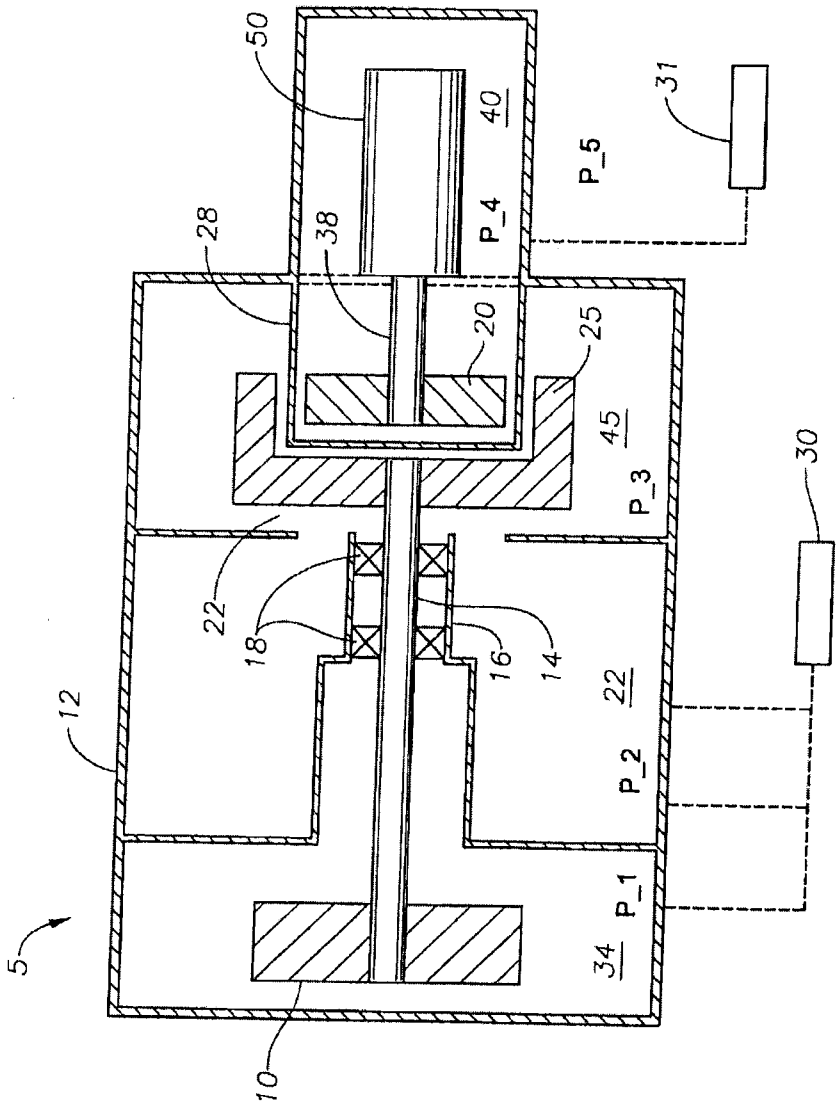

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/051744

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04D13/02 F04D13/06 F04D13/08 F04D29/10
ADD. F03B11/00 F03B13/10 B04C1/00 B01D45/12

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)
F04D F03B B01D B04C F01D

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 practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 213 736 B1 (WEISSER G LOUIS [US]) 10 April 2001 (2001-04-10) column 1, lines 7-9 column 1, lines 53-67 figure 1 -----	1-6,8, 14,15
X	DE 94 12 591 U1 (FRIATEC RHEINHUETTE GMBH & CO [DE]) 6 October 1994 (1994-10-06) page 5, paragraph 2 page 6, last paragraph figure 1 -----	1-6,8, 14,15
X	EP 0 499 504 A1 (BERTIN & CIE [FR]) 19 August 1992 (1992-08-19) column 1, lines 28-50 column 5, line 38 - column 6, line 17 figure 1 figure 2 ----- -/--	1-3,5, 7-14

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

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent 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 when the document is taken alone

"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

Date of the actual completion of the international search	Date of mailing of the international search report
23 June 2015	30/06/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	de Verbigier, L

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/051744

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 386 315 A1 (BURGMANN DICHTUNGSWERK FEODOR [DE]) 12 September 1990 (1990-09-12) the whole document -----	1-15
A	EP 0 617 999 A1 (DRAISWERKE GMBH [DE]) 5 October 1994 (1994-10-05) the whole document -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2015/051744

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6213736 B1	10-04-2001	NONE	
DE 9412591 U1	06-10-1994	NONE	
EP 0499504 A1	19-08-1992	CA 2060793 A1	13-08-1992
		DE 69205597 D1	30-11-1995
		EP 0499504 A1	19-08-1992
		FR 2672636 A1	14-08-1992
		US 5334004 A	02-08-1994
EP 0386315 A1	12-09-1990	NONE	
EP 0617999 A1	05-10-1994	DE 4310266 A1	06-10-1994
		EP 0617999 A1	05-10-1994