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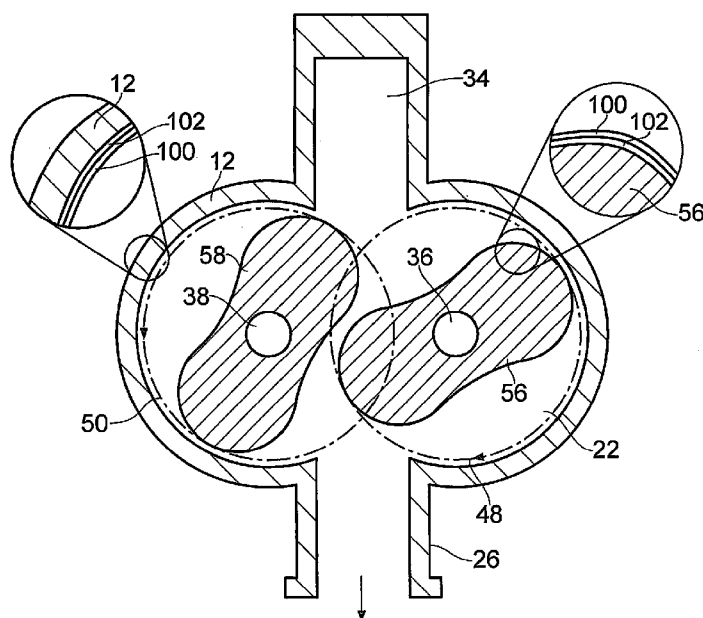


FIG. 2

(57) Abstract: The present invention relates to an improved vacuum pump, in particular an improved coating for internal shaft, rotor and/or stator components of dry vacuum pumps with a first layer comprising a high phosphorous nickel plating (NiP) and wherein the first layer is coated with a second layer comprising a high phosphorous nickel with nickel phosphorous and fluoropolymer (NiP-PTFE).

MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
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VACUUM PUMP COMPONENT

TECHNICAL FIELD OF THE INVENTION

The present invention relates to an improved vacuum pump, in particular an improved coating for a dry pump component such as the internal
5 shaft, rotor and/or stator components of dry vacuum pumps.

BACKGROUND OF THE INVENTION

Dry vacuum pumps are widely used in industrial processes to provide a clean and/or low-pressure environment for the manufacture of products. Applications include the pharmaceutical, semiconductor and flat panel
10 manufacturing industries. Such pumps include an essentially dry (or oil free) pumping mechanism, but generally also include some components, such as bearings and transmission gears, for driving the pumping mechanism that require lubrication in order to be effective. Examples of dry pumps include Roots, Northey (or “claw”), screw and scroll pumps. Dry pumps incorporating
15 Roots and/or Northey rotor components are commonly multi-stage positive displacement pumps comprising a stator component defining a plurality of pumping chambers each housing a respective pair of intermeshing rotor components. The rotor components are located on contra-rotating shafts, and may have the same type of profile in each chamber or the profile may change
20 from chamber to chamber.

Spheroidal graphite iron (SG) castings have for a long time been used in the manufacture of shaft, stator and rotor components for dry vacuum pumps due to its strength and machinability. However, in the semiconductor

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industries the increasing use of high temperature, typically greater than 150 Celsius and high flow rates of relatively corrosive gases such as chlorine, boron trichloride, hydrogen bromide, fluorine and chlorine trifluoride has led to severe corrosion, and therefore relatively short lifetime, of, spheroidal graphite
5 iron shaft, stator and rotor components. As a matter of fact an increase of 10 Celsius degrees in temperature nearly doubles the corrosion rate. Such corrosion can lead to equipment failure, leakage of process gases and possible process contamination, in addition to the costs associated with the replacement of the pump or the corroded parts and consequential process
10 downtime.

In view of this, it is known to passively protect these components by the formation of a resin or polymeric coating of a fluoropolymer or polyimide material on the component surfaces which are exposed to the corrosive gases and high temperatures. Such coatings have a tendency to degrade with time,
15 with the resultant peeling or flaking of the coating exposing the underlying cast iron to the corrosive gases.

Another alternative is to form these components from a nickel-rich cast iron, for example ductile Ni-resist, or a stainless steel having superior corrosion resistance. However, Ni-resist cast iron and stainless steel are
20 relatively expensive and difficult to machine, and so do not provide cost-effective options for use in the manufacture of the rotor and stator components. Furthermore, Ni-resist cast iron and stainless steel have a high level of thermal expansion in use at high temperatures and therefore lose performance.

Another alternative is to form these components from a high phosphorous nickel plating (NiP) which typically contains 10-12% phosphorous. The benefits of high phosphorous NiP plating are that it provides high corrosion resistance because the surface is more uniform and is without pin holes, which lead to corrosion. Additionally, the machinability of the substrate is unchanged and the addition of NiP plating does not significantly change the thermal properties of a part. However, the use of NiP plating on cast iron and stainless steel in dry vacuum pumps has the great disadvantage of causing seizures of the pumping mechanism when there is rotor to stator contact. Otherwise known as galling, the surface materials of both components can adhere when in sliding contact, for example when a rotating rotor contacts a stator in a dry vacuum pump. NiP plating will gall when rubbed on cast iron, stainless steel, or on NiP plating itself.

A known approach to the prevention of galling is to incorporate a layer comprising a nickel phosphorous and a fluoropolymer (PTFE) in the NiP plating, thereby creating NiP-PTFE.

With a NiP-PTFE plating it solves the problem of galling in NiP plating alone, however, the NiP-PTFE has less chemical resistance than a pure NiP plating of the same thickness.

It is the aim of the present invention to overcome these issues by creating a plating that is both high in chemical resistance and prevents galling.

SUMMARY OF THE INVENTION

The present invention provides a dry pump component coated with a first layer comprising a high phosphorous nickel plating (NiP) of at least 5 μm thickness and wherein the first layer is coated with a second layer comprising
5 a high phosphorous nickel with nickel phosphorous and a fluoropolymer (NiP-PTFE) of at least 5 μm thickness, wherein the ratio of the thickness of the first layer of NiP to the thickness of the second layer of NiP-PTFE provides high corrosion resistance and galling resistance.

It has been surprisingly found that a combination of a first layer
10 comprising a high phosphorous nickel plating of at least 5 μm thickness coated with a second layer comprising a high phosphorous nickel (NiP) with a nickel phosphorous and a fluoropolymer (PTFE), NiP-PTFE coating of at least 5 μm thickness, provides both long lived excellent corrosion resistance as with NiP alone, but with low galling effects as with fluorinated polymers alone.

15 Other preferred and/or optional aspects of the invention are defined in the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the present invention may be well understood, an
20 embodiment thereof, which is given by way of example only, will now be described with reference to the accompanying drawings, in which:

Figure 1 is a cross-section through a multi-stage dry vacuum pump;

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Figure 2 is a view along line A-A in Figure 1 showing the layers according to the present invention;

Figure 3 illustrates a dual layer nickel plating of the present invention;

5

Figure 4 illustrates a single layer nickel plating of the prior art.

DETAILED DESCRIPTION OF THE INVENTION

With reference to Figures 1 and 2, a multi-stage dry vacuum pump 10 comprises a stator component 12, preferably coated with a first layer 102 comprising a high phosphorous nickel plating (NiP) and the first layer is coated with a second layer 100 comprising a high phosphorous nickel with a nickel phosphorous and a fluoropolymer (NiP-PTFE), having a series of walls that define a plurality of pumping chambers 14, 16, 18, 20, 22. An inlet conduit 24 for conveying gas to be pumped to the inlet pumping chamber 14, and an exhaust conduit 26 for exhausting pumped gas from the exhaust pumping chamber 22, are also formed in the stator 12. Circumferential passages 28, 30, 32 and 34 formed in the stator 12 connect the pumping chambers 14, 16, 18, 20, 22 in series.

20 The stator 12 houses a first shaft 36 and, spaced therefrom and parallel thereto, a second shaft 38. Bearings 40 for supporting the shafts 36, 38 are provided in the end plates 42, 44 of the stator 12. One of the shafts 36 is connected to a drive motor 46, the shafts being coupled together by means of timing gears 47 so that in use the shafts 36, 38 rotate at the same speed

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but in opposite directions, as indicated by arrows 48 and 50 in Figure 2. A gear box 52 attached to the side of the pump 10 contains oil 54 for lubricating the timing gears 47.

Within each pumping chamber, the shafts 36, 38 support respective
5 rotor components 56, 58, which may also be coated with a first layer 102 comprising a high phosphorous nickel plating (NiP) and the first layer is coated with a second layer 100 comprising a high phosphorous nickel with nickel phosphorous and a fluoropolymer (NiP-PTFE). In this embodiment, the rotors 56, 58 have a Roots-type profile within each pumping chamber,
10 although a mixture of Roots and/or Northey-type profiles may be provided within the pump 10. Alternatively the rotors may be of a screw type rotor profile. The rotors 56, 58 are located in each pumping chamber relative to an internal surface of the stator 12 such that the rotors 56, 58 can act in an intermeshing manner known per se.

15 In use, gas is urged into the pump 10 through the inlet conduit 24 and passes into the inlet pumping chamber 14. The gas is compressed by the rotors 56, 58 located within the inlet pumping chamber 14, and is fed by passage 28 into the next pumping chamber 16. The gas fed in the pumping chamber 16 is similarly compressed by the rotors 56, 58 therein, and fed by
20 the passage 30 to the next pumping chamber 18. Similar gas compressions take place in the pumping chambers 18, 20 and 22, with the pumped gas finally being exhaust from the pump 10 through exhaust conduit 26.

By coating the shaft, rotor and/or stator and/or end plate components 12, 42, 44, 56, 58 with a first layer 102 comprising a high phosphorous nickel plating (NiP) of at least 5 μm thickness and a second layer 100 comprising a high phosphorous nickel with nickel phosphorous and fluoropolymer (NiP-PTFE) of at least 5 μm thickness, a particularly corrosion resistant dry vacuum pump with low chance of seizure due to rotor to stator contact is formed. The application of both layers of at least 5 μm thickness provides a synergistic effect of greater coating strength and adhesion properties than if only one of the two layers are applied to a dry vacuum pump component.

As illustrated in Figures 3 and 4, the first layer 102 may comprise several coatings of high phosphorous nickel; that is the first layer may be produced by coating the dry pump component a plurality of times. By forming a plurality of coatings of high phosphorous nickel by, for example, electroless plating, a much stronger first layer is formed that reduces both defect continuities in the first layer and reduces the overall porosity of the coating. The total phosphorous content in the first layer is, on average, between 10 and 12%. The first layer of NiP may be formed by a single or multiple coatings to form a layer of at least 5 μm thickness, preferably form a total first layer thickness of between 6.2 μm and 15.5 μm .

The second layer 100, which is a high phosphorous nickel matrix containing sub particles of PTFE (Polytetrafluoroethylene), NiP-PTFE, is formed over the first layer, again, by electroless plating. The total thickness of the second layer is at least 5 μm thickness, preferably around 8.8 μm to 14.1 μm thick, but it can be more or less than this if required. It is also possible to

use other fluorinated polymers in the matrix, for example PFA (Perfluoroether) or PEI (Polyethylenimine).

Examples:

- 5 In a series of chemical tests on plated surfaces, the number of blisters on 12.5 μm NiP first layer with a second layer of 12.5 μm NiP-PTFE (as illustrated in Figure 3) was less than half the number of blisters than in comparison to a single layer of 25 μm NiP (as illustrated in Figure 4).

- An Array test was carried out on Atotech plating chemistry. 24 coupons
10 were exposed to fluorine in a chamber at 200°C. 12 of the coupons had 25 μm base layer of NiP and the other 12 coupons had 12.5 μm base layer of NiP + 12.5 μm top layer of NiP-PTFE.

- The coupons were weighed before and after the test. The average weight change for each layer system is shown in Table 1 below. There is
15 some weight loss for the single plating layer and a smaller weight gain for the dual layer (duplex) plating. The coupons were also observed with a Zeiss microscope after the 800 hours of exposure to fluorine. Taguchi analysis has been used to calculate the average numbers of blisters found on the faces of each coupon; these are shown in Table 1. The average for the single layer is
20 more than twice the number for the dual layer.

Layer thickness and type	Weight change (μg)	Number of blisters
25 μm base of NiP alone (no top layer)	-2.16	2.92
12.5 μm base of NiP + 12.5 μm top layer of NiP-PTFE	1.45	1.42

Table 1: Average weight change and number of blisters versus plating layer system

5 This example illustrates the surprising effect that the use of specific combinations of NiP and NiP-PTFE plating provides superior chemical resistance to pure NiP plating alone, whilst maintaining the galling resistance of NiP-PTFE.

10 Similarly, any combination of NiP and NiP-PTFE may be used to deliver the same benefits as outlined above in Table 1, providing there is at least a 5 μm base layer of NiP and at least a 5 μm top layer of NiP-PTFE. Examples of ratios of a NiP base layer to a NiP-PTFE top layer is shown below in Table 2.

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NiP base layer in μm	NiP-PTFE top layer in μm
5	20
5	30
10	15
10	25
12.5	12.5
15	10
15	20
20	5
20	15
25	10
30	5

Table 2: Specific combination ratios of NiP base layer thickness to NiP-PTFE layer thickness.

Claims

1. A dry pump component coated with a first layer comprising a high phosphorous nickel plating (NiP) of at least 5 μm thickness coated with a second layer comprising a high phosphorous nickel with nickel phosphorous and fluoropolymer (NiP-PTFE) of at least 5 μm thickness, wherein the ratio of the thickness of the first layer of NiP to the thickness of the second layer of NiP-PTFE provides high corrosion resistance and galling resistance.
2. The dry pump component according to claim 1, wherein the first layer of NiP has a range of thickness from about 6.2 μm to about 15.5 μm .
3. The dry pump component according to claim 1, wherein the second layer of NiP-PTFE has a range of thickness from about 8.8 μm to about 14.1 μm .
4. The dry pump component according to claim 1, wherein the ratio of the first layer of NiP to the second layer of NiP-PTFE is at least one of the following thicknesses in μm : 5 +20, 5+30, 10+15, 10+25, 12.5+12.5, 15+10, 15+20, 20+5, 20 +15, 25 + 5, 25+10 or 30+5.
5. The dry pump component according to any preceding claim, wherein the fluoropolymer in the second layer includes at least one of polytetrafluoroethylene, perfluoroether, and Polyethylenimine.

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6. A dry pump component according to any preceding claim wherein the pump component is at least one of a stator component, an end plate, a rotor shaft component and a rotor component.
- 5 7. A dry pump component according to claim 6, wherein the rotor component has one of a Northey (claw) rotor, a Roots rotor or a Screw rotor profile.
8. A dry vacuum pump comprising at least one dry component according
10 to any preceding claim.

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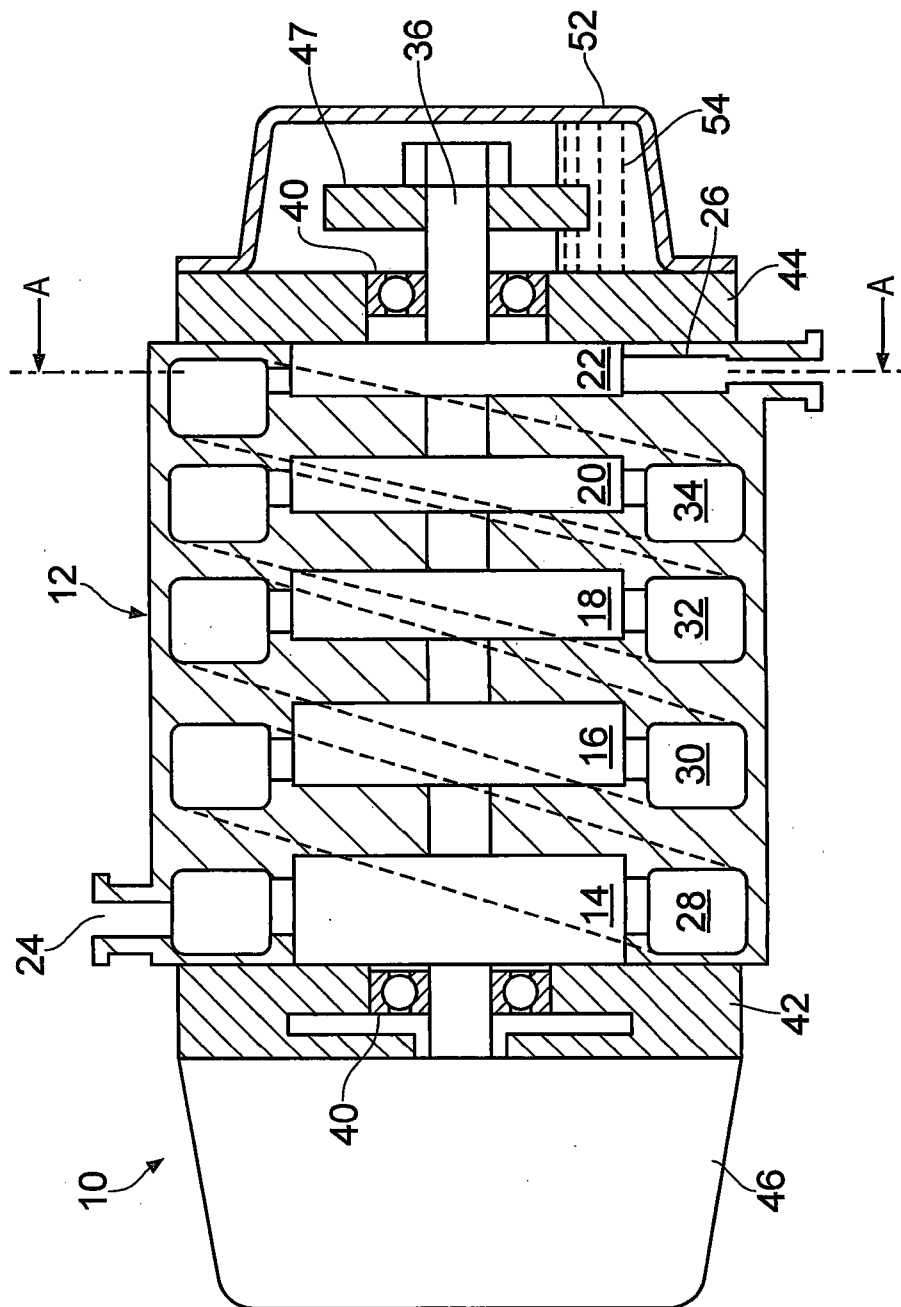


FIG. 1

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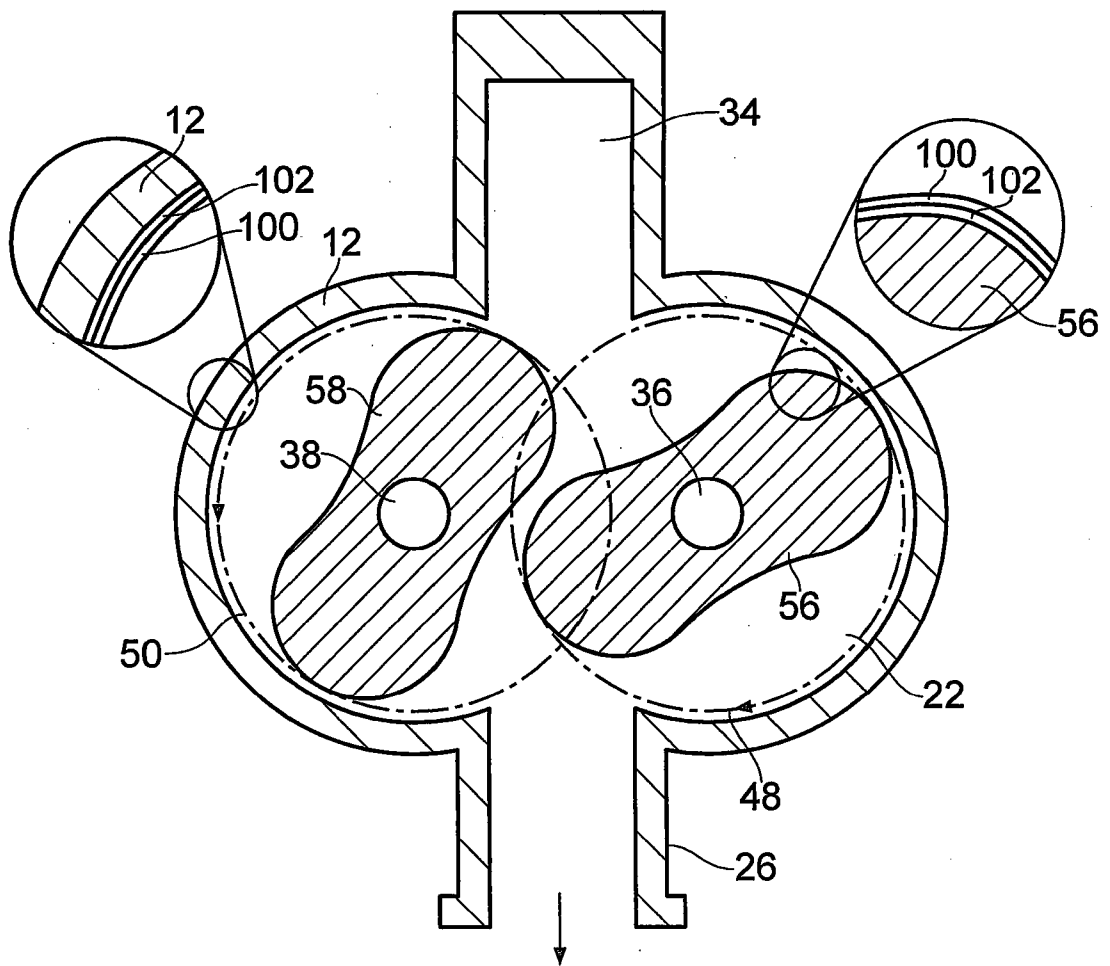


FIG. 2

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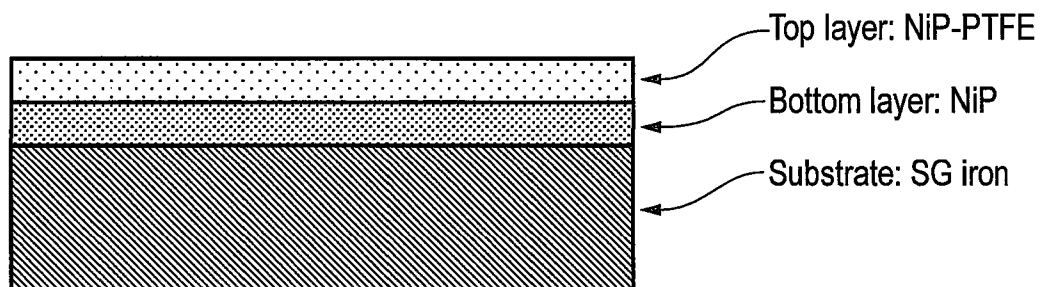


FIG. 3

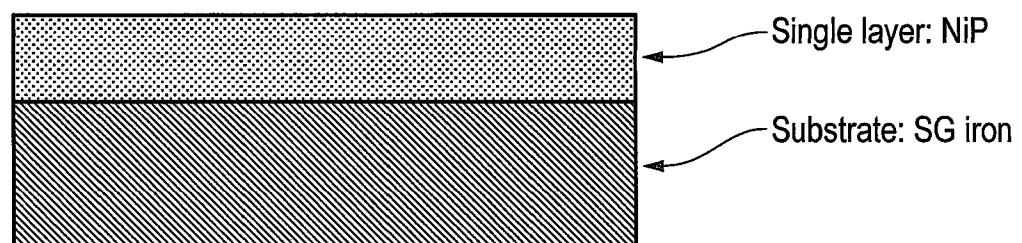


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/051081

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04C2/12
ADD.

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

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

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Y	column 1, line 29 - line 35 column 5, line 38 - column 6, line 9 column 7, line 55 - line 67 -----	6-8
X	WO 2015/049097 A1 (VALLOUREC OIL & GAS FRANCE [FR]; NIPPON STEEL & SUMITOMO METAL CORP [J]) 9 April 2015 (2015-04-09)	1,2,4,5
Y	page 14, line 7 - line 8 page 6, line 1 - line 3 -----	6-8
Y	EP 1 640 611 A1 (MATSUSHITA ELECTRIC IND CO LTD [JP]) 29 March 2006 (2006-03-29) paragraph [0015] -----	6-8



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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