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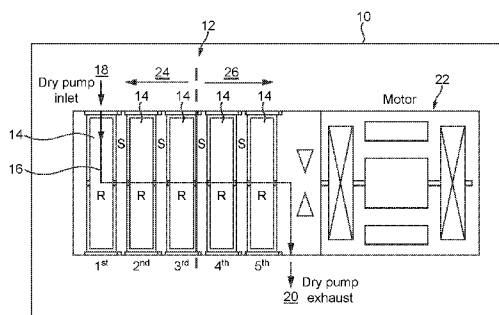


FIG. 1

(57) Abstract: A multi stage vacuum pump for pumping corrosive fluid with a first flow path of less corrosion material than the material of a second flow path downstream of the first flow path.

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VACUUM PUMP

The present invention relates to a vacuum pump, and particular to a vacuum pump suitable for pumping corrosive fluids.

5 A known vacuum pump 50 is shown in Figure 7 which comprises a pumping mechanism 52. The pumping mechanism comprises a plurality of pumping stages 54 for pumping fluid along a fluid flow path 56 between an inlet 58 for fluid at high vacuum and an outlet 60 for fluid at low vacuum to atmospheric pressure. Five pumping stages 54 are shown. A motor 62 drives rotation of the rotors R relative to the stators S in each of the
10 pumping stages 54.

 If the fluid being pumped comprises a corrosive agent, such as fluorine, corrosion is caused to the pumping mechanism 52. Over time, corrosion causes build up of deposits on the surface of components of the pumping mechanism which causes a reduction in the running clearances between the rotors R and the stators S of the pumping stages 54. After
15 continued operation of the pump over many hours the corrosion can bring the rotors and stators of the pumping stages into contact causing pump failure.

 It is possible to reduce corrosion in vacuum pumps by manufacturing the pumping mechanism from a corrosion resistant material but typically such materials are expensive.

 The present invention provides a vacuum pump for pumping corrosive fluid, the
20 pump comprising: a pumping mechanism comprising a plurality of pumping stages along a fluid flow path between an inlet for fluid at high vacuum and an outlet for fluid at low vacuum, and wherein the material of the pumping mechanism at a first section of said flow path is less resistant to corrosion than the material of the pumping mechanism at a second section of said flow path downstream of said first section.

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

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

Figure 1 shows a simplified section through a vacuum pump;

Figure 2 is a graph showing corrosive build-up over time against pump reference temperature for a pump having a pumping mechanism made from a material which is relatively non-corrosion resistant;

10 Figure 3 is a graph showing corrosive build-up over time against pump reference temperature for a pump having a pumping mechanism made from a material which is relatively corrosion resistant;

Figure 4 is a graph showing corrosive build-up over time against pump reference temperature for a pump having a pumping mechanism made from a material which is
15 relatively non-corrosion resistant and a material which is relatively corrosion resistant;

Figure 5 is a table showing properties of corrosion and non-corrosion resistant materials;

Figure 6 is a table showing an example of the constituents of a corrosion resistant material; and

20 Figure 7 is a simplified section through a prior art vacuum pump.

Referring to Figure 1, a multi-stage vacuum pump 10 is shown for pumping corrosive fluid. A pumping mechanism 12 comprises a plurality of pumping stages 14 for pumping fluid along a fluid flow path 16 between an inlet 18 for fluid at high vacuum and an outlet 20 for fluid at low vacuum to atmospheric pressure. Five pumping stages 14 are

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shown in this example. A motor 22 drives rotation of a rotor R relative to a stator S in each of the pumping stages 14.

In arriving at the present invention, an analysis of the prior art pump shown in Figure 7 was conducted and Figure 2 shows a graph in which corrosion build-up over
5 time (10,000 hours in this example) is plotted against pump reference temperature for the prior art pump. In the graph a first line shows build-up at the faces of the rotor and stator of a middle pumping stage along the flow path 56 and a second line shows build-up at the faces of the rotor and stator of a final pumping stage along the flow path 56. The middle pumping stage in this example is the 3rd stage. Corrosive build-up is measured in microns
10 and temperature is measured in degrees centigrade. The temperature used in the graph is a pump reference temperature taken at the final pumping stage. It will be appreciated that the temperature of the middle pumping stage is less than that shown in the graph but for simplicity has not been shown. The pump reference temperature increases during
operation and the increase is dependent on a number of factors such as the type of fluid
15 which is pumped and the work exerted by the pump.

In Figure 7, the material from which the pumping mechanism is made is relatively non-corrosion resistant. An example of such a material is SG iron. It will be seen from Figure 2 that corrosive build-up of the final stage is considerably greater than that of the middle pumping stage, particularly when the pump reference temperature is at 200°C. At
20 this reference temperature, corrosive build-up at the final stage is just lower than 400µm, whereas at the middle stage, build-up is only just higher than 50µm.

Figure 3 shows an equivalent graph as shown in Figure 2, except in this analysis the material from which the pump is made is relatively corrosion resistant. An example of such a material is Ni-rich SG iron. In Figure 3, corrosive build-up at both the middle

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and final pumping stages is reduced, but build-up at the final pumping stage has been reduced by around 300 μ m to just lower than 100 μ m whereas build-up at the middle pumping stage has been reduced by only around 30 μ m to around 20 μ m.

When considering the pump shown in Figure 7, the pressure of fluid along the flow path 56 increases from the inlet 58 to the outlet 60 as fluid is compressed by each pumping stage 54, typically with the compression ratio increasing from one pumping stage to the next pumping stage along the flow path. The temperature of the fluid and the pumping mechanism also increases along the flow path.

Accordingly, if the fluid being pumped comprises a corrosive agent, such as fluorine, the amount of corrosion caused to the pumping mechanism 52 increases along the flow path 56 as temperature and pressure increase. Increased pressure increases the amount of corrosive molecules available for corroding the pumping mechanism and increased temperature increases corrosive reaction. Therefore, corrosive build-up is greater at the final pumping stage than at the middle pumping stage. Accordingly, pump failure occurs because of the reduction in running clearance at the final stage of the pumping mechanism where build-up is greatest. Whilst corrosion resistance can be increased as shown in Figure 3, pump failure often occurs at the final stage of the pumping mechanism.

In the pump shown in Figure 1, the pumping mechanism comprises a first section 24 and a second section 26. The second section 26 is downstream of the first section 24. During operation, the temperature and pressure of the downstream section 26 is greater than the temperature and pressure of the upstream section 24. Therefore, when pumping a corrosive fluid, corrosion of section 24 is less than corrosion of section 26. As the build-up of corrosion deposits on the rotors and stators in section 24 is less than in section

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26, the first section 24 is required to be less resistant to corrosion than the second section 26. The first section 24 can therefore be made from a material which is relatively less expensive than the material of the second section.

The first section 24 and the second section 26 comprise a respective plurality of pumping stages 14. The first section is adjacent to the second section along the fluid flow path. In Figure 1, the first section comprises 1st, 2nd and 3rd pumping stages whilst the second section 26 comprises 4th and 5th pumping stages. In another arrangement, one of the first and the second sections may comprise a single pumping stage. For instance, the first section may comprise 1st to 4th pumping stages whilst the second section may
10 comprise the 5th pumping stage. As temperature and pressure increase to the greatest extent at the final downstream pumping stage it may be desirable to manufacture this stage from a corrosion resistant material whereas stages 1 to 4 may be manufactured from a material which is less corrosion resistant. Alternatively, the first section may comprise the 1st pumping stage and the second section may comprise the 2nd to 5th pumping stages.

15 A graph equivalent to the graphs shown in Figures 2 and 3 is shown in Figure 4, which plots corrosive build-up against pump reference temperature for the pump shown in Figure 1. Figure 4 shows at 200°C that corrosive build-up at the final stage of the pumping mechanism has been reduced from around 400µm as shown in Figure 2 to just lower than 100µm as is the case with a corrosion resistant pump according to Figure 3.
20 However, in Figure 4, corrosive build-up at the middle, or 3rd, stage is the same as that shown in Figure 2 for a non-corrosion resistant pump. In this regard, the corrosive build-up of the middle stage is around 50µm which is less than that of the final stage even though the middle stage is made from a non-corrosion resistant material (e.g. SG iron) and the final stage is made from a corrosion resistant material (e.g. Ni-rich iron).

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Therefore, there is no benefit to be gained from making both the first section and the second section of a pumping mechanism from a corrosion resistant material and doing so would unnecessarily add to the cost of a pump.

Materials should be selected for the first and second sections so that the build-up
5 of corrosive deposits at the first section is less than or equal to the build-up of corrosive deposits at the second section. Preferably, the components of said pumping stages are fabricated from selected materials such that the build-up of corrosion deposits in each stage during pumping of corrosive gas is generally equal one stage to another stage. In this way, the materials for the various pumping stages can be selected in a cost efficient
10 manner whilst maintaining acceptable resistance to corrosion. In Figure 1, the rotor R and stator S of each pumping stage 14 of the second section 26 is made from a Nickel rich iron, whilst the rotor R and stator S of each pumping stage 14 of the first section 24 is made from an SG (spheroidal graphite) iron.

Examples of these materials are shown in Figure 5, although other materials may
15 be selected according to requirements. For instance, Nickel is resistant to fluorine but if the fluid being pumped contains other corrosive agents it would be desirable to select an appropriately resistant material. Further, the first section of the pumping mechanism may be made from materials other than SG iron.

If the pump is to be used for pumping particularly corrosive fluid, the first section
20 may be made from a corrosion resistant material for instance NI-rich SG iron, whilst the second section may be made from a more corrosion resistant material such as cast stainless steel or nickel alloy.

Figure 5 shows three examples of both SG iron and Ni-rich SG iron. It is preferable to select materials for the first and second section with similar linear expansion

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coefficients. In this regard, Ni-res D-5S is a preferred corrosion resistant material as its linear expansion coefficient is 12.6 m/mK which is similar to the coefficient of SG iron of 12.5 m/mK.

5 The constituents of an Ni-rich SG iron material, which exhibits good corrosion resistant properties and also good strength and stiffness in high temperature conditions are shown in Figure 6. In such a material, it will be seen that the Nickel content is relatively high between 24 % and 32 % by weight.

10 The same or similar material is preferably used for the rotor R and stator S in each section to avoid problems associated with having components of different thermal expansion coefficients.

The vacuum pump 10 is shown in simplified form in Figure 1. The vacuum pump may comprise a claw type pumping mechanism or roots type pumping mechanism or other type of dry pumping mechanism, particular in which running clearance between components of the pumping mechanism is required to be small to increase efficiency.

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CLAIMS

1. A vacuum pump for pumping corrosive fluid, the pump comprising: a pumping
5 mechanism comprising a plurality of pumping stages along a fluid flow path
between an inlet for fluid at high vacuum and an outlet for fluid at low vacuum,
and wherein the material of the pumping mechanism at a first section of said flow
path is less resistant to corrosion than the material of the pumping mechanism at a
second section of said flow path downstream of said first section.
10
2. A vacuum pump as claimed in claim 1, wherein the respective materials of the
first section and the second section are such that build-up of corrosive deposits at
the first section is less than or equal to build-up of corrosive deposits at the second
section.
15
3. A vacuum pump as claimed in claim 1 or 2, wherein said first section and said
second section are defined by a respective plurality of said pumping stages.
4. A vacuum pump as claimed in any preceding claim, wherein said first section is
20 adjacent to said second section along said fluid flow path.
5. A vacuum pump as claimed in any preceding claim, wherein each of said pumping
stages comprises a stator and a rotor.

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6. A vacuum pump as claimed in any preceding claim, wherein the or each pumping stage of the second section comprises components made from a Nickel rich iron.

7. A vacuum pump as claimed in any preceding claim, wherein the or each pumping stage of the first section comprises components made from Spheroidal graphite iron.

8. A vacuum pump as claimed in any preceding claim, wherein the components of said pumping stages are fabricated from selected materials such that the build-up of corrosion deposits in each stage during pumping of corrosive gas is generally equal one stage to another stage.

9. A vacuum pump as claimed in any preceding claim, wherein pumping stages comprise a roots pumping mechanism or a claw pumping mechanism.

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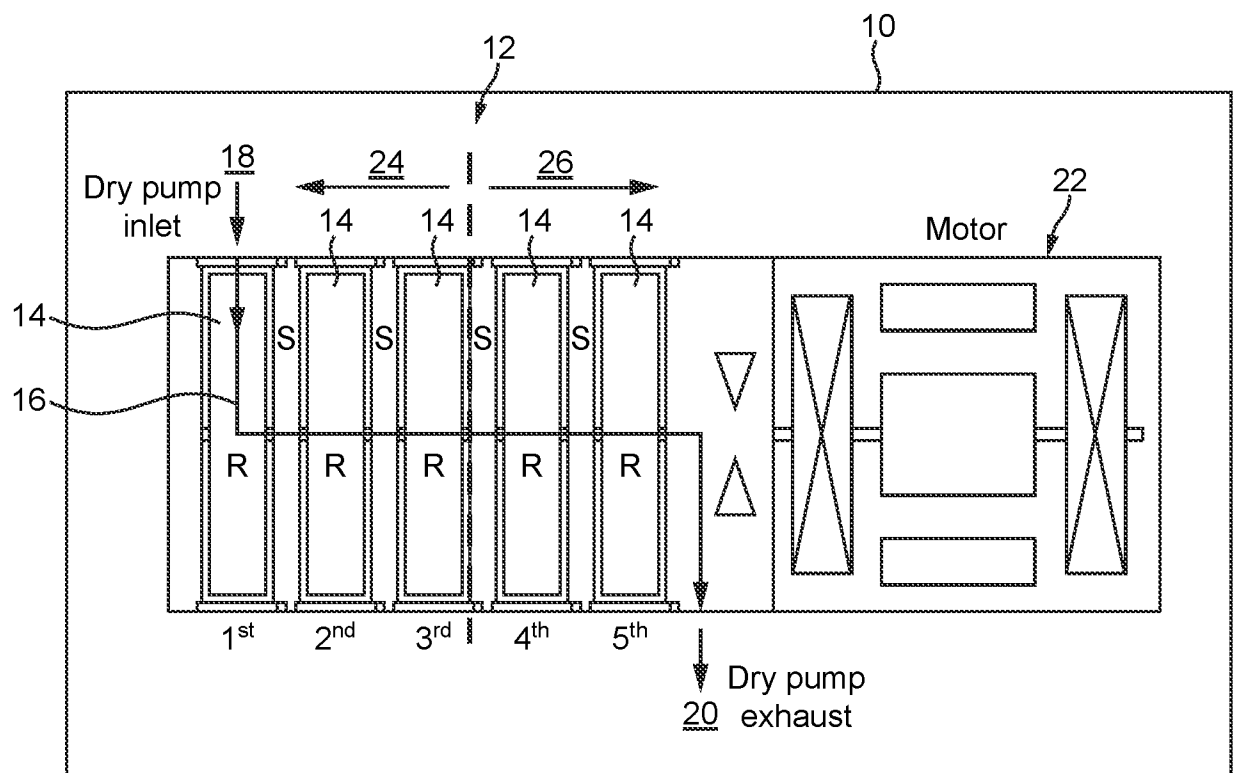
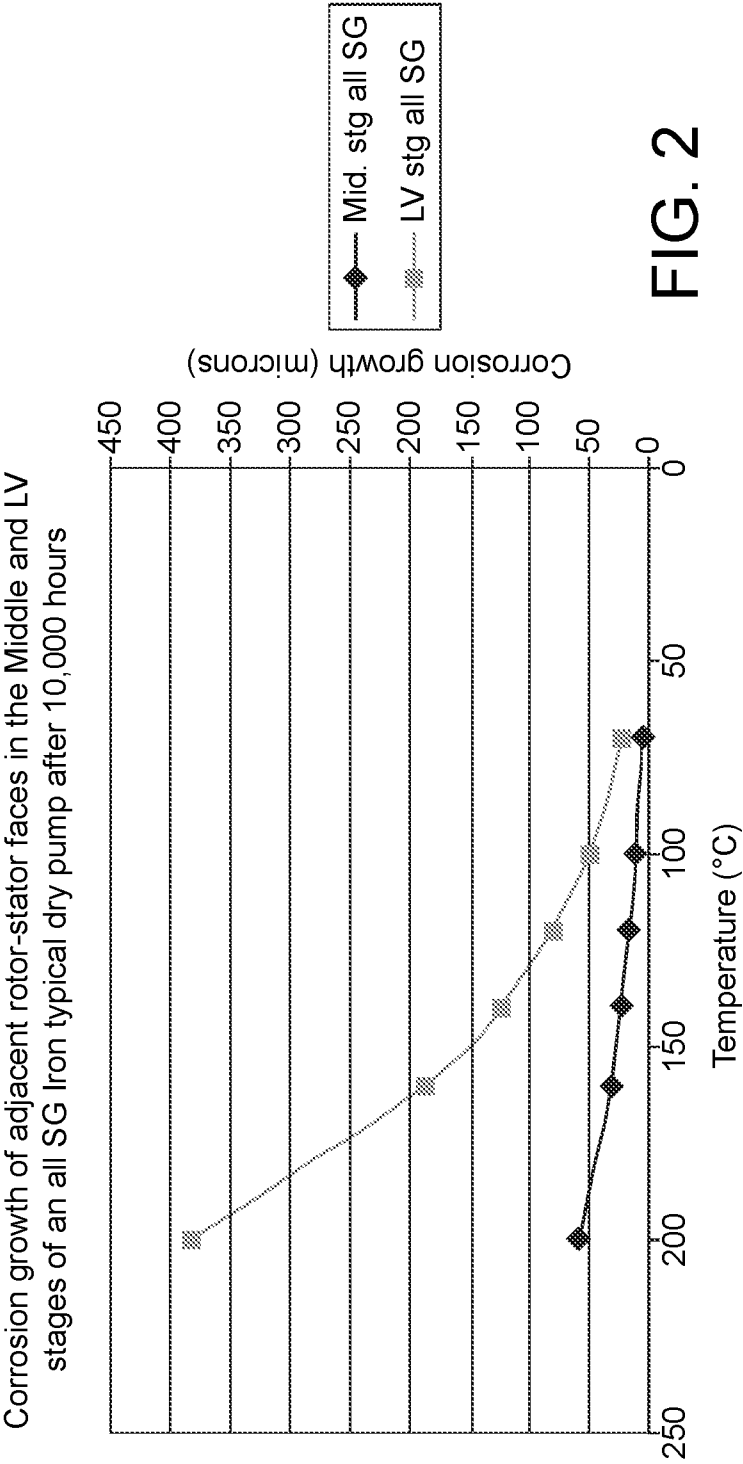
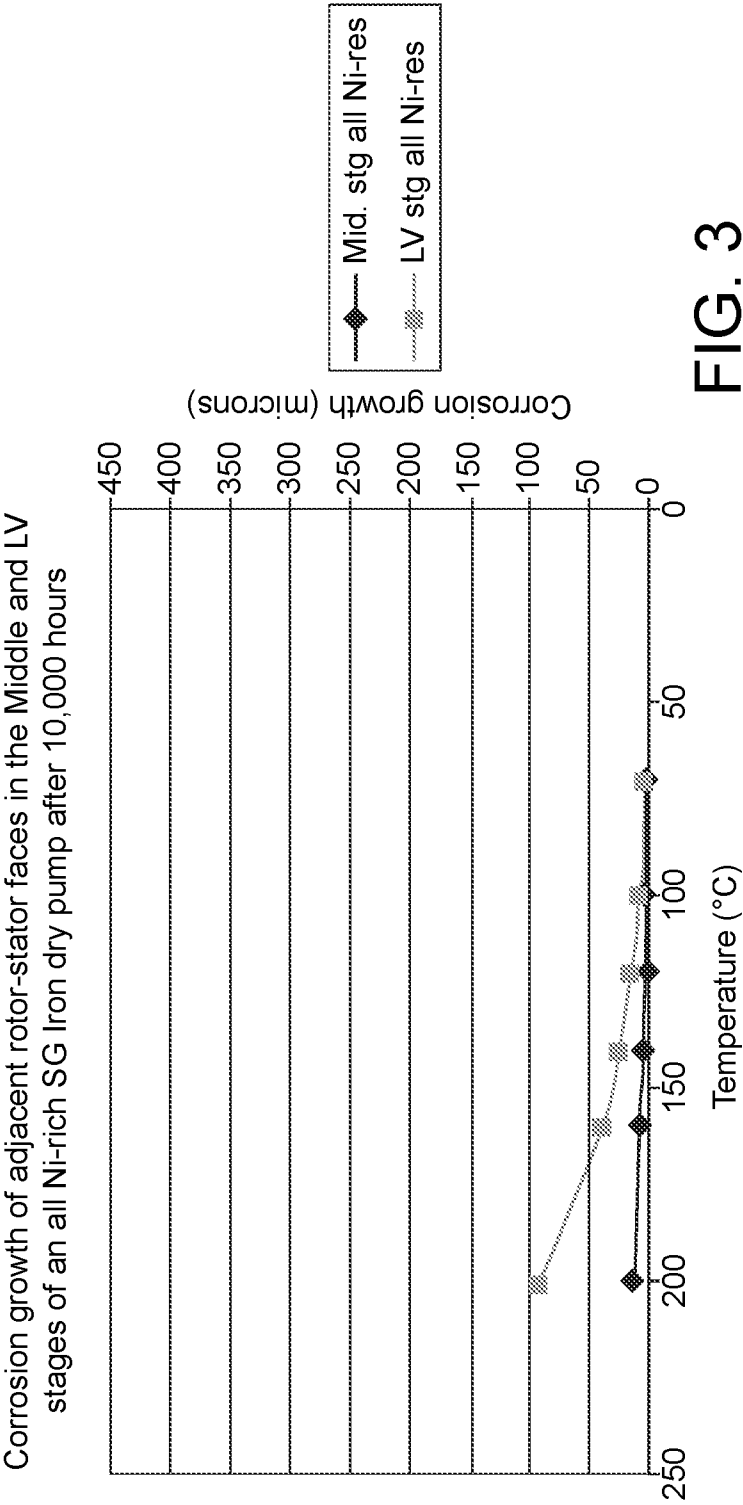
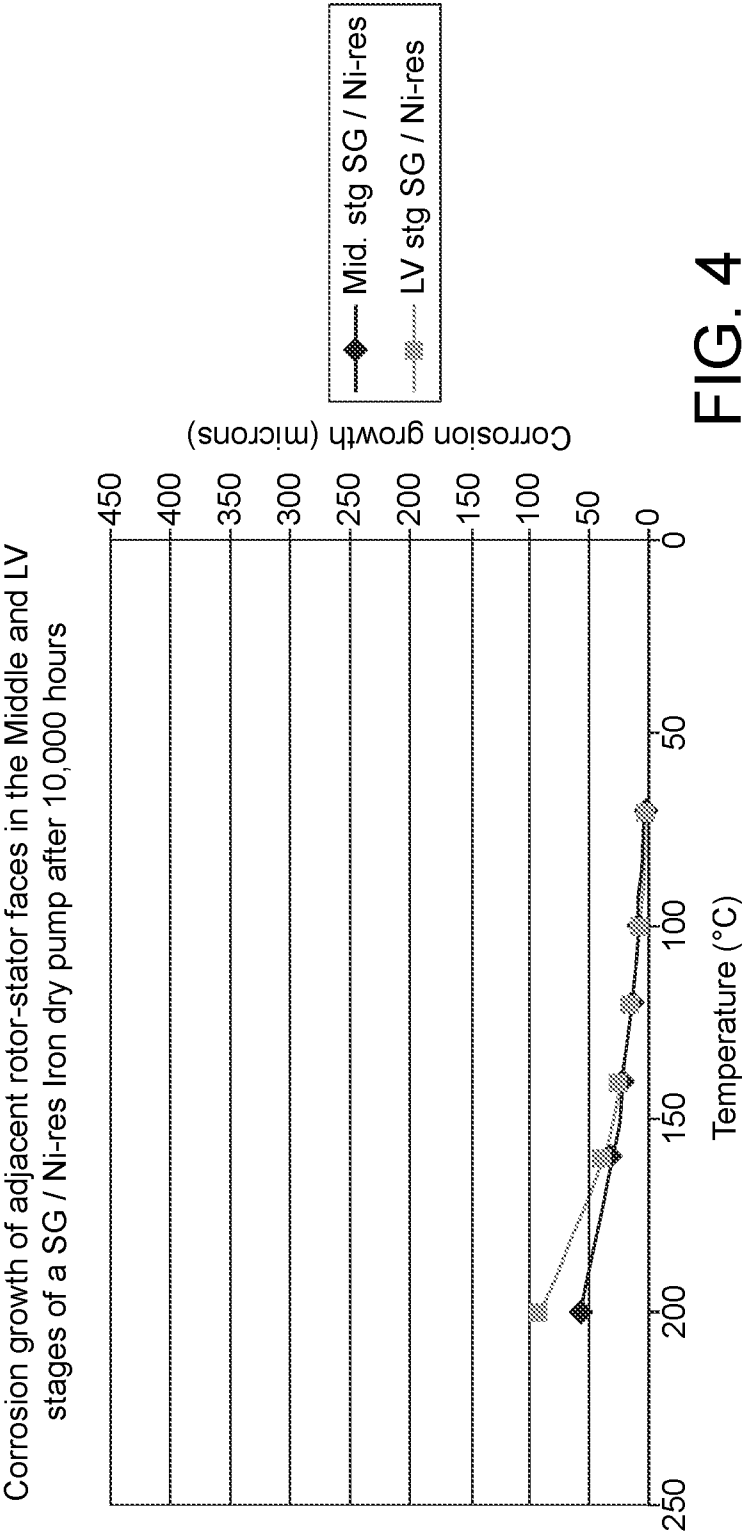


FIG. 1







Material Designation	Material type	UTS (min) MPa	0.2% Proof stress MPa	Elongation (min) %	Linear exp. Coeff. α m/(m.K)	Thermal Conductivity W/(m.K)	Modulus of Elasticity (min) GPa
EN-GJS-400-15	SG 400-15	400	250	15	12.5	36.2	169
EN-GJS-450-10	SG 450-10	450	310	10	12.5	36.2	169
EN-GJS-500-7	SG 500-7	500	320	7	12.5	35.2	169
EN-GJSA-XNiMn23-4	Ni-res D-2M	440	210	25	14.7	12.6	120
EN-GJSA-XNiCr30-3	Ni-res D-3	370	210	7	12.6	12.6	93
EN-GJSA-XNiSiCr35-5-2	Ni-res D-5S	370	210	10	15.1	12.6	130

FIG. 5

Material	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
New Material	max 2.5	3.0 - 4.0	2.5 - 3.5	max 0.08	0.004	0.2 - 1.0	0.4 - 1.0	24.0 - 32.0	0.13 - 0.50

FIG. 6

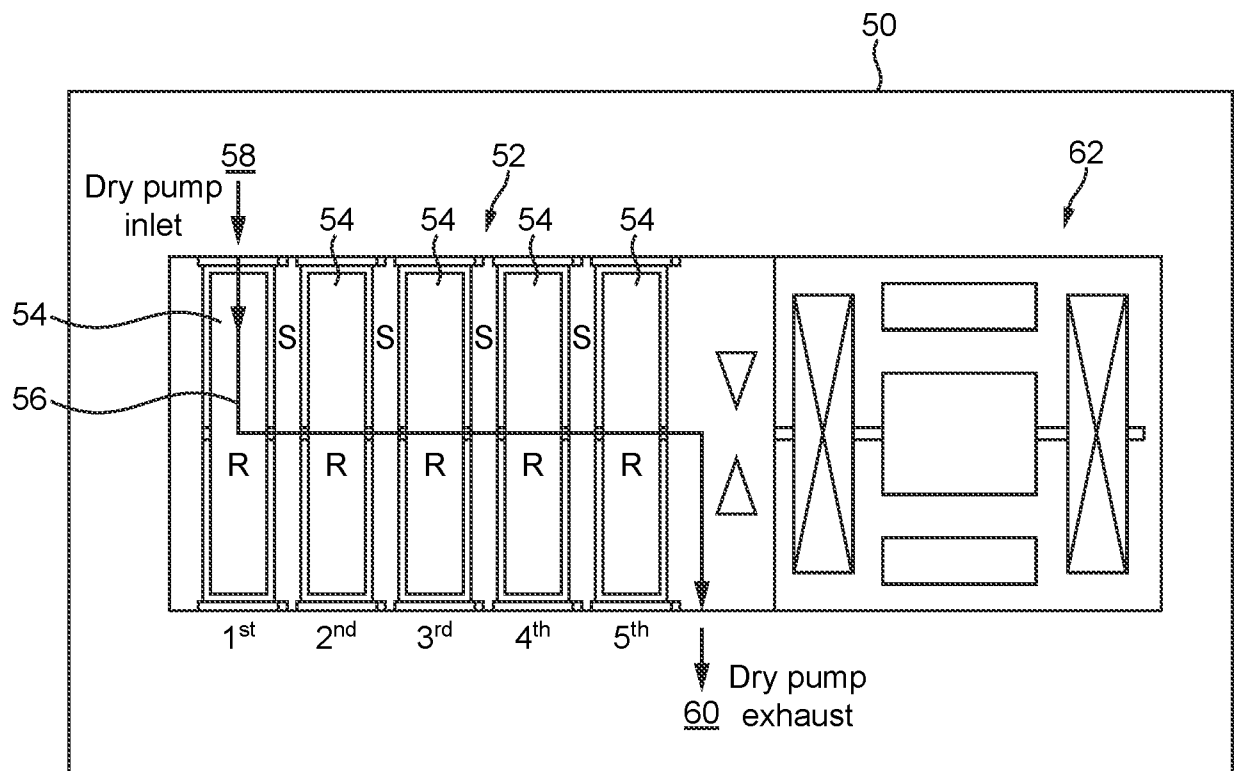


FIG. 7