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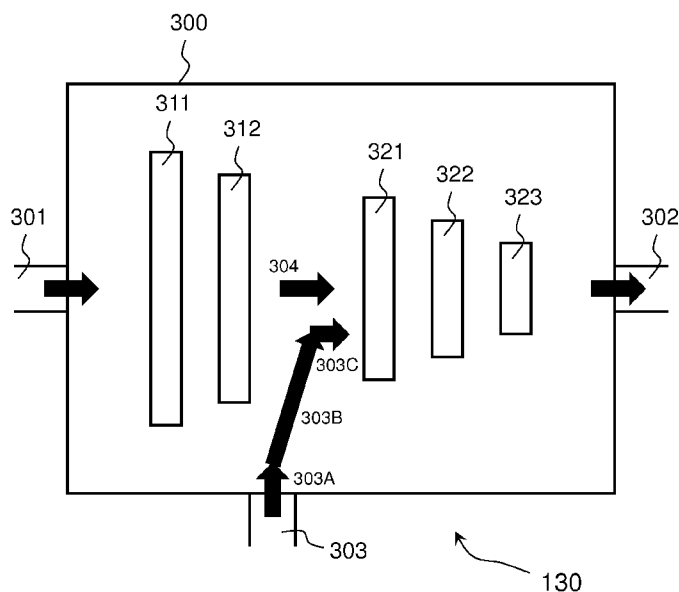


Fig. 3

(57) Abstract: The LNG plant comprises a compres-
 sion train (100) and a further compression train (200),
 and may advantageously implement for example 3-
 cycles pure-refrigerants liquefaction technologies or
 multiple-cycles pure-refrigerant and mixed-refrigerant
 liquefaction technologies. The compression train
 (100) comprises a first and a second set of axial com-
 pression stages (321, 322, 323), one main inlet (301),
 one main outlet (302), one auxiliary inlet (303) and/or
 one auxiliary outlet, wherein a fluid entering the com-
 pressor (130) through the auxiliary inlet (303) is redi-
 rected from a substantially radial direction to a sub-
 stantially axial direction and/or a fluid exiting the
 compressor (130) through the auxiliary outlet is redi-
 rected from a substantially axial direction to a sub-
 stantially radial direction. The further compression
 train (200) comprises a first set of impellers (411, 412)
 being centrifugal and unshrouded and a second set of
 impellers (421, 422, 423) being centrifugal and
 shrouded.

LNG PLANT INCLUDING AN AXIAL COMPRESSOR AND A CENTRIFUGAL COMPRESSOR

DESCRIPTION

TECHNICAL FIELD

- 5 Embodiments of the subject matter disclosed herein correspond to LNG [= Liquefied Natural Gas] plants including an axial compressor and a centrifugal compressor.

BACKGROUND ART

- 10 In the field of “Oil & Gas”, i.e. machines and plants for exploration, production, storage, refinement and distribution of oil and/or gas, there is always a search for improved solutions.

Improvements may derive from e.g. the structure and/or operation of the machines, the connection of machines, or the combination of machines (for example trains of machines).

- 15 Improvements may consist in e.g. increased efficiency and/or reduced losses, increased production and/or decreased wastes, increased functions, reduced cost, reduced size and/or footprint.

Two main LNG processes are known in the field of “Oil & Gas”:

- 20 - the C3-MR process designed by Air Products & Chemicals Inc., therefore sometimes referred to simply as “APCI”; this process uses a pure-refrigerant (“C3”), i.e. propane, and a mixed refrigerant (“MR”), i.e. a mixture of typically propane, ethylene, and methane; this process is a 2-cycles (one) pure-refrigerant and (one) mixed-refrigerant liquefaction technology;
- 25 - the cascade process designed by Conoco Phillips, therefore sometimes referred to simply as “CPOC”; this process uses three pure-refrigerants, i.e.

typically propane, ethylene or ethane, and methane; this process is a 3-cycles (three) pure-refrigerants liquefaction technology.

A further LNG process is known in the field of "Oil & Gas" as "AP-X"; this process uses two pure-refrigerants, i.e. propane and nitrogen, and a mixed
5 refrigerant, i.e. a mixture of typically propane, ethylene, and methane; this process is a 3-cycles (two) pure-refrigerants and (one) mixed-refrigerant liquefaction technology; this process is an evolution of the "APCI" process.

It is to be noted that the expression "pure refrigerant" actually means that one substance is predominant (for example, at least 90% or 95% or 98%) in the
10 refrigerant; the substance may be a chemical compound (for example, propane, ethane, ethylene, methane) or a chemical element (for example, nitrogen).

These known processes are already optimized in term of process but improvements in particular in terms of number of machines and/or footprint of machines used in an LNG plant are still sought.

15 SUMMARY

Embodiments of the subject matter disclosed herein relate to LNG plants.

According to such embodiments, the LNG plant comprises a compression train and a further compression train. The compression train comprises an engine and a compressor driven by the engine; the compressor is an axial compressor and
20 comprises a first set of axial compression stages and a second set of axial compression stages arranged downstream the first set of axial compression stages; at least the first set and the second set of axial compression stages are housed inside one case; the compressor has: one main inlet arranged upstream the first set of axial compression stages, one main outlet arranged downstream
25 the second set of axial compression stages, at least one auxiliary inlet and/or at least one outlet arranged downstream the first set of axial compression stages and upstream the second set of axial compression stages; the compressor is configured so that a fluid entering the compressor through the auxiliary inlet is

redirected from a substantially radial direction to a substantially axial direction and/or a fluid exiting the compressor through the auxiliary outlet is redirected from a substantially axial direction to a substantially radial direction. The further compression train comprises a further engine and a further compressor
5 driven by the further engine; the further compressor is a centrifugal compressor and comprises a first set of impellers and a second set of impellers arranged downstream or upstream the first set of impellers; the impellers of the first set are centrifugal and unshrouded; the impellers of the second set are centrifugal and shrouded; at least the impellers of the first set and of the second set are
10 housed inside one case; the impellers of the first set and of the second set are coupled to each other through mechanical connections.

This kind of axial compressor is a high-flow compressor and hereinafter is also referred to as “high-flow axial compressor”.

The above mentioned “substantially axial direction” is a direction parallel to the
15 direction of the compressor axis or a direction substantially tangential to the compression flow path, the compression flow path being the path defined by the flow of the fluid during its compression.

Such LNG plant may advantageously implement, for example, 3-cycles pure-refrigerants liquefaction technologies or multiple-cycles pure-refrigerant and
20 mixed-refrigerant liquefaction technologies.

BRIEF DESCRIPTION OF DRAWINGS

The accompanying drawings, which are incorporated herein and constitute an integral part of the present specification, illustrate exemplary embodiments of the present invention and, together with the detailed description, explain these
25 embodiments. In the drawings:

Fig. 1 shows a schematic diagram of a first embodiment of a compression train;

Fig. 2 shows a schematic diagram of a second embodiment of a compression train;

Fig. 3 shows a schematic diagram of a first embodiment of a compressor that may be a component of the compression train of Fig. 1;

Fig. 4 shows a schematic diagram of a second embodiment of a compressor that may be a component of the compression train of Fig. 2;

5 Fig. 5 shows a schematic diagram of a first embodiment of a LNG plant; and

Fig. 6 shows a schematic diagram of a second embodiment of a LNG plant.

DETAILED DESCRIPTION

The following description of exemplary embodiments refers to the accompanying drawings.

10 The following description does not limit the invention. Instead, the scope of the invention is defined by the appended claims.

Reference throughout the specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with an embodiment is included in at least one
15 embodiment of the subject matter disclosed. Thus, the appearance of the phrases “in one embodiment” or “in an embodiment” in various places throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments.

20 In the following (and according to its mathematical meaning) the term “set” means a group of one or more items.

Fig. 1 shows a compression train 100 comprising an engine 110 and a compressor 130 driven by the engine 110. The compressor 130 is an axial (i.e. axial flow) compressor and comprises at least a first set of axial compression
25 stages (i.e. one or more stages) and at least a second set of axial compression stages (i.e. one or more stages) arranged downstream the first set of axial compression stages. According to the embodiment of Fig. 3, the first set

includes two stages 311 and 312, but any number of stages from 1 to e.g. 20 is suitable. According to the embodiment of Fig. 3, the second set includes three stages 321 and 322 and 323, but any number of stages from 1 to e.g. 20 is suitable. At least the first set and the second set of axial compression stages are
 5 housed inside one case 300; typically, all the sets of stages are housed inside this case. The compressor 130 has:

- one main inlet 301 for receiving a fluid to compressed (labelled 131 in Fig. 1) arranged upstream the first set of axial compression stages – the inlet may be directly (i.e. nothing in-between) arranged upstream these stages,
- 10 - one main outlet 302 for providing a compressed fluid (labelled 132 in Fig. 1) arranged downstream the second set of axial compression stages – the outlet may be directly (i.e. nothing in-between) arranged downstream these stages,
- at least one auxiliary inlet and/or at least one outlet arranged downstream the first set of axial compression stages and upstream the second set of axial
 15 compression stages – according to the embodiment of Fig. 3, there is only one auxiliary inlet 303 that is arranged directly downstream stages 311 and 312 and directly upstream stages 321 and 322 and 323.

The first set and the second set of axial compression stages may be arranged to compress the same type of working fluid or different types of working fluid.

- 20 When the type of working fluid is the same, for example, the axial compression stages of the first set process a first flow of the working fluid (see e.g. arrow 301 in Fig. 3), while the axial compression stages of the second set process the first flow of the working fluid after that it has been processed by stages of the first set (see e.g. arrow 304 in Fig. 3), and a second flow of the working fluid (see e.g.
 25 arrow 303C in Fig. 3) entering in an auxiliary inlet (see e.g. arrow 303 in Fig. 3).

When the types of working fluid are different, for example, a first working fluid enters in the main inlet (e.g. inlet 301 in Fig. 3) and exits from an auxiliary outlet (Fig. 3 does not show an auxiliary outlet), while the second working fluid enters

in an auxiliary inlet (e.g. inlet 303 in Fig. 3) and exits from the main outlet (e.g. outlet 302 in Fig. 3).

In the embodiment of Fig. 3, the main inlet 301 is used for receiving a first fluid flow to be compressed and the auxiliary inlet 303 is used for receiving a second fluid flow to be compressed; the auxiliary inlet 303 is substantially radially (or perfectly) oriented on an external side 303A and provides an injection of a fluid flow that is substantially (or perfectly) axially oriented on an internal side 303C; the first fluid flow that is already partially compressed by stages 311 and 312 and that flows axially (304) and the second fluid flow that is not yet compressed and that flows axially (303C) meet and are compressed by stages 321 and 322 and 323; the second fluid flow is redirected, i.e. bent, from the radial direction to the axial direction along an intermediate path 303B from the external side 303A to the internal side 303C.

The sets of axial compression stages may be more than two, for example three or four.

There may be one or more auxiliary inlets.

There may be one or more auxiliary outlets.

According to the configuration of the axial compressor defined above, the machine results very compact and only one casing is required for processing more than one flows of fluid.

Moreover, the axial injection of one or more side streams of working fluid in the main stream of working fluid processed by the compressor, can increase the overall efficiency of the compressor.

Axial compressor is a type of compressor that, on equal terms, can process higher flow rates than other types of compressor.

In general, axial compressors are more efficient than centrifugal compressors, so, at the same power, they can compress more fluid, i.e. a higher flow rate of fluid.

Therefore, it is advantageous to use axial compressors for propane as the quantity of liquefied natural gas produced is directly proportional to the flow rate of propane.

5 In general, axial compressors are, at the same power, smaller than centrifugal compressors. Therefore, it is advantageous to use axial compressors for propane as the size and/or the number of compressors in a plant, in particular an LNG plant, is reduced.

10 The auxiliary inlet/s and/or auxiliary outlet/s enable the compressor to be more flexible and to adapt the operative conditions of the machine to the process where the compressor is used. For example, the auxiliary inlet/s and auxiliary outlet/s may be used to extract working fluid from the compressor and refrigerate it before being reinjected.

15 The engine 110 may be an electric motor or a steam turbine or a gas turbine, in particular an aeroderivative gas turbine. It is to be noted that, in addition to a main engine, there may be an auxiliary engine which is connected to the shaft of the compression train (in particular of a LNG plant) to help the main engine when the power absorbed by the compressor exceeds certain thresholds; such auxiliary engine is sometimes called “helper”.

20 The engine 110 and the compressor 130 may be connected directly or through a gear train 120 (that is usually part of a gearbox), as shown in Fig. 1.

A train identical or similar to the one shown in Fig. 1 (and Fig. 3) is particularly advantageous when arranged to provide compressed propane. For example, this is the case of LNG plants that implement liquefaction technologies with 3-cycles of three pure-refrigerants (e.g. “CPOC”), LNG plants that implement 25 liquefaction technologies with 2-cycles of one pure-refrigerant and one mixed-refrigerant (e.g. “APCI”), and LNG plants that implement liquefaction technologies with 3-cycles of two pure-refrigerants and one mixed-refrigerant (e.g. “AP-X”).

Fig. 2 shows a compression train 200 comprising an engine 210 and a high-compression-ratio compressor 230 driven by the engine 210. The high-compression-ratio compressor 230 is a centrifugal (i.e. centrifugal flow) compressor and comprises a first set of impellers (i.e. one or more impellers) and a second set of impellers (i.e. one or more impellers) arranged downstream or upstream the first set of impellers. According to the embodiment of Fig. 4, the first set includes two impellers 411 and 412, but any number of impellers from 1 to e.g. 20 is suitable. According to the embodiment of Fig. 4, the second set includes three impellers 421 and 422 and 423, but any number of impellers from 1 to e.g. 20 is suitable. The impellers 411 and 412 of the first set are centrifugal and unshrouded. The impellers 421 and 422 and 423 of the second set are centrifugal and shrouded. At least impellers 411 and 412 and 421 and 422 and 423 of the first set and of the second set are housed inside one case 400. The impellers 411 and 412 and 421 and 422 and 423 of the first set and of the second set are coupled to each other through mechanical connections.

The sets of axial compression stages may be more than two, for example three or four.

There may be one or more auxiliary inlets.

There may be one or more auxiliary outlets.

Advantageously, as in the embodiment of Fig. 4, at least some of the impellers of said high-compression-ratio centrifugal compressor are stacked on each other and mechanically coupled by means Hirth joint. The stacked and coupled impellers are tightened together by means of a tie rod, in this way, a very stable and reliable mechanical connection is achieved. Each impeller has for example a passing hole at its rotational axis and is configured so that the tie rod can pass through it. A rotor is achieved when the impellers are stacked and tightened together.

In the embodiment of Fig. 4 all impellers 411, 412, 421, 422, 423 of the two sets are stacked, coupled by Hirth joints 440A, 440B, 440C, 440D, and tightened together by a tie rod 430.

Compressor 230 has a main inlet 401 (labelled 231 in Fig. 2), a main outlet 402 (labelled 232 in Fig. 2), and at least one auxiliary inlet and/or at least one auxiliary outlet at an intermediate position along the flow path from the main inlet 401 to the main outlet 402; Fig. 4 shows the general case of one intermediate tap 403, being in some embodiments an auxiliary inlet (see upward arrow) and being in some embodiments an auxiliary outlet (see downward arrow).

Advantageously, as in the embodiment of Fig. 4, the second set of impellers (421 and 422 and 423) are downstream the first set of impellers (411 and 412), and the impellers (421 and 422 and 423) of the second set may have a smaller diameter than the impellers (411 and 412) of the first set.

According to the embodiment of Fig.4, the impellers of the first set of impellers (411 and 412) are unshrouded and with a larger diameter than those of the second set of impellers (421 and 422 and 423).

Unshrouded impellers can rotate faster than shrouded impellers, due to the absence of the shroud; in fact, when the impeller rotates the shroud is pulled outwardly by the centrifugal force acting on it and over a certain rotary speed the shroud risks to pull out the impeller.

Thanks to the rotor configuration of the high-compression-ratio centrifugal compressor defined above, the compressor can rotate faster than traditional centrifugal compressors thus achieving a greater compression ratio.

It is to be noted that unshrouded impellers and shrouded impellers may alternate between each other; this happens, in particular, when there is one or more auxiliary inlets and/or outlets.

The engine 210 may be an electric motor or a steam turbine or a gas turbine, in particular an aeroderivative gas turbine. It is to be noted that, in addition to a main engine, there may be an auxiliary engine which is connected to the shaft of the compression train (in particular of a LNG plant) to help the main engine
5 when the power absorbed by the compressor exceeds certain thresholds; such auxiliary engine is sometimes called “helper”.

The engine 210 and the compressor 230 may be connected directly or through a gear train 120 (that is usually part of a gearbox), as shown in Fig. 1.

Centrifugal compressors identical or similar to the one shown in Fig. 2 (and Fig.
10 4) may rotate very quickly and so they can reach a very high compression ratio. Therefore, a single innovative centrifugal compressor in a single (and small) case may replace two or more traditional centrifugal compressors in distinct cases.

Furthermore, thanks to high rotation speeds of the impellers, high flow coefficients may be obtained.

15 A train identical or similar to the one shown in Fig. 2 (and Fig. 4) is particularly advantageous when arranged to provide compressed methane. For example, this is the case of LNG plants that implement liquefaction technologies with 3-cycles of three pure-refrigerants (e.g. “CPOC”).

A train identical or similar to the one shown in Fig. 2 (and Fig. 4) is particularly
20 advantageous when arranged to provide compressed mixed refrigerant. For example, this is the case of LNG plants that implement liquefaction technologies with 2-cycles of one pure-refrigerant and one mixed-refrigerant (e.g. “APCI”), and LNG plants that implement liquefaction technologies with 3-cycles of two pure-refrigerants and one mixed-refrigerant (e.g. “AP-X”).

25 A train identical or similar to the one shown in Fig. 2 (and Fig. 4) is particularly advantageous when arranged to provide compressed nitrogen. For example, this is the case of LNG plants that implement liquefaction technologies with 3-cycles of two pure-refrigerants and one mixed-refrigerant (e.g. “AP-X”).

One or more train identical or similar to the one shown in Fig. 1 (and Fig. 3) and/or one or more train identical or similar to the one shown in Fig. 2 (and Fig. 4) may be included into a LNG plant.

By using such trains with such compressors, a higher LNG production may be obtained in a smaller space and/or in a smaller footprint and with a lesser number of machines.

It is to be noted that having only one case instead of two or more cases is advantageous from many points of view:

- it simplifies installation and maintenance,
 - 10 - it reduces maintenance time,
 - it increases reliability (less components and less likelihood of failure),
 - it reduces footprint and weight of machines,
 - it reduces leakages of gasses,
 - it reduces the complexity and size of the lubricant oil system.
- 15 Fig. 5 and Fig. 6 show embodiments of LNG liquefaction lines 500 and 600 of LNG plants. Labels 501 and 601 indicate the gaseous natural gas inlets and labels 502 and 602 indicate the liquefied natural gas outlets. Labels 540 and 640 indicate the equipment of the line that processes the natural gas, cools it and liquefies it. The other components of the line provide pressurized refrigerant
- 20 gasses to such equipment.

For example, equipment 540 implements a 2-cycles pure-refrigerant and mixed-refrigerant liquefaction technology (e.g. “APCI”); therefore, it uses pressurized propane and pressurized mixed refrigerant.

For example, equipment 640 implements a 3-cycles pure-refrigerants liquefaction technology (e.g. "CPOC"); therefore, it uses pressurized propane, pressurized methane and pressurized ethane or ethylene.

5 In the LNG liquefaction line of Fig. 5, there is at least one high-flow axial compressor 510 (driven by an engine not shown in the figure) in a single case for compressing propane from at least two different lower pressures to a higher pressure. The low-pressure propane inlets may be typically two or three or four.

10 In the LNG liquefaction line of Fig. 5, there is at least one high-compression-ratio centrifugal compressor 520 (driven by an engine not shown in the figure) in a single case for compressing mixed refrigerant from at least two different lower pressures to at least two different higher pressures. The compressor 520 is fluidly connected to an intercooler 550 by means of a corresponding auxiliary inlet and a corresponding auxiliary outlet of the compressor 520 to provide an inter-refrigeration step. There may be more than one inter-refrigeration steps,
15 for example two or three, in such LNG liquefaction line.

In the LNG liquefaction line of Fig. 5, there may be at least one compressor (not shown) (driven by an engine not shown in the figure) in a single case for compressing nitrogen from a lower pressure to a higher pressure.

20 In the LNG liquefaction line of Fig. 6, there is at least one high-flow axial compressor 610 (driven by an engine not shown in the figure) in a single case for compressing propane from at least two different lower pressures to a higher pressure. The low-pressure propane inlets may be typically two or three or four.

25 In the LNG liquefaction line of Fig. 6, there is at least one high-compression-ratio centrifugal compressor 620 (driven by an engine not shown in the figure) in a single case for compressing methane from at least two different lower pressures to a higher pressure. The low-pressure methane inlets may be typically two or three or four.

In the LNG liquefaction line of Fig. 6, there is at least one compressor 630 (driven by an engine not shown in the figure) in a single case for compressing ethane or ethylene from at least two different lower pressures to a higher pressure. The low-pressure ethane or ethylene inlets may be typically two or
5 three or four.

It is to be noted that, depending on the power of the engines used and the power of the compressors used, a single engine may drive one or more compressors.

When a single engine drives e.g. two compressors, a gear train (that is usually part of a gearbox) may be used for rotating the two compressors at two different
10 speeds.

CLAIMS:

1. A LNG plant comprising a compression train (100);

wherein the compression train (100) comprises an engine (110) and a compressor (130) driven by the engine (110); wherein the compressor (130) is an axial compressor and comprises a first set of axial compression stages (311, 312) and a second set of axial compression stages (321, 322, 323) arranged downstream the first set of axial compression stages (311, 312);

at least the first set and the second set of axial compression stages (311, 312, 321, 322, 323) being housed inside one case (300);

the compressor (130) having:

- one main inlet (301) arranged upstream the first set of axial compression stages (311, 312),
- one main outlet (302) arranged downstream the second set of axial compression stages (321, 322, 323),
- at least one auxiliary inlet (303) and/or at least one auxiliary outlet arranged downstream the first set of axial compression stages (311, 312) and upstream the second set of axial compression stages (321, 322, 323),

wherein the compressor (130) is configured so that a fluid entering the compressor (130) through the auxiliary inlet (303) is redirected from a substantially radial direction to a substantially axial direction and/or a fluid exiting the compressor (130) through the auxiliary outlet is redirected from a substantially axial direction to a substantially radial direction;

wherein the LNG plant further comprises a further compression train (200), wherein the further compression train (200) comprises a further engine (210) and a further compressor (230) driven by the further engine (210); wherein the further compressor (230) is a centrifugal compressor and comprises a first set of impellers (411, 412) and a second set of impellers (421, 422, 423) arranged downstream or upstream the first set of impellers (411, 412);

the impellers (411, 412) of the first set being centrifugal and unshrouded;

the impellers (421, 422, 423) of the second set being centrifugal and shrouded;

at least the impellers (411, 412, 421, 422, 423) of the first set and of the second set being housed inside one case (400);

the impellers (411, 412, 421, 422, 423) of the first set and of the second set being coupled to each other through mechanical connections (430, 440).

2. The LNG plant of claim 1, wherein said fluid is redirected by means of an intermediate path (303B) extending from an external side (303A) of the auxiliary inlet/outlet to an internal side (303C) of the auxiliary inlet/outlet.

3. The LNG plant of claim 1 or 2, wherein the engine (110) is an electric motor or a steam turbine or a gas turbine, in particular an aeroderivative gas turbine.

4. The LNG plant of claim 1 or 2 or 3, wherein the engine (110) and the compressor (130) are connected directly or through a gear train (120).

5. The LNG plant (600) of any preceding claim from 1 to 4, wherein said compression train is a first compression train (610) and is arranged to compress propane, wherein said further compression train is a second compression train (620) and is arranged to compress methane, comprising further a third compression train (630) arranged to compress ethylene or ethane; the first compression train (610), the second compression train (620) and the third compression train (630) cooperating to liquefy a flow (601) of gaseous natural gas into a flow (602) of liquid natural gas.

6. The LNG plant of any preceding claim from 1 to 4, wherein said compression train is a first compression train and is arranged to compress propane, wherein said further compression train is a second compression train and is arranged to compress ethylene or ethane, comprising further a third

compression train arranged to compress methane; the first compression train, the second compression train and the third compression train cooperating to liquefy a flow of gaseous natural gas into a flow of liquid natural gas.

7. The LNG plant of claim 5 or 6, wherein the third compression train comprises at least one centrifugal compressor.

8. The LNG plant of claim 7, wherein said at least one centrifugal compressor of said fourth train comprises a first set of impellers and a second set of impellers arranged downstream or upstream the first set of impellers;

the impellers of the first set being centrifugal and unshrouded;

the impellers of the second set being centrifugal and shrouded;

at least the impellers of the first set and of the second set being housed inside one case;

the impellers of the first set and of the second set being coupled to each other through mechanical connections.

9. The LNG plant (500) of any preceding claim from 1 to 4, wherein said compression train is a first compression train (510) and is arranged to compress propane, wherein said further compression train is a second compression train (520) and is arranged to compress mixed refrigerant; the first compression train (510) and the second compression train (520) cooperating to liquefy a flow (501) of gaseous natural gas into a flow (502) of liquid natural gas.

10. The LNG plant of any preceding claim from 1 to 4, wherein said compression train is a first compression train and is arranged to compress propane, wherein said further compression train is a second compression train and is arranged to compress mixed refrigerant, comprising further a fourth compression train arranged to compress nitrogen; the first compression train, the second compression train and the fourth compression train cooperating to liquefy a flow of natural gas.

11. The LNG plant of claim 10, wherein the fourth compression train comprises at least one centrifugal compressor.

12. The LNG plant of claim 11, wherein said at least one centrifugal compressor of said fourth train comprises a first set of impellers and a second set of impellers arranged downstream or upstream the first set of impellers;

the impellers of the first set being centrifugal and unshrouded;

the impellers of the second set being centrifugal and shrouded;

at least the impellers of the first set and of the second set being housed inside one case;

the impellers of the first set and of the second set being coupled to each other through mechanical connections.

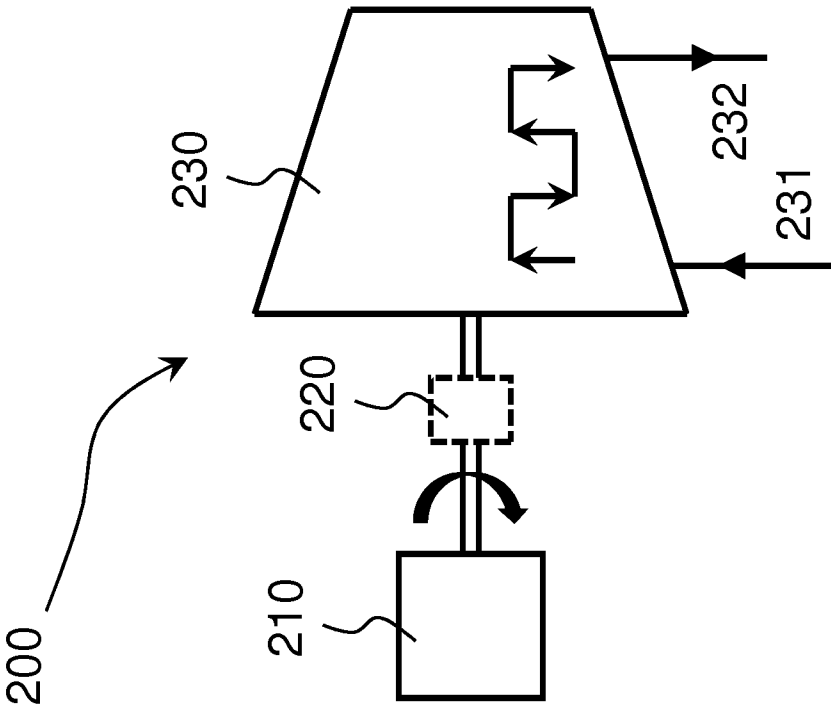


Fig. 2

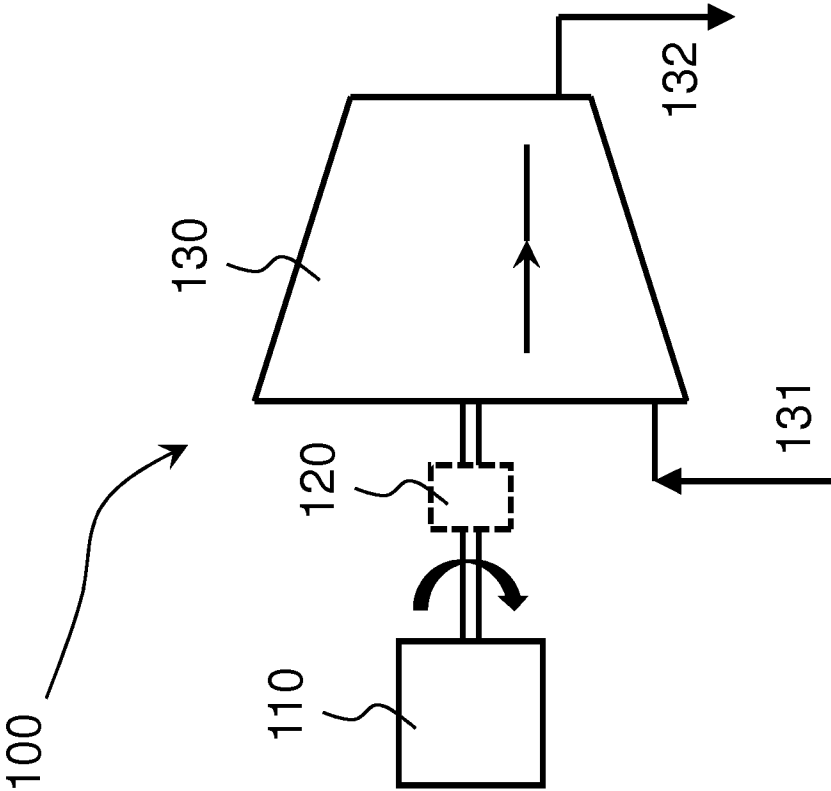


Fig. 1

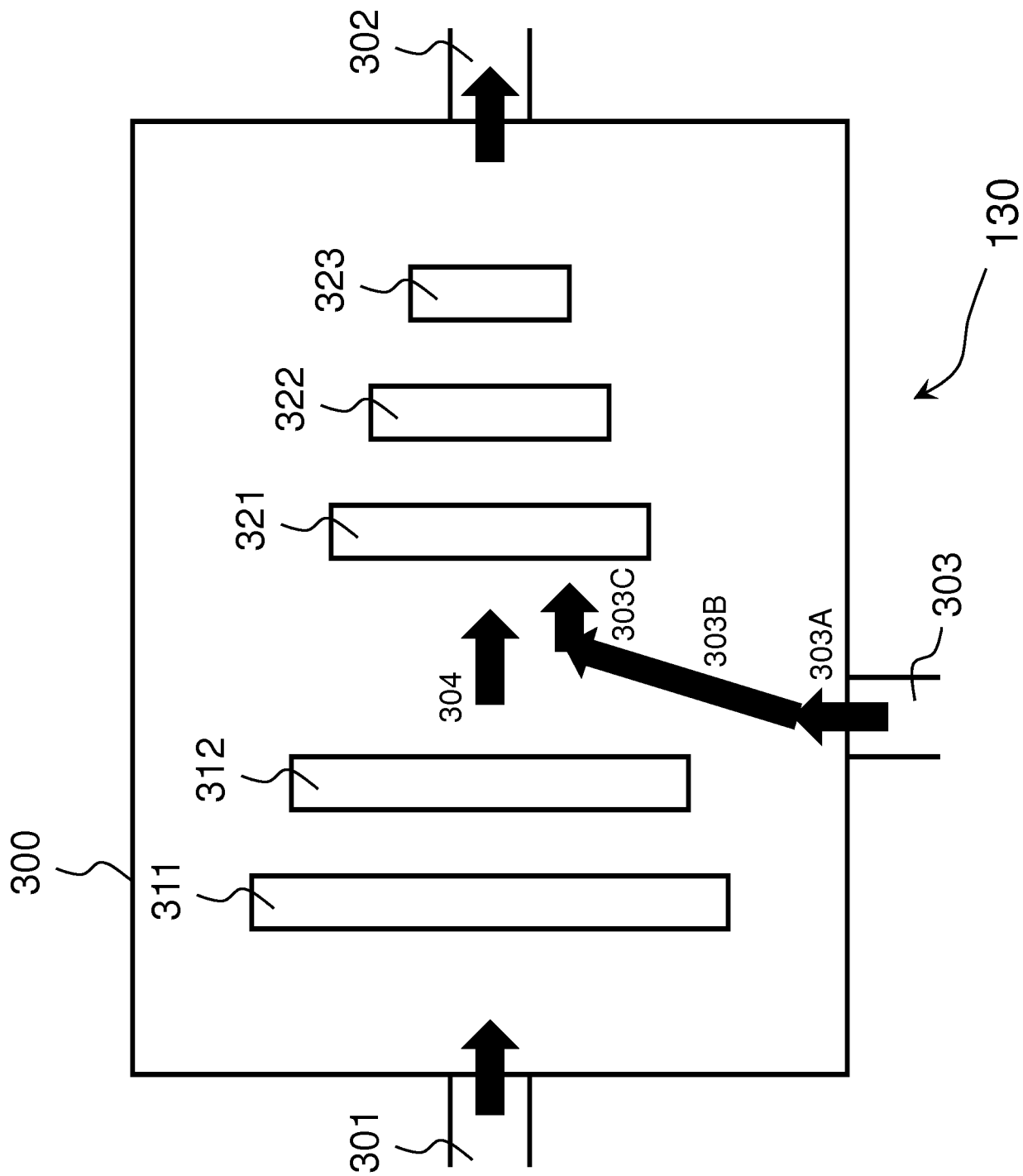


Fig. 3

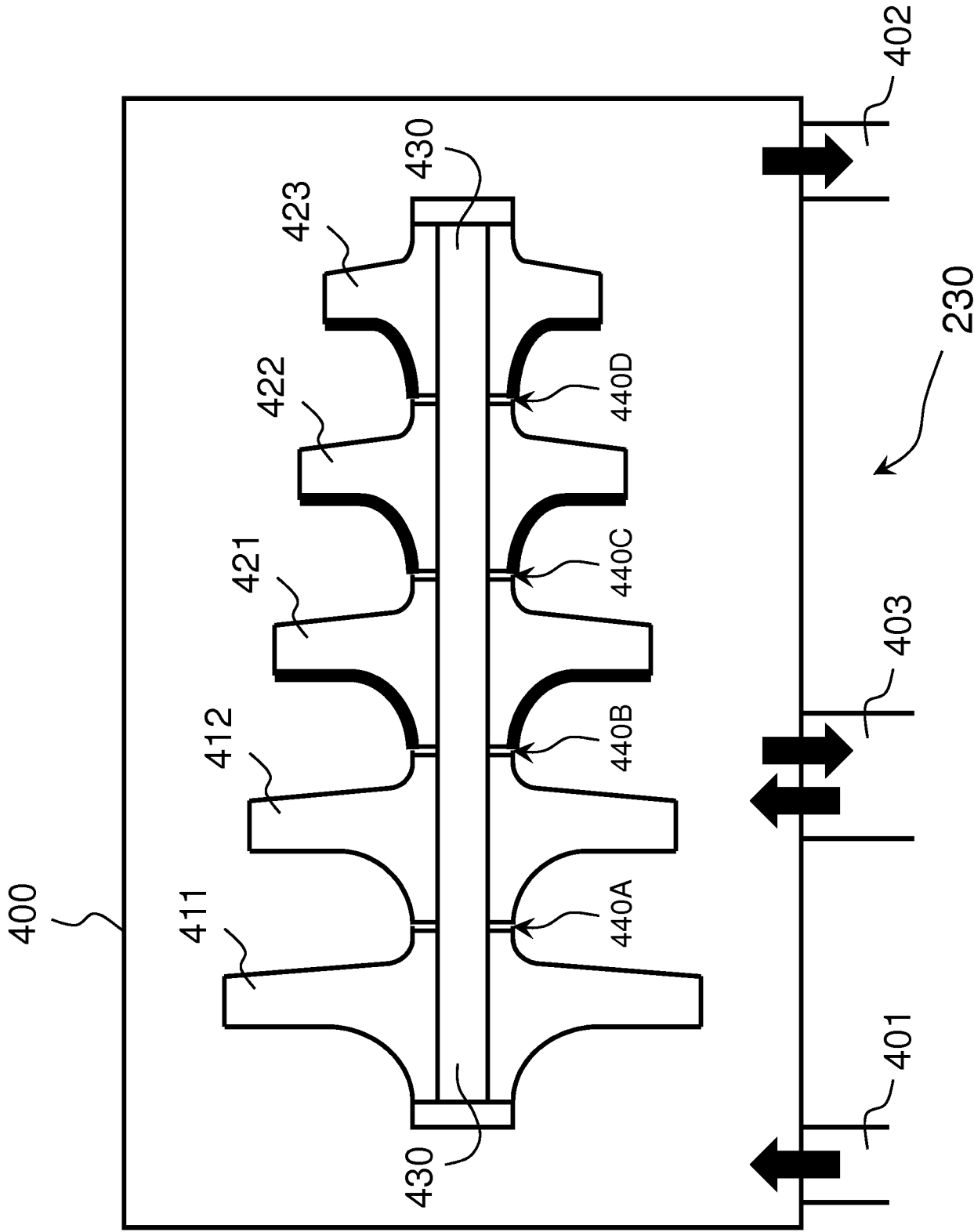


Fig. 4

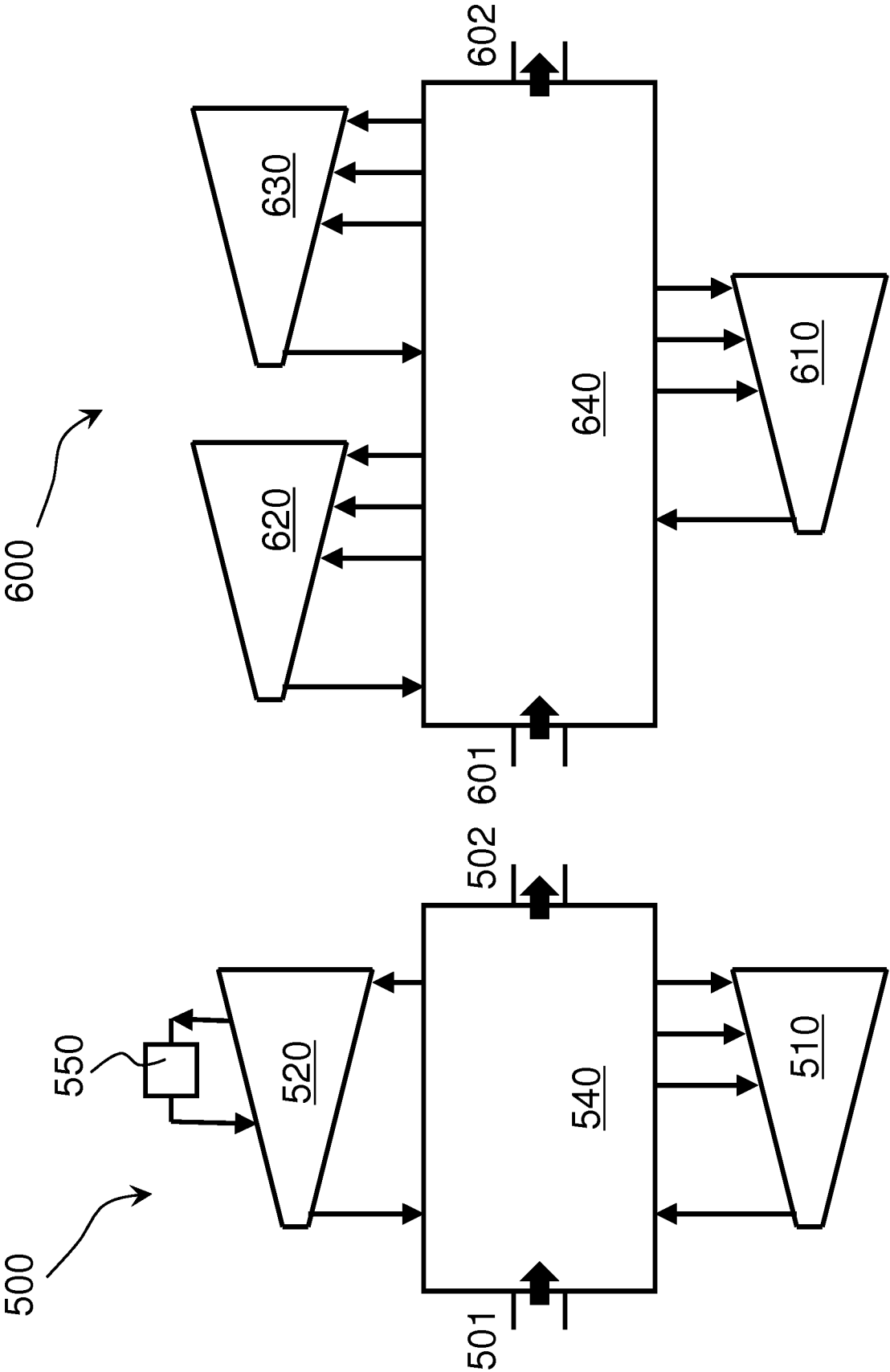


Fig. 6

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/067567

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04D17/12 F04D25/16 F04D29/28 F04D27/02 F04D19/02
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)
F04D F25J

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 A	WO 2013/182492 A1 (NUOVO PIGNONE SRL [IT]) 12 December 2013 (2013-12-12) page 1, line 4 - line 16 page 4, line 19 - line 24; figure 1 page 5, line 4 - line 13 -----	1-4,7,8, 11,12 5,6,9,10
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

18 October 2016

Date of mailing of the international search report

04/11/2016

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/067567

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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