US 20070204649A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2007/0204649 A1**

Kaart et al. (43) **Pub. Date: Sep. 6, 2007**

(54) **REFRIGERANT CIRCUIT**

(76) Inventors: **Sander Kaart**, The Hague (NL); **Adriaan Johannes Kodde**, Amsterdam (NL)

Correspondence Address:
SHELL OIL COMPANY
P O BOX 2463
HOUSTON, TX 772522463

(21) Appl. No.: **11/680,732**

(22) Filed: **Mar. 1, 2007**

(30) **Foreign Application Priority Data**

Mar. 6, 2006 (EP) 06110684.5

Publication Classification

(51) **Int. Cl.**
F25B 7/00 (2006.01)
F25J 1/00 (2006.01)

(52) **U.S. Cl.** **62/612**; 62/335

(57) **ABSTRACT**

The present invention relates to a refrigerant circuit (**1**), in particular for use in a liquefaction plant, the refrigerant circuit (**1**) at least comprising:

a refrigerator (**2**) having an inlet (**21**) for refrigerant (**10**) and at least one outlet (**22**) for refrigerant (**20**) evaporated in the refrigerator (**2**);

a compressor (**3**) having an inlet (**31**) for receiving the evaporated refrigerant (**20**) from the refrigerator (**2**) and an outlet (**34**) for compressed refrigerant (**11***a*);

a cooler (**5**) having an inlet (**81**) for compressed refrigerant (**110***a*) and an outlet (**82**) for cooled compressed refrigerant (**120***a*);

a stream splitter (**6**) suitable for splitting the cooled compressed refrigerant (**120***a*) in at least two streams (**10***a*, **130***a*);

a first valve (**7**), a second valve (**8**) and a first relief valve (**9**).

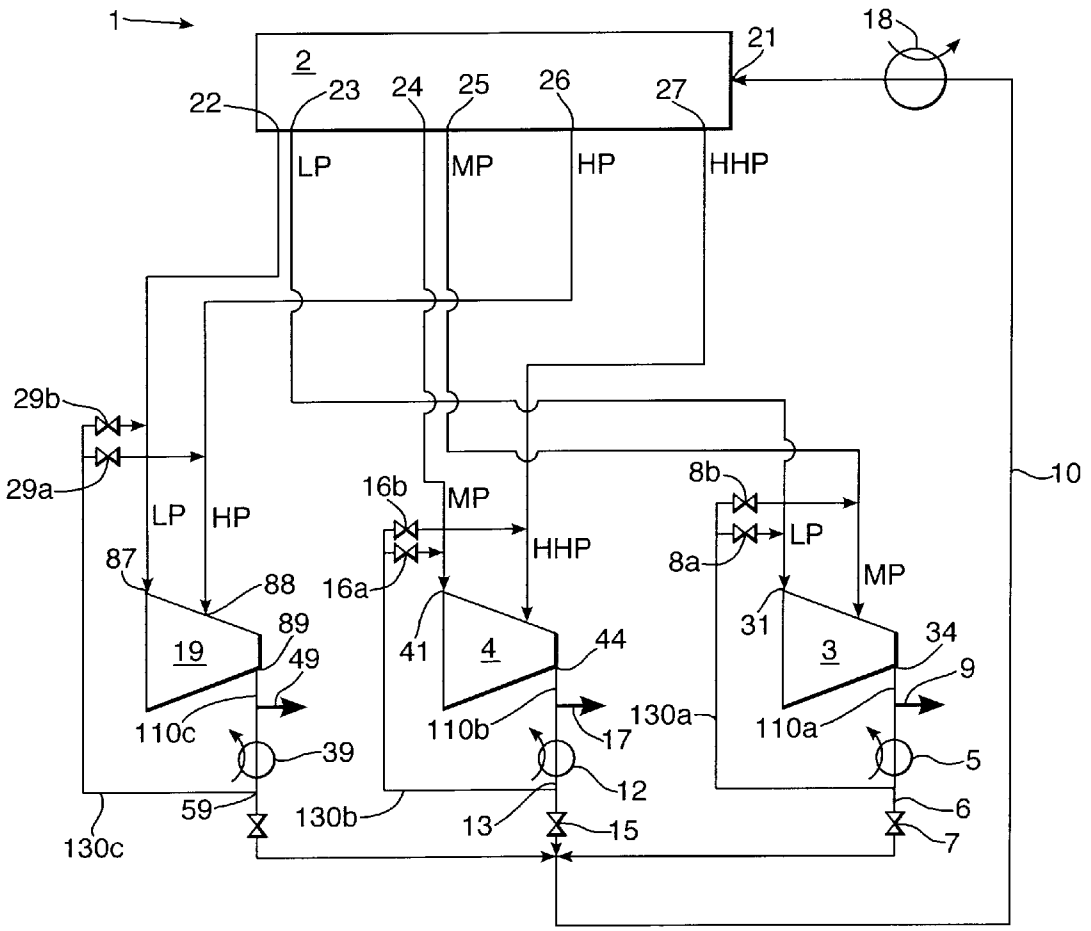


Fig.1.

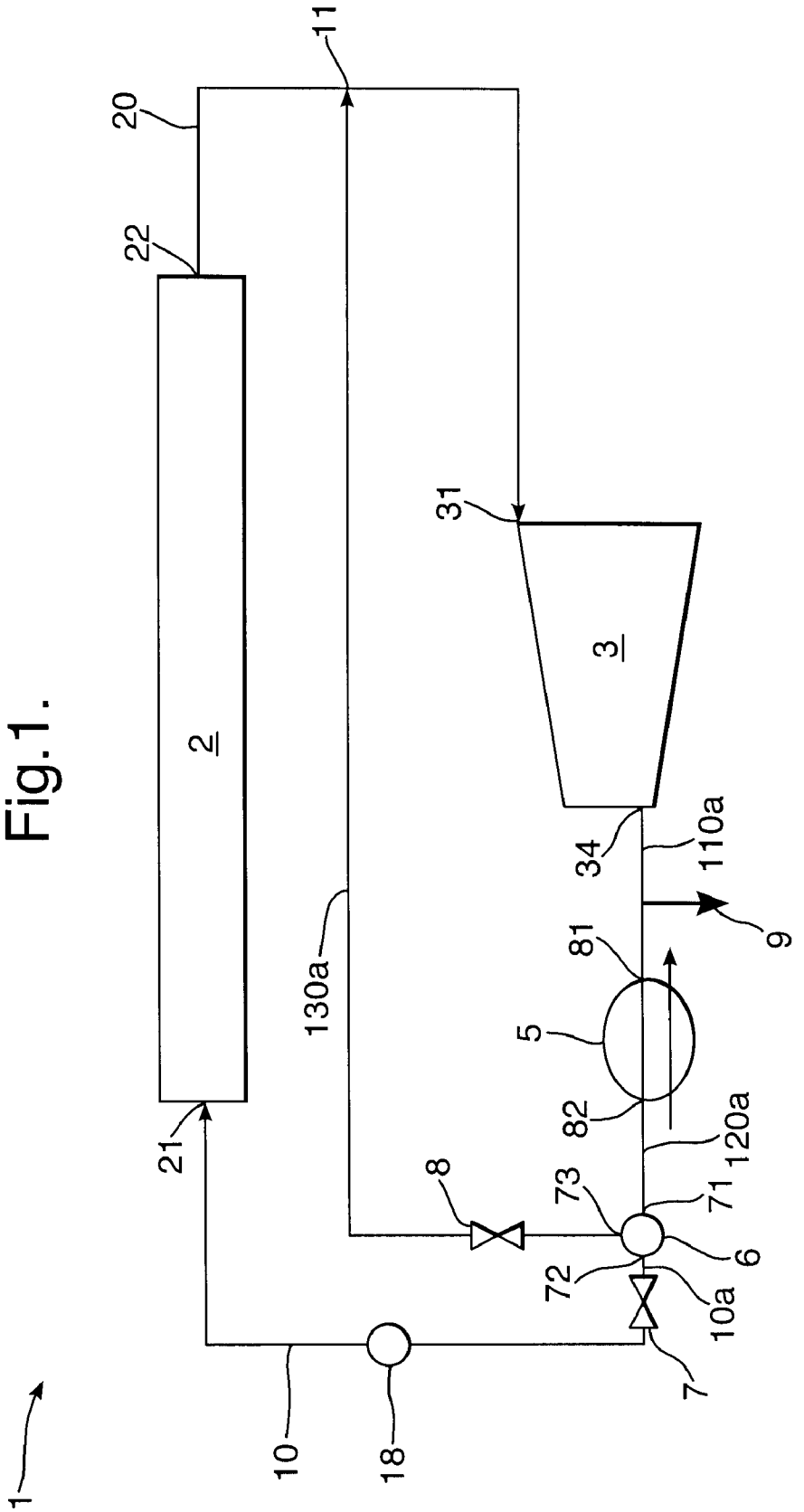


Fig.2.

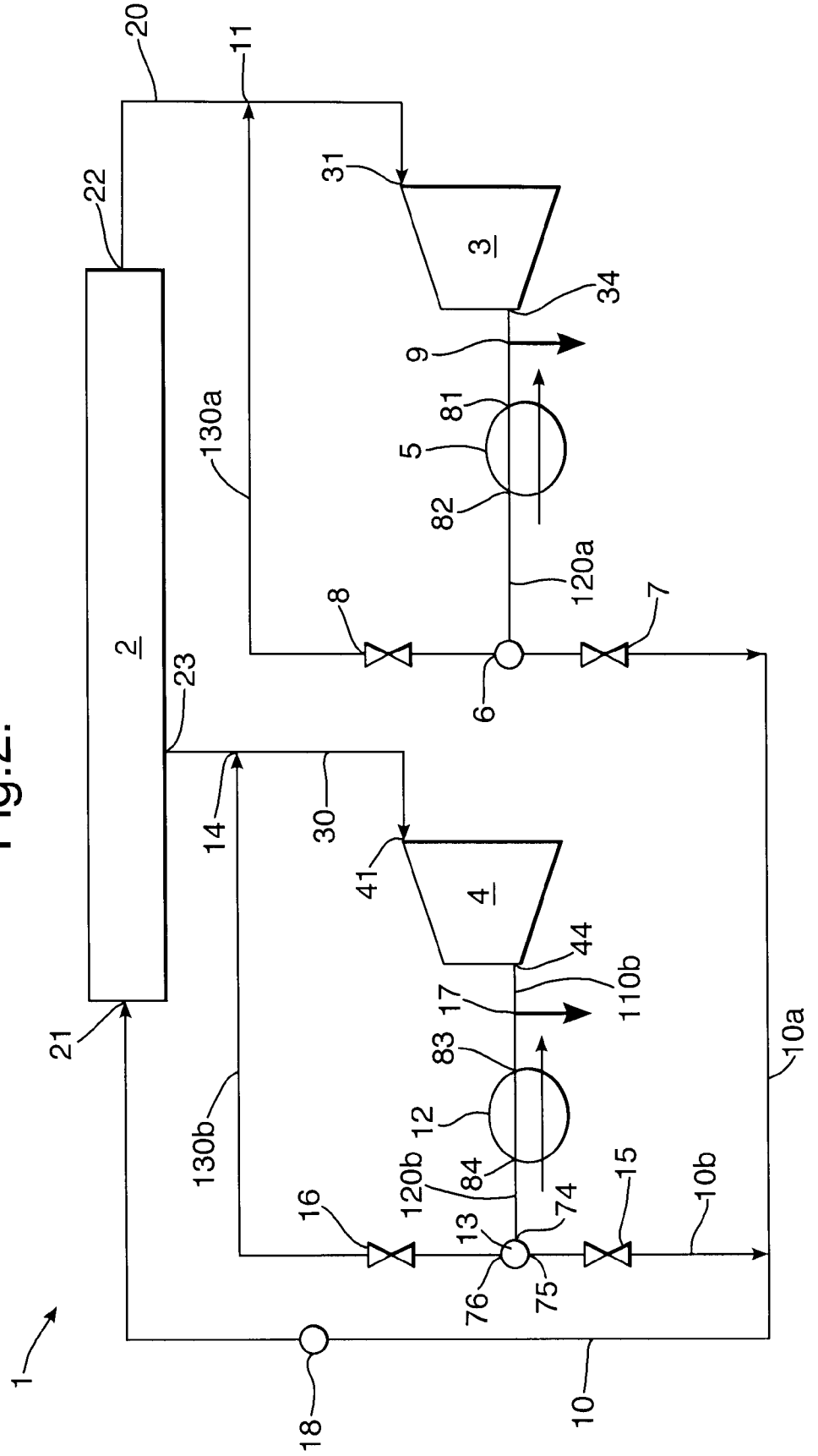
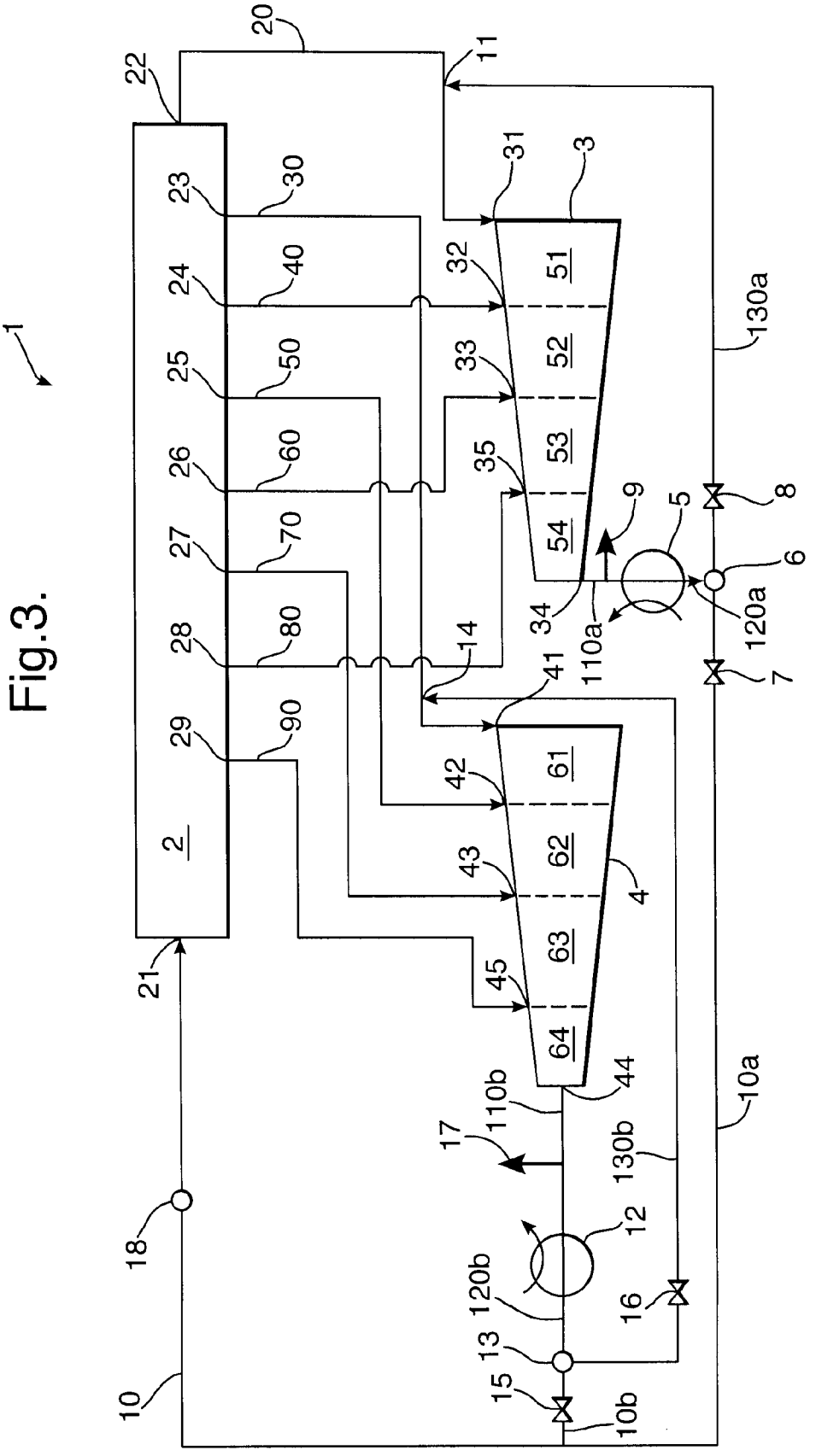

20
11
22
31
3
34
9
81
5
82
130a
120a
8
7
6
2
23
14
30
41
4
44
110b
17
83
12
84
120b
130b
16
13
74
15
10b
10a
76
75
21
1
18
10

Fig.3.


1
2
3
4
5
6
7
8
9
10
10a
10b
11
12
13
14
15
16
17
18
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
40
41
42
43
44
45
50
51
52
53
54
60
61
62
63
64
70
80
90
110a
110b
120a
120b
130a
130b

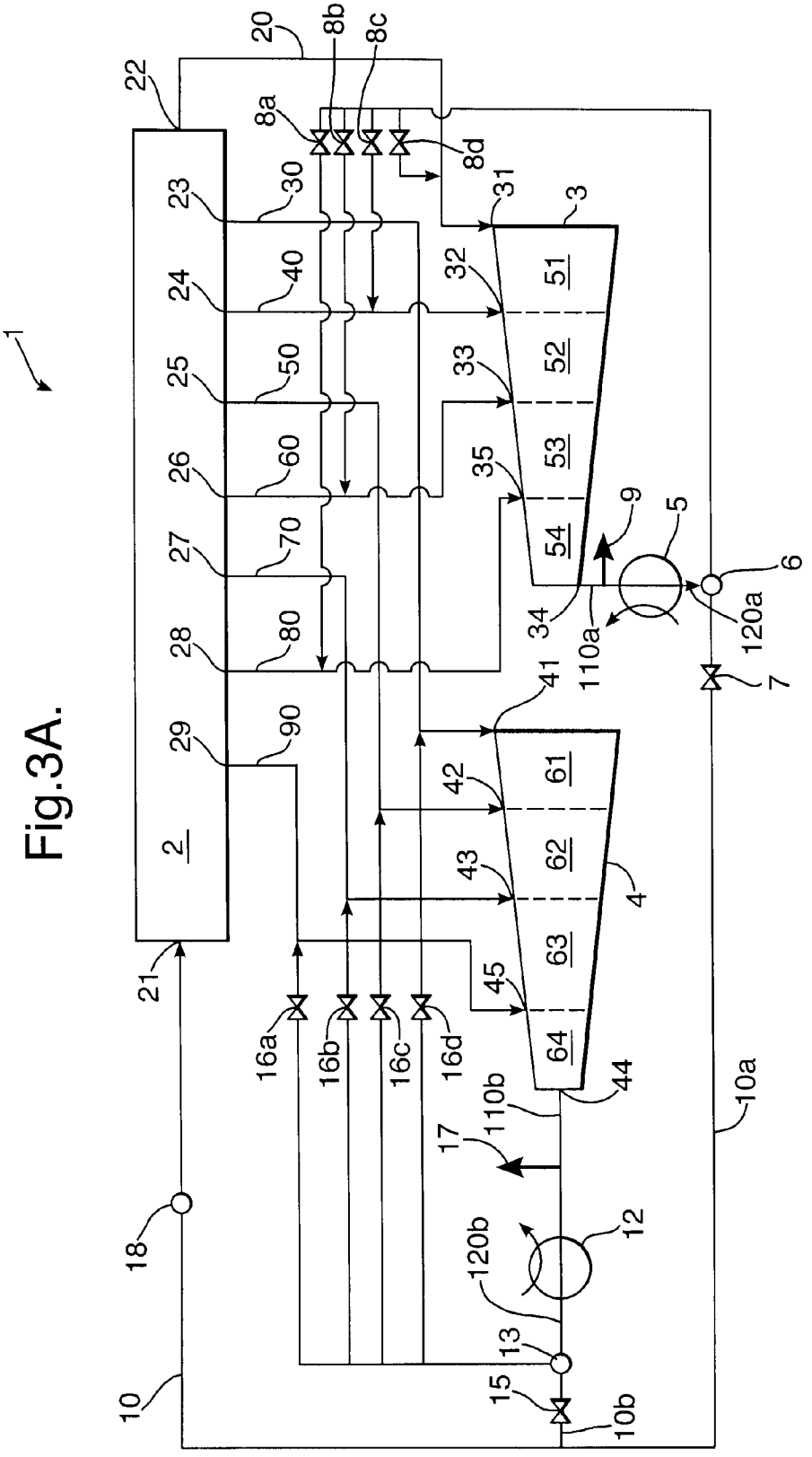

1
2
3
4
5
6
7
8a
8b
8c
8d
9
10
10a
10b
12
13
15
16a
16b
16c
16d
17
18
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
40
41
42
43
44
45
50
51
52
53
54
60
61
62
63
64
70
80
90
110a
110b
120a
120b

Fig.3A.

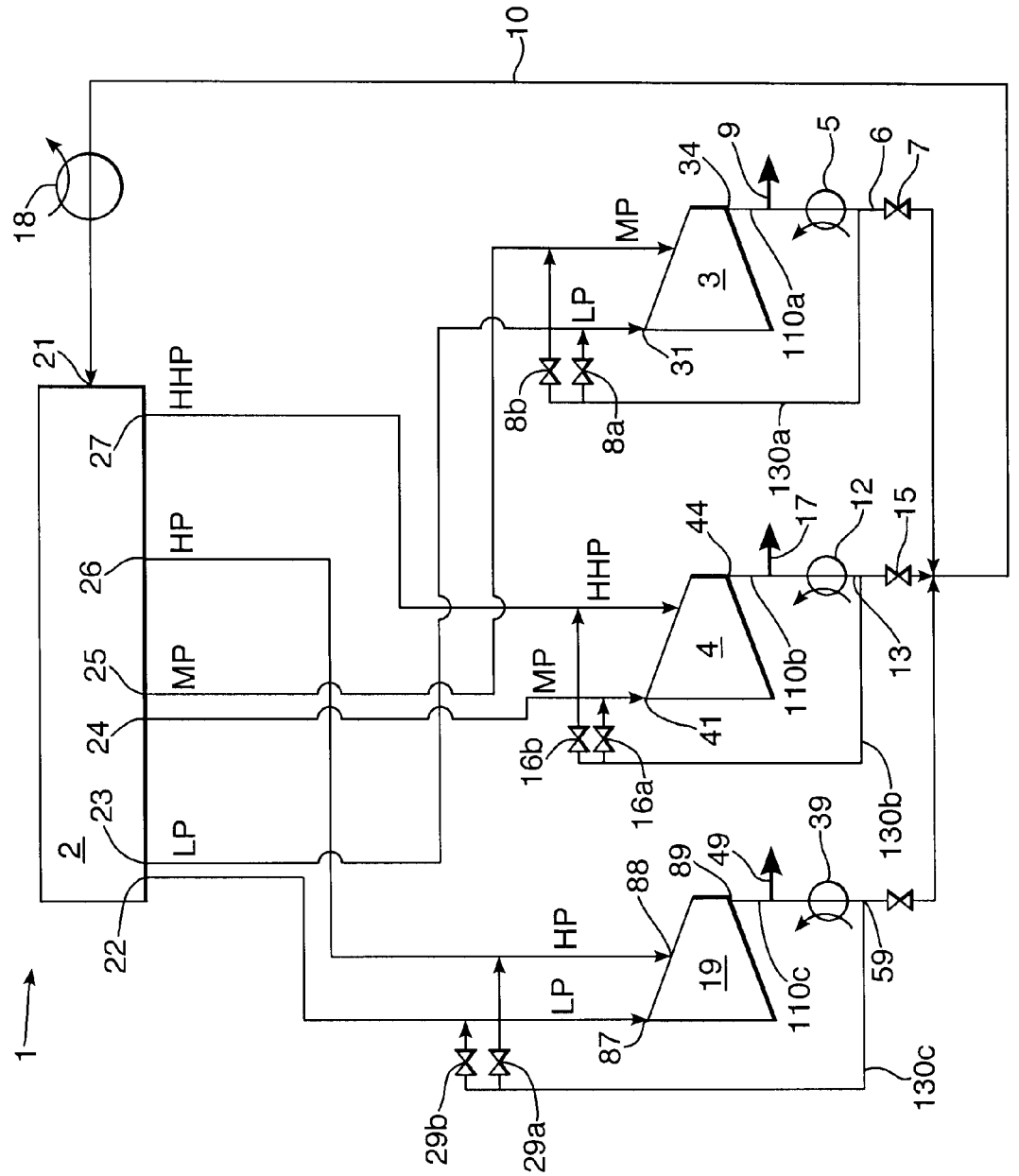

10
18
21
HHP
27
HP
26
MP
25
24
LP
23
2
22
1
MP
LP
3
31
34
9
5
6
7
110a
8b
8a
130a
HHP
4
44
17
12
15
13
110b
MP
41
16b
16a
130b
39
49
89
88
HP
LP
19
87
110c
59
29b
29a
130c

Fig.4.

REFRIGERANT CIRCUIT

[0001] The present invention relates to a refrigerant circuit, in particular for use in a liquefaction plant.

[0002] From practice several line-ups for a refrigerant circuit are known. Usually, a refrigerant circuit comprises a refrigerator (or 'refrigeration zone') in which the refrigerant is evaporated in one or more stages thereby withdrawing heat from the stream to be cooled; a compressor for recompressing the evaporated refrigerant(s); and return lines for returning the recompressed refrigerant to the refrigerator.

[0003] A problem of the known refrigerant circuit is that it may be damaged as a result of an overloading of the lines used in the circuit.

[0004] The above problem is even more pertinent in the liquefaction of natural gas, as plants for the liquefaction of natural gas and other gas processing plants are being designed for ever-increasing production rates in order to realize the favourable economic benefits associated with larger plants.

[0005] It is an object of the present invention to solve the above problem.

[0006] It is a further object to provide an alternative refrigerant circuit.

[0007] One of the above or other objects can be achieved according to the present invention by providing a refrigerant circuit, in particular for use in a liquefaction plant, the refrigerant circuit at least comprising:

[0008] a refrigerator having an inlet for refrigerant at a refrigeration pressure, and at least one outlet for refrigerant evaporated in the refrigerator;

[0009] a first compressor having an inlet for receiving the evaporated refrigerant from the refrigerator and an outlet for compressed refrigerant;

[0010] a first cooler having an inlet for compressed refrigerant and an outlet for cooled compressed refrigerant;

[0011] a first stream splitter suitable for splitting the cooled compressed refrigerant in at least two streams, the first stream splitter having an inlet for receiving the cooled compressed refrigerant, a first outlet connected to the inlet of the refrigerator and a second outlet intended for returning refrigerant to upstream of the inlet of the first compressor at a first connection point;

[0012] a first valve between the first outlet of the first stream splitter and the inlet of the refrigerator;

[0013] a second valve between the second outlet of the first stream splitter and the first connection point; and

[0014] a first relief valve downstream of the outlet of the first compressor and upstream of both the first and second valves.

[0015] An important advantage of the present invention is that it provides a surprisingly simple protection for the refrigerant circuit in the event that one of the valves (in particular the first valve) in the refrigerant circuit dysfunctions.

[0016] The refrigerator may have different line-ups as long at is allows refrigerant to evaporate at one or more pressure levels. To that end the refrigerator may have more than one inlet and outlet. In this respect reference is made to WO 01/44734 and US 2005/0126219, showing a refrigerator having four outlets, which are hereby incorporated by reference. As the person skilled in the art understands what is meant with a refrigerator, this is not further discussed here.

[0017] Usually, the refrigerator is preceded by a condenser to partially or fully condense the refrigerant to be evaporated in the refrigerator. If, as a result of the line-up chosen, the refrigerant to be evaporated is already in a partially or fully condensed state when approaching the refrigerator, the condenser can be dispensed with.

[0018] The first compressor may be any suitable compressor. If desired, two or more compressors may be present. Also, the first (and optionally further) compressor(s) may each comprise one or more compression stages.

[0019] The first cooler may be any suitable cooler, and will usually be a water or air cooler. Also a heat exchanger may be used. If desired, more than one cooler may be present.

[0020] The first stream splitter may have various embodiments as long as it is suitable for splitting the cooled compressed refrigerant into at least two streams. Usually the splitter will be a T-piece.

[0021] The first and second valve may be any kind of valves, while the first relief valve should be suitable for handling an overload of the line on which the relief valve is situated.

[0022] Preferably the first relief valve is located between the outlet of the first compressor and the inlet of the first cooler.

[0023] Further it is preferred that the refrigerator has at least two outlets for refrigerant evaporated in the refrigerator, the at least two outlets being connected to the first compressor.

[0024] According to especially preferred embodiment according to the present invention, the refrigerant circuit further comprises:

[0025] a second compressor having an inlet for receiving evaporated refrigerant from the refrigerator and an outlet for compressed refrigerant;

[0026] a second cooler having an inlet for compressed refrigerant and an outlet for cooled compressed refrigerant;

[0027] a second stream splitter suitable for splitting the cooled compressed refrigerant in at least two streams, the second stream splitter having an inlet for receiving the cooled compressed refrigerant, a first outlet connected to the inlet of the refrigerator and a second outlet intended for returning refrigerant to upstream of the inlet of the second compressor at a second connection point;

[0028] a third valve between the first outlet of the second stream splitter and the inlet of the refrigerator;

[0029] a fourth valve between the second outlet of the second stream splitter and the connection point; and

[0030] a second relief valve downstream of the outlet of the second compressor and upstream of both the third and fourth valves.

[0031] A special advantage of the above embodiment is that he first and second relief valves can be kept relatively small when compared with an embodiment in which only one relief valve would be present.

[0032] The first compressor may be any suitable compressor. If desired, two or more compressors may be present. Also, the first (and optionally further) compressor(s) may each comprise one or more compression stages.

[0033] Again, the second cooler may be any suitable cooler, and will usually be a water or air cooler. Also a heat exchanger may be used. If desired, more than one cooler may be present.

[0034] The second stream splitter may have various embodiments as long as it is suitable for splitting the cooled compressed refrigerant into at least two streams. Usually the splitter will be a T-piece.

[0035] The third and fourth valves may be any kind of valves, while the second relief valve should be suitable for handling an overload of the line on which the relief valve is situated.

[0036] Preferably, the second relief valve is located between the outlet of the second compressor and the inlet of the second cooler. If desired more than the two indicated relief valves may be present.

[0037] Further it is preferred that the refrigerator has at least two outlets for refrigerant evaporated in the refrigerator, the at least two outlets being connected to the second compressor.

[0038] In another aspect the present invention provides a plant for the production of liquefied natural gas, the plant comprising the refrigerant circuit according to the present invention for cooling a natural gas stream to be liquefied.

[0039] Preferably, the refrigerant circuit according to the present invention is used as a refrigerant circuit for a pre-cooling heat exchanger as mentioned in U.S. Pat. No. 6,389,844, which is hereby incorporated by reference. In the above patent a plant is described for liquefying natural gas, wherein the plant comprises a pre-cooling heat exchanger having an inlet for natural gas and an outlet for cooled natural gas, a distributor having an inlet connected to the outlet for cooled natural gas and having at least two outlets, and at least two main heat exchangers each comprising a first hot side having one inlet connected to one outlet of the distributor and an outlet for liquefied natural gas, which plant further comprises a pre-cooling refrigerant circuit for removing heat from the natural gas in the pre-cooling heat exchanger, and at least two main refrigerant circuits for removing heat from natural gas flowing through the first hot side of the corresponding main heat exchanger.

[0040] In a further aspect the present invention provides a method for the production of liquefied natural gas, wherein the natural gas stream to be liquefied is cooled using the refrigerant circuit according to the present invention. To this end the method preferably at least comprises the steps of:

[0041] evaporating a refrigerant in a refrigerator thereby cooling a stream to be cooled and obtaining an evaporated refrigerant;

[0042] compressing the evaporated refrigerant in a compressor thereby obtaining a compressed refrigerant;

[0043] cooling the compressed refrigerant thereby obtaining a cooled compressed refrigerant;

[0044] splitting the cooled compressed refrigerant in at least two streams;

[0045] forwarding a first stream to the refrigerator and a second stream to a connection point downstream of the refrigerator and upstream of the compressor;

[0046] removing refrigerant from the refrigerant circuit by means of a relief valve, if the pressure of the refrigerant at the relief valve exceeds a pre-selected value.

[0047] The invention will now be described by way of example in more detail with reference to the accompanying non-limiting drawings, wherein:

[0048] FIG. **1** schematically shows a first embodiment of a refrigerant circuit according to the present invention;

[0049] FIG. **2** schematically shows a second embodiment of a refrigerant circuit according to the present invention;

[0050] FIG. **3** schematically shows a third embodiment of a refrigerant circuit according to the present invention;

[0051] FIG. **3**A schematically shows a variation to the embodiment of FIG. **3**; and

[0052] FIG. **4** schematically shows a fourth embodiment of a refrigerant according to the present invention.

[0053] For the purpose of this description, a single reference number will be assigned to a line as well as a stream carried in that line. Same reference numbers refer to similar components.

[0054] Reference is made to FIG. **1** showing schematically a refrigerant circuit **1** containing a refrigerator (or 'refrigeration zone') represented by a box **2**, a first compressor **3**, a first cooler **5** such as an air or water cooler or a heat exchanger (as shown in FIG. **1**) and a first stream splitter **6**.

[0055] Since the refrigerator **2** is well known, it is here only schematically shown for the sake of clarity. The refrigerator **2** has an inlet **21** intended for at least partially condensed refrigerant **10** at a refrigeration pressure. More than one inlet **21** may be present. In the embodiment of FIG. **1** the refrigerator **2** has one outlet **22** for refrigerant **20** evaporated in the refrigerator **2**. As will be further illustrated in FIGS. **2**, **3** and **4**, the refrigerator **2** may have more than one outlet **22**.

[0056] The first compressor **3** may comprise one or more impellers, wherein an impeller is sometimes referred to as a stage. The first compressor **3** has an inlet **31** and an outlet **34** for compressed refrigerant **110***a*. For the sake of clarity the driver(s) of the compressor **3** is not shown.

[0057] The outlet **34** of the first compressor **3** is connected to the inlet **81** of the first cooler **5** by means of conduit **110***a*. The outlet **82** of the first cooler **5** is connected to the inlet **71** of the first stream splitter **6**, which in the embodiment of FIG. **1** is in the form of a T-piece. The first stream splitter **6** has a first outlet **72** connected to the inlet of the refrigerator **2** by means of conduits **10***a*, **10** and a second outlet **73** for returning refrigerant to upstream of the inlet **31** of the first compressor **3** at a first connection point **11** by means of a conduit **130***a*.

[0058] The refrigerant circuit **1** further comprises a first valve **7** between the first outlet **72** of the first stream splitter **6** and the inlet **21** of the refrigerator **2**, and a second valve **8** between the second outlet **73** of the first stream splitter **6** and the first connection point **11**.

[0059] Furthermore the refrigerant circuit **1** comprises a first relief valve **9** downstream of the outlet **34** of the first compressor **3** and upstream of both the first and second valves **7**,**8**. Preferably, the first relief valve **9** is located between the outlet **34** of the first compressor **3** and the inlet **81** of the first cooler **5**, i.e. on line **110***a*.

[0060] Second valve **8** and piping **130***a* are provided to recycle gaseous refrigerant to the suction side of first compressor **3** to prevent surge (flow reversal) in the first compressor **3**.

[0061] In the embodiment of FIG. **1**, the refrigerant circuit **1** further comprises a condenser **18** to at least partially condense the refrigerant stream just upstream of the inlet **21** of the refrigerator **2**, i.e. on line **10**. The condenser may be any suitable means, such as an air cooler, water cooler, heat-exchanger, etc., as long as it at least partially condenses the refrigerant stream.

[0062] During normal operation, the first compressor **3** compresses the refrigerant obtained from and evaporated in the refrigerator **2**, which is subsequently cooled in the first cooler **5** and—after at least partially condensing in condenser **18**—returned at the refrigeration pressure to the inlet **21** of the refrigerator **2** via conduits **120***a*, **10***a*, **10**. In the refrigerator **2** the at least partially condensed refrigerant **10** is allowed to evaporate thereby cooling a stream (such as natural gas in a liquefaction plant) to be cooled (not shown). If e.g. the first valve **7** dysfunctions and the pressure of the refrigerant at the first relief valve **9** exceeds a pre-selected value, the first relief valve **9** removes refrigerant from the refrigerant circuit **1**. Hereby, the first relief valve **9** avoids an overload of the lines in the refrigerant circuit **1**.

[0063] In the embodiment of FIG. **1** the first cooler **5** functions as a desuperheater, i.e. it only cools the cooled compressed stream **120***a* without condensing it.

[0064] Reference is made to FIG. **2** showing schematically an alternative embodiment of the refrigerant circuit **1** of FIG. **1**.

[0065] The refrigerant circuit **1** now further comprises a second compressor **4**, a second cooler **12**, a second stream splitter **13**, third and fourth valves **15**, **16** and a second relief valve **17**.

[0066] The second compressor **4** has an inlet **41** for receiving a further evaporated refrigerant stream **30** from the second outlet **23** of the refrigerator **2**, and an outlet **44** for compressed refrigerant **110***b*. The compressors **3** and **4** are arranged in separate casings.

[0067] The second cooler **12** has an inlet **83** for the compressed refrigerant **10***b* and an outlet **84** for cooled compressed refrigerant **120***b*. Similar to FIG. **1**, first and second coolers **5**, **12** function as desuperheaters, without condensing the respective refrigerant streams **120***a* and **120***b*.

[0068] The second stream splitter **13** splits the gaseous cooled compressed refrigerant **120***b* in at least two streams **10**,**130***b*, and has to this end an inlet **74** for receiving the cooled compressed refrigerant **120***b*, a first outlet **75** connected to the inlet **21** of the refrigerator **2** and a second outlet **76** for returning refrigerant **130***b* to upstream of the inlet **41** of the second compressor **4** at a second connection point **14**.

[0069] The third valve **15** is located between the first outlet **74** of the second stream splitter **13** and the inlet **21** of the refrigerator **2**, while the fourth valve **16** is located between the second outlet **73** of the second stream splitter **13** and the second connection point **14**. The second relief valve **17** is placed downstream of the outlet **44** of the second compressor **4** and upstream of both the third and fourth valves **15**,**16**. Preferably the second relief valve is placed on line **10***b*.

[0070] The person skilled in the art will understand that more than two compressors (like the first and second compressors **3**,**4**) with corresponding coolers and splitters may be used.

[0071] Furthermore, the person skilled in the art will understand that each of the lines **10***a* and **10***b* may be directly connected to inlets of the refrigerator **2**, instead of first combining into the stream **10** as shown in FIG. **1**.

[0072] Also, instead of or in addition to one condenser **18**, separate condensers may be present on the lines **10***a* and **10***b*.

[0073] The refrigerant circuit **1** according to FIG. **2** is especially suitable to be used as a refrigerant circuit for a pre-cooling heat exchanger as mentioned in U.S. Pat. No. 6,389,844, which is hereby incorporated by reference. In the above patent a plant is described for liquefying natural gas, wherein the plant comprises a pre-cooling heat exchanger having an inlet for natural gas and an outlet for cooled natural gas, a distributor having an inlet connected to the outlet for cooled natural gas and having at least two outlets, and at least two main heat exchangers each comprising a first hot side having one inlet connected to one outlet of the distributor and an outlet for liquefied natural gas, which plant further comprises a pre-cooling refrigerant circuit for removing heat from the natural gas in the pre-cooling heat exchanger, and at least two main refrigerant circuits for removing heat from natural gas flowing through the first hot side of the corresponding main heat exchanger.

[0074] In the embodiment of FIG. **3**, the refrigerator **2** has five outlets **22**, **23**, **24**, **25**, **26** for refrigerant evaporated at different pressure levels, with increasing pressures from the first outlet **22** to the fifth outlet **26**. As an example, first outlet **22** is intended for gaseous refrigerant **20** at a low pressure, second outlet **23** for gaseous refrigerant **30** at an intermediate pressure, third outlet **24** for gaseous refrigerant **40** at a high pressure, fourth outlet **25** for gaseous refrigerant **50** at a high-high pressure and fifth outlet **26** for gaseous refrigerant **60** at a high-high-high pressure. In FIG. **3** further outlets **27**, **28**, **29** (for corresponding evaporated streams **70**, **80**, **90**) have also been shown, to illustrate that these can be present too, if desired.

[0075] The first compressor **3** and second compressor **4** are each arranged in a single casing. The first compressor **3** has three interconnected sections **51**, **52** and **53**, and the second compressor **4** has two interconnected sections **61** and **62**. Each section can comprise one or more impellers, wherein an impeller is sometimes referred to as a stage. The

sections **51**, **52**, **53**, **61** and **62** are referred to as the low pressure sections **51** and **61**, intermediate pressure section **52** and high pressure sections **53** and **62**. As has also been exemplified in the same FIG. **3**, the first and second compressors **3**, **4** may have more interconnected sections (i.e. **54**, **63**, **64**, . . .) if desired.

[**0076**] The first compressor **3** has a main inlet **31**, a first side inlet **32**, a second side inlet **33** and an outlet **34**. The second compressor **4** has a main inlet **41**, a first side inlet **42** and an outlet **44**. The main inlet **32** of the first compressor **3** opens into the low pressure section **51**, and the first side inlet **32** opens into the intermediate pressure section **52**. The second side inlet **33** opens into the high pressure section **53**. The main inlet **41** of the second compressor **4** opens into the low pressure section **61**, and the first side inlet **42** opens into the high pressure section **62**. For the sake of clarity the drivers of the compressors **3** and **4** are not shown.

[**0077**] The outlets **34** and **44** of the compressors **3** and **4** are connected to the inlet **21** of the refrigerator **2** by means of conduits **110***a*, **120***a*, **10***a*, **10** and **110***b*, **120***b*, **10***b*, **10**, respectively. The first outlet **22** of the refrigerator **2** is connected to the main inlet **31** of the first compressor **3** by means of conduit **20**, and the second outlet **23** is connected to the main inlet **41** of the second compressor **4** by means of conduit **30**. The third outlet **24** is connected to first side inlet **32** of the first compressor **3** by means of conduit **40**, the fourth outlet **25** is connected to the first side inlet **42** of the second compressor **4** by means of conduit **50**, and the fifth outlet **26** is connected to second side inlet **33** of the first compressor **3** by means of conduit **60**.

[**0078**] During normal operation, the two compressors **3** and **4** each compress a part of the refrigerant to the refrigeration pressure, so that all refrigerant is supplied at the refrigeration pressure via conduit **10** to the inlet **21** of the refrigerator **2**. In at least five heat exchangers (not shown) in series the refrigerant **10** is allowed to evaporate in the refrigerator **2** (in the embodiment of FIG. **3** at five different pressure levels).

[**0079**] In the first heat exchanger within the refrigerator **2** the refrigerant is allowed to partly evaporate at a high-high-high pressure, which is below the refrigeration pressure; the liquid part of the refrigerant is passed to the second heat exchanger and the remaining vapour is returned to the first compressor **3** through conduit **60**. In the second heat exchanger the refrigerant is allowed to partly evaporate at a high-high pressure, which is below the high-high-high pressure; the liquid part of the refrigerant is passed to the third heat exchanger and the remaining vapour is returned to the second compressor **4** through conduit **50**. In the third heat exchanger the refrigerant is allowed to partly evaporate at a high pressure, which is below the high-high pressure; the liquid part of the refrigerant is passed to the fourth heat exchanger and the remaining vapour is returned to the first compressor **3** through conduit **40**. In the fourth heat exchanger the refrigerant is allowed to partly evaporate at an intermediate pressure, which is below the high pressure; the liquid part of the refrigerant is passed to the fifth heat exchanger and the remaining vapour is returned to the second compressor **4** through conduit **30**. In the fifth heat exchanger the refrigerant is allowed to evaporate at a low pressure, which is below the intermediate pressure, and the refrigerant leaving the fifth heat exchanger is returned to the first compressor **3** through conduit **20**.

[**0080**] If desired, economizers may be connected to one or more of the outlets of the refrigerator **2**. Preferably, the outlet of the refrigerator **2** intended for the refrigerant evaporated at the highest pressure (i.e. fifth outlet **26** in FIG. **3**) is connected to an economizer.

[**0081**] If the refrigerator has multiple outlets and two compressors, preferably the odd (i.e. first, third, fifth, seventh, . . .) outlets are connected to the second compressor and the even (i.e. second, forth, sixth, eighth, . . .) outlets are connected to the first compressor, wherein the pressure of the evaporated outlet increases from the first outlet to the fifth and optional higher outlet.

[**0082**] If desired, economizers may be connected to one or more of the outlets of the refrigerator. As economizers are known in the art (see e.g. John M. Campbell, "*Gas Conditioning and Processing—Vol. 2: The Equipment Modules*", 8th Edition edited by Robert A. Hubbard, 2004 page 219) this is not further discussed here. Preferably, the outlet of the refrigerator intended for the refrigerant evaporated at the highest pressure is connected to an economizer.

[**0083**] Alternative to the line-up as shown in FIG. **3**, FIG. **3***a* shows that, if desired, one or more separate lines may (and preferably will) be used to recycle (a part of) the gaseous stream to the suction side of first and second compressors **3**,**4**. In the latter case one or more of the valves **8***a*-**8***d* and **16***a*-**16***d* may be used instead of the valves **8** and **16** as shown in FIG. **3**. An advantage of the embodiment of FIG. **3***a* is that the size of the safeguarding system connected downstream of the relief valves **9** and **17** can be based on the largest of the streams, rather than the sum of the streams.

[**0084**] The person skilled in the art will readily understand that the present invention may be modified in many ways without departing from the scope of the appended claims.

[**0085**] As an example, the refrigerant circuit **1** may have more than the two parallel compressors **3**, **4** shown in FIGS. **2** and **3**; the refrigerator **2** may have more than one inlet **21** and more than five outlets **22**, **23**, **24**, **25**, **26** (as already exemplified in FIGS. **3** and **3***a*); not all the evaporated refrigerants **20**, **30**, **40**, **50**, **60** need to be evaporated at different pressure levels in the refrigerator **2**; the evaporated refrigerants **20**, **30**, **40**, **50**, **60** may be supplied in various ways to the two (or more) compressors **3**, **4**; etc. In this respect special reference is made to FIG. **2** of WO 01/44734 and FIGS. **3** and **4** of US 2005/0126219, which are hereby incorporated by reference.

[**0086**] Some of the above modifications are exemplified in FIG. **4**, in which the refrigerant circuit **1** comprises **3** compressors: **5**, **12** and **19**. The third compressor **19** comprises inlets **87** and **88** and an outlet **89**. Furthermore the refrigerant circuit **1** according to FIG. **4** comprises a third cooler **39**, a third relief valve **49** and a third stream splitter **59**. Further, valves **29***a* and **29***b* are present, which are similar to the valves **8***a*, **8***b* (and **16***a*, **16***b*) belonging to the first compressor **3** (second compressor **4**). The abbreviations LP, MP, HP and HHP in the Figure refer to low, medium, high and high-high pressure, respectively.

1. Refrigerant circuit (**1**), in particular for use in a liquefaction plant, the refrigerant circuit (**1**) at least comprising:

a refrigerator (**2**) having an inlet (**21**) for refrigerant (**10**) at a refrigeration pressure, and at least one outlet (**22**) for refrigerant (**20**) evaporated in the refrigerator (**2**);

a first compressor (**3**) having an inlet (**31**) for receiving the evaporated refrigerant (**20**) from the refrigerator (**2**) and an outlet (**34**) for compressed refrigerant (**11***a*);

a first cooler (**5**) having an inlet (**81**) for compressed refrigerant (**110***a*) and an outlet (**82**) for cooled compressed refrigerant (**120***a*);

a first stream splitter (**6**) suitable for splitting the cooled compressed refrigerant (**120***a*) in at least two streams (**10***a*, **130***a*), the first stream splitter (**6**) having an inlet (**71**) for receiving the cooled compressed refrigerant (**120***a*), a first outlet (**72**) connected to the inlet (**21**) of the refrigerator (**2**) and a second outlet (**73**) intended for returning refrigerant (**130***a*) to upstream of the inlet (**31**) of the first compressor (**3**) at a first connection point (**11**);

a first valve (**7**) between the first outlet (**72**) of the first stream splitter (**6**) and the inlet (**21**) of the refrigerator (**2**);

a second valve (**8**) between the second outlet (**73**) of the first stream splitter (**6**) and the first connection point (**11**); and

a first relief valve (**9**) downstream of the outlet (**34**) of the first compressor (**3**) and upstream of both the first and second valves (**7**,**8**).

2. Refrigerant circuit (**1**) according to claim 1, wherein the first relief valve (**9**) is located between the outlet (**34**) of the first compressor (**3**) and the inlet (**81**) of the first cooler (**5**).

3. Refrigerant circuit (**1**) according to claim 1 or 2, wherein the refrigerator (**2**) has at least two outlets (**22**, **24**, . . .) for refrigerant (**20**, **40**, . . .) evaporated in the refrigerator (**2**), the at least two outlets (**22**, **24**, . . .) being connected to the first compressor (**3**).

4. Refrigerant circuit (**1**) according to one or more of the preceding claims, wherein the refrigerant circuit (**1**) further comprises:

a second compressor (**4**) having an inlet (**41**) for receiving evaporated refrigerant (**30**) from the refrigerator (**2**) and an outlet (**44**) for compressed refrigerant (**110***b*);

a second cooler (**12**) having an inlet (**83**) for compressed refrigerant (**110***b*) and an outlet (**84**) for cooled compressed refrigerant (**120***b*);

a second stream splitter (**13**) suitable for splitting the cooled compressed refrigerant (**120***b*) in at least two streams (**10***b*, **130***b*), the second stream splitter (**13**) having an inlet (**74**) for receiving the cooled compressed refrigerant (**120***b*), a first outlet (**75**) connected to the inlet (**21**) of the refrigerator (**2**) and a second outlet (**76**) intended for returning refrigerant (**130***b*) to upstream of the inlet (**41**) of the second compressor (**4**) at a second connection point (**14**);

a third valve (**15**) between the first outlet (**74**) of the second stream splitter (**13**) and the inlet (**21**) of the refrigerator (**2**);

a fourth valve (**16**) between the second outlet (**73**) of the second stream splitter (**13**) and the connection point (**11**); and

a second relief valve (**17**) downstream of the outlet (**44**) of the second compressor (**4**) and upstream of both the third and fourth valves (**15**,**16**).

5. Refrigerant circuit (**1**) according to claim 4, wherein the second relief valve (**16**) is located between the outlet (**44**) of the second compressor (**4**) and the inlet (**83**) of the second cooler (**12**).

6. Refrigerant circuit (**1**) according to claim 4 or 5, wherein the refrigerator (**2**) has at least two outlets (**23**, **25**, . . .) for refrigerant (**30**, **50**, . . .) evaporated in the refrigerator (**2**), the at least two outlets (**23**, **25**, . . .) being connected to the second compressor (**4**).

7. Plant for the production of liquefied natural gas, comprising the refrigerant circuit (**1**) according to one or more of the preceding claims for cooling a natural gas stream to be liquefied.

8. Plant according to claim 7, further comprising a pre-cooling heat exchanger having an inlet for natural gas and an outlet for cooled natural gas, a distributor having an inlet connected to the outlet for cooled natural gas and having at least two outlets, and at least two main heat exchangers each comprising a first hot side having one inlet connected to one outlet of the distributor and an outlet for liquefied natural gas, which plant further comprises a pre-cooling refrigerant circuit for removing heat from the natural gas in the pre-cooling heat exchanger, and at least two main refrigerant circuits for removing heat from natural gas flowing through the first hot side of the corresponding main heat exchanger,

wherein the pre-cooling refrigerant circuit is a refrigerant circuit **1** according to one or more of the preceding claims **1**-**6**.

9. Method for the production of liquefied natural gas, wherein the natural gas stream to be liquefied is cooled using the refrigerant circuit (**1**) according to one or more of the preceding claims **1**-**8**.

10. Method according to claim 9, at least comprising the steps of:

evaporating a refrigerant in a refrigerator (**2**) thereby cooling a stream to be cooled and obtaining an evaporated refrigerant (**20**);

compressing the evaporated refrigerant (**20**) in a compressor (**3**) thereby obtaining a compressed refrigerant (**110***a*);

cooling the compressed refrigerant (**11***a*) thereby obtaining a cooled compressed refrigerant (**120***a*);

splitting the cooled compressed refrigerant (**120***a*) in at least two streams (**10***a*, **130***a*);

forwarding a first stream (**10***a*) to the refrigerator (**2**) and a second stream (**130***a*) to a connection point (**11**) downstream of the refrigerator (**2**) and upstream of the compressor (**3**);

removing refrigerant from the refrigerant circuit (**1**) by means of a relief valve (**9**), if the pressure of the refrigerant at the relief valve (**9**) exceeds a pre-selected value.

* * * * *