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(71) Applicant (*for all designated States except US*): **SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.** [NL/NL]; Carel van Bylandtlaan 30, NL-2596 HR The Hague (NL).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **JAGER, Marco Dick** [NL/NL]; Carel van Bylandtlaan 16, NL-2596 HR The Hague (NL). **KLEIN NAGELVOORT, Robert** [NL/NL]; Carel van Bylandtlaan 16, NL-2596 HR The Hague (NL).

(74) Agent: **SHELL INTERNATIONAL B.V.**; Intellectual Property Services, PO Box 384, NL-2501 CJ The Hague (NL).

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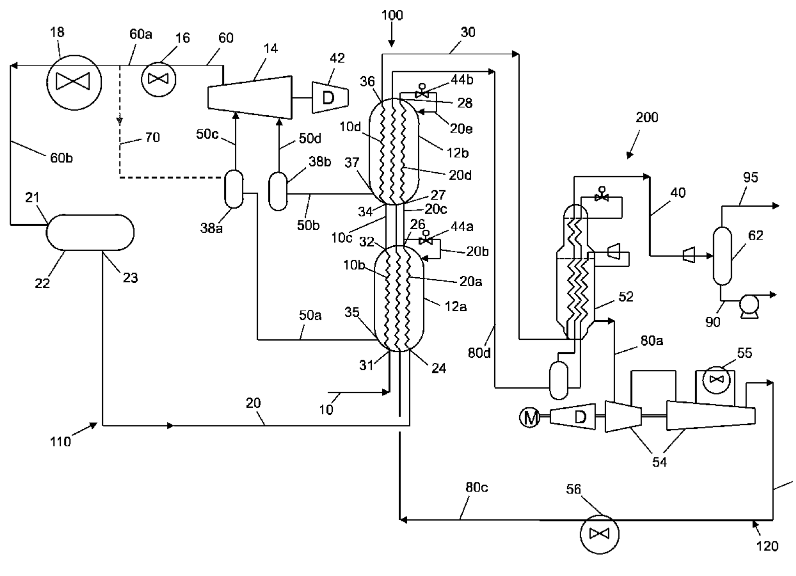

(57) Abstract: A method of treating a hydrocarbon stream such as natural gas from a feed stream (10), the method at least comprising the steps of: (a) passing the feed stream (10) and a first refrigerant stream (20) through a cooling stage (100) including one or more heat exchangers (12a, 12b) to provide a cooled hydrocarbon stream (30); and (b) circulating the first refrigerant stream (20) around a first refrigerant circuit (110) which includes one or more compressors (14), one or more coolers (16, 18) after the compressor(s), and a refrigerant accumulator (22) after the cooler(s); wherein there are no further coolers between the refrigerant accumulator (22) and the heat exchanger, or the first of more than one heat exchanger (12a, 12b).

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METHOD AND APPARATUS FOR TREATING A HYDROCARBON STREAM

The present invention relates to a method and apparatus for treating a hydrocarbon stream, particularly but not exclusively natural gas.

Several methods of liquefying a natural gas stream thereby obtaining liquefied natural gas (LNG) are known. It is desirable to liquefy a natural gas stream for a number of reasons. As an example, natural gas can be stored and transported over long distances more readily as a liquid than in gaseous form, because it occupies a smaller volume and does not need to be stored at a high pressure.

Natural gas can be liquefied by passing it through a plurality of cooling stages with heat exchanges to progressively reduce its temperature until liquefaction is achieved. Usually there are two or three cooling stages, each having its own refrigerant.

The first cooling stage is sometimes also termed 'pre-cooling' or 'initial cooling', and is usually designed to lower the temperature of the natural gas to below -20°C. The temperature is reduced by passing the natural gas through one or more heat exchangers against a refrigerant which has a refrigerant circuit. The refrigerant circuit generally comprises a compressor for compressing the warmed refrigerant after it passes through the heat exchangers, and one or more coolers thereafter in order to reduce the heat of the compressed refrigerant.

US 2004/0065113 A1 shows in its Figure 1 an installation for liquefying natural gas wherein after compression and two coolers, the refrigerant for the propane heat exchanger is accumulated in an accumulator before passage through a final water cooler labelled 105. The final water cooler is to subcool the already fully condensed refrigerant, i.e. cool the refrigerant below its bubble point. A problem of US 2004/0065113 A1 is the requirement for an extra cooler.

It is an object of the present invention to reduce the capital and running costs for a method and apparatus for liquefying a hydrocarbon stream.

One or more of the above or other objects can be achieved by the present invention providing a method of treating a feed stream comprising a hydrocarbon stream such as natural gas, the method at least comprising the steps of:

(a) passing the feed stream and a first refrigerant stream (20) through a cooling stage including one or more heat exchangers to provide a cooled hydrocarbon stream; and

(b) circulating the first refrigerant stream around a first refrigerant circuit which includes one or more compressors, one or more coolers after the compressor(s), and a refrigerant accumulator after the cooler(s); wherein there are no further coolers between the refrigerant accumulator and the heat exchanger, or the first of more than one heat exchanger.

An advantage of the elimination of a cooler or coolers between the refrigerant accumulator and the heat exchanger(s) is a reduction in the capital and running costs of a liquefying method and apparatus. Efficiency of the first refrigerant circuit can be maintained by an arrangement with the coolers prior to the refrigerant accumulator.

The hydrocarbon stream may be any suitable gas stream to be treated, but is usually a natural gas stream obtained from natural gas or petroleum reservoirs. As an alternative the natural gas stream may also be obtained from another source, also including a synthetic source such as a Fischer-Tropsch process.

Usually the natural gas stream is comprised substantially of methane. Preferably the feed stream comprises at least 60 mol% methane, more preferably at least 80 mol% methane.

Depending on the source, the natural gas may contain varying amounts of hydrocarbons heavier than methane such as ethane, propane, butanes and pentanes as well as some aromatic hydrocarbons. The natural gas stream may also contain non-hydrocarbons such as H_2O, N_2, , Hg, CO_2, H_2S and other sulphur compounds.

If desired, the feed stream containing the natural gas may be pre-treated before use. This pre-treatment may comprise removal of undesired components such as H_2O, CO_2, Hg, H_2S and other sulphur compounds or other steps such as pre-cooling or pre-pressurizing. As these steps are well known to the person skilled in the art, they are not further discussed here.

The term “feed stream” as used herein relates to any hydrocarbon-containing composition usually containing a large amount of methane. In addition to methane, natural gas contained various amounts of ethane, propane and heavier hydrocarbons. The composition varies depending upon the type and location of the gas. Hydrocarbons heavier than methane generally need to be removed from natural gas for several reasons, such as having different freezing or liquefaction temperatures that may cause them to block parts of a methane liquefaction plant. C2-4 hydrocarbons can be used as a source of natural gas liquids.

The term “feed stream” also includes a composition prior to any treatment, such treatment including cleaning, dehydration and/or scrubbing, as well as any composition having been partly, substantially or wholly treated for the reduction and/or removal of one or more compounds or substances, including but not limited to sulfur, sulfur compounds, carbon dioxide, water, and C_2^+ hydrocarbons.

The cooling stage may be any part or step of a bigger or larger method or process for treating a hydrocarbon stream. Where the treatment of the hydrocarbon stream is to liquefy the hydrocarbon stream in two or three stages, the cooling stage may be part of or one of the cooling stages of the liquefying method.

In one embodiment of the present invention, the cooling stage is adapted to reduce the temperature of the feed stream to below -0°C, more preferably below -20°C, and optionally between -20°C and -50°C. Such temperatures are equivalent to a pre-cooling or initial cooling stage of a method of liquefying natural gas.

In a further aspect, the present invention provides apparatus for treating a hydrocarbon stream such as a natural gas stream from a feed stream, the apparatus at least comprising:

a first cooling stage including one or more heat exchangers through which the feed stream and a first refrigerant stream can pass; and

a first refrigerant circuit around which the first refrigerant stream circulates, the first refrigerant circuit having one or more compressors, one or more coolers after the compressor(s), and a refrigerant accumulator after the cooler(s),

wherein there are no further coolers between the refrigerant accumulator and the cooling stage.

An embodiment of the present invention will now be described by way of example only, and with reference to the accompanying non-limiting drawings in which:

Figure 1 is a general scheme of a liquefying process according to one embodiment of the present invention; and

Figure 2 is a modified general scheme of Figure 1.

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.

Figure 1 shows a general scheme for a liquefying a hydrocarbon stream such as natural gas. It shows an initial feed stream containing natural gas 10, which feed stream may be pre-treated to separate out the presence of any of at least some heavier hydrocarbons and impurities such as carbon dioxide, nitrogen, helium, water, sulfur and sulfur compounds, including but not limited to acid gases.

The feed stream 10 passes through a cooling stage 100. The cooling stage 100 may comprise any number of heat exchangers, the heat exchangers being in parallel, series or a combination of same. Commonly, a cooling stage can comprise a number of heat exchangers in series, which is sometimes termed a ‘train’. A feed stream may be divided amongst the heat exchangers in an equal or unequal manner. Generally, the complete feed stream passes through a series of aligned heat exchangers to be further cooled by each heat exchanger.

The heat exchanger(s) used in the present invention, especially for any ‘first’ or ‘pre-cooling’ stage, may be any of, or any combination of, heat exchangers known in the art, including kettles, spiral-wound or spool-wound, plate-fin, etc, heat exchangers.

In Figure 1, the cooling stage 100 comprises two heat exchangers, 12a, 12b. Through the heat exchangers 12a, 12b also passes a first refrigerant stream 20 circulating around a first refrigerant circuit 110.

The first refrigerant of the first refrigerant stream 20 may be a single component such as nitrogen or propane. Preferably it is a mixed refrigerant of two or more components, more preferably selected from the group comprising nitrogen, methane, ethane, ethylene, propane, propylene, butane and pentane.

Where the first refrigerant is a mixed refrigerant, it is possible to use different cool side pressure levels in each heat exchanger 12a, 12b, in a manner known in the art.

In Figure 1, the feed stream 10 enters the first heat exchanger 12a through inlet 31, and passes along line 10b to exit through outlet 32 as a first cooled hydrocarbon stream 10c, which stream then passes through inlet 34 into the second heat exchanger 12b and passes along line 10d to exit through outlet 36 as a cooled hydrocarbon stream 30.

The first refrigerant stream 20 passes into the first heat exchanger 12a through inlet 24, passes through the heat exchanger 12a as line 20a, and exits through outlet 26 where the stream is divided into two parts, one part passing through a first expansion valve 44a to form an expanded and further cooled refrigerant stream 20b which passes back into the first heat exchanger 12a to provide the cooling for the lines 10b, 20a in a manner known in the art. The second part 20c passes through inlet 27 into the second heat exchanger 12b, before outflowing through outlet 28, being expanded through a second expansion valve 44b to form an expanded refrigerant stream 20e, which passes back into the second heat exchanger 12b to cool the lines 10d, 20d in a manner known in the art.

The refrigerant stream vaporised in the first heat exchanger 12a can be collected through outlet 35 as a first vapour refrigerant stream 50a, which passes into a separator 38a to provide a fully vaporised stream 50c which passes into a compressor 14. Separator 38a is typically a suction drum to prevent any entrained liquid entering compressor 14. The vapourised refrigerant in the second heat exchanger 12b can be collected through outlet 37 to form a second vapour refrigerant stream 50b, which passes through a second separator 38b to form a second fully vapourised refrigerant stream 50d which also passes into the compressor 14. Separator 38b is typically a suction drum to prevent any entrained liquid entering compressor 14.

The compressor 14 is driven by a driver 42, and compresses the first refrigerant to provide a compressed refrigerant stream 60. The compressed refrigerant stream 60 is warmed due to the compression, and requires to be cooled so as to re-condense.

The compression of the vapourised refrigerant stream may involve more than one compressor: only one is shown in Figure 1.

The compressed refrigerant stream 60 may be cooled using one or more coolers. Such coolers may be any apparatus, unit or device able to cool a stream. These include water coolers, air coolers as well as other heat exchangers known in the art. Water and air coolers are common in the art.

Figure 1 shows a first water and/or air cooler 16, which provides a cooler refrigerant stream 60a, and a second water and/or air cooler 18 which provides a more cooled refrigerant stream 60b. In order to ensure that the refrigerant is fully condensed back into a liquid before it reaches the subsequent refrigerant accumulator 22, one or more further coolers may be added between the compressor 14 and the refrigerant accumulator 22, or one or more of the coolers may be increased in size or capacity. Preferably, the lattermost cooler 18 in the first refrigerant circuit 110 in the direction of the flow of the first refrigerant stream 20 is larger than the first cooler 16 after the compressor 14 in the direction of the flow of the first refrigerant 20.

In Figure 1, the example is shown wherein the second cooler 18 is larger than the first cooler 16. As an example, the area of the second cooler 18 could be equivalent to the combined area hitherto used for an air cooler in the same location and a subcooler used after the refrigerant accumulator.

It will be understood by those skilled in the art that “larger” as used in this specification in relation to coolers relates to a larger heat exchange area in the cooler. Depending on the design of the cooler, the heat exchange area is sometimes referred to as bare tube area. Thus, preferably the heat exchange area in second cooler 18 is larger than the heat exchange area in first cooler 16, more preferably in the range of from 2 to 8 times larger.

The temperature of the cooler refrigerant stream 60a is typically in the range of from 90 to 60 °C.

The temperature of the further cooled refrigerant stream 60b could be in the range 60 to 30°C.

Via inlet 21, the stream 60b is accumulated in a refrigerant accumulator 22. A refrigerant accumulator can be any form, shape or design required, and generally is some form of container or tank able to act as a reservoir of liquid refrigerant ready for use in one or more heat exchangers. Usually, there is no other major outlet from the refrigerant accumulator other than that to the inlet of a heat exchanger. Some accumulators may include a control system for controlling the level and/or pressure in the refrigerant accumulator in a manner known in the art.

In the first refrigerant circuit 110, the liquid refrigerant in the refrigerant accumulator 22 passes via outlet 23 to the first inlet 24 of the first heat exchanger 12a to be circulated as described above.

The refrigerant accumulator 22 will generally have no other liquid refrigerant outlets other than outlet 23 shown in Figure 1. Any control of the flow of liquid refrigerant from the refrigerant accumulator 22 could be carried out by a subsequent valve with a recycle line (not shown) back into the accumulator 22. Optionally, there may be a vapour refrigerant outflow from the refrigerant accumulator 22 to accommodate any evaporating refrigerant, but such outflow is not intended to be significant. Thus, it is usual that a refrigerant accumulator only has one outlet, and this is for the liquid refrigerant to go to the first cooling stage.

In the first refrigerant cycle 110, there may also be a recycle line 70 between the first and second coolers

16, 18 and the first separator or suction drum 38a, in order to provide a control system, for example amount/rate/mass, of refrigerant passing through the compressor 14, in order to have the compressor 14 running efficiently when the level of refrigerant entering the compressor 14 is variable. As the cooler refrigerant stream passing through recycle line 70 has a significantly higher temperature than the normal temperature of refrigerant passing through lines 50a and 50c, any liquid entrained in suction drum 38a may in addition be heated and vapourised such as to further increase the flow of refrigerant to compressor 14. Typically, the temperature difference between refrigerant in recycle line 70 and refrigerant in line 50a, and line 50c, in normal operation, i.e. without recycle through recycle line 70, is in the range of from 20 to 60 °C.

The absence of any coolers between the refrigerant accumulator 22 and the first inlet 24 reduces the equipment count of the first refrigerant circuit 110, thereby reducing not only the capital costs but the running costs of the first refrigerant circuit 110. The cooling previously effected by any subcooler between a refrigerant accumulator and a first inlet can, by the present invention, be accommodated by the coolers 16, 18 between the compressor 14 and the refrigerant accumulator 22. The scaling up required of any such cooler(s) is still less expensive than having one or more separate sub-cooler(s) after the refrigerant accumulator.

In a particular embodiment of the present invention, the heat exchangers 12a, 12b are tube-in-shell heat exchangers, one example of which are spiral-wound or spool-wound heat exchangers. Such heat exchangers generally involve a tube circuit for the substance being cooled, sometimes termed “tube side” or “warm side”, (usually with separate tube circuits for different substances being cooled within the same heat exchanger), and the surrounding part of the tube circuits within the shell of the heat exchanger being for the refrigerant, and sometimes termed “shell side”. Thus, in one or both of the heat exchangers 12a, 12b shown in Figure 1, there could be separate tube circuits for the lines 10b and 10d for the hydrocarbon stream in each heat exchanger 12a, 12b, separate circuits for lines 20a and 20d for upflowing first refrigerant, and separate circuits for the lines of second refrigerant 80c, as described hereinafter. The first refrigerant streams 20b and 20e that pass back into the heat exchangers 12a, 12b to provide cooling are on the outside of the tubes, i.e. on the “shell side” or “cool side” of the heat exchangers 12a, 12b. The cooling is effected by heat exchange through the tubes as the first refrigerant evaporates.

From the cooling stage 100, the cooled hydrocarbon stream 30 can then pass through a second cooling stage 200, which stage could be a liquefaction system. The second cooling stage 200 will generally comprise one or more heat exchangers, and a second refrigerant circuit, which refrigerant circuit is optionally part convergent with the first refrigerant circuit 110.

In Figure 1, the second cooling stage 200 has a main cryogenic heat exchanger 52, through which the cooled hydrocarbon stream 30 passes to provide a liquefied hydrocarbon stream 40. A second refrigerant also passes through the cryogenic heat exchanger 52, to exit as a wholly or substantially vapourised stream 80a, which is compressed by one or more compressors 54 using a water/air cooler 55, to provide a compressed stream 80b which is cooled by a water/air cooler 56 to provide a cooled compressed stream 80c, which then can be further cooled by passage through the first and second heat exchangers 12a, 12b to provide a second refrigerant stream 80d.

The liquefied hydrocarbon stream 40 could then undergo a third cooling, such as sub-cooling against a third refrigerant, or for example by passage through an end-flash vessel 62 as shown in Figure 1. The end-flash vessel 62 can provide a vapour stream 95 for use as, for example, fuel gas, and a final liquefied hydrocarbon stream 90 which can then be transported and/or stored.

Further the person skilled in the art will readily understand that after liquefaction, the liquefied natural gas may be further processed, if desired. As an example, the obtained LNG may be depressurized by means of a Joule-Thomson valve or by means of a cryogenic turbo-expander.

Figure 2 shows several modifications to the liquefying process shown in Figure 1. In Figure 2, there is still shown a feed stream 10 passing through a first cooling stage 100 using two heat exchangers 12a, 12b, through which a first refrigerant stream also passes as part of a first refrigerant circuit 110. As before, the vapourised first refrigerant is collected from the heat exchangers 12a, 12b as vapour refrigerant streams 50a, 50b, which pass through first and second separators, typically in the form of suction drums, 38a, 38b, into a compressor 14, from which a compressed refrigerant stream 60 passes through first and second water and/air coolers 16, 18 to be collected in the refrigerant accumulator 22. Figure 2 also shows a similar second cooling stage 200 to that shown in Figure 1.

In a first modification, the first cooled hydrocarbon stream 10c after it outflows the first heat exchanger 12a is passed into a first feed separator 13, which provides a lighter stream 10e and a heavier stream 15 in a manner known in the art. Generally, the lighter stream 10e is methane-enriched, and can then pass into and through the second heat exchanger 12b. The heavier stream, which will generally be enriched with heavier hydrocarbons, could be used as NGL or fuel, optionally in another part of the liquefying process.

In a second modification, the second cooled hydrocarbon stream 10f that outflows the second heat exchanger 12b is passed into a second feed separator 17, in order to separate the inflowing stream into a lighter stream 30 and heavier stream 19. The lighter stream 30 will generally be methane-enriched, and can then be used as the cooled hydrocarbon stream for the second cooling stage 200 as hereinbefore described. The heavier stream 19 from the second feed separator 17 will generally be heavier-hydrocarbon enriched, and can be used in the first feed separator 13 in a manner known in the art.

In a third modification, the first cooling stage 100 includes a third pre-cool heat exchanger 12c adapted to provide cooling to the first refrigerant of the first refrigerant circuit 110, and the second refrigerant of the second refrigeration circuit. The first refrigerant stream 20 is supplied by the refrigerant accumulator 22, and passes via inlet 24a into the third heat exchanger 12c, passes upwardly therethrough, and outflows the third heat exchanger 12c as a cooled stream 20f, part of which passes directly up into the first heat exchanger 12a through inlet 24 as described above for Figure 1, and part of which passes through a third expansion valve 44c to form an expanded and further cooled refrigerant stream 20g which passes back into the third heat exchanger 12c to provide the cooling for the lines of first and second refrigerant in the third heat exchanger 12c in a manner known in the art. The refrigerant stream vapourised in the third heat exchanger 12c can be collected through an outlet 35a as a third vapour refrigerant stream 50e, which passes into a separator, typically in the form of a suction drum, 38c, which is similar to the separators 38a and 38b shown in Figures 1 and 2, to provide a fully vapourised stream 50f, which passes into the compressor 14 of the first refrigerant circuit 110.

A non-limiting example of the embodiment of the invention shown in Figure 2 is given in Table 1. The data shows the refrigerant flows, pressure and temperature levels of various streams involved with producing 191 kg/s of LNG. The condensing temperature of stream 60b given in Table 1 is effectively the temperature at which the pre-cool refrigerant is sent to the pre-cool exchanger 12c, as no further sub-cooling is done.

Table 1.

Stream Number	Temperature (°C)	Pressure (bar)	Mass flow (kg/s)	Phase
10	20.0	65.7	195	Mixed
10c	-7.0	63.9	195	Mixed
10e	-20.1	63.8	218	Mixed
30	-48.5	61.9	191	Mixed
40	-153.0	57.1	191	Liquid
80a	-50.8	3.2	302	Vapour
80b	102.9	44.9	302	Vapour
80d	-48.5	40.0	302	Mixed
50d	-22.5	3.3	276	Vapour
50c	17.5	11.0	220	Vapour
50f	42.5	21.7	242	Vapour
60	95.1	38.1	778	Vapour
60a	64.1	37.7	778	Vapour
60b	45.0	37.2	778	Liquid

An advantage of the invention is shown in Table 2. This table compares liquefaction with and without a process subcooler in the first refrigerant circuit shown in the arrangement of Figure 2, and liquefying 191 kg/s of LNG. Table 2 shows that each arrangement has nearly identical total ambient heat exchanger area, nearly identical total effective cryogenic exchanger area, and near identical pre-cool refrigerant compressor duty. But, the arrangement shown in Figure 2 is without a sub-cooler, and so has one equipment item less. Thus, similar performance can be achieved with a lower equipment count and commensurate lower refrigerant circuit piping.

Table 2. Comparative data

Bare tube area	Unit	WITH sub-cooler	Without sub-cooler
Air cooler 16	m2	4023	4314
Air cooler 18	m2	16632	19163
Sub cooler	m2	3012	0
Air cooler 55	m2	1905	1905
Air cooler 56	m2	2796	2796
Total		28368	28179
Duty compressor 14	MW	85.8	85.7
Effective area 12c	kW/K	18393	18042
Effective area 12a	kW/K	25553	25545
Effective area 12b	kW/K	22290	22314
suction flow	m3/h	168858	168905

The person skilled in the art will understand that the present invention can be carried out in many various ways without departing from the scope of the appended claims.

CLAIMS

1. A method of treating a feed stream comprising a hydrocarbon stream such as natural gas, the method at least comprising the steps of:
(a) passing the feed stream and a first refrigerant stream through a cooling stage including one or more heat exchangers to provide a cooled hydrocarbon stream; and
(b) circulating the first refrigerant stream around a first refrigerant circuit which includes one or more compressors, one or more coolers after the compressor(s), and a refrigerant accumulator after the cooler(s);
wherein there are no further coolers between the refrigerant accumulator and the cooling stage.

2. A method according to claim 1 wherein the first refrigerant of the first refrigerant stream is a mixed refrigerant comprising a mixture of gases, preferably selected from the group comprising nitrogen, methane, ethane, ethylene, propane, propylene, butane and pentane.

3. A method according to claim 1 of claim 2 wherein the cooling stage comprises two or three heat exchangers.

4. A method according to claim 3 wherein each heat exchanger involves a different first refrigerant pressure.

5. A method according to one or more of the preceding claims wherein one or more of the heat exchangers,

preferably all the heat exchangers, is or are spiral-wound or spool-wound heat exchanger(s).

6. A method according to one or more of the preceding claims wherein the first refrigerant circuit comprises two coolers between the one or more compressors and the refrigerant accumulator.

7. A method according to claim 6 wherein the lattermost cooler in the first refrigerant circuit in the direction of the flow of the first refrigerant stream is larger than the first cooler after the compressor(s) in the direction of the flow of the first refrigerant.

8. A method according to one or more of the preceding claims wherein the method comprises the further step of:
(c) passing the cooled hydrocarbon stream through a second cooling stage comprising one or more heat exchangers through which a second refrigerant stream also passes, to provide a liquefied hydrocarbon stream.

9. A method as claimed in claim 8 to liquefy natural gas and provide a liquefied natural gas stream.

10. A method as claimed in one or more of the preceding claims wherein the temperature of the first refrigerant stream outflowing the refrigerant accumulator is wholly or substantially, preferably less than 10°C, more preferably less than 5°C, even more preferably less than 3°C, most preferably substantially equal to the temperature of the first refrigerant stream entering the first of one or more heat-exchanger(s) through an inlet.

11. A method as claimed in one or more of the preceding claims wherein at least one, optionally all, of the heat exchangers of step (a) are tube-in-shell heat exchangers, preferably having separate tubes for each stream being cooled therein.

12. A method as claimed in claim 11 wherein partial condensation of the feed stream and any second refrigerant stream is carried out in at least one heat exchanger that has first refrigerant on the cold (shell) side of the heat exchanger, and different tube circuits for the feed stream and any second refrigerant stream located in the same shell.

13. Apparatus for treating a feed stream comprising a hydrocarbon stream such as a natural gas, the apparatus at least comprising:

a first cooling stage including one or more heat exchangers through which the feed stream and a first refrigerant stream can pass; and

a first refrigerant circuit around which the first refrigerant stream circulates, the first refrigerant circuit having one or more compressors, one or more coolers after the compressor(s), and a refrigerant accumulator after the cooler(s),

wherein there are no further coolers between the refrigerant accumulator and the cooling stage.

14. Apparatus according to claim 13 wherein the first refrigerant circuit has two heat exchangers, one compressor, and sequentially a first cooler and a second cooler, which second cooler is larger than the first cooler.

15. Apparatus according to claim 13 or claim 14 further comprising:

a second cooling stage to liquefy the cooled hydrocarbon stream of the first cooling stage to provide a liquefied hydrocarbon stream, preferably a liquefied natural gas stream.

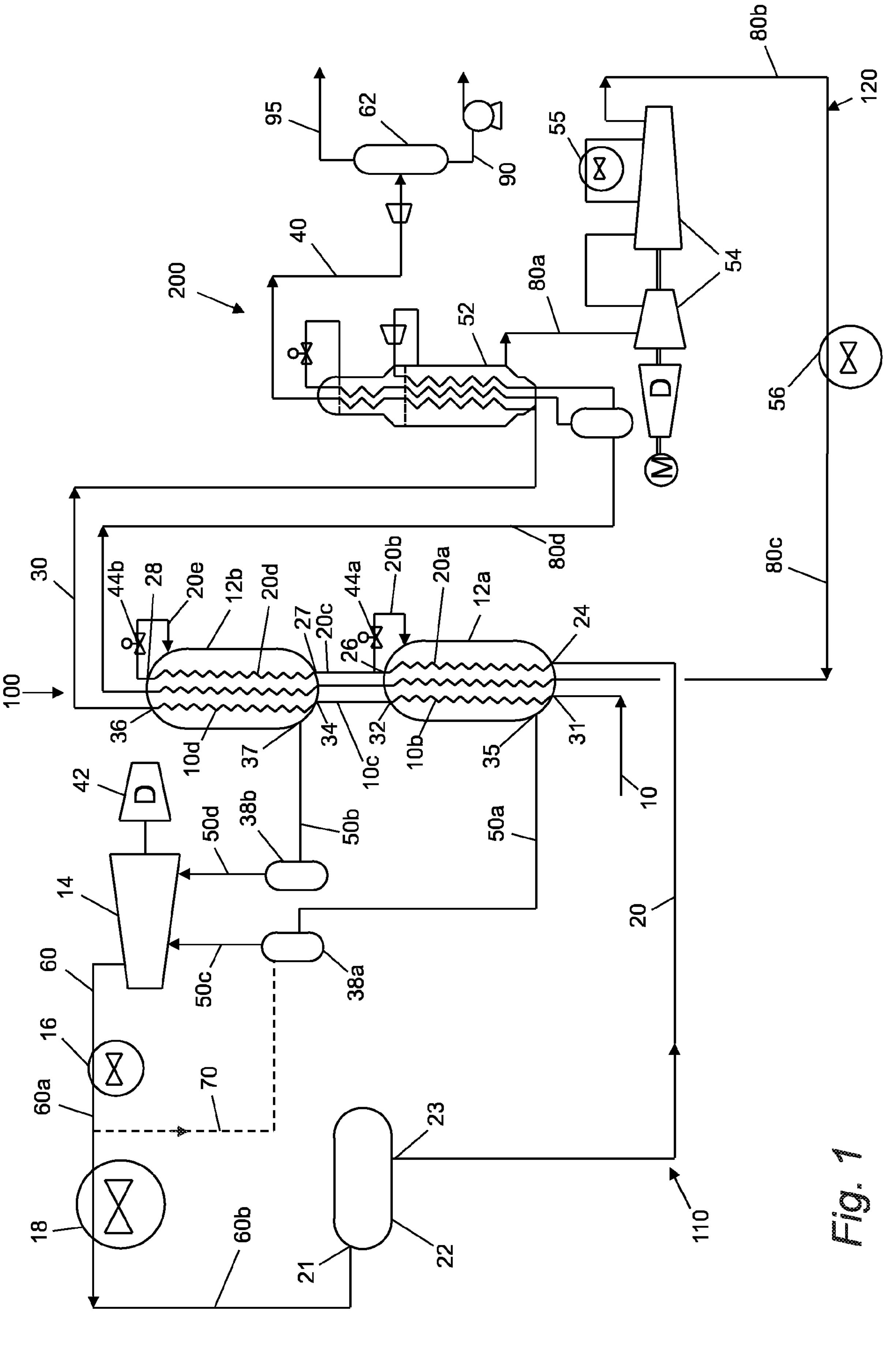
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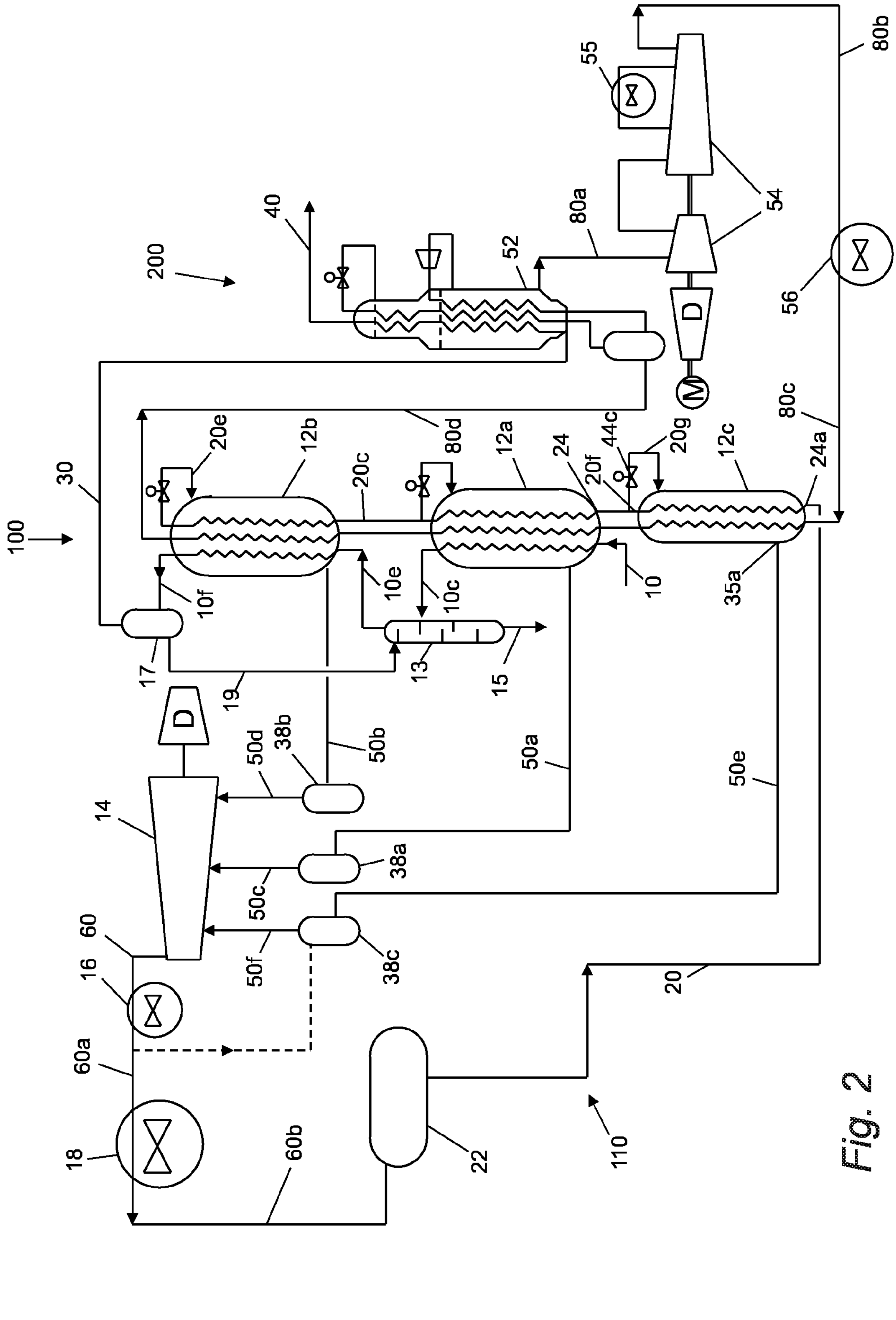
Fig. 1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38c
40
44c
50a
50b
50c
50d
50e
50f
52
54
55
56
60
60a
60b
80a
80b
80c
80d
D
D
D
M

Fig. 2