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(54) A PLANT FOR LIQUEFYING METHANE GAS

(57) A plant for liquefying methane gas, comprising: a power section (100) comprising: a molecular filter (2) supplied by a low-pressure methane supply network (1), a compression unit (5) of the methane, connected to the outlet of the filter, destined to supply in outlet a methane main flow (Φ) having a predetermined temperature and pressure, and heat exchangers (11, 12, 13, 14) for cooling the methane crossing the compression unit (5); a first cryogenic section (200) connected to the outlet of the power section (100) by which it is supplied from the main flow (ϕ) and, in turn, supplying the power section (100) with at least a methane recycling flow (ϕ_2, ϕ_4, ϕ_7), which supplies the compression unit and which cooperates with the heat exchangers for cooling the compression unit; a second cryogenic section (300) connected to the first cryogenic section (200) in inlet and in outlet by means of channels (19, 22, 24) crossed by the relative methane flows (ϕ_1, ϕ_4, ϕ_7), the second cryogenic section (300) being destined to liquefy a predetermined amount of the main flow (ϕ); a storage cryogenic section (400) connected to the second cryogenic section (300) so as to receive therefrom the liquefied methane.

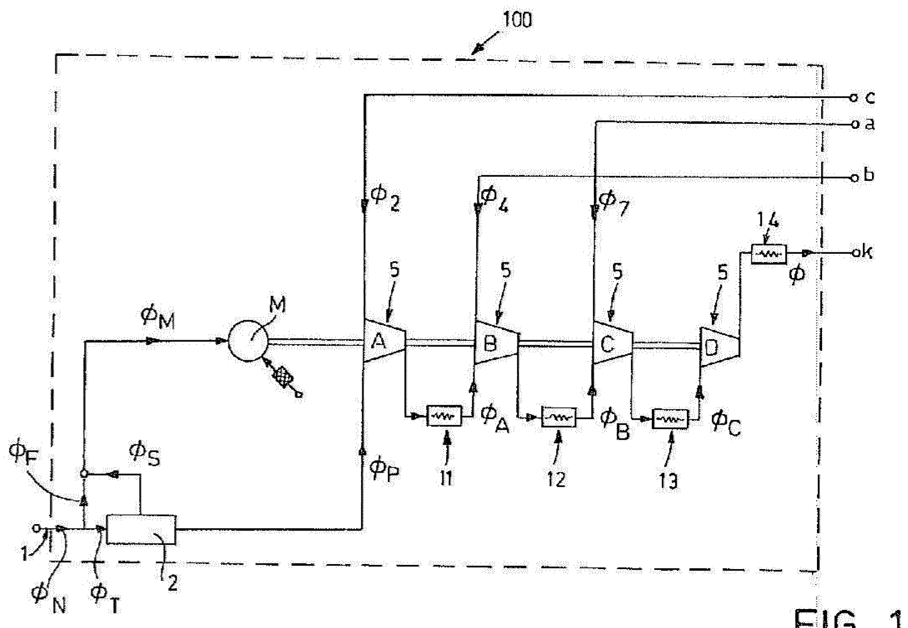

FIG. 1

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Description

DESCRIPTION OF THE INVENTION

[0001] It is known that liquefied natural gas (LNG) is obtained by subjecting natural gas, following suitable purifying and dehydrating treatments, to successive cooling and liquefying stages.

[0002] For liquefaction a temperature of a little less than -160°C is required so that the gas can be stored at atmospheric pressure, or a little above.

[0003] The present invention relates to a medium-sized plant for methane gas liquefaction, the methane being collected from a low-pressure supply network.

[0004] The prior art includes methane liquefaction plants which comprise a compression unit, drawn by a suitable motor, and devices for generating the required frigories (for example turbines, Joule-Thompson valves) in which a suitable gas is used.

[0005] These motors use relative energy sources, different to methane gas, and gases for generating the frigories, different to the gas to be liquefied, in the present case methane.

[0006] This leads to plant complications and drawbacks deriving from the need to include systems for supplying and storing of both the energy source for the motors and the gas for activating the sources of cooling generation.

[0007] The aim of the invention is to obviate the drawbacks of the prior art by using a plant for liquefaction of methane gas that can realise small or medium-sized flows, the functioning of which is actuated using only methane gas collected from a supply network.

[0008] A further aim is to provide a plant for methane liquefaction that is functional and reliable and able to guarantee an average daily productivity of liquefied methane gas, for example 5÷10 tonnes a day.

[0009] The above-indicated aims are attained as set down in the contents of the claims.

[0010] Further characteristics and advantages of the invention will emerge from the following description which makes reference to the accompanying tables of drawings in which:

- figure 1 schematically illustrates a possible functional diagram of the part of the plant termed "hot";
- figure 2 schematically illustrates the remaining function part of the plant, the cryogenic part.

[0011] With reference to the figures of the drawings, the plant of the invention is constituted by a first cryogenic section 200, a second cryogenic section 300 and a storage section 400.

[0012] In relation to the power section 100, 1 denotes a pipeline which collects a flow ϕ_N of methane at low pressure (3-4 bar) and ambient temperature (for example about 15°C).

[0013] A fraction of the network flow ϕ_N, denoted by ϕ_F, supplies the gas motor M.

[0014] The remaining part ϕ_T of the network ϕ_N crosses a filter 2, precisely an adsorbent bed molecular filter which eliminates all damaging components from the flow ϕ_T (water, carbon dioxide, sulphurous compounds, etc.); a flow of purified methane ϕ_P reaches the filter outlet 2.

[0015] The comburent part ϕ_S of the above-mentioned damaging components goes to supply, together with the flow ϕ_F, the gas motor M which is supplied with a flow ϕ_M.

[0016] The motor M draws in rotation an intercooled reciprocating compressor 5 with four compression stages A, B, C, D, respectively a first, second, third and fourth.

[0017] The first stage (or first phase) of compression is supplied, at an inlet thereof, by the flow ϕ_P coming from the filter 2 and at the remaining inlet by a recycling flow ϕ_2 (of which more in the following) coming from the first cryogenic section 200.

[0018] The flow ϕ_A in outlet from the first stage A is cooled by a first heat exchanger 11 (air cooler) and sent to one of the inlets of the second compression stage B; a further recycling flow ϕ_4 (of which more in the following) arrives at the second inlet, coming from the first cryogenic section 200.

[0019] The flow ϕ_B in outlet from the second stage B (at a pressure of 33 bar) is cooled by a second heat exchanger 12 (air cooler) and sent to one of the inlets of the third compression stage C; a further inlet of the flow is supplied by a further recycling flow ϕ_7 (of which more in the following) coming from the first cryogenic section 200.

[0020] The pressure at outlet from the third stage C is about 90 bar.

[0021] The flow ϕ_C in outlet from the third stage C is cooled by means of a third heat exchanger 13 and sent to the inlet of the fourth stage D.

[0022] The flow ϕ, or main flow in outlet from the fourth stage, is cooled by a fourth heat exchanger (or chiller) 14; this main flow has a pressure of about 250 bar and a temperature of -5°C.

[0023] The main flow ϕ involves, in order, a first circuit C_1, included in a first cryogenic exchanger 250 that is a part of the first cryogenic section 200 and, by means of a pipeline 17, a first Joule-Thompson valve 10.

[0024] In the same pipeline 17, the main flow ϕ, downstream of the valve 20, crosses a liquid-steam separator 15.

[0025] The separator supplies two pipelines 18, 19 crossed by corresponding flows ϕ_1, ϕ_2, respectively a first and a second flow.

[0026] The first flow ϕ_1 is at a pressure of about 33 bar and a temperature of about -96°C.

[0027] The second flow ϕ_2 comprises traces of methane vapours and methane liquid; the second flow involves a second circuit C_2 of the first main cryogenic heat exchanger 250, by crossing which it yields frigories and therefore heats up; this leads to a passage of the methane vapours and the traces of methane liquids from the gaseous phase.

[0028] The second flow ϕ_2, via the pipeline 18, is sent on to one of the inlets of the first compression stage A and thus to constitute a recycling flow.

[0029] The first flow ϕ_1 is sent to the second cryogenic section 300 by means of the pipeline 19 which supplies a second Joules-Thompson valve 20 the function of which consists in further lowering both the methane pressure (about 15 bar) and the temperature thereof (about -15°C.

[0030] The first flow ϕ_1, downstream of the second valve, is sent on to a second liquid-vapour separator 16 which carries out the same functions as the first separator 15, as it supplies two pipelines 21, 27 involved by the relative third and fourth methane flows ϕ_3, ϕ_4.

[0031] The fourth flow ϕ_4 is sent into the first cryogenic exchanger 250, more precisely the third circuit C_3 comprised therein; the fourth flow ϕ_4 renders frigories to the exchanger 250, and therefore heats up, which enables passage of any methane vapour traces and/or methane drops in the gaseous phase thereof.

[0032] The fourth flow ϕ_4, in outlet from the exchanger 250, is sent on to one of the inlets of the second compression stage B to constitute a recycling flow.

[0033] The pipeline 21, crossed by the third flow ϕ_3, supplies two pipelines 22, 23, at least one of which is regulated by regulating means 70, the function of which is to regulate the fifth and sixth flow rates ϕ_5, ϕ_6, which cross the pipelines.

[0034] The fifth flow ϕ_5 is destined to be liquefied; for this purpose it is necessary to cool it further, at least down to -156°C, as well as reducing the pressure thereof (about 1.8 bar).

[0035] The above-mentioned cooling is actuated first by a second cryogenic heat exchanger 350 (located in the second cryogenic section 300) and lastly by a third Joule-Thompson valve 30 (see figure 2).

[0036] The second cryogenic exchanger 350 involves two circuits F_1,F_2, being a fifth and sixth circuit, with the fifth circuit F_1, crossed by the fifth flow ϕ_5.

[0037] The second circuit F_2 is crossed by a seventh flow ϕ_7 which is the sum of the sixth flow ϕ_6 and a flow of methane vapours ϕ_{VM} of which more in the following.

[0038] The flow ϕ_6 is destined, in the exchanger 350, to provide the frigories for cooling the fifth flow ϕ_5; for this purpose (see figure 2) a fourth Joule-Thompson valve 50 is included in the pipeline 23, which cools the sixth flow ϕ_6.

[0039] The flow ϕ_7 enters the relative circuit F_2 at about -142°C, crosses it and heats up; it follows that the steam ϕ_{VM} threshold passes to the gaseous phase of the methane.

[0040] The seventh flow ϕ_7 is directed, by means of a pipeline 24, into the fourth circuit C_4 of the first cryogenic exchanger 250 where it renders further frigories; at the outlet of the fourth circuit C_4, the flow ϕ_7 is sent to one of the inlets of the third compression stage C to constitute a recycling flow.

[0041] The fifth flow ϕ_5 at the outlet of the second cryogenic exchanger 350 has a temperature and pressure that are respectively about -138°C and 15 bar.

[0042] The third Joule-Thompson valve 30 causes a further lowering of the temperature (up to - 156°C) and the pressure (about 1.8 bar) which causes liquefaction of the methane; flow ϕ_L.

[0043] The flow of liquid methane ϕ_L is conveyed into the storage station 400, precisely into a cryogenic tank 450 (figure 2).

[0044] The methane vapours, flow ϕ_{VM}, which are generated by the methane contained in the tank, are conveyed by means of a pipeline 34 into the sixth circuit F_2 of the second cryogenic exchanger 350 to constitute the seventh flow ϕ_7 which has already been mentioned in the foregoing.

[0045] By way of example, taking as reference the main flow ϕ, the first flow ϕ_1 is about 39% of ϕ; obviously the recycling flow ϕ_2 (the one sent to one of the inlets of the first stage A of the compressor 5) is 61 % of ϕ.

[0046] The third flow ϕ_3 is about 29.5% of the main flow ϕ, while the recycling flow ϕ_4 (sent to one of the inlets of the second compression stage B) is 9.5% thereof.

[0047] The flow ϕ_L of methane liquid is about 25.8% of the main flow, while the recycling flow ϕ_7 (sent to one of the inlets of the third compression stage C) is about 3.7% thereof.

[0048] Definitively, only about a quarter of the main flow ϕ is liquefied; it follows that only this amount must be returned to the plant, so that the flow ϕ_P in outlet from the filter 2 is equal to the amount of liquefied methane gas.

[0049] A flow of methane is collected from the supply network 1 thereof that is such as to reintegrate the liquefied methane and so as to enable supply to the gas motor 10.

[0050] From the above description and illustration, it is clear that the motor 10-compressor 5 group supplies the methane with the power required for circulating in the plant with the aim of cooling and liquefying an amount thereof.

[0051] The lowering of the methane to cryogenic levels is entrusted to the main flow ϕ, first flow ϕ_1 and fifth flow ϕ_5 which are cooled following the crossing of the corresponding first 10, second 20 and third 30 Joule-Thompson valve.

[0052] The main flow ϕ is also cooled by the first cryogenic exchanger 250 due to the frigories yielded thereto, more precisely the first circuit C_1, from flows ϕ_2, ϕ_4, ϕ_7 passing in circuits C_2,C_3,C_4 of the heat exchanger 250.

[0053] The fifth flow ϕ_5 is cooled, upstream of the third Joule-Thompson valve, by the second cryogenic exchanger 250; the cooling is made possible by the accentuated cooling of the sixth flow ϕ_6 by means of the fourth Joule-Thompson valve 50.

[0054] This enables the sixth flow to yield frigories, crossing the sixth circuit F_2 of the exchanger 350, to the fifth flow ϕ_5 which involves the fifth circuit F_1 of the exchanger.

[0055] The steps listed below are actuated by the above-described plant:

- compression of the methane by means of a four-stage (A,B,C,D) reciprocating compressor 5 so as to reach high pressures (for example up to 250 bar); the recycling of the methane, actuated by flows ϕ_2, ϕ_4, ϕ_7 conveyed to the inlets respectively of the compression stages A, B, C, combines to cool the compressor;

- pre-cooling of the main flow ϕ of the methane to a predetermined temperatures (e.g - 5°C);

- liquefaction of the methane, more precisely by an amount of the main flow ϕ of about 25%: the sources generating frigories are the four Joule-Thompson valves which exploit the significant range of pressure available (from 250 bar to about 2 bar);

- storage of the liquid methane in the cryogenic tank 450.

[0056] The plant of the invention comprises the above-mentioned power section 100, the first and second cryogenic section 300, 400 and lastly the storage section 400.

[0057] The power section comprises the gas motor 10 supplied by the low-pressure methane gas network 1 and the comburent part ϕ_S separated from the filter 2 by the purified methane.

[0058] The first cryogenic section 200 is supplied by the power section 100 via the main flow and, in turn, supplies the main flow via the recycling flows ϕ_2, ϕ_4, ϕ_7.

[0059] The second cryogenic section 300 is supplied by the first cryogenic section via the main flow ϕ_1 and, in turn, supplies the main flow via the recycling flows ϕ_4, ϕ_7.

[0060] The storage section is supplied by the liquid flow ϕ_L coming from the second section 300, and in turn the second section 300 is supplied by the methane vapour flow ϕ_{VM}.

[0061] Definitively, for its functioning the plant of the invention only uses the methane gas flow ϕ_N collected from the supply network 1.

[0062] In fact, the motor 10, of the gas motor type, which provides the power to the plate, is supplied by an amount of flow ϕ_F collected by the network that is mixed with the comburent substances ϕ_S separated by the methane gas by means of the filter 2.

[0063] At working regime only 25% of the flow circulating in the plant is liquefied and stored; the remaining part is used both for supplying the sources which "generate the cooling" (the four Joule-Thompson valves 10,20,30,50) both for the recycling with which both the circuits C_2,C_3,C_4 are supplied, the function of which circuits consists in cooling the methane flow involving the circuit C_1, and the circuit F2, the function of which is to cool the fifth methane flow ϕ_5 involving the fifth circuit F_1.

[0064] It follows that the plant is made operative only with the methane gas collected from the network 1.

[0065] The above-described and illustrated plant is advantageously provided for obtaining medium liquefied methane gas flows, for example comprised between 5 and 20 tonnes of methane per day.

[0066] It is understood that the above has been described by way of example; any variations of a technical and/or functional nature fall within the protective scope of the invention that is described and illustrated and claimed in the following.

Claims

1. A plant for liquefying methane gas, **characterised in that** it comprises:

  - - a power section (100) comprising: a molecular filter (2) supplied by a low-pressure methane supply network (1), a compression unit (5) of the methane, connected to the outlet of the filter, destined to supply in outlet a methane main flow (Φ) having a predetermined temperature and pressure, and heat exchangers (11, 12, 13, 14) for cooling the methane crossing the compression unit (5);
  - - a first cryogenic section (200) connected to the outlet of the power section (100) by which it is supplied from the main flow (Φ) and, in turn, supplying the power section (100) with at least a methane recycling flow (Φ_2, Φ_4, Φ_7), which supplies the compression unit and which cooperates with the heat exchangers for cooling the compression unit;
  - - a second cryogenic section (300) connected to the first cryogenic section (200) in inlet and in outlet by means of channels (19, 22, 24) crossed by the relative methane flows (Φ_1, Φ_4, Φ_7), the second cryogenic section (300) being destined to liquefy a predetermined amount of the main flow (Φ);
  - - a storage cryogenic section (400) connected to the second cryogenic section (300) so as to receive therefrom the liquefied methane.

2. The plant for liquefying methane gas of the preceding claim, **characterised in that** the first cryogenic section comprises: a first cryogenic exchanger (250) comprising four circuits (C_1, C_2, C_3, C_4), with the first circuit (C_1) supplied by the main flow (Φ) which is cooled by the flows (Φ_2, Φ_4, Φ_7) crossing correspondingly the remaining circuits (C_2, C_3, C_4), respectively second, third and fourth, the third and fourth circuits being crossed by respectively the fourth and the seventh relative recycling flows (Φ_4, Φ_7), coming, via relative pipelines (22, 24), from the second cryogenic section (300) and conveyed, downstream of the relative third and fourth circuits

(C_3, C_4) of said first cryogenic exchanger (250), towards the compression unit (5); a Joule-Thompson valve (10) inserted in the pipeline (17) supplied by the first circuit (C_1), destined both to cool the main methane flow (Φ) and to reduce the pressure thereof; a first phase separator (15) supplied by the main flow (Φ) coming from the Joule-Thompson valve (10) and in turn supplying a pipeline (19) crossed by a first flow (Φ_1), conveyed to the second cryogenic section (300), and a further pipeline (18) crossed by a second recycling flow (Φ_2) directed to the second circuit (C_2) of the cryogenic exchanger (250) and successively conveyed to the compression unit (5) of the power section (100).

3. The plant for liquefying methane gas of the preceding claim, **characterised in that** the second cryogenic section (300) comprises: a second Joule-Thompson valve (20) inserted in the pipeline (19) crossed by the first flow (Φ_1) coming from the first phase separator (15), and destined to lower the temperature and pressure of the first flow; a second phase separator (16) supplied by the first flow (Φ_1) coming from said second valve (20) and supplying in turn two pipelines (21, 22) crossed by relative third and fourth flows (Φ_3, Φ_4), the fourth flow being conveyed to the third circuit (C_3) of the first cryogenic exchanger (250) and successively directed to the compression unit (5) so as to define a corresponding recycling flow; a second cryogenic exchanger (350) comprising two circuits (F_1, F_2), being respectively a fifth and a sixth circuit, the fifth circuit being crossed by a fifth flow (Φ_5) coming from a pipeline (22) supplied by the pipeline (21) crossed by the third flow (Φ_3), the fifth flow (Φ_5) being equal to a predetermined level of the third flow (Φ_3); a fourth Joule-Thompson valve (50) arranged on a pipeline (23) supplied by the pipeline (21) crossed by the third flow (Φ_3) and in turn supplying the sixth circuit (F_2), the fourth valve being crossed by a sixth flow (Φ_6) equal to the remaining level of the third flow (Φ_3), the fourth valve (50) being destined to lower the temperature and pressure of the sixth flow (Φ_6) for cooling the fifth flow (Φ_5) crossing the fifth circuit (F_1) of said second cryogenic exchanger (350); a third Joule-Thompson valve (30) located on a pipeline connected to the outlet of the fifth circuit (F_1), destined to lower the temperature of the fifth methane flow (Φ_5) up to liquefaction thereof, the outlet of the third valve (30) being connected to the storage section (400).

4. The plant for liquefying methane gas of claim 2, **characterised in that** the compression unit comprises: an reciprocating compressor (5) having four compression stages (A, B, C, D) activated by a gas motor (10), the first compression stage (A) being supplied by the methane flow (Φ_P) coming from the filter (2) and by the second recycling flow (Φ_2) coming from the second circuit (C_2) of the first cryogenic exchanger (250), the second compression stage (B) supplied by the methane flow (Φ_A) coming from the first compression stage (A) and from the fourth recycling flow (Φ_4) coming from the third circuit (C_3) of the first cryogenic exchanger (250), the third compression stage (C) being supplied both by the methane flow (Φ_B) coming from the second compression stage (B) and from the seventh recycling flow (Φ_7) coming from the fourth circuit (C_4) of the first cryogenic exchanger (250), and lastly the fourth compression stage (D) being supplied by the flow (Φ_C) in outlet from the third compression stage (C) and destined to supply in outlet the main flow (Φ).

5. The plant for liquefying methane gas of the preceding claim, **characterised in that** it further comprises: at least a first heat exchanger (11) for cooling the methane flow (Φ_A) in outlet from the first compression stage; at least a second heat exchanger (12) for cooling the methane flow (Φ_B) in outlet from the second compression stage (B); at least a third heat exchanger (13) for cooling the methane flow (Φ_C) in outlet from the third compression stage (C); at least a fourth heat exchanger (14) for cooling the main methane flow (Φ) in outlet from the fourth compression stage (D).

6. The plant for liquefying methane gas of claim 4, **characterised in that** the gas motor (10) is supplied by a flow (Φ_F) branching from the methane supply network (1), upstream of the filter (2), to which is added the flow (Φ_S) of the comburent part filtered by the filter (2).

7. A plant for liquefying methane gas, **characterised in that** it comprises: The plant for liquefying methane gas of claim 3, **characterised in that** the storage section (400) comprises a cryogenic tank (450) for receiving the liquid methane flow (Φ_L) coming from the outlet of the third Joule-Thompson valve (30).

8. The plant for liquefying methane gas of claim 7, **characterised in that** it comprises a pipeline (34) connecting a top of the tank (450) with a pipeline, connected to the inlet of the sixth circuit (F_2) of the second cryogenic exchanger (350), destined to convey the methane vapours flow (Φ_{VM}) which are released by the liquid methane contained by the tank.

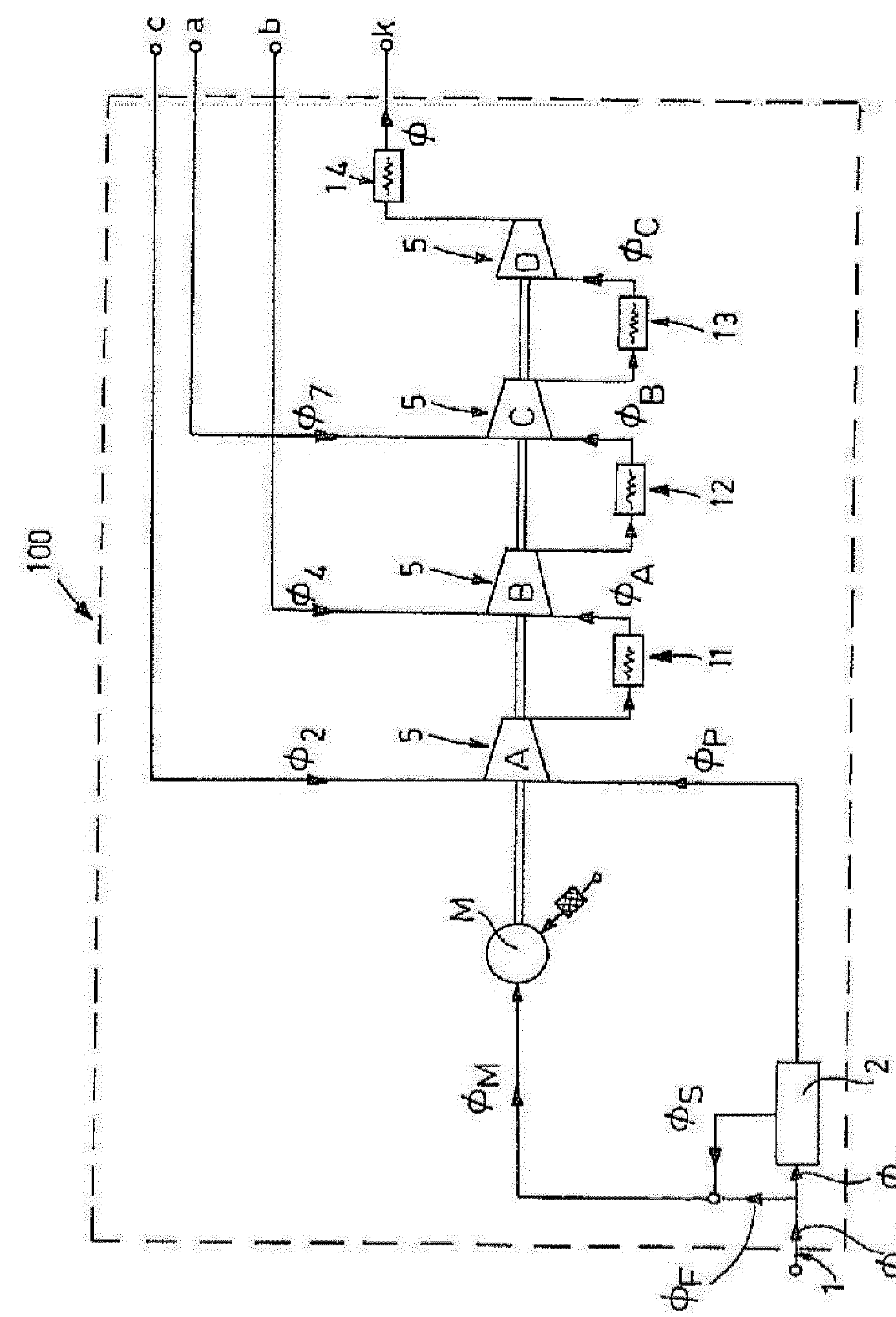
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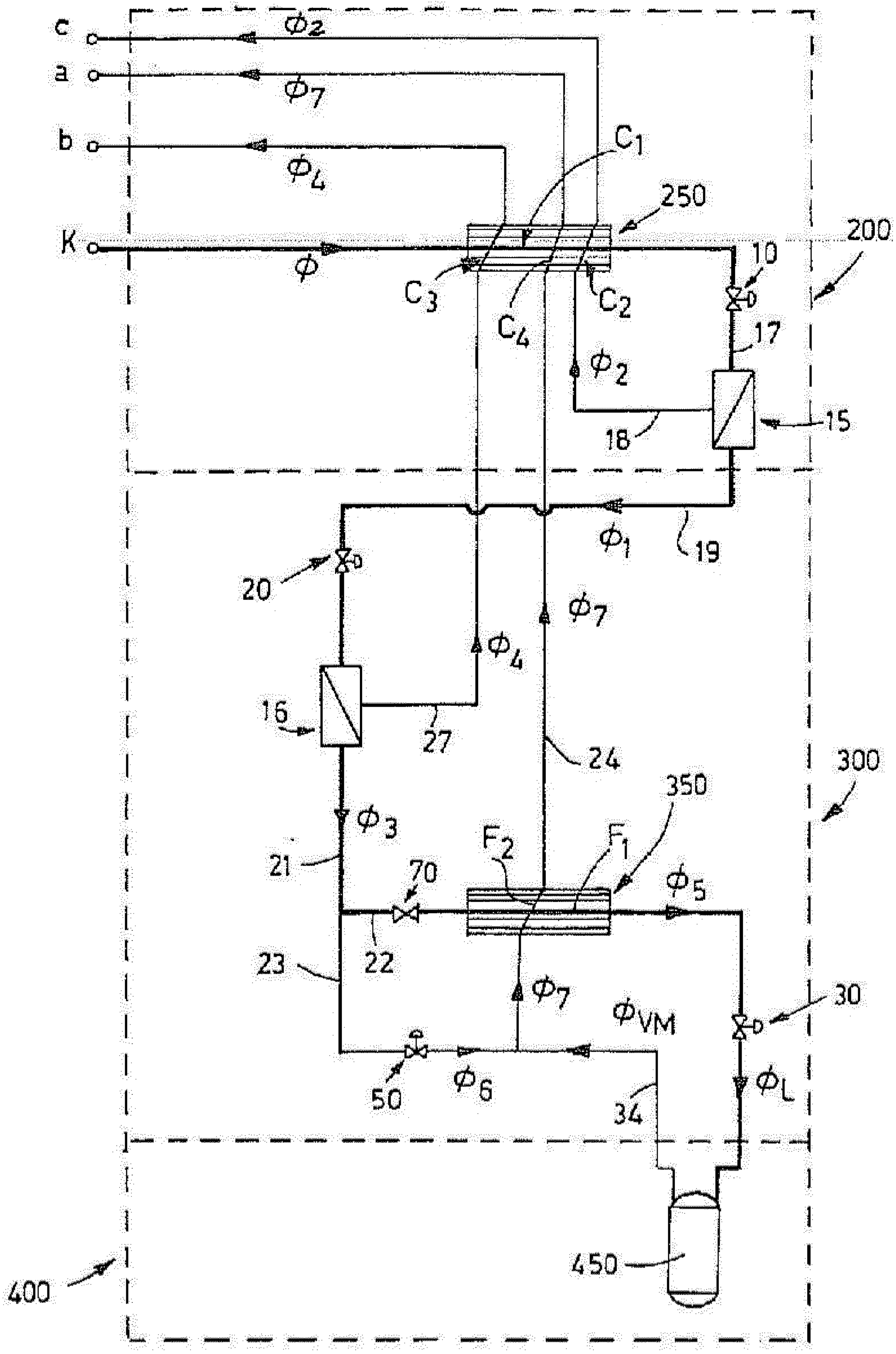
FIG. 1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Φ6
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ΦL
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FIG. 2