(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 January 2009 (15.01.2009)

PCT

(10) International Publication Number
WO 2009/007938 A2

(51) International Patent Classification:
B01D 53/00 (2006.01) *F25J 3/06* (2006.01)
F25J 3/02 (2006.01)

(21) International Application Number: PCT/IB2008/052794

(22) International Filing Date: 10 July 2008 (10.07.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/776,492 11 July 2007 (11.07.2007) US

(71) Applicant *(for all designated States except US)*: **L'AIR LIQUIDE-SOCIETE ANONYME POUR L'ETUDE ET L'EXPLOITATION DES PROCEDES GEORGES CLAUDE** [FR/FR]; 75 Quai d'Orsay, F-75321 Paris Cedex 07 (FR).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **DARDE, Arthur** [FR/FR]; 32 boulevard Saint-Marcel, F-75005 Paris (FR). **HA, Bao** [US/US]; 208 Dandelion Lane, San Ramon, California 94583 (US). **TRANIER, Jean-Pierre** [FR/FR]; 15 sentier des Jardins, F-94240 L'hay-les-roses (FR).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

(54) **Title:** PROCESS AND APPARATUS FOR THE SEPARATION OF A GASEOUS MIXTURE

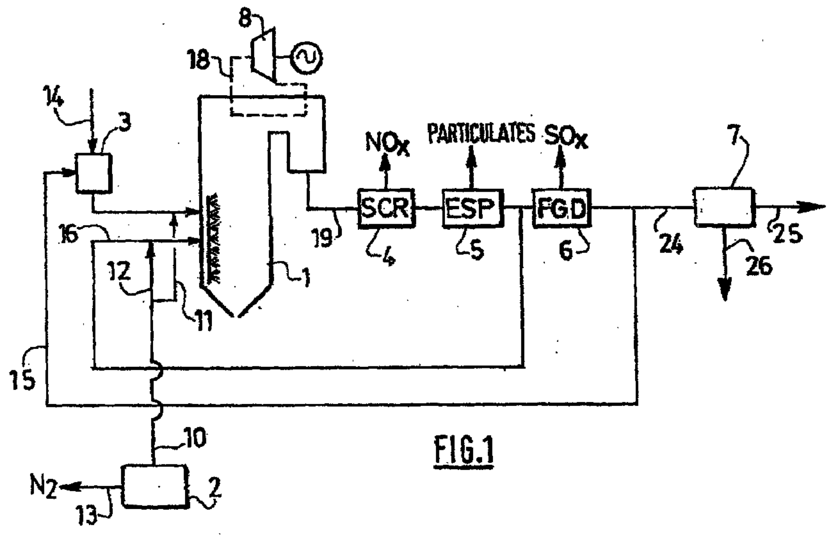

FIG.1

(57) **Abstract:** A process for separating carbon dioxide from a compressed, dried and cooled carbon dioxide containing fluid comprises separating the fluid into at least a carbon dioxide enriched stream, and a carbon dioxide depleted stream, expanding at least part of the carbon dioxide lean stream in an expander, compressing a process stream wherein the power for the compression step is at least in part provided by the power generated by the expander.

WO 2009/007938 A2

PROCESS AND APPARATUS FOR THE SEPARATION OF A GASEOUS MIXTURE

Technical Field

The present invention relates to a process and apparatus for the separation of gaseous mixture containing carbon dioxide as main component. It relates in particular to processes and apparatus for purifying carbon dioxide, for example coming from combustion of a carbon containing fuel, such as takes place in an oxycombustion fossil fuel or biomass power plant.

Background Art

The combustion of carbon containing fuels (biomass, waste, fossil fuels such as coal, lignite, hydrocarbons,...) produces CO_2 and gases, such as SO_2, SO_3, NOx, which pollute the atmosphere and are major contributors to the greenhouse effect especially CO_2. These emissions of CO_2 are concentrated in four main sectors: power generation, industrial processes, transportation, and residential and commercial buildings. The main application of CO_2 capture is likely to be in power generation and large energy consuming industries, particularly cement, iron and steel and chemical production and oil refining. Capturing CO_2 directly from small and mobile sources in the transportation and domestic and commercial buildings sectors is expected to be significantly more difficult and expensive. Most of the emissions of CO_2 to the atmosphere from the electricity generation and industrial sectors are currently in the form of flue gas from combustion, in which the CO_2 concentration is typically 4-14% by volume, although CO_2 is produced at high concentrations by a few industrial processes. In principle, flue gas could be stored, to avoid emissions of CO_2 to the atmosphere it would have to be compressed to a pressure of typically more than 100 bar abs and this would consume an excessive amount of energy. Also, the high volume of the flue gas would mean that storage reservoirs would be filled quickly. For these reasons it is preferable to produce relatively high purity stream of CO_2 for transport and storage; this process is called CO_2 capture. This carbon dioxide could be used for enhanced oil recovery or just injected in depleted gas and oil fields or in aquifers.

The present invention is based on application to the power generation sector. Nevertheless, it could also be applied to flue gases coming from other industrial processes with a relatively high purity, above 50% by volume (dry base).

There are three main techniques for capture of CO_2 in power plants:

- Post-combustion: the flue gas from a power station is scrubbed with a chemical solvent such as an aqueous solution of amines which will remove the CO_2 by absorption;
- Pre-combustion: the fuel together with oxygen is sent to a gasifier where a synthesis gas (main component of the mixture: H_2, CO and CO_2) is produced. CO is then shifted to H_2 and CO_2 (CO + H2O <> $CO_2 + H_2$) and CO_2 is scrubbed by a physical or chemical solvent. A mixture containing essentially H_2 and N_2 is sent to a gas turbine where it is burnt; and
- Oxycombustion: in order to increase the carbon dioxide content in the flue gas, the fuel is burnt with a mixture of mainly carbon dioxide and oxygen instead of air. This mixture of oxygen and carbon dioxide is obtained by recycling part of the flue gas rich in carbon dioxide and mixing it with oxygen (typically at 95% purity) coming from a cryogenic air separation unit. The flue gas is then purified in order to remove components like water and oxygen and compressed to a pressure between 100 and 200 bar abs in order to be injected underground (see Figure 1). It should be noted that the recycling of flue gases would not be necessary with high temperature materials for the boiler. However, they do not exist at the time of invention. The recycling of flue gases is not mandatory for the invention disclosed here in.

EP-A-0503910 describes a process for the recovery of carbon dioxide and other acid gases from flue gases coming from a power plant using the oxycombustion technique.

A more recent document on the same subject is “Oxy-Combustion Processes for CO_2 Capture from Power Plant" IEA Report No. 2005/9, September 2005, Process Flow Diagrams 6, p. 1, and 11, p. 1.

The purpose of this invention is to improve the solution proposed in this patent both in term of specific energy and/or carbon dioxide recovery and/or carbon dioxide product purity.

Summary of the Invention

According to an aspect of the invention, there is provided a process for separating carbon dioxide from a compressed, dried, and cooled carbon dioxide containing fluid comprising the steps of:

i) separating the fluid into at least a carbon dioxide enriched stream, and at least a carbon dioxide depleted stream;

ii) expanding at least part of the carbon dioxide depleted stream in an expander; and

iii) compressing a stream chosen from the group comprising the fluid upstream of step i) and at least part of one of the streams of step i),

wherein the power for the compression step iii) is at least in part provided by the power generated by the expander of step ii).

According to optional features:

- part of a fluid chosen from the group comprising the carbon dioxide depleted stream(s) is compressed in step iii);

- the carbon dioxide depleted stream is richer in carbon dioxide than another stream separated in step i);
- at least part of the carbon dioxide enriched stream is compressed in step iii);
- the stream compressed in compression step iii) is the fluid to be separated;
- the compression of step iii) takes place in a single stage impeller and the expansion of step ii) takes place in a single stage impeller on the same shaft rotating at the same speed;
- the compressed stream of step iii) is recycled upstream of the separation step i); and
- the separation step i) comprises cooling the compressed, dried fluid to form a cooled compressed dried fluid, sending the cooled, compressed dried fluid to a phase separator, sending at least one stream from the phase separator to a column, removing the carbon dioxide enriched stream from the column and separating the carbon dioxide depleted stream by means of phase separation alone.

According to further aspects of the invention, there is provided an apparatus for separating carbon dioxide from a flue gas comprising:

i) A separation unit for separating the flue gas into at least a carbon dioxide enriched stream, and at least a carbon dioxide depleted stream

ii) An expander and a conduit for sending at least part of the carbon dioxide depleted stream in the expander to be expanded

iii) A compressor and a conduit for sending at least part of one of the streams of step i) to the compressor wherein the compressor is coupled to the expander.

Other optional aspects include:

- a conduit for sending at least part of one fluid from the group of the carbon dioxide depleted streams to the compressor;
- a conduit for sending at least part of the carbon dioxide enriched stream to the compressor;
- a conduit for sending at least part of the fluid to be separated to the compressor;
- the separation unit comprises at least first and second phase separators, a conduit for sending at least one of feed gas and gas derived from the feed gas to the first phase separator, a conduit for removing gas from the first phase separator, said conduit being connected to the compressor, a conduit for sending compressed gas from the compressor to the second phase separator, a conduit for removing gas from the second phase separator and a conduit for sending the gas from the second phase separator to the expander; and
- the apparatus further comprises a distillation column and at least one conduit for sending liquid from at least one of the first and second phase separators to the column.

Brief Description of Drawings

For a further understanding of the nature and objects for the present invention, reference should be made to the following detailed description, taken in conjunction with the accompanying drawings, in which like elements are given the same or analogous reference numbers and wherein:

- Figure 1 is a schematic representation of an oxycombustion process wherein the flue gas is purified in order to remove components like water and oxygen and compressed in order to be injected underground.
- Figure 2 is a schematic view of a compression and purification unit which could be used as unit **7** in Figure 1.

- Figure 3 shows a low temperature purification unit that could be used as unit **104** in Figure 2.
- Figure 4 shows a heat exchange diagram for heat exchange between a vaporizing high purity carbon dioxide stream and a cooling and condensing feed stream.
- Figure 5 shows a heat exchange diagram for heat exchange between an intermediate purity carbon dioxide stream and a cooling and condensing feed stream as observed in exchanger **55** of Figure 3.

Description of the Invention

The invention will now be described in further detail with reference to the figures of which Figures 1, 2 and 3 show apparatuses according the invention, in varying degrees of detail, going from Figure 1 which is the least detailed to Figure 3 which is the most detailed. Figures 4 and 5 show heat exchange diagrams for the prior art and one of the exchangers of Figure 3 respectively. Figure 6 shows an alternative version of Figure 3.

Figure 1 is a schematic view of an oxycombustion plant. Air separation unit **2** produces an oxygen stream **10** at a typical purity of 95-98 mol. % and a waste nitrogen stream **13**. Oxygen stream **10** is split into two sub streams **11** and **12**. The primary flue gas recycle stream **15** passes through coal mills **3** where coal **14** is pulverized. Substream **11** is mixed with the recycle stream downstream of the coal mills **3** and the mixture is introduced in the burners of the boiler **1**. Sub stream **12** is mixed with secondary flue gas recycle stream **16** which provides the additional ballast to the burners to maintain temperatures within the furnace at acceptable levels. Water stream(s) is introduced in the boiler **1** in order to produce steam stream(s) **18** which is expanded in steam turbine **8**. Flue gas stream **19** rich in CO_2, typically containing more than 70 mol. % on a dry basis, goes through several treatments to remove some impurities. Unit **4** is NOx removing system like selective catalyst reduction. Unit **5** is a dust removal system such as electrostatic precipitator and/or baghouse filters. Unit **6** is a desulfurization system to remove SO_2 and/or SO_3. Units **4** and **6** may not be necessary depending on the CO_2 product specification. Flue gas stream **24** is then introduced in a compression and purification unit **7** in order to produce a high CO_2 purity stream **25** which will be sequestrable and a waste stream **26**.

Figure 2 is a schematic view of a compression and purification unit which could be used as unit **7** in Figure 1. Flue gas stream **110** (corresponding to stream **24** of Figure 1) enters a low pressure pretreatment unit **101** where it is prepared for compression unit **102**. This unit could include, for example, among other steps:

- a dust removal step in a wet scrubber and/or a dry process either dynamic, such as pulse-jet cartridges or static, such as pockets and cartridges;
- a (further) desulfurization step in a wet scrubber with water and/or soda ash or caustic soda injection; and
- a cooling step in order to minimize the flow through water condensation and the power of compression unit both due to flow and temperature reduction.

Waste stream(s) **111** could consist of condensed water, dust and dissolved species like H_2SO_4, HNO_3, Na_2SO_4, $CaSO_4$, Na_2CO_3, CaCO …

Compression unit **102** compresses stream **112** from a pressure close to atmospheric pressure to a high pressure typically between 15 and 60 bar abs, preferably around 30 bar abs. This compression could be done in several stages with intermediate cooling. In this case, some condensate(s) **113** could be produced. Heat of compression could also be recovered in these intermediate cooling step, for example to preheat boiler feed water. Hot stream **114** leaves the compression unit **102** and enters a high pressure pretreatment unit **103**. This unit at least includes:

- one or several cooling step(s) in order to decrease the temperature and decrease the water content; and
- a drying step to remove most of the water, for example by adsorption,

and could include (non-exhaustive list):

- a high pressure washing column for cooling and/or purification; and
- a mercury removal step.

Effluents from this unit are gaseous stream **115** (regeneration stream of the drying step) and could be liquid stream(s) **116**/**117** (from the cooling step and/or the high pressure washing column).

The stream **114** may contain NO_2. In this case, it is sometimes preferable to remove the NO_2 by adsorption upstream of the unit **104**. In this case, the stream **114** may be treated by adsorption and the regeneration gas used to regenerate the adsorbent is removed having a content enriched in NO_2 with respect to that of stream **114**. The gaseous stream **115** may be recycled at least in part upstream of the compression unit **102**, upstream of the pretreatment unit **101** or to the boiler **1** of the combustion unit.

Below 158º C., NO_2 is in equilibrium with its polymer/dimer N_2O_4. The lower the temperature, the higher the concentration of N_2O_4 compared to NO_2. In this document, the word NO_2 is used to mean not only NO_2 but also its polymer/dimer N_2O_4 in equilibrium.

Unit **104** is a low temperature purification unit. In this case, low temperature means a minimum temperature in the process cycle for the purification of the flue gas below 0º C. and preferably below -20º C. as close as possible to the triple point temperature of pure CO_2 at -56.6º C. In this unit, stream **118** is cooled down and partially condensed in one (or several steps). One (or several) liquid phase stream(s) enriched in CO_2 is (are) recovered, expanded and vaporized in order to have a product enriched in CO_2 **119**. One (or several) non-condensible high pressure stream(s) **120** is (are) recovered and could be expanded in an expander.

CO_2 enriched product **119** is further compressed in compression unit **105**. In unit **106** compressed stream **121** is condensed and could be further compressed by a pump in order to be delivered at high pressure (typically 100 to 200 bar abs) as stream **122** to a pipeline to be transported to the sequestration site.

Figure 3 shows a low temperature purification unit that could be used as unit **104** in Figure 2. At least one process according to the invention operates within such a unit.

Stream **118** comprising flue gas at around 30 bar and at a temperature of between 15º C. and 43º C. is filtered in **3** to form stream **5**. Stream **118** contains mainly carbon dioxide as well as NO_2, oxygen, argon and nitrogen. It may be produced by unit **103** directly at the high pressure or may be brought up to the high pressure using optional compressor **2** shown in dashed lines. Stream **5** cools in heat exchange line **9** and is partially condensed. Part **7** of stream **5** may not be cooled in the heat exchange but is mixed with the rest of stream **5** downstream of the heat exchange line to vary its temperature. The partially condensed stream is sent to first phase separator **11** and separated into gaseous phase **13** and liquid phase **17**. The gaseous phase **13** is divided in two to form stream **15** and stream **21**. Stream **21** is used to reboil column **43** in exchanger **25** and is then sent to a second phase separator **22**. Stream **15** by-passes the reboilers in order to control the reboiling duty.

Liquid stream **17** from the first phase separator **11** is expanded in valve **19** and liquid stream **29** is expanded in valve **31**, both streams being then sent to the top of column **43**. Column **43** serves principally to remove the incondensable components (oxygen, nitrogen, and argon) from the feed stream.

A carbon dioxide depleted stream **33** is removed from the top of column **43** and sent to compressor **35**. The compressed stream **37** is then recycled to stream **5**.

A carbon dioxide enriched or rich stream **67** is removed from the bottom of column **43** and divided in two. One part **69** is pumped by pump **71** to form stream **85**, further pumped in pump **87** and then removed from the system. Stream **85** corresponds to stream **25** of Figure 1. The rest **73** provides the frigorific balance.

It is desirable to provide means for removing NO_2 from the fluid **118** to be separated. In general this involves separating at least part of the fluid **118** into a carbon dioxide enriched stream, a carbon dioxide depleted stream comprising CO_2 and at least one of oxygen, argon, and nitrogen and a NO_2 enriched stream, and recycling the NO_2 enriched stream upstream of the separation step.

The incondensable removal step (removing mainly O_2 and/or N_2 and/or Ar) may take place before or after the NO_2 removal step.

Several types of NO_2 removal step may be envisaged, involving distillation and/or phase separation and/or adsorption. The adsorption step may be carried out on a product of the CO_2 separation step or the fluid itself before separation.

In Figure 3, after stream **69** is removed, the rest of the carbon dioxide enriched stream **73** is vaporized in heat exchange line **9** and sent to NO_2 removal column **105**.

This column may have a top condenser and a bottom reboiler, as shown, the feed being sent to an intermediate point. Alternatively, there need be no bottom reboiler, in which case the feed is sent to the bottom of the column. A NO_2 depleted stream **79** is removed from the column and sent back to the heat exchange line. This stream is further warmed, compressed in compressors **75**,

77, sent to heat exchanger **65**, removed therefrom as stream **78**, cooled in exchangers **81**, **83** and mixed with stream **69** to form stream **85**. Exchanger **81** may be used to preheat boiler feed water. Exchanger **83** is cooled using a refrigerant stream **185** which may be R134a, ammonia, water, water mixed with glycol or any other suitable fluid. The warmed fluid is designated as **187**. A NO_2 enriched stream **84** is removed from the bottom of the column **105**. This stream **84** is then recycled to a point upstream of filter **3**.

Alternatively or additionally the separation phase may consist of producing the NO_2 enriched stream by adsorption of the NO_2 contained in stream **67** in adsorption unit **68**.

In either case, at least part of the NO_2 enriched stream may be recycled to a unit producing the fluid, such as the combustion zone of a boiler **1**, as seen previously for stream **115**. It should be noted that recycling NO_x in the combustion zone does not increase the NO_x content in the flue gas. In other words, recycling NO_x to the combustion zone eliminates NOx.
Additionally or alternatively at least part of the NO_2 enriched stream may be recycled to a unit for treating the fluid.

For example the NO_2 enriched stream may be recycled upstream of the compressor **2** (if present) or one of units **101**, **102**.

It may be advantageous to recycle at least part of the NO_2 enriched stream to a wash column, such as that of pretreatment unit **103**. In this case, the NO_2 may be converted to nitric acid in the wash column and subsequently removed from the system.

In a wash column where SO_2 is present in the flue gas, the recycled NO_2 enriched stream will react with SO_2 to form NO and SO_3 that will immediately turn to H_2SO_4

with water and be removed in the water drain. Therefore, if enough NO_2 is present in the recycled stream, it is a means to remove SO_x from the flue gas and to avoid the injection of reactants like soda ash or caustic soda or even a classical flue gas desulphurization.

Top gas **32** from the second phase separator **22** is cooled in heat exchanger **55** and sent to third phase separator **133**. Part of the liquid from the phase separator **133** is sent to the column **43** and the rest as the intermediate purity stream **45** is divided in two streams **47**, **141**. Stream **47** is vaporized in heat exchanger **55** and sent to the top of column **43** or mixed with stream **33**.

Stream **141** is expanded in a valve, warmed in heat exchangers **55**, **9**, compressed in compressor **59**, cooled as stream **91** in heat exchanger **60**, and mixed with compressed stream **5**. The valve used to expand stream **141** could be replaced by a liquid expander.
The top gas from the third phase separator **133** is cooled in heat exchanger **55**, optionally after compression by compressor **134** and sent to a fourth phase separator **143**. The carbon dioxide lean top gas **157** from fourth phase separator **143** is warmed in heat exchanger **55**, then in heat exchanger **9** as stream **157**, warmed in exchanger **65** and expanded as stream **23** in expander **63**, coupled to compressor **35**. The carbon dioxide lean top gas **157** contains between 30 and 45% carbon dioxide and between 30 and 45% nitrogen. It also contains substantial amounts of oxygen and argon. The bottom liquid **51** from phase separator **143** is sent to the column with stream **47**.

The stream expanded in expander **63** is mixed with stream **115** which does not pass through the expander and then warmed in **89**. Part **97** of the warmed stream is expanded in expander **61** and sent as stream **99**, **101** to the atmosphere.

The optional compressor **2** may be powered by one of expanders **61**, **63**.

Expander **61** is coupled to compressor **59** in the figure.

Molar fractions in % (example) for O_2, N_2, Ar, CO_2.

FLUIDS / Components	118	33	67	84	157	141	78
O_2	2.5	4.8	0	0	13.3	2.3	0
N_2	7.8	11	0	0	43.8	0.1	0
Ar	1.9	4.9	0	0	9.5	2.6	0
CO_2	87.8	79.3	99.95	99	33.4	95	100
NOx	250 ppm	50 ppm	500 ppm	1	5 ppm	500 ppm	0

Table 1

Figure 4 shows a heat exchange diagram for heat exchange between a vaporizing high purity carbon dioxide stream and a cooling and condensing feed stream as known from the prior art.

Figure 5 shows a heat exchange diagram for heat exchange between an intermediate purity carbon dioxide stream and a cooling and condensing feed stream as observed in exchanger **55** of Figure 3.

Figure 6 shows another low temperature purification unit that could be used as unit **104** in Figure 2. At least one process according to the invention operates within such a unit.

Stream **118** comprising flue gas at around 30 bar and at a temperature of between 15º C. and 43º C. is dried in **3** to form stream **5**. Stream **118** contains mainly carbon dioxide as well as NO_2, oxygen, argon and nitrogen. It may be produced by unit **103** directly at the high pressure or may be brought up to the high pressure using optional compressor **2** shown in dashed lines. Stream **5** cools in heat exchange line **9** and is partially condensed. As in Figure 3 but not illustrated here, part of stream **5** may not be cooled in the heat exchange but may be mixed with the rest of stream **5** downstream of the heat exchange line to vary its temperature. The partially condensed stream is sent to first phase separator **11** and separated into gaseous phase **13** and liquid phase **17**. The gaseous phase **13** is compressed in compressor **601** to a pressure of 60 bars, cooled in the heat exchanger **9** and sent to the second phase separator **22** which separates the stream **13** at this high pressure. Liquid stream **17** from the first phase separator **11** is sent to the top of column **43**.

The second phase separator **22** produces gaseous stream **32** and liquid stream **29**. Liquid stream **29** is sent to the top of column **43**. Column **43** has a bottom reboiler **25** and serves principally to remove the incondensable components (oxygen, nitrogen, and argon) from the feed stream.

The gaseous stream **32** is warmed in exchanger **9**, then further warmed in a steam heater **605** and sent to expander **602**. Expander **602** is preferably coupled to compressor **61**.

A carbon dioxide depleted stream **33** is removed from the top of column **43**, warmed in exchanger **9**, and sent to expander **603**. The expander **603** may be coupled to a compressor of the system.

A carbon dioxide enriched or rich stream **67** is removed from the bottom of column **43** and sent to exchanger **9**. Following warming and vaporization, it is compressed to more than **11**0 bars in compressor **604** to form a product stream.

Means for removing NO_2 from the fluid **118** to be separated may be provided as described above.

Claims:

1. A process for separating carbon dioxide from a compressed, dried, and cooled carbon dioxide containing fluid comprising the steps of:

    i) separating the fluid into at least a carbon dioxide enriched stream, and at least a carbon dioxide depleted stream;

    ii) expanding at least part of the carbon dioxide depleted stream in an expander; and

    iii) compressing a stream chosen from the group comprising the fluid upstream of step i) and at least part of one of the streams of step i),

wherein the power for the compression step iii) is at least in part provided by the power generated by the expander of step ii).

2. The process of claim 1, wherein part of a fluid chosen from the group comprising the carbon dioxide depleted stream(s) is compressed in step iii).

3. The process of claim 3, wherein the carbon dioxide depleted stream is richer in carbon dioxide than another stream separated in step i).

4. The process of claim 1, wherein at least part of the carbon dioxide enriched stream is compressed in step iii).

5. The process of claim 1, wherein the stream compressed in compression step iii) is the fluid to be separated.

6. The process of claim 1, wherein the compression of step iii) takes place in a single stage impeller and the expansion of step ii) takes place in a single stage impeller on the same shaft rotating at the same speed.

7. The process of claim 1, wherein the compressed stream of step iii) is recycled upstream of the separation step i).

8. The process of claim 1, wherein the separation step i) comprises cooling the compressed, dried fluid to form a cooled compressed dried fluid, sending the cooled, compressed dried fluid to a phase separator, sending at least one stream from the phase separator to a column, removing the carbon dioxide enriched stream from the column and separating the carbon dioxide depleted stream by means of phase separation alone.

9. An apparatus for separating carbon dioxide from a flue gas comprising:

- i) a separation unit for separating the flue gas into at least a carbon dioxide enriched stream, and at least a carbon dioxide depleted stream;
- ii) an expander and a conduit for sending at least part of the carbon dioxide depleted stream in the expander to be expanded; and
- iii) a compressor and a conduit for sending at least part of one of the streams of step i) to the compressor wherein the compressor is coupled to the expander.

10. The apparatus of claim 9 comprising a conduit for sending at least part of one fluid from the group of the carbon dioxide depleted streams to the compressor.

11. The apparatus of claim 9 comprising a conduit for sending at least part of the carbon dioxide enriched stream to the compressor.

12. The apparatus of claim 9 comprising a conduit for sending at least part of the fluid to be separated to the compressor.

13. The apparatus of claim 9, wherein the separation unit comprises at least first and second phase separators, a conduit for sending at least one of feed gas and gas derived from the feed gas to the first phase separator, a conduit for removing gas from the first phase separator, said conduit being connected to the compressor, a conduit for sending compressed gas from the compressor to the second phase separator, a conduit for removing gas from the second phase separator and a conduit for sending the gas from the second phase separator to the expander.

14. An apparatus of claim 13 comprising a distillation column and at least one conduit for sending liquid from at least one of the first and second phase separators to the column.

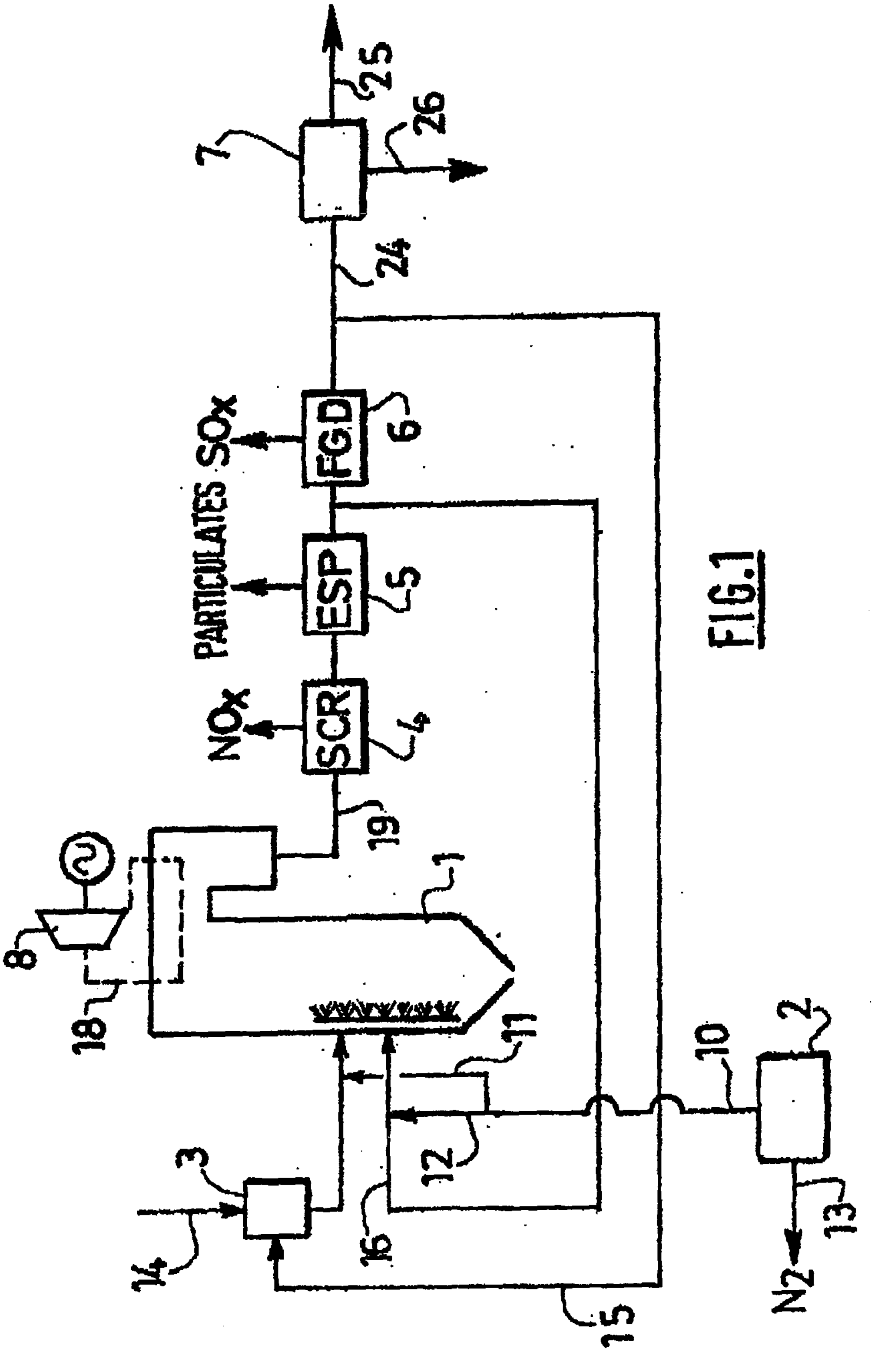
NOx
SCR
ESP
FGD
PARTICULATES
SOx
N2
1
2
3
4
5
6
7
8
10
11
12
13
14
15
16
18
19
24
25
26

FIG.1

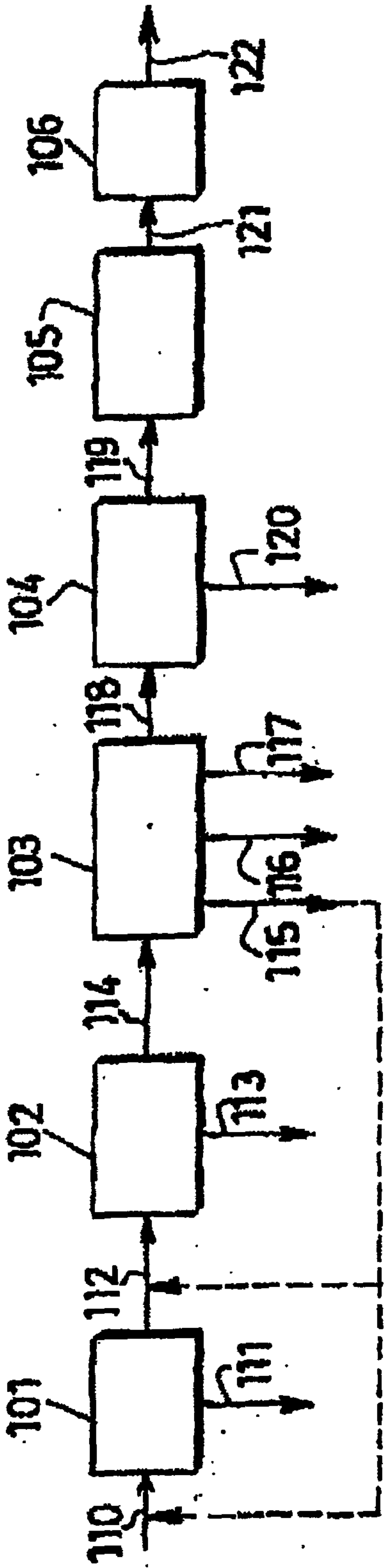
101
102
103
104
105
106
110
111
112
113
114
115
116
117
118
119
120
121
122

FIG.2

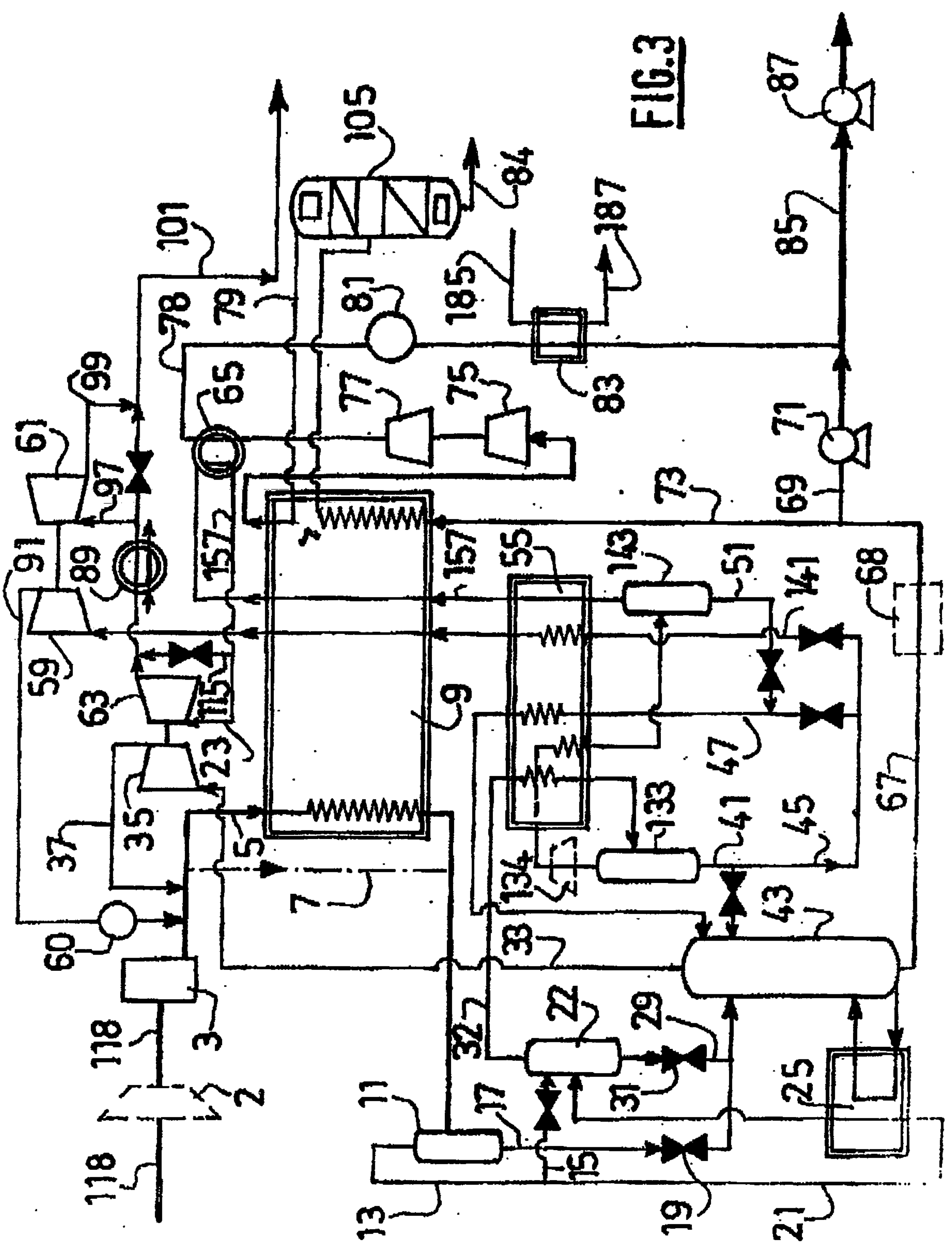
118
118
2
3
60
37
35
5
7
23
63
115
59
91
89
61
97
99
101
78
79
65
157
157
9
55
143
51
141
68
47
45
41
133
134
43
33
32
22
29
31
11
17
15
13
19
21
25
67
73
69
71
77
75
81
83
185
187
105
84
85
87

FIG.3

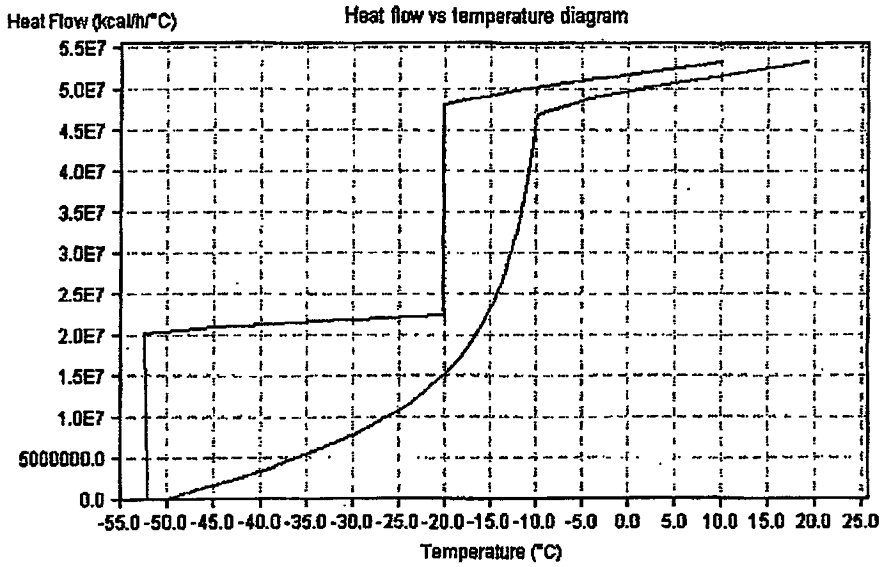
Heat Flow (kcal/h/°C)
Heat flow vs temperature diagram
5.5E7
5.0E7
4.5E7
4.0E7
3.5E7
3.0E7
2.5E7
2.0E7
1.5E7
1.0E7
5000000.0
0.0
-55.0 -50.0 -45.0 -40.0 -35.0 -30.0 -25.0 -20.0 -15.0 -10.0 -5.0 0.0 5.0 10.0 15.0 20.0 25.0
Temperature (°C)

FIG. 4

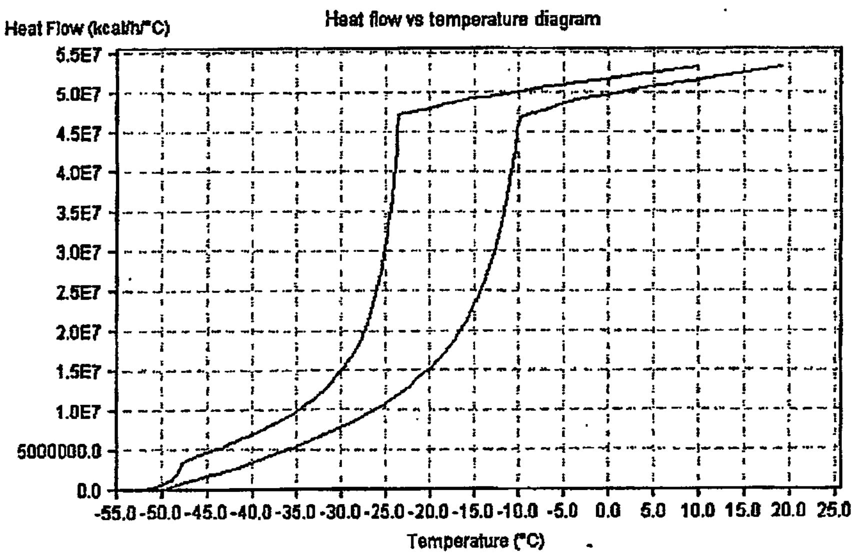
Heat Flow (kcal/h/°C)
Heat flow vs temperature diagram
5.5E7
5.0E7
4.5E7
4.0E7
3.5E7
3.0E7
2.5E7
2.0E7
1.5E7
1.0E7
5000000.0
0.0
-55.0 -50.0 -45.0 -40.0 -35.0 -30.0 -25.0 -20.0 -15.0 -10.0 -5.0 0.0 5.0 10.0 15.0 20.0 25.0
Temperature (°C)

FIG. 5

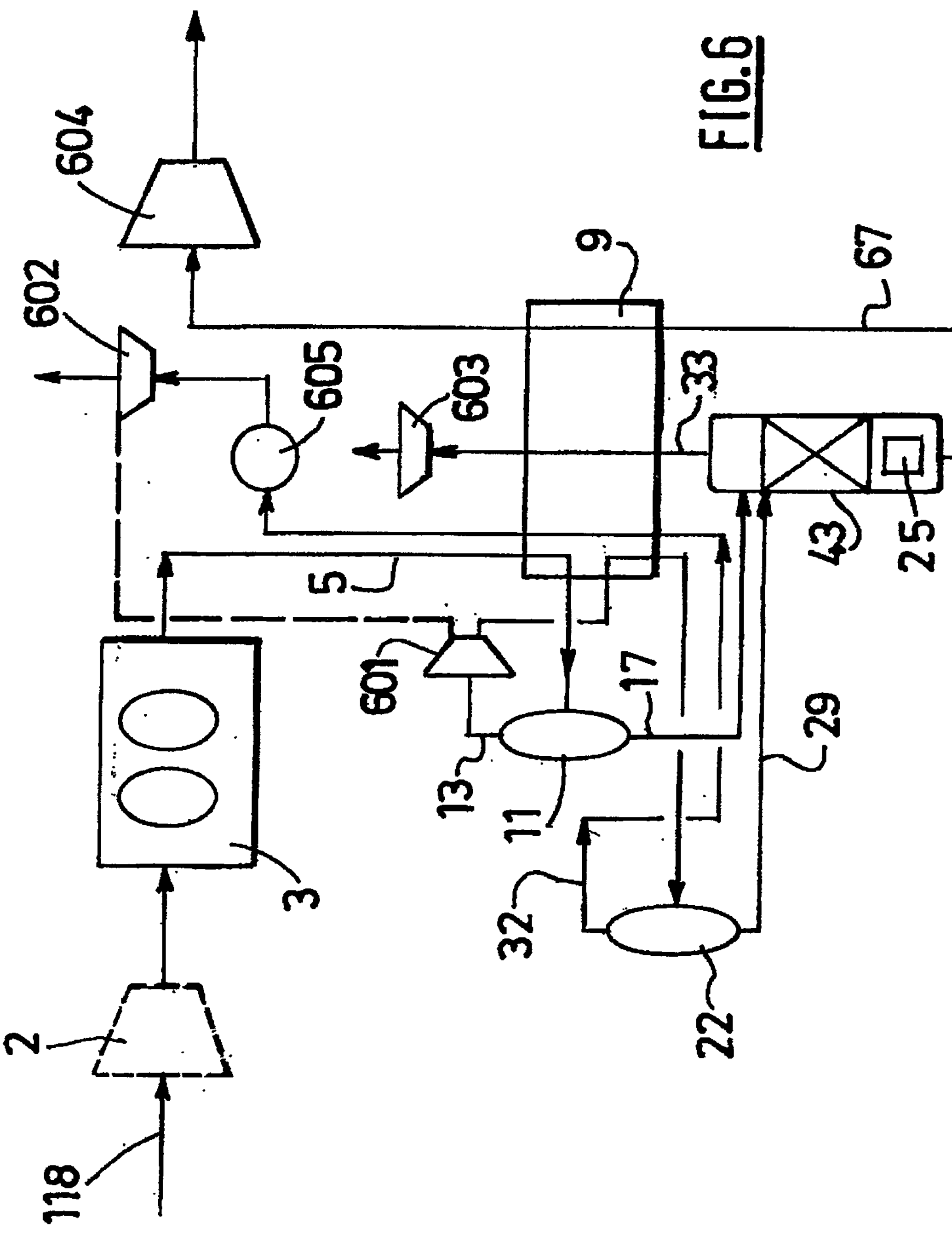

FIG.6