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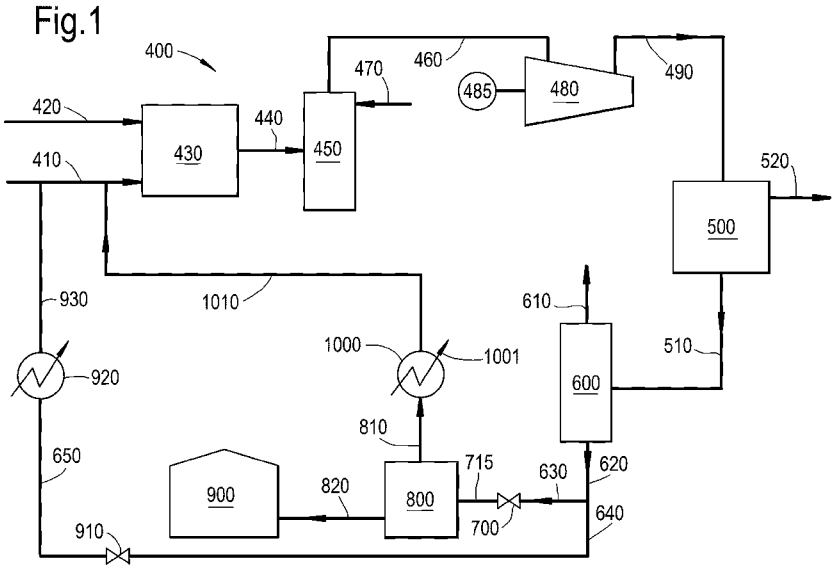
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[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR PROVIDING CONDITIONED ETHANE

Fig.1



(57) Abstract: In a method and an apparatus ethylene and an ethane stream are produced from a C2 hydrocarbon stream (510) comprising ethane and ethylene. The C2 hydrocarbon stream (510) is fractionated in a C2 fractionator (600) to provide a C2 overhead stream (610) comprising ethylene and a C2 bottoms stream (620) comprising ethane. A portion of the C2 bottoms stream (620) comprising ethane is conditioned, wherein expanding the portion (630) of the C2 bottoms stream (620) to form an expanded portion (710), and wherein removing a gaseous C2 stream (810) from the expanded portion (710) to provide a conditioned ethane stream (820). The conditioned ethane stream (820) is in the liquid state and at a pressure in the range of from about 1 to 2 bar, and at least 95 mol% thereof consists of ethane.

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METHOD AND APPARATUS FOR PROVIDING CONDITIONED ETHANE

The present invention relates to a method of providing conditioned ethane, using an apparatus for the cracking of a C2+ hydrocarbon stream to produce ethylene and an ethane stream, and an apparatus therefor.

Natural gas liquefaction processes often utilise a refrigerant to reduce the natural gas to cryogenic temperatures. The refrigerant is preferably a mixed refrigerant of a multi-component composition, often comprising one or more hydrocarbon components, such as ethane or ethylene, and propane. Depending on circumstances, operators may want to avoid the use of ethylene and revert to ethane, instead.

The natural gas itself may provide a source of ethane and propane, such that these refrigerant components can sometimes be produced as part of the liquefaction process. However, not all hydrocarbon reservoirs contain natural gas with sufficient concentrations of hydrocarbon refrigerant components such as ethane and propane. Furthermore, even if the hydrocarbon reservoir contains natural gas with sufficient concentrations of the hydrocarbon refrigerant components, it may not be possible to produce one or more of the hydrocarbon refrigerant components at the liquefaction facility, for instance if the space required for the fractionation equipment to produce the refrigerant substance from the natural gas is unavailable. This is a particular consideration when the liquefaction facility is an off-shore structure, such as a floating structure, where deck space is at a premium. Consequently, the production of

ethane at the liquefaction site for use as a refri substance may be impractical.

US Patent Application Publication No. 2010/0000251 discloses a method of liquefying a hydrocarbon stream such as natural gas, the method at least comprising the steps of: (a) providing a hydrocarbon stream at a first location, wherein the first location is situated onshore; (b) treating the hydrocarbon stream in the first location thereby obtaining a treated hydrocarbon stream; (c) transporting the treated hydrocarbon stream via a pipeline over a distance of at least 2 km to a second location, wherein the second location is situated off-shore; (d) liquefying the treated hydrocarbon stream at the second location thereby obtaining liquefied hydrocarbon product at atmospheric pressure.

US Patent Application Publication No. 2010/0000251 discloses liquefaction of a treated hydrocarbon stream using one or more refrigerants. The refrigerants may be produced in a second location, or may be produced elsewhere and transported to the second location. The refrigerants needed for liquefying the treated hydrocarbon stream may be produced in a location that is geographically removed from the second location where liquefaction takes place. In a preferred embodiment, a mixed refrigerant comprising at least two refrigerants is used and the refrigerants are transported to the second location separately as relatively pure refrigerant substances. As used herein, the term “relatively pure refrigerant substance” is intended to mean a substance having a pre-determined minimum level of purity in a single refrigerant component, for instance whereby at least 95 mol% of the substance consists of the refrigerant component. In the case of ethane being

selected as the refrigerant component, the relativ pure refrigerant substance may consist for at least 95 mol% of ethane.

One problem associated with importing refrigerant components from a different location, as suggested in US Patent Application Publication No. 2010/0000251, is that ethane is at present not commercially available at one or more of an appropriate level of purity, in an appropriate quantity and in a suitable state (e.g. in terms of phase and pressure) for such a use. A further problem is the provision of ethane in a suitable state, in terms of phase and pressure, for safe transportation to and charging to the liquefaction facility.

In a first aspect, there is provided a method of providing ethane, using an apparatus for the cracking of a C2+ hydrocarbon stream to produce ethylene and an ethane stream, said method comprising at least the steps of:

- providing a C2 hydrocarbon stream comprising ethane and ethylene;
- separating the C2 hydrocarbon stream in a C2 fractionator into a C2 overhead stream comprising ethylene and a C2 bottoms stream comprising ethane;
- conditioning a portion of the C2 bottoms stream comprising ethane, said conditioning comprising at least the steps of expanding the portion of the C2 bottoms stream thereby forming an expanded portion and removing a gaseous C2 stream from the expanded portion to provide a conditioned ethane stream, wherein said conditioned ethane stream is in the liquid state and at a pressure in the range of from about 1 to 2 bar, and for at least 95 mol% consists of ethane.

In a second aspect, there is provided an appar for providing ethane, from the cracking of a C2+ hydrocarbon stream to produce ethylene, said apparatus comprising at least:

- a C2 fractionator in fluid communication with a C2 hydrocarbon stream comprising ethane and ethylene to separate the C2 hydrocarbon stream into a C2 overhead stream comprising ethylene and a C2 bottoms stream comprising ethane;
- conditioning means configured to expand a portion of the C2 bottoms stream and to remove a gaseous C2 stream from the expanded portion of the C2 bottoms stream, to provide a conditioned ethane stream, wherein said conditioned ethane stream is in the liquid state and at a pressure in the range of from about 1 to 2 bar, and for at least 95 mol% consists of ethane.

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying non-limited drawings in which:

Figure 1 is a diagrammatic scheme of one embodiment of a method and apparatus for the manufacture of a conditioned ethane stream described herein;

Figure 2 is a diagrammatic scheme of another embodiment of a method and apparatus for the manufacture of a conditioned ethane stream described herein;

Figure 3 is a diagrammatic scheme of one embodiment of a method and apparatus for the step of cooling and separating a compressed hydrocarbon stream described herein;

Figure 4 is a diagrammatic scheme of another embodiment of a method and apparatus for the step of cooling and separating a compressed hydrocarbon stream described herein.

The method and apparatus disclosed herein prov conditioned ethane stream from a C2+ hydrocarbon cracker.

As used herein, the term “conditioned ethane” is intended to mean ethane provided at a pre-determined level of ethane purity, for instance at least 95 mol% ethane, or preferably at least 98 mol% ethane, and in a particular phase state, as defined by its temperature and pressure. The conditioned ethane stream is in the liquid state and at a pressure in the range of from about 1 to 2 bar. Such a conditioned stream is suitable for use as a refrigerant substance in the liquefaction of a hydrocarbon stream such as natural gas.

The present invention unlocks a commercially beneficial source of conditioned ethane at one location for the use as a refrigerant substance in a different location. This means that fractionation columns necessary for the separation and purification of ethane from the natural gas at the liquefaction site may be dispensed with, thereby freeing up plot space. This is particularly useful if the location for the use of the conditioned ethane as refrigerant substance is on board of an offshore floating vessel, such that no deck space needs to be occupied by fractionation columns necessary for the separation and purification of ethane from the natural gas.

The method described herein provides ethane in a sufficient quantity, of an appropriate quality and in an appropriate physical state in terms of phase and pressure range for it to be transferred, preferably to an off-shore liquefaction facility, and used as a refrigerant substance.

Conditioned ethane consisting for at least 95 mol% of ethane is suitable for use as a refrigerant substance

without further fractionation or with only minimal fractionation, for instance only for accomplishing removal of undesired components which make the conditioned ethane unsuitable for use as refrigerant substance at temperatures below for instance -50 °C. Examples of such undesired components include one or both of water and mercury.

Providing the conditioned ethane in the liquid phase and at a pressure of from about 1 to 2 bar allows the conditioned ethane to be cryogenically stored and transported at or near atmospheric pressure, preferably at atmospheric pressure. This alleviates a number of logistical and safety issues associated with the transportation of the conditioned ethane. For instance, the conditioned ethane does not have to be transported in a pressurised tank. In addition, the conditioned ethane can be discharged to the liquefaction facility in a liquid state, for instance via suitable cryogenic pipework such as transfer arms or flexible pipes. The conditioned ethane can then be stored in a liquid state in cryogenic storage tanks at or near atmospheric pressure. No further processing of the conditioned ethane, such as one or more of fractionation, temperature adjustment and pressure adjustment may be required when it is provided in a conditioned state.

Providing ethane in a conditioned state is particularly advantageous when the liquefaction facility is located off-shore. An off-shore structure, such as a floating structure, for the liquefaction of a hydrocarbon such as natural gas is advantageous because it provides an off-shore alternative to on-shore liquefaction plants. A floating structure for the liquefaction of hydrocarbon can be moored off the coast, or close to or at a gas

field, in waters deep enough to allow off-loading liquefied product onto a carrier vessel. It also represents a movable asset, which can be relocated to a new site when the gas field is nearing the end of its productive life, or when required by economic, environmental or political conditions.

Examples of such floating structures include a Floating Liquefaction Storage Off-shore facility which combines the natural gas liquefaction process, storage tanks, loading systems and other infrastructure into a single floating structure, with a preferred type being a Floating Liquefaction of Natural Gas (FLNG) facility. Another suitable floating structure is a Floating Production, Liquefaction, Storage and Off-loading (FPLSO) facility which can additionally carry out the function of a production facility and separate at least a portion of the hydrocarbons from the reservoir.

The conditioned ethane may for at least 95 mol%, preferably at least 98 mol%, consist of ethane with the balance being one or more further components. As used herein, the term “further component” means compounds such as other hydrocarbons (i.e. hydrocarbons other than ethane) and inerts at a total concentration of less than 5 mol%, preferably less than 2 mol% of the hydrocarbon load or conditioned hydrocarbon. The one or more further components may comprise, for instance, one or both of ethylene and propylene. Other further components such as further hydrocarbons (i.e. hydrocarbons other than those comprising ethane, ethylene and propylene), mercury and/or water may be present. Preferably the further components do not preclude the operation of the conditioned ethane as a refrigerant substance at the temperature and pressure under which the refrigerant is

intended to be used. In this respect, particular used in aluminium-based heat exchangers, it is preferred that the conditioned ethane comprises less than 50 ng/m^3, preferably less than 10 ng/m^3, and more preferably less than 5 ng/m^3 mercury.

The conditioned ethane as proposed in the present invention may meet a level of less than 5 ng/m^3 mercury without any particular effort needed, because the C2+ hydrocarbon stream which is to be cracked is preferably already de-mercurized any way in order to avoid mercury contamination of the cracking apparatus. Suitable methods of lowering the mercury content of a hydrocarbon stream are known in the art.

The conditioned ethane may be provided at a temperature of less than or equal to -88 °C, preferably in the range of from -100 °C to -88 °C and at a pressure in the range of from about 1 to 2 bar. Herewith the ethane is in liquid state.

Figure 1 illustrates an apparatus 400 for providing a stream of conditioned ethane 820. Figure 2 illustrates another embodiments of such an apparatus wherein several not necessarily interrelated options for modification of the apparatus of Figure 1 are illustrated.

In both Figure 1 and Figure 2, a C2 fractionator 600 is in fluid communication with a C2 hydrocarbon stream 510. The C2 hydrocarbon stream 510, which contains substantial amounts of ethane and ethylene, may be obtained from a hydrocracker, as will be explained later. The C2 fractionator 600 is configured to separate the C2 hydrocarbon stream 510 into a C2 overhead stream 610 consisting mostly of ethylene, and a C2 bottoms stream 620 consisting mostly of ethane. Conditioning means is

provided, comprising a conditioning pressure reduc device 700 and a conditioning gas/liquid separator 800.

The apparatus 400 can be used to produce ethylene and a conditioned ethane stream 820. The C2 hydrocarbon stream 510 is separated in the C2 fractionator 600 into the C2 overhead stream 610 and the C2 bottoms stream 620. A portion 630 of the C2 bottoms stream 620 is conditioned using the conditioning means. The conditioning includes at least the steps of expanding the portion 630 of the C2 bottoms stream 620, preferably in the conditioning pressure reducing device 700, whereby an expanded portion 710 of the C2 bottoms stream 620 is formed. The conditioning further includes removing a gaseous C2 stream 810 from the expanded portion 710, to provide the conditioned ethane stream 820.

The conditioned ethane stream 820 is in the liquid state, at a pressure in the range of from about 1 to 2 bar, and consists for at least 95 mol% of ethane, with the balance containing one or both of ethylene and propylene.

The C2 hydrocarbon stream 510 may be obtained from a hydrocarbon cracker used for the cracking of a C2+ hydrocarbon feed stream 410. The apparatus shown in Figure 1 is an apparatus 400 for the production of ethylene, which has been adapted to produce the conditioned ethane stream 820 as well.

The C2+ hydrocarbon feed stream 410 is provided at the inlet of a cracking zone 430. The C2+ hydrocarbon feed stream 410 being fed to the cracking zone 430 comprises at least one hydrocarbon having two or more carbon atoms. Preferably the C2+ hydrocarbon stream may comprise one or more of the group comprising ethane, propane, butane, naphtha such as C_5–C_{12} hydrocarbons, gas

oil and hydrocracked vacuum gas oils. The C2+ hydrocarbon feed stream may be provided at a pressure of greater than 4 bar, more preferably at a pressure in the range of from 5 to 10 bar.

The cracking zone 430 is configured to crack the C2+ hydrocarbon feed stream 410 into a cracked hydrocarbon stream 440. The cracking zone 430 may comprise or form part of a cracking furnace, such as a pyrolysis furnace, in which the C2+ hydrocarbon feed stream 410 can be thermally cracked. It is preferred that the thermal cracking takes place in the presence of stream, which can be provided to the cracking zone 430 as steam stream 420.

The cracking zone 430 may be operated at a temperature of greater than 650 °C, preferably in a range of from 750 to 950 °C, to promote free radical reactions in which at least C2 hydrocarbons including ethylene are produced. Typically the thermal cracking is carried out without the presence of oxygen. The cracked hydrocarbons exit the cracking zone 430 as cracked hydrocarbon stream 440. The cracked hydrocarbon stream 440 typically comprises ethylene and ethane, and it may contain other components, such as typically methane, propane, propylene, butane and optionally acetylene. The ethane is provided in the cracked hydrocarbon stream 440 as one or both of uncracked ethane which may have been present as a component of the C2+ hydrocarbon feed stream 410 and ethane produced as part of the cracking reaction, for instance from the break-up of longer chain hydrocarbons (i.e. those having more than two carbon atoms).

A quenched hydrocarbon stream 460 is obtained by quenching the cracked hydrocarbon stream 440. To this end, the cracked hydrocarbon stream 440 may then be passed to a quench zone 450 in which the temperature of

the cracked hydrocarbon stream 440 is reduced to s cracking reaction. In the embodiment shown in Figure 1, the cracked hydrocarbon stream 440 is quenched by direct contact with a quench stream 470, which may be one or more streams comprising water and/or quench oil to provide a quenched hydrocarbon stream 460. The quenched hydrocarbon stream 460 may further comprise water and/or quench oil used in the quench zone 450.

In an embodiment not shown in Figure 1 or 2, the cracked hydrocarbon stream 440 may be first cooled, preferably by indirect (i.e. non-contact) heat exchange, against a heat exchange fluid, such as a heat exchange fluid stream, in a quench heat exchanger prior to direct contact with the quench stream 470. The heat exchange fluid may be liquid water, such that after heat exchange, a steam stream is generated.

A compressed hydrocarbon stream 490 may next be obtained by compressing the quenched hydrocarbon stream 460. To this end, the quenched hydrocarbon stream 460 may be passed to a quenched stream compressor 480 which is arranged in fluid communication with the quench zone 450 and the quenched hydrocarbon stream 460. Prior to passage to the suction of the quenched stream compressor 480, the quenched hydrocarbon stream 460 may be passed through a quenched stream gas/liquid separation device (not shown), such as a knock-out drum, to remove liquid from the stream. The quenched stream compressor 480 may be a single compressor or a plurality of compressors in series. The quenched stream compressor 480 may be single or multi-stage. If a plurality of compressors are present, these may or may not share the same drive shaft. The quenched stream compressor 480 can be driven by a

compressor driver 485, such as an electric motor c turbine, such as a gas or steam turbine.

The quenched stream compressor 480 provides a compressed hydrocarbon stream 490 at its discharge. The compressed hydrocarbon stream 490 may have a pressure in the range of from 10 to 50 bar. An optional step comprising removal of acid gasses may be applied to the compressed hydrocarbon stream 490 and/or the quenched hydrocarbon stream 460. This is option if the compressed hydrocarbon stream 490 and/or the quenched hydrocarbon stream 460 comprises acid gas such as carbon dioxide and/or gaseous oxides of sulphur and it is desired to lower their concentration. An example is shown in Figure 2, where an acid gas removal system 495 is provided in the compressed hydrocarbon stream 490, wherein the compressed hydrocarbon stream 490 can be contacted with an acid gas absorbent liquid 496. Examples of acid gas absorbent liquid 496 include monoethanolamine or an aqueous alkali solution such as an alkali metal hydroxide, for instance sodium hydroxide solution.

The compressed hydrocarbon stream 490, optionally after treatment to lower the concentration of acid gas, may then be passed to a hydrocarbon separation zone 500 in which the compressed hydrocarbon stream 490 is cooled and fractionated to provide the C2 hydrocarbon stream 510 as one of the fractionated streams. The hydrocarbon separation zone 500 is arranged to receive the discharge outlet of the quenched stream compressor 480. The C2 hydrocarbon stream 510 is enriched in ethane and ethylene relative to the cracked hydrocarbon stream 440, such that it comprises a higher mol% concentration of these components. The C2 hydrocarbon stream 510 may be in vapour phase.

Typically, the step of cooling and separating compressed hydrocarbon stream 490 in the hydrocarbon separation zone 500 further provides a C1 hydrocarbon stream 520 comprising methane. The step of cooling and separating the compressed hydrocarbon stream 490 is discussed in greater detail with respect to the embodiments of Figures 3 and 4 below, and generally provides cooling and multiple fractionation steps.

The C2 hydrocarbon stream 510 may be provided at a temperature of less than -10 °C, more preferably in the range of from -40 to -20 °C, still more preferably at about -30 °C. The C2 hydrocarbon stream 510 may be a pressurised stream with respect to atmospheric pressure, and preferably has a pressure of greater than 10 barg, more preferably in the range of from 10 to 25 barg, still more preferably about 17 barg.

The pressures of the C2 overhead stream 610 and C2 bottoms stream 620 will be similar to that of the C2 hydrocarbon stream 510 with only a small pressure drop in C2 fractionator 600. Preferably, the pressures of the C2 overhead stream 610 and C2 bottoms stream 620 will be in the range of from 10 to 25 barg, more preferably about 17 barg.

The C2 overhead stream 610 may be provided at a temperature of less than -25 °C, more preferably in a range of from -40 to -30 °C, still more preferably at about -35 °C. The C2 overhead stream 610 may comprise ethylene vapour. The C2 bottoms stream 620 may be provided at a temperature of less than 0 °C, more preferably in a range of from -15 to -5 °C, still more preferably about -10 °C. The C2 bottoms stream may comprise ethane liquid. At least 95 mol% of the C2 bottoms stream may consist of ethane.

The portion 630 of the C2 bottoms stream 620 t subject to the conditioning in the conditioning means, as described above, may be a C2 bottoms slip stream. A remainder of the C2 bottoms stream 620, which is not included in the portion 630 of the C2 bottoms stream 620, may be employed as a C2 recycle stream 640. In such cases, the remainder of the C2 bottom stream 620 is recycled to form part of the C2+ hydrocarbon feed stream 410. The C2 recycle stream 640 may be passed to a first recycle stream pressure reduction device 910, such as a Joule-Thomson valve, to provide a first expanded C2 recycle stream 650 having a pressure of about or above that of the C2+ hydrocarbon feed stream 410.

Cold from the C2 recycle stream 640 and/or from the first expanded C2 recycle stream 650 after the optional pressure reduction step in the pressure reduction device 910 may be recovered by heat exchanging with a cold recovery stream. The resulting C2 recycle stream from which the cold has been recovered is a first warmed C2 recycle stream 930. The first warmed C2 recycle stream 930 may be allowed to form part of the C2+ hydrocarbon feed stream 410, which completes the recycling.

Figure 1 illustrates an embodiment wherein, prior to passing the first expanded C2 recycle stream 650 to the C2+ hydrocarbon feed stream 410, a portion of the cold is recovered from this stream. In this example, the first expanded C2 recycle stream 650 may be passed to a first recycle heat exchanger 920 in which it is heat exchanged against a heat exchange fluid, such as a refrigerant, thereby heating the first expanded C2 recycle stream 650 to provide a first warmed C2 recycle stream and a cooled heat exchange fluid. The first recycle heat exchanger 920 may be a shell and tube or a plate and fin heat

exchanger. The heat exchange fluid such as a refr may be used in the hydrocarbon separation zone 500. The first warmed C2 recycle stream 930 comprising ethane vapour may be injected into the C2+ hydrocarbon feed stream 410.

After having passed through the conditioning pressure reduction device 700 it has become an expanded C2 slip stream 710. The conditioning pressure reduction device 700 may suitably be a Joule-Thomson valve. The expanded portion 710, such as the expanded C2 slip stream, may be a multi-phase stream that comprises gaseous and liquid phases. The gaseous C2 stream 810 that is removed from the expanded portion 710 comprises the gaseous phase from the multi-phase stream. Said removing of the gaseous C2 stream 810 from the expanded C2 slip stream comprises separating the expanded C2 slip stream into the gaseous C2 stream 810 and a liquid C2 stream. To this end, the expanded portion 710 may be passed to the conditioning gas/liquid separator 800.

The conditioned ethane stream 820 is obtained from the liquid C2 stream. In one group of embodiments, illustrated in Figure 1, the liquid C2 stream may be in the form of the conditioned ethane stream 820, without further steps. In such cases, the liquid C2 stream is already conditioned to meet the predetermined target for the conditioned ethane stream 820 wherein the conditioned ethane stream is in the liquid phase and at a pressure of about 1 to 2 bar. Thus, the liquid C2 stream may have a temperature in the range of from less than or equal to -88 °C, preferably in the range of from -100 °C to -88 °C.

An alternative embodiment is shown in Figure 2 wherein the liquid C2 stream is subject to further

cooling, before it is discharged as the conditione ethane stream 820. This will be further explained below.

In any case, including each of the embodiments of Figures 1 and 2, the conditioned ethane stream 820 may be conveyed directly to a conditioned ethane storage tank 900. The conditioned ethane storage tank 900 is preferably a heat-insulated storage tank. The conditioned ethane storage tank 900 may be an intermodal container.

As a result of the C2 separation in C2 fractionator 600, the liquid C2 stream preferably consists for at least 95 mol%, more preferably at least 98 mol%, of ethane. The balance of the liquid C2 stream may be one or both of ethylene and propylene, together with other further components.

The gaseous C2 stream 810 comprising ethane from the conditioning gas/liquid separating device may be recycled to the C2+ hydrocarbon feed stream 410 to form part of the C2+ hydrocarbon feed stream. Optionally the pressure of the stream is adjusted in a pressure adjustment step, to a pressure about that of, or just above that of, the C2+ hydrocarbon feed stream 410. This pressure adjustment may require the compression of the gaseous C2 stream 810, for instance in a second recycle stream compressor (not shown).

Cold from the gaseous C2 stream 810, either before or after the optional pressure adjustment step if such step is employed, may be recovered by heat exchanging with a cold recovery stream. Figures 1 and 2 show embodiments wherein, prior to passing the gaseous C2 stream 810 to the C2+ hydrocarbon feed stream 410 or a second recycle stream compressor, at least a portion of the cold is recovered from this stream. For example, the gaseous C2

stream 810 may be passed to a second recycle heat exchanger 1000, such as a shell and tube or a plate and fin heat exchanger, in which it is heat exchanged against a heat exchange fluid, such as a refrigerant, thereby heating the gaseous C2 stream 810 and cooling the heat exchange fluid.

The resulting gaseous C2 stream 810 from which the cold has been recovered may be a second warmed C2 recycle stream 1010. The second warmed C2 recycle stream 1010 may be allowed to form part of the C2+ hydrocarbon feed stream 410, which completes the recycling. Figure 2 shows an example wherein the optional pressure adjustment step 1005 is applied to the second warmed C2 recycle stream 1010 after the optional cold recovery.

The cooled heat exchange fluid 1001 may be used in the hydrocarbon separation zone 500. The second warmed C2 recycle stream 1010 comprising ethane vapour may be injected into the C2+ hydrocarbon feed stream 410 after optional compression as discussed above.

The recovered cold from the C2 recycle stream 640 and/or from the first expanded C2 recycle stream 650 and/or from the gaseous C2 stream 810, either before or after the optional pressure adjustment step if such step is employed, may be used in the hydrocarbon cracker to assist in the cracking process, such as in the cooling of the compressed hydrocarbon stream 490 in the hydrocarbon separation zone 500, or in the part cooling of a refrigerant stream which may be used in one or both first and second conditioning heat exchangers that will be discussed below.

As illustrated in Figure 2, the C2 bottoms slip stream 630 may be heat exchanged and cooled against (i) a portion of the C2 recycle stream 640 after a pressure

reduction step and/or (ii) a portion of the gaseou stream 810, optionally after an pressure reduction step. In a still further embodiment, the liquid C2 stream 815 may be heat exchanged and cooled against (i) a portion of the C2 recycle stream 640 after a pressure reduction step and/or (ii) a portion of the gaseous C2 stream 810, optionally after a pressure reduction step. Thus, within the meaning of the present disclosure, one or both of the C2 recycle stream 640, or a portion thereof, and the gaseous C2 stream 810, or a portion thereof may be used as refrigerant stream.

In an embodiment shown in Figure 2, the liquid C2 stream 815 from the conditioning gas/liquid separator 800 can be heat exchanged against a refrigerant stream 831 in a first conditioning heat exchanger 830, whereby transferring heat from the liquid C2 stream 815 to the refrigerant stream 831. In such embodiments the conditioned ethane stream 820 is formed by the liquid C2 stream 815 from which heat has been extracted in the first conditioning heat exchanger 830. The liquid C2 stream 815 can thus be cooled against the refrigerant stream 831 to provide the conditioned ethane stream 820 in a sub-cooled condition, for instance as a sub-cooled conditioned ethane stream, and a warmed refrigerant stream 832. The sub-cooled conditioned ethane stream may have a temperature of less than -90 °C. The refrigerant stream 831 may be a refrigerant in an external cooling circuit dedicated for this purpose, or part of an integrated cooling circuit with at least one further heat-exchange elsewhere in the ethylene production facility, for instance in hydrocarbon separation zone 500. The refrigerant in the refrigerant stream 831 may be methane or mainly consist of methane.

Alternatively, the refrigerant stream 831 may portion of the gaseous C2 stream 810 which has been expanded in a second recycle pressure reduction device, such as a Joule-Thomson valve, to provide an expanded gaseous C2 stream. The heat exchange of the liquid C2 stream 815 against the expanded gaseous C2 stream provides the conditioned ethane stream 820, for instance as a subcooled stream and a warmed gaseous C2 stream. The warmed gaseous C2 stream may be subsequently compressed in a pressure adjustment step, for instance in a second recycle stream compressor, to provide a second warmed C2 recycle stream which can be passed to the C2+ hydrocarbon feed stream 410.

In another alternative embodiment, the refrigerant stream 831 may be a portion of the C2 recycle stream 640, which may have been expanded in a first recycle stream pressure reduction device 910, such as a Joule-Thomson valve, to provide a first expanded C2 recycle stream 650. The liquid C2 stream 815 can be heat exchanged against the first expanded C2 recycle stream 650 to provide the conditioned ethane stream 820, for instance as a subcooled stream and a warmed further first expanded C2 recycle stream. The warmed first expanded C2 recycle stream 650 can be passed to the C2+ hydrocarbon feed stream 410, for instance after compression in a first recycle stream compressor to provide a first compressed C2 recycle stream.

In such alternative embodiments, the first conditioning heat exchanger 830 may therefore be provided by first or second recycle heat exchangers 920, 1000.

In a further alternative embodiment, the C2 bottoms slip stream 630 may be heat exchanged against a refrigerant stream 731 in a second conditioning heat

exchanger 730. The C2 bottoms slip stream 630 car cooled against the refrigerant stream 731 to provide a cooled C2 bottoms slip stream 635, and a warmed refrigerant stream 732. In a similar manner to the previous embodiments, the refrigerant stream 731 may be a refrigerant in an external cooling circuit dedicated for this purpose, or part of an integrated cooling circuit with at least one further heat-exchange elsewhere in the ethylene production facility, for instance in hydrocarbon separation zone 500. Alternatively, the refrigerant stream may be a portion of the first expanded C2 recycle stream 650 and/or a portion of the gaseous C2 stream 810. In these cases, the second conditioning heat exchanger 730 may therefore provided by said first or second recycle heat exchangers 920, 1000.

Still referring to Figure 2, the so optionally cooled C2 bottoms slip stream 635 can be passed through the conditioning pressure reduction device 700, which has already been described herein above, to provide the expanded C2 slip stream 710 as a multi-phase stream comprising gaseous and liquid phases.

In all embodiments represented by Figures 1 and 2, the expanded C2 slip stream 710 can be passed to the conditioning gas/liquid separator 800, in which the multi-phase stream is separated to provide the gaseous C2 stream 810 comprising ethane vapour, and the liquid C2 stream 820 comprising ethane liquid. The cooling of the C2 bottoms slip stream 630 by heat exchange against said refrigerant 731 is advantageous because this produces a higher proportion of the liquid C2 stream 815 compared to the gaseous C2 stream 810 after expansion and gas/liquid separation, thereby allowing for producing a higher proportion of the conditioned ethane stream 820.

Figures 3 and 4 disclose two embodiments of th hydrocarbon separation zone 500 for the cooling and separating of the compressed hydrocarbon stream 490 to provide the C2 hydrocarbon stream 510 comprising ethane and ethylene.

In the scheme of Figure 3, the compressed hydrocarbon stream 490 may comprise ethylene, ethane and other components, typically methane, propane, propylene, butane and optionally acetylene. As discussed above, the compressed hydrocarbon stream may be treated to remove acid gases. After any acid gas removal, the stream may also be treated to remove water, for instance by drying it over a water absorbent molecular sieve. The stream may also be treated to remove any acetylene, for instance by catalytic hydrogenation (not shown).

The compressed hydrocarbon stream 490 can be passed to a C3 separator 1100, in which the components of the stream are separated into a C1-3 hydrocarbon stream 1110 comprising hydrocarbon compounds having from 1 to 3 carbon atoms, such as methane, ethane, ethylene, propane and propylene and a C4+ hydrocarbon stream 1120 comprising butane and any other hydrocarbons having four or more carbon atoms.

If acetylene is present and has not already been removed, the C1-3 hydrocarbon stream 1110 can be treated to remove acetylene at this stage, for instance by catalytic hydrogenation. The C1-3 hydrocarbon stream 1110 may then be heat exchanged, for instance against one or more refrigerant streams in one or more first hydrocarbon heat exchangers 1200. The heat exchange cools the C1-3 hydrocarbon stream 1110 to provide a cooled C1-3 hydrocarbon stream 1210. The refrigerant may be provided in a refrigerant cooling circuit for this purpose. The

refrigerant may be a hydrocarbon refrigerant, such mixed refrigerant and may comprise one or more of methane, ethane and propane.

The cooled C1-3 hydrocarbon stream 1210 may then be passed to a C1 separator 1300, such as a demethaniser, in which the components of the stream are separated to provide a C1 hydrocarbon stream 520 comprising methane, typically as an overhead gaseous stream and a C2-3 hydrocarbon stream 1310 comprising ethane, ethylene, propane and propylene, typically as a liquid bottoms stream.

The C2-3 hydrocarbon stream 1310 may then be passed to a C2 separator, such as a deethaniser, in which the components of the stream are separated to provide the C2 hydrocarbon stream 510 comprising ethane and ethylene and a C3 hydrocarbon stream 1410 comprising propane and propylene.

In a further embodiment not shown in Figure 3, the C3 hydrocarbon stream 1410 may be passed to a C3 fractionator to separate the propane and propylene components to provide a C3 overhead stream comprising propylene vapour and a C3 bottoms stream comprising propane liquid. The C3 bottoms stream may then be treated to provide a conditioned propane stream. As used herein, the term “conditioned propane” is intended to mean propane in the liquid state at a pressure of about 1 to 2 bar. The propane may have a temperature of less than -42 °C, more preferably in the range of from -42 to -55 °C. The treatment of the C3 bottoms stream to provide a conditioned propane stream may occur in a similar manner to that of the C2 bottoms stream discussed above. For instance, a portion of the C3 bottoms stream may be removed as a slip stream and passed through a

second conditioning pressure reduction device to p an expanded C3 stream comprising gaseous and liquid phases. The expanded C3 stream may then be passed to a second conditioning gas/liquid separation device to provide a gaseous C3 stream comprising propane and a liquid C3 stream comprising propane as a conditioned propane stream.

In a further embodiment, the liquid C3 stream may be heat exchanged against a refrigerant stream to cool the liquid C3 stream to provide a sub-cooled conditioned propane stream. In a still further embodiment, the C3 bottoms slip stream may be cooled prior to pressure reduction in a similar manner to that discussed for the preparation of the conditioned ethane stream.

Figure 4 shows a schematic of an alternative embodiment of the hydrocarbon separation zone 500. The compressed hydrocarbon stream 490, after optional treatment to remove one or both of acid gas and acetylene, can be heat exchanged, for instance against one or more refrigerant streams in one or more second hydrocarbon heat exchangers 1500. The heat exchange cools the compressed hydrocarbon stream 490 to provide a cooled compressed hydrocarbon stream 1510. The refrigerant may be provided in a refrigerant cooling circuit for this purpose. The refrigerant may be a hydrocarbon refrigerant, such as a mixed refrigerant and may comprise one or more of methane, ethane and propane.

The cooled compressed hydrocarbon stream 1510 may then be passed to a C1 separator 1600, such as a demethaniser, in which the components of the stream are separated into a C1 hydrocarbon stream 520 comprising methane and a C2+ hydrocarbon stream 1610 comprising

hydrocarbons having two or more carbon atoms, such ethane, ethylene, propane, propylene and butane.

The C2+ hydrocarbon stream 1610 may then be passed to a C2 separator 1700, such as a deethaniser, in which the components of the stream are separated into the C2 hydrocarbon stream 510 comprising ethane and ethylene and a C3+ hydrocarbon stream 1710 comprising hydrocarbons having three or more carbon atoms, such as propane, propylene and butane.

In a further embodiment not shown in Figure 4, the C3+ hydrocarbon stream 1710 may be passed to a C3 separator such as a depropaniser, to separate the components of the stream into a C3 hydrocarbon stream comprising propane and propylene and a C4+ hydrocarbon stream comprising butane. The C3 hydrocarbon stream may be passed to a C3 fractionator to separate the propane and propylene components to provide a C3 overhead stream comprising propylene vapour and a C3 bottoms stream comprising propane liquid. The C3 bottoms stream may then be treated to provide a conditioned propane stream as discussed in the embodiment of Figure 3.

As used herein, the term “C#” in which # is a positive integer, relates to a the number of carbon atoms in the hydrocarbon molecule. For instance, a C2 hydrocarbon stream comprises hydrocarbons having two carbon atoms per molecule, such as one or both of ethane and ethylene. Similarly, a C2+ hydrocarbon stream comprises hydrocarbons having two or more carbon atoms per molecule, such as one or more of ethane, ethylene, propane, propylene, butane etc.. A C# separator, where # is a positive integer, is a device to separate hydrocarbons having # carbon atoms per molecule for a composition. For instance, a C2 separator is a device to

separate hydrocarbons having two carbon atoms per molecule, such as one or both of ethane and ethylene, from a composition of hydrocarbons, which may further comprise hydrocarbons having more than two and/or less than two carbon atoms e.g. a deethaniser. Similarly, a C# fractionator, where # is a positive integer, is a device for separating different hydrocarbon molecules having # carbon atoms. For example, a C2 fractionator can separate ethane and ethylene.

An intermodal container is a movable container which can be transported from one location to another, and from one transporter to another, without off-loading and reloading of the contents of the container (in this case the conditioned ethane). An intermodal container is ideally suited to this purpose because it can be used in a global containerised intermodal freight transport system and used with and transferred between any mode of transport such as ship, rail or truck.

The intermodal container may be thermally insulated and vapour-tight. As used herein, the term “vapour-tight” is intended to mean that the tank has a pressure loss of less than 0.0075 bar over 5 minutes after having pressurised to the maximum allowable working pressure of the tank. As used herein, the term “thermally insulated” is intended to mean that the tank has a heat influx of less than 75 W/m^2 at the bubble point temperature of the contents of the tank over at least 90% of the outer surface area of the tank at a 50% filling ratio and +15 °C ambient temperature such as defined in engineering standard EN 12213. Thermal insulation may be provided by vacuum jacketing the storage tank in the intermodal container.

Suitable intermodal containers, for instance 2 (6.1 m) in length with a capacity of 20000 litres, or 40 feet (12.2 m) in length with a capacity of 43500 litres, are available from Chart Industries Group D&S (Chart Ferox as, Děčin, the Czech Republic).

Furthermore, the pressure unit “bar”, as used herein, is identical to “bar absolute” or “bara”. The term “liquid state” is intended to represent a fluid at or below its bubble point at the governing pressure.

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.

C L A I M S

1. A method of providing ethane, using an apparatus for the cracking of a C2+ hydrocarbon stream to produce ethylene and an ethane stream, said method comprising at least the steps of:

- providing a C2 hydrocarbon stream comprising ethane and ethylene;

- separating the C2 hydrocarbon stream in a C2 fractionator into a C2 overhead stream comprising ethylene and a C2 bottoms stream comprising ethane;

- conditioning a portion of the C2 bottoms stream comprising ethane, said conditioning comprising at least the steps of expanding the portion of the C2 bottoms stream thereby forming an expanded portion and removing a gaseous C2 stream from the expanded portion to provide a conditioned ethane stream, wherein said conditioned ethane stream is in the liquid state and at a pressure in the range of from about 1 to 2 bar, and for at least 95 mol% consists of ethane.

2. The method of claim 1, wherein the expanded portion is an expanded C2 slip stream drawn from the C2 bottoms stream and comprises gaseous and liquid phases; and wherein said removing of the gaseous C2 stream from the expanded portion comprises phase separating the expanded C2 slip stream into the gaseous C2 stream comprising ethane and a liquid C2 stream comprising ethane, wherein the conditioned ethane stream is obtained from the liquid C2 stream.

3. The method of claim 2, wherein the liquid C2 stream is the conditioned ethane stream.

4. The method of claim 2, further comprising the cooling the liquid C2 stream by heat exchanging the liquid C2 stream against a refrigerant stream to provide the conditioned ethane stream in a sub-cooled condition.

5. The method of claim 1, wherein the step of conditioning the C2 bottoms stream comprises, prior to expanding:

- cooling the portion of the C2 bottoms stream by heat exchanging the portion of the C2 bottoms stream against a refrigerant stream to provide a cooled C2 bottoms slip stream.

6. The method of any of the preceding claims, wherein the C2 hydrocarbon stream is provided by the steps of:

- providing a C2+ hydrocarbon feed stream;
- cracking the C2+ hydrocarbon feed stream to provide a cracked hydrocarbon stream comprising ethane, ethylene and other components;
- quenching the cracked hydrocarbon stream to provide a quenched hydrocarbon stream;
- compressing the quenched hydrocarbon stream, with optional removal of acid gasses, to provide a compressed hydrocarbon stream;
- cooling and fractionating the compressed hydrocarbon stream to provide at least the C2 hydrocarbon stream comprising ethane and ethylene, wherein the C2 hydrocarbon stream is enriched in ethane and ethylene relative to the cracked hydrocarbon stream.

7. The method of claim 6, wherein a remainder of the C2 bottoms stream, which is not included in the portion of the C2 bottoms stream, is employed as a C2 recycle stream comprising ethane comprising recycling the remainder of the C2 bottom stream to form part of the C2+ hydrocarbon feed stream.

8. The method of claim 7, further comprising the of:

- recovering cold from the C2 recycle stream, optionally after a pressure reduction step in the C2 recycle stream, to provide a first warmed C2 recycle stream; and/or
- recovering cold from the gaseous C2 stream, optionally before or after a pressure adjustment step of the gaseous C2 stream, to provide a second warmed C2 recycle stream.

9. The method of claim 8, further comprising:

- allowing the first warmed C2 recycle stream to form part of the C2+ hydrocarbon feed stream and/or
- allowing the second warmed C2 recycle stream to form part of the C2+ hydrocarbon feed stream.

10. The method of any of the preceding claims, wherein at least 95 mol% of the conditioned ethane stream consists of ethane, with the balance containing one or both of ethylene and propylene.

11. The method of any of the preceding claims, wherein the conditioned ethane stream comprises less than 5 ng/m^3 mercury.

12. The method of any of the preceding claims, further comprising:

- passing the conditioned ethane stream to at least one cryogenic storage tank.

13. The method of claim 12, wherein the at least one cryogenic storage tank is an intermodal container.

14. An apparatus for providing ethane, from the cracking of a C2+ hydrocarbon stream to produce ethylene, said apparatus comprising at least:

- a C2 fractionator in fluid communication with a C2 hydrocarbon stream comprising ethane and ethylene to separate the C2 hydrocarbon stream into a C2 overhead

stream comprising ethylene and a C2 bottoms stream comprising ethane;

- conditioning means configured to expand a portion of the C2 bottoms stream and to remove a gaseous C2 stream from the expanded portion of the C2 bottoms stream, to provide a conditioned ethane stream, wherein said conditioned ethane stream is in the liquid state and at a pressure in the range of from about 1 to 2 bar, and for at least 95 mol% consists of ethane.

15. The apparatus of claim 14, wherein the conditioning means comprises:

- a conditioning pressure reducing means in fluid communication with the C2 bottoms stream to reduce the pressure of the portion of the C2 bottoms stream, to provide an expanded C2 slip stream comprising liquid and gaseous phases;

- a conditioning gas/liquid separator in fluid communication with the expanded C2 slip stream to separate the expanded C2 stream into a C2 gaseous stream comprising ethane and the conditioned ethane stream.

16. The apparatus of claim 15, wherein the conditioning means further comprises at least one of a first conditioning heat exchanger, arranged in fluid communication with the conditioning gas/liquid separator to receive a liquid C2 stream from the conditioning gas/liquid separator, and a second conditioning heat exchanger arranged in the portion of the C2 bottoms stream between the C2 bottoms stream and the conditioning pressure reducing means.

17. The apparatus of any one of claims 14 to 16, further comprising:

- a cracking zone to crack a C2+ hydrocarbon feed to provide a cracked hydrocarbon stream comprising at least ethane, ethylene and other components;
- a quench zone in fluid connection with the cracked hydrocarbon stream to quench the cracked hydrocarbon stream to provide a quenched hydrocarbon stream;
- a quenched stream compressor in fluid connection with the quenched hydrocarbon stream to compress the quenched hydrocarbon stream to provide a compressed hydrocarbon stream;
- a hydrocarbon separation zone in fluid communication with the compressed hydrocarbon stream to cool and fractionate the compressed hydrocarbon stream to provide the C2 hydrocarbon stream, wherein the C2 hydrocarbon stream is enriched in ethane and ethylene relative to the cracked hydrocarbon stream.

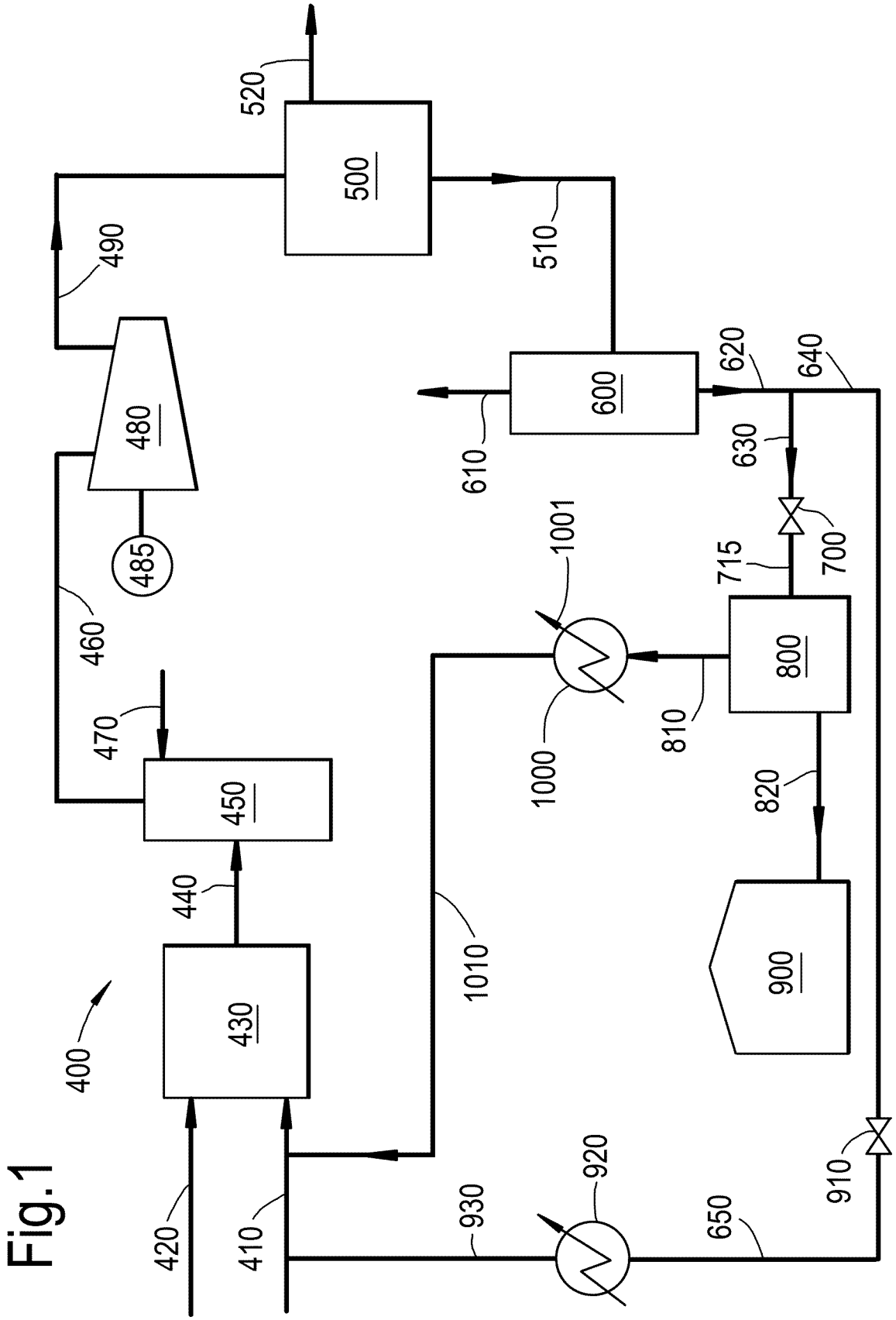

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Fig.1

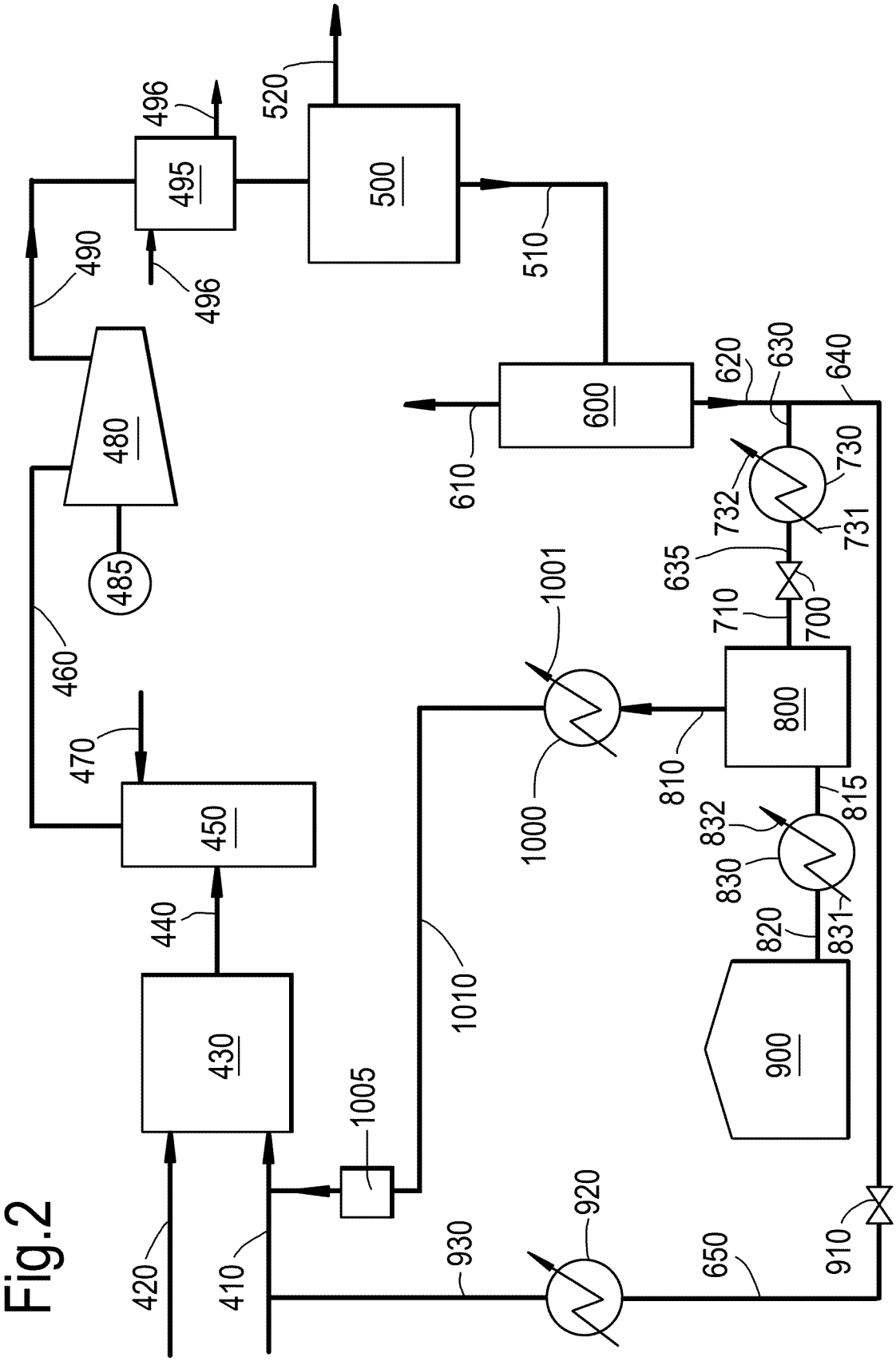

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Fig.2

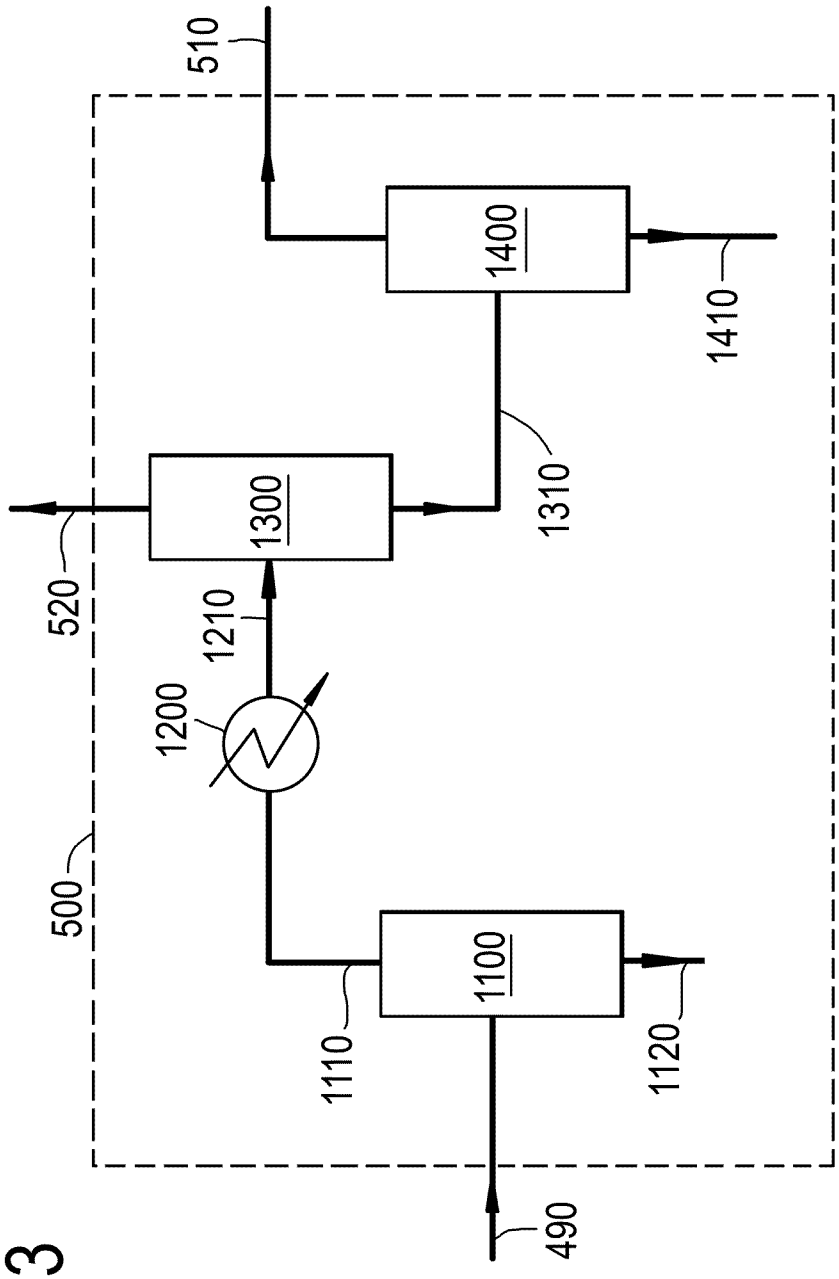


Fig.3

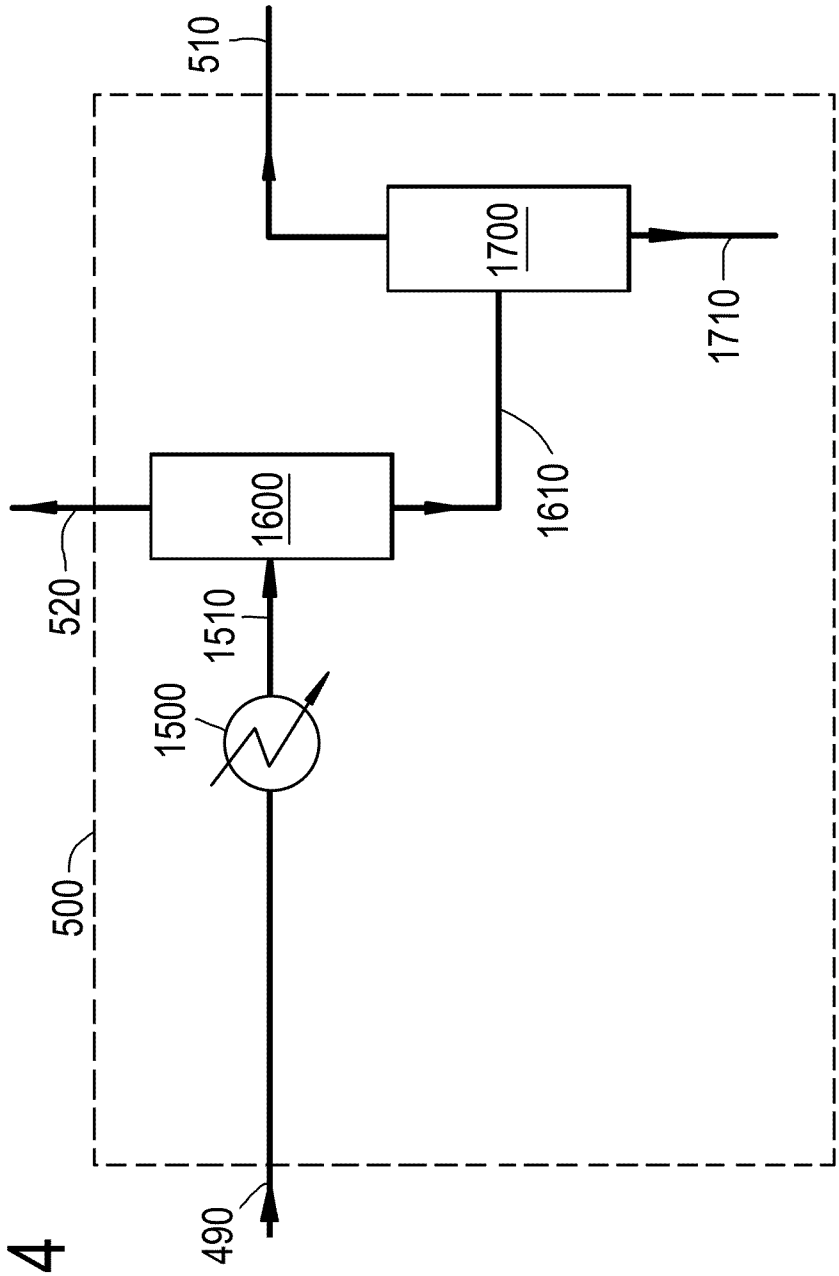


Fig.4