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(54) **Process for the purification of a gas**

(57) The system for the purification of feed gas comprises a compressor (20) with an inlet for feed gas (A), an inlet for a recirculation gas stream (86), and an outlet for compressed gas; cooling means (22) for cooling the compressed gas; a gas-liquid separator (30) arranged downstream of the cooling means (22) for removal of condensate (37) formed during treatment of the compressed gas with the cooling means (22); a solvent absorber (40) for absorbing impurities including volatile organic compounds (VOCs) and carbon dioxide from the compressed and at least partially dried gas, and a separation unit (80) provided with a recirculation outlet for a recirculation gas stream (86), and an outlet for the thus purified gas (B). The solvent absorber (40) is arranged in a solvent circulation circuit (10) comprising a first and a second treatment means (140, 240) for regeneration of the solvent to remove absorbed impurities, said first treatment means (140) being configured for operating at a higher pressure than the second treatment means (240). The solvent recirculation circuit (10) is configured for splitting off a removal stream (145), and a reclaimer unit (60) is present for reducing the VOC concentration of the removal stream (145), a solvent outlet (65) of the reclaiming unit (60) being coupled to the solvent recirculation circuit (10). The system is used for the process of purification of feed gas.

Process for the purification of a gas

Field of the invention

The invention relates to a process for purification of a feed gas comprising the steps of:

- compressing the feed gas;
- removing water from the compressed gas;
- treating the dried and compressed gas for the removal of impurities.

The invention also relates to a system for the purification of feed gas, comprising

- a compressor with an inlet for feed gas, an inlet for a recirculation gas stream, and an outlet for compressed gas;
- cooling means for cooling the compressed gas;
- a gas-liquid separator arranged downstream of the cooling means for removal of condensate formed during treatment of the compressed gas with the cooling means;
- means for absorbing impurities including volatile organic compounds (VOCs) and carbon dioxide from the compressed and dried gas, provided with an recirculation outlet for a recirculation gas stream, and an outlet for the thus purified gas.

Background of the invention

Such a process and such a system are known from WO2007/080169A2. The known process is particularly intended for methane recovery from either landfill feed gas or other anaerobic digesters, for example digesters used for processing farming waste or food processing waste. In the present invention, the feed gas may be biogas, landfill feed gas or any other type of natural gas. Alternatively, the feed gas may be a biogas or landfill gas that has already been treated for the removal of hydrogen sulphide (H2S). Typically and also in the context of the present invention, the feed gas suitably comprises alkanes, particularly lower alkanes, such as C1-C6 alkanes, more particularly C1-C4 alkanes as its key component. Typically, the alkane that is primarily present is methane. Prior to purification, the methane content of the gas is for instance 20-80vol% of the gas, typically 30-60vol%. Other components of the gas are CO2, for instance in 20-60vol%, water, for instance in 1-15vol%, and volatile organic compounds (hereinafter also referred to as VOCs).
The known process is based thereon that the feed gas is first treated to remove hydrogen sulphide, and is subsequently compressed and then treated to remove further impurities. The treatment involves the chilling, i.e. cooling, the compressed gas to between 0.1^0C and 10^0C. Subsequently, water is removed, particularly in a so-called Pressure Swing Adsorption (PSA) drier, in which operation VOCs may be removed as well. In order to further remove the VOCs, a Granulated

Active Carbon (GAC) column is placed after the PSA drier. A membrane separation unit is present downstream of the GAC column to removed the bulk of the carbon dioxide (CO_2) content of the stream. The combination is deemed beneficial, as the membrane needs to be protected from VOCs and any particulates in order to have a long life. Another PSA drier is present downstream of the GAC column to remove the bulk of any nitrogen and most of the remainder of the oxygen, as well as polishing the final traces of the CO_2.

It is a disadvantage of the known process that a GAC column is needed. The use of such a column with activated carbon has the disadvantage that the active carbon needs to be replaced regularly. This leads to significant costs for the operation of a biogas purification plant, which may endanger viability in the long run. Still, it is desired that the resulting gas meets the specifications for gas with respect to its contents of impurities.

Summary of the invention

It is therefore an object of the invention to provide an improved process for the purification of a feed gas of the type mentioned in the opening paragraph, particularly a biogas such as originating from farmers or biological wastes, or a land fill feed gas, which may be operated in a cost-effective manner without any need for an activated carbon column, or wherein any activated carbon column is intended for special purposes and/or for an emergency, such that the frequency of replacement of the active carbon is strongly reduced.

This object is achieved in a process as claimed in claim 1, comprising the steps of compressing the feed gas; removing water from the compressed gas, and treating the at least partially dried and compressed gas for the removal of impurities, wherein the treatment step comprises passing the at least partially dried and compressed gas through a solvent absorber to remove volatile organic compounds (VOCs) and carbon dioxide and any water. Herein, wherein the solvent absorber is arranged in a solvent circulation circuit comprising a first and a second treatment means for regeneration of the solvent to remove the absorbed impurities, said first treatment means being configured for operating at a higher pressure than the second treatment means. Part of the solvent is removed from the solvent recirculation circuit in a removal stream, which is after reduction of its VOC and water concentration returned to the solvent recirculation circuit.

The object is further achieved in a system for the purification of feed gas comprising: a compressor with an inlet for feed gas, an inlet for a recirculation gas stream, and an outlet for compressed gas; cooling means for cooling the compressed gas; a gas-liquid separator arranged downstream of the cooling means for removal of condensate formed during treatment of the compressed gas with the

cooling means; means for absorbing impurities including volatile organic compounds (VOCs), carbon dioxide and any water from the compressed and at least partially dried gas, provided with an recirculation outlet for a recirculation gas stream, and an outlet for the thus purified gas. Herein, the means for absorbing impurities comprise a solvent absorber, which is provided with an inlet for solvent, and with an outlet for the thus treated gas. The solvent absorber is arranged in a solvent circulation circuit comprising a first and a second treatment means for regeneration of the solvent to remove the absorbed impurities, said first treatment means being configured for operating at a higher pressure than the second treatment means. The solvent recirculation circuit is further configured for splitting off a removal stream, wherein a reclaimer unit is present for reducing the VOC concentration of the removal stream, and wherein a solvent outlet of the reclaiming unit is coupled to the solvent recirculation circuit.

According to the invention, a solvent absorber is used instead of an activated carbon column. The removal of impurities in the solvent absorber is operated in a substantially isothermal manner; that is that both the feed gas and the solvent absorber have been cooled in advance of the separation to approximately the same temperature. Herewith, VOCs, a major portion of the carbon dioxide (CO2) and any water can be removed from the at least partially dried and compressed gas. Typically, a major portion of the water that is initially present, is condensed in a preceding condenser. The condensed water is then suitably separated in a vapour-liquid separator. VOCs, water and CO2 absorbed by the solvent are at least partially desorbed in the first and second treatment means.

Particularly, in an important embodiment, the treatment occurs by pressure reduction, so as to generate a (flash) gas. This has the advantage that no treatment gas needs to be supplied for the regeneration of the solvent. Notwithstanding, it is not excluded that the treatment means would involve the treatment with a supplied gas. Preferably, the pressure of the first treatment is controlled at a sufficiently high level, so as to limit loss of methane. In other words, the extent of pressure reduction in the first treatment means is limited. Preferably, the pressure in the second treatment means is sufficiently low, so as to liberate carbon dioxide.

Preferably, the temperature is between 0.1^0C and 10^0C; more preferably the temperature is at most 8^0C or even at most 5^0C. Suitably, the solvent absorber is arranged for countercurrent flow of the solvent stream and the dried and compressed gas stream. It has been understood by the inventors that the methane over CO2 selectivity increases with decreasing temperature, while the overall CO2 capacity of the solvent also increases. It has been further understood by the inventors that the solvent may be regenerated in the solvent recirculation circuit. The CO_2 and the VOCs can herein

be removed from the solvent, at least to a sufficient extent, by treatments with at least one treatment gas at different pressures.

Preferably, the solvent is a so-called physical solvent, as known in the art of gas treatment, wherein the absorbed gas physically dissolves into the solvent, but does not react with the solvent or any other component therein. It is observed for clarity that a physical solvent is known in the art and is typically an organic solvent such as a dialkyl ether of polyethylene glycol (particularly the dimethyl ether also known as DMPEG), N-methylpyrrolidon, propylene carbonate, methanol, N-formylmorpholine. Commercially available examples include Genosorb® and Selexol®. Another solvent such as a so-called hybrid solvent is however not excluded. The advantage of a physical solvent over chemical solvents such as ethanolamines is that physical solvents are non-corrosive, requiring only carbon steel constructions and are easily regenerated by flashing. A physical solvent, particularly a physical solvent with a high boiling point, such as a dialkyl ether of polyethylene glycol is however preferred. This is suitable for a most advantageous embodiment of the invention, wherein a stripper is used at elevated temperature, for instance 100-200^{0}C with the intention that the solvent remains in the liquid state.

Preferably, a removal stream of solvent containing VOCs and any water is taken away from the recirculation circuit and moved to a reclaiming unit for further separation of the VOCs and water from the solvent. The removal stream is suitably divided out of the solvent recirculation circuit in or directly downstream of the first treatment means. It has been found that the removal stream may for instance be 0.5% to 10% of the solvent stream in the recirculation circuit. The magnitude of the removal stream depends strongly on the type of VOCs to be removed and on any specifications for the purified gas with respect to the type of VOC to be removed. For example in the case of biogas, one relevant type of VOCs is formed by terpenes. One of the most volatile terpenes in biogas is alpha-pinene. The concentration of terpenes in the purified gas typically should not exceed 1 to 2 ppm. The removal stream is then in the order of 2% to ensure sufficient removal of alpha-pinene. In the reclaiming unit, the removal stream is suitably treated to lower the concentration of VOCs and water. In this manner, the VOC concentration in the recirculation circuit is stabilized. Suitably, the reclaiming unit thereto comprises treatment means for treatment with a gas. More particularly, these treatment means are embodied as a stripper. The reclaiming unit may contain further means so as to increase the efficiency, and therewith limit the flow rate of removal stream.
It has been found in investigations leading to the present invention, that the use of solvent absorption for the removal of VOCs and CO2 may reduce the need for recirculation of the purified gas back into the compressor. In conventional operations, such as the one described in WO2007/080169A1, the recirculation ratio is typically 1.32. This recirculation ratio is typically

defined as the gas stream after the compression divided by the gas stream before compression. As an alternative to the recirculation ratio, it is also known in the art to refer to the double compression rate. The double compression rate is defined as the magnitude of the recirculation stream to be compressed for the second time relative to the magnitude of the feed stream and is expressed in %. The double compression rate corresponding to a recirculation ratio of 1.32 is 32%. According to the present invention, this recirculation ratio may be reduced to less than 1.3, preferably less than 1.25 or even less than 1.2. This reduction of the recirculation ratio has a major impact on cost effectiveness, since the compression is by far the most energy intensive and thus expensive step of the process – excluding the active carbon column used in the prior art.

The reduction of the recirculation ratio is particularly significant in an embodiment wherein the solvent absorber is combined with a membrane separation unit downstream of the solvent absorber. Rather than using the membrane separation unit for removing the bulk of the carbon dioxide, as in the prior art, it is used herein as an additional CO2 removing operation. In dependence of the size of the solvent absorber and the specifications for the purified gas, the membrane separation unit could even be left out. In an alternative arrangement, merely a portion of the gas treated by the solvent absorber needs to pass the membrane separation unit; i.e. a bypass around the membrane separation unit may be foreseen. In one example, the CO2 concentration of the treated gas ranges from 9 to 16 vol%. The specification on the CO2 content of purified gas is typically in the range of 0 to 10 vol%. However, an advantage of using both a solvent absorber and a membrane separation unit is that the solvent does not need to be very lean. As a consequence, regeneration of the solvent may be achieved by adiabatic flashing, which is considered a most economical regeneration method in terms of installed equipment and operational costs.

In one advantageous embodiment, the at least partially dried and compressed gas is contacted in the solvent absorber with a solvent in a substantially isothermal manner. This has the advantage that the absorption and desorption of carbon dioxide from the physical solvent occurs at substantially the same temperature. Thereto, the solvent circulation circuit further comprises, according to this embodiment, cooling means arranged downstream of said first and second cooling means to cool the solvent to a temperature substantially corresponding to a temperature of the compressed and at least partially dried gas. The use of the same temperature for absorption and regeneration prevents use of additional energy. Preferably, any cooling in the solvent recirculation circuit serves for compensation of heat losses with the environment. However, it is principally not excluded that another temperature would be used. In one important embodiment, the reclaiming operation comprises the steps of:

- Scrubbing a recirculation gas stream from the vapour-liquid separator with the removal stream in a scrubber;
- Stripping the stream of solvent in a stripper with a strip gas to obtain a solvent stream and a gas stream enriched in VOCs;
- Condensing at least part of the VOCs in a vapour-liquid separator into an outlet stream, wherein remaining gas is at least partially recirculated as the recirculation gas stream to the scrubber.

In this embodiment, a cycle of the VOCs is created. Therewith, the concentration of the VOCs can be maintained at a sufficiently high level that allows condensing at least part of the VOCs. The cycle of VOCs involves the scrubbed removal stream (primarily or substantially in a liquid state), the strip gas stream and the remaining partially condensed gas stream from the separator, which is preferably a three-phase separator. It is observed that this process could also be applied separately from the rest of the process, even though its most advantageous application is in the framework of the process as described herein before. It is further observed, as discussed before, that the reclaiming unit may also be operated without a scrubber. However, it has been found that the use of a scrubber, and the created cycle of VOCs leads to a very efficient process.

The yield of the overall process using the preferred reclaiming process may be further enhanced in several optimizations. First of all, the flash gas resulting from the first treatment means of the solvent recirculation circuit may be used, at least partially as the strip gas in the reclaiming unit. This embodiment is not only advantageous for minimization of gas use, but also enables that any VOCs in the strip gas can be added into the reclaiming unit and thus be used to increase the VOC concentration therein.

Furthermore, the solvent stream that is produced in the stripper and is at least largely stripped of any VOCs and water may further be heat exchanged with the scrubbed stream. The stripping process is suitably carried out at a temperature of 100-200°C, whereas the scrubbed stream may for instance be at room temperature or even below room temperature. The heat exchange reduces the need for warming up the solvent in the stripper with heat from an external source, for instance electricity from the grid or from solar panels. It may be implemented by means of one or a series of heat exchangers. They are suitably configured for countercurrent operation.

Preferably, the reclaimed solvent that may be substantially free of VOCs and water is returned to the solvent recirculation circuit. Suitably, the reclaimed solvent is added thereto in the second

treatment means. In this second treatment means, the CO2 is typically flashed off. As a consequence, the resulting flash gas may consist almost entirely of CO2.

In one further embodiment, the liberated CO2 stream is scrubbed with the reclaimed solvent stream, prior to the addition of the latter to the solvent recirculation circuit. This allows obtaining a very dry CO2 stream that is suitable for subsequent liquefaction.

Brief introduction to the figures

These and other aspects of the invention will be further elucidated with respect to the Figures, in which:

Fig. 1 shows schematically a first embodiment of the process and the system of the invention;

Fig. 2 shows schematically the reclaiming unit of the invention;

Fig. 3 shows schematically a second embodiment of the process and the system of the invention, and

Fig. 4 shows schematically a third embodiment of the process and the system of the invention.

Detailed description of illustrated embodiments

The figures are purely schematical. Equal reference numerals in different figures refer to the same or corresponding elements. In the figures, solid lines are used to indicate a gas stream. Dotted lines are used to indicate a stream of solvent. Dash-dotted lines are used to indicate condensate streams, being in particular water and/orVOCs. It is understood that the feed gas used in the process has been pre-treated to remove hydrogen sulphide in known manner.

Fig. 1 shows schematically, in the form of a block scheme, a first embodiment of the system of the invention. According to the invention, a feed gas A is purified into purified gas B. Thereto, it passes subsequently a compressor 20, a cooler 22, a vapour-liquid separator 30, a solvent absorber 40 and a membrane separator 80. Part of the gas stream is recirculated from the membrane separation unit 80 to the compressor 20 via recirculation line 86. The solvent absorber 40 is present within a solvent recirculation circuit 10. In this embodiment, use is made of a physical solvent, which is regenerated by means of pressure reduction without a need for application of heat. The regeneration occurs by means of first treatment means 140 and second treatment means 240. The solvent circulation circuit 10 comprises a solvent line 45 out of the solvent absorber 40 and a further solvent return line 245 out of the second treatment means 240.

The first treatment means 140 is operated by reducing the pressure. The produced gas results from the instantaneous evaporation of a liquid in a pressure-reducing device, therewith cooling the stream to the evaporating temperature obtained at the reduced pressure. The flash gas 146 resulting

from the first treatment means 140 is recirculated to the compressor 20. A portion 146A is split off to the reclaiming unit 60. A removed removal stream 145 of solvent is also taken off in or downstream of the first treatment means and transmitted to the reclaiming unit 60. After the treatment in the reclaiming unit 60, the solvent is returned via solvent return line 65 to solvent recirculation circuit. Preferably, the solvent line 65 is added to the second treatment means 240, wherein the pressure at the same level or even lower than in the solvent line 65. This addition avoids the need of an additional pump. However, it is not excluded that the solvent line 65 is added anywhere else to the solvent recirculation circuit 10 and/or that a pump is added. The second treatment means in which the pressure is lowered, result in liberation of the carbon dioxide through gas line 246. Typically, the bulk of the CO2 is liberated in the second treatment means (the low-pressure flash). This results in a CO2 product C.

The reclaiming unit 60 furthermore comprises an outlet for flash gas, which is returned to the compressor 20 via gas line 66. The reclaiming unit 60 additionally comprises an outlet for condensate. This condensate is led via condensate line 37A, The condensate may also contain amines like ammonia and CO2, particularly dissolved in water (and optionally converted to ions such as HCO_3^- by reaction with the condensed water). The reclaiming unit further contains an outlet for VOC condensate, that is led away via VOC condensate line 67.This results in an aqueous condensate product D, possibly a waste stream, and a VOC condensate product E, which for instance contains terpenes and siloxanes, dependent on the VOC content of the feed gas A.

In the operation of the system, the feed gas A is typically compressed in the compressor 20 to a pressure of 7 to 20 barg depending on the desired pipeline pressure or sales gas specifications. The compressor 20 also has further gas inlets, particularly for gas from the gas line 66 originating from the reclaiming unit 60, and recirculated gas coming via recirculation line 86 from the membrane separation unit 80, as well as for gas originating via line 146 from the first treatment means 140.

In a next step, the feed gas A is cooled to a temperature below 10°C, while preventing ice formation. Coolers are known per se to the skilled person. Preferably, use is made of a two-step cooling process. The first cooling step is done in an air cooled condenser while the second cooling step is done in a condenser cooled with a chiller.

A further cooler 42 is present in the solvent return line 245 of the solvent recirculation circuit 10. This cooler 42 brings the solvent back to a temperature below 10°C, for instance 5^0C or lower prior to the entry of the solvent absorber 40. It is observed that the temperatures reached in the cooler 22 and the cooler 42 are suitably substantially the same, so as to have a truly isothermal absorption

process in the solvent absorber 40. However, it is not excluded that some temperature variations occur, wherein the dried and compressed gas is for instance in the range of 5-10^{0}C, whereas the solvent entering the absorber 40 has a temperature below 5°C. This is acceptable and deemed a substantially isothermal absorption process.

In the following step, condensate is removed in a vapour-liquid separator 30. The condensate is led away via condensate line 37. Such vapour-liquid separators are known per se. An example is a knockout drum.

The now partially dry and pressurized gas is sent to a pressurized solvent absorber 40. The absorber 40 is for instance trayed or packed. The pressurized gas is suitably contacted counter currently with regenerated physical solvent from the solvent return line 245 at a temperature below 10°C while preventing ice formation. The use of such a low temperature is beneficial, as the methane over CO2 selectivity increases with decreasing temperature while the overall CO2 capacity of the physical solvent increases. The treated gas leaves the absorber 40 virtually dry (dew point <-30°C) and nearly free of VOC's (<10 ppm or less, depending on the reclaimer operation) via treated gas line 46. It is observed that the VOC concentration is understood not substantially to depend on the inlet concentration of the VOC in the feed gas A, but only on the VOC concentration in the physical solvent entering the absorber 40. This VOC concentration is controlled by the reclaimer unit 60 which will be described later. The CO2 concentration of the treated gas in the treated gas line 46 typically ranges from 9 to 16 vol%.

In this embodiment, the treated gas line 46 brings the treated gas to the membrane separation unit 80. Herein, the CO2 concentration of the gas is modified so as to be in the specified range for purified gas B. In one embodiment, this concentration ranges from 9 to 16 vol% in the treated gas before membrane separation, for instance 11-14 vol%. After membrane separation, the CO2 concentration is in the range of 0-10%. The exact level of CO2 in the purified gas coming from the membrane separation unit 80 may be controlled in accordance with specifications. Normally membranes are damaged by condensation of water and loose selectivity when VOC's are present in the gas. VOCs need to be removed from the gas by using costly activated carbon. Water is removed by a drying step consisting of cooling the gas, separating the condensate and finally reheating the gas so condensate formation in the membranes is prevented. This mode of operation causes membrane processes to be normally operated at 20-25°C.

According to the present invention, no reheating of the treated gas in treated gas line 46 is necessary. This enables operating of the membrane separation unit 80 at any desired temperature,

such as a temperature below room temperature, for instance at 0^0C or even lower. In one embodiment, the temperature is the outlet temperature of the absorber. Such operation of the membrane separation unit 80 at reduced temperature is beneficial, since the CO2 over methane selectivity increases with decreasing temperature. The selectivity at for example 0°C is 60% higher than at 25°C. Since the treated gas coming from the absorber 40 in the process of the invention is virtually dry and free of VOCs, it is perfectly suited for treatment at or below the freezing point of water, i.e. 0^0C or lower. Preferably, use is made of state-of-the art gas treatment membranes like for example Sepuran supplied by Evonik.

Due to the process of the invention wherein a solvent absorber 40 is used, and particularly in combination with the membrane separation unit 80, a reduced recycle ratio is achieved. The recirculation line 86 leads last amounts of CO2 removed from the treated gas in the membrane separation unit 80 together with a small amount of methane and even less water, to the inlet of the compressor 20. The thus resulting purified gas B that leaves the membrane separation unit 80 is dry (dew point <-40°C), nearly free of VOCs (<10 ppm or less, depending on the reclaimer operation) and is provided with a CO2 concentration between 0 and 10 vol%. The exact CO2 concentration in the purified gas B can be fine tuned by adjusting the pressure of the permeate in the membrane separation unit 80. Herein, lowering the permeate pressure results in a reduced CO2 concentration in the purified gas B.

It is observed that the use of a membrane separation unit 80 in combination with a solvent absorber 40 is also beneficial, as it allows a more robust and simplified configuration of the solvent recirculation circuit 10. Particularly, the first and second treatment means 140, 240 in the solvent recirculation circuit 10 can then be embodied as adiabatic flash vessels. Regeneration by adiabatic flashing is the most economical regeneration method with respect to CAPEX as well as OPEX. Even the temperature drop in the second treatment means, a ‘low pressure flash vessel’ as will be discussed hereinafter, which is per se detrimental to the regeneration process, does not have a negative impact on the overall process. It turns out that CO2 concentrations of 9 to 16% in the treated gas line 46 are easily attained and the membrane unit 80 can easily remove the remainder of the CO2 without adding much to the overall recycle ratio. If however, no membrane separation unit 80 were present and the process should nevertheless be sufficiently versatile for variations both in the feed gas A and to the purified gas B, the regeneration might become too expensive. Particularly, if a 10% CO2 concentration would be needed in the purified gas B, the pressure in the solvent absorber 40 should be at least 10 bara and preferably 14 bara to achieve sufficient mass transfer. If a lower CO2 concentration were desired than 10vol%, the pressure in the absorber 40 would even be higher, leading to very high compression costs, in combination with adiabatic flash.

As an alternative, the physical solvent should be regenerated by air stripping, temperature swing, vacuum flashing or a combination thereof. These techniques are not impossible, but less cost-effective than adiabatic flash operations and have disadvantages. Disadvantages of regeneration by air stripping include dilution of the CO2 product, introduction of additional O2 in the purified gas and oxidation of the physical solvent. Temperature swing regeneration needs repeated heating and cooling of the physical solvent, which is adding to the overall energy consumption making the process uneconomical. Furthermore, special measures should be taken to avoid evaporation losses of the physical solvent adding to the total CAPEX of the process. Vacuum flash regeneration has several disadvantages relating to evaporation losses of the physical solvent, NPSH issues and high energy and investment costs.

In operation, the physical solvent leaving the absorber 40 via solvent line 45 has absorbed most of the CO2 and nearly all water and VOC's. Together with the CO2 some of the methane is absorbed, however at low absorption temperatures (<10°C) the selectivity for CO2 over methane is high. In order to retrieve most of the absorbed methane the physical solvent is regenerated using first and second treatment means 140, 240, which are in this embodiment two adiabatic flash vessels. The first flash vessel 240 is preferably operated at an intermediate pressure (2 to 6 barg) in order to reduce methane losses. The flash gas from the first flash vessel is recycled to the inlet of the compressor 20 via gas line 146. A small part 146A is first sent to the reclaimer unit 60 to be used as a strip gas before it is recycled to the inlet of the compressor 20 via gas line 66. From the first treatment means 140 the physical solvent continues within the solvent recirculation circuit 10 to the second treatment means 240, which is in this embodiment a low pressure flash vessel. Herein, the pressure will normally be 0 bar but can range from 0.5 barg to vacuum. If post treatment of the CO2 gas is needed, for example when the CO2 product is to be liquefied, the pressure in the low pressure flash may range from 0 to 0.2 barg. The regeneration of the physical solvent coming from the absorber40 with respect to CO2 can be done by simple flashing off the CO2 gas at a lower pressure in the second treatment means 240. The flash gas 246 from the low pressure flash 240 suitably consists of nearly pure CO2 at about 0 barg. This means that the physical solvent in the solvent return line 245 coming from the flash vessel 240 is in equilibrium with CO2 gas with a partial pressure of 1 bar.

In the physical solvent reclaiming unit 60, the water and VOCs from the removal stream 145 are removed that would otherwise accumulate over time in the solvent recirculation circuit 10 and eventually result in a failing process. While a mayor part of all water and VOCs is removed by condensation in the cooler 22 and separated in vapour-liquid separator 30, remaining water and VOCs will be transported with the dried and compressed gas to the solvent absorber 40 and will be

usually available at saturation concentrations in the at least partially dried and compressed gas. The water and VOCs will absorb into the physical solvent in the absorber 40 according to Raoult's law. With insufficient removal of these impurities from the physical solvent, the mole fractions of water and VOCs in the solvent circulation circuit 10 could easily exceed 0.2. Therefore, a small side stream varying from 0.5% to 10 volume% of the total physical solvent in the solvent line 45 of the solvent circulation circuit 10 is removed for purification. The size of this removal stream 145 depends strongly on which type of VOC needs to be removed and on the relevant specifications for the purified gas B. For example in the case of biogas the total amount of terpenes in the purified gas B should typically not exceed 1 to 2 ppm. And in the case of alpha-pinene, which is one of the most volatile terpenes in biogas, the size of the removal stream 145 would be less than 2% of the total physical solvent recycle.

While it is deemed beneficial that the removal stream 145 is continuously removed from the solvent circulation circuit 10, it is not excluded that the removal would be carried out batchwise, or semi-continuously (i.e. as batches that are regularly removed and then combined). One preferred implementation is however continuous, since that avoids the provision of a separate pump for the removal stream 145. A valve at the inlet of the reclaiming unit 60, under control of a system controller appears sufficient. As a general observation, it will be understood that the control of pressures and temperatures in the process and system of the invention are to be carried out by means of a controller. The controller is suitably provided with software and settings that ensure that the process is well controlled rather than running away, i.e. and that pressures and temperatures and flows in different portions of the system are balanced.

Figure 2 shows a block scheme of the reclaiming unit 60. The reclaiming unit 60 comprises a scrubber 62, a stripper 70, a condenser 72 and a phase-separator 74 as its prime components. These components are interconnected such that a condensation circuit is generated comprising a feed stream 77, a partially condensed gas stream 78 enriched in VOCs and water and a recirculated gas stream 76. In the scrubber 62, the VOC content of the recirculated gas stream 76 is added into the feedstream 77, which is based on a solvent, preferably a physical solvent. In the stripper 78, the VOCs are transferred from the physical solvent onto a strip gas 146A to form gas stream 78. After cooling, in the shown embodiment in a separate condenser 72, part of the VOCs are condensed in the separator 74 to generate a VOC condensate stream in VOC condensate line 67. In this embodiment, use is made of a three-phase separator to separate an aqueous condensate into aqueous condensate line 37A, condensed VOCs and a remaining gas stream. While such three-phase separator is very beneficial, it is not excluded that alternative implementations are used. Essential is that part of the VOCs is separated from the stream 78. For energy efficiency, the

physical solvent stream 75 from the stripper is heat exchanged in heat exchanger 64 with the feed stream 77 and thereafter returned to the solvent circulation circuit 10 via solvent return line 65. Typically, the VOC concentration in the stream 145 prior to entering the scrubber 62 is in the order of 1%. The strip gas 146A typically contains approximately 0-2 ppm of VOCs. The gas stream 78 however has a VOC concentration that is higher than 1000 ppm, under steady state operation conditions. The recirculated gas stream 76 is typically saturated with VOCs and with water. Thus, due the transfer of the VOCs and water from solvent to strip gas and back via the recirculation line 76 and the scrubber 62, the VOC concentration can be maintained at concentration levels that are far higher than those in the removal stream 145 and the gas stream 146A entering the reclaiming unit 60.

In a preferred embodiment, the scrubber 62 is a packed absorber. More preferably, the stripper 70 is provided with an upper trayed section and a packed bottom section. The packed sections may also be replaced by trayed sections. The removal stream 145 of the physical solvent comes from the first treatment means 140 (see figure 1) and enters the scrubber 62 of the reclaiming unit 60. This particularly occurs at the top at nearly atmospheric conditions. The solvent is contacted in the scrubber 62 with the recirculated gas 76 coming from the separator 74. The recirculated gas 76 is strip gas saturated with VOCs and water. These VOCs and the water are absorbed in the scrubber 62 before the strip gas is recycled to the inlet of the compressor 20 (figure 1) via gas line 66. The now even more enriched physical solvent stream (i.e. feed stream) 77 is sent to a heat exchanger 64 where it exchanges heat with the purified and hot physical solvent 75 coming from the stripper 70. After heat exchanging the solvent is led through the solvent return line 65 to the solvent circulation circuit 10. It suitably passes a further cooler 242, where it is cooled down to a suitable temperature, for instance less than 10 ^{0}C, or even less than 5°C. It is however observed that the cooling down in the cooler 242 may be tuned in combination with the cooling in cooler 42 (see figure 1): if the physical solvent is cooled in further cooler 242 to for instance 0^{0}C, cooling in the cooler 42 may be very limited, or in certain embodiment, cooler 42 may not be necessary at all. Conversely, the function of cooler 242 may also be taken over by cooler 42.

The heated feed stream 77 is transmitted to the stripper 70. In one specific embodiment, the feed 77 enters the packed column of the stripper 70 just below the trayed section. At the bottom of the stripper flash gas 146A coming from the first treatment means 140 (figure 1) is introduced in the heated section of the stripper 70. Preferably, the stripper is configured such that the flash gas 146A moves counter currently to the solvent coming from the top. At the bottom of the stripper 70, the solvent is collected and electrically heated to 100-200°C. Due to this heating and the use of a main heat exchanger 64, the stripping process is carried out at temperatures between 100 and 200°C. The

flash gas stream 146A is typically dry and usually virtually free of VOCs. It is not necessary to use all the flash gas 146 coming from the first treatment means 140. Anything between 5 and 100% may be enough.

Due to the comparatively high temperature in the stripper 70 high stripping factors are obtained and all water and VOCs are carried to the top into a gas stream 78, and to a cooler 72. A main part of the water and VOCs is condensed and sent to a separator 74 for separation of water and the VOCs into VOC condensate line 67 and aqueous condensate line 37A. The separator 74 is for instance embodied as a settler. A small part of the VOCs are refluxed from the VOC condensate line 67 to the stripper in order to wash out the physical solvent from the strip gas (resulting in stream 78) and to reduce evaporation losses of the physical solvent. The solvent washing section suitably comprises 1 or more separation trays. Once the solvent has reached the bottom section of the stripper 70 and has been heated, it is free of water and VOCs. It is then suitable for transport the main heat exchanger 64, where it is cooled while heating the incoming rich feed stream 77 from the scrubber 62.

Figure 3 shows a second embodiment of the system of the invention. This system is optimized to achieve an extremely dry CO2 product, more particularly a CO2 product that is sufficiently dry for liquefaction. However, it is not excluded that this embodiment is applied even in other conditions without the need for CO2 liquefaction. Herein, the solvent return line 65 is not coupled directly to the second treatment means 240. Rather, the solvent return line 65 is led to a further absorber 260, and is then led, via line 265 to the second treatment means 240. In this embodiment, the CO2 gas 246 coming from the low pressure flash vessel 240 is scrubbed in the scrubber 260 by the reclaimed and purified physical solvent 65 coming from the reclaimer 60.

Figure 4 shows a third embodiment of the system of the invention. Herein, the solvent circulation circuit 10 comprises a third treatment means 340 in addition to the first and the second treatment means 140, 240. The third treatment means 340 is effectively arranged upstream of the first treatment means 140. In this embodiment, the third treatment means is again embodied as an adiabatic flash vessel. The pressures in the first, second and third treatment means 140, 240, 340 are controlled such as to be intermediate, low and high, comparatively to each other, and particularly in the context of the pressures used within the system. The flash gas 346 coming from the third treatment means 340 is subsequently combined with the flash gas 146 coming from the first treatment means 140. An advantage of this embodiment is a further reduction of the recycle ratio, while maintaining a very low methane slip. In the case of biogas or landfill gas treatment the addition of an additional flash vessel 340 decreases the overall energy demand by 0.01 kWhe/Nm3

of feed gas. While not specified, it will be understood that the third embodiment shown in Figure 4 may be combined with the second embodiment shown in Figure 3. Again, the reclaiming unit 60 is preferably embodied as shown in Figure 2. However, it is not excluded that variations are applied.

Example

Example 1: Upgrading of 1000 Nm3/h Biogas with 1000 ppm alpha-pinene

In this example the upgrading of 1000 Nm3/h of biogas is described using the process and system of the invention. The biogas A is coming from a household waste digester and contains significant amounts of terpenes. In this example it contains 1000 ppm of alpha-pinene, one of the most volatile terpenes present in biogas. H2S has been removed before the biogas is processed in the system of the invention. Reference will be made in the following to the Figures 1 and 2.

First, feed gas A is mixed with the recycle streams 146 66 and 86 coming from the high pressure flash 140, reclaimer unit 60 and membrane unit 80 respectively. The total flow of recycle streams is 180 Nm3/h. This means that the recycle ratio is 1.18 or that the double compression rate is 18% The collected gas streams are entered into the compressor 20, that is in this example embodied as an oil screw compressor. Herein the feed A is compressed to 11 bara and subsequently cooled to 5°C in the cooler 20. The vapor pressure of alpha-pinene is 1.73 mbar at 5°C and at 5°C and 11 bara 81% of all alpha-pinene is condensed together with the 42.8 kg/h of water. In total about 47.7 kg/h of condensate is separated from the gas steam into condensate line 37 using the gas/liquid separator 30.

The cooled, dried and compressed gas is transmitted to the solvent absorber 40, that is in this implementation packed with 5 m of Mellapak 250.Y and has a diameter of 0.5 m. The gas is scrubbed in the absorber 40 with 29.000 kg/h of physical solvent. The treated gas 46 leaving the absorber 40, in a flow rate of 617 Nm3/h, is now dry and contains 41 ppm of water and only 1 ppm alpha-pinene. The CO2 concentration is 12.4 vol%. This gas 46 is excellently suited for membrane treatment and it is sent to a membrane unit 80 consisting of 15 SEPURAN GREEN (100x1200) Membranes. At 1 bara permeate pressure the CO2 concentration of the purified gas B is 7.22 vol%, whereas at a permeate pressure of 1.9 bara the CO2 concentration is 10.0 vol%.

The physical solvent is regenerated in the solvent circulation circuit 10. The first treatment means 140, embodied as a high pressure flash, is operating at a pressure of 3.7 barg. The second treatment means 240, embodied as a low pressure flash, is operating at 0 barg. As will be understood, the terms high and low are used herein in their relative sense.

From the 29740 kg/h of physical solvent coming from the high pressure flash 140 only 325 kg/h is sent to the reclaimer unit 60 via removal line 145. The reclaimer unit 60 of this example comprises a scrubber 62 with a packed height of 2 meters and a diameter of 0.15 m. The packing type is Mellapak 250.Y. About 99.8 Nm3/h saturated strip gas 76 recirculated from the stripper 70 via the condenser 74 enters the scrubber 62, particularly at the bottom. From the scrubber 62, the solvent stream 77 is heated in the heat exchanger 62 and enters the stripper 70, particularly at the top of the stripper 70. The solvent obtains a temperature of 150°C within the stripper 70, due to the hot solvent coming from the bottom of the stripper 70. The solvent in the bottom is electrically heated tot 175°C. The total heating duty is 14.9 kW.

About 98.5 Nm3/h of flash gas 146A from the first treatment means 140 (high pressure flash) is used to strip all terpenes and water from the physical solvent stream 77. The enriched strip gas 78 leaves the stripper 70 and is cooled and partially condensed in a cooler 72 and separated in a separator 74. A condensate consisting of water (0.5 kg/h) and alpha-pinene (1.1 kg/h) is formed into VOC condensate line 67 and aqueous condensate line 37. A small reflux 67A of 6 kg/h is needed to reduce or even eliminate physical solvent losses. The stripper 70 has packed height of 3 meters and a diameter of 0.2 m. The packing type is Mellapak 250.Y.

Table 1 demonstrates the changes in composition of the biogas according to the invention, using the settings of the example. For the membrane separation 80, a permeate pressure of 1 bara has been used. The methane concentration is increased from 52.2 vol% in the feed gas A to 90.2 vol% in the purified gas B. The carbon dioxide content is reduced from 41.3 vol% to 7.6vol%. As is apparent from Table 1, the membrane separation results in a further reduction of close to 40% relative to the CO2 content in the treated gas 46. The content of the VOC alpha-pinene is reduced from 1000 ppm to 1 ppm. This result is achieved by means of the condenser 30 and the solvent absorber 40.

Component	*Concentration of feed A*	*Concentration in treated gas (46) downstream of solvent absorber*	*Concentration in purified gas B,*
Methane	52.2 vol%	85.6 vol%	90.2 vol%
CO2	41.3 vol%	12.4 vol%	7.6 vol%
Water	5.4 vol%	0.0041 vol%	0.0010 vol%
H2S	<3 ppm	<3 ppm	<3 ppm
Nitrogen	0.9 vol%	1.6 vol%	1.6 vol%

Oxygen	0.2 vol%	0.4 vol%	0.4 vol%
Alpha-pinene	1000 ppm	1 ppm	1 ppm

Table 1. Composition of Biogas

Table 2 shows the composition of the CO2 product. The methane composition is herein only 1.2%, which demonstrates that the loss in the process is very small. The overall methane yield of the process is 99.1%.

Component	*Concentration*
Methane	1.2 vol%
CO2	98.7 vol%
Water	0.043 vol%
H2S	<3 ppm
Nitrogen	0 vol%
Oxygen	0 vol%
Alpha-pinene	0 ppm

Table 2. CO2 product gas 246 coming from the second treatment means 240

Category	*Duty*
Compression	153.6
Heating	14.9
Cooling	4.5
Pumping	10.2
Total	183.2

Table 3. Duties of the process divided for the different categories

Table 3 shows the duties for the different categories in the process of the invention. The major part (83.8%) of the energy is consumed by the compressor. This compressor duty is needed for every upgrading process for biogas. Biogas is generally available at a pressure of 0 - 50 mbarg. The pipeline specifications require a green gas pressure of at least 8 barg. Pressurizing 1000 Nm3/h of biogas to 8 barg without any treatment would consume about 123.7 kW electrical power.

Thus, in summary, the prevent invention relates to a process and a system for the purification of feed gas. The system comprises a compressor (20) with an inlet for feed gas (A), an inlet for a recirculation gas stream (86), and an outlet for compressed gas; cooling means (22) for cooling the compressed gas; a gas-liquid separator (30) arranged downstream of the cooling means (22) for

removal of condensate (37) formed during treatment of the compressed gas with the cooling means (22). The system further comprises a solvent absorber (40) for absorbing impurities including volatile organic compounds (VOCs) and carbon dioxide from the compressed and at least partially dried gas, and a separation unit (80) provided with a recirculation outlet for a recirculation gas stream (86), and an outlet for the thus purified gas (B). The solvent absorber (40) is arranged in a solvent circulation circuit (10) comprising a first and a second treatment means (140, 240) for regeneration of the solvent to remove absorbed impurities, said first treatment means (140) being configured for operating at a higher pressure than the second treatment means (240). The solvent recirculation circuit (10) is configured for splitting off a removal stream (145), and a reclaimer unit (60) is present for reducing the VOC concentration of the removal stream (145), a solvent outlet (65) of the reclaiming unit (60) being coupled to the solvent recirculation circuit (10). The system is used for the process of purification of feed gas.

Conclusies

1. Proces voor het zuiveren van een voedingsgas omvattende de stappen van:
   - Compressie van het voedingsgas;
   - Verwijdering van water uit het samengedrukte gas;
   - Behandeling van het ten minste gedeeltelijk gedroogde en samengedrukte gas ter verwijdering van verontreinigingen,

   waarin de behandelingsstep omvat het leiden van het ten minste gedeeltelijk gedroogde en samengedrukte gas door een absorptiemiddel voor oplosmiddel voor het verwijderen van vluchtige organische koolwaterstoffen (VOC), koolstofdioxide en water,
   waarin het absorptiemiddel voor oplosmiddel onderdeel is van een oplosmiddelcirculatiecircuit omvattende een eerste en een tweede behandelingsmiddel voor opwerking van het oplosmiddel om de geabsorbeerde verontreinigingen te verwijderen, welk eerste behandelingsmiddel opgezet is voor het werken op een hogere druk dan het tweede behandelingsmiddel, en waarin een deel van het oplosmiddel verwijderd wordt uit het oplosmiddelcirculatiecircuit naar een verwijderingsstroom, die na vermindering van diens VOC-concentratie teruggevoerd wordt naar het oplosmiddelcirculatiecircuit.

2. Proces volgens conclusie 1, waarin het behandelde gas verder door een membraaneenheid geleid wordt, die zich stroomafwaarts van het absorptiemiddel voor oplosmiddel bevindt, om zo het koolstofdioxide-gehalte van het gas te verminderen en gezuiverd gas te verkrijgen.

3. Proces volgens conclusie 1 of 2, waarin het behandelde gas gedeeltelijk teruggevoerd wordt naar de compressor, waarbij een recirculeringsverhouding kleiner is dan 1,3, en waarin de recirculeringsverhouding gedefinieerd is als de verhouding van de gasstroom na compressie en de voedingsgasstroom voorafgaand aan compressie.

4. Proces volgens conclusie 3, waarin de recirculeringsverhouding kleiner is dan 1,2.

5. Proces volgens één van de voorgaande conclusies, waarbij het absorptiemiddel voor oplosmiddel wordt bedreven bij een temperatuur tussen 0 en 10 °C.

6. Proces volgens conclusie 1, waarbij de vermindering van het VOC-gehalte in de verwijderingsstroom het strippen van het oplosmiddel met behulp van een strip-gas omvat.

7. Proces volgens conclusie 7, waarin de vermindering van het VOC-gehalte in de verwijderingsstroom uitgevoerd wordt volgens de werkwijze volgens één van de conclusies 15-19.

8. Proces volgens één van de voorgaande conclusies, waarin de behandeling in de eerste en de tweede behandelingsmiddelen een drukverlaging omvat, zodanig dat flash gas ontstaat.

9. Proces volgens conclusie 6, waarin het strip-gas flash gas is dat afkomstig is uit het eerste behandelingsmiddel in het oplosmiddelcirculatiecircuit.

10. Proces volgens conclusie 6, waarin de oplosmiddelstroom toegevoegd wordt aan het oplosmiddelcirculatiecircuit in het tweede behandelingsmiddel.

11. Proces volgens één van de voorgaande conclusies, waarin koolstofdioxide vrijkomt bij de regeneratie van het oplosmiddel in het tweede behandelingsmiddel.

12. Proces volgens conclusie 11, waarin de resulterende koolstofdioxide stroom gescrubt wordt met de oplosmiddelstroom voorafgaande aan diens toevoeging aan het oplosmiddelcirculatiecircuit.

13. Proces volgens één van de voorgaande conclusies, waarin het voedingsgas gekozen is uit biogas, gas van een afvalstortplaats en/of aardgas, en waarbij waterstofsulfide verwijderd is uit het voedingsgas voorafgaand aan de compressie.

14. Proces volgens één van de voorgaande conclusies, waarin het ten minste gedeeltelijk gedroogde en samengedrukte gas in het absorptiemiddel voor oplosmiddel in contact gebracht wordt met een oplosmiddel op een in hoofdzaak isotherme wijze.

15. Werkwijze voor het afscheiden van vluchtige organische koolwaterstoffen (VOCs) uit een voedingsstroom omvattend een oplosmiddel, waarin gebruikt gemaakt wordt van een condensatiecircuit met een scrubber, een stripper, een koeler en een damp-vloeistofscheider, omvattende de stappen van:
    - Het scrubben van een recirculatiegasstroom uit de damp-vloeistofscheider met de voedingsstroom in de scrubber;

- Het strippen van de voedingsstroom in de stripper met een strip-gas ter verkrijging van een oplosmiddelstroom en een gasstroom verrijkt met VOCs;
- Het condenseren van ten minste een deel van de VOCs aanwezig in de gasstroom verrijkt met VOCs in de koeler;
- Het afscheiden van gecondenseerde VOCs in een uitgangsstroom, waarbij overblijvend gas ten minste gedeeltelijk teruggevoerd wordt als de recirculatiegasstroom naar de scrubber.

16. Werkwijze volgens conclusie 15, waarin warmte-uitwisseling plaats heeft tussen de oplosmiddelstroom en de voedingsstroom in een warmtewisselaar stroomafwaarts van de scrubber.

17. Werkwijze volgens conclusie 15 of 16, waarin een deel van de uitgangsstroom van gecondenseerde VOCs teruggevoerd wordt naar de stripper.

18. Werkwijze volgens één van de conclusies 15-17,, waarin de gasstroom verrijkt in VOCs stroomafwaarts van de stripper gekoeld wordt tot een temperatuur beneden 10 °C,, bij voorkeur tot beneden 5 °C.

19. Werkwijze volgens één van de conclusies 15-18, waarin de voedingsstroom verder water omvat, en waarin tenminste een deel van het water gecondenseerd wordt in de condensatiestap en dan afgescheiden wordt in een tweede waterige uitgangsstroom.

20. Systeem voor de zuivering van een voedingsgas, omvattend:
- een compressor met een inlaat voor voedingsgas, een inlaat voor een recirculatiegasstroom en een uitlaat voor samengedrukt gas;
- een koelmiddel voor het koelen van het samengedrukte gas;
- een gas-vloeistofscheider die stroomafwaarts van het koelmiddel geplaatst is, voor het verwijderen van een condensaat gevormd tijdens behandeling van het samengedrukte gas met het koelmiddel;
- middel voor de absorptie van verontreinigingen inclusief vluchtige organische koolwaterstoffen (VOCs) en koolstofdioxide uit het samengedrukte en ten minste gedeeltelijk gedroogde gas, voorzien van een recirculatie-uitlaat voor een recirculatiegasstroom, en een uitlaat voor het aldus gezuiverde gas,

waarin:

- het middel voor absorptie van verontreinigingen een absorptiemiddel voor oplosmiddel omvat, dat voorzien is van een inlaat voor oplosmiddel en van een uitlaat voor het aldus behandelde gas;
- het absorptiemiddel voor oplosmiddel geplaatst is een oplosmiddelrecirculatiecircuit comvattend een eerste en een tweede behandelingsmiddel voor opwerking van het oplosmiddel om geabsorbeerde verontreinigingen te verwijderen, welk eerste behandelingsmiddel opgezet is om te werken bij een hogere druk dan het tweede behandelingsmiddel;
- het oplosmiddelcirculatiecircuit opgezet is voor het afsplitsen van een verwijderingsstroom;
- een reclaimer-eenheid aanwezig is voor het verminderen van de VOC-concentratie van de verwijderingsstroom, waarbij een oplosmiddeluitlaat van de reclaiming-eenheid gekoppeld is aan het oplosmiddelrecirculatiecircuit.

21. Systeem volgens conclusie 20, waarin de reclaimer-eenheid een stripper omvat.

22. Systeem volgens conclusie 20 of 21, waarin de reclaimer-eenheid het apparaat volgens één van de conclusies 25-27 omvat.

23. Systeem volgens één van de conclusies 20-22, waarin het absorptiemiddel verder een scheidingseenheid stroomafwaarts van het absorptiemiddel voor oplosmiddel omvat, welke scheidingseenheid voorzien is van e en recirculatie-uitlaat en de uitlaat voor gezuiverd gas, welke scheidingseenheid opgezet is om een koolstofdioxide gehalte van het behandelde gas verder te verminderen en bij voorkeur een membraanscheidingseenheid is.

24. Systeem volgens één van de conclusies 2-0-23, waarin het genoemde oplosmiddelrecirculatiecircuit verder een koelmiddel omvat dat zich stroomafwaarts van de genoemde eerste en tweede behandelingsmiddelen bevat om het oplosmiddel te koelen tot een temperatuur in hoofdzaak overeenkomend met een temperatuur van het samengedrukte en gedroogde gas.

25. Apparaat voor het afscheiden van vluchtige organische koolwaterstoffen (VOCs) uit een voedingsstroom, omvattend een condensatiecircuit voorzien van:
- een scrubber omvattend een inlaat voor de voedingsstroom omvattend een oplosmiddel met VOCs en een uitlaat voor de voedingsstroom verrijkt in VOCs, een inlaat voor een teruggevoerde gastroom en een uitlaat voor een gescrubte gasstroom;

- een stripper stroomafwaarts van de scrubber van het oplosmiddel, met een inlaat voor strip-gas, een inlaat voor de voedingsstroom, een gasuitlaat voor een gas verrijkt in VOCs en een uitlaat voor een oplosmiddelstroom;
- een koeler stroomafwaarts van de stripper en bestemd voor het koelen van de gasstroom;
- een damp-vloeistofscheider gekoppeld aan de koeler, met een uitlaat voor een vloeistofstroom en een recirculatie-uitlaat voor een gasstroom, waarbij de genoemde gasstroom van de recirculatie-uitlaat ten minste gedeeltelijk teruggevoerd wordt naar de scrubber.

26. Apparaat volgens conclusie 25, verder omvattend een warmtewisselaar voor warmte-uitwisseling tussen de voedingsstroom stroomafwaarts van de scrubber en de oplosmiddelstroom.

27. Apparaat volgens conclusie 25 of 26, waarin de damp-vloeistofscheider een driefasescheider is met een eerste uitlaat voor een vloeistofstroom primair of in hoofdzaak bestaande uit VOCs, een tweede uitlaat voor een waterige vloeistofstroom en de recirculatie-uitlaat.

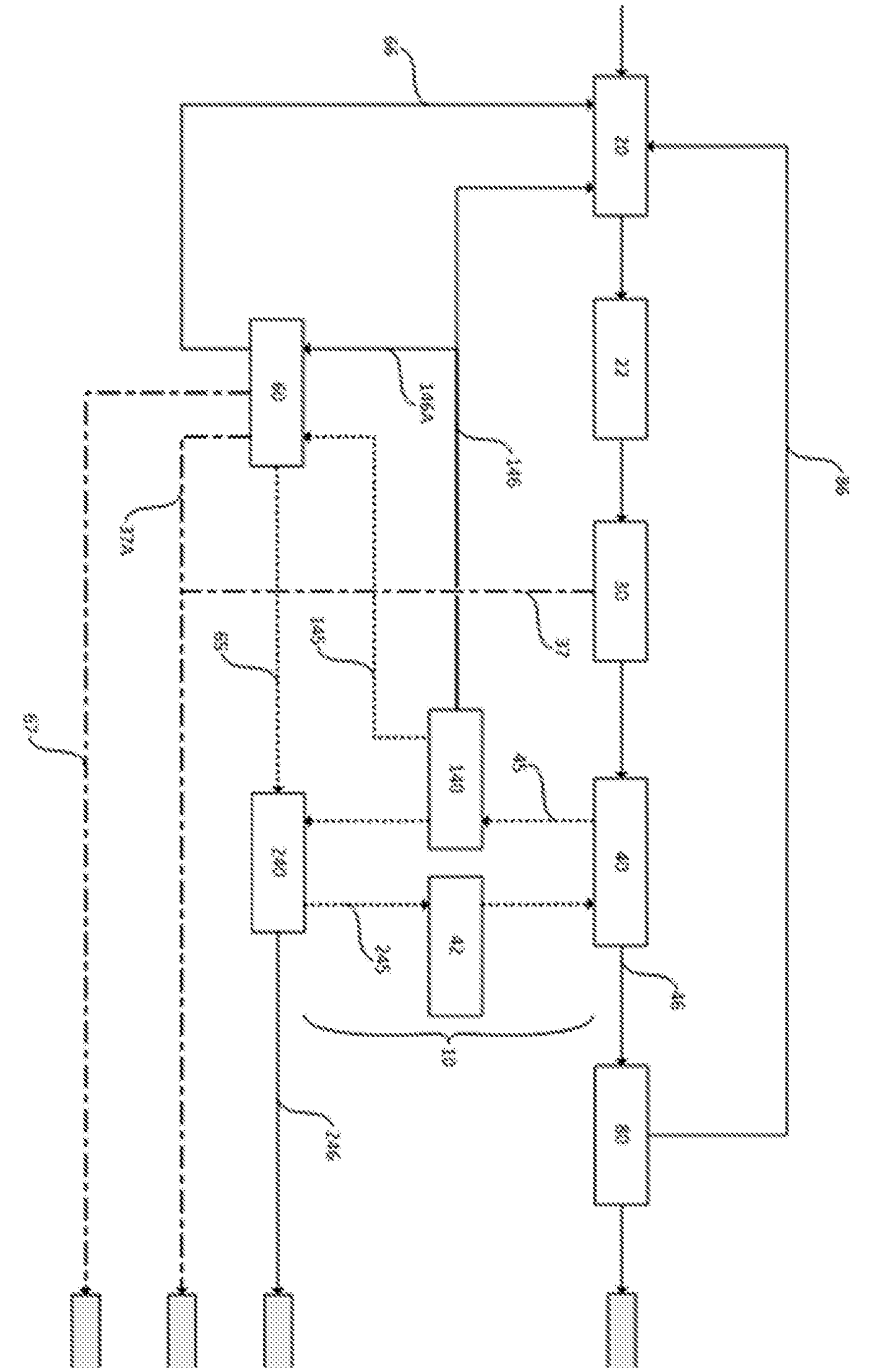

Fig. 1

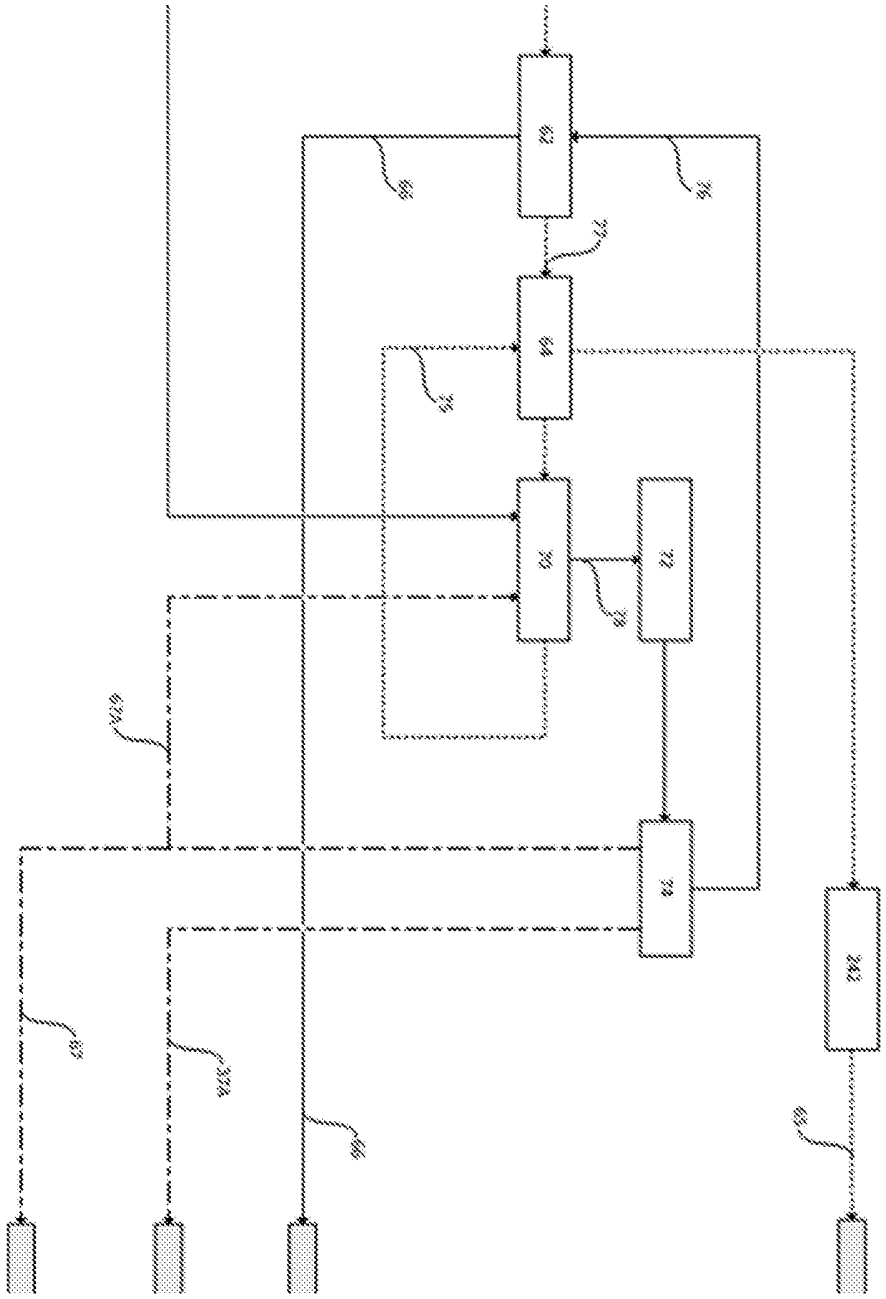

Fig. 2

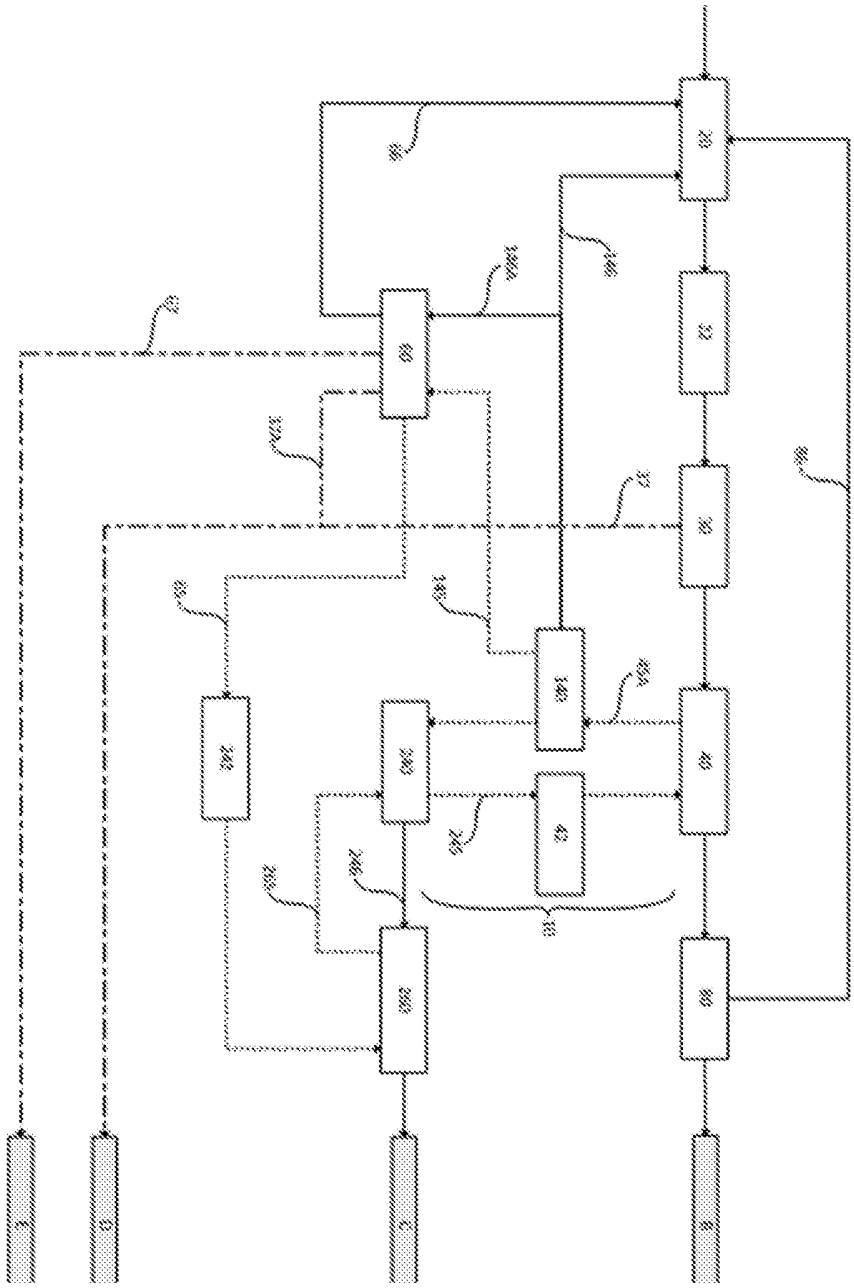

Fig. 3

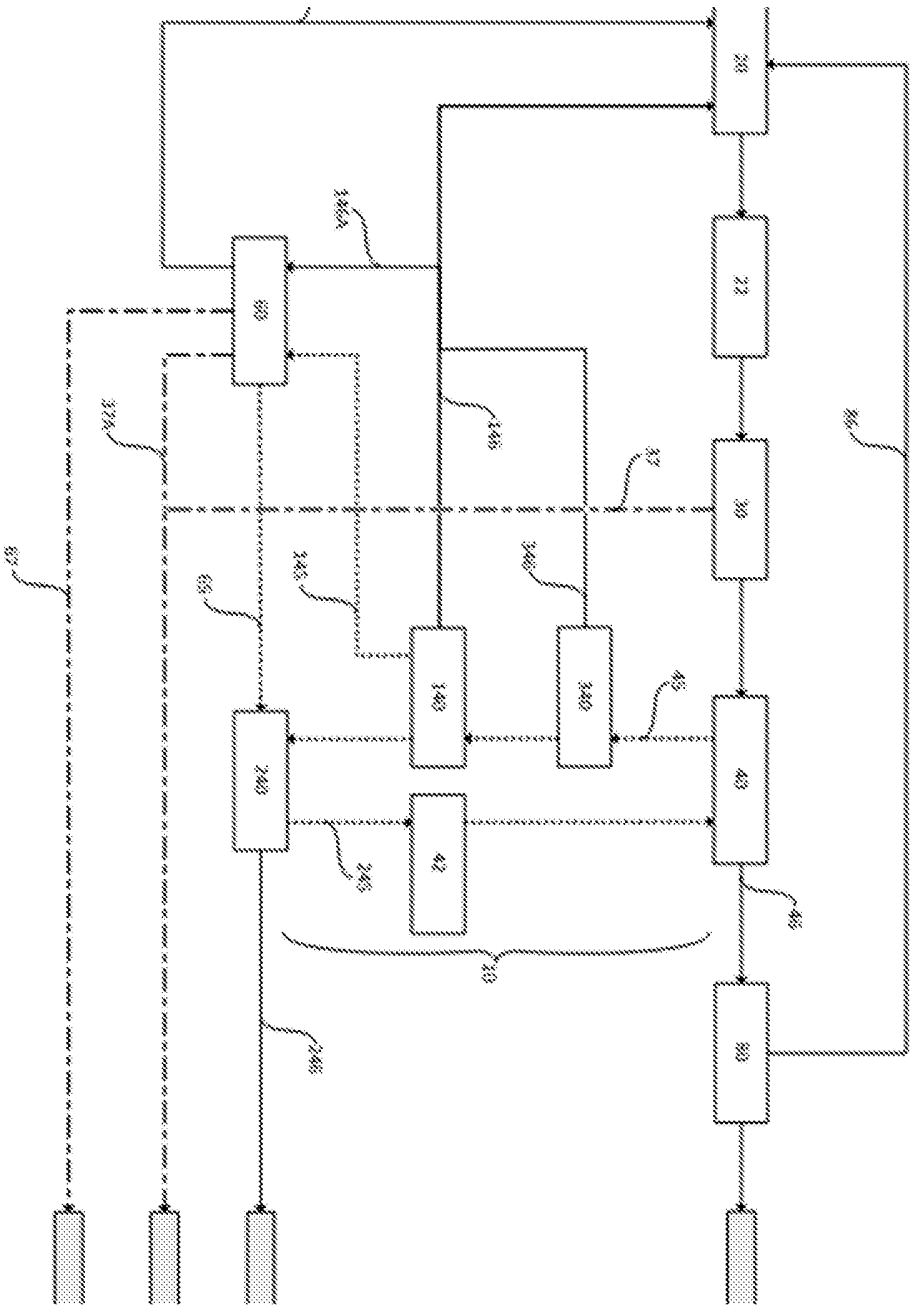

Fig. 4

Abstract

The system for the purification of feed gas comprises a compressor (20) with an inlet for feed gas (A), an inlet for a recirculation gas stream (86), and an outlet for compressed gas; cooling means (22) for cooling the compressed gas; a gas-liquid separator (30) arranged downstream of the cooling means (22) for removal of condensate (37) formed during treatment of the compressed gas with the cooling means (22); a solvent absorber (40) for absorbing impurities including volatile organic compounds (VOCs) and carbon dioxide from the compressed and at least partially dried gas, and a separation unit (80) provided with a recirculation outlet for a recirculation gas stream (86), and an outlet for the thus purified gas (B). The solvent absorber (40) is arranged in a solvent circulation circuit (10) comprising a first and a second treatment means (140, 240) for regeneration of the solvent to remove absorbed impurities, said first treatment means (140) being configured for operating at a higher pressure than the second treatment means (240). The solvent recirculation circuit (10) is configured for splitting off a removal stream (145), and a reclaimer unit (60) is present for reducing the VOC concentration of the removal stream (145), a solvent outlet (65) of the reclaiming unit (60) being coupled to the solvent recirculation circuit (10). The system is used for the process of purification of feed gas.

Fig. 1

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	4H/2SS39/ASe/1
Nederlands aanvraag nr. **2015921**	Indieningsdatum **08-12-2015**
	Ingeroepen voorrangsdatum

Aanvrager (Naam)

Frames Renewable Energy Solutions B.V.

Datum van het verzoek voor een onderzoek van internationaal type	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr.
06-08-2016	**SN67055**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

B01D53/14

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC	**B01D**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.		**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	X	**GEBREK AAN EENHEID VAN UITVINDING**	(opmerkingen op aanvullingsblad)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2015921

A. CLASSIFICATIE VAN HET ONDERWERP
INV. B01D53/14
ADD.

Volgens de internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)
B01D

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)
EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
	EENHEID VAN UITVINDING ONTBREEKT zie aanvullingsblad B -----	
Y	US 8 840 708 B1 (MORROW DAVID C [US] ET AL) 23 september 2014 (2014-09-23) * kolom 1; figuur 4 * -----	1-14, 20-24
Y	US 2014/134710 A1 (GRILL JEFFREY J [US]) 15 mei 2014 (2014-05-15) * alineas [0065], [0068]; figuren 3,4 * * samenvatting * -----	1-14, 20-24
A	US 2014/329299 A1 (GUENTHER LOTHAR [DE]) 6 november 2014 (2014-11-06) * alinea [0048]; figuur 1 * -----	1-14, 20-24

-/--

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

* Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid	Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type
30 september 2016	

Naam en adres van de instantie	De bevoegde ambtenaar
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Gruber, Marco

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ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2015921

C. (Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
A	TENTSCHER, W.: "Anforderungen und Aufbereitung von Biogas zur Einspeisung in Erdgasnetze", GWF DAS GAS- UND WASSERFACH, GAS-ERDGAS, deel 148 (2007), nr. 9, 2007, XP009191826, * het gehele document *	1-14, 20-24
A	DE 103 56 276 A1 (TENTSCHER WOLFGANG [DE]) 30 juni 2005 (2005-06-30) * het gehele document *	1-14, 20-24
A	US 2010/107872 A1 (BETHELL WARWICK JAMES [NZ]) 6 mei 2010 (2010-05-06) * het gehele document *	1-14, 20-24

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GEBREK AAN EENHEID VAN UITVINDING

Octrooiaanvrage Nr.:
SN 67055
NL 2015921

AANVULLINGSBLAD B

De instantie belast met het uitvoeren van het onderzoek naar de stand van de techniek heeft vastgesteld dat deze aanvrage meerdere uitvindingen bevat, te weten:

1. conclusies: 1-14, 20-24

Process and system for purifying a feed gas by removing carbon dioxide, volatile organic carbons (VOCs) and water by absorption in a solvent absorber and comprising first and second means for treating the loaded solvent for removing the absorbed gases wherein the first and second means operate at different pressures, the first one at higher pressure than the second one and further comprising a solvent circulation circuit (reclaimer) for further reducing the content of VOCs in the solvent and recirculating the lean solvent.

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2. conclusies: 15-19, 25-27

Process and system for separating volatile organic carbons (VOCs) from a feed stream comprising a condensation circuit with a scrubber for scrubbing VOCs with a solvent, a stripper for contacting the loaded solvent with a stripping gas and obtaining a gas rich in VOCs and a lean solvent, a cooler for the gas rich in VOCs and a vapor-liquid separator for the cooled gas rich in VOCs wherein at least a part of gas rich in VOCs is recirculated to the scrubber.

Het vooronderzoek werd tot het eerste onderwerp beperkt.

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek: NL 2015921

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 8840708 B1	23-09-2014	GEEN	
US 2014134710 A1	15-05-2014	GEEN	
US 2014329299 A1	06-11-2014	CN 104023819 A	03-09-2014
		DE 112011105958 A5	28-08-2014
		EP 2790810 A1	22-10-2014
		RU 2014128160 A	10-02-2016
		US 2014329299 A1	06-11-2014
		WO 2013087046 A1	20-06-2013
DE 10356276 A1	30-06-2005	GEEN	
US 2010107872 A1	06-05-2010	EP 2134446 A1	23-12-2009
		NZ 553992 A	31-10-2008
		US 2010107872 A1	06-05-2010
		WO 2008115079 A1	25-09-2008

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN67055	08.12.2015		NL2015921

International Patent Classification (IPC)
INV. B01D53/14

Applicant
Frames Renewable Energy Solutions B.V.

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☒ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☒ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the application
- ☐ Box No. VIII Certain observations on the application

Examiner
Gruber, Marco

Application number

WRITTEN OPINION

NL2015921

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Application number

WRITTEN OPINION

NL2015921

Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step, or to be industrially applicable have not been examined in respect of

☐ the entire application

☒ claims Nos. 15-19, 25-27

because:

☐ the said application, or the said claims Nos. relate to the following subject matter which does not require a search *(specify)*:

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed *(specify)*:

☒ no search report has been established for the whole application or for said claims Nos. 15-19, 25-27

☐ a meaningful opinion could not be formed as the sequence listing was either not available, or was not furnished in the international format (WIPO ST25).

☐ a meaningful opinion could not be formed without the tables related to the sequence listings; or such tables were not available in electronic form.

☐ See Supplemental Box for further details.

Box No. IV Lack of unity of invention

1. The requirement of unity of invention is not complied with for the following reasons:

   see separate sheet

2. This report has been established in respect of the following parts of the application:

   ☐ all parts.

   ☒ the parts relating to claims Nos. (see Search Report)

Application number

WRITTEN OPINION

NL2015921

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	1-14, 20-24
	No:	Claims	
Inventive step	Yes:	Claims	
	No:	Claims	1-14, 20-24
Industrial applicability	Yes:	Claims	1-14, 20-24
	No:	Claims	

2. Citations and explanations

see separate sheet

Re Item IV

1 Unity of invention

1.1 With regard to the independent claims of the present application, i.e. claims 1,15,20 and 25, it is noted that two groups of inventions have been identified:

Group 1 (claims 1-14,20-24):

Process and system for purifying a feed gas by removing carbon dioxide, volatile organic carbons (VOCs) and water by absorption in a solvent absorber and comprising first and second means for treating the loaded solvent for removing the absorbed gases wherein the first and second means operate at different pressures, the first one at higher pressure than the second one and further comprising a solvent circulation circuit (reclaimer) for further reducing the content of VOCs in the solvent and recirculating the lean solvent.

Group 2 (claims 15-19, 25-27)

Process and system for separating volatile organic carbons (VOCs) from a feed stream comprising a condensation circuit with a scrubber for scrubbing VOCs with a solvent, a stripper for contacting the loaded solvent with a stripping gas and obtaining a gas rich in VOCs and a lean solvent, a cooler for the gas rich in VOCs and a vapor-liquid separator for the cooled gas rich in VOCs wherein at least a part of gas rich in VOCs is recirculated to the scrubber.

1.2 Having regard to the independent claims which are to be considered in the first place, no special common technical features can be identified. The only features that both groups have in common are a solvent adsorber for volatile organic carbons (VOCs), means for removing absorbed VOCs from the solvent and recirculation means for the lean solvent.

These features, however, are not special technical features since they are known in the art, ref. e.g. D1 (US 8 840 708 B1), where (ref. Fig. 2 in combination with col. 1, l. 39 to 65) aromatics are absorbed by a physical solvent such as SELEXOL in an absorber (12), the loaded solvent (32) is fed to a column (16) acting as a stripper for the solvent by using a stripping gas (100) and the lean solvent (32) being recirculated via pump (110) to the absorber column (12).

Although both groups appear to solve the same problem, i.e. to extract VOCs from a gas stream, this problem has already be solved in the art, i.e. in D1.

Hence, no general inventive concept based on special common features can be identified between the two groups. Consequently, unity of invention is not present between the two groups.

The search and the written opinion have been established for the first group.

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

2 Reference is made to the following documents:

D1 US 8 840 708 B1 (MORROW DAVID C [US] ET AL) 23 september 2014 (2014-09-23)

D2 US 2014/134710 A1 (GRILL JEFFREY J [US]) 15 mei 2014 (2014-05-15)

3 Group 1 (claims 1-14,20-24)

3.1 The present application does not meet the criteria of patentability, because the subject-matter of claims 1 to 14 and 20 to 24 does not involve an inventive step.

3.2 Document D1 discloses a concept for cleaning a feed gas (landfill gas) by removing carbon dioxide, volatile organic carbons (aromatics) and water (ref. col. 1, l. 39 to 65) by absorption with a physical absorbent such as SELEXOL (ref. col. 1, l. 61) comprising the following steps (ref. Fig. 4):

- compression of the feed gas by means of a compressor (blower 34,40,44);

- treatment of the pressurised gas for removing impurities, the treatment comprising

* leading the compressed gas through a solvent absorber (14') to remove volatile organic compounds (VOCs) and carbon dioxide and any water;

* wherein the solvent absorber (14') is arranged in a solvent circulation circuit comprising a first (flash vessel 76) and a second treatment means (84,94) for regeneration of the solvent to remove the absorbed impurities;

* said first treatment means (76) being configured for operating at higher pressure (250 psig) than the second treatment means (flash vessel 84 operating at atmosph. pressure and flash vessel 94 operating at negative pressure)

* a part of the solvent is removed from the solvent recirculation circuit in a removal stream (148,182) which is, after reduction of VOC and water concentration, returned to the solvent recirculation circuit (via line 166).

The subject matter of claims 1 and 20 **differs** from D1 in that water is removed from the compressed feed gas by means of a gas cooler and a water separator prior to the absorption treatment.

However, this difference is a standard procedure in the present technical field. As an example, D2 can be used, ref. Fig. 3.

No inventive step can be justified by the presence of that differentiating feature.

3.3 D1 further discloses the features of claims 5 (col. 2, l. 48),8,11,12,13,14,21 (ref. Fig. 1: stripper 130), 24 (cooler 122).

3.4 At present, the subject matter of those claims not addressed here above is not considered to cause unexpected or surprising effects with respect to what is disclosed in the above mentioned prior art. Therefore, no inventive activity can be acknowledged for the time being.