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Andrian et al.

(54) **PROCESS FOR REMOVING GASEOUS CONTAMINANTS FROM A FEED GAS STREAM COMPRISING METHANE AND GASEOUS CONTAMINANTS**

(76) Inventors: **Diki Andrian**, Rijswijk (NL); **Rick Van Der Vaart**, Rijswijk (NL)

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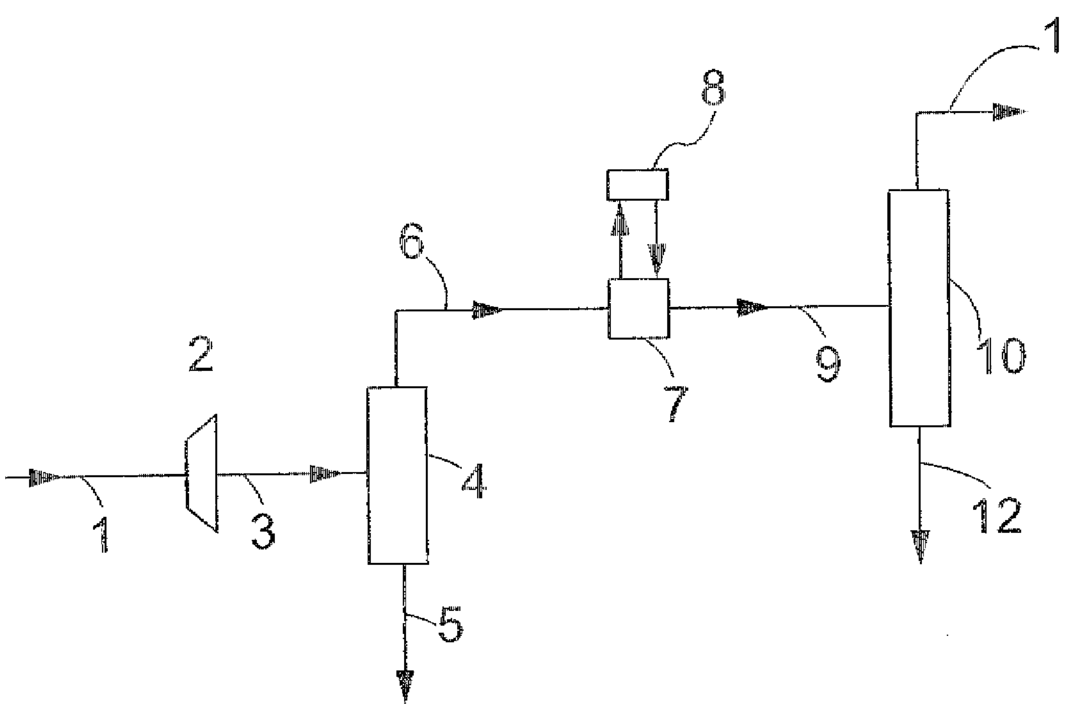
(57) **ABSTRACT**

The invention provides a process for removing gaseous contaminants from a feed gas stream which comprises methane and gaseous contaminants, the process comprising: 1) providing the feed gas stream; 2) cooling the feed gas stream to a first temperature at which liquid phase contaminant is formed as well as a methane enriched gaseous phase; 3) separating the two phases obtained in step 2) by means of a first gas/liquid separator; 4) cooling the methane enriched gaseous phase obtained in step 3) at least party by means of an external refrigerant to a second temperature at which liquid phase contaminant is formed as well as a methane enriched gaseous phase; and 5) separating the two phases obtained in step 4) by means of a second gas/liquid separator. The invention further concerns a device for carrying out the present process, the purified gas stream, and a process for liquefying a feed gas stream.



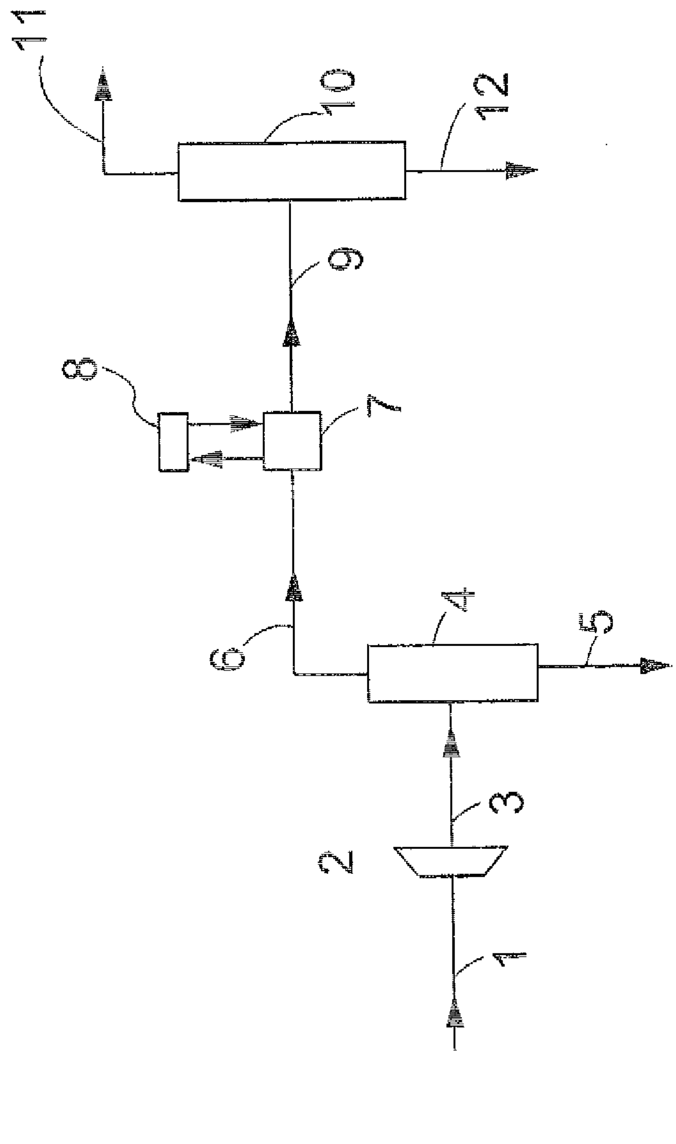



FIG. 1

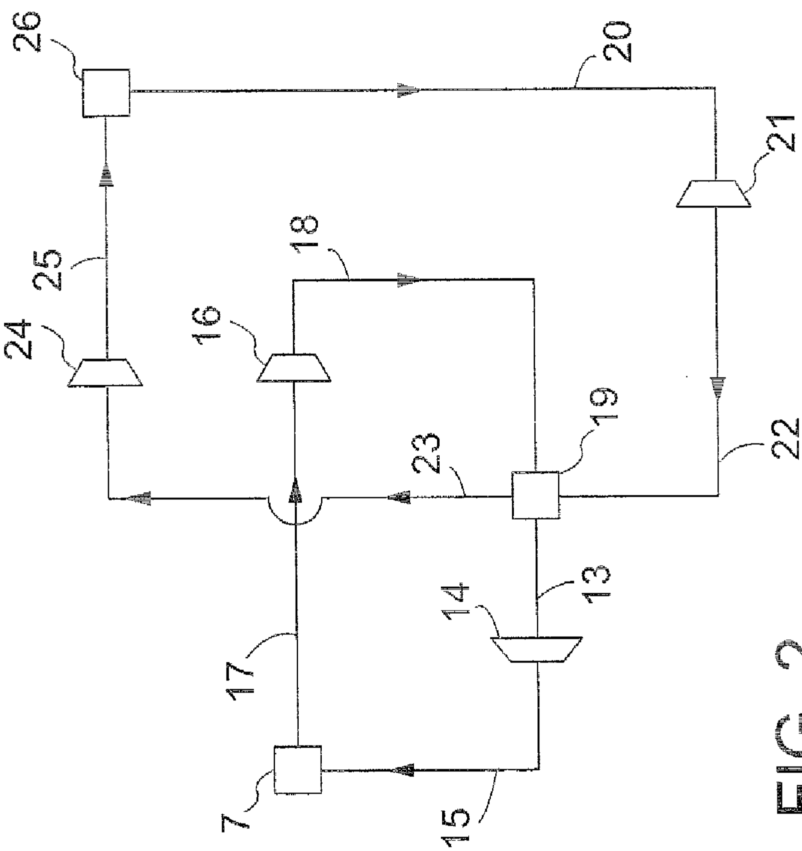



FIG. 2

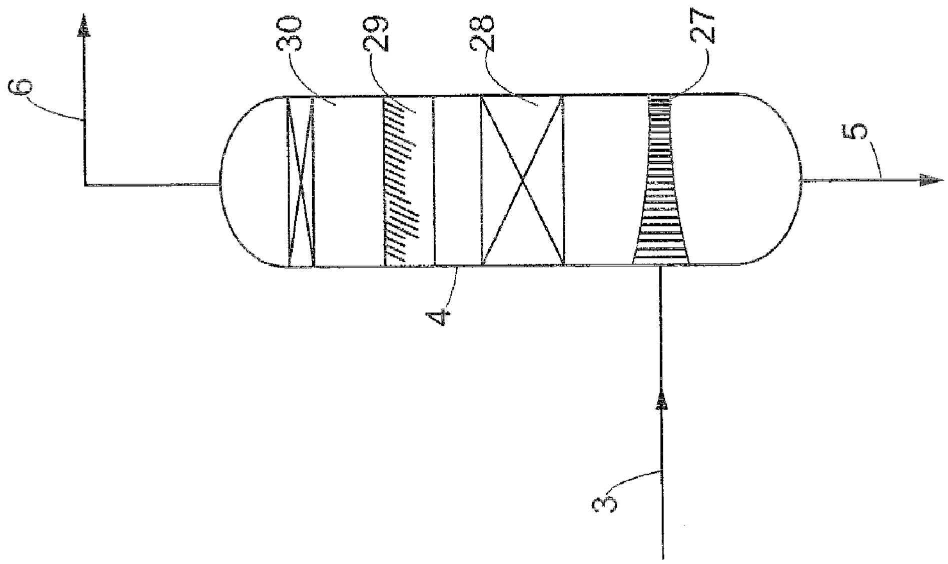



FIG. 3

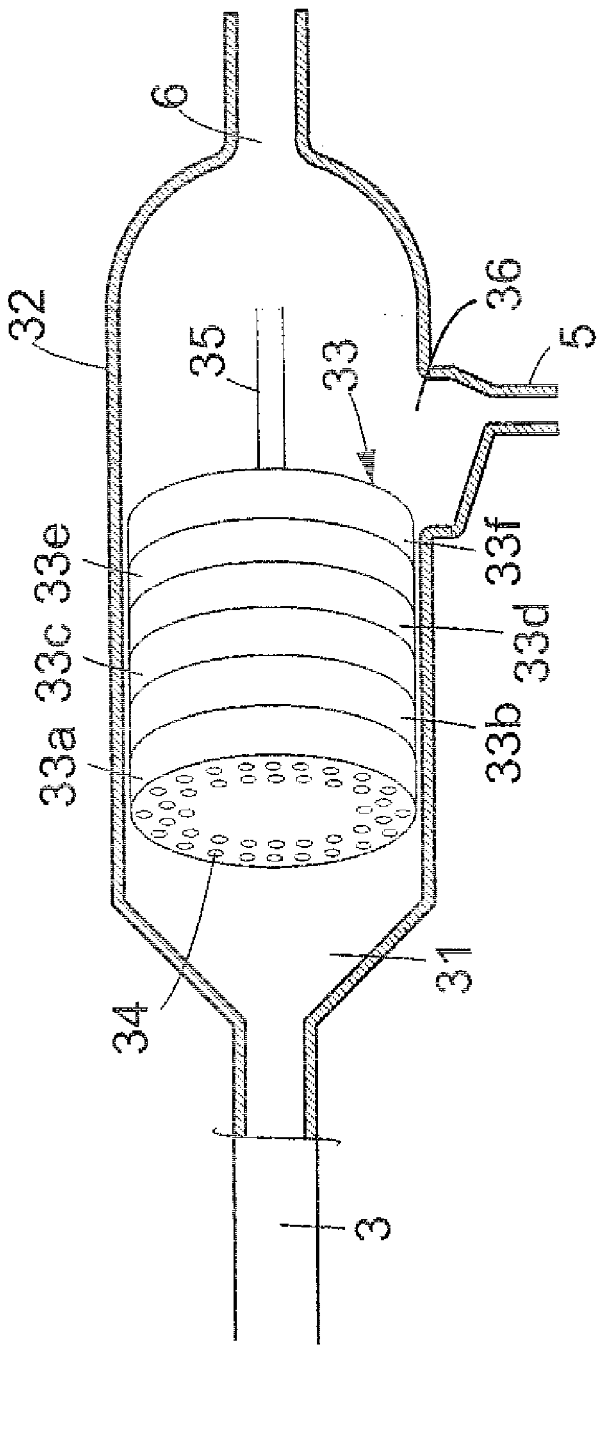



FIG. 4

# PROCESS FOR REMOVING GASEOUS CONTAMINANTS FROM A FEED GAS STREAM COMPRISING METHANE AND GASEOUS CONTAMINANTS

**[0001]** The present invention concerns a process for the removal of gaseous contaminants from a feed gas stream which comprises methane and gaseous contaminants, in particular the removal of gaseous contaminants such as carbon dioxide and hydrogen sulphide from a natural gas.

**[0002]** Methane comprising gas streams produced from subsurface reservoirs, especially natural gas, associated gas and coal bed methane, usually contain contaminants as carbon dioxide, hydrogen sulphide, carbon oxysulphide, mercaptans, sulphides and aromatic sulphur containing compounds in varying amounts. For most of the applications of these gas streams, the contaminants needs to be removed, either partly or almost completely, depending on the specific contaminant and/or the use. Often, the sulphur compounds need to be removed into the ppm level, carbon dioxide sometimes into ppm level, e.g. LNG applications, or down to 2 or 3 vol. percent, e.g. for use as heating gas. Higher hydrocarbons may be present, which, depending on the use, may be recovered.

**[0003]** Processes for the removal of carbon dioxide and sulphur compounds are know in the art. These processes include absorption processes using e.g. aqueous amine solutions or adsorption processes using e.g. molecular sieves. These processes are especially suitable for the removal of contaminants, especially carbon dioxide and hydrogen sulphide, that are present in relatively low amounts, e.g. up till several vol %.

**[0004]** In WO 2006/087332, a method has been described for removing contaminating gaseous components, such as carbon dioxide and hydrogen sulphide, from a natural gas stream. In this method a contaminated natural gas stream is cooled in a first expander to obtain an expanded gas stream having a temperature and pressure at which the dewpointing conditions of the phases containing a preponderance of contaminating components, such a carbon dioxide and/or hydrogen sulphide are achieved. The expanded gas stream is then supplied to a first centrifugal separator to establish the separation of a contaminants-enriched liquid phase and a contaminants-depleted gaseous phase. The contaminants-depleted gaseous phase is then passed via a recompressor, an interstage cooler, and a second expander into a second centrifugal separator. The interstage cooler and the second expander are used to cool the contaminants-depleted gaseous phase to such an extent that again a contaminants-enriched liquid phase and a further contaminants-depleted gaseous phase are obtained which are subsequently separated from each other by means of the second centrifugal separator. In such a method energy recovered from the first expansion step is used in the compression step, and air, water and/or an internal process stream is used in the interstage cooler.

**[0005]** A disadvantage of this known method is that the use of a recompressor, interstage cooler and an expander between the two centrifugal separators affects the hydrocarbon efficiency of the separation process, which hydrocarbon efficiency is a measure of the fuel gas consumption and the hydrocarbon loss in the liquid phase contaminant streams during the process.

**[0006]** It has now been found that in an integrated process for removing gaseous contaminants from a gas stream the hydrocarbon efficiency can be considerably improved when between a first and a second gas/liquid separation the contaminants-depleted gaseous phase is at least partly cooled by means of an external refrigerant which allows an excellent separation of gaseous contaminants, whereas the use of an expander between the first and second gas/liquid separation can be avoided.

**[0007]** Thus, the present invention concerns a process for removing gaseous contaminants from a feed gas stream which comprises methane and gaseous contaminants, which process comprises:

1) providing the feed gas stream;

2) cooling the feed gas stream to a first temperature at which liquid phase contaminant is formed as well as a methane enriched gaseous phase;

3) separating the two phases obtained in step 2) by means of a first gas/liquid separator;

4) cooling the methane enriched gaseous phase obtained in step 3) at least partly by means of an external refrigerant to a second temperature at which liquid phase contaminant is formed as well as a methane enriched gaseous phase; and

5) separating the two phases obtained in step 4) by means of a second gas/liquid separator.

**[0008]** Suitably, the feed gas stream is a natural gas stream in which the gaseous contaminants are carbon dioxide and/or hydrogen sulphide.

**[0009]** The natural gas stream suitably comprises between 1 and 90 vol % of carbon dioxide, preferably between 5 and 80 vol % of carbon dioxide.

**[0010]** The natural gas stream suitably comprises between 0.1 to 60 vol % of hydrogen sulphide, preferably between 20 and 40 vol % of hydrogen sulphide.

**[0011]** The feed gas stream to be used in accordance with the present invention comprises between 20 and 80 vol % of methane.

**[0012]** Suitably, the feed gas stream in step 1) has a temperature between −20 and 150° C., preferably between −10 and 70° C., and a pressure between 10 and 150 bara, preferably between 80 and 120 bara.

**[0013]** The raw feed gas stream may be pre-treated to partially or completely remove water and optionally some heavy hydrocarbons. This can for instance be done by means of a pre-cooling cycle, against an external cooling loop or a cold internal process stream. Water may also be removed by means of pre-treatment with molecular sieves, e.g. zeolites, or silica gel or alumina oxide or other drying agents such as glycol, MEG, DEG or TEG, or glycerol. The amount of water in the gas feed stream is suitably less than 1 vol %, preferably less than 0.1 vol %, more preferably less than 0.0001 vol %.

**[0014]** The cooling in step 2) of the feed gas stream may be done by methods known in the art. For instance, cooling may be done against an external cooling fluid. In the case that the pressure of the feed gas is sufficiently high, cooling may be obtained by expansion of the feed gas stream.

**[0015]** Combinations may also be possible. A suitable method to cool the feed gas stream is done by nearly isentropic expansion, especially by means of an expander, preferably a turbo expander or laval nozzle. Another suitable method is to cool the feed gas stream by isenthalpic expansion, preferably isenthalpic expansion over an orifice or a valve, especially over a Joule-Thomson valve.

[0016] Preferably, the expansion is done using at least two expansion devices and the operating parameters of the expansion devices are chosen such that the liquefied contaminants in the cooled stream have a certain droplet size distribution. The use of at least two expansion devices allows the control of the droplet size distribution of condensed contaminants.

[0017] In a preferred embodiment the feed gas stream is pre-cooled before expansion. This may be done against an external cooling loop or against a cold process stream, e.g. liquid contaminant. Preferably the gas stream is pre-cooled before expansion to a temperature between 15 and −35° C., preferably between 10° C. and −20° C. Pre-cooling may be done against internal process streams. Especially when the feed gas stream has been compressed, the temperature of the feed gas stream may be between 100 and 150° C. In that case air or water cooling may be used to decrease the temperature first, optionally followed by further cooling.

[0018] Another suitable cooling method is heat exchange against a cold fluidum, especially an external refrigerant, e.g. a propane cycle, an ethane/propane cascade or a mixed refrigerant cycle, optionally in combination with an internal process loop, suitably a carbon dioxide stream (liquid or slurry), a cold methane enriched stream or washing fluid.

[0019] Suitably the feed gas stream is cooled in steps 2) and 4) to a temperature between −30 and −80° C., preferably between −40 and −65° C. At these temperatures liquid phase contaminant will be formed.

[0020] Suitably, the pressure applied in step 4) can be higher than the pressure applied in step 2).

[0021] Preferably, the second temperature in step 4) is lower than the first temperature in step 2).

[0022] Preferably, the second temperature in step 4) is up to 20° C. lower than the first temperature in step 2). More preferably, the second temperature is between 5 and 10° C. lower than the first temperature in step 2).

[0023] The cooling in step 4) can be carried out by means of an internal process stream such as a stream of liquid phase contaminant which is separated from the methane enriched gaseous phase in step 3).

[0024] In accordance with the present invention the cooling of the methane enriched gaseous phase in step 4) can suitably at least partly be done by means of an external refrigerant.

[0025] Preferably, the external refrigerant to be used in step 4) has a higher molecular weight than the methane enriched gaseous phase to be cooled. Suitable examples of such cooling medium include ethane, propane and butane. Preferably, the cooling medium comprises ethane and/or propane.

[0026] More preferably, the external refrigerant to be used comprises a propane cycle, an ethane/propane mixed refrigerant or an ethane/propane cascade. Such an ethane/propane cascade is described in more detail hereinbelow.

[0027] The cooling in step 4) can suitably be partly done by means of an external refrigerant and partly by means of an internal process stream, e.g. a stream of liquid phase contaminant which is separated from the methane enriched gaseous phase in step 3).

[0028] The cooling in step 4) as, for instance, done by use of an external refrigerant can very attractively replace the sequence of the recompressor, interstage cooler and the expander which is used between the two centrifugal separators as described in WO 2006/087332, improving the hydrocarbon efficiency of the separation process.

[0029] In another embodiment of the present invention the methane enriched gaseous phase obtained in step 3) is recompressed in one or more compression steps before step 4) is carried out.

[0030] In another embodiment of the present invention the methane enriched gaseous phase obtained in step 3) is firstly cooled by means of an interstage cooler before the cooling in step 4) is carried out.

[0031] In yet another embodiment of the present invention, the methane enriched gaseous phase obtained in step 3) is firstly recompressed in one or more compression steps, than cooled by means of an interstage cooler, and subsequently cooled in step 4).

[0032] Suitably, such an interstage cooler will be based on a internal process stream and air or water cooling.

[0033] Suitably, in the case liquid is formed inside the cooler, this cooler is designed in such a way that liquid is effectively removed form the cooling device without impairing heat transfer.

[0034] In the one or more compression steps suitably energy is used that is recovered in step 2).

[0035] In the process according to the present invention a variety of gas/liquid separators can suitably be used in steps 3) and 5), such as, for instance, rotating centrifuges or cyclones.

[0036] In steps 3) and 5) use can be made of different types or similar types of gas/liquid separators. Suitably, in steps 3) and 5) is made of similar types of gas/liquid separators.

[0037] Suitable gas/liquid separators to be used in accordance with the present invention have, for instance, been described in WO 2008/082291, WO 2006/087332, WO 2005/118110, WO 97/44117, WO 2007/097621 and WO 94/23823, which documents are hereby incorporated by reference.

[0038] Typically, the gas/liquid separator requirements in step 3) are more stringent than the requirements in step 5) since homogeneous droplet nucleation after expansion does produce smaller droplets than heterogeneous nucleation in a heat exchanger, cooled by an external process stream.

[0039] In a preferred embodiment of the present invention, the first and/or second gas/liquid separator comprises a gas/liquid inlet at an intermediate level, a liquid outlet arranged below the gas/liquid inlet and a gas outlet arranged above the gas/liquid inlet, in which vessel a normally horizontal coalescer is present above the gas/liquid inlet and over the whole cross-section of the vessel and in which vessel a centrifugal liquid separator is arranged above the coalescer and over the whole cross-section of the vessel, the liquid separator comprising one or more swirl tubes.

[0040] When using a vertical gas/liquid separator vessel, the process only needs a relatively small area.

[0041] According to a preferred embodiment, the gas/liquid inlet comprises an admittance with a supply and distribution assembly extending horizontally in the separator vessel. In its most simple form, the inlet is a simple pipe, having a closed end and a number of perforations evenly distributed over the length of the pipe. Optionally, the pipe may have a tapered or conical shape. One or more cross pipes may be present to create a grid system to distribute the gas-liquid mixture more evenly over the cross-section of the vessel. Preferably, the assembly includes a chamber, e.g. a longitudinal box-like structure, connected to the gas inlet and having at least one open vertical side with a grid of guide vanes disposed one behind each other, seen in the direction of the flow. By means of this supply and distribution assembly, the gas is evenly distributed by the guide vanes over the cross-section of the column, which brings about an additional improvement of the liquid separation in the coalescer/centrifugal separator combination. A further advantage is that the supply and distribution assembly separates from the gas any slugs of liquid which may suddenly occur in the gas stream, the separation being effected by the liquid colliding with the guide vanes and falling down inside the column. Suitably, the box structure narrows down in the direction of the flow. After having been distributed by the vanes over the column cross-section, the gas flows up to the coalescer.

**[0042]** In a preferred embodiment the longitudinal chamber has two open vertical sides with a grid of guide vanes.

**[0043]** Suitable gas/liquid inlets are those described in e.g. GB 1,119,699, U.S. Pat. No. 6,942,720, EP 195,464, U.S. Pat. No. 6,386,520 and U.S. Pat. No. 6,537,458. A suitable, commercially available gas/liquid inlet is a Schoepentoeter.

**[0044]** There are numerous horizontal coalescers available, especially for vertical columns. A well-known example of a mist eliminator is the demister mat. All of these are relatively tenuous (large permeability) and have a relatively large specific (internal) surface area. Their operation is based on drop capture by collision of drops with internal surfaces, followed by drop growth on these surfaces, and finally by removal of the grown drop either by the gas or by gravity.

**[0045]** The horizontal coalescer can have many forms which are known per se and may, for example, consist of a bed of layers of gauze, especially metal or non-metal gauze, e.g. organic polymer gauze, or a layer of vanes or a layer of structured packing. Also unstructured packings can be used and also one or more trays may be present. All these sorts of coalescers have the advantage of being commercially available and operating efficiently in the column according to the invention. See also Perry's Chemical Engineers' Handbook, Sixth edition, especially Chapter 18. See also EP 195464.

**[0046]** The centrifugal liquid separator in one of its most simple forms may comprise a horizontal plate and one or more vertical swirl tubes extending downwardly from the plate, each swirl tube having one or more liquid outlets below the horizontal plate at the upper end of the swirl tube. In another form, the centrifugal liquid separator comprises one or more vertical swirl tubes extending upwardly from the plate, each swirl tube having one or more liquid outlets at the upper end. The plate is provided with a downcomer, preferably a downcomer that extends to the lower end of the separator vessel.

**[0047]** In a preferred embodiment of the invention, the centrifugal liquid separator comprises two horizontal trays between which vertical open-ended swirl tubes extend, each from an opening in the lower tray to some distance below a coaxial opening in the upper tray, means for the discharge of secondary gas and of liquid from the space between the trays outside the swirl tubes, and means provided in the lower part of the swirl tubes to impart to the gas/liquid a rotary movement around the vertical axis.

**[0048]** The liquid separator is also preferably provided with vertical tube pieces which project down from the coaxial openings in the upper tray into the swirl tubes and have a smaller diameter than these latter. This arrangement enhances the separation between primary gas on the one hand and secondary gas and liquid on the other hand, since these latter cannot get from the swirl tubes into the openings in the upper tray for primary gas.

**[0049]** According to a preferred embodiment, the means for discharging the secondary gas from the space between the trays consist of vertical tubelets through the upper tray, and the means for discharging liquid from the space between the trays consist of one or more vertical discharge pipes which extend from this space to the bottom of the column. This arrangement has the advantage that the secondary gas, after having been separated from liquid in the said space between the trays, is immediately returned to the primary gas, and the liquid is added to the liquid at the bottom of the column after coming from the coalescer, so that the secondary gas and the liquid removed in the centrifugal separator do not require separate treatment.

**[0050]** In order to improve even further the liquid separation in the centrifugal separator, openings are preferably provided in accordance with the invention at the top of the swirl tubes for discharging liquid to the space between the trays outside the swirl tubes. This has the advantage that less secondary gas is carried to the space between the trays. A suitable, commercially available centrifugal separator is a Shell Swirltube deck.

**[0051]** In a preferred embodiment, the separation vessel comprises a second normally horizontal liquid coalescer above the centrifugal liquid separator and over the whole cross-section of the vessel. This has the advantage that any droplets still present in the gas stream are removed. See for a further description hereinabove. Preferably, the second coalescer is a bed of one or more layers of gauze, especially metal or non-metal gauze, e.g. organic polymer gauze. In another preferred embodiment, the second normally horizontal liquid coalescer is situated above the secondary gas outlets, for instance in the way as described in EP 83811, especially as depicted in FIG. **4**.

**[0052]** In a most preferred embodiment, a first and/or second separator is used comprising:

a) a housing comprising a first, second and third separation section for separating liquid from the mixture, wherein the second separation section is arranged below the first separation section and above the third separation section, the respective separation sections are in communication with each other, and the second separation section comprises a rotating coalescer element;

b) tangentially arranged inlet means to introduce the mixture into the first separation section;

c) means to remove liquid from the first separation section;

d) means to remove liquid from the third separation section; and

e) means to remove a gaseous stream, lean in liquid, from the third separation section.

**[0053]** In the present invention the first and/or second gas/liquid separator may suitably comprise a centrifugal separator which comprises a bundle of parallel channels that are arranged within a spinning tube parallel to an axis of rotation of the spinning tube.

**[0054]** Suitably, in the present process the centrifugal separator is spinned by introducing a swirling gas stream into the spinning tube.

**[0055]** Preferably, the centrifugal separator to be used in accordance with the present invention comprises a housing with a gas inlet for contaminated gas at one end of the vessel, a separating body, a gas outlet for purified gas at the opposite end of the housing and a contaminants outlet downstream of the separating body or upstream and downstream of the separating body, wherein the separating body comprises a plurality of ducts over a part of the length of the axis of the housing, which ducts have been arranged around a central axis of rotation, in which apparatus the separating body has been composed of a plurality of perforated discs wherein the perforations of the discs form the ducts.

**[0056]** It will be appreciated that the discs can be easily created by drilling or cutting a plurality of perforations into the relatively thin discs. By attaching several discs to together these discs form a separating body. By aligning the perforations ducts are obtained.

**[0057]** It is now also very easy to attach the discs such that the perforations are not completely aligned. By varying the number and nature of the non-alignment of the perforations the resulting ducts can be given any desired shape. In such cases not only ducts are obtainable that are not completely parallel to the central axis of rotation, but also ducts that form a helix shape around the axis of rotation. So, in this way very easily the preferred embodiment of having non-parallel ducts can be obtained. Hence it is preferred that the perforations of the discs have been arranged such that the ducts are not parallel to the central axis of rotation or form a helix shape around the axis of rotation.

**[0058]** Further, it will be appreciated that it is relatively easy to increase or decrease the diameter of the perforations. Thereby the skilled person has an easy manner at his disposal to adapt the (hydraulic) diameter of the ducts, and thereby the Reynolds number, so that he can easy ascertain that the flow in the ducts is laminar or turbulent, just as he pleases. The use of these discs also enables the skilled person to vary the diameter of the duct along the axis of the housing. The varying diameter can be selected such that the separated liquid or solid contaminants that are collected against the wall of the duct will not clog up the duct completely, which would hamper the operation of the apparatus.

**[0059]** The skilled person is also now enabled to maximise the porosity of the separating body. The easy construction of the discs allows the skilled person to meticulously provide the disc with as many perforations as he likes. He may also select the shape of the perforations. These may have a circular cross-section, but also square, pentagon, hexagon, octagon or oval cross-sections are possible. He may therefore minimise the wall thickness of the separating body and the wall thicknesses of the ducts. He is able to select the wall thicknesses and the shape of the ducts such that the surface area that is contributed to the cross-section of the separating body by the walls is minimal. That means that the pressure drop over the separating body can be minimised.

**[0060]** The apparatus can have a small or large number of ducts. Just as explained in the prior art apparatuses the number of ducts suitably ranges from 100 to 1,000,000, preferably from 500 to 500,000. The diameter of the cross-section of the ducts can be varied in accordance with the amount of gas and amounts and nature, e.g., droplet size distribution, of contaminants and the desired contaminants removal efficiency. Suitably, the diameter is from 0.05 to 50 mm, preferably from 0.1 to 20 mm, and more preferably from 0.1 to 5 mm. By diameter is understood twice the radius in case of circular cross-sections or the largest diagonal in case of any other shape.

**[0061]** The size of the apparatus and in particular of the separating body may vary in accordance with the amount of gas to be treated. In EP-B 286 160 it is indicated that separating bodies with a peripheral diameter of 1 m and an axial length of 1.5 m are feasible. The separating body according to the present invention may suitably have a radial length ranging from 0.1 to 5 m, preferably from 0.2 to 2 m. The axial length ranges conveniently from 0.1 to 10 m, preferably, from 0.2 to 5 m.

**[0062]** The number of discs may also vary over a large number. It is possible to have only two discs if a simple separation is needed and/or when the perforations can be easily made. Other considerations may be whether parallel ducts are desired, or whether a uniform diameter is wanted. Suitably the number of discs varies from 3 to 1000, preferably from 4 to 500, more preferably from 4 to 40. When more discs, are used the skilled person will find it easier to gradually vary the diameter of the ducts and/or to construct non-parallel ducts. Moreover, by increasing or decreasing the number of discs the skilled person may vary the duct length. So, when the conditions or the composition of the gas changes, the skilled person may adapt the duct length easily to provide the most optimal conditions for the apparatus of the present invention. The size of the discs is selected such that the radial diameter suitably ranges from 0.1 to 5 m, preferably from 0.2 to 2 m. The axial length of the discs may be varied in accordance with construction possibilities, desire for varying the shape etc. Suitably, the axial length of each disc ranges from 0.001 to 0.5 m, preferably from 0.002 to 0.2 m, more preferably from 0.005 to 0.1 m.

**[0063]** Although the discs may be manufactured from a variety of materials, including paper, cardboard, and foil, it is preferred to manufacture the discs from metal or ceramics. Metals discs have the advantage that they can be easily perforated and be combined to firm sturdy separating bodies. Dependent on the material that needs to be purified a suitable metal can be selected. For some applications carbon steel is suitable whereas for other applications, in particular when corrosive materials are to be separated, stainless steel may be preferred. Ceramics have the advantage that they can be extruded into the desired form such as in honeycomb structures with protruding ducts.

**[0064]** Typically, the ceramics precursor material is chosen to form a dense or low-porosity ceramic. Thereby the solid or liquid contaminants are forced to flow along the wall of the ducts and not, or hardly, through the ceramic material of the walls. Examples of ceramic materials are silica, alumina, zirconia, optionally with different types and concentrations of modifiers to adapt its physical and/or chemical properties to the gas and the contaminants.

**[0065]** The discs may be combined to a separating body in a variety of ways. The skilled person will appreciate that such may depend on the material from which the discs have been manufactured. A convenient manner is to attach the discs to a shaft that provides the axis of rotation. Suitable ways of combining the discs include clamping the discs together, but also gluing them or welding them together can be done. Alternatively, the discs may be stacked in a cylindrical sleeve. This sleeve may also at least partly replace the shaft. This could be convenient for extruded discs since no central opening for the shaft would be required. It is preferred to have metal discs that are welded together.

**[0066]** In a preferred embodiment of the invention, the methane enriched gaseous phase obtained in accordance with the present invention is further purified, e.g. by extraction of remaining acidic components with a chemical solvent, e.g. an aqueous amine solution, especially aqueous ethanolamines, such as DIPA, DMA, MDEA, etc., or with a physical solvent, e.g. cold methanol, DEPG, NMP, etc.

**[0067]** The contaminated gas stream is continuously provided, continuously cooled and continuously separated.

**[0068]** The present invention also relates to a device (plant) for carrying out the process as described above, as well as the purified gas stream obtained by the present process. In addition, the present invention concerns a process for liquefying a feed gas stream comprising purifying the feed gas stream by means of the present process, followed by liquifying the purified feed gas stream by methods known in the art.

**[0069]** The invention will be further illustrated by means of the following Figures.

**[0070]** Referring to FIG. **1**, natural gas via a conduit **1** is passed through an expansion means **2**, whereby a stream is obtained comprising liquid phase contaminant and a methane enriched gaseous phase. The stream flows via a conduit **3** into a gas/liquid separator **4** wherein the two phases are separated from each other. The liquid phase contaminant is recovered via a conduit **5**, whereas the methane enriched gaseous phase is passed via a conduit **6** into a heat exchanger **7**. In heat exchanger **7** ethane is used as an external refrigerant whereby the ethane is cooled by means of an ethane/propane cascade **8** as depicted in more detail in FIG. **2**. The methane enriched gaseous phase is cooled in the heat exchanger **7** to a temperature whereby a liquid phase contaminant and an methane enriched gaseous phase are formed. The stream which comprises these two phases is then passed via a conduit **9** into a gas/liquid separator **10** from which a further enriched methane enriched gaseous phase is recovered via a conduit **11** and liquid phase contaminant is recovered via a conduit **12**.

**[0071]** In FIG. **2** the heat exchanger **7** is shown using ethane that is cooled by means of an ethane/propane cascade which comprises an ethane loop and a propane loop. In the ethane loop an ethane stream is passed via a conduit **13** into an expander **14** (e.g. a turbine expander or a Joule-Thomson valve), and the cooled ethane stream so obtained is passed via a conduit **15** into the heat exchanger **7**. A stream of warm ethane is then passed from the heat exchanger **7** to a recompressor **16** via a conduit **17** to increase the pressure of the ethane stream. The compressed stream of ethane obtained from recompressor **16** is then passed via a conduit **18** into a heat exchanger **19** wherein the ethane stream is cooled and at least partly condensed. Via the conduit **13** the ethane stream is then recycled to the expander **14**. In the propane loop a propane stream is passed via a conduit **20** into an expander **21** (e.g. a turbine expander or a Joule-Thomson valve), and the cooled propane stream so obtained is passed via a conduit **22** into the heat exchanger **19** of the ethane loop. A stream of warm propane is then passed from the heat exchanger **19** via a conduit **23** into a recompressor **24** to increase the pressure of the propane stream. The compressed stream of propane obtained from recompressor **24** is then passed via a conduit **25** into heat exchanger **26** wherein the propane stream is cooled and at least partly condensed by means of water or air. Via the conduit **20** the propane stream is then recycled to the expander **21**.

**[0072]** In FIG. **3** a suitable gas/liquid separator is shown for use in steps 3) and 5) of the present process. Both the gas/liquid separators **4** and **10** as shown in FIG. **1** can be of this type. The stream comprising liquid phase contaminant and a methane enriched gaseous phase is passed via the conduit **3** (or the conduit **9**) into the gas/liquid separator **4** (or the gas/liquid separator **10**) via supply and distribution assembly **27**. Most of the liquid will flow down to the lower end of the separator and leave the separator via the liquid outlet **5**. The gaseous stream comprising larger and smaller droplets will flow upwards via liquid coalescer **28**, centrifugal separator **29** and a second liquid coalescer **30** to the top of the separator vessel, and leave the separator vessel via the gas outlet **6**.

**[0073]** In FIG. **4** another suitable gas/liquid separator is shown for use in steps 3) and 5) of the present process. Both the gas/liquid separators **4** and **10** as shown in FIG. **1** can be of this type. The stream comprising liquid phase contaminant and a methane enriched gaseous phase is passed via the conduit **3** (or the conduit **9**) to a gas inlet **31** in a housing **32** of the gas/liquid separator **4** (or the gas/liquid separator **10**). The housing **32** further comprises a separating body **33** which shows a large number of ducts **34** which are arranged around a shaft **35**, which provides an axis of rotation. Separating body **33** has been composed of six discs **33**_a_, **33**_b_, **33**_c_, **33**_d_, **33**_e_ and **33**_f_ that have been combined by welding or gluing. In the rotating separating body droplets of carbon dioxide and/or hydrogen sulphide are separated from the natural gas. The separated contaminants are discharged from the housing via a contaminants outlet **36** which has been arranged downstream of the separating body **33**, and via the discharge conduit **5**. Purified natural gas leaves housing **32** via the gas outlet **6** arranged at the opposite end of the housing **32**.

**1**. A process for removing gaseous contaminants from a feed gas stream which comprises methane and gaseous contaminants, the process comprising:
1) providing the feed gas stream;
2) cooling the feed gas stream to a first temperature at which liquid phase contaminant is formed as well as a methane enriched gaseous phase;
3) separating the two phases obtained in step 2) by means of a first gas/liquid separator;
4) cooling the methane enriched gaseous phase obtained in step 3) at least partly by means of an external refrigerant to a second temperature at which liquid phase contaminant is formed as well as a methane enriched gaseous phase; and
5) separating the two phases obtained in step 4) by means of a second gas/liquid separator.

**2**. A process according to claim **1**, in which at least one of the first and second gas/liquid separators comprises a centrifugal which comprises a bundle of parallel channels that are arranged within a spinning tube parallel to an axis of rotation of the spinning tube.

**3**. A process according to claim **1**, in which the first and/or second gas/liquid separator comprises a housing with a gas inlet for contaminated gas at one end of the vessel, a separating body, a gas outlet for purified gas at the opposite end of the housing and a contaminants outlet downstream of the separating body wherein the separating body comprises a plurality of ducts over a part of the length of the axis of the housing, which ducts have been arranged around a central axis of rotation, in which apparatus the separating body has been composed of a plurality of perforated discs wherein the perforations of the discs form the ducts.

**4**. A gas separation system, comprising:
a) a housing comprising a first, second and third separation section for separating liquid from a gas mixture, wherein the second separation section is arranged below the first separation section and above the third separation section, the respective separation sections are in communication with each other, and the second separation section comprises a rotating coalescer element;

b) tangentially arranged inlet means to introduce the mixture into the first separation section;

c) means to remove liquid from the first separation section;

d) means to remove liquid from the third separation section; and

e) means to remove a gaseous stream, lean in liquid, from the third separation section.

**5**. A process according claim **1**, in which the feed gas stream is a natural gas stream in which the gaseous contaminants are carbon dioxide and/or hydrogen sulphide.

**6**. A process according to claim **5**, in which the natural gas stream comprises between 1 and 90 vol % of carbon dioxide, and between 0.1 and 60 vol % of hydrogen sulphide.

**7**. A process claim **1**, in which the feed gas stream comprises between 20 and 80 vol % of methane.

**8**. A process according to claim **1**, in which the feed gas stream in step 1) has a temperature between −20 and 150° C., preferably between −10 and 70° C., and a pressure between 10 and 150 bara, preferably between 80 and 120 bara.

**9**. A process according to claim **1**, in which the cooling in step 2) is done by isenthalpic expansion.

**10**. A process according to claim **9**, wherein the expansion is done using at least two expansion devices and the operating parameters of the expansion devices are chosen such that the liquefied acidic contaminants have a certain droplet size distribution.

**11**. A process claim **1**, in which the feed gas stream is cooled in steps 2) and 4) to a temperature between −30 and −80° C., preferably between −40 and −65° C.

**12**. A process claim **1**, in which the pressure applied in step 4) is higher than the pressure applied in step 2), and in which the second temperature in step 4) is lower than the first temperature in step 2).

**13**. A process according claim **1**, in which the external refrigerant has a higher molecular weight than the methane enriched gaseous phase to be cooled.

**14**. A process according to claim **1**, in which the first and/or second gas/liquid separator comprises a gas/liquid inlet at an intermediate level, a liquid outlet arranged below the gas/liquid inlet and a gas outlet arranged above the gas/liquid inlet, in which vessel a normally horizontal coalescer is present above the gas/liquid inlet and over the whole cross-section of the vessel and in which vessel a centrifugal liquid separator is arranged above the coalescer and over the whole cross-section of the vessel, the liquid separator comprising one or more swirl tubes.

**15**. (canceled)

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