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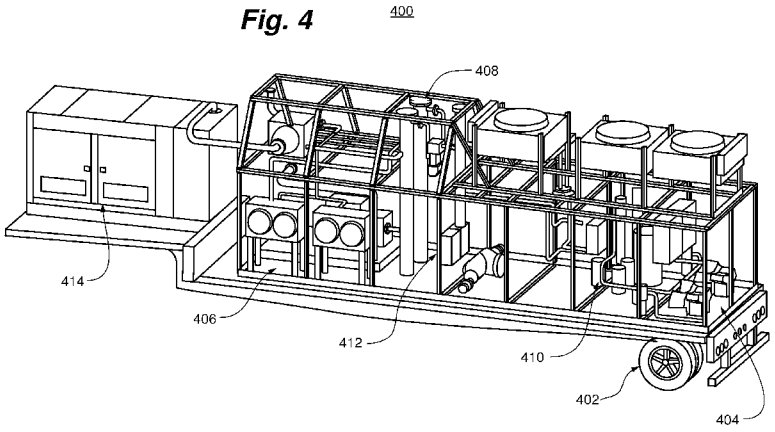
— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) Date of publication of the international search report:
19 February 2015

(54) Title: SYSTEMS AND METHODS FOR SEPARATING ALKANE GASES WITH APPLICATIONS TO RAW NATURAL GAS PROCESSING

Fig. 4



(57) Abstract: A field-deployable system for separating methane and natural gas liquids (NGLs) from a raw gas stream comprising a compressor; a dehydrator; a refrigerator having one or more stages; and a separation subsystem adapted to separate the raw gas stream into three useable product streams: (1) a methane stream that is at least 70% methane, (2) an ethane-rich stream, and (3) a NGLs stream having a vapor pressure of no more than 17 bar (250 psi) at 38 degrees Centigrade (100 Fahrenheit). The methane stream is sufficiently lean to be useable in existing natural gas engines without modification. The NGLs stream has a sufficiently low vapor pressure to be transportable in standard propane containers. The system can be utilized to reduce flaring from liquids-rich gas production sites, produce natural gas liquids for transport, and provide dry methane gas suitable for use in existing field generators.

WO 2014/204817 A3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 14/42437

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-- Please See Extra Sheet --

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 14/42437

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F25B 1/08, F17C 9/02, F25J 3/02 (2014.01)
CPC - F25B 1/08, F17C 9/02, F25J 3/0214
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8)- F25B 1/08, F17C 9/02, F25J 3/02 (2014.01);
CPC- F25B 1/08, F17C 9/02, F25J 3/0214

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC- 62/115, 62/633, 208/839, 585/15, 585/801;
Patents and NPL (classification, keyword; search terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Pub West (US EP JP WO), Pat Base (AU BE BR CA CH CN DE DK EP ES FI FR GB IN JP KR SE TH TW US WO), Google Patent, Google Scholar, Free Patents Online; search terms: compress, natural, gas, dehydrate, dessicate, separate, remove, water, H2O, moisture, vapor, vapour, natural, refrigerate, cryogenic, cool, cold, methane, ethane, chassis

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2013/037012 A1 (KIRK et al.) 21 March 2013 (21.03.2013), Fig. 1; pg 3, ln 12-21; pg 5, ln 18 to pg 6, ln 13; pg 7, ln 2-8; pg 8, ln 26-30; pg 12, ln 1-22; pg 13, ln 21-29; pg 14, ln 11-32; pg 15, ln 23-31; pg 17, ln 9-27; pg 18, ln 24 to pg 19, ln 13; pg 20, ln 2-11; pg 25, ln 14-21	1-40
Y	WO 2005/059459 A1 (HARWOOD et al.) 30 June 2005 (30.06.2005), pg 3, para 3 to pg 4, para 2; pg 4, para 5; pg 6, para 4; pg 12, para 1	1-40
Y	US 2010/0011663 A1 (COYLE) 21 January 2010 (21.01.2010), para [0027], [0080], [0092], [0097], [0107], [0126]	9-11, 14, 27, 31-37
Y	WO 2013/022529 A1 (KELLEY et al.) 14 February 2013 (14.02.2013), para [0021]-[0195]	1-40
Y	US 2010/0281775 A1 (LOGUE) 11 November 2010 (11.11.2010), para [0014]-[0046]	1-40
Y	US RE 39,826 E (LU) 11 September 2007 (11.09.2007), col 2, ln 15 to col 6, ln 40	1-40
Y	US 2006/0076076 A1 (DARLING IV et al.) 13 April 2006 (13.04.2006), para [0010]-[0099]	1-40
Y	US 2003/0037567 A1 (LU) 27 February 2003 (27.02.2003), para [0009]-[0046]	1-40
Y	US 6,105,390 A (BINGHAM et al.) 22 August 2000 (22.08.2000), col 2, ln 62 to col 12, ln 50	1-40
Y	US 3,763,658 A (GAUMER, JR. et al.) 09 October 1973 (09.10.1973), col 1, ln 54 to col 7, ln 13	1-40
Y	US 3,354,663 A (HENDRIX) 28 November 1967 (28.11.1967), col 1, ln 63 to col 11, ln 38	1-40

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 December 2014	16 DEC 2014
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 14/42437

Continued from Box No. III, Observations where unity of invention is lacking,

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-19, drawn to an apparatus for separating methane and natural gas liquids from a natural gas stream, comprising:
a chassis adapted to hold the system for field deployment;
one or more compressors adapted to compress the natural gas stream;
one or more dehydrators adapted to remove water from the compressed natural gas stream;
a refrigerator having one or more stages adapted to lower a temperature of the dehydrated, compressed natural gas stream; and
a separation subsystem adapted to separate the dehydrated, compressed, and refrigerated natural gas stream into three product streams consisting essentially of a methane stream that is at least 70% methane, an ethane-rich stream that is high in ethane content, and a natural gas liquids stream having a vapor pressure of no more than 17 bar at 38 degrees Centigrade.

Group II: Claims 20-30 and 38-40, drawn to a method for separating useable gas streams from a natural gas stream, comprising:
a compression step for compressing the natural gas stream to a pressure range of 6 to 35 bar;
a dehydration step for removing trace moisture from the compressed natural gas stream;
a refrigeration step for reducing a temperature of the dehydrated, compressed natural gas stream to a temperature range of -40 degrees Centigrade to -80 degrees Centigrade; and
a separation step for separating the dehydrated, compressed, and refrigerated natural gas stream into three product streams consisting essentially of a methane stream of at least 70% methane, an ethane rich stream that is high in ethane content, and a natural gas liquids stream having a vapor pressure of no more than 17 bar at 38 degrees Centigrade.

Group III: Claims 31-37, drawn to a system for separating a natural gas stream into three useable streams, comprising:
one or more compressors adapted to compress the natural gas stream;
a dehydration subsystem adapted to remove trace humidity from the compressed natural gas stream;
a refrigeration subsystem adapted to lower a temperature of the dehydrated, compressed natural gas stream to a low temperature, the refrigeration subsystem comprising a high-stage cascade refrigeration loop and a low-stage autocascade refrigeration loop having mixed hydrocarbon refrigerants;
a separation subsystem adapted to separate the dehydrated, compressed, and refrigerated natural gas stream into three product streams consisting essentially of a methane stream that is at least 70% methane, an ethane-rich stream that is high in ethane content, and a natural gas liquids stream having a vapor pressure of no more than 17 bar at 38 degrees Centigrade; and
a power generation subsystem tuned to run on the ethane-rich stream adapted to provide electricity to run the one or more compressors and the refrigeration subsystem.

The inventions listed as Groups I through III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Groups II and III do not require an apparatus for separating methane and natural gas liquids from a natural gas stream, comprising:
a chassis adapted to hold the system for field deployment;
one or more dehydrators adapted to remove water from the compressed natural gas stream;
a refrigerator having one or more stages adapted to lower a temperature of the dehydrated, compressed natural gas stream, as required by Group I.

Groups I and III do not require a method for separating useable gas streams from a natural gas stream, comprising:
a compression step for compressing the natural gas stream to a pressure range of 6 to 35 bar;
a dehydration step for removing trace moisture from the compressed natural gas stream;
a refrigeration step for reducing a temperature of the dehydrated, compressed natural gas stream to a temperature range of -40 degrees Centigrade to -80 degrees Centigrade, as required by Group II.

Group I and II do not require a system for separating a natural gas stream into three useable streams, comprising:
a dehydration subsystem adapted to remove trace humidity from the compressed natural gas stream;
a refrigeration subsystem adapted to lower a temperature of the dehydrated, compressed natural gas stream to a low temperature, the refrigeration subsystem comprising a high-stage cascade refrigeration loop and a low-stage autocascade refrigeration loop having mixed hydrocarbon refrigerants, as required by Group III.

Shared Common Features

The only feature shared by Groups I through III that would otherwise unify the groups is separating gas streams comprising a separation subsystem adapted to separate the dehydrated, compressed, and refrigerated natural gas stream into three product streams consisting essentially of a methane stream that is at least 70% methane, an ethane-rich stream that is high in ethane content, and a natural gas liquids stream having a vapor pressure of no more than 17 bar at 38 degrees Centigrade. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is obvious over WO 2005/059459 A1 to Harwood, et al. (hereinafter 'Harwood'). Harwood discloses separating gas streams comprising a separation subsystem adapted to separate dehydrated, compressed, and refrigerated natural gas stream into three product streams (pg 3, para 3 to pg 4, para 1, steps ii-vi, including distillation which inherently dehydrates the stream.) consisting essentially of a methane stream that is methane (pg 3, para 3, steps v., vi.), an ethane-rich stream that is high in ethane content (pg 4, para 2, ethane steam from deethaniser column.), and a natural gas liquids stream having a vapor pressure of no more than 17 bar at 38 degrees Centigrade (pg 3, para 3 (steps v., ix.); pg 6, para 4, pressure of 2 to 6 barg... cryogenic process temperature of -170 to -150 degrees Centigrade...); but does not specifically disclose at least 70% methane. To a person of ordinary skill in the art, it would have been obvious through routine experimentation to select amongst conventional methane distillation apparatus or method in order to optimize the purity of the methane product stream.

-- Please see following extra sheet --

Continued from Box No. III, Observations where unity of invention is lacking,

The only feature shared by Groups I and II that would otherwise unify the groups is one or more compressors adapted to compress the natural gas stream. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is anticipated by Harwood. Harwood discloses one or more compressors adapted to compress the natural gas stream (pg 3, para 3, step iii.).

As the technical features were known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the groups.

Groups I through III therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.