



(51) International Patent Classification:

G01N 33/00 (2006.01) G01N 33/22 (2006.01)
G01F 1/74 (2006.01) G01N 1/22 (2006.01)
G01N 23/12 (2006.01)

(21) International Application Number:

PCT/GB2014/052794

(22) International Filing Date:

15 September 2014 (15.09.2014)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: STATOIL PETROLEUM AS [NO/NO]; For-
usbeen 50, N-4035 Stavanger (NO).

(71) Applicant (for MG only): STEVENS, Jason [GB/GB]; 10
Salisbury Square, London EC4Y 8JD (GB).

(72) Inventors: DUPUY, Pablo Matias; Åsbergveien 11, N-
7550 Hommelvik (NO). NILSSEN, Oddbjørn Rekaa;
Peter Eggesv. 12, N-7021 Trondheim (NO).

(74) Agent: STEVENS, Jason; 10 Salisbury Square, London,
EC4Y 8JD (GB).

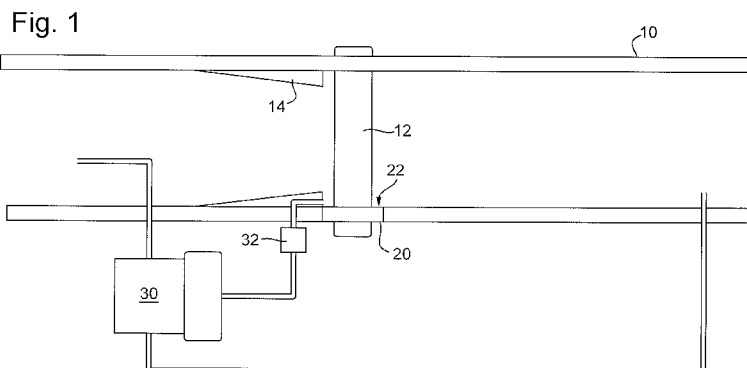
(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP,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

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

Published:

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

(54) Title: MULTIPHASE STREAM CONDITIONING



(57) Abstract: The invention is concerned with conditioning a multi-phase stream, and in particular a gas stream with low liquid content. Specifically, the invention provides a method of conditioning a multi-phase flow of gas with entrained liquid droplets in a process stream section where a multi-phase measurement sensitive to the hold-up is to be made, comprising heating a surface within the section to a temperature such that droplets of liquid contacting the heated surface are subject to the Leidenfrost effect. This prevents the heated surface from being wetted by any droplets of liquid which may come into contact with it, so that liquid does not accumulate on the surface, but remains in the gas flow. As a result, accurate measurements of the overall density of the gas, and thus the amount of liquid entrained in the gas, can be made.

MULTIPHASE STREAM CONDITIONING

The invention relates to a method for conditioning a multi-phase stream, and in particular a gas stream with low liquid content.

5 It is often necessary to measure the liquid content of a process stream. In particular, during the extraction of natural gas, it is important to measure the amount of liquid chemicals, oil, condensed hydrocarbons and/or water in the gas, to meet quality specifications. The presence of too much liquid in the gas can cause serious damage to equipment intended to operate on gas (such as compressors).
10 It is particularly important to measure the liquid content of gas emerging from a gas scrubber or other device for separating liquid from the gas, to monitor the performance of the scrubber.

 A known apparatus for measuring fluid density, and specifically the density of a natural gas stream, is disclosed in WO 2011/039534. The apparatus includes
15 a source of beta particles, and a detector capable of detecting the beta particles. The fluid (which in practice is a gas with a small amount of entrained liquid) passes between the source and the detector, and the amount of beta particles detected by the detector varies with the density of the fluid. Since the density depends to some degree on the amount of liquid entrained in the gas, a variation in the amount of
20 beta particles detected by the detector can be correlated with a variation in the amount of liquid entrained in the gas.

 There are several known apparatus for the measurement of liquid content in a gas based on a measurement of the hold-up, that is, the liquid to gas area fraction at a given cross-section or representative volume.

25 A problem which can arise with devices of this type when used in gas streams with very low liquid content (around 1 part per million by volume) is the formation of liquid film on measuring surfaces (as a result of droplet deposition or condensation). As liquid film will move at a lower velocity than the gas, a measurement of the hold-up (area ratio) will not be representative of the liquid to
30 gas flow ratio. For example, if a liquid film were to form on the detector of WO 2011/039534, the film would have a considerable effect on beta particles passing through it. Further, if that liquid were to move (say) 100 times slower than the gas flow, it could be interpreted as 100 times the amount of liquid moving at the gas velocity. Other types of density or phase measuring device are also prone to errors
35 arising from the presence of liquid films, and a liquid film with a thickness of only a

few micrometres can produce errors up to two orders of magnitude on instrument reading.

It is possible to form water-repellent coatings on surfaces. If such a coating were to be formed on the surface of a detector as described above, it would prevent water in the gas stream from being deposited or condensing on the coated surfaces. However, as mentioned above, a natural gas stream can also include condensed hydrocarbons, and a water-repellent coating will not necessarily prevent the condensed hydrocarbons from forming a film. In addition, the uncertainty due to aging or service fouling is difficult to account for.

It is also possible to calibrate the relationship between area ratio and flux ratio, or use some empirical terms or models. However, such a solution is less attractive due to the need for calibration and increased uncertainty of fluid composition, and general reduced flexibility.

The invention has been made in view of the above problems, and aims to condition the multiphase stream to prevent formation of a liquid film, to allow more accurate measurement of the liquid content of a gas stream.

According to a first aspect of the present invention, there is provided a method of conditioning a multi-phase flow of gas with entrained liquid droplets in a process stream section where a multi-phase measurement sensitive to the hold-up is to be made, comprising heating a surface within the section to a temperature such that droplets of liquid contacting the heated surface are subject to the Leidenfrost effect.

As will be explained in detail below, the Leidenfrost effect prevents the heated surface from being wetted by any droplets of liquid which may come into contact with it. As a result, liquid does not accumulate on the surface, but remains in the gas flow, and so accurate measurements of the overall density of the gas, and thus the amount of liquid entrained in the gas, can be made.

In a preferred form, the surface is heated by means of a heater located beneath the surface. This arrangement allows the surface to be heated without affecting the flow within the pipe.

In an alternative arrangement, the surface is heated by means of a hot gas which is directed towards or along the surface. As well as heating the surface, the hot gas will also tend to blow any liquid away from the surface.

The hot gas can be supplied from outside the pipe; however, it is preferred for a part of the multi-phase flow of gas is dried and heated to produce the hot gas. This avoids any risk of the gas in the pipe being contaminated.

5 An additional element of the invention is placing a liquid film breaker upstream of the measurement section. The film breaker (which may be an entrainment disk) is a device which acts to ensure that most of the annular flow (at the outer edge of the process stream section) is entrained into the gas flow. This will facilitate the heating discussed above, as it is easier to prevent deposition of a few droplets than it is to evaporate the entire annular liquid film.

10 As mentioned above, the presence of a film of liquid on the detector can have a very significant effect on the accuracy of the measurements made. The Leidenfrost effect prevents a film of liquid from forming on the detector, and thus allows accurate measurements to be made.

15 A preferred embodiment of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic cross-sectional view of a part of a natural gas pipe with a detector, incorporating means according to the preferred embodiment.

20 As mentioned above, Figure 1 shows a part of a pipe 10 for carrying a natural gas stream. The natural gas stream will include some liquid, in the form of water and/or condensed hydrocarbons.

The pipe is provided with a detector 12 for measuring the density of the gas stream flowing past, and this density can be used to determine the liquid content of the gas flow in a known manner. In the current embodiment, the detector 12 is arranged downstream of a venturi 14.

25 In order to avoid the formation of liquid films on the surfaces of the detector where such films would cause problems, heating means are provided to raise the temperature of these surfaces. More specifically, the surfaces are heated to a sufficiently high temperature for the Leidenfrost effect to occur.

30 The Leidenfrost effect occurs when a drop of liquid comes into contact with a surface whose temperature is well above the boiling point of the liquid. At the initial contact of the drop with the hot surface, the bottom part of the drop boils immediately. This produces a layer of gas between the hot surface and the droplet, and this layer of gas supports the rest of the droplet, preventing further direct contact between the drop and the hot surface. Since the gas will normally have a much lower thermal conductivity than the liquid, further heat transfer between the

35

- 4 -

hot surface and the drop is reduced, so the drop remains suspended above the hot surface and does not come into further contact with it.

Thus, as long as the surfaces are heated to above the critical temperature for the Leidenfrost effect to occur (hereinafter "the Leidenfrost temperature"), liquid
5 will not form a film on the surfaces, but will instead form discrete droplets. The Leidenfrost temperature for water (or aqueous phase) depends on a number of factors (such as the nature of the surface); however, the Leidenfrost temperature for water is greater than the Leidenfrost temperature for the condensed hydrocarbons likely to be found in a natural gas stream, and so it is only necessary
10 to heat the surfaces to the Leidenfrost temperature for water (or aqueous phase) to ensure that the liquids in the natural gas stream form discrete droplets rather than a film. Other hydrocarbon mixtures can have a different Leidenfrost temperature, but this can easily be found theoretically or through a routine lab-scale test.

Since the surfaces are exposed to the flowing gas stream, the motion of the
15 gas will tend to push the droplets off the surfaces, thus keeping the surfaces entirely liquid-free and ensuring accuracy of the density measurements made by the detector.

Two different ways of heating the surface are shown in Figure 1. In practice, either or both methods can be used.

20 Firstly, a heating element 20 can be located underneath the surfaces 22 where condensation is to be avoided, in order to increase the temperature of these surfaces. Figure 1 shows a heating element 20 disposed in the wall of the pipe.

Secondly, it is possible to draw off a part of the gas flow upstream of the detector. Some of this drawn-off gas is dried using a meshpad 30 or similar device,
25 passed through a heater 32 where it is heated to above the Leidenfrost temperature, and then injected back into the pipe so that it flows along the surface 22 to be heated generally parallel thereto. The remainder of the drawn-off gas is reintroduced into the pipe downstream of the detector 12. In an alternative form, the drier device may be located inside the process pipe, so that the drawn-off gas is
30 already dried. The heated gas will heat the surface 22 to raise its temperature to above the Leidenfrost temperature, and will also have the effect of helping to blow droplets away from the surface.

The Leidenfrost effect prevents a film of liquid from being formed on the surfaces; instead, liquid will form droplets that do not come into contact with the
35 surface, and the movement of the gas stream will tend to sweep the droplets from

- 5 -

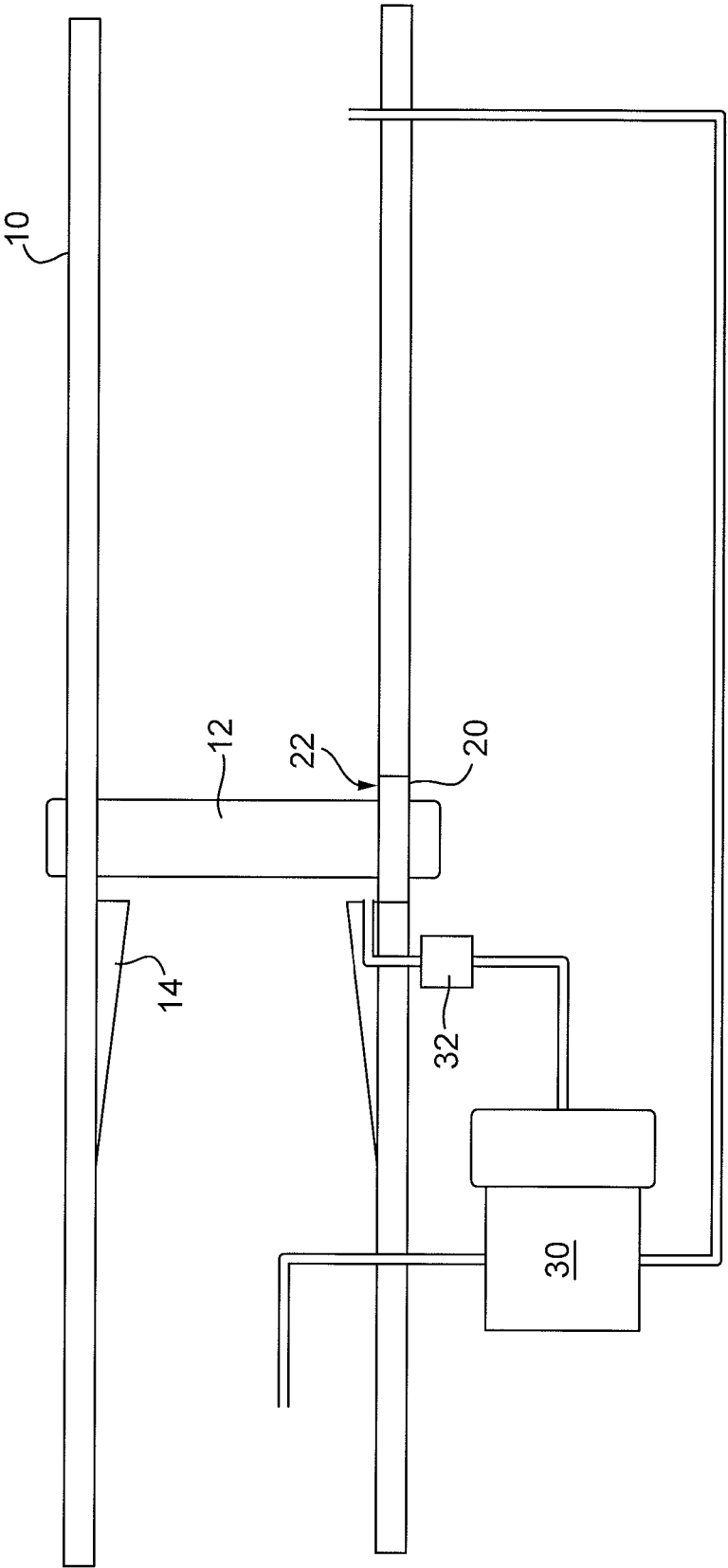
the surface. Thus, the surfaces will remain free of liquid, so that the accuracy of the flow density measurements can be improved.

Further, since no liquid is deposited on the surfaces, the liquid will remain dispersed in the gas. As a result, the average velocity of the liquid phase will be
5 very close to the average velocity of the gas phase, and so the slip ratio (the ratio
between the velocity of the gas phase and the velocity of the liquid phase) will be
close to unity (that is, a “no slip” condition). The “no-slip” condition reduces the
need to calibrate multi-phase meters such as the detector described in WO
2011/039534. Trustable (and calibration-free) multiphase metering is particularly
10 important for subsea applications and monitoring of subsea processes.

CLAIMS

1. A method of conditioning a multi-phase flow of gas with liquid in a process stream section where a multiphase measurement sensitive to hold-up is to be made, comprising heating a surface within the section to a temperature such that droplets of liquid contacting the heated surface are subject to the Leidenfrost effect.
2. A method as claimed in claim 1, wherein the surface is heated by means of a heater located beneath the surface.
3. A method as claimed in claim 1, wherein the surface is heated by means of a hot gas which is directed towards or along the surface.
4. A method as claimed in claim 3, wherein a part of the multi-phase flow of gas is dried and heated to produce the hot gas.
5. A method as claimed in any preceding claim, wherein a liquid film breaker, such as an entrainment device, is installed upstream of the process stream section to facilitate the conditioning.

Fig. 1



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/052794

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01N33/00 G01F1/74
ADD. G01N23/12 G01N33/22 G01N1/22

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)

G01N G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/209055 A1 (DIMARZO MARINO [US] ET AL) 13 November 2003 (2003-11-13)	1,2
Y	paragraph [0005] - paragraphs [0007], [0020] paragraph [0072] - paragraph [0078]; figures 1, 2	5
Y	----- US 2004/011139 A1 (DANIEL PAUL RICHARD [GB] ET AL) 22 January 2004 (2004-01-22) paragraphs [0009], [0013] - paragraph [0015]; figure 1	5
A	----- WO 2011/039534 A1 (JOHNSON MATTHEY PLC [GB]; HUSEBO MAGNE KJETIL [NO]; SAEVAREIDE TOR MAG) 7 April 2011 (2011-04-07) cited in the application the whole document ----- -/-	1-5



Further documents are listed in the continuation of Box C.



See patent family annex.

* 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

28 January 2015

Date of mailing of the international search report

05/02/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Pagels, Marcel

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2014/052794

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SBASTIEN CADALEN ET AL: "A mechanics approach for wet gas flow metering, theory and application to flow loop tests", INTERNATIONAL JOURNAL OF MULTIPHASE FLOW, ELSEVIER, AMSTERDAM, NL, vol. 37, no. 3, 22 September 2010 (2010-09-22), pages 260-267, XP028369048, ISSN: 0301-9322, DOI: 10.1016/J.IJMULTIPHASEFLOW.2010.09.006 [retrieved on 2010-10-12] the whole document -----	1-5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2014/052794

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003209055	A1	13-11-2003	CA 2441879 A1 03-10-2002
			EP 1390728 A1 25-02-2004
			MX PA03008628 A 15-03-2006
			US 2003041650 A1 06-03-2003
			US 2003209055 A1 13-11-2003
			US 2003209056 A1 13-11-2003
			WO 02077625 A1 03-10-2002

US 2004011139	A1	22-01-2004	AU 7081101 A 05-02-2002
			BR 0112634 A 10-06-2003
			EP 1305579 A1 02-05-2003
			GB 2367138 A 27-03-2002
			JP 3631233 B2 23-03-2005
			JP 2004505236 A 19-02-2004
			NO 20030308 A 21-03-2003
			US 2004011139 A1 22-01-2004
			WO 0208702 A1 31-01-2002

WO 2011039534	A1	07-04-2011	EP 2483659 A1 08-08-2012
			GB 2486617 A 20-06-2012
			US 2012256086 A1 11-10-2012
			WO 2011039534 A1 07-04-2011
