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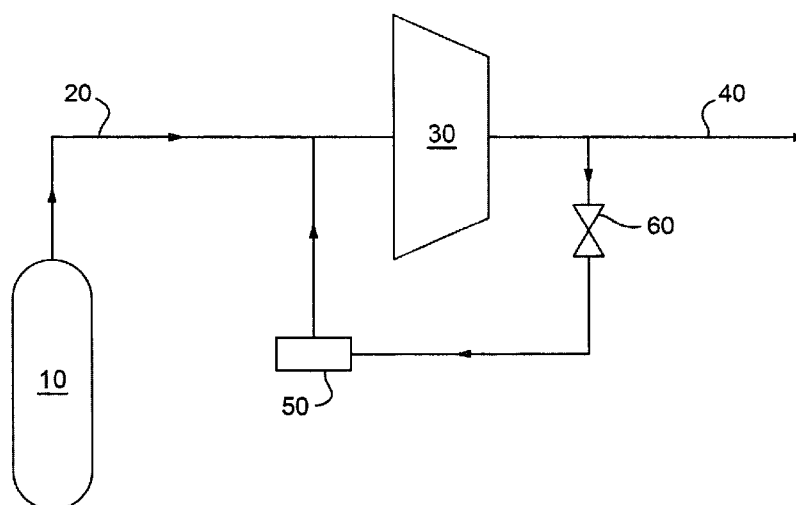
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(54) Title: DEW POINT AND CARRY-OVER MONITORING

Fig. 1



(57) Abstract: The invention relates to a method for automatically monitoring the liquid content in a gas, and in particular the gas leaving a scrubber and entering a compressor. In the method, a sample of fluid is taken from the outlet of the compressor, its temperature and pressure are automatically varied, and the pressure and temperature at which condensation forms is automatically detected. The pressure and temperature thus detected can be used to determine the liquid content in the gas. In a variant method, the temperature and pressure of the sample are automatically varied, and the rate of liquid condensation is measured to determine the liquid content.

DEW POINT AND CARRY-OVER MONITORING

The invention relates to a method for monitoring the liquid content in gas entering a compressor, and more particular to monitoring the liquid content in gas exiting a scrubber before it enters a compressor.

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. Further, the presence of too much liquid in the gas can cause serious damage to equipment intended to operate on gas (such as compressors). 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, and to avoid damage to the compressor.

A scrubber which is close to being overloaded can be a bottleneck in a production facility, and may for example limit the maximum amount of gas that can be produced. It is thus very useful to know how much liquid is in the gas exiting the scrubber (often referred to as "carryover") when evaluating the need for modification in the facility.

One way of assessing the amount of liquid in the gas (the carryover) is through a manual dew point sensor (such as a chilled mirror hygrometer). In a sensor of this type, a sample of gas is taken from a process stream, and the pressure of the gas is reduced. The low pressure gas is then passed over a cold surface, usually a mirror. If the pressure and temperature of the sample are at appropriate levels, then condensation will form on the cold surface, and the presence (or absence) of condensation can be detected by observation with the naked eye.

The pressure and temperature at which condensation forms is referred to as the dew point line, and will vary depending on the amount of liquid in the gas. Thus, it is possible to determine the amount of liquid in the gas by varying the pressure and temperature until condensation occurs, and then using the pressure and temperature at which condensation forms to determine the amount of liquid in the gas. Quantification of the amount of liquid can be achieved with the help of an off-line gas composition. The process is carried out at discrete intervals (during a particular hour on a given day), rather than continuously, and so it cannot take account of carryover at a different time.

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Online dew point sensors are known, and are normally installed on export gas lines to check that the gas complies with required dew point specifications. These online dew point sensors cannot use naked-eye observations of condensation on a cold mirror; instead, various other methods of detecting the presence of condensation on a cold surface, such as those discussed in US 6126311 and US 2011/0188535, can be used. So far, online sensors of this type have not been used for online monitoring of liquid carryover from scrubbers.

Another problem with using dew point sensors to monitor two-phase (liquid in gas) flows in this way is that it is difficult to guarantee that the sample taken from the flow is representative. For example, the sample taken may well have more or less liquid than the average amount.

According to a first aspect of the invention, there is provided a method of monitoring the dew point at the outlet of a compressor, comprising the steps of: taking a sample of fluid from the outlet of the compressor, the fluid being in a supercritical state or a superheated gas; passing the sample through a regulator to thereby change the flow rate and pressure of the sample, and passing the sample through a temperature changing means to thereby change the temperature of the sample; varying the pressure and temperature of the sample and detecting the pressure and temperature at which condensation forms; wherein the variation of the pressure and temperature and the detection is carried out automatically.

With this method, the fluid sample is taken from the outlet of the compressor in a uniform superheated single phase. There is thus no risk of the sample having an anomalously high or low liquid fraction.

Further, as the pressure and temperature of the sample are varied automatically, and the detection of the pressure and temperature at which condensation forms is also carried out automatically, the entire monitoring process can be carried out without human intervention. This allows continuous monitoring of the compressor outlet, and so an alarm can be given as soon as anything untoward is detected. It also allows monitoring of flows in areas which are inaccessible or dangerous.

Any suitable method of detecting the condensation can be used; however, it is preferred for the detection to be carried out using a method that can provide additional information regarding the type of liquid phase which has formed, such as optical means, and more preferably near infra-red absorption or Raman spectroscopy. These methods have the advantage that absorption is different for

water and hydrocarbon condensate, and so it is possible to determine what liquid has condensed. Further, the wavelengths used can pass through heavy oil, and thus the detection technique is robust with regard to fouling of the cold surface.

Preferably, the compressor is directly downstream of a scrubber, and the pressure and temperature at which condensation forms is used to determine the amount of liquid in the gas exiting the scrubber.

This allows a more convenient monitoring of the outlet of the scrubber. As discussed above, sampling a two-phase flow of gas with carryover brings the disadvantage that the sample may not be representative of the entire flow. By allowing the compressor to heat and compress the flow of gas with carryover into a uniform state (superheated gas or supercritical state), it is possible to be more sure that the sample is representative of the flow.

According to a second aspect of the present invention, there is provided a method of monitoring the liquid content in a gas stream downstream of a superheating unit, comprising the steps of: taking a sample of fluid downstream of the superheating unit, the fluid being in a supercritical state or a superheated gas; passing the sample through a regulating arrangement to change the flow rate and pressure of the sample, and passing the sample through a heat exchanger to change the temperature of the sample; and measuring the rate of liquid condensation; wherein the variation of the pressure and temperature and the measurement is carried out automatically.

As with the first aspect, the fluid sample is taken from the outlet of the compressor in a uniform superheated single phase, and so there is no risk of the sample having an anomalously high or low liquid fraction. Further, the entire monitoring process can be carried out without human intervention.

Measuring the rate of liquid condensation provides an additional route to determining the liquid content. Any suitable means may be provided for measuring the rate of liquid condensation, but in a preferred form, the measurement is carried out by a densitometer, and preferably an oscillating U-tube densitometer.

The superheating unit may be a compressor or a heater.

The invention also extends to a system for carrying out the methods defined above.

Preferred embodiments of the invention will now be described by way of example only and with reference to the attached Figures, in which:

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Figure 1 is a schematic view of the dew point monitoring apparatus of the present invention installed in the vicinity of a scrubber and a compressor for monitoring the carry-over from the scrubber;

Figure 2 is a schematic view a liquid content monitoring apparatus; and

Figure 3 is a graph relating to measurement of condensation rate.

As shown in Figure 1, a scrubber or separator 10 is provided to remove liquid from a gas flow. The dried gas exiting the scrubber then passes along line 20 to a compressor 30. The compressed gas leaves the compressor along line 40. As a result of the compression, the compressed gas leaving the compressor is a single phase (corresponding to a supercritical fluid); any residual liquid (carryover) entering the compressor with the dried gas will also be present as supercritical fluid.

A dew point sensor 50 is provided to monitor the amount of liquid in the gas stream exiting the scrubber 10. A small amount of the compressed gas is bled from line 40 downstream of the compressor, passes through a regulating valve 60, and then passes through the dew point sensor 50. The gas leaving the dew point sensor 50 is readmitted to line 20, upstream of the compressor. It is also possible to flare or dump the gas leaving the sensor, but this is wasteful and is not preferred.

Compressors routinely include small nozzles or connectors in the piping upstream and downstream of the compressor, and so there is no difficulty in installing the system in existing plants. It is also possible to install the sensor in association with a surge control loop, which in practice will be present on the compressor.

The dew point sensor 50 operates in a similar manner to a manual dew point sensor, in that the gas is passed over a cold surface, and condensation on the surface is detected. However, rather than relying on naked-eye observations to determine the presence of condensation, a different form of sensing means is used.

The regulating valve 60 can be controlled to vary the pressure of the gas at the valve outlet. The pressure at the valve outlet can be varied between the compressor suction pressure (the pressure in line 20) and the compressor discharge pressure (the pressure in line 40). It is also possible to use a venturi tube to reduce the pressure further, if desired.

Similarly, the temperature of the cold surface in the dew point sensor can be varied. The cold surface can be cooled using a Peltier cooling element (in which heat is removed from an electrical junction between two different metals), or by using the Joule-Thomson effect (where a fluid is cooled by throttling).

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By varying the pressure at the valve outlet and the temperature of the cold surface, the gas exiting the compressor 30 in line 40 can be subjected to a range of differing pressures and temperatures during its period in contact with the cold surface. The particular combination of pressure and temperature at which condensation occurs can be determined.

From this information and by using an appropriate equation of state, the amount of liquid in the gas exiting the compressor can be determined, and thus the degree of carryover from the scrubber can be determined.

In the presently preferred embodiment, the detection of condensation on the cold surface is carried out using optical means, and preferably near infra-red absorption or Raman spectroscopy. These methods have the advantage that the wavelengths used can pass through heavy oil, and are more robust with regard to deposition on or fouling of the cold surface in the dew point sensor.

Detection of condensation is initially an either/or process (that is, simply determining whether or not there is any condensation on the cold surface); the temperature and pressure at which condensation forms can then be used to determine the amount of liquid in the gas. Once the presence of condensation has been detected, it is possible to determine the nature of the liquid on the cold surface (for example, whether the liquid is water or a liquid hydrocarbon).

The embodiment described above is intended for dew point measurement, to determine the amount of liquid in a gas stream exiting a scrubber. However, the embodiment may be used to monitor the entire dew point line, including cricodenbar point (that is, the pressure in a two-phase system above which no gas can form, regardless of the temperature, and the fluid remains in a supercritical state).

The dew point sensor described above allows reliable measurements of the liquid fraction to be made, even when the liquid fraction is relatively small. With these measurements, it is possible to assure that the gas leaving the compressor is of the correct specification, and to monitor the performance of a separation unit (such as a scrubber) upstream of the compressor. If it is determined that the separation unit is allowing too much liquid to pass through, then steps can be taken to avoid damage to the compressor and to any equipment downstream thereof.

Figure 2 is a schematic view of a liquid content monitoring apparatus 100 which can be used in the invention, with its ancillary components.

As shown in Figure 2, a sample is taken from a gas flow, the liquid content of which is to be measured. The sample is heated in a heater 102, to ensure that

the fluid is in a supercritical state or is a superheated gas. The sample then passes through a pressure regulator 104 to change its pressure, and through a cooler 106 to change its temperature. The sample, with a specific pressure and temperature, then passes through an automatic dew point sensor 108. Flow, pressure and temperature are all automatically regulated, and so the measurement of the dew point can be automated.

After passing through the sensor 108, the sample is fed through a separator 110, where the liquid fraction is separated from the gas in chamber 112. The gas passes through a regulating valve 118, and is then returned to the gas flow at a lower pressure (such as at the suction side of a compressor). The amount of liquid can be measured, to provide further information on the amount of liquid in the flow, and can also be analyzed to determine the nature of the liquid. Measurement and analysis of the liquid can also be automatically regulated.

The liquid accumulates in a reservoir 114, and the reservoir can be flushed as necessary through operation of a valve 116. Liquid accumulation can be achieved by a set-up where the bottom of the chamber 112 has a funnel shape, so as to increase the change in height for a change in accumulated liquid volume.

In a presently preferred form, the lower end of the funnel leads to the opening of a U-tube oscillator densitometer, which can be used to determine the nature of the accumulated liquid (water, hydrocarbon, etc). Further, the rate of filling of the densitometer can be used as a further measurement of the liquid content of the flow. Figure 3 shows the relationship between partial filling and volume for two different fluids (decane and isopropanol) with different viscosities and differing rates of filling.

The apparatus as described with reference to Figure 2 is effectively an automated apparatus for carrying out the method described in ISO 6570 ("Natural gas - Determination of potential hydrocarbon liquid content - Gravimetric methods"). Automation of the process allows for online monitoring of the liquid content. Further, since the process is automated and can be carried out without any human intervention, it can be used to monitor liquid content in flows which are normally inaccessible to humans.

In addition, the gas from the sample is returned to the original flow, rather than being flared or dumped to atmosphere. The process can therefore be used to monitor liquid content in situations such as a subsea environment, where flaring is not possible.

CLAIMS

1. A method of monitoring the dew point at the outlet of a compressor, comprising the steps of:
 - taking a sample of fluid from the outlet of the compressor, the fluid being in a supercritical state or a superheated gas;
 - passing the sample through a regulator to thereby change the flow rate and pressure of the sample, and passing the sample through a temperature changing means to thereby change the temperature of the sample;
 - varying the pressure and temperature of the sample and detecting the pressure and temperature at which condensation forms;
 - wherein the variation of the pressure and temperature and the detection is carried out automatically.
2. A method as claimed in claim 1, wherein said detection is carried out using optical means.
3. A method as claimed in claim 2, wherein said detection is carried out using near infra-red absorption or Raman spectroscopy.
4. A method as claimed in any preceding claim, wherein the sample is passed over a cold surface, the temperature of which can be varied automatically, and the pressure and temperature at which condensation forms on the cold surface is detected automatically.
5. A method as claimed in any preceding claim, wherein the compressor is directly downstream of a scrubber, and the pressure and temperature at which condensation forms is used to determine the amount of liquid in the gas exiting the scrubber.
6. A method of monitoring the liquid content in a gas stream downstream of a superheating unit, comprising the steps of:
 - taking a sample of fluid downstream of the superheating unit, the fluid being in a supercritical state or a superheated gas;

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passing the sample through a regulating arrangement to change the flow rate and pressure of the sample, and passing the sample through a heat exchanger to change the temperature of the sample; and

measuring the rate of liquid condensation;

wherein the variation of the pressure and temperature and the measurement is carried out automatically.

7. A method as claimed in claim 6, wherein said superheating unit is a compressor.
8. A method as claimed in claim 6, wherein said superheating unit is a heater.
9. A method as claimed in any of claims 6 to 8, wherein said measurement of the rate of liquid condensation is carried out by a densitometer.
10. A system for carrying out the method of any preceding claim.

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Fig. 1

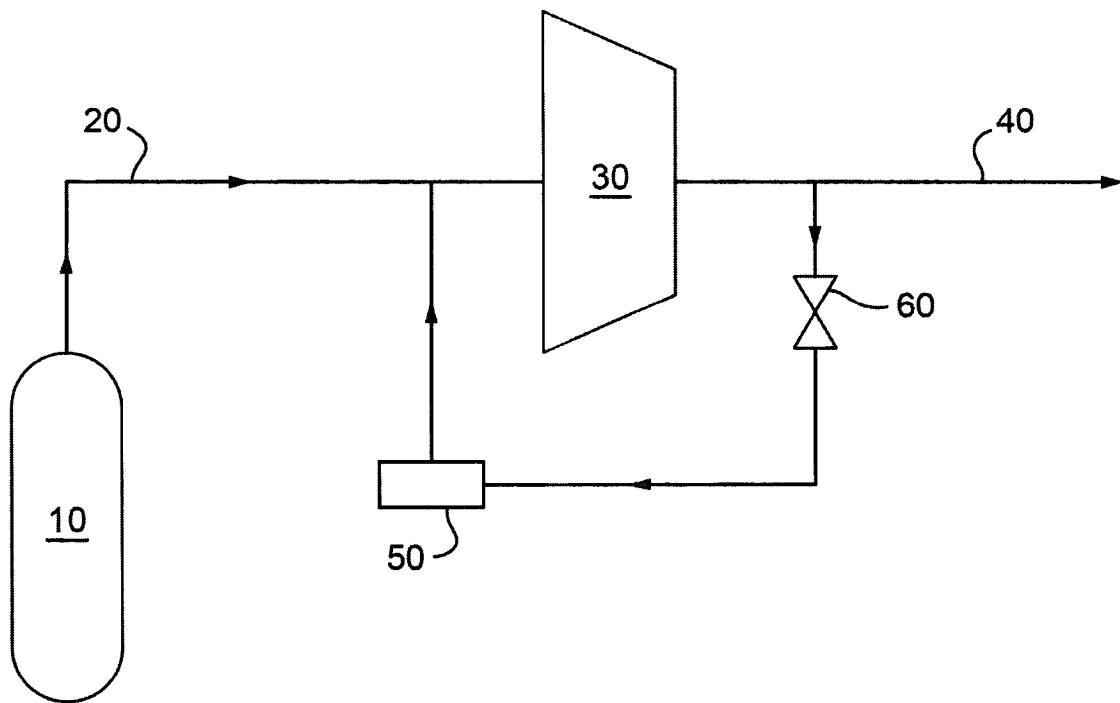
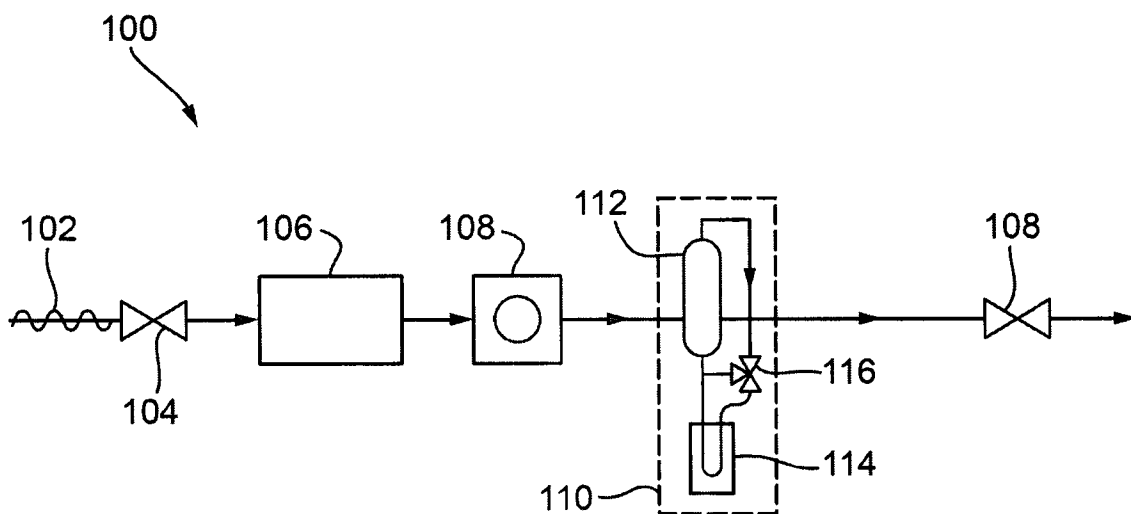
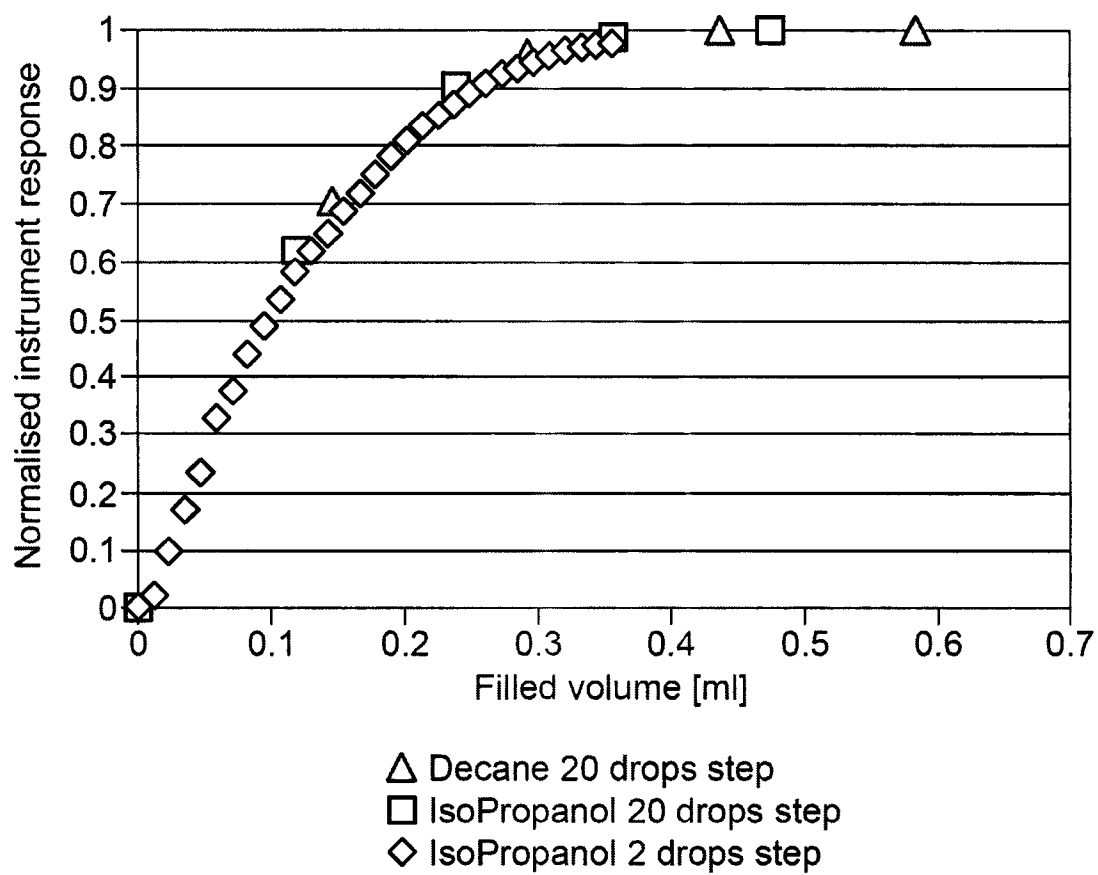


Fig. 2



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Fig. 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2015/050774

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01N25/14 G01N25/58 G01N25/66 G01N25/68 G01N25/70
G01N33/22 G01N21/359 G01N21/65

ADD.

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

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	WO 2007/046139 A1 (KAWASAKI PLANT SYSTEMS KK [JP]; SAKO MASAOKI; FUJISAKI YUJIRO; KOKETSU) 26 April 2007 (2007-04-26) abstract; paragraphs: 39, 42, 56 and 65.; figure 4	1-10
A	----- US 7 581 877 B1 (ZARRABIAN SOHRAB [US]) 1 September 2009 (2009-09-01) claims 1-17	1-10
A	----- US 2 106 593 A (DENISTON ROBERT F ET AL) 25 January 1938 (1938-01-25) the whole document -----	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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