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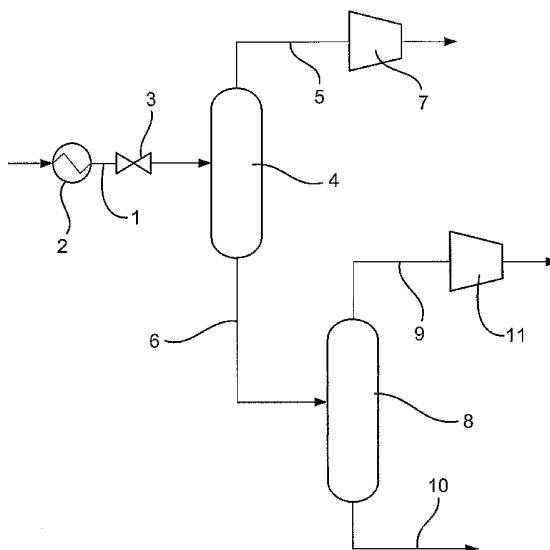
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[Continued on next page]

(54) Title: PROCESS FOR PRODUCING NITROGEN DEPLETED LIQUIFIED NATURAL GAS



(57) Abstract: A separation process comprising: (a) introducing a feed stream (1) comprising methane and at least one high-volatility component into a first separation vessel (4) that is operated at a pressure in the range 2 to 30 bar absolute and withdrawing from the first separation vessel (4) a first liquid stream enriched in methane (6) and a first vapour stream enriched in the high-volatility component (5); and (b) introducing the first liquid stream enriched in methane (6) into a second separation vessel (8) operated at a pressure in the range 1 to 10 bar absolute with the proviso that the second separation vessel (8) is operated at a pressure below the operating pressure of the first separation vessel (4) and withdrawing from the second separation vessel (8) a second liquid stream that is further enriched in methane (10) and a second vapour stream (9) having a high volatility component content less than that of the first vapour stream (5).

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- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE,

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PROCESS FOR PRODUCING NITROGEN DEPLETED LIQUIFIED NATURAL GAS

The present invention relates to a process for separating a multi-component stream containing methane and at least one high volatility component having a relative volatility greater than that of methane and for producing liquefied natural gas ("LNG"). Because of its clean burning qualities and convenience, natural gas has become widely
5 used in recent years. When pipeline transportation is not feasible, produced natural gas is often processed into LNG for transport to market.

In general, most known liquefaction plants for natural gas comprise at least four distinct stages. These include (1) a preliminary gas treatment stage for the removal of water and acidic gases such as carbon dioxide and hydrogen sulphide, (2) a natural gas
10 liquids product separation stage using low but non-cryogenic temperatures for the separation and recovery of the propane and heavier hydrocarbon components, (3) a cooling stage wherein the natural gas is at least partially liquefied and (4) a nitrogen separation or rejection stage. The nitrogen rejection stage is generally effected by fractionating the at least partially liquefied natural gas in a separation column to
15 produce a vapour stream and a liquid stream. The vapour stream from the separation column is rich in nitrogen (for example, about 20 mole %) and is generally used as fuel for the gas turbines that provide power to the liquefaction plant. Although various arrangements have been proposed for separating the nitrogen, including multiple separators, the gaseous products of the separation stages are generally combined to form
20 the fuel gas.

Where a liquefaction plant is located in a geographical area having elevated summer temperatures, the LNG production capacity of the plant is constrained because

the performance of the air coolers that are used to reject the process heat to atmosphere is reduced. It has been found that this decrease in capacity of the LNG plant under summer temperature conditions can be significantly mitigated by a combination of increasing the flow rate of the natural gas feed to the liquefaction plant and of running the cooling stage at a slightly increased outlet temperature. However, a disadvantage of operating the plant in this manner is that an increased amount of vapour is separated in the nitrogen separation or rejection stage. Accordingly, the separated vapour may exceed the amount required as fuel gas for the turbines that provide power to the liquefaction plant. Although the vapour from the nitrogen separation stage is acceptable for use as fuel gas for the turbines, the excess vapour may not be suitable for use as feed to a domestic gas network as its high nitrogen content reduces its heating value. Thus, domestic fuel gas is generally required to have a content of nitrogen and other high-volatility gases of less than 5.5 mole%. Accordingly, there is a need for a method of reducing the nitrogen content of the excess vapour from the nitrogen rejection stage.

Thus, the present invention relates to a liquefaction process comprising:

- (a) introducing a feed stream comprising methane and at least one high-volatility component into a first separation vessel that is operated at a pressure in the range 2 to 30 bar absolute and withdrawing from the first separation vessel a first liquid stream enriched in methane and a first vapour stream enriched in the high-volatility component; and
- (b) introducing the first liquid stream enriched in methane into a second separation vessel operated at a pressure in the range 1 to 10 bar absolute with the proviso that the second separation vessel is operated at a pressure below the operating pressure of the first separation vessel and withdrawing from the second separation vessel a second liquid stream that is further enriched in methane and a second vapour stream having a high volatility component content less than that of the first vapour stream.

The present invention is particularly suitable as a process for producing liquefied natural gas. Thus, the second liquid stream enriched in methane is liquefied natural gas, the first vapour stream is fuel gas and the second vapour stream is domestic gas.

An advantage of performing the separation of the high-volatility component in two separation vessels is that the first separation vessel is operated at a higher pressure than the second separation vessel so that a larger proportion of the high-volatility

component is separated in the first separation vessel than the second separation vessel. It is preferred that the pressures of the first and second separation vessels are selected such that the second vapour stream from the second separation vessel has a high-volatility component content that meets the specification for domestic gas while the amount of the first vapour stream that is withdrawn from the first separation vessel is not in excess of the amount that can be consumed in the liquefaction plant and/or in a plant that is co-located with or in the vicinity of the liquefaction plant (hereinafter referred to as "co-located plant"). Suitably, the first vapour stream may be consumed as fuel for the gas turbines that power the liquefaction plant, and/or as feed to a gas-fired heater or boiler of the liquefaction plant and/or may be consumed in a co-located chemical plant or electric power generation plant. For avoidance of doubt, the liquefaction plant may be of any capacity (small or large scale) provided that the amount of the first vapour stream is not in excess of the amount that can be consumed in the liquefaction plant and/or in a co-located plant.

As discussed above, prior art liquefaction processes have a high volatility component separation stage that may employ a single separation vessel to separate a vapour stream that is enriched in the high-volatility component from a liquid stream enriched in methane or may employ more than one separation vessel wherein the vapour streams are combined to form a fuel gas. The LNG production rate is limited by the constraint on the amount of the vapour stream that can be consumed in the liquefaction plant and/or in a co-located plant. As discussed above, under summer temperature conditions, the performance of the air coolers that are used to reject heat to atmosphere is reduced. Therefore, the temperature of the feed stream to the single separation vessel may be higher than under winter temperature conditions thereby increasing the amount of flashed vapour. Accordingly, the maximum feed rate to the separation stage must be reduced so that the amount of the vapour stream that is withdrawn from the separation stage is not in excess of the amount that can be consumed in the liquefaction plant and/or in the co-located plant. Thus, the LNG production capacity of the prior art liquefaction plant is constrained by the summer temperature conditions.

The process of the present invention removes the constraint on the amount of vapour that may be flashed in the high-volatility component separation stage so that, the reduction in the LNG production capacity of the liquefaction plant during summer

temperature conditions may be mitigated by increasing the flow rate of the natural gas feed to the liquefaction plant. Advantageously, the additional gas that is vaporised in the high-volatility component separation stage during summer temperature conditions provides a conditioned gas stream for the domestic gas market. A further advantage of the process of the present invention is that by increasing the flow rate of the natural gas feed to the liquefaction plant, increased amounts of gas condensate (a high value product) may be separated therefrom.

Thus, advantages of the process of the present invention include:

- a) mitigating the decrease in the LNG production capacity of a liquefaction plant under summer temperature conditions;
- b) producing a conditioned natural gas stream for the domestic gas market;
- c) increasing the natural gas feed rate to the liquefaction plant thereby increasing the amount of gas condensate that is separated therefrom;
- d) the ability to debottleneck an existing liquefaction plant by retrofitting an additional high-volatility separation vessel thereto; and
- e) the nitrogen content of the first vapour stream flowing to plant fuel may be reduced as a result of its dilution in a larger overall vapour off-take. This is beneficial to the operation of any gas turbines on the liquefaction plant which are fuelled with this first vapour stream.

As would be evident to the person skilled in the art, the separation of the high-volatility component may be achieved using 3 or more separation vessels arranged in series, for example, 3 or 4 separation vessels arranged in series, with each separation vessel in the series being operated at a lower pressure than the preceding separation vessel. Suitably the separation vessels in the series are simple gas liquid separation drums or distillation/fractionation columns. Where 3 vessels are arranged in series, the first liquid stream that is withdrawn from the first separation vessel is fed to the second separation vessel in the series while the second liquid stream from the second separation vessel is fed to the third separation vessel in the series. The vapour stream withdrawn from the third separation vessel should have a high-volatility component content that meets the specification for domestic gas while the vapour streams withdrawn from the first and second separation vessels may be combined and consumed in the liquefaction plant and/or in a co-located plant. Accordingly, the operating pressures of the 3

separation vessels should be selected such that the combined amount of the first and second vapour streams does not exceed the amount that can be consumed in the liquefaction plant and/or co-located plant.

Typically, the high-volatility component is nitrogen. However, it is envisaged
5 that the feed stream to the first separation vessel may also comprise trace amounts of other high-volatility components such as helium, for example, less than 0.1 mole% of other high-volatility components.

The present invention will now be illustrated with reference to a nitrogen separation stage that employs two separation vessels.

10 Suitably, the feed stream to the first separation vessel is a liquefied natural gas feed stream or a mixture of liquefied natural gas and natural gas vapour. Preferably, the feed stream to the first separation vessel has a nitrogen content of greater than 0.5 mole %. Preferably, the feed stream to the first separation vessel has a nitrogen content of less than 10 mole %. Suitably, the feed stream is obtained by cooling natural gas in one
15 or more cooling stages upstream of the first separation vessel. Preferably, the feed stream exits the cooling stage at a temperature in the range -150 to -100°C, preferably -145 to -130°C, for example, about -135°C. Typically, the feed stream exits the cooling stage at a pressure of above 35 bar absolute.

Preferably, the feed stream to the first separation vessel is expanded by a
20 suitable expansion means, for example, an expansion valve or a turboexpander, to a lower pressure prior to being introduced to the first separation vessel. Suitably, the feed stream to the first separation vessel is expanded to a pressure in the range 2 to 30 bar absolute, preferably 3 to 15 bar absolute, for example 5 to 10 bar absolute. Expansion of the feed stream to a lower pressure effects further cooling of the feed stream.

25 The first separation vessel produces a first liquid stream that is lean in nitrogen and a first vapour stream that is enriched in nitrogen. Suitably, the first vapour stream that is enriched in nitrogen has a nitrogen content of at least 10 mole%, preferably in the range 10 to 30 mole%. Preferably, the mass flow rate of the first vapour stream is 5 to 10% of the mass flow rate of the feed stream to the first separation vessel. Suitably, the
30 first vapour stream that is enriched in nitrogen is employed as fuel gas for the gas turbines that power the liquefaction plant and/or as feed to a gas-fired heater or reboiler.

The first vapour stream is preferably pressurized to a pressure of at least 30 bar

absolute, preferably, at least 40 bar absolute prior to being fed to the gas turbines. It is also envisaged that the first vapour stream may be consumed in a co-located plant.

The first liquid stream that is withdrawn from the first separation vessel is passed to a second separation vessel that is operated at a pressure less than that of the first separation vessel. Preferably, the operating pressure of the second separation vessel is at least 2 bar below the operating pressure of the first separation vessel.

Suitably, the first liquid stream that is withdrawn from the first separation vessel has a temperature in the range -130 to -160°C. Suitably, the first liquid stream is expanded by a suitable expansion means, for example, an expansion valve or turboexpander, to a

lower pressure prior to being introduced to the second separation vessel. Expansion of the first liquid stream effects further cooling of the first liquid stream. Typically, the first liquid stream is expanded to a pressure in the range 1 to 10 bar absolute, preferably 1 to 5 bar absolute, more preferably 1 to 3 bar absolute, most preferably 1 to 2 bar absolute, for example, 1 to 1.5 bar absolute. Preferably, the first liquid stream is

expanded to at or near atmospheric pressure. The second separation vessel produces a second liquid stream that is leaner in nitrogen than the first liquid stream and a second vapour stream that has a reduced content of nitrogen compared with the first vapour stream. Suitably, the second vapour stream has a content of nitrogen of less than 5.5 mole %, preferably, less than 4.5 mole %. Thus, the second vapour stream meets the specification for a domestic gas distribution network. Preferably, the second vapour stream is then compressed to a pressure of at least 60 bar absolute, more preferably at least 80 bar absolute and is then fed into a domestic gas distribution network. Suitably, the second liquid stream that is withdrawn from the second separation vessel is introduced into an LNG storage tank.

A further advantage of the process of the present invention is that an increased amount of gas may be flashed in the separation stage compared with a conventional separation stage that employs a single separation vessel. Accordingly, a greater amount of cooling may be achieved in the separation stage of the present invention resulting in a reduced cooling duty for the cooling stage of the liquefaction plant.

Typically, the first and second separation vessels may be simple gas liquid separation drums. Alternatively, the first and second separation vessels may be distillation or fractionation columns wherein liquid and vapour phases are concurrently

contacted to effect separation of a fluid mixture, as for example, by contacting of the vapour and liquid phases on a series of vertically spaced trays or plates mounted within the column or alternatively on packing elements with which the column is filled.

Suitably, the distillation or fractionation columns are operated with reflux and/or reboil.

5 Suitably, the feed stream enters the first distillation column at an intermediate level. Preferably, the first vapour stream is withdrawn from at or near the top of the first distillation column. Preferably, the first liquid stream is withdrawn from at or near the bottom of the first separation column. Suitably, a small portion of the first liquid stream may be heated and returned to the first distillation column as a vapour return
10 stream.

 Suitably, the first liquid stream enters the second distillation column at an intermediate level. Preferably, the second vapour stream is withdrawn from at or near the top of the second distillation column. Preferably, the second liquid stream is withdrawn from at or near the bottom of the second separation column. Suitably, a
15 small portion of the second liquid stream may be returned to the second distillation column as a vapour return stream.

The process of this invention will now be described with reference to the flow diagram illustrated in Figure 1.

 A liquefied natural gas feed stream 1 exits a cooling stage 2 and is then
20 expanded by a suitable expansion means 3 such as a conventional hydraulic expander to reduce the stream pressure to a value in the range 2 to 30 bar absolute. Expansion of the liquefied natural gas feed stream 1 effects further cooling of the feed stream. The liquefied natural gas feed stream enters first separation column 4 at an intermediate level. In separation column 4, vapour enriched with nitrogen and liquid enriched with
25 methane are separated. The vapour leaves the column as a first vapour stream 5 and the liquid leaves separation column 4 as a first liquid stream 6. The first vapour fraction is compressed to a pressure of about 40 bar absolute in a fuel gas compressor 7 and is then fed as fuel gas to a power plant of the liquefaction plant to drive at least one gas turbine and/or is used as feed to a gas-fired heater or reboiler of the liquefaction plant. The first
30 liquid stream 6 is passed to a second separation column 8 that is similar to the first separation column 5 but is operated at a lower pressure. Suitably, the operating pressure of the second separation column is in the range 1 to 10 bar absolute, preferably at or

approaching atmospheric pressure. Suitably, the first liquid stream 6 from the first separation column 4 is expanded by a suitable expansion means (not shown) before being fed into the second separation column 8. The first liquid stream 6 enters the second separation column 8 at an intermediate level. In the second separation column 8 vapour enriched with nitrogen and a liquid enriched with methane are separated. The second vapour leaves the column as a second vapour stream 9 and the liquid leaves the column as a second liquid stream 10. The second vapour stream 9 has a nitrogen content that is substantially less than that of the first vapour stream 5. Preferably, the second vapour stream 9 has a nitrogen content of less than 5.5 mole%. The second vapour stream 9 is fed to a domestic gas compressor system 11 where it is pressurized to a pressure of about 80 bar absolute before being introduced into a domestic gas network. Suitably, the second liquid stream 10 is fed to a conventional LNG storage tank (not shown), preferably, a tank that stores the LNG at or near atmospheric pressure.

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CLAIMS:

1. A liquefaction process comprising:

(a) introducing a feed stream comprising methane and at least one high-volatility component into a first separation vessel that is operated at a pressure in the range 2 to 30 bar absolute and withdrawing from the first separation vessel a first liquid stream enriched in methane and a first vapour stream enriched in the high-volatility component; and

(b) introducing the first liquid stream enriched in methane into a second separation vessel operated at a pressure in the range 1 to 10 bar absolute with the proviso that the second separation vessel is operated at a pressure below the operating pressure of the first separation vessel and withdrawing from the second separation vessel a second liquid stream that is further enriched in methane and a second vapour stream having a high volatility component content less than that of the first vapour stream.

2. A process as claimed in claim 1 in which the second liquid stream enriched in methane is liquefied natural gas, the first vapour stream is fuel gas and the second vapour stream is domestic gas.

3. A process as claimed in claim 2 in which the content of high-volatility component in the second vapour stream is less than 5.5 mole%.

4. A process as claimed in any one of claims 1 to 3 in which the pressures of the first and second separation vessels are selected such that the second vapour stream has a high volatility component that meets the specification for domestic gas and the amount of the first vapour stream is not in excess of the amount that can be consumed by the liquefaction plant and/or co-located plant.

5. A process as claimed in any one of the preceding claims in which either or both of the first separation vessel and the second separation vessel comprises more than one separation vessel.

6. A process as claimed in any one of the preceding claims in which the high-
5 volatility component is nitrogen.

7. A process as claimed in claim 6 in which the feed stream is a liquefied natural gas or a mixture of liquefied natural gas and natural gas vapour comprising greater than 0.5 mole % and less than 10 mol % nitrogen.

8. A process as claimed in claim 6 or claim 7 in which the first vapour stream has a
10 nitrogen content of 10 to 30 mol %.

9. A process as claimed in any one of claims 1 to 8 in which the second separation vessel is operated at a pressure that is at least 2 bar below the pressure of the first separation vessel.

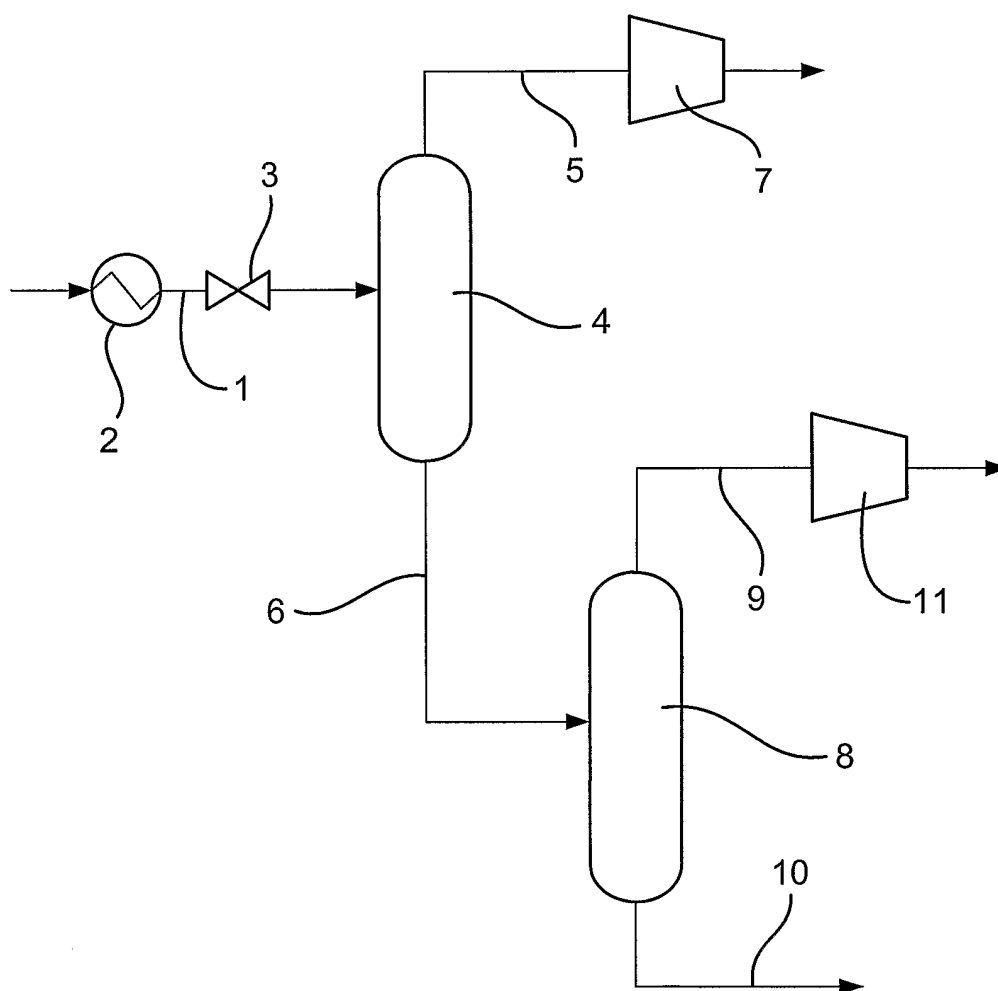
10. A process as claimed in any one of claims 1 to 9 in which the feed stream is at a
15 pressure of above 35 bar absolute.

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1/1

Fig.1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2004/004834

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F25J1/02 F25J3/02 F25J3/06

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 7 F25J

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 348 384 A (HARMENS ALEXANDER) 24 October 1967 (1967-10-24) column 2, line 45 - line 55; figure column 3, lines 3-14 -----	1,2,4-6, 8-10
X	US 3 360 944 A (KNAPP HELMUT ET AL) 2 January 1968 (1968-01-02) column 2, line 64 - column 3, line 16 column 3, line 63 - column 3, line 69 column 4, lines 12-15; figures -----	1,2,5-7, 9
X	US 2003/136146 A1 (FISCHER-CALDERON ERNESTO ET AL) 24 July 2003 (2003-07-24) paragraphs '0073! - '0077!, '0082! - '0086!, '0091!, '0094!, '0127!; figures; example 1 ----- -/--	1,2,4-7, 9,10

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
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- *P* document published prior to the international filing date but later than the priority date claimed

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- *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.
- *Z* document member of the same patent family

Date of the actual completion of the international search

1 February 2005

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB2004/004834

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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