Document FR2317649 discloses a method for checking the variations in porosity of the primary and secondary sealing membranes arranged on each side of an intermediate space. The secondary thermal insulation barrier is filled with a mixture of nitrogen and argon. The intermediate space between the two sealing membranes is swept with a stream of nitrogen, and the methane and argon contents of the stream of nitrogen are analyzed in order to detect leaks of the primary sealing membrane or of the secondary sealing membrane. The intermediate space is kept at a depression in order to encourage gas to migrate through the sealing membranes.

Summary

One idea underlying the invention is that of providing monitoring methods and devices suited to effective detection of the presence of the fuel gas in the thermally insulating barrier, even when the gaseous phase is kept under a negative relative pressure.

According to one embodiment, the invention provides a method for monitoring a sealed and thermally insulated tank intended to contain a low-temperature liquefied fuel gas,

in which method a wall of the tank comprises a multilayer structure mounted on a bearing wall, the multilayer structure comprising a sealing membrane in contact with the liquefied fuel gas contained in the tank and a thermally insulating barrier arranged between the sealing membrane and the bearing wall, the thermally insulating barrier comprising insulating solid substances and a gaseous phase kept under a negative relative pressure, the method comprising:

obtaining a sample of dilute gas by withdrawing a sample of the gaseous phase under negative relative pressure in the thermally insulating barrier through a sampling duct opening to the outside of the tank wall and by adding a controlled quantity of inert gas to the gaseous phase that has been withdrawn, compressing, namely raising the pressure of the dilute gas sample up to an operating pressure of a gas analyzer, and

measuring a concentration of the fuel gas in the dilute gas sample using the gas analyzer.

According to some embodiments, such a monitoring method may involve one or more of the following features.

According to one embodiment not covered by claim 1, the method further comprises:

determining a concentration of the fuel gas in the gaseous phase of the thermally insulating barrier as a function of the measured concentration and of the quantity of inert gas added to the gaseous phase.

According to one particular embodiment, the method comprises:

- determining a dilution ratio brought about by the addition of a controlled quantity of inert gas to the gaseous phase that has been withdrawn according to measurements of the pressure and of the temperature of the gaseous phase that has been withdrawn before and after the addition of the controlled quantity of inert gas to the gaseous phase; and
- determining a concentration of the fuel gas in the gaseous phase of the thermally insulating barrier as a function of the measured concentration and of the dilution ratio brought about by the addition of a controlled quantity of inert gas.

The fuel gas may consist of liquefied natural gas, liquefied petroleum gas (LPG), ethylene or the like.

The use of an inert gas makes it possible to increase the quantity of substance in the sample that is to be analyzed, without the risk of creating an explosive mixture. For example, the inert gas may be selected from the group consisting of dinitrogen, helium, argon and mixtures thereof

According to various embodiments, the negative relative pressure corresponds to an absolute pressure of below 10 kPa, preferably of below 1 kPa.

According to some embodiments, the operating pressure of the gas analyzer is comprised between 80 kPa and 120 kPa, preferably between 86 kPa and 108 kPa. With these operating pressures it is possible to use gas analyzers that are relatively inexpensive and readily available.

The fuel gas concentration may be measured using various known detection techniques. For example, the gas analyzer may comprise a fuel gas detector selected from the group consisting of infrared detectors, notably those that work by measuring absorbance and/or transmittance, and electrochemical-cell detectors.

There are two methods that can be used for diluting the low-pressure gaseous phase present in the insulating barrier. The first method not covered by claim 1 involves mixing the inert gas with the gaseous phase before the withdrawing of the sample, namely in the insulating barrier. A second method involves mixing the inert gas with the gaseous phase after the taking of the sample, namely in the monitoring device. These two methods may be combined.

According to an embodiment corresponding to the first aforementioned method, the step of obtaining the sample of dilute gas comprises:
adding a controlled quantity of inert gas to the gaseous phase in the thermally insulating barrier in order to increase the relative pressure of the gaseous phase in the thermally insulating barrier from a negative first value to a negative second value, and
withdrawing a sample of the gaseous phase under the relative pressure equal to the second negative value in the thermally insulating barrier through the sampling duct opening to the outside of the tank wall so as to obtain the dilute gas sample, and
reducing the relative pressure of the gaseous phase in the thermally insulating barrier from the second negative value to the first negative value after having withdrawn the sample of the gaseous phase.

According to some embodiments, the first negative value is less than 1 kPa, preferably less than or equal to 0.1 kPa, and the second negative value is greater than or equal to 1 kPa.

According to an embodiment corresponding to the second aforementioned method, the step of obtaining the dilute gas sample comprises:
withdrawing a sample of the gaseous phase under the negative relative pressure in the thermally insulating barrier through the sampling duct opening to the outside of the tank wall, and
adding a controlled quantity of inert gas to the withdrawn gaseous phase sample.

In that case, the steps of withdrawing, diluting and compressing the sample may be performed jointly by means of a Venturi-effect suction device, the Venturi-effect suction device comprising:
a main pipe having an inlet connected to a source of the inert gas under pressure and an outlet connected to a measurement enclosed space or to an intermediate enclosed space, and

- The dilute gas sample obtained is then analyzed in the measurement enclosed space 221, in the same way as described above.

For preference, a valve, not depicted, is also provided on the sampling duct 211 and is opened only after a stable stream of nitrogen has been established at an appropriate speed in the main pipe 35. That makes it possible to avoid reflux of dinitrogen towards the insulating barrier 203 during the phase of starting the stream of dinitrogen. Similarly, this valve can be closed at the end of the sampling before the stream of dinitrogen is interrupted.

The Venturi-effect suction device 220 of figure 4 may also be used in conjunction with an intermediate enclosed space situated upstream of the lateral duct 36.

In a corresponding embodiment which has not been depicted, the monitoring device 210 of figure 3 is connected to the intermediate enclosed space 12 of figure 1 in such a way that the lateral duct 36 of the Venturi-effect suction device 220 takes the place of the connecting duct 24 of figure 1. The function of the pump 20 can then be performed by the Venturi-effect suction device 220 which replaces the pump 20 and which also performs the dilution of the sample in the dinitrogen. As a result, a prior addition of dinitrogen to the intermediate enclosed space 12 is not absolutely essential in this case and the reservoir 15 of figure 1 may potentially be omitted.

The embodiments described hereinabove add dinitrogen to the gaseous phase sample taken in the insulating barrier. As an alternative not included in the scope of claim 1, an addition of dinitrogen may be made in the insulating barrier before the sample that is to be analyzed is withdrawn.

A corresponding embodiment which does not correspond to the claimed invention will now be described with reference to figures 5 and 6. Elements analogous or identical to those of figure 1 bear a reference numeral increased by 300 in relation to figure 1.

Figure 5 shows a double sealing membrane tank 301 in which a secondary sealing membrane 40 separates the insulating barrier into a primary insulating barrier arranged in a primary insulation space 41 situated between the primary membrane 304 and the secondary membrane 40 and a secondary insulating barrier arranged in a secondary insulation space 42 situated between the secondary membrane 40 and the bearing walls 302.

CLAIMS

1. A method for monitoring a sealed and thermally insulated tank (1, 201, 301) intended to contain a low-temperature liquefied fuel gas,

in which method a wall of the tank comprises a multilayer structure mounted on a bearing wall, the multilayer structure comprising a sealing membrane in contact with the liquefied fuel gas contained in the tank and a thermally insulating barrier (3, 203, 41, 42) arranged between the sealing membrane and the bearing wall, the thermally insulating barrier comprising insulating solid substances and a gaseous phase kept under a negative relative pressure, the method comprising:

obtaining a sample of dilute gas by withdrawing a sample of the gaseous phase under negative relative pressure in the thermally insulating barrier through a sampling duct (11, 111, 211, 311, 69) opening to the outside of the tank wall and by adding a controlled quantity of inert gas to the gaseous phase that has been withdrawn,

raising the pressure of the dilute gas sample up to an operating pressure of a gas analyzer (25, 125, 225, 325), and

measuring a concentration of the fuel gas in the dilute gas sample using the gas analyzer.

2. The method as claimed in claim 1, further comprising:

- determining a dilution ratio brought about by the addition of a controlled quantity of inert gas to the gaseous phase that has been withdrawn according to measurements of the pressure and of the temperature of the gaseous phase that has been withdrawn before and after the addition of the controlled quantity of inert gas to the gaseous phase; and
- determining a concentration of the fuel gas in the gaseous phase of the thermally insulating barrier as a function of the measured concentration and of the dilution ratio brought about by the addition of a controlled quantity of inert gas.

3. The method as claimed in one of claims 1 and 2, in which the fuel gas consists of methane.

4. The method as claimed in one of claims 1 to 3, in which the inert gas is selected from the group consisting of dinitrogen, helium, argon and mixtures thereof.

5. The method as claimed in one of claims 1 to 4, in which the negative relative pressure corresponds to an absolute pressure of below 10 kPa, preferably of below 1 kPa.

6. The method as claimed in one of claims 1 to 5, in which the operating pressure of the gas analyzer (25, 125, 225, 325) is comprised between 80 kPa and 120 kPa, preferably between 86 kPa and 108 kPa.

7. The method as claimed in one of claims 1 to 6, in which the gas analyzer comprises a fuel gas detector selected from the group consisting of infrared detectors and electrochemical-cell detectors.

8. The method as claimed in any one of claims 1 to 7, in which the step of raising the pressure of the dilute gas sample comprises:
storing the withdrawn sample of gaseous phase in an intermediate enclosed space (112, 321) connected to the sampling duct, and
moving a mobile wall in the intermediate enclosed space in order to confine the dilute gas sample to a measurement enclosed space (121) of smaller capacity than the intermediate enclosed space.

9. The method as claimed in one of claims 1 to 8, in which the step of obtaining the dilute gas sample comprises:
withdrawing a sample of the gaseous phase under the negative relative pressure in the thermally insulating barrier through the sampling duct opening to the outside of the tank wall, and
adding a controlled quantity of inert gas to the withdrawn gaseous phase sample.

10. The method as claimed in claim 9, in which the steps of withdrawing, diluting and compressing the sample are performed by means of a Venturi-effect suction device (220), the Venturi-effect suction device comprising:
a main pipe (35) having an inlet connected to a source of the inert gas under pressure and an outlet connected to a measurement enclosed space or to an intermediate enclosed space, and
a suction pipe (36) having an upstream end connected to the sampling duct and a downstream end opening laterally into a convergent-divergent of the main pipe in such a way that a stream of inert gas along the main pipe causes a depression in the suction pipe.

11. The method as claimed in claim 9 or 10, in which the step of taking the sample comprises:

pumping the gaseous phase sample through the sampling duct (11, 111, 211, 311) towards an intermediate enclosed space (12, 112, 221, 321), and

isolating the intermediate enclosed space from the thermally insulating barrier.

12. The method as claimed in claim 11, in which the controlled quantity of inert gas is added to the intermediate enclosed space (12, 112), the step of compressing the dilute gas sample comprising:

pumping the dilute gas sample from the intermediate enclosed space towards a measurement enclosed space (21, 121) coupled to the gas analyzer.

13. The method as claimed in claim 11, in which the steps of diluting and compressing the sample are performed by means of a Venturi-effect suction device (220), the Venturi-effect suction device comprising:

a main pipe (35) having an inlet connected to a source of the inert gas under pressure and an outlet connected to a measurement enclosed space, and

a suction pipe (36) having an upstream end connected to the intermediate enclosed space and a downstream end opening laterally into a convergent-divergent of the main pipe in such a way that a stream of inert gas along the main pipe causes a depression in the suction pipe.

14. A monitoring device (10, 210) suitable for a sealed and thermally insulated tank (1, 201) intended to contain a low-temperature liquefied fuel gas, in which tank a wall of the tank comprises a multilayer structure mounted on a bearing wall, the multilayer structure comprising a sealing membrane in contact with the liquefied fuel gas contained in the tank and a thermally insulating barrier (3, 203) arranged between the sealing membrane and the bearing wall, the thermally insulating barrier comprising insulating solid substances and a gaseous phase kept under a negative relative pressure,

the monitoring device comprising:

a sampling duct (11, 111, 211) connecting the thermally insulating barrier to the outside of the tank wall, said sampling duct (11, 111, 211) being equipped with an isolation valve (14):

an intermediate enclosed space (12, 112) connected to the thermally insulating barrier by the sampling duct;

a measurement enclosed space (21, 121, 221) connected to the intermediate enclosed space,

a gas analyzer (25, 125, 225) coupled to the measurement enclosed space for measuring a concentration of the fuel gas in the measurement enclosed space,

a pumping device (20, 112, 220, 320) connected to the sampling duct and able to withdraw a sample of the gaseous phase under the negative relative pressure in the thermally insulating barrier and to transfer the sample of the gaseous phase to the measurement enclosed space (21, 121, 221),

an inert gas reservoir (15, 215) connected to the intermediate enclosed space (12, 112) and designed to add a quantity of inert gas to the gaseous phase that has been withdrawn, in the intermediate enclosed space (12, 112), and

a measurement device (17, 217, 317) for measuring the quantity of inert gas added to the gaseous phase.

15. The device as claimed in claim 14, further comprising a data processing system (30, 330) able to determine a dilution ratio brought about by the addition of a controlled quantity of inert gas to the gaseous phase that has been withdrawn as a function of measurements of the pressure and temperature of the gaseous phase that has been withdrawn before and after the addition of the controlled quantity of inert gas to the gaseous phase and to determine a concentration of the fuel gas in the gaseous phase of the thermally insulating barrier as a function of the concentration measured by the gas analyzer and of the dilution ratio brought about by the addition of a controlled quantity of inert gas.

16. The device as claimed in claim 14 and 15, in which the pumping device comprises a vacuum pump (20).

17. The device as claimed in one of claims 14 to 16, in which the pumping device comprises a Venturi-effect suction device (220), the Venturi-effect suction device comprising:

a main pipe (35) having an inlet connected to the reservoir of inert gas and an outlet connected to the measurement enclosed space, and

a suction pipe (36) having an upstream end connected to the sampling duct by way of the intermediate enclosed space and a downstream end opening laterally into a convergent-divergent of the main pipe in such a way that a stream of inert gas along the main pipe causes a depression in the suction pipe.

18. A sealed and thermally insulated tank (71) intended to contain a low-temperature liquefied fuel gas and equipped with a monitoring device (10, 210, 310, 410) as claimed in one of claims 14 to 17,

in which tank a wall of the tank comprises a multilayer structure mounted on a bearing wall (302), the multilayer structure comprising a primary sealing membrane (304) in contact with the liquefied fuel gas contained in the tank, a secondary sealing membrane (40) arranged between the primary sealing membrane and the bearing wall, a primary thermally insulating barrier (41) arranged between the primary sealing membrane and the secondary sealing membrane, and a secondary thermally insulating barrier (42) positioned between the secondary sealing membrane and the bearing wall, and in which tank a or each thermally insulating barrier comprises insulating solid substances and a gaseous phase kept under a negative relative pressure, the monitoring device comprising a first sampling pipe (311) opening into the primary thermally insulating barrier and a second sampling pipe (69) opening into the secondary thermally insulating barrier.

19. A ship (70) for carrying a cold liquid product, the ship comprising a double hull (72) and a tank (71) as claimed in claim 18 arranged in the double hull.

20. A method for loading or unloading a ship (70) as claimed in claim 19, in which a cold liquid product is carried through insulated piping (73, 79, 76, 81) from or to a floating or on-shore storage facility (77) to or from the tank of the ship (71).

21. A transfer system for transferring a cold liquid product, the system comprising a ship (70) as claimed in claim 19, insulated piping (73, 79, 76, 81) arranged in such a way as to connect the tank (71) installed in the hull of the ship to a floating or on-shore storage facility (77) and a pump for causing the cold liquid product to flow in a stream through the insulated piping from or to the floating or on-shore storage facility to or from the tank of the ship.