The invention refers to a system for monitoring the condition of a pipeline (1) for gas and/or fluid, said pipeline (1) including an inner tube (2) for transporting said gas and/or fluid and an outer tube (3) being arranged around the inner tube (2) such that an annulus (4) is formed between the inner and outer tube (2, 3), where the annulus (4) includes one or more hermetic sections (H) along the longitudinal direction of the pipeline (1). The system includes a pressure sensing means (5) providing measurement data indicating the pressure inside each hermetic section (H) as well as an analysing means (6) for analysing the measurement data from the pressure sensing means (5), said analysing means (6) detecting an abnormal operation condition of the pipeline (1) if there is a change of the pressure in at least one of the hermetic sections (H), said change exceeding a predetermined threshold.
Description

A System for monitoring the condition of a pipeline for gas and/or fluid

The invention refers to a system and a method for monitoring the condition of a pipeline for gas and/or fluid as well as to a pipeline to be used in such a system.

The technical field of the invention is the detection of abnormal operation conditions of pipelines, particularly the detection of leakages or damages at pipelines.

Many different systems are known from the prior art in order to detect abnormal operation conditions of pipelines. In airborne systems, small aircrafts or helicopters are used for periodical pipeline patrol. The aircrafts or helicopters are carrying gas analysers (for detecting the leakages in gas pipelines) and/or video surveillance equipment. Those systems have low sensitivity so that only strong leaks in the pipelines can be detected.

Furthermore, there exist software based systems for condition monitoring of pipelines using existing sensors at the ends of the pipeline. The software contains statistical detection and hydraulic modeling algorithms to detect leakages or intrusions of third parties. Though such software based systems are low in prize, those systems are not precise and, thus, lack reliability.

Moreover, fibre optic sensors and acoustic sensors are known. Information from those sensors is used to detect leakages based on vibrations and local temperature changes in the surrounding of the pipeline. However, such systems have limitations with respect to the minimum leak volume which can be detected.
It is an object of the invention to provide a system for monitoring the condition of a pipeline which detects an abnormal operation condition of the pipeline with high sensitivity and reliability.

This object is solved by the independent claims. Preferred embodiments of the invention are defined in the dependent claims.

The system according to the invention is provided for a pipeline including an inner tube for transporting gas and/or fluid, particularly natural gas and/or oil, and an outer tube being arranged around the inner tube such that an annulus is formed between the inner and outer tube. The annulus includes one or more hermetic (i.e. airtight) sections along the longitudinal direction of the pipeline. The pipeline with the above defined features can be regarded as a part of the system.

The system of the invention further comprises a pressure sensing means providing measurement data indicating the pressure inside each hermetic section, i.e. at a position within the annulus between the inner and outer tube. Preferably, this pressure sensing means includes a separate pressure sensor in each hermetic section. Furthermore, the system includes an analysing means for analysing the measurement data from the pressure sensing means. The analysing means detects an abnormal operation condition of the pipeline if there is a change of the pressure in at least one of the hermetic section, said change exceeding a predetermined threshold.

The invention is based on the idea that the pressure of corresponding hermetic sections around the inner tube of a pipeline is a very good and precise indicator of abnormal operation conditions and particularly of leaks in the inner tube of the pipeline surrounded by the hermetic section.
The system has the advantage that small leak volumes can be detected. In the case of very small leaks, it will just take more time to detect the leakage. Furthermore, the spatial resolution for leakage detection or other damages can be easily adapted by varying the length of the hermetic section in the longitudinal direction of the pipeline. The monitoring system may be used for any types of pipelines regardless whether the pipeline is a gas or fluid pipeline. Furthermore, minimal changes in the pipeline construction have to be performed in order to install the monitoring system.

In a preferred embodiment, the pressure sensing means comprises an electric pressure sensing means providing measurement data based on electric signals. Such pressure sensing means are known from the prior art. E.g., piezoresistive or piezoelectric sensors may be used as the electric pressure sensing means.

In another embodiment, the pressure sensing means comprises an optical fibre sensing means providing measurement data based on optical signals transported in one or more optical fibres passing through said one or more hermetic sections. In one variant, the optical fibre sensing means includes at least one fibre bragg grating in each hermetic section. A change in pressure applied to the fibre bragg grating changes the period of this grating, resulting in a change of the wavelength of the optical signals reflected by the grating. Thus, by measuring the wavelength of the reflected optical signals, pressure changes can be detected. In another embodiment of an optical fibre sensing means, an OTDR reflectometer (OTDR = Optical Time Domain Reflectometry) is used. Such reflectometers are well-known and are based on the analysis of backscattered optical signals within an optical fibre in order to detect pressure changes.

In another embodiment of the invention, the pressure sensing means includes one or more electric power supplies. At least one power supply and particularly each power supply is based
on renewable energy and particularly solar and/or wind energy. E.g., solar cells or wind generators may be used for power supply. Hence, the power supply is a stand-alone unit independent on batteries or power provided by power lines, thus enhancing the reliability of the system.

In a particularly preferred embodiment, said one or more hermetic sections are positioned along the pipeline such that at least one hermetic section and particularly each hermetic section covers one or more joints of the inner tube of the pipeline. Joints are particularly susceptible to leakages and, thus, this embodiment provides a very reliable detection of leakages.

In another embodiment of the invention, the pressure inside at least one hermetic section and particularly each hermetic section during a normal operation condition of the pipeline corresponds to the atmospheric air pressure. This embodiment enables an easy implementation of the hermetic sections. However, the pressure inside at least one hermetic section and particularly each hermetic section during a normal operation condition may also be lower or higher than the atmospheric air pressure. This embodiment also enables a detection of damages in the outer tube of the pipeline. This is because the pressure inside the hermetic section differs from the atmospheric pressure outside the pipeline resulting in a pressure change when a leak occurs in the outer tube of the pipeline.

In a preferred embodiment of the invention, the analysing means comprises a central monitoring server where one or more wire-based and/or wireless communication paths for transmitting the measurement data are provided between the central server and the pressure sensing means. This embodiment enables an online detection of an abnormal operation condition in a central server. As a consequence, appropriate counter measures may be taken immediately. E.g., service staff may be
sent without delay to the position of an abnormal operation condition, e.g. in order to repair a leak in the pipeline.

In another embodiment of the invention at least one hermetic section and particularly each hermetic section includes thermal isolation material for protecting the gas or fluid, against very low temperatures. However, it is also possible that the hermetic sections do not include such material and are void (i.e. only including air).

Besides the above system, the invention also refers to a method for monitoring the condition of a pipeline for gas and/or fluid, particularly for natural gas and/or oil. The pipeline monitored by this method includes an inner tube for transporting said gas and/or fluid and an outer tube being arranged around the inner tube such that an annulus is formed between the inner and outer tube, where the annulus includes one or more hermetic sections along the longitudinal direction of the pipeline.

According to the method of the invention, measurement data are provided indicating the pressure inside each hermetic section by a pressure sensing means. Furthermore, the measurement data from the pressure sensing means is analysed by an analysing means, where an abnormal operation condition of the pipeline is detected if there is a change of the pressure in at least one of the hermetic sections, said change exceeding a predetermined threshold. Hence, this method is performed by a system according to the invention. Moreover, the method may also be performed by one or more preferred embodiments of the system according to the invention.

The invention also refers to a pipeline for gas and/or fluid to be used in the system of the invention or one or more preferred embodiments of this system. The pipeline comprises an inner tube for transporting gas and/or fluid and an outer tube around the inner tube such that an annulus is formed between the inner and outer tube, where the annulus includes
one or more hermetic sections along the longitudinal direction of the pipeline, wherein the pipeline further comprises a pressure sensing means providing measurement data indicating the pressure inside each hermetic section.

In the following, preferred embodiments of the invention will be described in detail with respect to the accompanying drawings wherein:

Fig. 1 shows a perspective view of a pipeline which can be monitored by the method of the invention; and

Fig. 2 is a schematic drawing showing an embodiment of a system for monitoring the condition of a pipeline.

Fig. 1 shows a perspective view of a pipeline which can be monitored by the method of the invention. The pipeline may be a gas or a fluid pipeline. In the following, the invention will be described based on a gas pipeline. The pipeline 1 includes an inner tube 2 for transporting the gas. The inner tube is preferably made of very rigid material, e.g. of metal. For gas pipelines, the diameter of the inner tube preferably lies in the range of 1.5 m (particularly 1.42 m). Contrary to that, the diameter of the inner tube for oil pipelines preferably lies in the range of 70 cm. The thickness of the inner tube is preferably in the range of 1 cm. The above mentioned dimensions are only examples and the invention is not limited to these dimensions.

An outer tube 3 which is preferably made of plastic material is provided around the inner tube 2. Between the inner tube 2 and the outer tube 3 an annulus 4 is formed. In the embodiment of Fig. 1, this annulus is filled with a thermal isolation material so that the pipeline can be installed in very cold regions. However, the annulus region may also include any other material or may even be void in other embodiments of the pipeline. In the longitudinal direction of the pipeline (indicated by the arrow P), the annulus is divided in
several hermetic sections and a pressure sensor is included in each hermetic section as will be apparent from Fig. 2 described in the following.

Fig. 2 shows an embodiment of a monitoring system for the pipeline shown in Fig. 1. In Fig. 2, the pipeline includes several adjacent hermetic sections which are formed between the inner tube 2 and the outer tube 3 and extend in the longitudinal direction of the pipeline. The hermetic sections are achieved by corresponding seals at both ends of the sections, e.g. the material of the outer tube 3 may extend at each end of the corresponding section to the inner tube 2. There exists a predefined pressure in each annular hermetic section during normal operation condition of the pipeline. E.g., this pressure may correspond to the atmospheric air pressure. Nevertheless, the pressure may also be higher or lower. Pressure changes inside the hermetic sections can be detected by corresponding pressure sensors which are installed in the hermetic sections. In the embodiment described herein, electric pressure sensors, e.g. piezoelectric sensors, are used for detecting pressure changes.

The embodiment shown in Fig. 2 is based on the realization that leaks in the inner tube 2 of the pipeline result in an immediate rise of the pressure in the corresponding hermetic section covering the part of the inner tube where the leak occurs. This pressure change is detected by the corresponding pressure sensor 5. Furthermore, also damages in the outer tube 3 of the pipeline may result in pressure changes which are also detected by the pressure sensor 5. Hence, abnormal operation conditions can be easily detected by the pressure sensors 5. The pressure sensors 5 are connected via communication lines 1 to a central analysing means in the form of a server 6. The server 6 collects the values of the pressure sensors. In case that a pressure change occurs which exceeds a predetermined threshold being indicative of an abnormal behaviour, a corresponding output is generated in the server 6.
Hence, human operators at the location of the server can be made aware of leakages or other damages and can initiate appropriate counter measures.

The invention shall not be limited to the above described embodiments. Particularly, several modifications to those embodiments can be made which lie within the scope of the invention as defined in the claims. E.g., the electric pressure sensors may be replaced by optical fibre sensors, e.g. OTDR reflectometers or fibre bragg gratings. To do so, a plurality of fibres extends in the longitudinal direction of the pipeline and passes through each of the hermetic sections H. In the case of a sensor using fibre bragg gratings, at least one grating is included within each of the hermetic sections.

When using optical fibre sensors, optical signals (i.e. light) which are reflected, transmitted or backscattered in the fibres are analysed in order to detect pressure changes. The optical fibres used for implementing the optical fibre sensors may also form the communication lines for transmitting pressure values to the analysing means.
Patent Claims

1. A system for monitoring the condition of a pipeline (1) for gas and/or fluid, said pipeline (1) including an inner tube (2) for transporting said gas and/or fluid and an outer tube (3) being arranged around the inner tube (2) such that an annulus (4) is formed between the inner and outer tube (2, 3), where the annulus (4) includes one or more hermetic sections (H) along the longitudinal direction of the pipeline (1), wherein the system includes:
   - a pressure sensing means (5) providing measurement data indicating the pressure inside each hermetic section (H);
   - an analysing means (6) for analysing the measurement data from the pressure sensing means (5), said analysing means (6) detecting an abnormal operation condition of the pipeline (1) if there is a change of the pressure in at least one of the hermetic sections (H), said change exceeding a predetermined threshold.

2. The system according to claim 1, wherein the pressure sensing means (5) includes a separate pressure sensor in each hermetic section.

3. The system according to claim 1 or 2, wherein the pressure sensing means (5) comprises an electric pressure sensing means providing measurement data based on electric signals.

4. The system according to one or the preceding claims, wherein the pressure sensing means (5) comprises an optical fibre sensing means providing measurement data based on optical signals transported in one or more optical fibres passing through said one or more hermetic sections (H).

5. The system according to claim 4, wherein the optical fibre sensing means includes at least one fibre bragg grating in each hermetic section (H).
6. The system according to claim 3 or 4, wherein the optical fibre sensing means includes an OTDR reflectometer (OTDR = Optical Time Domain Reflectometry).

7. The system according to one of the preceding claims, wherein the pressure sensing means (5) includes one or more electric power supplies, wherein at least one power supply and particularly each power supply is based on renewable energy and particularly solar and/or wind energy.

8. The system according to one of the preceding claims, wherein said one or more hermetic section (H) are positioned along the pipeline (1) such that at least one hermetic section (H) and particularly each hermetic section (H) covers one or more joints of the inner tube (2) of the pipeline (1).

9. The system according to one of the preceding claims, wherein the pressure inside at least one hermetic section (H) during a normal operation condition of the pipeline (1) corresponds to the atmospheric air pressure.

10. The system according to one of the preceding claims, wherein the pressure inside at least one hermetic section (H) during a normal operation condition of the pipeline (1) is lower or higher than the atmospheric air pressure.

11. The system according to one of the preceding claims, wherein the analysing means (6) comprises a central monitoring server where one or more communication paths (L) for transmitting the measurement data are provided between the central server and the pressure sensing means (5).

12. The system according to one of the preceding claims, wherein at least one hermetic section (H) and particularly each hermetic section (H) includes thermal isolation material.
13. A method for monitoring the condition of a pipeline (1) for gas and/or fluid, said pipeline (1) including an inner tube (2) for transporting said gas and/or fluid and an outer tube (3) being arranged around the inner tube (2) such that an annulus (4) is formed between the inner and outer tube (2, 3), where the annulus (4) includes one or more hermetic sections (H) along the longitudinal direction of the pipeline (1), the method comprising the steps of:

- providing measurement data indicating the pressure inside each hermetic section (H) by a pressure sensing means (5);
- analysing the measurement data from the pressure sensing means (5) by an analysing means, where an abnormal operation condition of the pipeline (1) is detected if there is a change of the pressure in at least one of the hermetic sections (H), said change exceeding a predetermined threshold.

14. The method according to claim 12, wherein the method is performed by a system according to one of claims 2 to 12.

15. A pipeline for gas and/or fluid to be used in the system according to one claims 1 to 12, wherein the pipeline (1) comprises an inner tube (2) for transporting gas and/or fluid and an outer tube (3) around the inner tube (2) such that an annulus (4) is formed between the inner and outer tube (2, 3), where the annulus (4) includes one or more hermetic sections (H) along the longitudinal direction of the pipeline (1), wherein the pipeline (1) further comprises a pressure sensing means (5) providing measurement data indicating the pressure inside each hermetic section.
## A. CLASSIFICATION OF SUBJECT MATTER

INV. G01M3/28

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)

G01M

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

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

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Date of the actual completion of the international search: 4 March 2013

Date of mailing of the international search report: 13/03/2013

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