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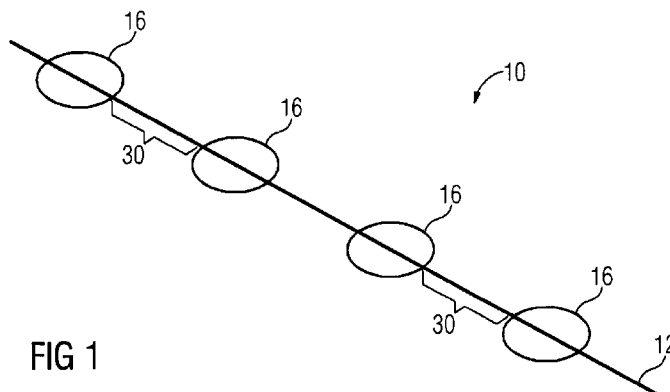


FIG 1

(57) Abstract: The invention relates to a system (10) for monitoring a technical installation, in particular a pipeline, comprising at least one acoustic sensor (12) for detecting noise emitted in a monitoring zone at least partially containing the technical installation. According to the invention, the at least one acoustic sensor (12) is at least partially arranged within a respective focal point (14) of at least one acoustic concentrator device (16).



SYSTEM FOR MONITORING A TECHNICAL INSTALLATION

DESCRIPTION

5 The invention relates to a system for monitoring a technical installation according to the preamble of claim 1.

Different kinds of technical installations need to be
10 constantly monitored for security reasons, so that technical failures as well as attempts of intruders to manipulate the installation can be detected in time. In certain cases, such as the monitoring of pipelines, this necessitates the monitoring of huge areas of land.

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A known technique for monitoring pipelines relies on acoustic detection of leaks and intrusions. Such systems consist of multiple acoustic sensors located along the pipeline, which are monitored by a central data
20 processing station.

The sensors can be distributed fiber optic sensors detecting vibrations by measuring coherent Rayleigh noise (CRN) or Brillouin backscatter. An example for such a
25 system is disclosed in GB 2 457 278.

All currently known pipeline security systems have limitation with regard to the minimum noise and minimum leak volume that can be detected. In order to improve the
30 signal to noise ratio, gaps between the fiber optic sensor and the sound source can be filled with materials that improve sound propagation to the sensor. Alternatively, sound amplifiers and converters can be

employed. However, both solution are expensive and require constant maintenance.

5 It is therefore the objective of the present invention to provide a system for monitoring a technical installation according to the preamble of claim 1 with an improved detection capability at low cost.

10 This objective is reached by a system according to claim 1.

Such a system for monitoring a technical installation, in particular a pipeline, comprises at least one acoustic sensor for detecting noise emitted in a monitoring zone
15 at least partially containing the technical installation.

According to the invention, the at least one acoustic sensor is at least partially arranged within a focal point of at least one acoustic concentrator device.
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By concentrating the sound waves on the sensor, a higher sensitivity can be achieved without the need for active components or special materials, thereby reducing costs and maintenance effort. The possibility to detect signals
25 at very low signal strengths enables the early detection of events such as the formation of pinholes in pipelines or the approach of intruders. Furthermore, such a systems does not necessitate any changes in the sensor design, so that existing systems can be fitted with acoustic
30 concentrators without any further modifications.

In a preferred embodiment of the invention, the acoustic concentrator device is an acoustic Fresnel lens. Such

lenses can yield an acoustic sound concentration of 40-80% at low focus lengths and are particularly cheap to manufacture.

- 5 Should a stronger concentration be needed, acoustic parabolic mirrors can be employed as acoustic concentrator devices. They reach a sound concentration ratio of up to 95%, albeit at longer focus lengths.
- 10 In both cases, dimensions of the acoustic concentrator device have to be significantly larger than the wavelength of the sound to be detected. In the particular example of pipeline leak detection, however, this is largely irrelevant, since the sound waves generated by
- 15 the supersonic or transonic fluid flow through pinhole leaks are of very short wavelengths.

In a further preferred embodiment of the invention, the at least one acoustic sensor is an optical fiber. This

20 allows for a particularly cheap and reliable monitoring of large areas.

Detection thresholds can further be improved, if at least one section of such an optical fiber arranged within the

25 focal point of an acoustic concentrator is coiled. By coiling the fiber, a longer portion of it is exposed to the concentrated sound waves within the focal point, thereby increasing the sensitivity of the system.

30 It is furthermore advantageous, if the system comprises a plurality of acoustic concentrator devices with different spatial orientations, allowing for a more complete monitoring of the technical installation. Additionally,

this allows for locating events more precisely due to the additional directional information.

In a further preferred embodiment of the invention, at least one portion of the acoustical sensor not arranged within a focal point of an acoustic concentrator device is acoustically isolated. The suppression of noise from the non-detecting parts of the sensor improves the signal-to-noise ratio of the system.

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In the following section, the invention and its preferred embodiments will be explained in detail with reference to the drawings. The figures show:

15 FIG 1: A schematic representation of an exemplary embodiment of a system according to the invention;

FIG 2: a detailed view of a holding arrangement for an acoustic concentrator device for a system according to FIG 1;

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FIG 3: a detailed view of a holding arrangement for an optic fiber sensor for a system according to FIG 1;

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FIG 4: a detailed view of a Fresnel type acoustic concentrator device for a system according to FIG 1;

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FIG 5: a detailed view of a mirror type acoustic concentrator device for a system according to FIG 1;

FIG 6: a schematic representation of an alternate embodiment of a system according to the invention and

5 FIG 7: a detailed view of an alternate holding arrangement for an optic fiber sensor for a system according to FIGs 1 or 6.

A system 10 for monitoring a technical installation, in particular a pipeline, comprises a fiber optic acoustical sensor 12 which is strung out along the area to be monitored and placed in a manner that it traverses the focal points 14 of a plurality of acoustic concentrators 16.

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Sound waves emanating from the area to be monitored, e.g. sounds caused by leaks in the pipeline, sounds produced by intruders and the like, are concentrated by the concentrator devices 16 onto the sensor 12 and cause vibrations within the optical fiber part of the sensor 12. Such vibrations can be detected and localized by means of Brillouin backscattering and/or coherent Rayleigh noise.

25 The concentrator devices are attached to clamps 18, which hold the fiber optic sensor 12 fixed to the respective focal points 14 of the acoustic concentrators 16.

Such a system 10 is suitable to detect particularly faint signals. For example, pinhole leaks in pipelines cause supersonic or transonic flow through the hole, emitting high frequency noise which tends to disperse on medium non-uniformities of the same scale as the wavelength and

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therefor tends to get attenuated before it can reach conventional sensors. Due to the use of acoustic concentrators 16, such leaks can be reliably detected using the system 10.

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The acoustic concentrators 16 have the form of acoustic Fresnel lenses, as depicted in FIG 4. Such a concentrator 16 comprises a plurality of concentric annular Fresnel zones 20. They reach concentration ratios of 40-80% and exhibit a very short focal length.

For higher acoustic concentration ratios of up to 95%, parabolic or spherical acoustic mirrors as shown in FIG 5 can be employed. Incoming sound waves are reflected on the parabolic inner surface of the concentrator 16. The reflected waves 24 are concentrated into the focal point 14 of the concentrator 16. Usually, the focal distance is longer for mirrors than for Fresnel lenses.

For all applications, it has to be considered that the concentrator device 16 has to be significantly larger than the wavelength of the sound to be concentrated. In the case of pipeline monitoring, however, the extremely short wavelength of sound created by pinhole leaks poses no practical restrictions on the design of the concentrators 16, which can have radii as small as dozens of centimeters.

The design of the concentrators 16 can be adapted to the monitoring task at hand. Form and size of the concentrators 16 determine not only the wavelengths that can be amplified, but also the spatial resolution of the system 10. In case of pipeline monitoring systems 10, the

spatial resolution has to be in the order of magnitude of the length of one pipe-tube section, e.g. about 10 m.

To enable directional monitoring of sound sources, the concentrator devices 16 can be oriented facing in different directions 26, as shown in FIG 6. This allows for determination of the precise direction from which a detected signal emanates.

10 An additional increase in sensitivity can be reached by using an arrangement as depicted in FIG 7. Here, a section 28 of the optical fiber sensor 12, which is located within the focal point 14 of the concentrator device 16 is coiled, so that a bigger part of the optical
15 fiber sensor 12 is exposed to the concentrated sound.

The sections 30 of the optical fiber sensor 12, which are located between the focal points 14 of the concentrators 16, can be used as reference readings to improve the
20 signal-to-noise ratio of the detection. Alternatively, it is possible to acoustically isolate those sections 30.

In summary, a system 10 as described above allows for high-sensitivity detection of events that are not
25 detectable with monitoring systems known from the state of the art, such as very small leaks in pipelines. Such events can therefore be detected particularly early, so that necessary maintenance can be performed before any significant damage has been done. The directional
30 monitoring capability offered by the system 10 makes it possible to precisely locate the source of sound events. Furthermore, no active sound amplification is necessary, so that such a system 10 is particularly cheap to install

and easily to integrate with existing fiber optic monitoring systems.

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List of reference signs

	10	system
	12	fiber optic sensor
5	14	focal point
	16	acoustic concentrator device
	18	clamp
	20	Fresnel zone
	22	incoming sound wave
10	24	reflected sound wave
	26	direction
	28	section
	30	section

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CLAIMS

1. System (10) for monitoring a technical installation, in particular a pipeline, comprising at least one
5 acoustic sensor (12) for detecting noise emitted in a monitoring zone at least partially containing the technical installation, characterized in that the at least one acoustic sensor (12) is at least partially arranged within a respective focal point (14) of at least
10 one acoustic concentrator device (16).

2. System (10) according to claim 1, characterized in that the acoustic concentrator device (16) is an acoustic Fresnel lens.
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3. System (10) according to claim 1, characterized in that the acoustic concentrator device (16) is an acoustic parabolic mirror.

20 4. System (10) according to any one of claims 1 to 3, characterized in that the at least one acoustic sensor (12) is an optical fiber.

5. System according to claim 4, characterized in that at
25 least one section (28) of the optical fiber (12) arranged within the focal point (14) of an acoustic concentrator device (16) is coiled.

6. System (10) according to claim 4 or 5, characterized
30 in that the system (10) comprises a plurality of acoustic concentrator devices (16) with different spatial orientations.

7. System (10) according to any one of claims 1 to 6,
characterized in that at least one portion (30) of the
acoustical sensor (12) not arranged within a focal point
(14) of an acoustic concentrator device (16) is
5 acoustically isolated.

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FIG 1

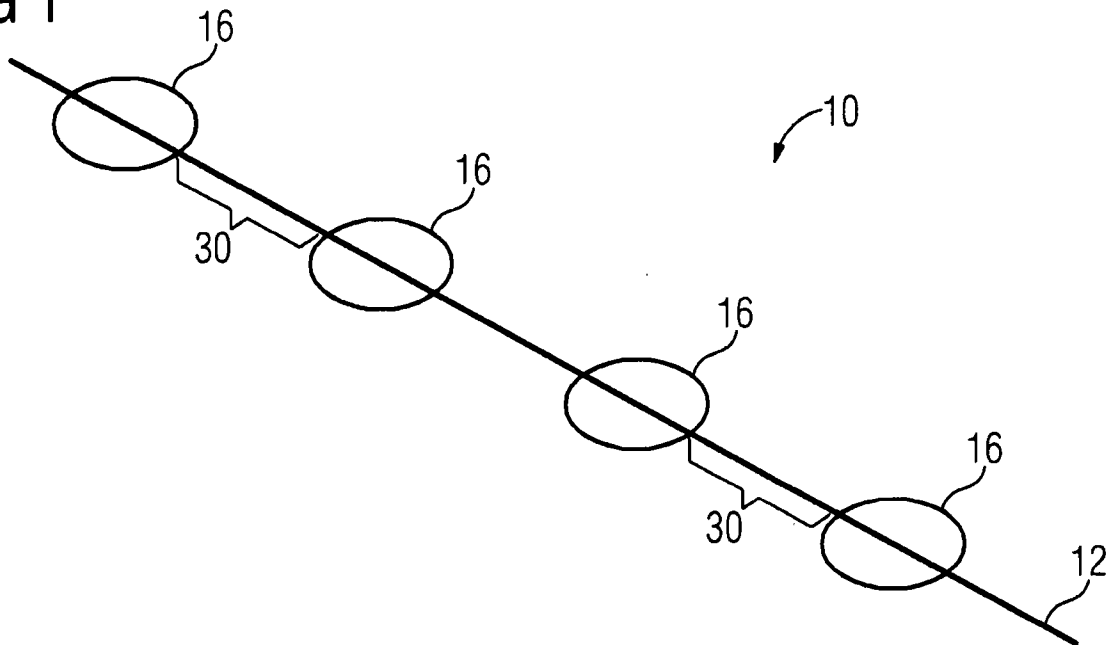


FIG 2

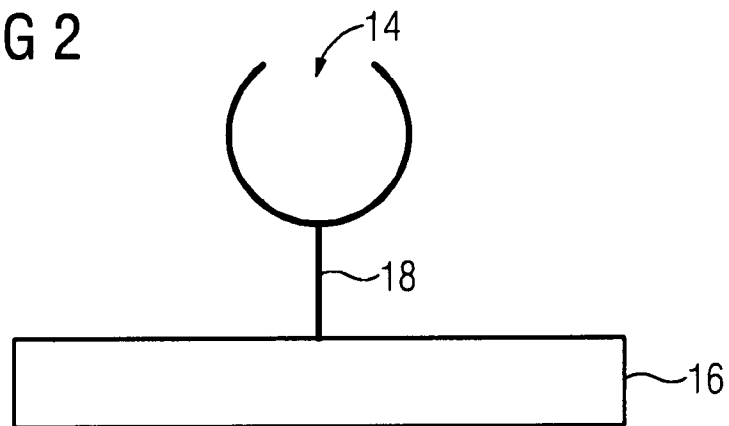
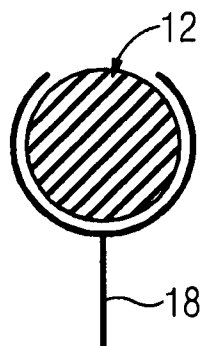


FIG 3



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FIG 4

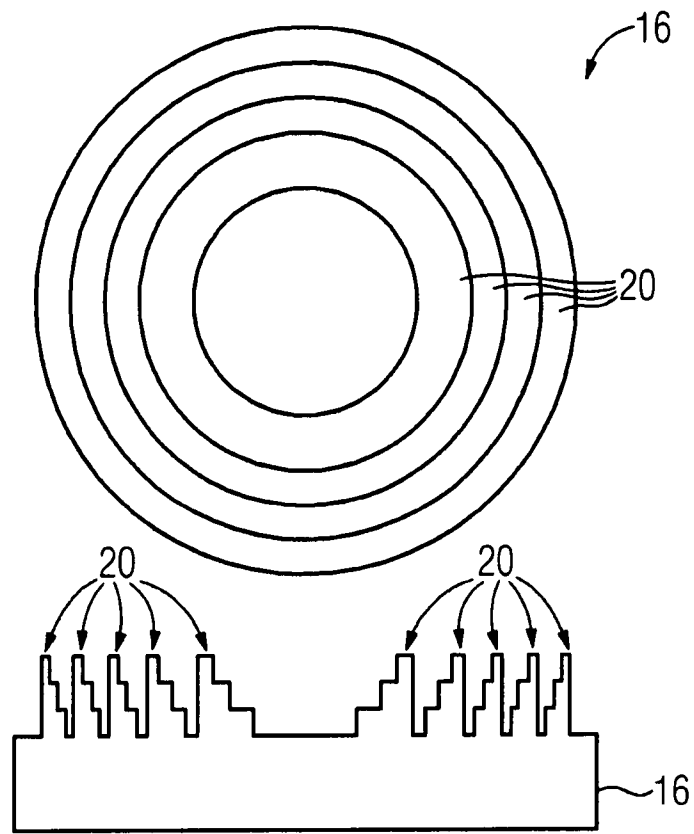
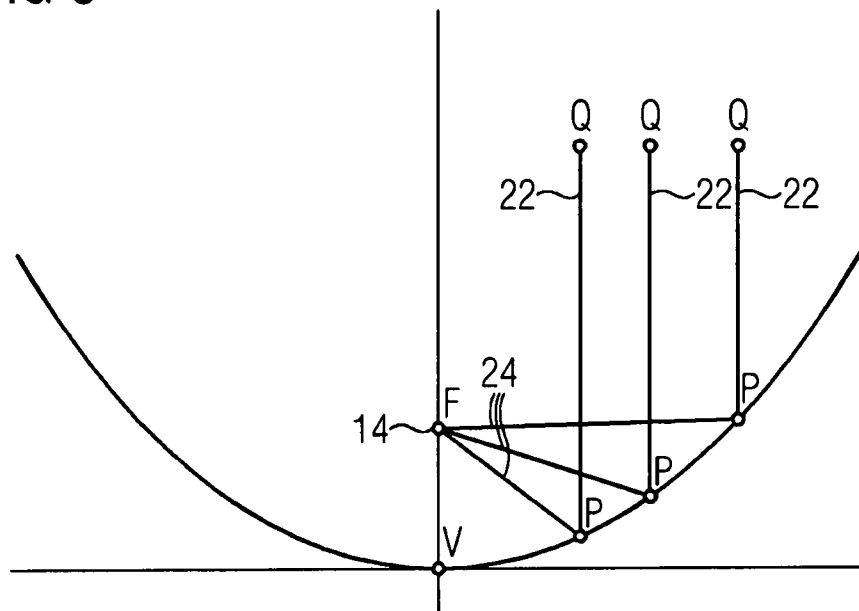


FIG 5



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FIG 6

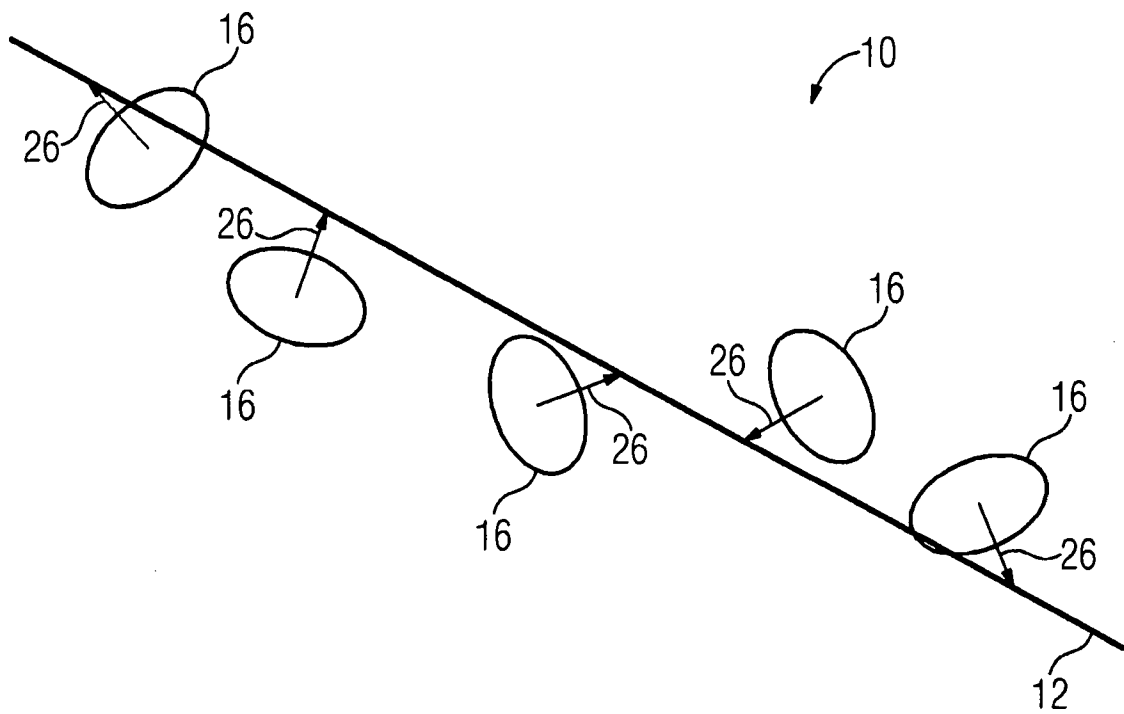
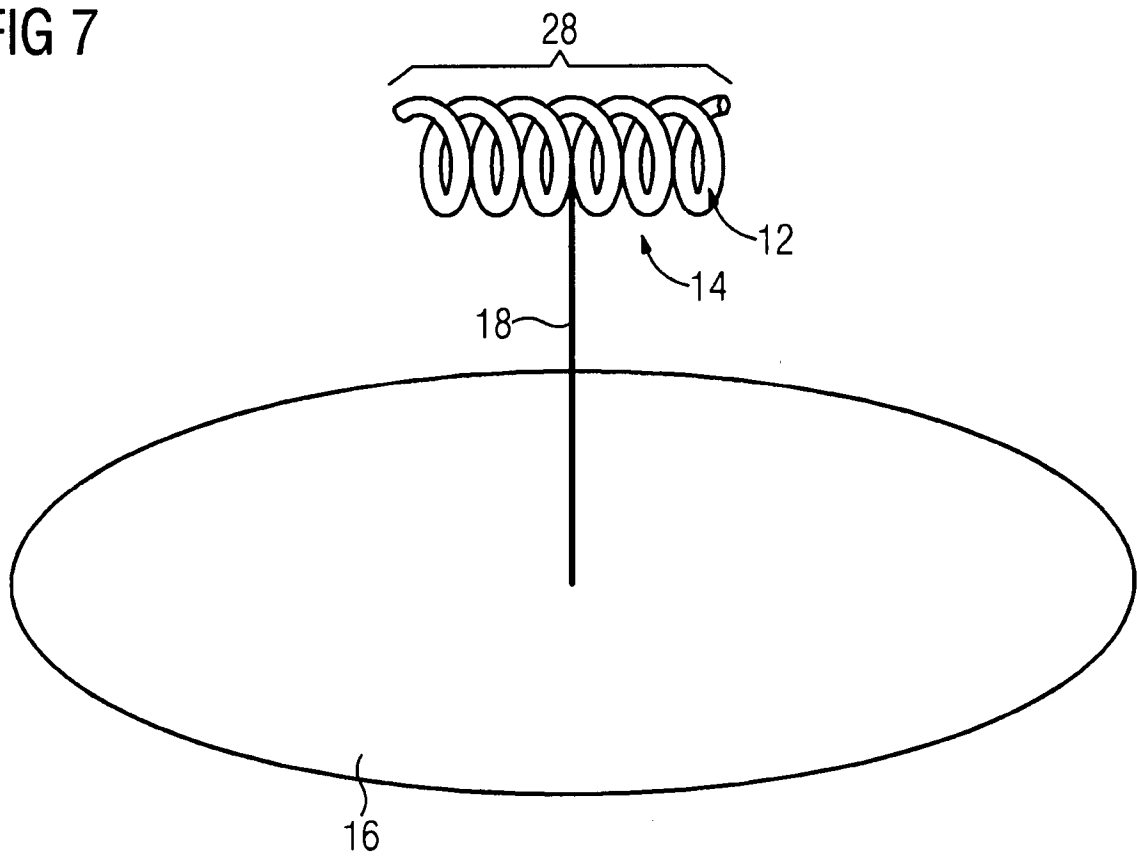


FIG 7



INTERNATIONAL SEARCH REPORT

International application No
PCT/RU2012/000590

A. CLASSIFICATION OF SUBJECT MATTER
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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)
G01H E21B F17D 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, 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	EP 2 418 466 A2 (WEATHERFORD LAMB [US]) 15 February 2012 (2012-02-15)	1-5,7
A	paragraph [0002] - paragraph [0003] paragraph [0022] - paragraph [0025] paragraphs [0043], [0047], [0050], [0051], [0054]	6
A	----- GB 2 456 300 A (SCHLUMBERGER HOLDINGS [VG]) 15 July 2009 (2009-07-15) abstract -----	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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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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