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(54) Benævnelse: **Skib med en indretning til tankovervågning**

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Description

SHIP WITH A DEVICE FOR MONITORING TANKS

The invention relates to a ship with an apparatus for tank monitoring according to the preamble to Claim 1. Tank monitoring is of great significance on ships, since the filling levels of the tanks are of central importance to a large number of state variables of the ship, such as, for example, the stability and the remaining operating range.

The fuel tanks on ocean-going ships are considered here by way of example. As a rule, large ocean-going ships use heavy fuel oil (HFO) with a viscosity of up to 700 - 900 cSt at 20°C. This heavy fuel oil must be brought to a temperature of between 50°C and 60°C in order to be able to pump it. Monitoring of both the filling level of the fuel tank and of the temperature of the fuel is therefore important for ship operation. The management system of the ship provides that, for reasons of energy saving, part of the bunker tank is not heated, part of the bunker tank is being heated up, and part of the bunker tank is kept at a temperature at which fuel can be pumped from it into the service tank.

At present there are several methods of monitoring the filling level used in ship tanks, such as for example

- by means of pressure measuring cells,
- by means of capacitive measuring instruments,
- by means of radar,
- by means of guided microwaves.

All of these sensors have specific disadvantages, so that in given ships a plurality of different types of sensor are used. One disadvantage of the said sensors is that a relatively large flange must always be attached to a tank in order to place a sensor at a defined location. In cases where binary sensors, each of which is to indicate whether a specified filling level is exceeded or not, are used, it is even necessary for a plurality of sensors to be attached along the side wall of the tank.

To date therefore it has been usual in order to monitor the filling level to fit 3 sensors (High Level, Low Level, Low Low Level) to the side wall of a bunker tank for providing an alarm as well as, for example, pressure measuring cells as analogue sensors. Sometimes a system for analogue filling level measurement (ultrasonic, radar, capacitive) is also installed at the top of the tank. Suitable temperature sensors are installed through the side wall of the tank for temperature measurement. What all these systems have in common is that the possibility of installing them depends on the accessibility of the relevant installation location.

DE 33 23 032 A1 discloses a ship with an apparatus for monitoring the filling level and an apparatus for regulating the temperature of liquid in a ship's tank. GB 2 184 229 discloses an apparatus for monitoring the filling level of a liquid in a tank, wherein the filling level is determined with reference to the light backscattered in an optical fibre.

It is therefore the object of the invention to create a new and useful apparatus for tank monitoring on a ship, which overcomes the disadvantages of conventional tank sensing, i.e. simplifies the installation at a tank and nevertheless provides adequate measurement precision and reliability.

This object is achieved according to the invention by a ship with an apparatus having the features of Claim 1. Advantageous embodiments are given in the dependent claims.

According to the invention, a sensor is used for tank monitoring on a ship consisting of an optical waveguide along which a measurement location is formed at at least one predetermined position at which light propagating in the optical waveguide is backscattered in a direction opposite to its original propagation direction. Light is radiated into the optical waveguide by a suitable light source. The signal processing device comprises a computing device for evaluating a characteristic property of the light backscattered to the at least one measurement location. The optical waveguide is arranged in the tank in such a way that the number of those measurement locations that are located underneath the liquid level of a liquid contained in the tank depends on the filling level of the tank. Since the characteristic property of the light backscattered at one measurement location is affected by whether the measurement location is located above or below the liquid level, evaluation of this property allows a conclusion to be drawn about the filling level. In addition, the signal processing device derives at least one signal from a signal delivered by the sensor which indicates a temperature in the tank.

Although a binary indication of the filling level of the tank can be made with a single measuring location, namely whether it is located above or below this measuring location, it is expedient for a multiplicity of measuring locations to be formed at predetermined positions along the optical waveguide in order to permit a more accurate measurement of the filling level.

Each measurement location is advantageously formed by a Bragg grating with a grating period d which is characteristic, or different, for the measuring location. The signal processing device accordingly comprises an analyser which determines the spectral composition as a characteristic property of the backscattered light, in order to permit a spectral identification of the component of the whole of the backscattered light that relates to each individual measuring location. In particular, up to 10 measuring locations are provided along an optical waveguide having Bragg gratings with different grating periods d. One light source preferably used here exhibits in particular a sufficiently wide spectral bandwidth to cover the spectral bandwidth of the Bragg gratings and of the light reflected back by them.

It has also been found valuable if each measurement location is formed by a Bragg grating having an identical or substantially identical grating period d, and if the signal processing device has an analyser which determines the spectral composition of the backscattered light as the characteristic property thereof, and furthermore has evaluation electronics which determine a propagating time of the backscattered light since the radiation of the light into the optical waveguide. This embodiment is particularly advantageous when a large number of measurement locations are required.

In such a case, when using Bragg gratings with different grating periods d, a light source with a spectral bandwidth given by the spectral bandwidth of the sensors being used and by the expected shifts of the spectral intensity distributions of the light backscattered from the existing sensors in response to a temperature change would be required. Even with a number, for example, of more than 10 measurement locations, it can happen that when Bragg ratings with different grating periods d are used, it becomes difficult to provide a light source with a suitable spectral bandwidth.

The position along an optical waveguide of Bragg gratings with the same or very similar grating periods d can not, however, be resolved solely by means of evaluating the shifts in the spectral intensity distributions of the light backscattered from the sensors that are present, since the backscattered, shifted wavelength ranges of all the sensors located below the liquid level are approximately the same. It is additionally necessary for this to determine the propagating time of a light or pulse of light sent into the optical waveguide, from the radiation of the light into the optical waveguide until the return of a wavelength range shifted with respect to the backscattered wavelength ranges. The propagating time determined can be assigned to a specific measurement location, wherein this measurement location can be assigned to a filling level in the tank. The implementation of measurement locations through Bragg gratings with the same or essentially the same grating periods d is particularly advantageous when a large number of measurement locations, in particular more than 10 measurement locations, preferably more than 50 measurement locations, are required. Any source of light is suitable here, in particular however a pulsed and/or monochromatic light source, preferably in the form of a laser or an LED light source.

Since, due to the thermal change in the length of the optical waveguide, the characteristic wavelength backscattered at a Bragg grating depends on the temperature, it is possible to conclude from the said wavelength whether a Bragg grating is surrounded by liquid or not if, as a result of heating, as is found in the bunker tanks of ships loaded with fuel, it has a higher temperature than the surroundings. Otherwise, a change in the temperature at a position of Bragg grating immersed in liquid can be caused by heating the whole of the optical waveguide. In this case, the increase in thermal transfer caused by the liquid can cause a reduction in the temperature of the most Bragg grating.

To measure the filling level of a tank, the optical waveguide is arranged in the tank in such a way that the number of Bragg gratings that are located underneath the liquid level of a liquid contained in the tank depends on the filling level of the tank. This permits a measurement of the filling level, wherein the resolution is given by the number of Bragg gratings and their separations.

Through the use of an optical waveguide as a sensor, it is possible, in comparison with the state of the art, to alleviate the problem of the restriction on the placement of sensors in the tank resulting from accessibility of the locations provided for them, and the size of the openings (flanges) required in the tank walls for the attachment of sensors can be reduced. An optical waveguide, in particular in the form of a glass fibre cable, can be inserted at any desired location into a tank, and only needs to be laid within the tank in such a way that a sensible measurement arrangement results. The course of the glass fibre cable in the tank can be determined by a carrier body along which the glass fibre cable is guided.

It has been found helpful here for the glass fibre cable merely to be inserted into the tank, but not brought back out again. One end of the glass fibre cable remains here in the tank. This saves space, and simplifies installation as well as, if relevant, the replacement of such a cable.

Through a suitable spatial arrangement of glass fibre cable in a tank it is possible, according to the invention, to carry out a measurement of the filling level and measurement of the temperature together, since the measurement of the filling level is only made through an evaluation of the measured temperature distribution along the glass fibre cable, and the temperature values are in any case generated as intermediate results in the course of measuring the filling level. This is a particular advantage of the invention, since both of these state variables usually have to be monitored in the tanks on board ships, for which purpose separate sensors have to be provided, according to the state of the art, for the two magnitudes. Because of the necessity, mentioned above, of heating the usual fuel, HFO, for its extraction, this applies particularly to the fuel tank of a ship.

The measurement does not depend on the local details of the insertion of the glass fibre cable into the tank, so that the most favourable location in any particular case for the access can can always be selected. It is also possible to insert the glass fibre into a pre-installed sleeve. This has the advantage that, if necessary, i.e. when a fault occurs, the glass fibre can be replaced without contact with the media. It is furthermore possible to install such sleeves for the purposes of reference measurements. Due to the low thickness of glass fibres and their high flexibility, they can also be installed much more easily into complicated arrangements than is the case for conventional measurement arrangements.

According to the invention, a single glass fibre cable performs both the functions of multiple individual sensor elements through the Bragg gratings that are incorporated in it, as well as, simultaneously, the function of a connecting line between the individual sensor elements and the signal processing device. This connecting line is not here configured as a star, but the individual sensor elements and the signal processing device are arranged on it in the same way as a bus line, and the communication between each of the individual sensor elements and the signal processing device is performed simultaneously through frequency multiplexing.

A further advantage of the invention is the fact that optical waveguide cables are not sensitive to electromagnetic interference, a problem that is found increasingly in modern shipbuilding.

An exemplary embodiment of the invention is described below with reference to the drawings. In these

Fig. 1

shows a schematic rear view of a ship with an example of an arrangement of a fuel tank,

Fig. 2

shows a schematic side view of the ship of Fig. 1,

Fig. 3

shows a schematic plan view of the ship of Fig. 1,

Fig. 4

shows the schematic structure of a measurement arrangement according to the invention,

Fig. 5

shows a magnified section of an optical waveguide with an integrated Bragg grating,

Fig. 6

shows a spectral intensity distribution of a wideband light source, and

Fig. 7

shows the functioning principle of a sensor according to the invention.

Figures 1 to 3 show, using the example of a ferry 1, the arrangement of bunker tanks 2 for fuel in a ship. The bunker tanks 2 in which the fuel is carried are indicated, in the usual way, by diagonal broken lines. In this example, the ferry 1 has a total of nine bunker tanks 2 that are arranged underneath the vehicle deck 3 next to one another in a 3x3 matrix.

It is not hard to see that the accessibility of the bunker tanks 2 in this part of the ship 1 is restricted. This applies in particular to the side walls of the tank 2 that run in the longitudinal direction of the ship 1. In this respect it is obviously problematic that, for the measurement of filling level and/or temperature, a plurality of flanges have to be attached to the side walls of the tank 2 to provide accesses for sensors to the interior of the tank 2 at various locations. Every flange, moreover, requires an opening in the tank wall, and therefore represents a potential leak location.

According to the invention, an optical waveguide, preferably in the form of a flexible glass fibre cable, with which in fact a temperature measurement is first made, is used for measuring the filling level. The filling level is then determined from the temperature. A schematic representation of the measurement arrangement is shown in Fig. 4.

The optical waveguide 4 is connected via a directional optical coupler 5 to a light source 6 and to a signal processing device 7. The directional coupler 5 couples light radiated by the light source 6 into the optical waveguide 4, and couples light backscattered from it to the signal processing device 7. A display unit 8 follows the signal processing device 7.

A large number of Bragg gratings, with the same or differing grating periods d, are formed at predetermined positions along the optical waveguide 4. If Bragg gratings with different grating periods d are used, then a light source 6 that radiates a wide bandwidth is preferably used. If, on the other hand, Bragg gratings with the same or essentially the same grating periods d are used, then a pulsed, monochromatic light source 6 is preferably used.

Fig. 4 shows three Bragg gratings 9A, 9B and 9C, purely by way of example. The optical waveguide 4 is inserted into a thin-walled tube 10 of metal or plastic, which is arranged vertically in a tank 2 containing fuel 11. Part of the optical waveguide 4 is located underneath the liquid level 12 of the fuel 11. Consequently, a portion of the Bragg gratings 9A, 9B and 9C are also located underneath the liquid level 12. These are Bragg gratings 9B and 9C in the illustrated example.

A heating apparatus 13, supplied by an energy source 14, is also arranged in the tube 10. The heating apparatus 13 can, for example, be a heating wire that is attached along the inner wall of the tube 10. The energy source 14 can, when required, be activated by the signal processing device 7, which will be considered in more detail later. When the energy source 14 is activated, the heating apparatus 13 heats the optical waveguide 4 equally along its entire length.

Figures 5 to 7 illustrate the functioning principle of a sensor according to the invention. Of these, Fig. 5 shows an enlarged schematic view of a section of the optical waveguide 4 consisting of a core 4K and a cladding 4M, being in particular a section in which a Bragg grating 9A, 9B or 9C is formed. This consists of a periodic sequence of disc-shaped regions having a refractive index n_1 that differs from the normal refractive index n_2 of the core 4K. The period of the gratings 9A, 9B or 9C is indicated in Fig. 5 by d, and may be the same or different for the gratings 9A, 9B and 9C.

If light with a broadband distribution 15 of the intensity I over the wavelength λ, as is illustrated in Fig. 6, is radiated into a Bragg grating 9A, 9B or 9C, having for example different grating periods d, a small portion of the light is backscattered at the Bragg gratings 9A, 9B and 9C, having in each case a characteristic spectral intensity distribution 16A, 16B and 16C, which depends on the grating period d of the grating 9A, 9B or 9C concerned. As can be seen in Fig. 7, the wavelength λ of the backscattered light is greater the greater is the grating period d.

A local change in temperature of the optical waveguide 4 in the region of a Bragg grating 9A, 9B or 9C results in a local longitudinal expansion or contraction, and thus to a change in the grating period d, which has the consequence of shifting the spectral intensity distribution 16A, 16B or 16C of the backscattered light. The extent of this shift is a measure for the change in length, and thus for the change in temperature.

The signal processing device 7 shown in Fig. 4 contains a spectral analyser for determination of the spectral distribution of the light backscattered from the individual Bragg gratings 9A, 9B and, 9C, and a computing device which determines the extent of the relevant shift with respect to the reference position, and converts this through calculation into a temperature change with respect to a reference temperature at which the spectral distribution is the reference position. This is done for each individual Bragg grating 9A, 9B and 9C, so that in this way the distribution of the temperature along the entire optical waveguide 4 at the locations provided with Bragg gratings 9A, 9B and 9C is obtained.

If Bragg gratings with the same or essentially the same grating periods d are used, the signal processing device 7 also comprises evaluation electronics which evaluate the propagation time of the backscattered light with changed spectral intensity distribution.

As explained above, bunker tanks 2 on ships from which fuel 11 is at the time being withdrawn are heated, so that in this case the fuel 11 has a significantly greater temperature than the environment, also differing from the temperature of the air in the space 17 above the liquid level 12, i.e. is higher than it. There is thus a step in the temperature distribution at the height of the liquid level 12. The computing device of the signal processing device 7 determines the position of this step, and, making reference to the known positions of the Bragg gratings 9A, 9B and 9C along the optical waveguide 4 and its known arrangement within the tank 2, determines a vertical position with respect to the tank, which is output as the filling level at the display unit 8. In this case, the heating apparatus 13 is not required, and therefore remains out of operation.

If the filling level of a tank 2 in which the fuel 11 is not heated is to be monitored, as a result of which its temperature is not significantly different from the ambient temperature, then the energy source 14 is activated, and delivers power to the heating apparatus 13 which results in heating the optical waveguide 4 with respect to its environment. Below the liquid level 12, the fuel 11, due to its greater thermal capacity, draws the heat being given out by the heating apparatus 13 away from the pipe 10 better than the air in the space 17 above the liquid level 12, so that in this case too, there is a temperature step at the height of the liquid level 12. In this case, however, the temperature below the liquid level 12 is lower than that above.

It is advantageous here if the heat energy given out by the heating apparatus 13 can be adjusted. In that case the heat power can be matched to the thermal material parameters of the liquid 11 in such a way that a temperature step develops in the optical waveguide 4 that can be reliably detected by the signal processing device 7 without using an excessive amount of power. The adjustment can be done automatically in that the power fed from the energy source 14 into the heating apparatus 13 is increased in steps, starting from a relatively low initial value, until the signal processing unit 7 determines an unambiguous temperature step along the optical waveguide 4.

The position of the temperature step is determined by the computing device of the signal processing device 7, and, as described above, converted by calculation into a measure of the filling level and output on the display unit 8. It should be obvious that the function of the measuring arrangement according to the invention does not depend on the type of liquid that is contained in the tank 2, but that in principle a tank 2 with an arbitrary liquid content can be monitored, i.e. also a ballast tank or a cargo tank. Whether or not use must here be made of the heating apparatus 13 depends on whether the temperature of the liquid under the current operating conditions of the ship 1 is above the ambient temperature or not.

The resolution of the filling level measurement is determined by the number and position of the Bragg gratings along the optical waveguide 4, and can be adjusted through appropriate design to the requirements of a particular application. With the three Bragg gratings 9A, 9B and 9C shown in Fig. 4 it is possible to determine three filling level steps, since the topmost Bragg grating 9A must always be located above the liquid level 12 as a reference. The topmost detectable step is therefore a filling level between the gratings 9A and 9B, as is sketched in Fig. 4, the middle step is a filling level between the gratings 9B and 9C, and the lowest step is a filling level below the grating 9C, after which no marked temperature step can be determined along the optical waveguide 4. The illustration of Fig. 4 is not to scale.

It emerges from the mode of operation described here of the filling level measurement according to the invention, that the temperature distribution along the optical waveguide 4 is necessarily also acquired. It is therefore possible for the measured temperature values also to be sent from the signal processing device 7 to the display unit 8 in order to display them there. As a result of the vertical distribution of the individual temperature measurement points in the form of the Bragg gratings 9A, 9B and 9C over the height of the tank 2, the measurements obtained represent a vertical temperature profile of the tank 2, knowledge of which is of great interest in the case, for example, of a heated fuel tank which is heated from the bottom, as a result of which the development of a marked vertical temperature gradient can be expected.

While the filling level measurement is based only on the determination of a temperature step, the absolute value of the temperature thus not playing a role, temperature measurement requires either a calibration of the measuring arrangement to the absolute value of the temperature or, according to the invention as given in Claim 1, the use of an additional reference sensor which is at the same temperature as one of the Bragg gratings and which supplies a signal indicating the absolute value of the temperature.

Patentkrav

1. Skib, især søgående skib, omfattende mindst en skibstank og mindst en skibstanksovervågningsindretning til overvågning af en påfyldningshøjde og en temperatur på en væske i mindst en skibstank, hvor skibstanksovervågningsindretningen omfatter mindst en sensor, der er anbragt i eller på skibstanken, og en signalbearbejdningsindretning, der er tilordnet sensoren, og som ud fra et signal, der afgives af sensoren, afleder mindst et signal, der viser påfyldningshøjden i skibstanken,
kendetegnet ved, at
sensoren består af et lyslederkabel (4), langs hvilket der i mindst en forudbestemt position er udformet et målested (9A, 9B, 9C), hvor lys, der udbreder sig i lyslederkablet (4), tilbagespredes mod sin oprindelige udbredningsretning, hvor der er tilvejebragt en lyskilde (6), der egner sig til indstråling af lys i lyslederkablet (4), hvor signalbearbejdningsindretningen (7) har en computerindretning til analyse af en karakteristisk egenskab ved lyset, der tilbagespredes ved det mindst ene målested (9A, 9B, 9C), hvor lyslederkablet (4) er anbragt i skibstanken (2) således, at antallet af de målesteder (9B, 9C), som befinder sig under væskeoverfladen (12) af en væske (11), der er indeholdt i skibstanken (2), afhænger af påfyldningshøjden i skibstanken (2), og hvor signalbearbejdningsindretningen (7) ud fra et signal, der afgives af sensoren, afleder yderligere mindst et signal, der viser en temperatur i skibstanken (2), hvor lyslederkablet (4) er anbragt i skibstanken således, at mindst et målested (9A) uafhængigt af påfyldningshøjden hele tiden befinder sig over væskeoverfladen (12), og at det lyssignal, der tilbagespredes fra dette målested (9A), benyttes af signalbearbejdningsindretningen (7) som referencesignal til sammenligning med de lyssignaler, der tilbagespredes fra de øvrige målesteder (9B, 9C).

2. Skib ifølge krav 1, hvor der langs lyslederkablet (4) er udformet flere målesteder (9A, 9B, 9C) i forudbestemte positioner.

3. Skib ifølge krav 1 eller 2, hvor hvert målested dannes ved hjælp af et bragg-gitter (9A, 9B, 9C) med en gitterperiode d, der er karakteristisk for målestedet, og at signalbearbejdningsindretningen (7) har en analysator, der fastslår den spektrale sammensætning som karakteristisk egenskab ved det tilbagespredte lys.

4. Skib ifølge krav 1 eller 2, hvor hvert målested dannes ved hjælp af et bragg-gitter (9A, 9B, 9C) med samme eller i det væsentlige samme gitterperiode d, og hvor signalbearbejdningsindretningen (7) har en analysator, der fastslår den spektrale sammensætning som karakteristisk egenskab ved det tilbagespredte lys, og endvidere har en analyseelektronik, der fastslår en løbetid for det tilbagespredte lys fra indstrålingen af lyset i lyslederkablet (4).

5. Skib ifølge et af kravene 1 til 4, hvor lyslederkablet (4) er anbragt i skibstanken (2), således at det i det mindste næsten strækker sig i vertikal retning.

6. Skib ifølge et af kravene 1 til 5, hvor lyslederkablet (4) er anbragt i eller på et stift bærerlegeme (10), hvis form fastlægger lyslederkablets (4) forløb i skibstanken (2).

7. Skib ifølge krav 6, hvor bærerlegemet (10) består af et rør og/eller en stav med en not.

8. Skib ifølge krav 6 eller 7, hvor lyslederkablet (4) er anbragt udskifteligt i et hulrum af bærerlegemet (10) og beskyttes mod umiddelbar kontakt med en væske (11) i skibstanken (2) af bærerlegemet (10).

9. Skib ifølge et af kravene 1 til 8, hvor en varmeindretning (13) er anbragt langs lyslederkablet (4) og naboliggende dertil, og gennem hvilken varmeindretning en forudbestemmelig varmeeffekt kan afgives pr. længdeenhed.

10. Skib ifølge et af kravene 3 til 9, hvor signalbearbejdningsindretningen afleder det signal, der viser påfyldningsstanden, ud fra forskydningen af positionen af den spektrale intensitetsfordeling (16A, 16B, 16C) af mindst et lyssignal, der tilbagespredes af et bragg-gitter (9A, 9B, 9C), i forhold til en tilordnet referenceposition.

11. Skib ifølge krav 10, hvor signalbearbejdningsindretningen (7) på baggrund af forskydningens omfang identificerer, om et bragg-gitter (9A, 9B, 9C) befinder sig over eller under væskeoverfladen (12), og hvor den på grund af den forudbestemte position af hvert bragg-gitter (9A, 9B, 9C) langs lysleder-kablet (4) afleder det signal, der viser påfyldningshøjden i skibstanken (2).

12. Skib ifølge et af kravene 1 til 11, hvor signalbearbejdningsindretningen (7) afleder hvert signal, der viser en temperatur, ud fra en forskydning af positionen af den spektrale intensitetsfordeling (16A, 16B, 16C) af et lyssignal, der tilbagespredes af et bragg-gitter (9A, 9B, 9C), i forhold til en tilordnet referenceposition, nemlig på baggrund af mindst en funktionel sammenhæng, der er gemt i signalbearbejdningsindretningen (7), mellem en spektral forskydning og en afvigelse fra en referencetemperatur.

13. Skib ifølge et af kravene 1 til 12, hvor den mindst ene skibstank er en brændstoftank, en ballasttank eller en lasttank.

14. Skib ifølge krav 13, hvor den mindst ene skibstank omfatter flere brændstoftanke, der er indrettet til opvarmning af indeholdt brændstof i form af tung brændselsolie.

FIG 1

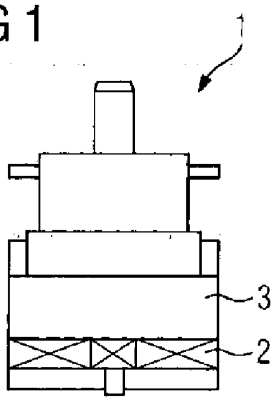

FIG 2

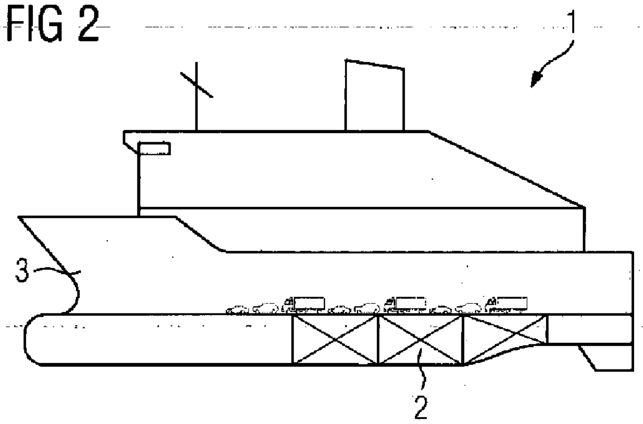

FIG 3

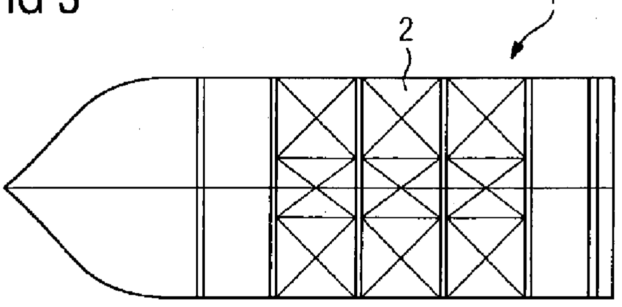

FIG 4

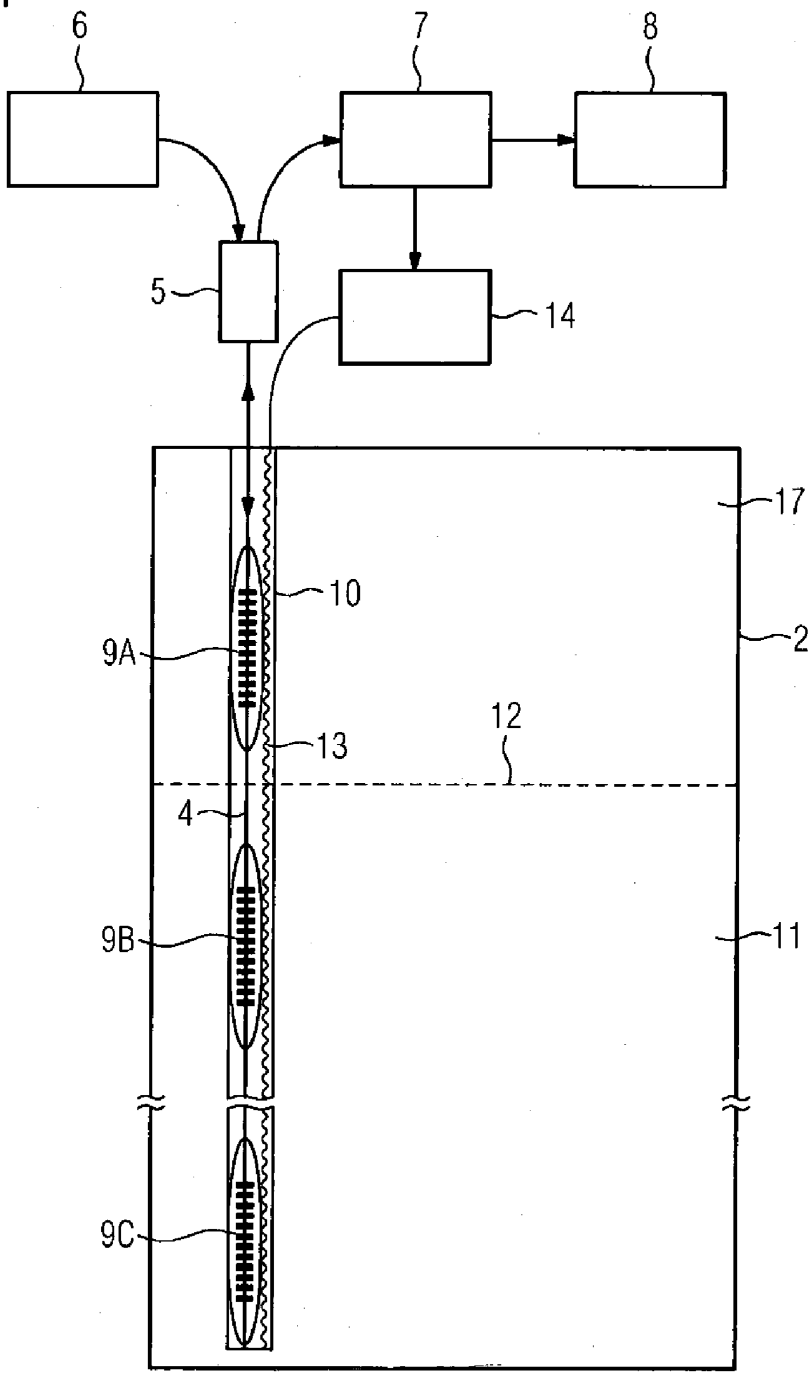

FIG 5

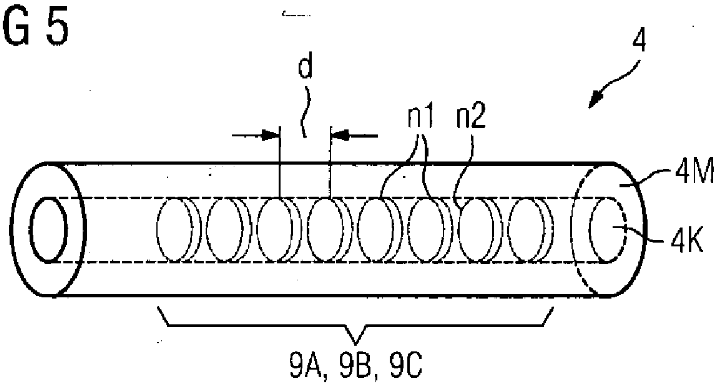

FIG 6

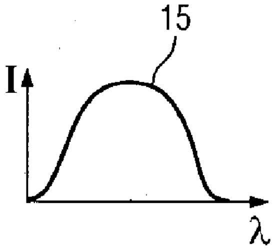

FIG 7