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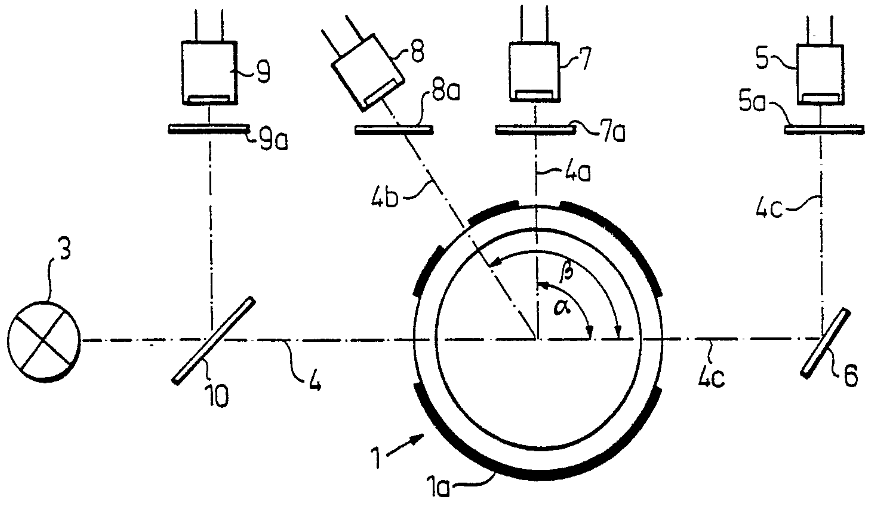

(57) Abstract

In a method for detecting the concentration of a primary and emulsifiable contaminant, e.g. oil, in water which also contains secondary, tertiary and possibly other non-mechanically emulsifiable contaminants, such as iron oxide and/or atapulgite, the contaminated liquid is prepared to repeated disintegration of the primary contaminant in an emulsifier to form discrete, homogenous and precise primary contaminant particles in order to maximize the light scatter effect. The liquid is then passed through a measuring cell and irradiated with light from a light source, wherewith the type of secondary and tertiary contaminants present, which cause the light to be scattered in a significant fashion, substantially in a rearward direction, are determined by a detecting primarily the quantity of light reflected at different angles and secondarily the quantity of light transmitted. The total quantity of the thus determined types of contaminants is determined primarily by detecting the quantity of light transmitted and secondarily by detecting the quantity of light reflected, thereby also enabling the concentration of the primary contaminant to be calculated.

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A method and apparatus for detecting the concentration of contaminants in a liquid.

Technical Field

The present invention relates to a method for detecting the concentration of a primary and emulsifiable contaminant, e.g. oil, in a liquid, e.g. water, which contains secondary, tertiary and possibly other non-mechanically emulsifiable contaminants, such as iron oxide and/or atapulgite for example, in which method the contaminated liquid is first prepared and then passed through a measuring cell and in which the contaminated liquid is irradiated with scattered light emanating from a light source and the quantity of transmitted and reflected light is measured.

The invention also relates to apparatus for carrying out such detection.

Background Prior Art

Various apparatus for detecting contaminants, such as oil, in a liquid, such as water, are known in the art.

GB-B 1 588 862 (Standard Telephones & Cables) describes light scattering apparatus with which it is endeavoured to avoid errors caused by particles suspended in the liquid. In this apparatus, reflected light is measured at an angle of 40-60° and at an angle which is smaller than 40°. The first mentioned measuring process is therewith independent of the concentration of oil present in the liquid, whereas both measurements are dependent on particle concentration. The apparatus utilizes laser beams and fibre optics. The signals obtained are evaluated in a microprocessor, which computes the oil concentration.

This apparatus is not sufficiently accurate, however, especially in those cases where the nature of further major contaminants in the liquid is known beforehand.

GB-A-2 097 529 (ITT) describes a detector for oil in water in which the response signal is substantially independent of the type of oil present. A measuring cell is exposed to a light beam from a light source and two detectors measure reflected light at mutually different angles. The oil concentration is measured on the basis of the difference between the two signals.

Since the oil itself contains comparatively high concentrations of contaminating substances, it is not possible with apparatus of this kind to determine the oil concentration with sufficient accuracy.

SE-B-7712231-5 (ITT) describes measuring apparatus for determining oil concentration, in which apparatus the scatter of penetrating light from a light source is measured by means of an arrangement comprising a semiconductor laser for operation in the infrared region of the spectrum, and in which there is used a first photodetector in-line with the laser beam, one or more additional photodetectors positioned at an angle to the laser beam, and a voltage controlled variable amplifier which is steered from the output of the first photodetector. In this way compensation is obtained automatically for variations in laser beam intensity. The apparatus is relatively complicated. It also fails to give satisfactory results when the liquid examined contains high concentrations of additional contaminants.

GB-A-2 097 529 (ITT) describes an arrangement for detecting oil in water, which comprises two or more photodetectors which are positioned at mutually different angles in relation to the light beam, and also a microcomputer for evaluating the signals obtained from the separate photodetectors and therewith determine the oil contaminant concentration. One serious drawback with this arrangement, however, is that it is not possible to establish accurately therewith either the type of oil constituting the contaminant or the types of secondary, tertiary, etc. contaminants present.

Other examples of such apparatus and arrangements are found described and illustrated in DE-A-2 835 380 (Berber et al), GB-A-2 105 028 (ITT), Derwent's abstract SU-890 170 (Vinnitsa Poly) and US-A-3,624,835 (Wyatt).

Another publication of interest in this respect is DE-A-30 09835 (Technicon Instruments).

Object of the Invention

One object of the present invention is to enable the contaminant concentration of a flowing liquid to be measured continuously and with great accuracy, while compensating for the influence of other contaminants of varying particle size, and while avoiding the drawbacks of previously known apparatus.

A further object is to provide a method of detection of the aforesaid kind with which the presence of secondary, tertiary etc., contaminants can also be detected and the concentration thereof accurately determined and the results of which determinations can be used as a basis for improving the level of accuracy to which the primary contaminant concentration is determined.

Another object is to provide a method of detection of the aforesaid kind which can be carried out safely with the aid of simple means in an explosion risk environment.

Summary of the Invention

These and other objects are fulfilled by a method according to the present invention which in its widest aspect is mainly characterized by passing the contaminated liquid through an emulsifier at a constant pressure and constant rate of flow, thereby to break up the primary contaminant into particles of uniform size which give maximum light scatter in the measuring cell; detecting primarily the quantity of light reflected at mutually different angles and secondarily the quantity of light transmitted, thereby to determine the types of secondary, tertiary and possible other non-mechanically emulsifiable contaminants present; detecting primarily the quantity of light transmitted and secondarily the quantity of light reflected, thereby to determine the total quantity of the thus determined types of primary, secondary, tertiary, etc. contaminants present; and subtracting the summated determined quantity of secondary, tertiary and possible other non-emulsifiable contaminants from said total quantity, thereby to establish the amount of primary contaminant present.

The primary contaminant is broken up in the emulsifier into discrete, homogenous particles which are unambiguous for each type of such contaminant and which produce maximum scattering of light within the cell, thereby enabling the type identity of the primary contaminant to be established with a high degree of accuracy.

When the primary contaminant is oil, the type of oil present in the liquid can therefore be established very accurately.

Different types of contaminant can be said to leave characteristic "fingerprints". These "fingerprints" can be traced with the aid of a computer, when practising the invention. One essential factor in this connection is the degree of repetitiveness afforded by the invention, mainly as a result of the conditioning to which the liquid is subjected in conjunction with the various detecting operations.

The types of secondary, tertiary and possible other non-mechanically emulsifiable contaminants present are determined on the basis that such contaminants will scatter light in a significant fashion, and essentially in a rearward direction, this extent to which the light is scattered being determined primarily by establishing the quantity of light reflected at mutually different angles and secondarily by the quantity of light transmitted.

The total quantity of the thus determined types of primary, secondary, tertiary, etc., contaminants is then determined primarily by detecting the quantity of light transmitted and secondarily the quantity of light reflected.

Thus, in short, the type of contaminant present in the liquid is primarily determined with the aid of the light reflected, while when determining the amount of contaminant it is primarily the transmitted light that is used to this end. However, in the former case the transmitted light is also utilized to determine the type of contaminant present, in order to achieve a more accurate result, while in the latter case the reflected light is also used, to the same end, so that the proportions in which the contaminants are present can be established more accurately.

The resultant signals are evaluated in a computer which has access to a comprehensive register of reference values and which can therefore rapidly reveal the type of contaminant concerned and also the quantities in which the contaminant is present.

It is essential to the accuracy of the assay carried out that the primary contaminant is vigorously emulsified, so as to break up the emulsifiable primary contaminant into discrete, clearly defined particles, which greatly affect the scattering of light, as beforementioned. This results in a significant difference in relation to the non-emulsifiable contaminants present, which reflect the beams of light passed through the cell in essentially a rearward direction.

The sum total of the established quantities of secondary, tertiary and possible other non-emulsifiable contaminants is subtracted from the total established quantity of contaminants, so as to establish the quantity of primary contaminant present.

When carrying out the method, a detector intended for detecting a secondary, tertiary, etc., contaminant is positioned so that the axis of the detector is located at such an angle to the axis of the transmitted light beam as to enable the maximum amount of light reflected by the contaminant concerned to be detected.

In order to enable a large quantity of scattered images to be recorded, the detectors are made adjustable. When the reflection angle of a given contaminant of interest is known, the axis of the detector is placed at the aforesaid angle at the beginning of the measuring process. It is possible, however, within the scope of the invention to use one or more movable secondary contaminant detectors, so that during the measuring process the detector (detectors) can be shifted, preferably rotated, in relation to the measuring cell axis, until a position is reached at which a maximum signal is detected.

One or more detectors can also be used to determine the concentration of a further contaminant in the liquid, this further contaminant optionally being one which was expected to be present. In this case, there is used the knowledge that a given type of particulate contaminant will cause a given portion of the light supplied to be reflected at a predetermined angle, and a further proportion of said light, e.g. a smaller proportion, to be reflected at a different angle.

For example, if there is reason to believe that the oil contaminated water contains a further contaminant, two detectors for instance are positioned at predetermined angles and caused to record the proportion of light reflected at these angles. If the values obtained coincide with the expected values, this can be seen as proof that the contaminant concerned is, in all propability, present in the liquid.

In practice, however, it is preferred to use the actual measuring cell itself as a lens for focusing transmitted and/or reflected light onto respective detectors. In addition hereto it should be ensured that the light beams pass parallel to the cell.

Accordingly, the thickness of the tube used as a measuring cell is selected so that the actual measuring cell itself can function as a lens and accurately focus the light transmitted from the light source onto the detector and produce the aforesaid parallel beam configuration or pattern. This obviates the need for an additional lens system for this purpose.

The contaminated liquid is preferably passed through an emulsifier, so as to finely divide the contaminants throughout the liquid, prior to introducing the liquid into the measuring cell, at least when the liquid is water and the primary contaminant is oil.

In practice it is often advantageous to emulsify the emulsifiable contaminant extremely vigorously, so as to ensure that at least certain kinds of contaminant particles obtain mutually the same size and therewith result in uniform light scatter and an accurate signal in correspondence therewith.

In accordance with one preferred embodiment, the measuring cell is irradiated with red light of shorter wavelength than infrared light. This is particularly advantageous in those cases when the oil concentration in water is to be determined after an emulsifying process, since the shorter wavelengths correspond to the small oil particles obtained in the emulsifier.

An improved result can be achieved, normally to advantage, when the measuring cell is coated with a light absorbent layer, with the exception of those areas which are to permit transmitted and reflected light to pass therethrough.

In order to facilitate the detection process and/or the positioning of the detectors, one or more mirrors may be arranged in a suitable manner in the path of the various light beams.

In addition, the contaminated liquid is preferably deaerated prior to commencing the detection process. When the liquid is to be emulsified, de-aeration of the liquid is preferably effected prior to emulsifying the contaminants present.

The invention also relates to apparatus operating in accordance with the method according to the invention, the main characteristic features of the apparatus being set forth in the following apparatus claims.

The invention will now be described in more detail with reference to two exemplifying embodiments thereof illustrated in the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a cross-sectional view of a measuring cell which functions as a lens and which is throughpassed by a contaminated liquid through which light beams from a light source are passed, the beams being detected by the detector.

Figure 2 illustrates the principles employed when carrying out the method of detection according to the invention.

Figure 3 is a principle view of components forming part of an apparatus according to the invention.

Figure 4 is a cross-sectional view of a measuring cell, and illustrates an associated photodiode and detecting means for operating in gas risk environments, and

Figure 5 is a view which corresponds to Figure 2 and which illustrates a modification of the principle described with reference thereto.

Description of a Preferred Embodiment

Fig. 1 is a cross-sectional view of a measuring cell in the form of a relatively thick-walled tube 1 through which a contaminated liquid flows. The liquid may be water in which a primary contaminant, in the form of oil 2a, is present. The liquid also contains a secondary and a tertiary contaminant. It is assumed in this embodiment that the secondary contaminant is iron oxide, in the form of finely divided particles 2b, and the tertiary contaminant is atapulgite, in the form of finely divided particles 2c.

A light source, e.g. a photodiode 3, transmits light beams 4, and the measuring cell, i.e. the tube 1, functions as a lens to focus the light beams onto a detector 5, located in the focal plane of the measuring cell 1, which as beforementioned functions as a lens.

A given proportion of the light supplied will be reflected and absorbed by the contaminating particles 2b and 2c present in the liquid 2, in dependence on the nature and concentration of the contaminants. Residual light detected by the detector 5 constitutes light transmitted through the cell 1.

Fig. 2 illustrates the principle construction of the measuring arrangement. The measuring cell in Fig. 2 is also referenced 1. The measuring cell is provided with an absorbent coating 1a, except in those regions through which transmitted and reflected light passes.

The photodiode 3 emits light beams, of which only the central light beam 4 is shown.

It is assumed here that the measuring cell contains water contaminated with oil and with two further contaminants, such as finely divided iron oxide and atapulgite.

The particulate iron oxide causes a plurality of light beams to be reflected at an angle β, of which the central beam is designated 4b, the number of light beams reflected corresponding to the concentration of said contaminant. A certain amount of light is also reflected at an angle α. The central beam in this case is referenced 4a. Correspondingly, the tertiary contaminant, atapulgite, causes light to be reflected at different angles of β and α respectively, the number of light beams thus reflected corresponding to the concentration of said contaminant. The residual transmitted light beam, here designated 4c, is deflected by a mirror 6 and subsequently detected by a detector 5. It will readily be apparent that the angles β and α are subtended together with the axis of the transmitted light beam 4.

The reflected light beam 4a is detector by a detector 7, the axis of which is located at the angle α to the light beam 4. Correspondingly, the light beam 4b is detected by a detector 8, the axis of which is located at the angle β to the beam 4.

The beam originally transmitted from the photodiode 3 passes a planar glass 10, which also reflects a small quantity of the transmitted light. The proportion of light reflected by the planar glass 10 is detected by a detector 9, which therewith records an accurate value of the light transmitted. A planar glass plate 5a, 7a, 8a and 9a is placed in front of each of the detectors 5, 7, 8 and 9.

The detectors 7 and 8 produce signals which correspond to the amount of light detected from the two secondary and tertiary contaminants, these signals being sent to a computer (not shown) and processed therein. This proportion of light is subtracted from the proportion of light transmitted through the cell, this latter proportion being detected by the detector 5. The detectors 7 and 8 are able to record the concentration of secondary and tertiary contaminants with a high degree of accuracy, therewith also enabling the concentration of the primary contaminant to be accurately calculated, this concentration corresponding to the signal produced by the detector 5 in response to the proportion of light transmitted.

In the event that the nature of secondary or tertiary contaminants present in the liquid is not fully known, and consequently the corresponding reflection β is also not known, the detector 7 or the detector 8 can be rotated in relation to the axis of the measuring cell, until maximum indication of the contaminant concerned is obtained. This angle to which the detector is adjusted in order to obtain maximum indication may also be used as proof of the presence of a specific type of contaminant expected to be present in the liquid.

Further evidence can be obtained by detecting that a weaker signal is obtained at another angle β. The ratio between the two signals can be determined and the value obtained may indicate the propability of the presence of a given type of contaminant, or show that the contaminant is definitely present.

The signals obtained from the various detectors are transmitted to a computer and there compared with a comprehensive register of references corresponding to all types of signals that are likely to occur, so that the identity of the contaminant present can be quickly established. As beforementioned, each type of contaminant can be said to leave its "fingerprint" in the liquid concerned. These "fingerprints" can be quickly traced through the agency of the aforesaid reference register, thereby identifying the contaminants concerned. Once this has been accomplished, the concentration of the contaminants can be calculated in the aforesaid manner.

Fig. 3 is a schematic illustration of an analyzer in which the aforedescribed method can be carried out. Prior to introducing the liquid into the measuring cell 1, the contaminated liquid is passed through a conduit 15 and into an emulsifier 16. A continuous flow of liquid in the circuit is maintained with the aid of a pressure regulator 17. Arranged in the path of the liquid is a temperature sensor 18 and a solenoid valve 19. Fresh water is supplied through a conduit 20, provided with a solenoid valve 21, and is de-aerated in a de-aerator 22. The de-aerated water passes from the de-aerator through a valve 23 incorporated in the conduit 20 to a junction point 24, at which the conduit 20 is joined with the conduit 15. Extending from the de-aerator 22 is a branch conduit 25, which is connected with the conduit 15 via a pressure regulator 26 and a valve 27. A pressure sensor 28 is arranged to sense the pressure in the conduits 15 and 20. The system is flushed with fresh water delivered through the conduit 20 at given, uniform intervals, solely fresh water being used for this purpose. When flushing the system the water bypasses the pressure regulator 17, along a branch conduit 30 incorporating a valve 31. The masuring cell 1 incorporates devices of the kind described in the aforegoing.

Fig. 4 illustrates an example of a measuring device for use in an explosion-risk atmosphere. The device is referenced 35 and comprises a part 35a which incorporates the measuring cell 1. The part 35a is sealed in relation to a part 35b, which incorporates the photodiode 3 and the detectors 9,7,8 and 5.

A mirror 36 reflects the light transmitted through the measuring cell before the light is delivered to the detector 5.

When the liquid contains further contaminants, the device is provided with a corresponding number of detectors arranged at pre-determined angles in accordance with the nature of respective contaminants.

Fig. 5 illustrates an arrangement according to the invention which is a modified version of the arrangement illustrated in Fig. 3 and which functions in accordance with the same principles as the Fig. 3 embodiment. Consequently, a detailed description of the Fig. 5 embodiment is not necessary.

The Fig. 5 embodiment differs from the Fig. 2 embodiment in that the embodiment according to Fig. 5 incorporates a gear type constant flow pump 29 incorporated in the conduit 15, at the location shown in the figure.

As with the Fig. 3 embodiment, the emulsifier 16 is connected immediately upstream of the measuring cell 1, and ensures that the oil present in the liquid is broken up into small, clearly defined, homogenous particles which ensure maximum light scatter. Each of the primary circuits incorporates a de-aerator 22. A branch conduit 25 and 25' extend from each de-aerator 22, each of said branch conduits communicating with the conduit 15 through a pressure regulating device 26 and 27 incorporated in said branch conduits. The references 39 identify respective connections for pressure sensors in the various conduits.

Industrial Application

A method and an apparatus according to the invention have been described in the aforegoing for use in detecting the type of contaminants present in a liquid and the concentrations of said contaminants therein. The apparatus required herefor is relatively uncomplicated and enables the identity of the various contaminants to be established reliably and the concentrations of said contaminants to be accurately determined.

CLAIMS

1. A method of detecting the concentration of a primary and emulsifiable contaminant, e.g. oil, in a liquid, e.g. water, which also contains secondary, tertiary and possibly other non-mechanical emulsifiable contaminants, e.g. iron oxide and/or atapulgite, in which the contaminated liquid is first prepared and then conducted through a measuring cell and irradiated with scattered light deriving from a light source, and in which the quantity of transmitted and reflected light is measured with the aid of detectors, characterized by passing the contaminated liquid through an emulsifier at a constant pressure and constant rate of flow, thereby to break up the primary contaminant into particles of uniform size which give maximum light scatter in the measuring cell; detecting primarily the quantity of light reflected at mutually different angles, and secondarily the quantity of light transmitted, thereby to determine the types of secondary, tertiary and possibly other non-mechanically emulsifiable contaminants present; detecting primarily the quantity of light transmitted and secondarily the quantity of light reflected, thereby to determine the total quantity of the thus determined types of primary, secondary, tertiary etc., contaminants present; and subtracting the determined, summated quantity of secondary, tertiary and possibly other non-emulsifable contaminants from said total quantity, thereby to establish the amount of primary contaminant present.

2. A method according to Claim 1, characterized in that the detectors for detecting reflected light are movably arranged so as to enable those positions at which maximum signals are emitted to be determined, thereby enabling the presence of a given, possibly expected contaminant to be established.

3. A method according to Claim 1 or Claim 2, characterized

by illuminating the measuring cell with red light of shorter wavelength than infrared light.

4. A method according to any of Claims 1-3, characterized by using the actual measuring cell itself as a lens for focusing transmitted and/or reflected light onto respective detectors, the measuring cell being caused to bend the light beams so that they pass parallel therethrough.

5. A method according to any of Claims 1-4, characterized by comparing in a computer the detected values of light reflected at mutually different angles and/or the detected values of the quantity of light transmitted with predetermined reference values, in order to establish the type identity of the contaminants present.

6. Apparatus for detecting the concentration of a primary contaminant, e.g. oil, in a liquid, e.g. water, which also contains secondary, tertiary and possibly other contaminants, e.g. iron oxide and atapulgite, said apparatus comprising

a) a measuring cell (1);

b) means (15) for causing the contaminated liquid to flow through the measuring cell at a constant pressure and at a constant rate of flow;

c) a temperature sensor (18) for compensating for the influence of the temperature of the liquid;

d) a light source (3) for transmitting a light beam (4) through the measuring cell (1);

e) a detector (9) for detecting the quantity of light transmitted from the light source and providing a signal proportional to the amount of light transmitted, for comparison purposes;

f) a detector (5) located in the path of the light beam transmitted through the measuring cell for detecting the light transmitted and providing a signal proportional hereto;

g) a computer for evaluating the signals produced by the detectors,

characterized by
h) an emulsifier (16) connected upstream of the measuring cell (1) in the flow path of the contaminated liquid, for dividing the contaminants into discrete particles;
i) at least one further detector (7) located at an angle to the light beam passing through the measuring cell, for detecting the quantity of light (4a) reflected by a primary contaminants in the measuring cell (1) and delivering to the computer a signal proportional to the quantity of light detected; and
j)at least one further detector (8) located at another angle to the light beam through the measuring cell, for detecting the quantity of light (4b) reflected by a secondary contaminant in the measuring cell (1), and delivering to the computer a signal proportional to the quantity of light detected.

7. Apparatus according to Claim 6, characterized in that the said further detectors (7,8) for detecting the type of primary and secondary contaminants present and the concentration of said contaminants are movably arranged.

8. Apparatus according to Claim 6 or Claim 7, characterized in that the measuring cell (1) is coated with a light absorbent layer, except in the regions thereof through which transmitted and reflected light is to pass.

9. Apparatus according to any of Claims 6-8, for use in detecting contaminants in an explosion risk atmosphere, e.g. when mixing a gas phase with a liquid phase, characterized in that the measuring cell (1) is arranged in a gas-hazardous part (35a) of the apparatus which is sealed in relation to the detectors (5,7,8,9); and in that a mirror (6) is provided to ensure passage of the light beam between the gas-hazardous part (35a) and the non gas-hazardous part (35b).

Fig. 3

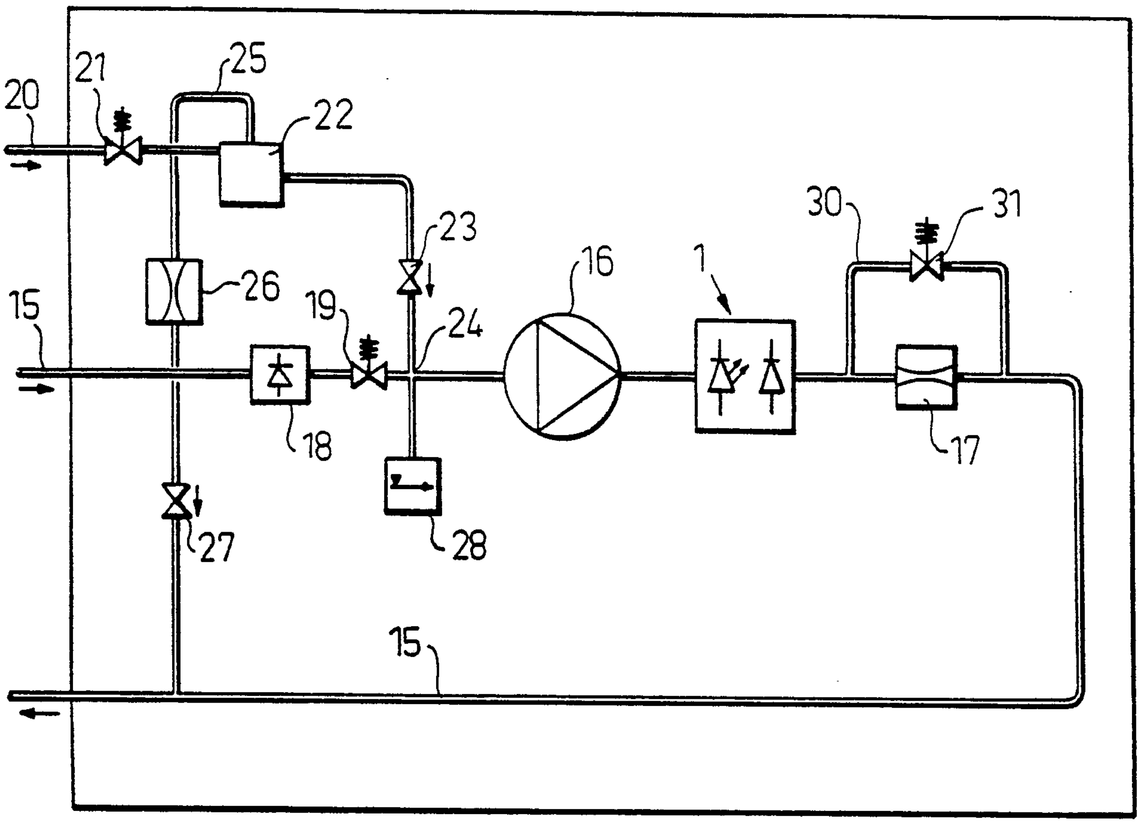


Fig. 1

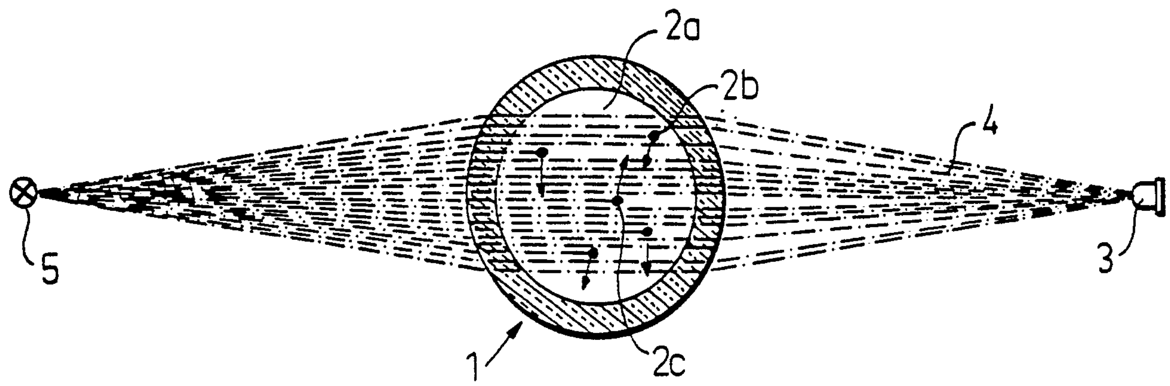


Fig. 2

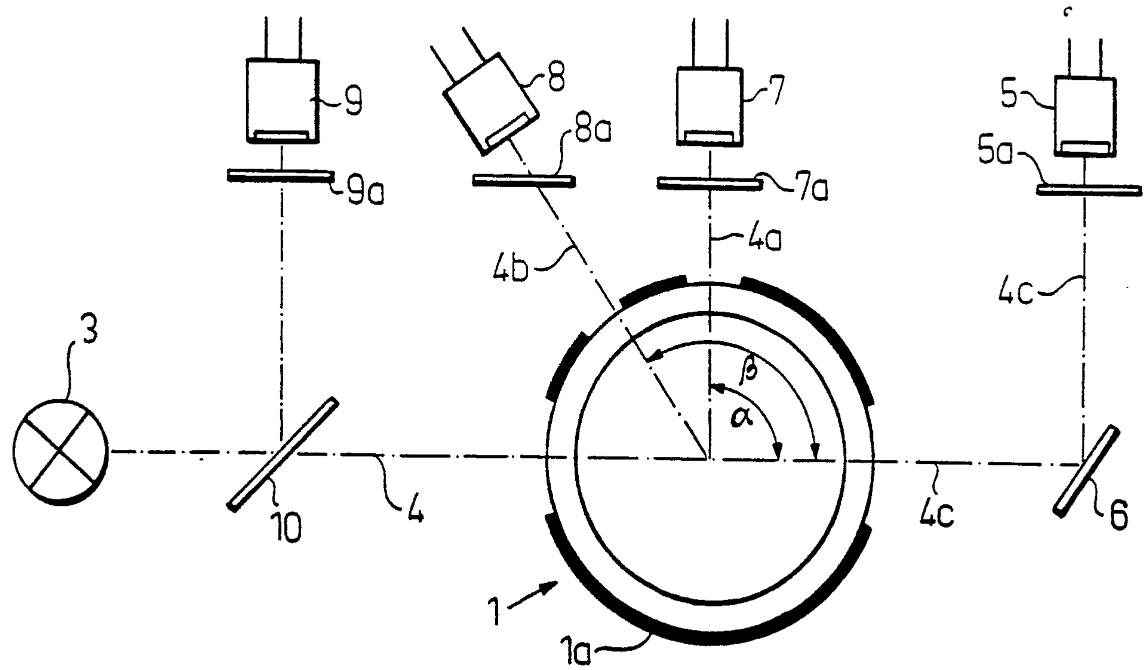


Fig. 4

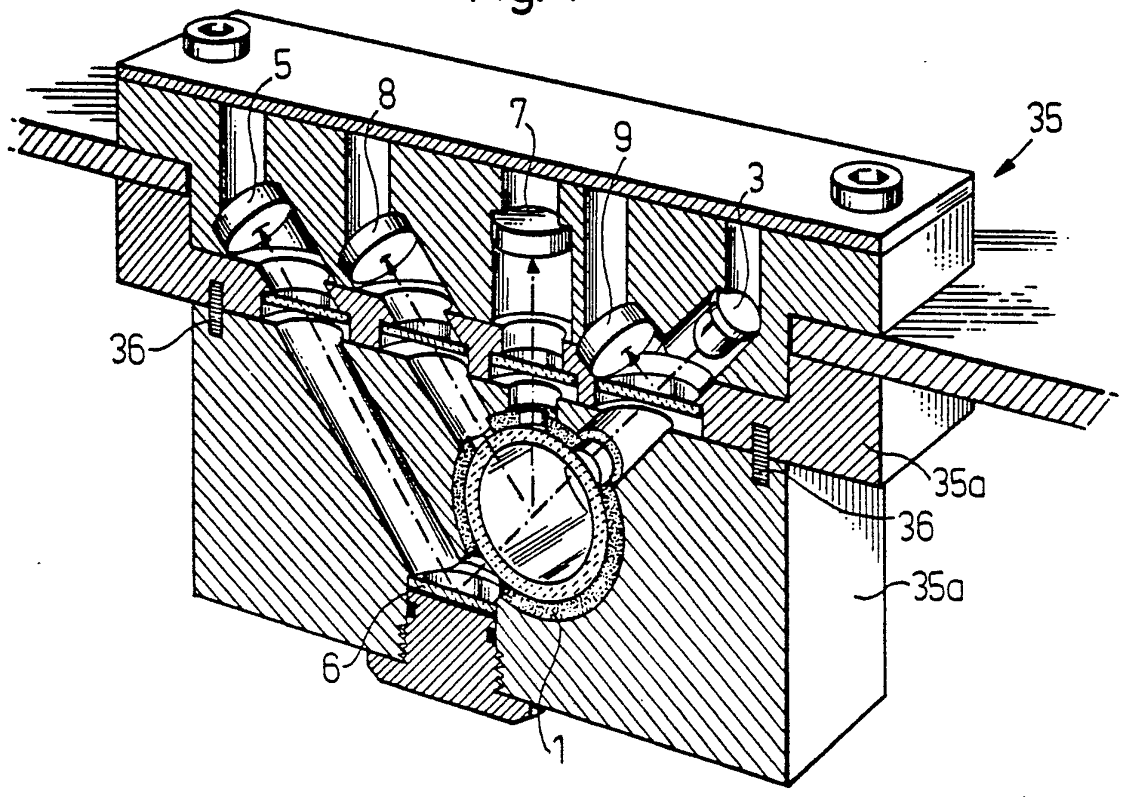
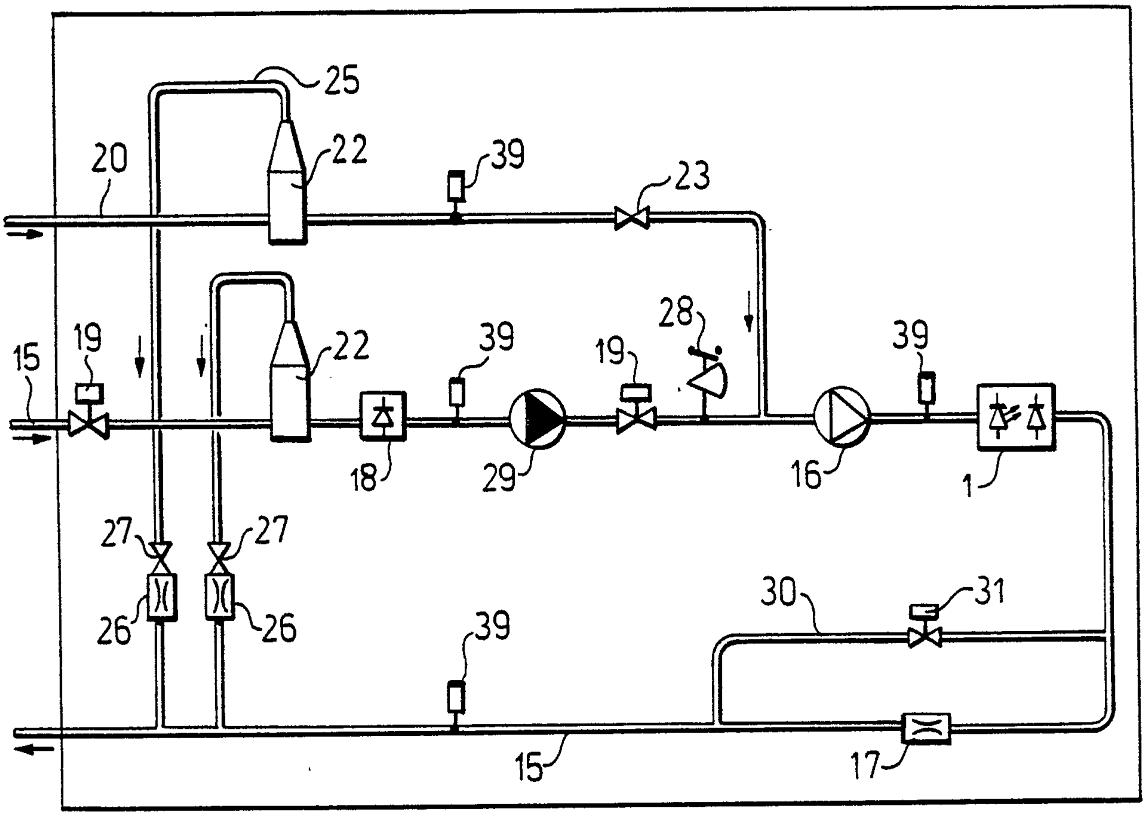


Fig. 5



INTERNATIONAL SEARCH REPORT

International Application No PCT/SE86/00527

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

G 01 N 21/49

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	G 01 N 21/05, /26, /28, /47, /49, /51, /53, /85
US Cl	356: 103, 208, 340, 343, 435, 441, 442

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	GB, A, 2 097 529 (ITT INDUSTRIES LTD) 3 November 1982	1-9
A	GB, A, 1 588 862 (STANDARD TELPHONES AND CABLES LTD) 29 April 1981	1-9
A	GB, A, 2 105 028 (ITT INDUSTRIES LTD) 16 March 1983	1-9
A	DE, A1, 3 009 835 (TECHNICON INSTRUMENTS CORP) 25 September 1980	4

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1987-01-30	1987-02-09
International Searching Authority	**Signature of Authorized Officer**
Swedish Patent Office	Stefan Israelsson

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