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(54) Apparatus for determining a change in the composition of a fluid

(57) Apparatus for determining a change in the composition of a fluid either liquid or gaseous includes an antenna (16) that is immersed in the fluid. Oscillations are induced into the antenna and then tuned to the natural frequency of the fluid to produce resonance. Any change that then occurs in the composition e.g. density, viscosity, of the fluid will present a different natural frequency at the antenna (16) and hence the tuned frequency of the antenna will no longer produce resonance. Detecting means are coupled to the antenna for sensing resonance and shifts away from resonance arising from a change in the composition of the fluid at the antenna.

The apparatus may be used to detect the interface between successive hydrocarbon products pumped along the

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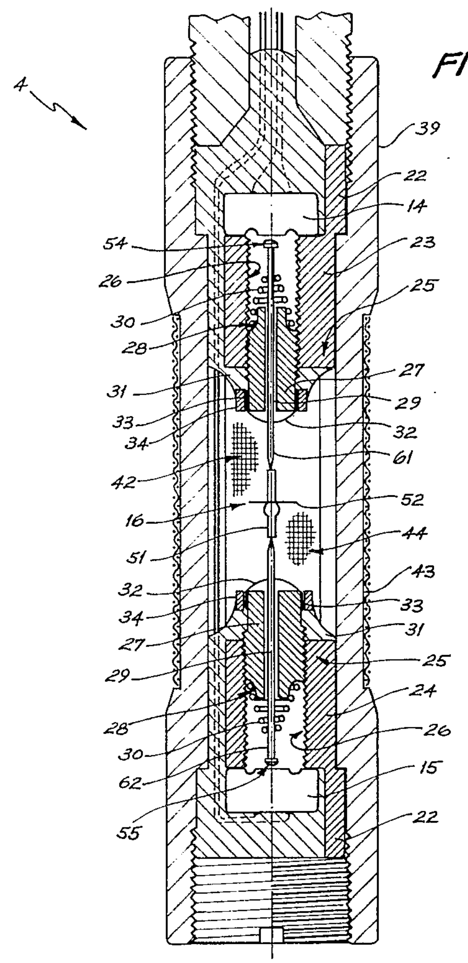
FIG. 2



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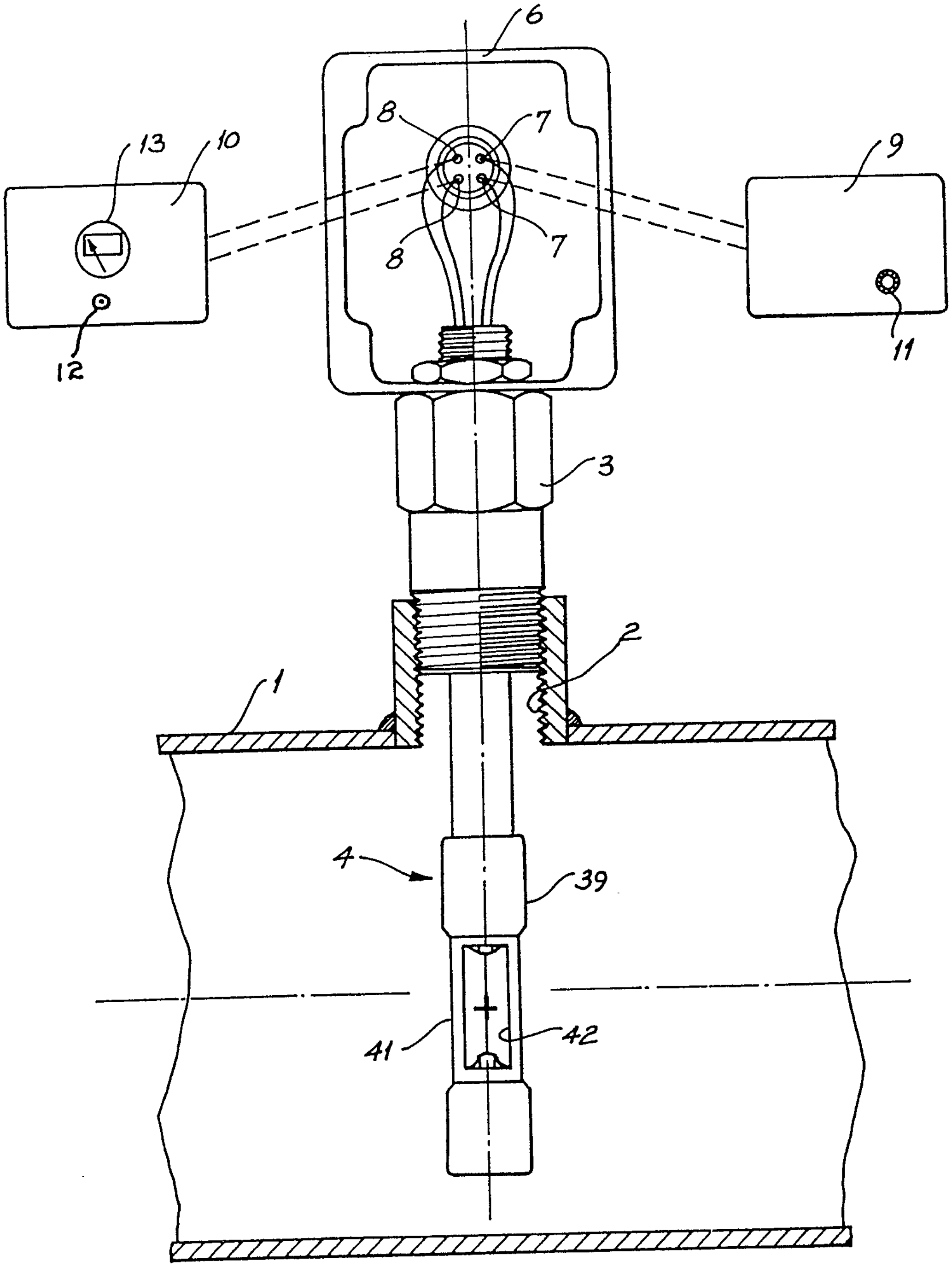
same pipeline or to detect contaminants in a liquid or gas.

The antenna (16) is vibrated generally perpendicular to the fluid flow by either electromagnetic or piezoelectric means (14,15). Various shapes of antenna are disclosed.

FIG. 1



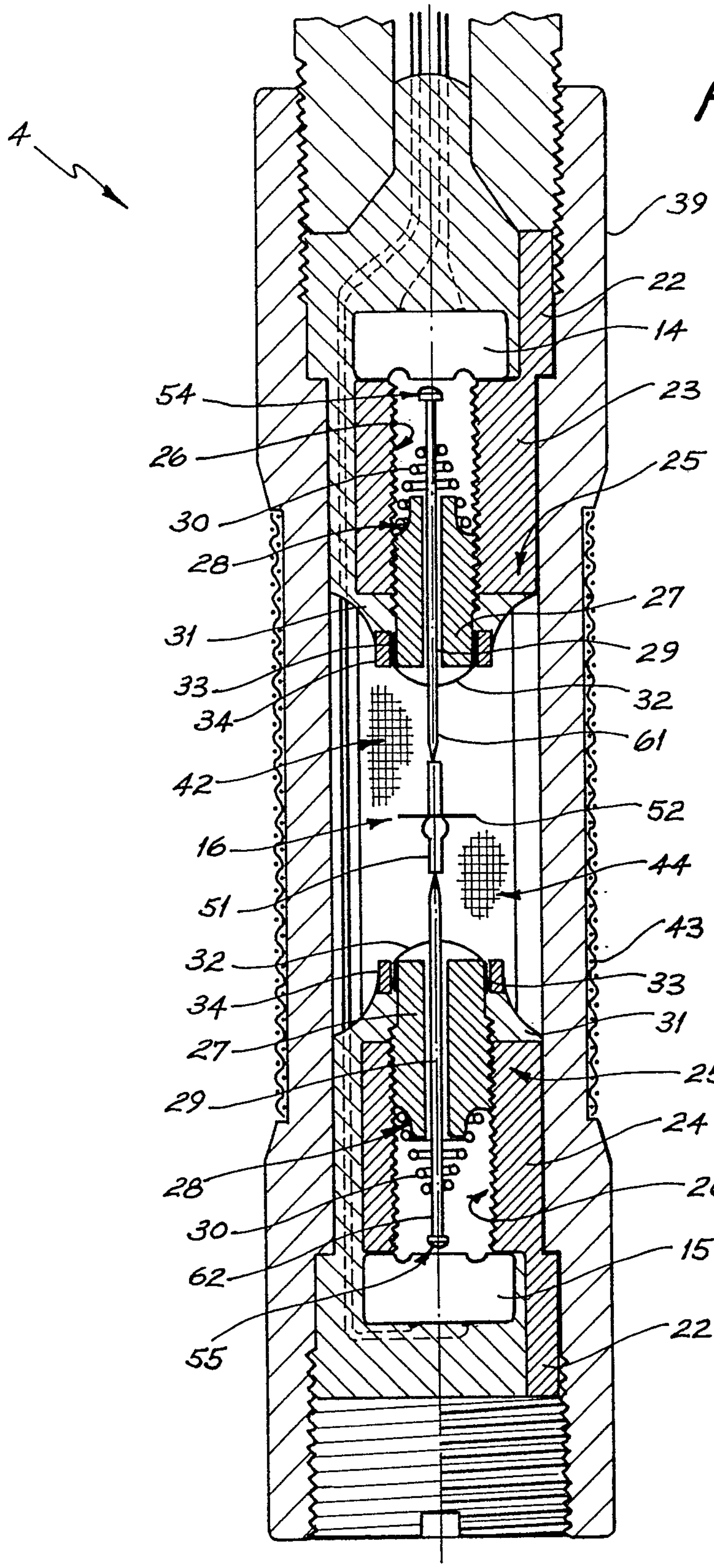

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FIG. 2

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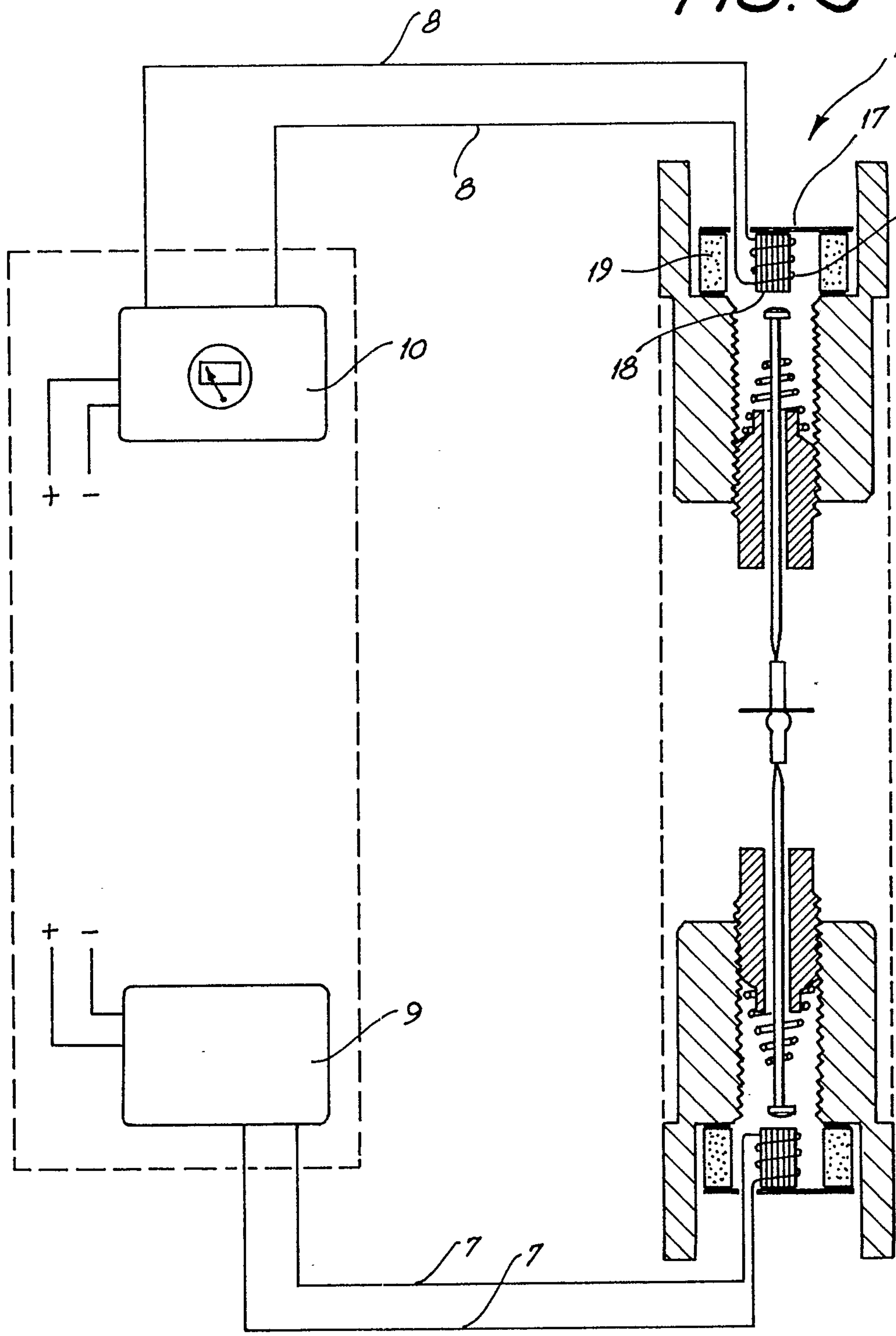


FIG. 3

FIG. 4

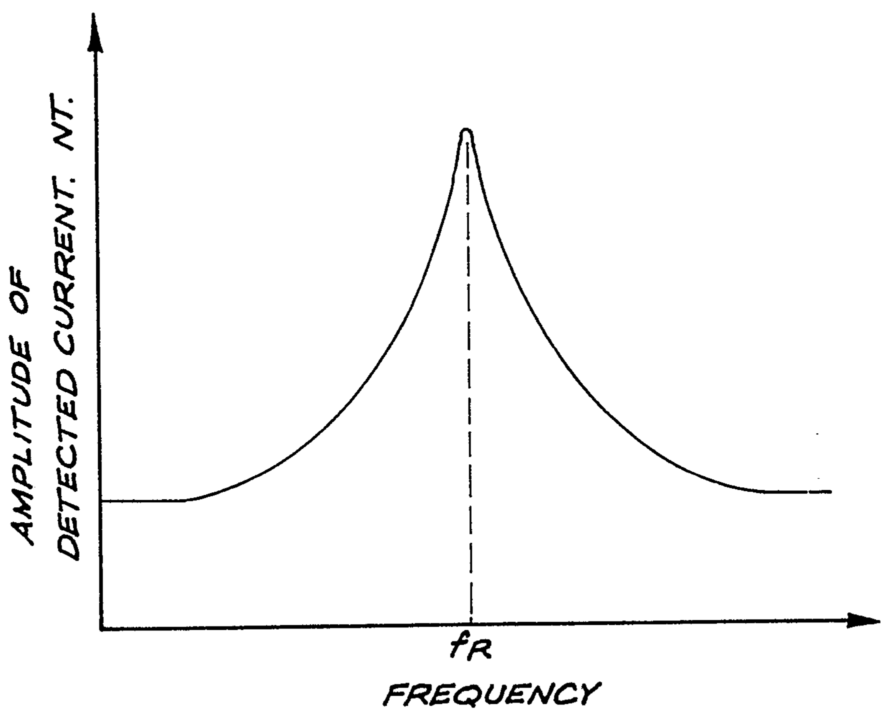
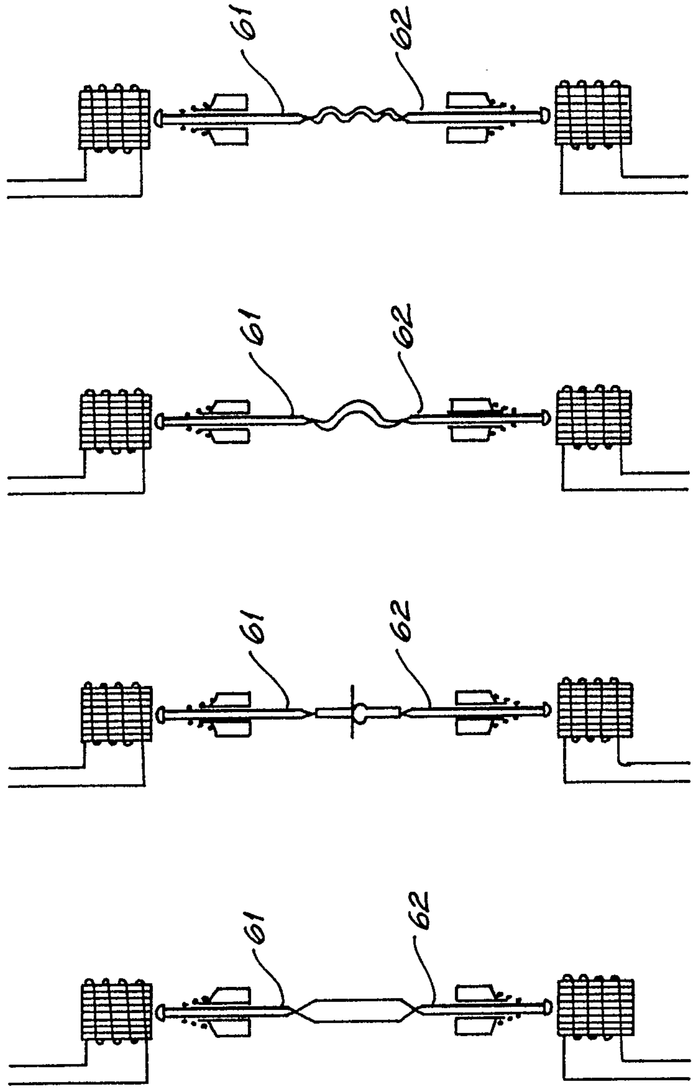


FIG. 5



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SPECIFICATION

Apparatus for determining a change in the composition of a fluid

This invention relates to the detection of changes in the composition of fluid in the vicinity of a sensor.

An example of the need to detect a change in the composition of a fluid occurs in the oil industry where a large number of different hydrocarbon products are pumped along the same pipeline between the refinery and the tank farm. There is no mechanical barrier between successive batches of different products; there is, of course, an interface between the two products and the pumping pressure acts to depress diffusion across the interface.

Correct allocation of a particular product at the tank farm depends upon a proper determination of the time at which its leading interface reaches the distribution valves. The interface arrival time can be estimated from the flow rate and a settling tank is usually used to receive the tail end of one product and the beginning of another. The user of a settling tank ensures that the second product does not enter the tank for the first product should changeover be delayed and that the first product does not enter the tank for the second product should changeover be premature.

Whilst it may be acceptable to allow one product to contaminate another because the adverse effects are negligible, it may well be that the reverse situation is to be avoided. Thus, the order of product flow can reduce the quantity of fluid discharged to a settling tank but nevertheless there remains a need for an improved means of detecting the product interface so as to reduce discharge.

Similar considerations occur in diverse industrial and other situations and although the invention is described in relation to the detection of an interface between different hydrocarbon products in a pipeline it is to be understood that it is not limited thereto. Moreover, apart from detection related to fluid flow, the invention is applicable to the reverse situation where relative flow between the sensor and fluid occurs through movement of the sensor.

The present inventon is based on the phenomenon that a fluid of particular composition has its own distinctive natural frequency and that with a particular natural frequency, induced oscillations of the same frequency result in resonance. Thus, the invention utilizes a sensor or antenna that can be tuned to produce oscillations having a frequency which matches the natural frequency of a particular fluid so as to produce a resonant condition. An output signal drawn from the antenna will reach a peak when the resonance condition for the particular fluid is achieved.

Once the antenna is tuned to the frequency which produces resonance for that particular fluid, any change that occurs in the composition of the fluid will present a different natural frequency and hence the tuned frequency of the antenna will no longer produce resonance. The resultant change in the output signal can be represented as a move away from the resonance peak on a suitable read out device. The new fluid composition will lead to a new resonance peak to which the antenna can be tuned and the antenna is again ready to detect a change away from the new composition.

According to the invention there is provided apparatus for determining a change in the composition of a fluid at a reference point comprising:-

(i) antenna means adapted to be immersed in the fluid at the reference point,

(ii) means for imparting oscillatory movement to the antenna to generate an output wave from the antenna into the fluid,

(iii) tuning means for varying the frequency of the output wave to align it with the natural frequency of the fluid at the antenna to establish resonance, and,

(iv) detecting means for sensing resonance and for determining a shift away from resonance as a consequence of a change in natural frequency arising from a change in the composition of the fluid at the antenna.

Preferably, the antenna has a resilient holding it in a tension-free mid position and the tuning means includes a variable frequency electrical oscillator circuit coupled to the antenna. An electrical detection circuit coupled to the antenna can be used as the detecting means. The couplings could be magnetic or piezo-electric.

Preferably, the antenna has a central member which offers an extended area to the fluid so as to be effectively mechanically coupled thereto. The central member may be a disc extending perpendicularly from the centre of a light spindle which is arranged to be oscillated axially by an oscillator circuit.

Conveniently the end portions of the spindle are supported by co-axial ferro-magnetic needles. The coupling of the oscillator circuit and the detecting circuit to the antenna may be achieved by locating the remote ends of respective needles adjacent, but not touching, respective poles of two magnetic circuits coupled to the oscillator circuit and to the detection circuit respectively. The antenna may be held resiliently at a mid position between the two poles by a pair of coil springs which allows the unit to oscillate sinusoidally axially of the two needles.

Preferably, the oscillator circuit should have the capacity to produce a pure sine wave output of constant amplitude over its range of operating frequencies. The signal amplitude is only adjustable after detection of resonance.

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic diagram partly in section of apparatus for detecting the passage of an interface between two liquids travelling consecutively through a pipe line according to one embodiment of the invention;

Figure 2 is a diagrammatic vertical section through the portion of the apparatus shown in Figure 1 located in the pipe line;

Figure 3 is a schematic diagram of the apparatus shown in Figure 1 showing the electromagnetic elements of the apparatus in greater detail;

Figure 4 is a response curve showing how the amplitude of the output signal of the apparatus varies with frequency for a given liquid; and

Figure 5 shows alternative forms of antenna which may be used with the apparatus of the invention.

Figure 1 shows a pipeline 1 carrying a particular hydrocarbon oil. It is formed with a side-opening 2 plugged by an assembly 3 which supports a probe 4 that extends into the oil flowing through the pipe 1.

At the outer end of the assembly 3 there is a junction box 6 from which pairs of leads 7 extend to an oscillator circuit 9 and from which pairs of leads 8 extend to a detecting circuit 10. The circuits 9 and 10 may be at a remote location.

The oscillator circuit 9 comprises a variable frequency oscillator providing a predetermined frequency range at its output. Throughout this range the amplitude of the output signal remains constant and its waveform is sinusoidal. A frequency oscillator or generator 11 and an output gain controller 12 are also provided. Under normal working conditions the output delivered by the oscillator circuit is typically 135 milli watts, having a constant output amplitude.

The detecting circuit 10 is electrically energised with the resonant current and incorporates an amplifier and meter 13 for indicating the magnitude of the alternating current signal received from the detector circuit.

As shown in Figure 2, the probe has two spaced electro-magnetic coil elements 14, 15 and an antenna 16. As the transmit and receive elements 14, 15 are similarly constructed, only element 14 will be described and it is to be understood that element 15 is identical.

The electromagnetic element 14 is shown in greater detail in Figure 3 and comprises an iron disc 17 to the centre of which is attached a pole piece rod 18 spaced radially inwardly of an annular permanent magnet 19. A coil 20 is wound on the pole piece 18 and its ends are connected to wires passing through the disc 17 and connected to the pair of leads 8. The element is potted in resin.

Returning to Figure 2, the elements 14, 15 are respectively mounted in enlarged ends 22 of a pair of axially spaced non-magnetic sleeves 23, 24. The small end-portion 25 of each sleeve is internally threaded at 26 to receive a screwed-in member 27 having an axial bore 29. The inner end of each member 27 has its radially outer surface 28 cut back to provide a seating for a conical biasing or compression spring 30. When the member 27 is in its correct position, it is held in place by epoxy resin 31. The outer end of each member 27 is protected against contamination entering the bore 29 by a domed gauze 32 held in place by having its cylindrical skirt 33 trapped beneath a surrounding collar 34. The collar is rigidly held in position by the resin 31.

The probe 4 includes a tube 39 of non-magnetic material having in its central portion windows 42 allowing the surrounding media to circulate through it. The outsides of the windows are covered by a protecting mesh screen 43. The interior of the central portion provides a chamber 44 in which the antenna 16 is located.

The antenna 16 comprises a central non-magnetic core 51 passing through the centre of a member 52 formed as a thin metal disc for mechanically coupling the antenna 16 to the liquid in the chamber 44. Each end of the core 51 is attached to a respective coaxially arranged needle 61, 62 of ferro-magnetic material. The respective needles 61, 62 pass through openings in the domed gauzes 32 and through the bores 29 of the members 27. Each needles 61, 62 terminates in a head 54, 55 spaced close to, but not touching, the end of one of the pole pieces 18 of the elements 14, 15. If desired, the needles 61, 62 need not be wholly ferro-magnetic; they could be made of any convenient material to which a magnetic head 54, 55 is bonded or otherwise secured. Each of the conical bias springs 30 is attached by one end to a respective one of the needles 61, 62. Thus the antenna 16 is held by the springs 30 so as to float with zero tension between the two elements 14, 15 and is resiliently biassed to a mid position between them by the springs 30.

The apparatus described is operated as follows:-

The oscillator circuit 9 and the detection circuit 10 are energised. The amplitude of current in the oscillator circuit is set to a fixed value and the frequency is progressively increased while viewing the ammeter 13 of the detection circuit.

The oscillator current induces a changing magnetic flux in the pole piece 18 of the element 14 which stimulates the attractive force it exerts on the adjacent head 54 of the needle 61. The head 55 of the other needle 62 is subject to a constant flux from the pole piece 18 of the element 15 of the detection circuit. The unit 16 is thus subjected to an axial magnetic force at the frequency of the oscillator circuit and is thus oscillated along its longitudinal axis. The amplitude of oscillation is dependent on a number of fixed factors, such as the coupling area of the antenna, the amplitude of the current, and the impedance of the sensor to the media surrounding the antenna which damps such movement until the natural resonant frequency of the fluid is reached.

For a particular composition of a fluid at a sensibly constant temperature there is a natural frequency of fluid oscillation. When aligned at this frequency, the energy of the oscillator coupling is released at a maximum rate in to the fluid. The magnitude of oscillation of the sensor 16 is then a maximum. The increase of the magnetic flux change in the detection circuit is consequently also at a maximum and this signal is then amplified and passed on to a suitable read out such as the meter 13 or to control circuits.

Figure 4 shows a typical resonant response curve producing a peak signal at the amplifier 13 obtained by plotting its current output with the aligned frequency centred on the natural response frequency f_R of the medium in tune. Taking for example, oil with known characteristics as a point of reference, the response frequency (f_R) is the peak frequency when the sensor is tuned by the oscillator to the natural frequency of the oil. If, say, the natural frequency of the oil is 5167Hz, a resonant peak will occur with the oscillator tuned to this frequency. At such a frequency, the actual movement of the antenna is approximately 1 to 5 microns untuned and approximately 20 microns when tuned to the resonant frequency.

Once the antenna is tuned to the frequency which produces resonance for that particular oil, any change in in the molecular composition of the fluid around the antenna 16 will present a different natural frequency and hence the tuned frequency of the antenna will no longer produce peak resonance. The amplitude of oscillation at the antenna 16 will then diminish and a fall at the detection section will occur. Once amplified, this signal can be used to trip an alarm or a relay to signify a change in composition of the fluid surrounding the antenna 16.

The apparatus of the invention is capable of signifying particular products while in contact with the probe. For example, a frequency meter can be calibrated in terms of different oils. Each time an oil interface passes the probe, the appropriate output signal is given and the apparatus can be retuned, manually or automatically, by a suitable self tuning-circuit, to the natural frequency of resonance of the new liquid flowing in the pipe-line. The reading of the frequency meter at that frequency will signify the new oil flowing in the pipe-line.

Although the invention has been described with reference to oil, it is to be understood that its use is not confined to that field. Any field, liquid or gaseous, has a natural frequency of vibration to which suitably-designed apparatus, utilising the invention, can be tuned. Also, the apparatus can be used to detect contaminants in a liquid or gas so long as their concentration is sufficient to produce a detectable shift in the natural frequency of vibration.

As will be apparent from the description of the preferred embodiment, the output from the detecting circuit may be employed in many ways. Apart from merely indicating a change on a read-out scale, it can be used to switch control circuits, open and close solenoid operated valves or activate alarms.

Various modifications to the apparatus are possible. For instance, it is not necessary that the member 43 is a disc extending perpendicular to the axis of oscillation. Figure 5 (A) shows a coupling member formed as an axially extending planar strip while Figure 5 (B) shows a coupling member in the form of a flat disc lying in the plane of the longitudinal axis of the needles 61, 62 and arranged symmetrically with respect thereto. Figure 5 (C) shows a coupling member in the form of a strip having its two end-portions lying on the longitudinal axis of the unit and its intermediate portion twisted into a helix. Figure 5 (D) again shows a coupling member formed by a strip of undulating form.

Various other modifications may be made in details of design and construction without departing from the scope and ambit of the invention. For example, piezo-electric crystals may be used in place of electro-magnetic couplings to the antenna, as they will produce the required oscillations at the antenna. As each end of the antenna is completely independent, a crystal may be used at one end only with the other end using an electro-magnetic coupling.

CLAIMS

1. Apparatus for determining a change in the composition of a fluid at a reference point comprising:-

(i) antenna means adapted to be immersed in the fluid at the reference point,

(ii) means for imparting oscillatory movement to the antenna to generate an output wave from the antenna into the fluid,

(iii) tuning means for varying the frequency of the output wave to align it with the natural frequency of the fluid at the antenna to establish resonance, and,

(iv) detecting means for sensing resonance and for determining a shift away from resonance as a consequence of a change in natural frequency arising from a change in the composition of the fluid at the antenna.

2. Apparatus according to claim 1 wherein the tuning means includes a variable frequency electrical oscillator.

3. Apparatus according to claim 2 wherein the means for imparting oscillatory movement to the antenna includes a magnetic or piezo-electric coupling between the oscillator and the antenna.

4. Apparatus according to claim 1 wherein detecting means includes an electrical detector circuit and a magnetic or piezo-electric coupling between that circuit and the antenna whereby oscillation of the antenna causes charges in the flux of the coupling to introduce an alternating current in the detector circuit.

5. Apparatus according to claim 1 wherein the antenna is biased towards a mid position and includes a central member by which it is mechanically coupled to the fluid.

6. Apparatus according to claim 5 wherein the central member is carried by a spindle the ends of which are supported by first and second needles, and wherein the first needle is oscillated axially by the oscillating means.

7. Apparatus according to claim 6 wherein the first needle has a magnetic or piezo-electric head that is oscillated by a first circuit coupled to a variable frequency electrical oscillator circuit which constitutes the tuning means;

8. Apparatus according to claim 6 wherein the second needle has a magnetic piezo-electric head which is oscillated by the antenna to produce flux changes in a second circuit which forms part of the detecting means.

9. Apparatus according to claim 8 wherein the detecting means further includes a coil or crystal energised by the change of flux in the second circuit and means for determining the magnitude of the alternating current generated by the oscillation of the second needle.

10. Apparatus according to claim 9 wherein the magnitude of the alternating current is indicated on a meter.

11. Apparatus according to claim 9 wherein the alternating current generated by the oscillations of the second needle are used to actuate a relay or alarm.

12. Apparatus according to claim 1 wherein the antenna includes a central member carried by a spindle the ends of which are supported by first and second needles each having a coupling head remote from the spindle, and wherein the central member is biased towards a mid position by a conical spring attached to each needle.

13. Apparatus according to claim 12 wherein the first and second needles each have coupling heads which are located adjacent to and in the field of magnetic circuits which form part of the tuning means and detecting means respectively.

14. Apparatus according to claim 12 including a probe body having ports through which the fluid may pass to and from a chamber in which the antenna is located.

15. Apparatus according to claim 14 wherein the probe body supports spaced apart non-magnetic sleeves each of which supports a member having an axial bore through which one of the needles passes, and wherein each conical spring is connected between a needle and its member.

16. Apparatus according to claim 1 wherein the oscillatory movement is of sinusoidal form.

17. Apparatus for determining a change in the composition of a fluid at a reference point substantially as herein described with reference to Figures 1 to 4, or Figures 1 to 4 modified as shown in Figure 5, of the accompanying drawings.

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