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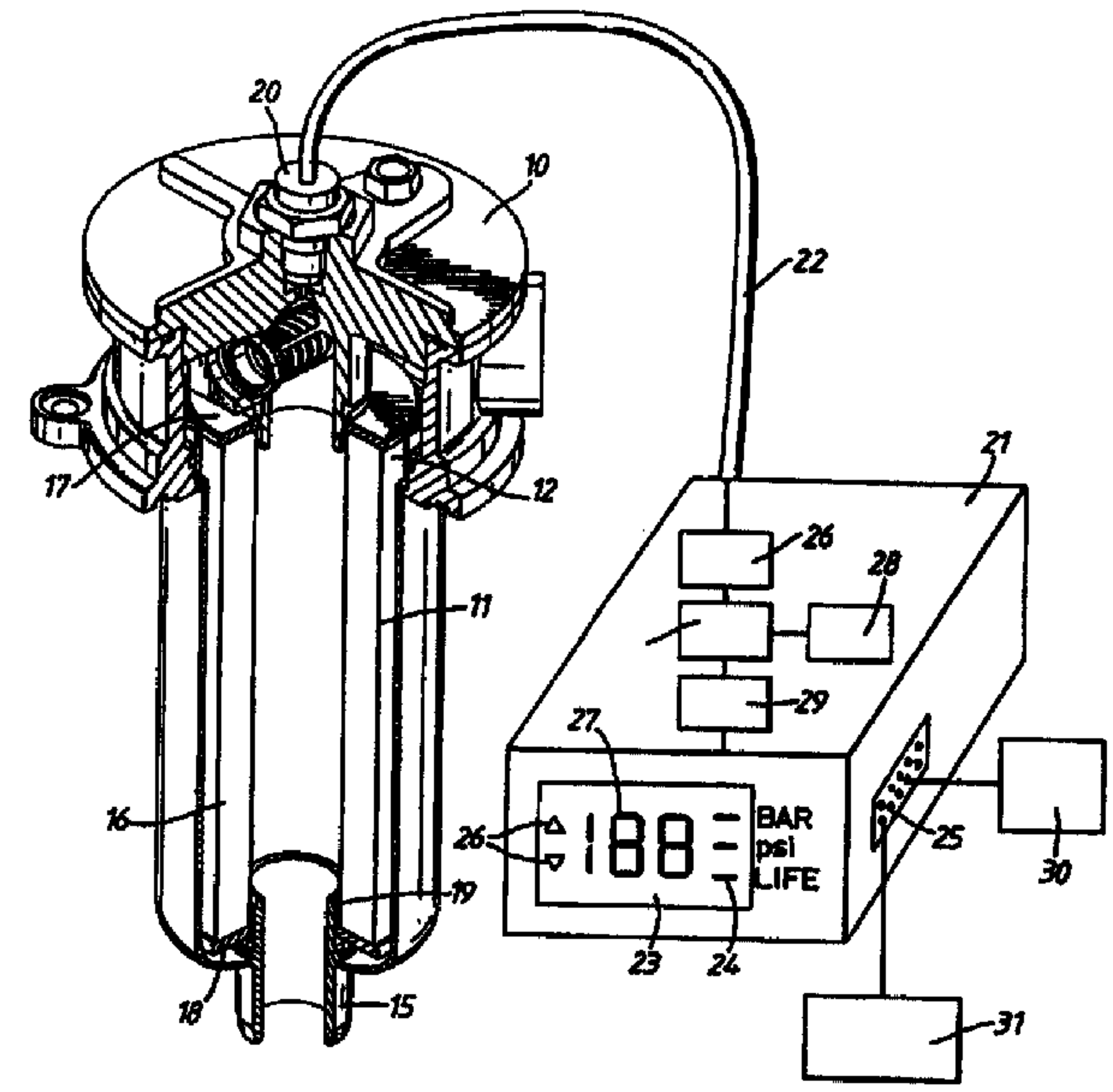
(54) **MESURE DE LA DUREE DE VIE D'UN FILTRE**
(54) **FILTER LIFE MEASUREMENT**



(57) L'invention concerne un filtre (11), relié à un dispositif de mesure, un fluide chargé de particules s'écoulant à travers ce filtre (11). Le dispositif de mesure permet de mesurer la pression différentielle au-dessus dudit filtre (11), avant de transmettre cette mesure à une unité de commande (21), contenant une mémoire (27) destinée à stocker les mesures de la durée de vie utile dudit filtre (11), cette durée variant linéairement dans le temps et étant liée aux mesures de ladite pression différentielle. Pour chaque mesure de cette pression différentielle produite par un transducteur (17), ladite unité de commande (21) produit la mesure correspondante de la durée de vie utile restante, jusqu'à ce que celle-ci égale zéro. A ce stade ou à tout autre stade prédéterminé, une alarme (26) peut être émise.

(57) A filter (11) is connected to a measurement device as a particulate-laden fluid is flowed through the filter (11). The device measures the differential pressure across the filter (11) and passes this measurement to a control unit (21) which contains a store (27) holding measurements of the remaining useful life of the filter (11) that vary linearly with time and correlated to measurements of differential pressure. For each measurement of differential pressure produced by a transducer (17), the control unit (21) outputs the corresponding measurement of remaining useful life. This continues until the remaining useful life is zero. An alarm (26) may be sounded at this stage or at any predetermined stage.

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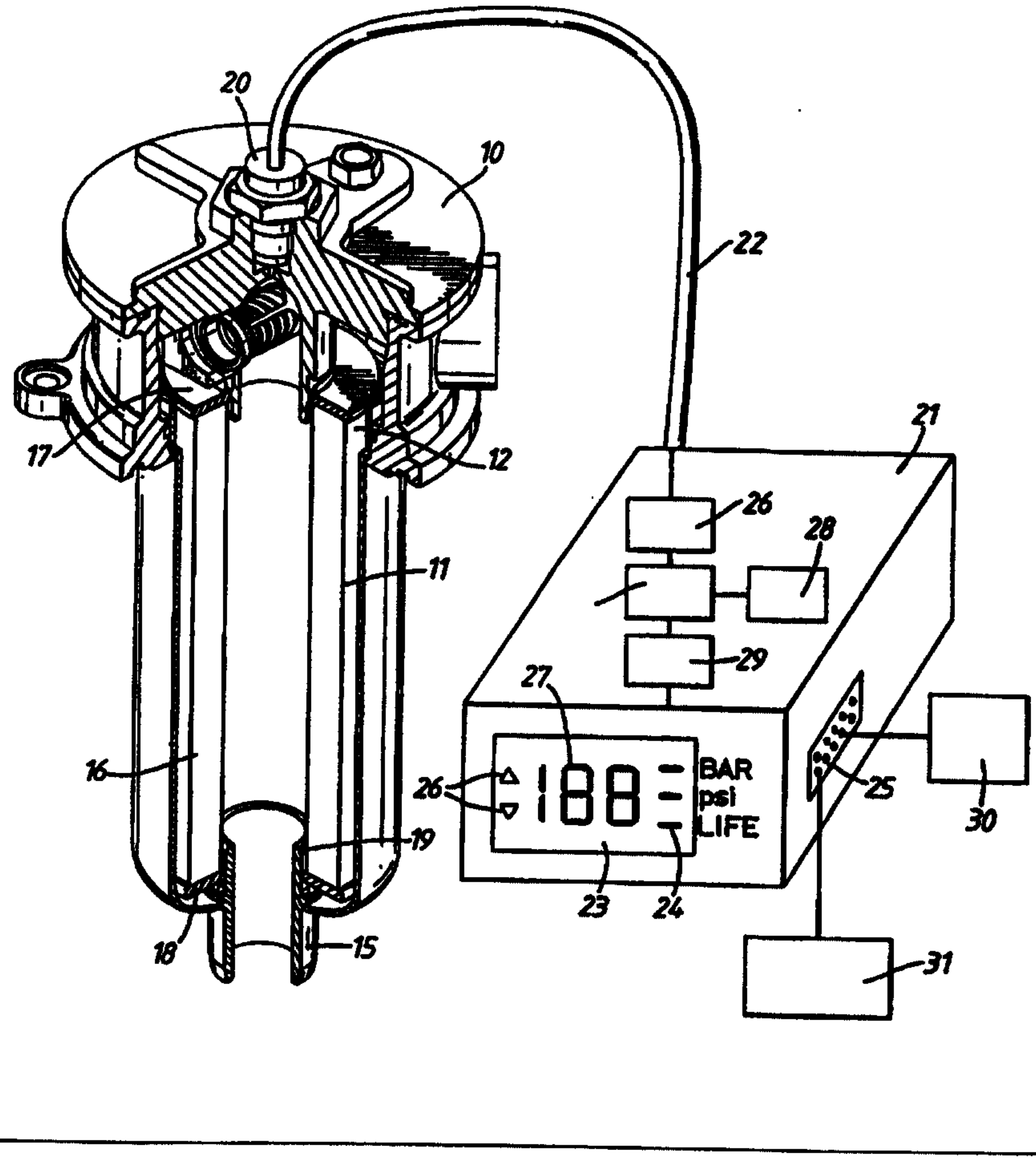
(54) Title: FILTER LIFE MEASUREMENT

(57) Abstract

A filter (11) is connected to a measurement device as a particulate–laden fluid is flowed through the filter (11). The device measures the differential pressure across the filter (11) and passes this measurement to a control unit (21) which contains a store (27) holding measurements of the remaining useful life of the filter (11) that vary linearly with time and correlated to measurements of differential pressure. For each measurement of differential pressure produced by a transducer (17), the control unit (21) outputs the corresponding measurement of remaining useful life. This continues until the remaining useful life is zero. An alarm (26) may be sounded at this stage or at any predetermined stage.



FILTER LIFE MEASUREMENT

The invention relates to methods and devices for measuring the remaining useful life of a filter during flow of a particulate-laden fluid through the filter.

As a particulate-laden fluid passes through a filter, the particulates are retained in the filter. It is generally desirable to change or clean a filter element of the filter before it becomes completely blocked with particulates as further clogging could lead to excessive differential pressures within the filter. The point at which such a change or cleaning is desirable is called the end of the useful life of the filter.

One known method of indicating the end of the useful life of a filter measures the differential pressure of the fluid across the filter as fluid is passed through the filter and particulates are retained by the filter. As the amount of retained particulates increases, the differential pressure increases and, by previous testing, a differential pressure can be determined at which the filter is at the end of its useful life.

A known device detects the differential pressure across the filter and gives an alarm signal when the previously determined differential pressure is reached. This apparatus provides no indication of the rate at which the filter is retaining the particulates and thus no indication of the remaining useful life and does not allow prediction of when the filter will have to be replaced or cleaned.

Another known device also detects the differential pressure of the fluid across the filter and provides a rough indication of the differential pressure using a light emitting diode bar-graph. The number of diodes that are illuminated increases roughly in linear proportion to the increases in differential pressure. This apparatus does not readily allow a prediction of when it will be necessary to replace or clean the filter, because the changes in differential pressure are not linearly related to the changes in the remaining useful life of the filter.

According to a first aspect of the invention, there is provided a method of measuring remaining useful life of a filter comprising flowing a particulate-laden fluid through said filter, measuring a parameter of said flow during said flowing and producing, from said measurements of said parameter, measurements of the remaining useful life of the filter that vary linearly during the time in which the fluid is flowing through said filter.

According to a second aspect of the invention, there is provided a device for measuring remaining useful life of a filter comprising measuring means for measuring a parameter of flow of a particulate-laden fluid through said filter and a control unit connected to said measuring means and for producing from said measurements of said parameter, measurements of the remaining useful life of the filter that vary linearly during the time in which the fluid is flowing through said filter.

According to a third aspect of the invention, there is provided a method of providing data relating to remaining useful life of a filter comprising flowing a particulate-laden fluid through a filter, measuring the variation with time during said flowing of a parameter related to said flow, measuring the remaining useful life of the filter during said flow in a measurement that varies linearly with time and producing data correlating said parameter with the remaining useful life.

The following is a more detailed description, by way of example, of an embodiment of the invention, reference being made to the accompanying drawings in which:-

Figure 1 shows a filter assembly including a filter element mounted in a housing, a differential pressure transducer of the filter assembly being connected to a data processor, and

Figure 2 is a graph plotting voltage output from a differential pressure transducer of the kind shown in Figure 1 against percentage remaining useful life of the filter element of the assembly of Figure 1.

Referring to Figure 1, the filter assembly comprises a housing 10 defining a chamber 12 having a fluid inlet 13 and a fluid outlet 14. A by-pass valve 30 is provided in a passage connecting the inlet 13 and the outlet 14 and opens to allow direct communication between the inlet 13 and the outlet 14 when excess differential pressure is detected. The outlet 14 is continuous with a mounting tube 15 which extends into the chamber 12. A filter element 11 is mounted within the housing 10 and comprises a cylinder of a filter medium 16 which is provided at one end with a first end cap 17 and which is provided at the other end with a second end cap 18. The fluid outlet 14 extends through the second end cap 18 and the by-pass passage leads through the first end cap 17. The filter medium 16 may be any suitable form of media such as a membrane or a depth filter medium. The second end cap 18 is provided centrally with an opening 19 which receives the mounting tube 15 so as to mount the filter element 11 within the housing 10. A seal (not shown) is provided between the mounting tube 15 and the perimeter of the opening 19.

The measuring device comprises a pressure transducer 20 and a processor 21. The transducer 20 is mounted in the housing 10 and detects the differential pressure between fluid in the inlet 13 and fluid in the outlet 14. The transducer 20 is connected via a cable 22 to the processor 21.

The processor 21 has a display 23, and a data inlet/outlet 25 provided with an RS 232 connector. The processor 21 also has a writable memory 26 and an analogue to digital converter 27.

The filter element 11 is used to filter a flow of fluid carrying suspended particulates. The fluid is pumped through the housing

10. The fluid passes through the inlet 13 into the chamber 12 (as shown by the arrows), where the fluid then passes around the filter element 11. The fluid flows through the filter medium 16 into the interior of the filter element 11. During the passage of the fluid through the filter medium 16, particulates from the fluid are retained by the medium 16. The filtered, particle-depleted fluid passes out from the element 11 through the mounting tube 15 and the outlet 14 as shown by the arrows in Figure 1.

The particulates retained by the filter medium 16 reduce the overall permeability of the medium 16. As more fluid passes through the medium 16, the volume of particulates retained by the medium 16 progressively increases and the overall permeability of the medium 16 progressively decreases. The remaining useful life thus decreases correspondingly. At the same time, the differential pressure of the fluid across the medium 16 increases.

The filter element 11 needs to be replaced or cleaned when the volume of particulates retained by the filter medium 16 reaches a predetermined level such that continued retention is likely to damage the filter medium 16 or is likely to render the filter medium 16 ineffective. Some filters are provided with a by-pass controlled by a valve that opens to allow direct fluid communication between the filter inlet 13 and the filter outlet 14 when the differential pressure across the by-pass valve exceeds a predetermined level. At this level, the remaining useful life of the filter material 16 is zero. As indicated above, this level can be related to a particular differential pressure and in this example, the attainment of the particular differential pressure is used to indicate when the filter element 16 has zero remaining useful life (as described below).

The measuring device 20, 21, 22 uses the measured differential pressure to provide an indication of the remaining useful life of the filter medium 16 as determined by the blockage of the filter elements 16 by particulates and indicates the estimated remaining useful life in a way that varies generally linearly during the time that fluid is flowing through the filter (plainly there is no variation in useful life when the filter is not operational - this will occur in a filter used intermittently). Thus, if a differential pressure of, say, 0.04 bar occurs 3 hours into a 10 hours useful life of a filter, the receipt of a differential pressure signal corresponding to 0.04 bar will result in an indication that 30% of the useful life of the filter element 11 has passed (or that 70% of the useful life remains).

The pressure transducer 20 detects the differential pressure between the fluid in the inlet 13 and the fluid in the outlet 14 (which, of course, corresponds to the differential pressure of the fluid across the medium 16) and generates an analogue signal which varies over time as a function of the differential pressure. The signal is passed to the analogue to digital converter 27 of the processor 21 via the cable 22. The analogue to digital converter 27 produces from the analogue signal a sequence of digital signals corresponding to successive instantaneous values of the analogue signal and thus to successive measurements of the differential pressure.

The processor 21 stores in the memory 26 a set of values of differential pressure and the remaining useful life represented by those values. These are formulated and input into the memory 26 in a manner to be described below. As a digital differential pressure signal is received by the memory 26, the memory 26 produces the corresponding value of the remaining useful life. Where the received differential pressure signal falls between two stored values, an interpolator 28 generates the corresponding value of the remaining useful life. The interpolation may be linear.

The measurements are output as digital signals. In this example, these digital signals are used to produce signals representing percentages indicating the remaining proportion of the useful life of the filter element 16. For example, when the remaining time value is indicated as 10%, 10% of useful life remains.

The current percentage of the remaining useful life is shown on the display 23; the display 23 being up-dated each time the remaining useful life changes by 1% (or any other suitable interval) to show the new value. The processor 21 also has a facility which allows the operator to display, when required, the current instantaneous measurement of the differential pressure. This is achieved by passing the instantaneous signal values from the transducer 20 to a display converter 29 which converts the instantaneous value signals into signals producing the appropriate indication on the display 23. The displayed value can be in any required units, such as psi or bar. As seen in Figure 1, the display 23 includes a mode indicator 24 that indicates whether the displayed digits 27 are bar, psi or % remaining life.

The measurements of the remaining useful life or the corresponding instantaneous values of the differential pressure are stored in the memory.

If it is desired to monitor the measurements of the remaining useful life or the differential pressure values remotely from the measuring device, these measurements may be output to remote data logging equipment 30 using the data inlet/outlet 25.

The processor 21 may be programmed to produce an alarm message on the display 23 on receiving a signal corresponding to a differential pressure indicating that the remaining useful life is zero. Alarm messages may also be produced in the absence of a filter medium or on the sensing of a differential pressure above a predetermined level. These may be indicated by the arrows 26 on the display 23. Alarm messages may be produced at other predetermined stages in the monitoring process.

An operator can use the displayed remaining time values to predict when replacement or cleaning of the element 11 will be necessary and replace or clean the element 11 as soon as (or before) zero remaining useful life is indicated.

If required, the measurements of remaining useful life or differential pressure that have been stored in the memory during filtration can be down loaded to a computer 31 for analysis. This analysis may involve comparing the useful life of a first filter used in the housing 10 with the useful life of a subsequent filter or filters. This down-loading is done using the data inlet/outlet 25 and a suitable interrogating computer 31 using Windows (Trade Mark) based or other suitable software. The same computer is used to programme the processor 21 before filtration is commenced.

The stored data may be formulated by performing a trial run using a trial filter element corresponding to the element 11 to filter a particulate-laden fluid corresponding to, or corresponding as nearly as possible to, the particulate-laden fluid to be filtered by the filter element 16. The fluid is passed through the trial filter element at a constant rate. A pressure transducer of a similar type as the pressure transducer 20 is used to measure the differential pressure across the trial filter element. The elapsed time from the start of the trial run is also noted.

During this trial, the temperature of the fluid is monitored and the instantaneous values of the signal are corrected for any variation in temperature.

The trial run is continued until the blockage of the trial filter element by particulates reaches a level at which the trial filter element should be replaced or cleaned. The level can be determined empirically by observing at what differential pressure the filter medium is close to damage or inutility and choosing a pressure lower than this by a safety margin.

After the trial run, the measurements of the differential pressure and the corresponding set of measurements of the remaining useful life so that for each differential pressure measurement an associated remaining useful life figure is calculated. This data is recorded on a magnetic disc and input into the memory of the processor 21 using the inlet/outlet 25 and a suitable computer using WINDOWS (TM) based software. The processor 21 is thus able, on receiving a measurement of differential pressure from the transducer 20 to produce the corresponding measurement of remaining useful life via the data using interpolation if necessary, as described above. A first example of such data is shown in Table 1 below.

TABLE 1

Differential Pressure (Bar)	Elapsed Useful Life(%)	Remaining Useful Life(%)
0	0	100
0.01	10	90
0.02	20	80
0.04	30	70
0.08	40	60
0.16	50	50
0.32	60	40
0.64	70	30
1.28	80	20
2.56	90	10
5.12	100	0

A second example of such data is shown in the graph that is Figure 2. In this graph, the voltage (v) of a transducer 20 measuring the pressure drop across a filter element 11 as particulate-laden fluid is flowed through the filter element 11 is plotted against the measured the percentage of remaining useful life. It will be seen that the relationship is non-linear but that for every voltage representing a differential pressure, it is possible to derive a percentage of remaining useful life.

It will be appreciated that a disc may contain data for many different filters and that a disc may be supplied with a new filter.

It will also be appreciated that the apparatus may be self-calibrating. This is achieved by measuring the differential pressure across the filter element 11 using the differential pressure transducer 20 and simultaneously measuring the time during which the filter is operational. If the filtration is halted at a differential pressure indicating the end of useful life of the filter, the processor can, from this data, derive the stored data needed for the processor 21 to output remaining life data during subsequent filtration operations. The time intervals are determined from the sampling intervals.

The apparatus described above is best suited for use when the flow-rate of the fluid through the element 11 does not vary with time. However, the processor 21 has an averaging programme and a peak detection programme, one or the other of which may be used when the flow rate is uneven. The averaging programme averages a predetermined number of the instantaneous signal values and uses the average value to determine the remaining time value from the stored data. The peak detection programme monitors a predetermined number of the instantaneous signal values and uses the highest value to determine the remaining time value from the stored data.

In addition to allowing the operator to predict with greater accuracy when the filter element 11 will need replacing or cleaning, the apparatus described above has a number of other advantages. For example, a number of different data sets corresponding to a number of alternative pressure detectors or alternative fluids or alternative particle sizes can be formulated for use with the same element.

Additionally, it is not necessary that the pressure transducer 20 generates a signal which is linearly proportional to the differential pressure. As the stored data is formulated using values derived from a detector corresponding to the detector 20 any non-linearity will be compensated for by use of the look-up table.

Up to eight monitors of the type described above may be connected together to a single serial data transmission line (RS 232) for remote system control and data acquisition.

It will be appreciated that the device and the method described above may be varied. For example, the signal generated by the transducer 20 may be a sequence of discrete signals, each being related by a function to corresponding instantaneous values of the differential pressure. The transducer 20 itself could produce digital signals and in this case the digital-to-analogue converter would be omitted. The transducer 20 may be provided with a thermal lockout device that prevents actuation due to viscosity effects of the fluid.

The stored data could correlate differential pressure measurements with values of elapsed time. The processor 21 would then contain data relating the elapsed time to the remaining time.

The stored data could relate differential pressure measurements to indications of the remaining useful life of the filter medium 16 other than the blockage of the medium by particulates. For example, the look-up table could relate signal values to the weight of particles retained by the medium 16. The display 23 would then indicate remaining useful life based on the weight of particles retained by the filter element. The flow parameter measured need not be differential pressure. It could, for example, be simply inlet or outlet pressure.

It will be appreciated that the techniques described above are not limited to use in filters. Other measurements that vary nonlinearly may be transformed to a linear measurement using these techniques and the scope of the invention encompasses such wider uses.

CLAIMS

1. A method of measuring remaining useful life of a filter (11) comprising flowing a particulate-laden fluid through said filter (11), measuring a parameter of said flow during said flowing and producing, from said measurements of said parameter, measurements of the remaining useful life of the filter (11) that vary linearly during the time in which fluid is flowing through said filter.

2. A method according to claim 1 wherein said parameter is the pressure drop across the filter (11) during said flowing.

3. A method according to claim 1 or claim 2 and comprising storing in a store (27) a previously measured correlation between said parameter and remaining life for a filter corresponding to said filter (11) on flowing a said particulate-laden fluid therethrough, the measurements of said parameter being received by said store (27) and the store (27) outputting measurements of said remaining useful life corresponding to the received measurements of said parameter and derived from said previously measured correlation.

4. A method according to any one of claims 1 to 3 wherein said

measurements of the remaining life are outputted from said store (27) as a sequence of data.

5. A method according to any one of claims 1 to 3 wherein said measurements of the remaining life are outputted from said store (27) as a sequence of visible numbers.

6. A method according to claim 5 wherein said sequence of visible numbers is a sequence of percentages with 0% representing zero remaining useful life.

7. A method according to claim 6 wherein said percentages are at 1% intervals commencing with 100% at the commencement of said flowing and ending at 0% when the remaining life is zero.

8. A method according to any one of claims 1 to 7 wherein the filter (11) has an internal volume, said measurement of remaining life being a measurement of the proportion of the internal volume of the filter blocked by said particulate during said flowing, the end of the life of the filter corresponding to a predetermined proportion of the internal volume blocked by said particulate.

9. A method according to any one of claims 1 to 8 and comprising flowing said particulate-laden fluid through said filter (11) at a rate that varies with time, the method including applying averaging/peak detection techniques to said parameter measurements to modify said measurements before producing said remaining life measurements from said modified parameter measurements.

10. A method according to any one of claims 1 to 9 and comprising storing said measurements of remaining useful life in a store (27).

11. A method according to any one of claims 1 to 10 and comprising producing an alarm signal (26) when the measurement of remaining life reaches a predetermined measurement at which the remaining useful life of the filter (11) is zero.

12. A device for measuring remaining useful life of a filter (11) comprising measuring means (20) for measuring a parameter of flow of a particulate-laden fluid through said filter (11) and a control unit (21) connected to said measuring means (20) for producing from said measurements of said parameter, measurements of the remaining useful life of the filter (11) that vary

linearly during the time in which fluid is flowing through said filter (11).

13. A device according to claim 12 wherein said measuring means comprise a pressure transducer assembly (17) for producing a measurement of the differential pressure across said filter (11).

14. A device according to claim 12 or claim 13 wherein said control unit (21) includes a store (27) containing a previously measured correlation between said parameter and remaining life for a filter (11) corresponding to said filter (11) on flowing a corresponding particulate-laden fluid therethrough, said control unit (21) receiving said measurements of said parameter and outputting from said store the stored measurements of said remaining useful life corresponding to said received measurements of said parameter.

15. A device according to any one of claims 12 to 14 wherein said control unit (21) produces said measurements of remaining useful life as a sequence of data.

16. A device according to any one of claims 12 to 15 and including a visual display (23) for providing a visual indication

of the remaining useful life of the filter.

17. A device according to claim 14 wherein the control unit includes an input device (25) for feeding to said store (27) said previously measured correlation.

18. A device according to any one of claims 12 to 17 wherein the control unit (21) applies to said measurements of said parameter averaging/peak detection techniques when the rate of flow of said fluid through the filter varies with time.

19. A device according to any one of claims 12 to 18 and including an alarm device (26) for producing an alarm signal when the measurement of remaining life of the filter (11) reaches a predetermined measurement at which the remaining useful life is zero.

20. A device according to any one of claims 12 to 19 and including a memory (27) for storing said measurements of the remaining life of the filter (11) produced by said control unit (21).

21. A device according to claim 20 wherein an output device (25) is provided to allow down loading of said stored measurements.

22. A device according to any one of claims 12 to 21 in combination with a filter assembly including a filter (11) mounted in a housing (10), said measuring means (20) measuring said parameter across said filter.

23. A device and filter assembly according to claim 22 wherein said filter (11) has an internal volume, said measurement of remaining life being a measurement of the proportion of said internal volume of the filter blocked by said particulates during said flowing, the end of the life of the filter (11) corresponding to a predetermined proportion of the internal volume blocked by said particulates.

24. A method of providing data relating to remaining useful life of a filter comprising flowing a particulate-laden fluid through a filter (11), measuring the variation with time during said flowing of a parameter related to said flow, measuring the remaining useful life of the filter (11) during said flow in a measurement that varies linearly with time and producing data correlating said parameter with the remaining useful life.

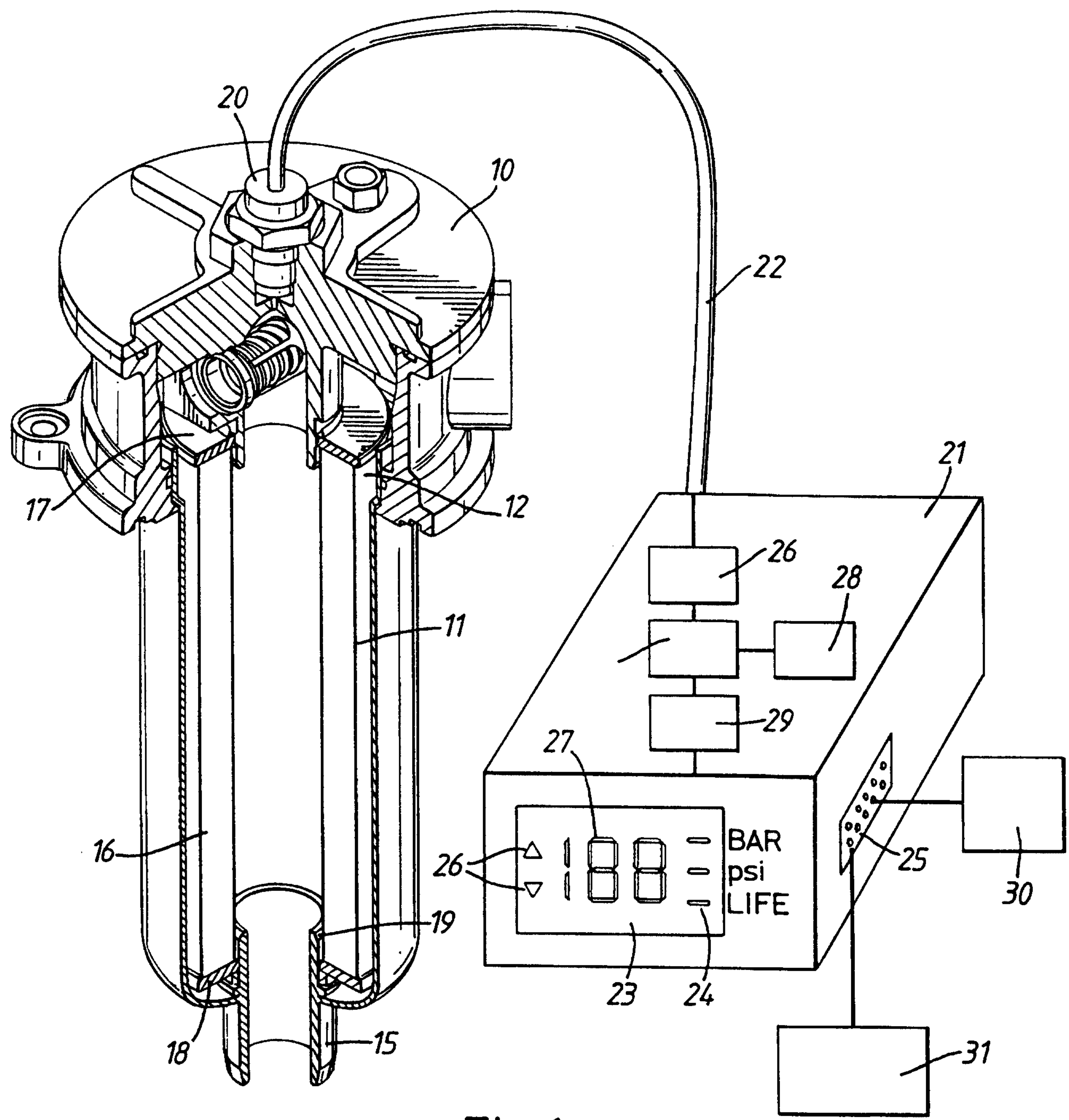

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Fig.1

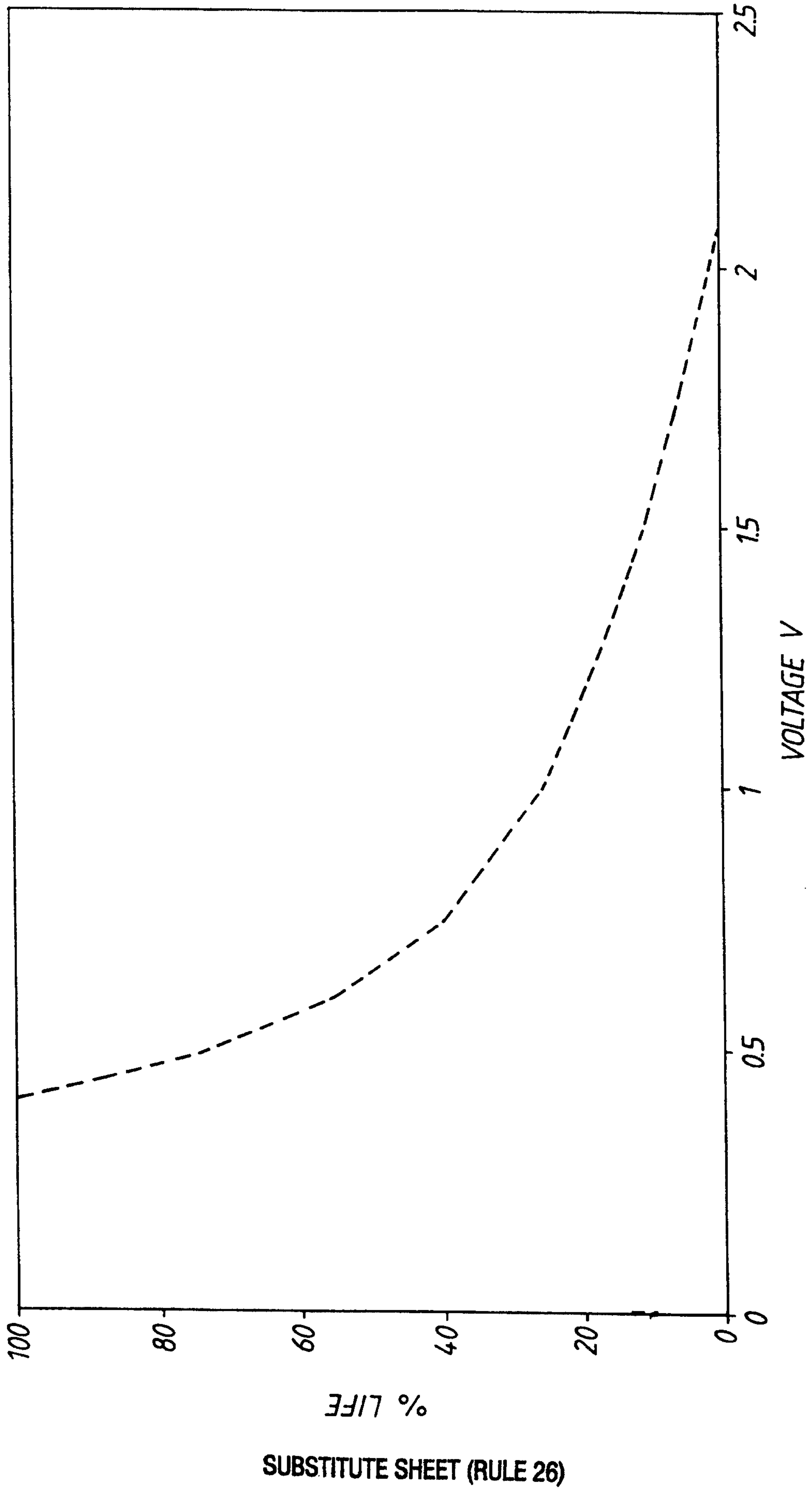

Fig.2