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(73)	Innehaver	Roxar Flow Measurement AS, Gamle Forusveien 17, 4031 STAVANGER, Norge
(72)	Oppfinner	Olav Espejord, Kong Inges gate 35, 7052 TRONDHEIM, Norge Cristian Iorga, Klæbuveien 155 B, 7037 TRONDHEIM, Norge
(74)	Fullmektig	CURO AS, Vestre Rosten 81, 7075 TILLER, Norge

(54)	Benevnelse	**Method of measuring metal loss from equipment in process systems**
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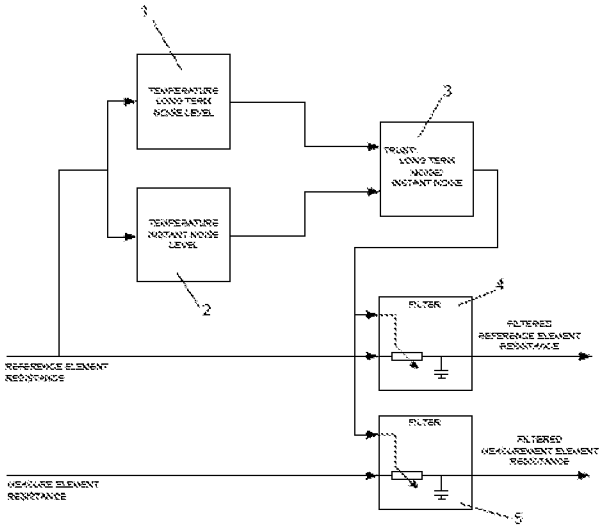
(57)	Sammendrag	

Method of measuring metal loss from equipment in process systems. Probes installed for monitoring of erosion and/or corrosion (metal loss) in process equipment use results from resistivity measurements in a measurement element and a reference element to produce a measurement of metal loss in the measurement element exposed to process flow and may trigger an alarm when measured metal loss exceeds a threshold level. Prior art methods produce numerous false alarms hiding true alarms. The present method ignores these false alarms by calculating confidence measures that are included in the metal loss calculations to attenuate noise that otherwise would produce false alarms or misinterpretation of the corrosion or erosion state in the process equipment being monitored.



The present invention is related to a method of measuring metal loss from equipment in process systems in accordance with the preamble of patent claim 1.

Background

Erosion in process equipment such as valves and pipe fittings is a severe problem in certain types of processes. This is particularly the case for process flows that contain sand in suspension in a fluid flow, where erosion is unavoidable. Another cause of metal loss is corrosion.

Usually, erosion and corrosion is detected by measuring change in electrical resistance in an element that is exposed to the process flow within a pipe. As the element becomes thinner because of erosion or corrosion, the electrical resistance increases and gives an indication of the degree of erosion and/or corrosion. Sand probes are one type of sensors which are used in process systems to monitor erosion and comprise a sacrificial element/measurement element arranged in e.g. a process flow line in a subsea well integral with pressure tight assembly arranged in a pipe wall. When the erosion in the measurement element in a sand probe, or a corrosion probe, reaches a predetermined limit or indicates increased development, an alarm may be triggered about action to be taken. For example in an oil well, metal loss caused by sand production may necessitate reduction of production rate to avoid damage to process equipment or even collapse in the well. In another case, a corrosion probe may provide information at an early point in time about increasing corrosion in the process equipment.

Unfortunately, the electrical resistance is heavily dependent on temperature, and in order to compensate for temperature variations, electrical resistance is measured on another element that is not exposed to process flow and hence not subject to erosion and/or corrosion. The latter element is called the reference element and the real erosion/corrosion measurement is the resistivity ratio between the two elements. The reference element is typically constructed of the same material as the measurement element and exhibits the same dimensions. The ratio between the respective resistivity values measured will represent a value for the metal loss in accordance with the following formula:

$$\Delta h_e = h_e - h_r \cdot (R_r/R_e) \qquad (1)$$

where Δh_e represents element metal loss, h_e represents the height or thickness of the original measuring element, h_r represents thickness of original reference element, R_r represents the resistance in the reference element and R_e represents the resistance in the measuring element. Accordingly, when the ratio between the respective resistivity values changes, the theoretical metal loss also changes, which can be used as an input in a system for generating an alarm which indicates an increased or critical erosion level in the process equipment.

However, the reference element cannot be located at the same place as the measurement element and as a result the reference element cannot follow the accurate same temperature variations as the measurement element and will typically lag behind the latter. Accordingly, as the term "theoretical metal loss" stated above indicates, the real systems behave differently. For example different changes in temperature between the measurement element and reference element may occur, e.g. during process start up, that may produce false metal loss or even metal "gain".

A system for measuring corrosion rate from a fluid medium is described in US patent 6,919,729 (Rohrback Cosasco Systems). The patent suggests a current feedback amplifier to maintain a constant AC voltage across the reference element to keep the corrosivity measurement independent of the probe's ambient temperature. In other words, the system provides corrosion measurements which are unaffected by noise in the form of resistivity variations caused by changes in temperature.

However, a temperature compensated measurement of resistivity in a sand probe is not sufficient to obtain reliable values of corrosion level. The resistivity measurements will also be affected by changes in the production regime, e.g. during shutdown and start-up of production in a subsea well where the sacrificing element can heat up differently from the reference element. Another contribution to unreliable measurements and hence false alarms about corrosion threshold are hits on the elements by items in the process flow, electromagnetic interference, faulty elements/probes. As a result, sand probes and corrosion probes may still produce numerous false alarms which hide a real alarm about a threshold corrosion level which may cause damage on and/or failure in the process equipment and process operation.

GB 2150300 A is another example from the prior art, describing an electrical resistance corrosion probe having a test element for exposure to a corrosive environment, and a reference element protected from corrosion. A second test element having a considerably greater diameter than the first test element is more resistant to corrosion than the first test element. Resistance measurements are taken between both the first and second test element, and the reference element. The results are compared and used to detect any corrosion. The probe arrangement is said to extend the useful life of the corrosion probe.

US 5,293,323 discloses calculation of confidence in a system to reduce the risk of false alarms. The patent is not related to sand probes or corrosion measurement in general. Confidence is calculated from numerous test, from which a confidence measure is calculated. The confidence measure itself may to a certain degree look like a confidence measure provided by the present invention: a value of -1 indicates that a test has failed by 100% probability, whereas a value of +1 indicates that a test has succeeded by 100% probability. Values therebetween is subjected to further analysis to detect "noise". In their example they apply +5V DC to a system and send 20 measurement values to further analysis (column 10, line 13-42 and Fig. 5a-5c). Accordingly, this patent prescribes the use of numerous test using several test locations (see claim 1 for example). The approach provided by US 5,293,323 cannot be combined directly by GB 2150300 A to solve the object set forth below and solved by the present invention.

Object

The main objective of the present invention is to provide a method of detecting erosion and/or corrosion in process equipment which is able to ignore false alarms while allowing detection of a true alarm when a threshold erosion level has been reached.

The invention

The object above is obtained by a method in accordance with the characterizing part of patent claim 1. Further advantageous features appear from the dependent claims.

<u>Definitions</u>

The term "resistivity change" as used herein, is intended to include resistivity change between a specific point in time (present value, *t*) and either a previous point in time (*t-1*) or an average value (a) for the resistivity for the reference element or the measurement element(s). The term "relative resistivity change" is the relative change in resistivity between the measurement element(s) on one hand and the reference element on the other hand. It should be noted that the point in time *t-1* can be a point in time before the point in time *t* and hence not necessarily after the point in time *t*.

The term "noise limit" or "noise threshold" as used herein, means an absolute value of a resistance jump above which there is no confidence. In other words, values above this noise limit are resistance changes caused by happenings in the process and not by metal loss in the measurement element. The noise limit is denoted as "L".

The term “*confidence*” as used herein, is intended to provide a value for how reliable a change in resistivity is. Low confidence indicates that a value for a resistivity change is caused by noise and not by true metal loss. On the other hand, high confidence indicates that a value for a resistivity change is caused by true metal loss and not by noise. A confidence measure varies stepless from absolutely no reliability to absolutely full reliability.

The term “alarm” as used herein, is intended to include alarms as used in traditional processing industry. The term is also intended to include a state of change that gives an early warning about material changes that necessarily not would require any action to be taken at that point in time, but predicts a state of change that needs attention and evaluation.

The terms “process” and “process systems” as used herein, are intended to include any process that includes equipment that is subjected to erosive and/or corrosive fluids, e.g. chemical plants, equipment arranged in connection with onshore oil wells as well as subsea oil fields.

Summary of the invention

The invention concerns a method of measuring metal loss from equipment in process systems in contact with erosive and/or corrosive process fluids, including pipelines and fittings in gas and oil wells exposed to fluids flowing from downhole formations, wherein the method comprises the steps of:

a) providing a monitoring probe in contact with the process fluids, said probe comprising one or more measurement elements exposed to the flow of the process fluids, and a reference element protected from flow of the process fluids,

b) measuring electrical resistance R_e across said one or more measurement element,

c) measuring electrical resistance R_r across the reference element,

d) calculating the metal loss Δh_e from the resistivity measured in accordance with the formula

$$\Delta h_e = h_e - h_r \cdot (R_r/R_e) \qquad (1)$$

where Δh_e, R_r and R_e are as defined above and h_e and h_r represents the original thickness of said at least one measurement element and the reference element, respectively.

According to the present invention, the method further comprises the steps of:

e) providing a confidence measure of the change in resistivity observed by calculating the variation of the reference element resistance value or variation of temperature of the probe measured by an additional temperature sensor, and

f) applying the confidence measure from step e) in a comparison of resistivity changes as a function of time, to provide a trustworthy value for real metal loss in said one or more measurement elements, thus attenuating resistivity changes caused by noise in the process system, and attenuating resistivity changes to a higher degree when the confidence measure is low and attenuating resistivity changes to a lower degree when the confidence measure is high.

It should be noted that the formula (1) above is just an example of how metal loss is provided by the prior art.

The confidence measure provided in step e) is a measure that is affected by noise, e.g. from changes in temperature and pressure during shut-in of an oil well. In systems with a high noise level, substantial parts of the relative resistivity changes are unreliable and hence the confidence value is low. In other words, the confidence value is a measure of how reliable the change in resistivity is. For example, during stable pressure and temperature conditions, the reference element is expected to exhibit stable resistivity over time (little or no change). When the resistivity in the reference element changes, the reason is caused by changes in the system as indicated above. In the latter case, the resistivity change measurements for both the reference element and the measurement element(s) must to a greater extent be filtered to reject transitory changes which are not caused by metal loss in the probe but from changes in operating conditions.

The trustworthy value for real metal loss provided in step f) may be used to encourage an observer to take some sort of action, e.g. to trigger an alarm or take preventive action, if its value exceeds a predetermined threshold value or shows unexpected or unwanted development.

The confidence measure can be provided in numerous ways. In one embodiment the confidence measure in step e) is calculated in accordance with formula (2):

$$confidence = (L - Abs(R_t - R_a)) / L \qquad (2)$$

where *confidence* represents calculated confidence with decimal values from ranging from 0 to 1, where the value 0 represents no or low confidence, and the value 1 represents high confidence, R_t represents the latest reference resistance value from a selected range of measurements, R_a represents a weighted average of resistance samples taken at previous points in time, and L

represents the noise limit, a measure of a expected noise under stable operating conditions. In systems with little noise, the value of L is low, and to the contrary the value of L is high in systems with a high noise level. In other words, a confidence value of 1 represents a 100% reliable measurement of resistivity change, whereas a confidence value of 0 represents 0% reliable measurement of resistivity change. However, the confidence must be calibrated for the specific system and weighted against a noise threshold.

The trustworthy value for real metal loss may be calculated in numerous ways, but in one embodiment its value provided in step f) is calculated in accordance with formula (3):

$$Y_t = X_t \cdot confidence + Y_{t-1} \cdot (1 - confidence) \quad (3)$$

where the output value Y_t is filtered resistance ratio between the measurement element and the reference element at a point in time t. The output value represents trusted metal loss. The input value X_t is unfiltered resistance ratio between the measurement element and the reference element at a point in time t. The input value represents untrusted metal loss. The input value Y_{t-1} represents filtered resistance ratio between the measurement element and the reference element at a previous point in time t-1. The input value *confidence* represents the confidence measure from step e). The time difference between observed resistivity taken at time *"t"* and *"t-1"* may vary. For example, for sand probes the time difference may typically have an order of magnitude of minute or minutes, whereas corrosion probes are operated with time intervals of hours or even days.

It should be noted that the calculation of the trustworthy value (filtering) for real metal loss in equation (3) above, also can be applied on resistance values for the reference element and on resistance values for the measurement element separately. Then, the resulting filtered resistance values are used to calculate a filtered ratio between the respective filtered resistance measurements, instead of from filtered resistance ratios as set forth in the preceding paragraphs.

Accordingly, step f) can be performed as follows: calculating a (filtered) trustworthy value for real metal loss in accordance with formula (3):

$$Y_t = X_t \cdot confidence + Y_{t-1} \cdot (1 - confidence) \quad (3)$$

where

the calculated output value Y_t is a filtered resistance measurement of the measurement element at a point in time *t,* representing trusted metal loss, the input value X_t is unfiltered resistance measurement of the measurement element at a point in time t, representing untrusted metal loss,

the input value Y_{t-1} represents calculated filtered resistance measurement of the measurement element at a previous point in time $t-1$,

said input value *confidence* representing the confidence measure calculated in step e),

repeating the calculation above, where X_t represents unfiltered resistance measurement for the reference element, Y_{t-1} represents calculated filtered resistance for the reference element at a previous point in time $t-1$, wherein the input value *confidence* is as defined above, and then

calculating the ratio between respective calculated filtered resistance values Y_t at selected points in time t.

Temperature compensation is advantageously applied at some stage during the calculation process to attenuate noise caused by temperature variations during the measurement period. Applying temperature compensation should be within the reach of a person skilled in the art and is not described in further detail here.

To summarize, the present method has shown to suppress up to 99 % of false alarms while retaining 100 % of the true alarms by applying the method on data sets from real subsea wells. I other words the method of the present invention ignores false alarms by calculating a confidence value (measure) of the measured changes in resistivity during a certain period of time.

Drawings

The invention is described below in further details by means of an example applying real resistivity measurements from a real subsea well and by means of drawings, where

Figure 1 shows a plot of relative resistivity; both filtered and unfiltered taken over a certain period of time,

Figure 2 is a block diagram that illustrates one example of an embodiment of the method in accordance with the present invention in the form of filtering noise and calculating confidence values for measured resistivity ratio, and

Figure 3 is a figure similar to Fig. 1, showing another exemplary embodiment of how to deploy the method of the present invention.

Example

The example described below is provided to describe one embodiment of the method of the present invention. In further detail, resistivity measurements from sand probe installations in a real subsea well in the Norwegian Sea were used to calculate trustworthy (filtered) changes in resistivity ratios which enabled detection of real metal loss and at the same time ignoring false indications of metal loss provided by changes in resistivity ratio.

Table 1

Sample number	**Unfiltered measurement element resistance**	**Unfiltered reference element resistance**	**Unfiltered ratio**	**Filtered ratio**
5270	0.015213815	0.01443745	1.05377449	1.053852
5271	0.015210943	0.01443801	1.05353443	1.053715
5272	0.015213096	0.01443702	1.05375618	1.053732
5273	0.015210225	0.01443654	1.05359214	1.053675
5274	0.0152137	0.01443657	1.05383045	1.053747
5275	0.015216318	0.01443591	1.05406031	1.05388
5276	0.015210754	0.01443757	1.05355362	1.053723
5277	0.015210677	0.01443539	1.05370725	1.053717
5278	0.015210349	0.01443808	1.05348816	1.053617
5279	0.015214076	0.01443887	1.05368892	1.053643
5280	0.015211896	0.01443889	1.05353617	1.053598
5281	0.015170436	0.01439668	1.05374535	1.053603
5282	0.015190904	0.01441449	1.05386378	1.053637
5283	0.01518785	0.01441478	1.05363054	1.053635
5284	0.015092505	0.0143309	1.05314394	1.053622
5285	0.015030649	0.01426469	1.05369613	1.053631
5286	0.0152099	0.0144321	1.05389348	1.053646
5287	0.015228192	0.01444705	1.05406969	1.053709
5288	0.015225774	0.01444663	1.05393268	1.053732
5289	0.015206368	0.01443498	1.05343865	1.053675
5290	0.015218641	0.01444019	1.05390888	1.053739
5291	0.015215305	0.01444235	1.05352022	1.053681
5292	0.015219591	0.01444038	1.05396039	1.053776
5293	0.015216938	0.01444245	1.05362578	1.053715
5294	0.015215776	0.01444193	1.05358294	1.053654
5295	0.015219602	0.01444369	1.05372001	1.053688
5296	0.015219434	0.01444311	1.05375051	1.053723
5297	0.015218635	0.01444185	1.05378704	1.053762
5298	0.015222493	0.01444067	1.05414048	1.054008
5299	0.01522616	0.01444164	1.05432365	1.054224

Table 1

Sample number	Unfiltered measurement element resistance	Unfiltered reference element resistance	Unfiltered ratio	Filtered ratio
5300	0.015228103	0.01444117	1.05449215	1.054416
5301	0.015232788	0.01444014	1.05489168	1.05477
5302	0.0152305	0.01444339	1.05449611	1.05458
5303	0.015233966	0.01443906	1.05505268	1.054906
5304	0.015230507	0.01444025	1.05472589	1.054776
5305	0.015229926	0.01444013	1.05469451	1.054715
5306	0.015226683	0.01444005	1.05447553	1.05453
5307	0.01523411	0.01443914	1.05505638	1.054949
5308	0.015231647	0.01443939	1.05486762	1.054883
5309	0.015233433	0.01443901	1.05501954	1.054997
5310	0.015227948	0.01443614	1.05484918	1.054907

Table 1 above illustrates measurements with their unfiltered and filtered ratio (ratio is measurement element resistance divided by reference element resistance). The filtered resistances used to compute the filtered ratio are not shown. The data is taken from a set of erosion measurements where a few temperature variations are followed by a legitimate step in erosion.

Now referring to Fig. 1, the uppermost curve indicated at 11 represents resistance measurements as a function of time (left axis). Resistance measurements from the reference element as a function of time is shown in the curve below, indicated at reference numeral 12 (left axis). At reference numeral 13, the unfiltered ratio (right axis) between the two abovementioned resistance measurements is shown as a function of time. As is evident from the diagram, a resistance jump has been detected in the time interval from about 5283 to about 5288. This resistance jump does not represent any real metal loss and is a result of noise in the process system. As a result, an observer might take unnecessary action, e.g. reduced production to decrease or prevent erosion in process equipment or prevent formation collapse from sand production in an oil well. A filtered ratio provided by the method of the present invention (right axis) is indicated at reference numeral 14. Here, the resistance jump in the time interval from about 5283 to about 5288 has been attenuated by the use of the confidence measure in the calculation of the (filtered) ratio. Accordingly, the filtered ratio does not, correctly, indicate any metal loss in the time interval mentioned above, and an observer is not encouraged to take any unnecessary action. The result is enhanced up-time and cost savings, for example in view of prevented shutdown or maintained production rate.

However, at sample number 5298 there is a significant increase in both the unfiltered and filtered resistance ratios, and the resistance ratios are from that point in time substantially congruent. This resistance ratio jump represents a true metal loss which tells the observer that some sort of action should be taken.

Accordingly, the method in accordance with the present invention successfully suppresses temperature noise while admitting legitimate data caused by real material changes in the form of corrosion and/or erosion.

Figure 2 shows a block diagram of a device for implementation of the method described above, in a sand probe comprising a measurement element and a reference element arranged within the process flow of, e.g., a pipeline.

Figure 3 is a drawing similar to Figure 2 but where the reference element is implemented as the pipeline itself.

As can be seen from Figure 2, the temperature long term noise level L is computed in step 1, whereas the temperature instant noise level is provided in step 2. The long term noise level may in its simplest form be represented by the noise floor of the instrument itself. However, this will not provide a good result in a pipe where the temperature is noisy in normal operation. Therefore, some calculation should be performed in order to determine the normal noise. The instant noise level is the absolute value of the high pass filtered temperature. The respective values are used to calculate confidence in step 3 in the figure, and in accordance with equation 2 above. Step 3 in the figures corresponds to step e) in the method according to the present method. The calculated confidence is used as input values in step 4 and 5 to calculate filtered resistance values for the reference element and the measurement element, respectively, which again are used as input values to calculate trusted metal loss (step f) of the method according to the present invention), which enabled suppression of about 99 % of false alarms produced by prior art methods while retaining 100 % of the true alarms indicating detrimental corrosion or erosion in the process equipment being monitored.

Figure 3 illustrates another embodiment of the present invention applied in the applicant’s Field Signature (FSM) method. Here the measurement element is the pipe wall itself whereas the reference element may be a bracket attached to the outer surface of the pipe, where the bracket comprises an array of non-intrusive sensing pins distributed over the area to be monitored. Here the time lag is even greater and the risk of false alarms even higher. The input to step 1 and 2 is temperature measurements from process equipment, e.g. a pipe temperature sensor or a reference bracket temperature sensor.

Accordingly, the present invention discloses a novel method of monitoring corrosion and/or erosion in process equipment with a reliability which has been unavailable with prior art solutions. As a result, time between maintenance can be increased, with higher process throughput and increased profit as a result. The present invention may also avoid shutdowns and even accidents caused by a failure from metal loss in process equipment, where the operator has decided to ignore alarms that have been proven to be false, whereupon real alarms also are being ignored. In subsea oil well applications, the present method may detect sand production at an early point in time and allow reduction of production rate to prevent collapse of the formation.

Claims

1. Method of measuring metal loss from equipment in process systems in contact with erosive and/or corrosive process fluids, including pipelines and fittings in gas and oil wells exposed to fluids flowing from downhole formations, wherein the method comprises the steps of:

a) providing a monitoring probe in contact with the process fluids, said probe comprising one or more measurement elements exposed to the flow of the process fluids, and a reference element protected from flow of the process fluids,

b) measuring electrical resistance R_e across said one or more measurement element,

c) measuring electrical resistance R_r across the reference element,

d) calculating the metal loss Δh_e from the resistivity measured in accordance with the formula

$$\Delta h_e = h_e - h_r \cdot (R_r/R_e) \qquad (1)$$

where Δh_e, R_r and R_e are as defined above and h_e and h_r represents the original thickness of said at least one measurement element and the reference element, respectively,

characterized in

e) providing a confidence measure of change in resistivity observed, by calculating the variation of the reference element resistance value or variation of temperature of the probe measured by an additional temperature sensor, wherein the confidence measure is calculated in accordance with formula (2):

$$\textit{confidence} = (L - \mathrm{Abs}(R_t - R_a)) / L \qquad (2)$$

where *confidence* represents calculated confidence with decimal values from ranging from 0 to 1, where the value 0 represents no or low confidence, and the value 1 represents high confidence, R_t represents the latest reference resistance value from a selected range of measurements, R_a represents a weighted average of resistance samples taken at previous points in time, and L represents the noise limit, and

f) applying the confidence measure from step e) in a comparison of resistivity changes as a function of time, to provide a trustworthy value for real metal loss in said one or more measurement elements, wherein the trustworthy value for real metal loss is calculated in accordance with formula (3):

$$Y_t = X_t \cdot confidence + Y_{t-1} \cdot (1 - confidence) \qquad (3)$$

where

the calculated output value Y_t is filtered resistance ratio between the measurement element and the reference element at a point in time *t,* representing trusted metal loss,

the input value X_t is unfiltered resistance ratio between the measurement element and the reference element at a point in time *t*, representing untrusted metal loss,

the input value Y_{t-1} represents calculated filtered resistance ratio between the measurement element and the reference element at a previous point in time *t*-1, and

the input value *confidence* represents the confidence measure calculated in step e),

thus attenuating resistivity changes caused by noise in the process system, and attenuating resistivity changes to a higher degree when the confidence measure is low and attenuating resistivity changes to a lower degree when the confidence measure is high.

2. The method of claim 1, **characterized in** that the method further comprises the step:

g) triggering an alarm if the trustworthy value for real metal loss exceeds a predetermined threshold value.

3. The method of claim 1 or 2, **characterized in** calculating the trustworthy value for real metal loss according to step f),

repeating the calculation above, where X_t represents unfiltered resistance the measurement for reference element, Y_{t-1} represents calculated filtered resistance for the reference element at a previous point in time *t-1*, wherein the input value *confidence* is as defined above, and then

calculating the ratio between filtered resistance values Y_t for resistance values for the measurement element and the reference element, respectively, at selected points in time *t*.

4. The method of any one of the preceding claims, **characterized in** that the time difference between observed resistivity taken at time *"t"* and *"t-1"* has an order of magnitude of minute for sand probes.

5. The method of any one of the preceding claims, **characterized in** that the time difference between observed resistivity taken at time *"t"* and *"t-1"* has an order of magnitude of hours or days for corrosion probes.

Patentkrav

1. Framgangsmåte for måling av metalltap fra utstyr i prosess-systemer i kontakt med eroderende og/eller korrosive prosessfluider, inkludert rørledninger og armatur i gass- og oljebrønner eksponert for fluider som strømmer fra formasjoner nedihulls, hvori framgangsmåten omfatter trinnene med å:

a) framskaffe en overvåkingsprobe i kontakt med prosessfluidene, hvilken probe omfatter ett eller flere måleelementer eksponert for strømmen av prosessfluidene, og et referanseelement beskyttet mot strøm av prosessfluidene,

b) måle elektrisk resistens R_e over ett eller flere måleelementer,

c) måle elektrisk resistens R_r over referanseelementet,

d) beregne metalltapet Δh_e fra motstanden målt i henhold til formelen

$$\Delta h_e = h_e - h_r \cdot (R_r/R_e) \qquad (1)$$

der Δh_e, R_r og R_e er som definert foran og h_e og h_r representerer den opprinnelige tykkelsen av henholdsvis nevnte i det minste ett måleelement og referanseelementet,

karakterisert ved

e) framskaffe en konfidensmåling for endring i observert resistivitet, ved å beregne variasjonen av resistensverdien for referanseelementet eller variasjon av temperatur i proben målt med en ekstra temperaturføler, hvori konfidensmålingen beregnes i henhold til formelen (2):

(2):

$$k\mathit{onfidens} = (L - \mathrm{Abs}(R_t - R_a)) / L \qquad (2)$$

hvor *konfidens* representerer beregnet konfidens med desimalverdier som varierer fra 0 til 1, hvor verdien 0 representerer ingen eller lav konfidens, og verdien 1 representerer høy konfidens, R_t representerer den ferskeste verdien for referanseresistens fra et valgt intervall med målinger, R_a representerer en vektet middelverdi for resistensprøver tatt på tidligere tidspunkt, og L representerer støygrensen, og

f) anvende konfidensmålingen fra trinn e) i en sammenlikning av resistivitetsendringer som funksjon av tid, for å framskaffe en pålitelighetsverdi for reelt metalltap i nevnte ett eller flere måleelementer, hvori pålitelighetsverdien for reelt metalltap beregnes I henhold til formel (3):

$$Y_t = X_t \cdot konfidens + Y_{t-1} \cdot (1 - konfidens) \quad (3)$$

der

den beregnede utgangsverdien Y_t er filtrert resistensforhold mellom måleelementet og referanseelementet ved et tidspunkt t, som representerer et pålitelig metalltap,

inngangsverdien X_t er ufiltrert resistensforhold mellom måleelementet og referanseelementet ved et tidspunkt t, som representerer upålitelig metalltap,

inngangsverdien Y_{t-1} representerer beregnet ufiltrert resistensforhold mellom måleelementet og referanseelementet ved et tidspunkt t,

inngangsverdien *konfidens* representerer konfidensmålingen beregnet i trinn e),

for slik å dempe resistivitetsendringer forårsaket av støy i prosess-systemet, og dempe resistivitetsendringer i større grad når konfidensmålet er lavt og dempe resistivitetsendringer i mindre grad når konfidensmålingen er høy.

2. Framgangsmåte ifølge krav 1, **karakterisert ved** at framgangsmåten i tillegg omfatter trinnet:

g) fyre en alarm dersom pålitelighetsverdien for reelt metalltap overskrider en forhåndsbestemt grenseverdi.

3. Framgangsmåte ifølge krav 1 eller 2, **karakterisert ved** å beregne pålitelighetsverdien for reelt metalltap i henhold til trinn f),

gjenta beregningen foran, der X_t representerer ufiltrert resistens fra målingen for referanseelementet, Y_{t-1} representerer beregnet filtrert resistens for referanseelementet ved et tidligere tidspunkt *t-1*, der inngangsverdien *konfidens* er som definert foran, og deretter

beregne forholdet mellom filtrerte resistensverdier *Yt* for resistensverdier for henholdsvis måleelementet og referanseelementet, ved valgte tidspunkt t.

4. Framgangsmåte ifølge et av kravene foran, **karakterisert ved** at tidsforskjellen mellom observert resistivitet tatt ved tidspunkt «*t*» og «*t-1*» har en størrelsesorden lik minutter for sandprober.

5. Framgangsmåte ifølge et av kravene foran, **karakterisert ved** at tidsforskjellen mellom observert resistivitet tatt ved tidspunkt «*t*» og «*t-1*» har en størrelsesorden lik timer eller dager for korrosjonsprober.

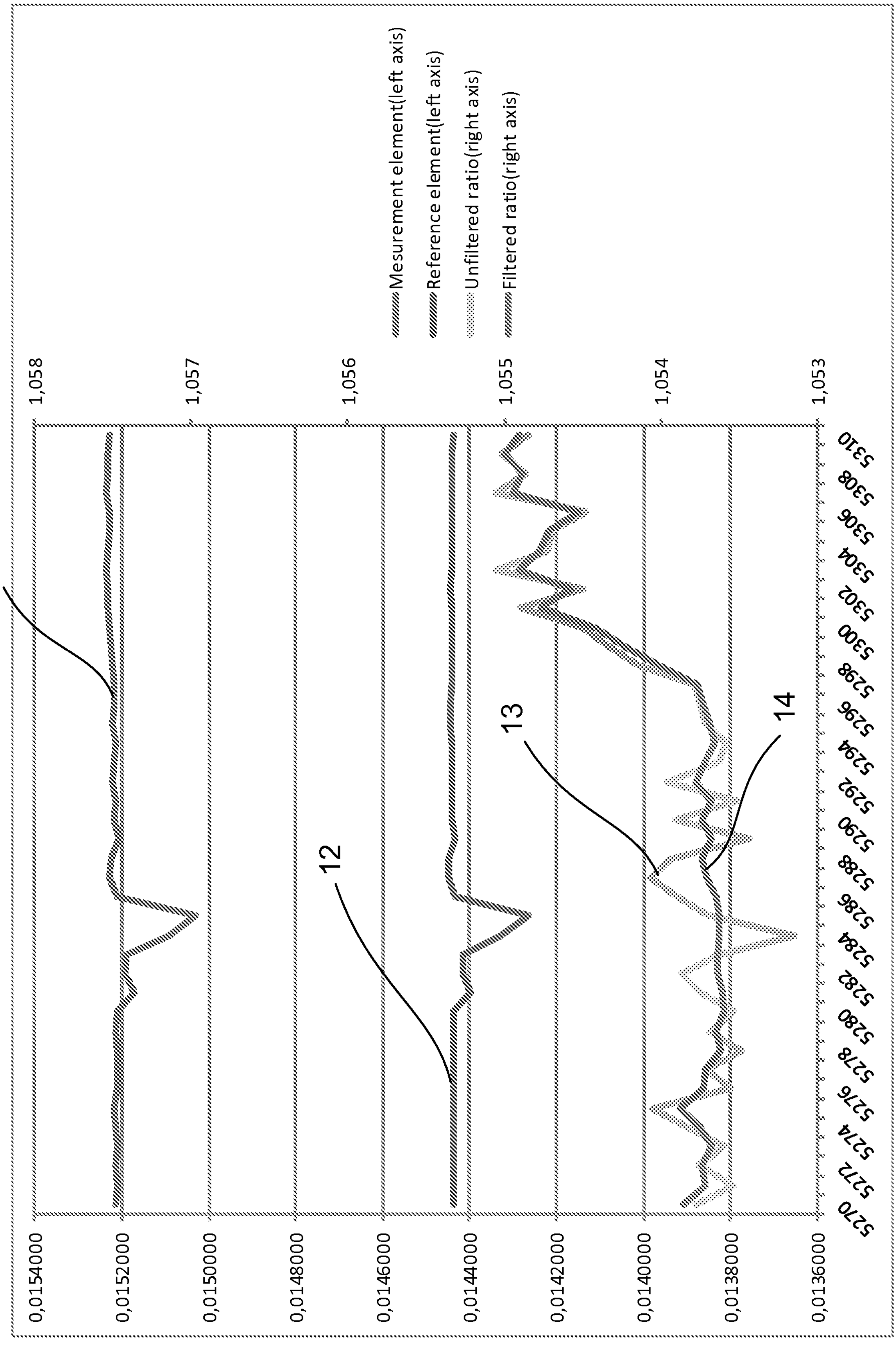

Mesurement element(left axis)
Reference element(left axis)
Unfiltered ratio(right axis)
Filtered ratio(right axis)
0,0154000
0,0152000
0,0150000
0,0148000
0,0146000
0,0144000
0,0142000
0,0140000
0,0138000
0,0136000
1,058
1,057
1,056
1,055
1,054
1,053
5270
5272
5274
5276
5278
5280
5282
5284
5286
5288
5290
5292
5294
5296
5298
5300
5302
5304
5306
5308
5310
11
12
13
14

Fig. 1

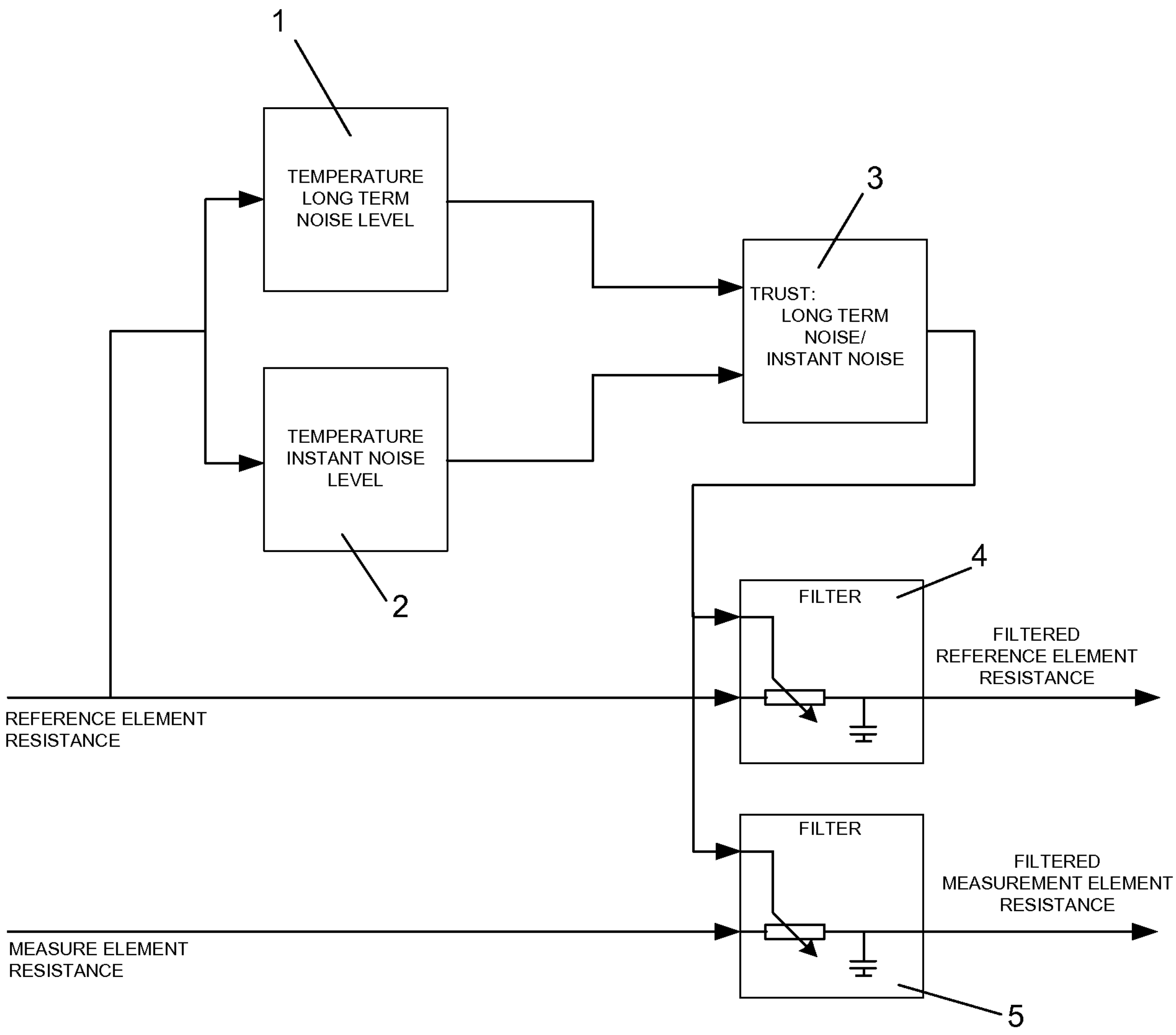

1
TEMPERATURE LONG TERM NOISE LEVEL
3
TRUST: LONG TERM NOISE/ INSTANT NOISE
TEMPERATURE INSTANT NOISE LEVEL
2
4
FILTER
FILTERED REFERENCE ELEMENT RESISTANCE
REFERENCE ELEMENT RESISTANCE
FILTER
FILTERED MEASUREMENT ELEMENT RESISTANCE
MEASURE ELEMENT RESISTANCE
5

Fig. 2

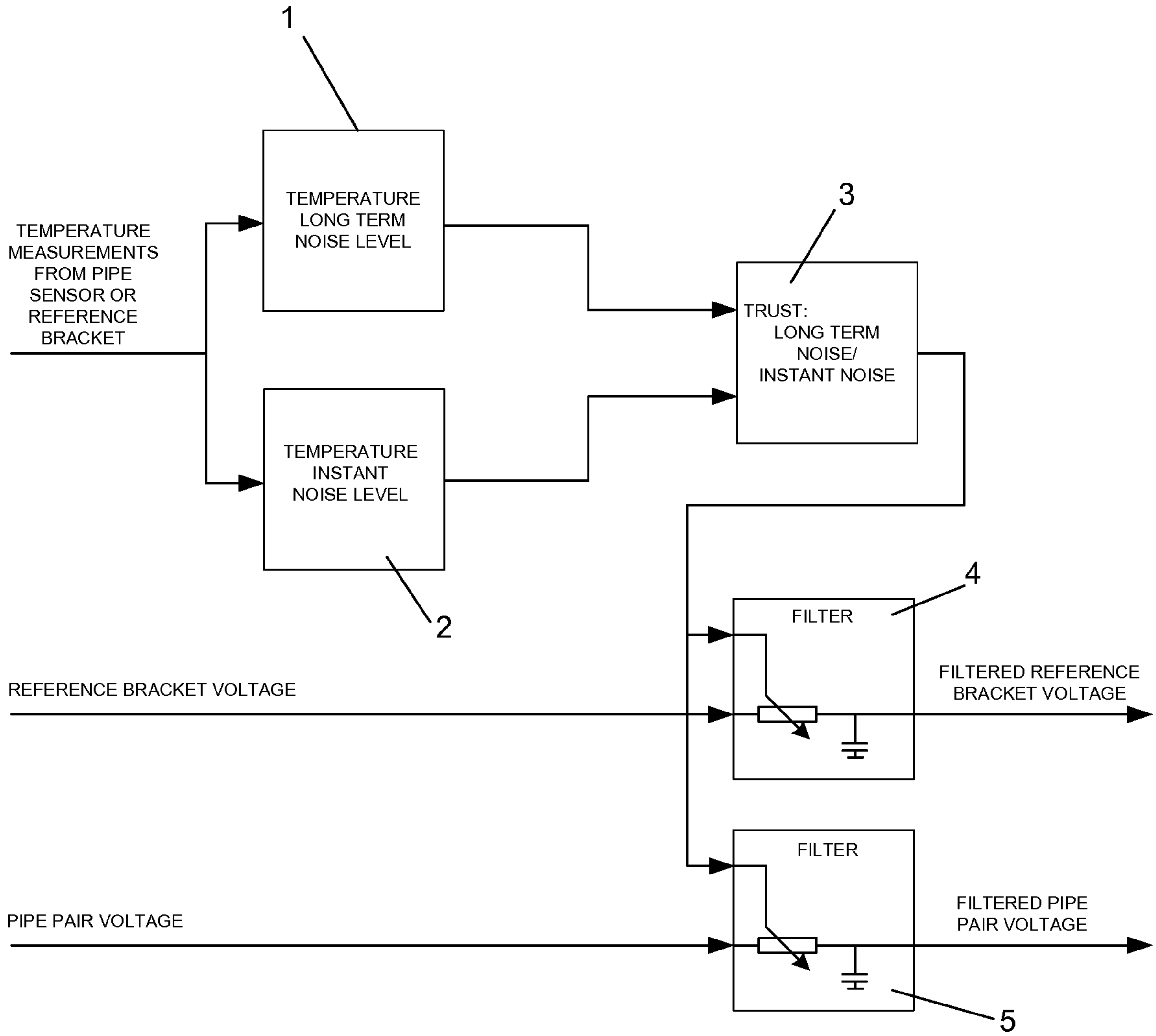

1
TEMPERATURE LONG TERM NOISE LEVEL
TEMPERATURE MEASUREMENTS FROM PIPE SENSOR OR REFERENCE BRACKET
3
TRUST: LONG TERM NOISE/ INSTANT NOISE
TEMPERATURE INSTANT NOISE LEVEL
2
4
FILTER
REFERENCE BRACKET VOLTAGE
FILTERED REFERENCE BRACKET VOLTAGE
FILTER
PIPE PAIR VOLTAGE
FILTERED PIPE PAIR VOLTAGE
5

Fig. 3