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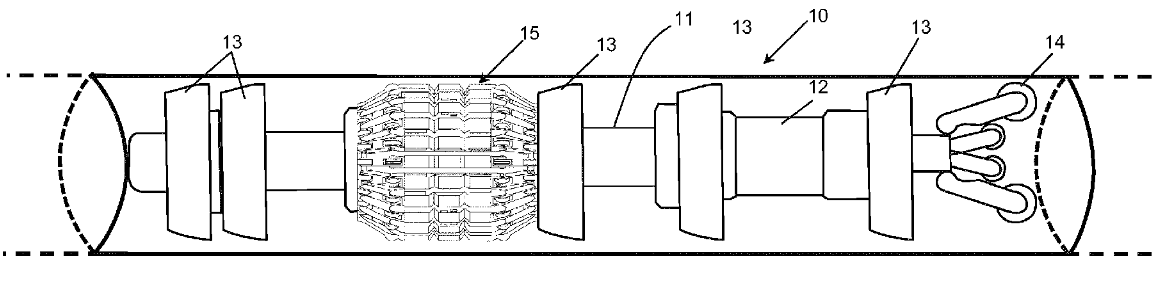

FIG. 1

(57) Abstract: An in-line inspection device and methods of operation thereof for identifying and characterizing features of a metallic pipe structure are disclosed. An in-line inspection device with a central body supports an instrument apparatus which includes a plurality of magnetic members to magnetically saturate the pipe, and a plurality of magnetic sensor assemblies to detect magnetic flux leakage signals caused by pipe features. The plurality of magnetic sensor assemblies are positioned such that some are as close as practicable to the internal surface of the pipe, and others are at a predetermined offset distance from the internal surface of the pipe. By analyzing and comparing the outputs of the magnetic sensor assemblies, pipeline features can be identified and characterized.

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SYSTEM AND METHOD FOR DETECTING AND CHARACTERIZING DEFECTS IN A PIPE

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Patent Application No. 62/339,423 filed on May 20, 2016, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The following relates to systems and methods for detecting and/or characterizing defects in pipes and other tubular members, including pipelines.

DESCRIPTION OF THE RELATED ART

[0003] Pipelines are often used to transport petroleum products, natural gas, hazardous liquids, and the like. Once installed, a pipeline is found to inevitably corrode or otherwise develop defects. Such defects include metal loss, dents, cracks, and other mechanical damage.

[0004] Magnetic flux leakage inspection devices, commonly referring to as “pigs”, are tools that are propelled along a pipeline by the pressure of a fluid in the pipeline, for various servicing purposes. The use of magnetic flux leakage inspection devices in pipelines is an established technology. Typically, by using a plurality of magnets, a magnetic field may be created which substantially magnetically saturates a portion of the circumferential length of the pipe through which the device moves. Sensors can then identify and measure the magnetic flux leakage caused by defects, and this information can further be recorded to provide inspection data.

[0005] Some in-line inspection devices include primary sensor assemblies to identify defects that occur in a ferromagnetic pipeline, both on the internal surface and on the external surface of the pipeline. Modern magnetic flux leakage measuring technologies typically rely on Hall-effect sensors for this purpose. However, the current conventional configuration of magnetic sensors may be unable to discriminate between which defects occur on the internal pipeline surface and which ones occur on the external surface.

[0006] Consequently, other in-line inspection devices have been developed to include secondary sensor assemblies, which may be of a different type than the primary sensors, to discriminate between inner-diameter (ID) which occur on the internal surface of a pipeline, and outer-diameter (OD) defects which occur on the external surface of a pipeline. The secondary sensors are typically eddy current sensors. Eddy currents may be induced by the instrument and the signals can be detected by the sensors. Due to the limited range of eddy currents, the eddy current sensor systems reveal only internal defects. Used in conjunction with the information collected by the primary sensor systems, internal and external defects can be distinguished. However, typical eddy current sensing systems can consume significant amounts of power and reduce battery life. Further, such secondary sensor assemblies need additional space and storage, which leads to a higher cost associated with materials, constructing the device, and employing the device inside a pipeline.

[0007] It is an object of the following to provide a system and method that addresses the aforementioned concerns.

SUMMARY

[0008] The in-line inspection device described herein is used to identify and characterize the features of a metallic pipe structure through which it passes. The device moves within a pipeline in the direction of a fluid flow, and is enabled to move through the pipeline via a plurality of annular cups supported by the device body which trap the fluid and engage the internal pipeline wall.

[0009] In an implementation, the in-line inspection device supports an instrument apparatus. The instrument apparatus includes a plurality of magnetic assemblies for providing a magnetic field to magnetically saturate the length of pipe through which the in-line inspection device passes. Also supported by the instrument apparatus is a plurality of near-wall magnetic sensor assemblies positioned as close as practicable to the internal pipeline wall, and a plurality of offset magnetic sensor assemblies positioned at an offset distance from the internal pipeline wall, wherein both near-wall and offset magnetic sensor assemblies may detect magnetic flux leakage signals caused by pipeline features. Due to their positions relative to the internal pipeline wall, the near-wall magnetic sensor assemblies may detect a different range of magnetic flux leakage signals than the offset magnetic sensor assemblies. By combining the data collected by the near-wall and offset magnetic assemblies, additional details about pipeline features can be determined than what may be determined with only near-wall magnetic sensor assemblies. These additional details may include, but are not limited to: shape, size, radial position, and clock position of the features, wherein the radial position refers to the internal/external nature of a feature, and the clock position refers to the circumferential position of a feature.

[0010] Various implementations may also further provide a method for characterizing the features of a metallic pipe structure, comprising: generating a magnetic field using the magnetic assemblies, instructing the magnetic sensor assemblies to continuously perform measurements to detect magnetic flux leakage signals that may be caused by a pipeline feature, processing each signal in a processing circuit, storing the processed information in a recorder, and utilizing the information to determine desired characteristics about pipeline features.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Embodiments will now be described by way of example only with reference to the appended drawings wherein:

[0012] FIG. 1 is an elevational view of one embodiment of an in-line inspection device.

[0013] FIG. 2 is an enlarged view of the instrumentation apparatus of the in-line inspection device depicted in FIG. 1.

[0014] FIG. 3 is a perspective cross-sectional view of the instrumentation apparatus depicted in FIG. 2.

[0015] FIG. 4 is a diagrammatic view of a portion of the instrumentation apparatus depicted in FIG. 2, including a schematic illustration of functional processing blocks for operating the inspection device.

[0016] FIG. 5 is an enlarged view, as viewed in a circumferential direction, of a pipeline wall and a section of the instrumentation apparatus which contains a plurality of magnetic sensor assemblies.

[0017] FIG. 6 is a schematic diagram, as viewed in an axial direction, which illustrates the spatial relationships between a plurality of magnetic sensor assemblies supported by a section of the instrumentation apparatus of the inspection device, and an internal feature along a pipeline surface.

[0018] FIG. 7 is a schematic diagram, as viewed in an axial direction, which illustrates the spatial relationships between a plurality of magnetic sensor assemblies supported by a section of the instrumentation apparatus of the inspection device, and an external feature along a pipeline surface.

[0019] FIG. 8 is a graph which shows the magnetic amplitudes obtained by a near-wall sensor and offset sensor for an internal feature.

[0020] FIG. 9 is a graph which shows the magnetic amplitudes obtained by a near-wall sensor and offset sensor for an external feature.

[0021] FIG. 10 is a flow chart which illustrates a set of operations that can be performed in inspecting a pipeline for defects.

DETAILED DESCRIPTION

[0022] Referring to FIG. 1, an in-line inspection device **10** used for various pipeline servicing purposes is shown. The in-line inspection device **10** in this example includes a plurality of annular cups **13** affixed around the circumference of the central body **11** which serve to center the inspection device **10** within the pipeline and also to engage the internal pipeline wall so as to trap the flowing fluid, enabling the device to be pushed along the pipeline by the fluid. In the embodiment shown, the in-line inspection device **10** has an instrumentation apparatus **15** that supports magnetic sensor assemblies as discussed below, and a support module **12** that may house the batteries and other electronic and/or recording equipment. Further, the tail end of the device **10** may comprise one or more odometers **14** which measure the distance travelled by the device **10** and provide signals that reveal the location of a pipeline feature.

[0023] The inspection device **10** shown is illustrated by way of example only and not by limitation. That is, other inspection device sizes and configurations are possible. Depending on the configuration of the in-line inspection device **10** and the size of the pipeline to be inspected, the arrangement and number of components may also vary.

[0024] The instrumentation apparatus **15** is shown in greater detail in FIGS. 2 – 5. Referring to FIG. 2, the instrumentation apparatus **15** includes end plates **20A** and **20B**, and is supported by or otherwise attached to the central body **11**. Between the end plates **20A**, **20B** is a plurality of armatures **21** aligned parallel with respect to each other and arranged circumferentially around the central body **11**. Magnets of opposing polarities **22A** and **22B** are affixed to either end of each armature **21**. The magnets **22A** and **22B** generate a magnetic field such that the length of pipe between them is substantially continuously magnetically saturated as the inspection device **10** moves through the pipeline.

[0025] Referring to FIG. 3, the ends of each armature **21** are connected to a forward arm **30** and rearward arm **31**. The other end of each forward arm **30** is attached to the end plate **20A**. Similarly, the other end of each rearward arm **31** is attached to the end plate **20B**. The forward and rearward arms **30** and **31** link the plurality of armatures **21** to the central body **11** and allow variance in the radial position of each armature **21** such that the instrumentation apparatus **15** can tailor to any variances in the interior dimensions of the pipe wall through which the inspection device **10** moves. In order to keep the magnets **22A** and **22B** from being damaged (e.g., due to contact with the interior of the pipeline wall), spacers **35** are employed in order to ensure that the magnets **22A** and **22B** are in close proximity to, but not in physical contact with, the interior of the pipeline wall.

[0026] Referring to FIG. 4, a portion of the instrumentation apparatus **15** is shown, which provides further detail for one of the armatures **21**, the magnets of opposing polarities **22A** and **22B**, forward and rearward arms **30** and **31** which link the armature **21** to the central body **11** of the inspection device **10**, and a head assembly **40** between the magnets **22A**, **22B**, which contains a plurality of magnetic sensor assemblies **51** and **52**. The head assembly **40** contains at least one near-wall magnetic sensor assembly **51** positioned as close as practicable to the internal pipeline wall **58**, and at least one offset magnetic sensor assembly **52** positioned at a predetermined offset distance from the internal wall **58**. The at least one near-wall magnetic sensor assembly **51** and the at least one offset magnetic sensor assembly **52** collect magnetic flux leakage signals as the in-line inspection device **10** moves through the pipeline. Due to the difference in position with respect to the pipeline wall, an offset magnetic sensor assembly **52** may capture signals of a different range and magnitude than a near-wall magnetic sensor assembly **51** located in the same head assembly **40**. The data obtained by the sensor assemblies **51** and **52** for a particular feature may then be compared to determine various characteristics of the feature. For example, the ratio of the amplitudes of the magnetic signals acquired by the two types of sensor assemblies **51** and **52** may be used to reveal whether a feature is located on the internal surface or external surface of a pipeline. Thus, the incorporation of the offset magnetic sensor assembly **52** may allow additional information to be collected about pipeline anomalies that may otherwise be unattainable with just the near-wall magnetic sensor assembly **51**.

[0027] The conductor **400** connects and carries signals from the near-wall magnetic sensor assembly **51** to the sensor process circuit **42**. The conductor **410** connects and carries signals from the offset magnetic sensor assembly **52** to the sensor process circuit **42**. The process signal produced by the sensor process circuit **42** is sent to the processing and output circuit **44** by the conductor **420**. One or more odometers **14** supply signals to an odometer circuit **43** which in turn provides position signals to a signal processing and output circuit **44**. The resulting data is then sent to a recorder **45** which records and stores the data.

[0028] Referring to FIG. 5, an enlarged schematic view of the portion of the instrumentation apparatus **15** depicted in FIG. 4 is shown. An external pipeline feature **201,** located on the external pipeline wall **59**, responds to the magnetic field generated by the magnets **22A** and **22B** by causing magnetic flux leakage which may be detected by a plurality of magnetic sensor assemblies **51** and **52**. The near-field magnetic flux leakage is detected by the near-wall magnetic sensor assembly **51** as indicated by the inner dotted line **54** and the far-field magnetic flux leakage is detected by the offset magnetic sensor assembly **52** as indicated by the outer dotted line **55**. In one embodiment, all of the near-wall and offset magnetic sensor assemblies **51** and **52** are Hall-effect sensors. If only near-wall Hall-effect sensors assemblies **51** were present as is typical in many in-line inspection devices, the data would indicate the existence of a pipeline feature but would be unable to reveal the radial position of the feature, i.e. whether the feature lies on the inner-diameter (ID) or the outer-diameter (OD) of the pipeline wall. It is the addition of the offset Hall-effect sensor assembly **52** which enables additional information to be collected to better interpret the magnetic flux leakage signals. One of the benefits of this additional information is the ability to discriminate between internal and external features without the need for eddy-current sensor systems, as is currently being used for this purpose, which generally consume a greater amount of power than, for example, the Hall effect-type sensor systems **51** and **52**.

[0029] In another embodiment, particularly in a case in which energy consumption is not a large concern, the magnetic sensors may comprise Hall-effect sensors, eddy current sensors, and other magnetic sensors, or a combination thereof, with an arrangement such as that shown in FIG. 5 wherein one sensor is offset from another.

[0030] It should be noted that while FIGS. 4 and 5 show two magnetic sensor assemblies supported by the head assembly **40**, various embodiments may include head assemblies which house more than two magnetic sensor assemblies. That is, there may be more magnetic sensor assemblies, however at least one near-wall magnetic sensor assembly **51** and at least one offset magnetic sensor assembly **52** are supported by each head assembly **40**.

[0031] Referring to FIGS. 6 and 7, two schematics illustrate the spatial relationships between a plurality of magnetic sensors **61** and **62**, and pipeline features **200** and **201**. For simplicity's sake, other components which may be contained alongside the sensors **61** and **62** in magnetic sensor assemblies **51** and **52** are not shown. The distance between a near-wall magnetic sensor **61** and an internal or external pipeline feature **200** or **201** is d_1, and the distance between an offset magnetic sensor **62** and an internal or external pipeline feature **200** or **201** is d_2.

[0032] The pipeline wall has thickness t. The magnetic amplitude A_1 at the near-wall magnetic sensor **61** is proportional to:

[0033] $A_1 \propto \frac{1}{d_1^3}$,

[0034] and the magnetic amplitude A_2 at the offset magnetic sensor **62** is proportional to:

[0035] $A_2 \propto \frac{1}{d_2^3}$.

[0036] The radial position (internal-external position) of the feature can be determined by calculating the ratio of the amplitudes $R = A_2/A_1$. For an external feature **201**, the distances r_1 and r_2 are similar, whereas for an internal feature **200**, d_1 is much less than d_2. Thus, the ratio for external features R_{ext} will be somewhat greater than the ratio R_{int} for internal features is:

[0037] $R_{ext} > R_{int}$

[0038] Using some typical dimensions, one can calculate the expected values of R for internal and external features. The following numbers are provided by way of example only and not by limitation. Depending on factors such as the configuration of the in-line inspection device **10**, the pipeline size, the dimensions may vary.

$t = 6.35$ mm	Pipe wall thickness.
$z_1 = 3$ mm	Distance of near-wall magnetic sensor **61** above the pipe wall
$z_2 = 6$ mm	Distance of offset magnetic sensor **62** above the pipe wall
$x_1 = 3$ mm	Horizontal distance of the feature from near-wall magnetic sensor **61**
$x_2 = 3$ mm	Horizontal distance of the feature from the offset magnetic sensor **62**

[0039] From these example numbers, the distances d_1 and d_2 for an internal feature **200** and an external feature **201** can be calculated. For the internal feature **200**,

[0040] $d_1 = \sqrt{z_1^2 + x_1^2} = \sqrt{3^2 + 3^2} = 4.243$ mm,

[0041] and

[0042] $d_2 = \sqrt{z_2^2 + x_2^2} = \sqrt{6^2 + 3^2} = 6.708$ mm.

[0043] Thus for an internal feature **200**, the ratio of the amplitudes recorded by the offset magnetic sensor **62** to the near-wall magnetic sensor **61** is:

[0044] $R_{int} = \frac{4.243^3}{6.708^3} = 0.2530$

[0045] For the external feature **201**,

[0046] $d_1 = \sqrt{(z_1 + t)^2 + x_1^2} = \sqrt{9.35^2 + 3^2} = 9.819$ mm,

[0047] and

[0048] $d_2 = \sqrt{(z_2 + t)^2 + x_2^2} = \sqrt{15.35^2 + 3^2} = 12.709$ mm.

[0049] Thus for an external feature **201**, the ratio of the amplitudes recorded by the offset magnetic sensor **62** to the near-wall magnetic sensor **61** is:

[0050] $R_{ext} = \frac{10.170^3}{15.862^3} = \frac{1051.9}{3990.9} = 0.4612$

[0051] As the example calculation illustrates, the ratio, R, of the amplitude recorded by the offset magnetic sensor **62** to the amplitude recorded by the near-wall magnetic sensor **61** is lower for internal features when compared to the ratio for external features.

[0052] This effect is increased if the feature to be analyzed is directly below the sensors such that $x_1 = 0$ and $x_2 = 0$.

[0053] $R_{ext}(x = 0) = 0.434$

[0054] $R_{int}\,(x = 0) = 0.125$

[0055] At the sensor location which records the maximum signal from a single feature, if $R < 0.36$, then the feature may be interpreted as being an internal metal-loss feature. If $R \geq 0.36$, then the feature is external.

[0056] FIGS. 8 and 9 are example graphs which show the magnetic amplitudes obtained by a near-wall sensor **61** and an offset sensor **62** for an internal feature **200** and external feature **201**, respectively. Depending on the distance between a feature **200** or **201** and a sensor **61** or **62**, and the characteristics of a feature **200** or **201**, the magnitude and relative ratios of the magnetic amplitudes may vary. For the example graphs, the values of R_{int} and R_{ext} can be calculated to be:

[0057] $R_{int} = 0.333$

[0058] and

[0059] $R_{ext} = 0.4621$

[0060] As R_{int} is less than 0.36 and R_{ext} is greater than 0.36, the values show that the radial position of a feature **200** or **201** can be determined by examining the ratio of the amplitudes recorded by the offset magnetic sensor **62** to the near-wall magnetic sensor **61**.

[0061] Referring to FIG. 10, an example of a method for generating, acquiring, and processing signals from a plurality of magnetic and position sensor assemblies is illustrated. In step **1000**, the in-line inspection device **10** is enabled to travel inside a pipeline by using a fluid pressurize the pipeline and push the device **10** through **41** In step **1010**, one or more odometers **14** supply continuous position signals to an odometer circuit **43**, which may be used to determine chainage (i.e. the distance from launch) . In an alternative embodiment, chainage may instead be determined by an inertial navigation unit, not shown in the figures. In step **1020**, a plurality of magnet assemblies **22A** and **22B** create a magnetic field strong enough to substantially saturate the circumferential length of pipe in between them. In step **1030**, the magnetic assemblies **22A** and **22B** generate signals as they detect magnetic flux leakage caused by pipeline features. According to one embodiment, in step **1040**, the individual signals are acquired, processed, and analyzed by the sensor process circuit **42** in order to determine information about a feature, such as its size, and shape, radial position, and clock position. In step **1050**, the information from the sensor process circuit **42** and the odometer circuit **43** are combined and processed in the signal processing and output circuit **44**. In step **1060**, the processed data from step **1050** is recorded by a recorder **45**. In an alternative embodiment, step **1040** may involve the sensor process circuit only acquiring and storing the data, leaving the analysis to be performed at a later stage after the pipeline inspection, following step 1060. This analysis stage may be completed by a combination of software and human analysts to detect and characterize a pipeline's features.

[0062] While the above examples discuss particular sensor technologies such as Hall effect and Eddy current sensors, it can be appreciated that the principles discussed herein may also be applied to other technologies, such as magneto-diode, magneto-transistor, AMR magnetometer, GMR magnetometer, magnetic tunnel junction magnetometer, magneto-optical sensor, Lorentz force based MEMS sensor, Electron Tunneling based MEMS sensor, MEMS compass, Nuclear precession magnetic field sensor, optically pumped magnetic field sensor, fluxgate magnetometer, search coil magnetic field sensor and SQUID magnetometer, etc.

[0063] For simplicity and clarity of illustration, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the examples described herein. However, it will be understood by those of ordinary skill in the art that the examples described herein may be practiced without these specific details. In other instances, well-known methods, procedures and components have not been described in detail so as not to obscure the examples described herein. Also, the description is not to be considered as limiting the scope of the examples described herein.

[0064] It will be appreciated that the examples and corresponding diagrams used herein are for illustrative purposes only. Different configurations and terminology can be used without departing from the principles expressed herein. For instance, components and modules can be added, deleted, modified, or arranged with differing connections without departing from these principles.

[0065] For example, it will be appreciated that while certain examples described above are in the context of a “free-swimming” inspection device **10**, i.e., that which operates autonomously inside a pipe by being pushed along through the pipe by the fluid inside; the principles discussed herein can also be applied to tethered inspection devices (referred to as “tethered pigs” in the art), which maintain a continuous connection with units outside of the pipe, to control, power, and propel the inspection device.

[0066] It will also be appreciated that any module or component exemplified herein that executes instructions may include or otherwise have access to computer readable media such as storage media, computer storage media, or data storage devices (removable and/or non-removable) such as, for example, magnetic disks, optical disks, or tape. Computer storage media may include volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data. Examples of computer storage media include RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by an application, module, or both. Any such computer storage media may be part of the inspection device **10**, any component of or related thereto, etc., or accessible or connectable thereto. Any application or module herein described may be implemented using computer readable/executable instructions that may be stored or otherwise held by such computer readable media.

[0067] The steps or operations in the flow charts and diagrams described herein are just for example. There may be many variations to these steps or operations without departing from the principles discussed above. For instance, the steps may be performed in a differing order, or steps may be added, deleted, or modified.

[0068] Although the above principles have been described with reference to certain specific examples, various modifications thereof will be apparent to those skilled in the art as outlined in the appended claims.

Claims:

1. An in-line inspection device to be used in identifying and characterizing features of a metallic pipe structure through which it passes, the in-line inspection device comprising:

a body for travelling inside the pipe structure; and

an instrument apparatus supported by the body, the instrument apparatus comprising a plurality of armatures arranged parallel to each other and positioned circumferentially around the body, a pair of magnetic members of opposing polarities supported at either end of each armature to magnetically saturate a portion of the pipe structure therebetween, and a head assembly positioned between each pair of magnetic members:

a first magnetic sensor assembly to detect signals generated by the magnetic members; and

a second magnetic sensor assembly to detect signals generated by the magnetic members, the second magnetic sensor assembly being offset from the first magnetic sensor assembly to be further from an inner surface of the pipe structure than the first magnetic sensor assembly.

2. The device of claim 1, further comprising:

a plurality of annular cups supported by the body, which center the inspection device and allow the device to be pushed in the direction of fluid flow within the pipe structure.

3. The device of claim 1, further comprising:

at least one odometer to measure the distance travelled by the inspection device.

4. The device of claim 1, further comprising a signal processor for analyzing signals obtained by the magnetic sensor assemblies to determine characteristics about the features of the pipe structure.

5. The device of claim 1, wherein radial positions of the plurality of instrument assemblies are adjustable to conform to variances in the interior pipe dimensions as the device moves through the pipe structure.

6. The device of claim 1, wherein the magnetic sensor assemblies contain Hall-effect sensors.

7. The device of claim 1, further comprising at least one additional magnetic assemblies.

8. The device of claim 1, wherein the device is propelled by either fluid in the pipe structure, or by a tethered system.

9. A method of identifying and characterizing features of a metallic pipe structure comprising:

introducing an in-line inspection device into the pipe structure;

having the in-line inspection device travel within the pipe structure;

generating, by a plurality of magnetic assemblies, a magnetic field to magnetically saturate a portion of the pipe through which the in-line inspection device is passing;

detecting and collecting, by a plurality of near-wall and offset magnetic sensor assemblies, magnetic flux leakage signals;

providing the magnetic flux leakage signals to a signal processor; and

using the signal processor to process the provided signals.

10. The method of claim 8, further comprising providing processed data to a data recorder.

11. The method of claim 8, further comprising generating, by at least one odometer, position signals and providing the positions signals to an odometer circuit.

12. The method of claim 8, wherein the magnetic flux leakage signals are processed to determine at least one characteristic of the pipe structure that can discriminate between inner diameter and outer diameter defects.

13. The method of claim 9, wherein the inspection device is propelled by either fluid in the pipe structure, or by a tethered system.

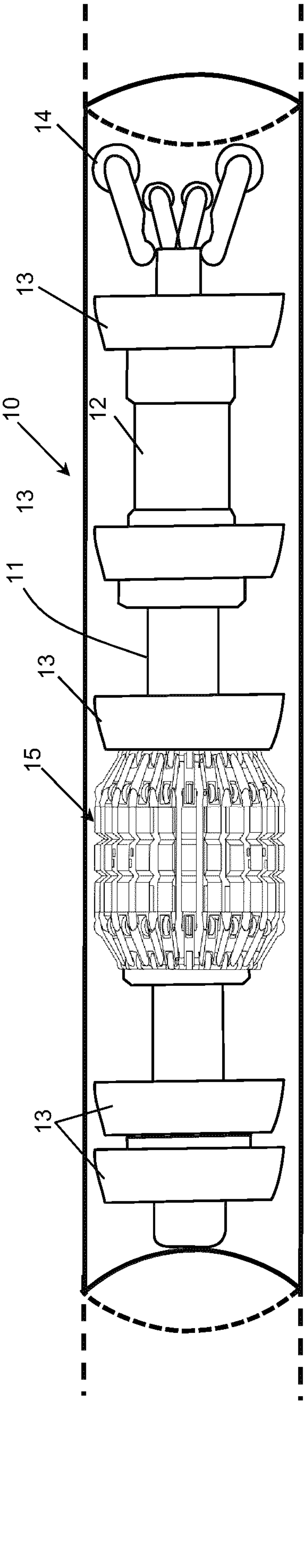
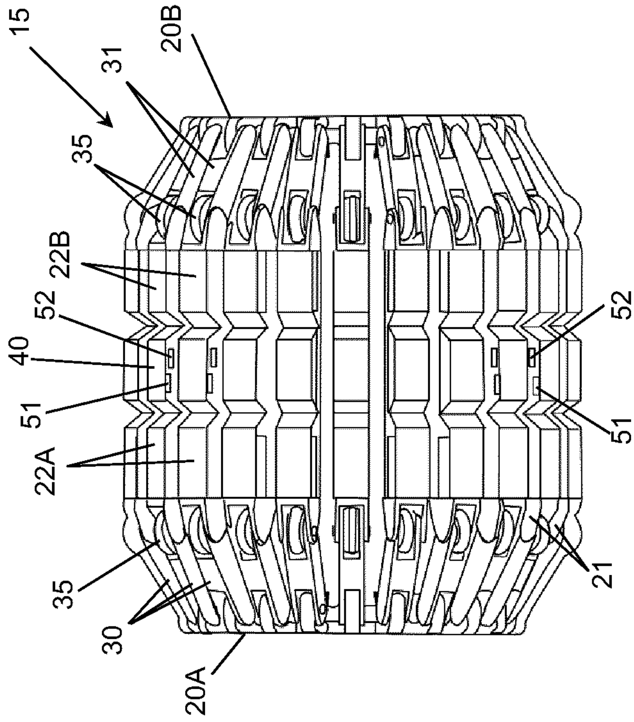


FIG. 1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52
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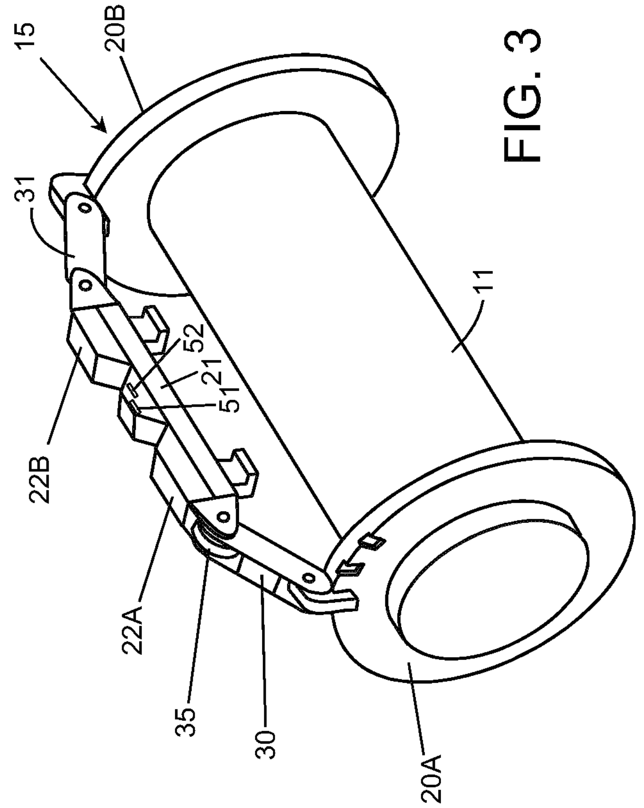
FIG. 2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22B
11
22A
35
30
20A

FIG. 3

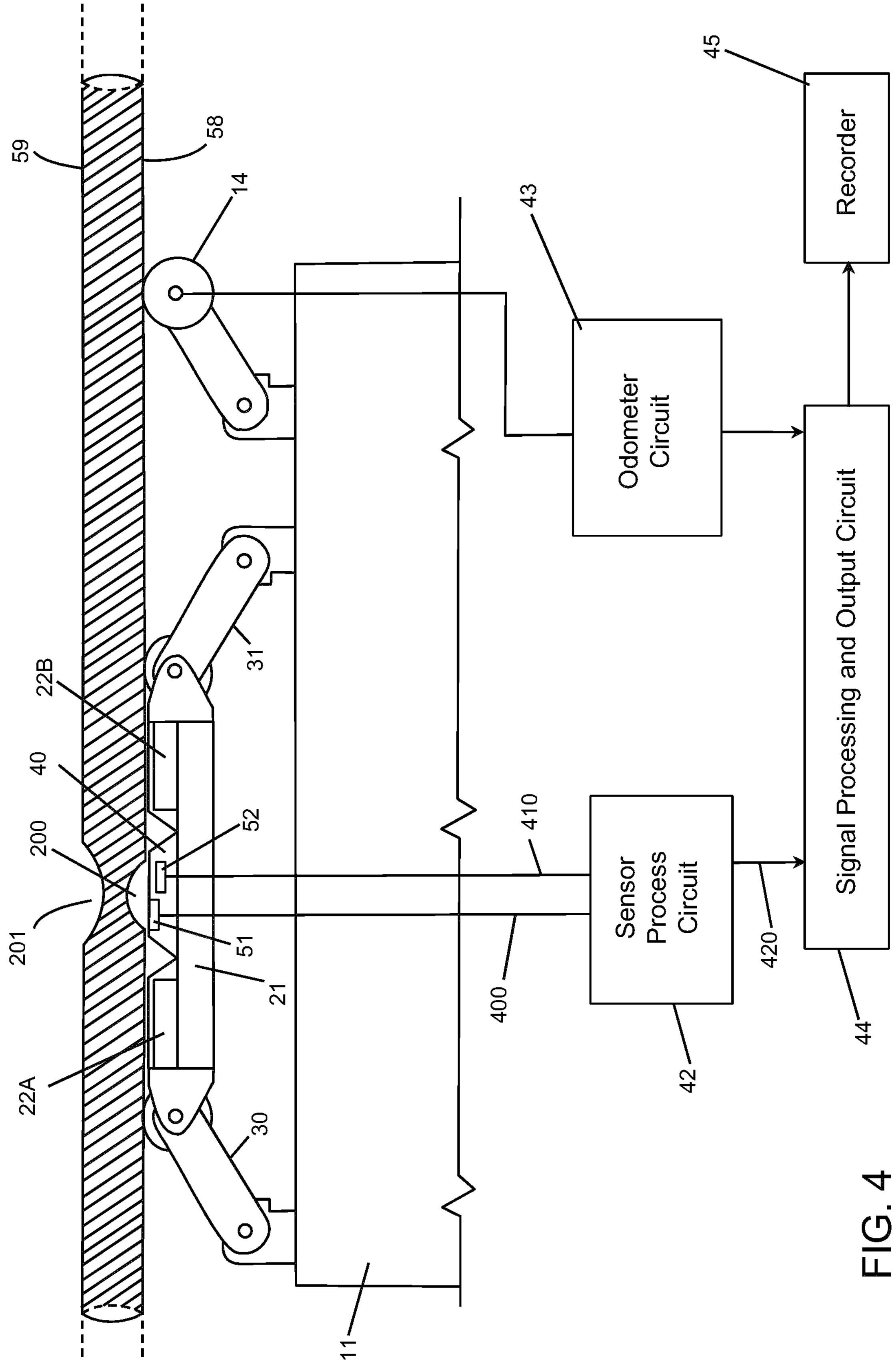

59
58
14
43
45
Recorder
Odometer Circuit
Signal Processing and Output Circuit
Sensor Process Circuit
22B
40
200
201
52
51
31
410
400
420
21
22A
30
11
42
44

FIG. 4

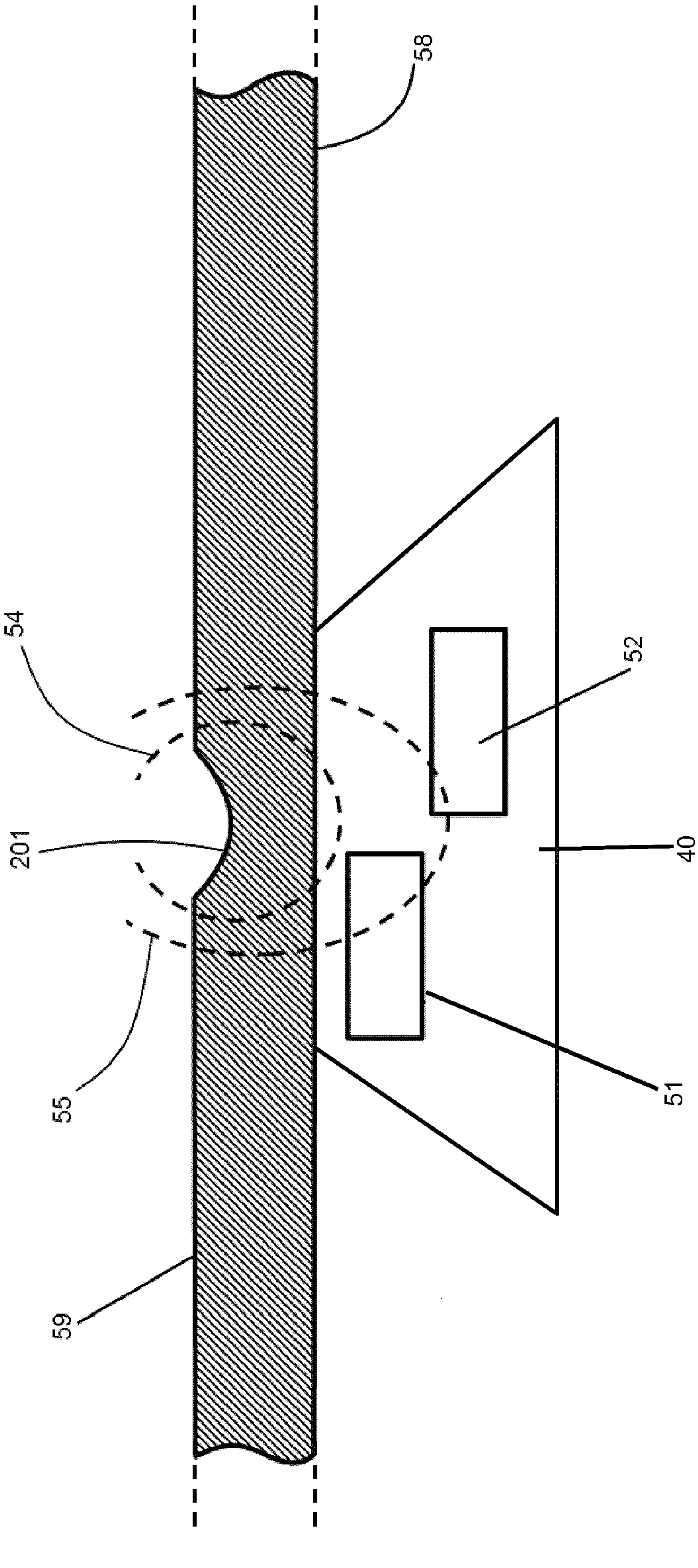


FIG. 5

FIG. 7

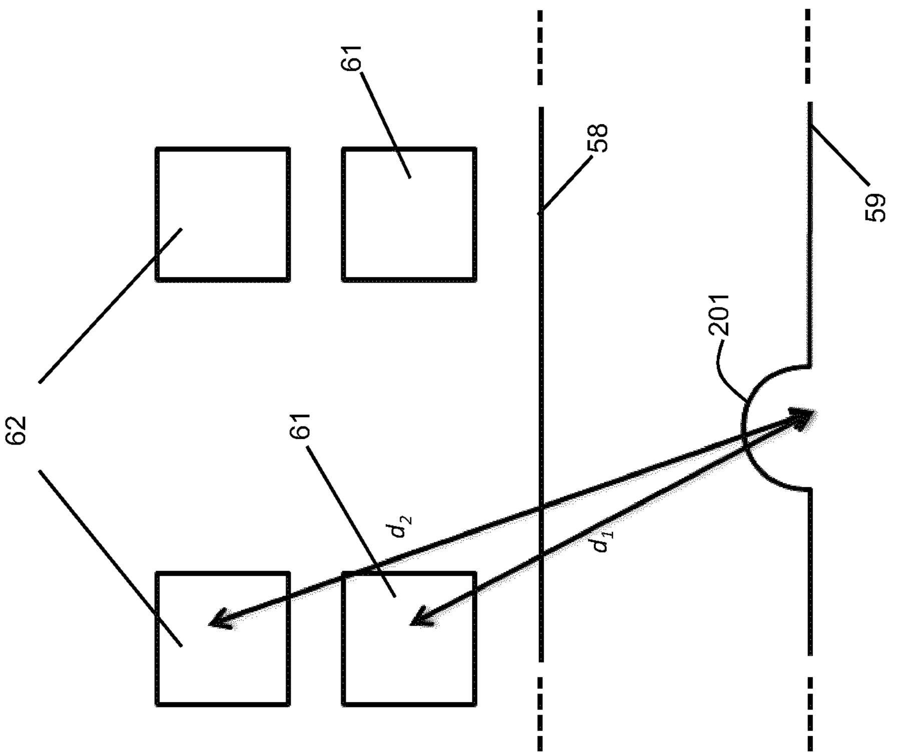


FIG. 6

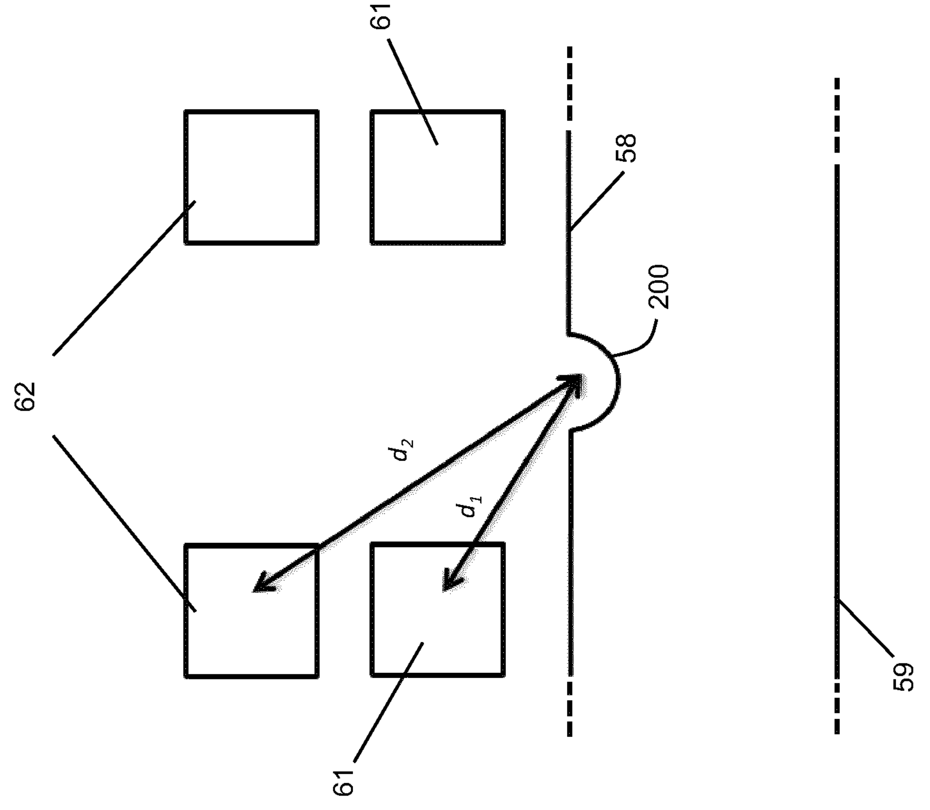


FIG. 8

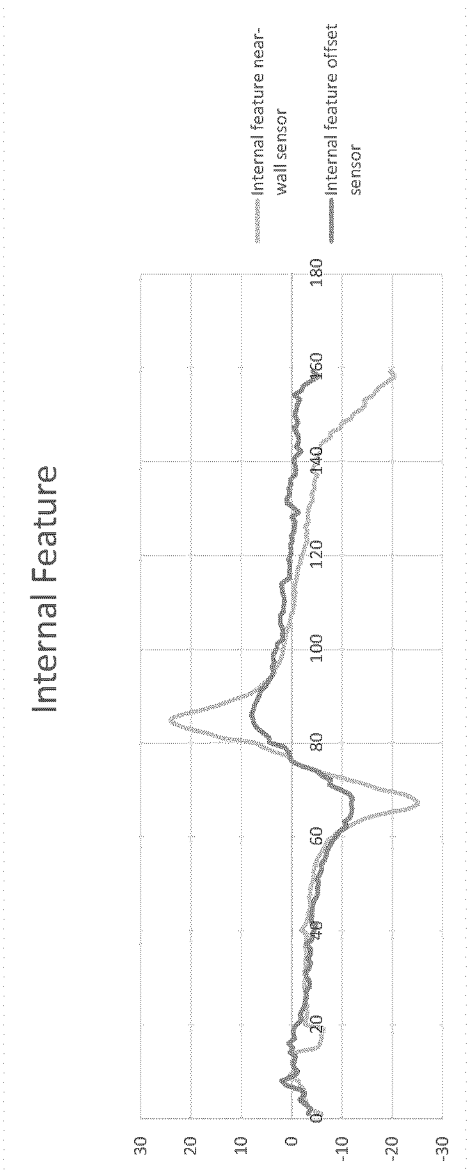
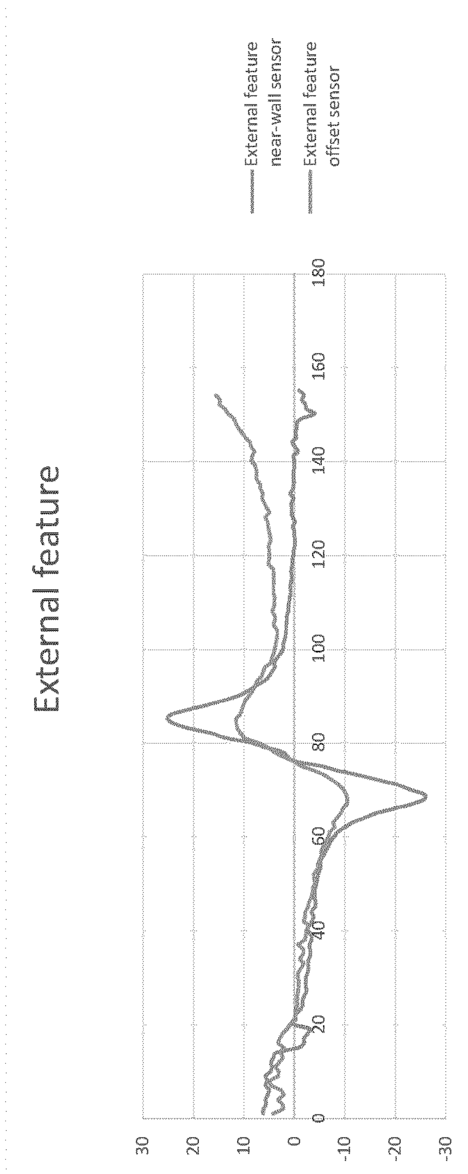

Internal Feature
Internal feature near-wall sensor
Internal feature offset sensor
30
20
10
0
-10
-20
-30
0
20
40
60
80
100
120
140
160
180

FIG. 9


External feature
External feature near-wall sensor
External feature offset sensor
30
20
10
0
-10
-20
-30
0
20
40
60
80
100
120
140
160
180

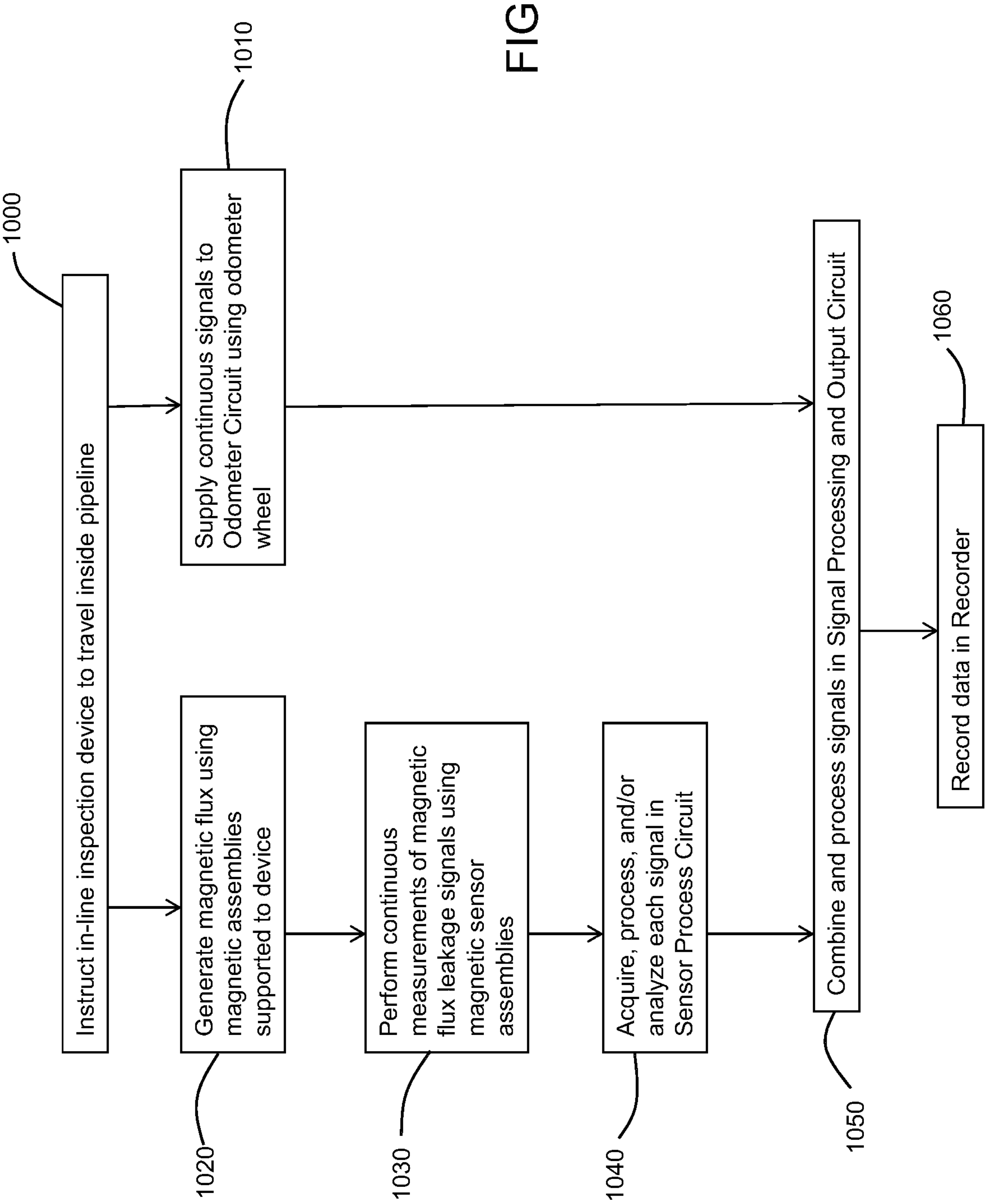

1000
Instruct in-line inspection device to travel inside pipeline
1010
Supply continuous signals to Odometer Circuit using odometer wheel
1020
Generate magnetic flux using magnetic assemblies supported to device
1030
Perform continuous measurements of magnetic flux leakage signals using magnetic sensor assemblies
1040
Acquire, process, and/or analyze each signal in Sensor Process Circuit
1050
Combine and process signals in Signal Processing and Output Circuit
1060
Record data in Recorder

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2017/050579

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***G01N 27/83*** (2006.01) , ***G01R 33/07*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: ***G01N*** (2006.01) , ***G01R*** (2006.01) (using keywords)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Canadian Patent Database, Espacenet, Google, Questel Orbit, United States Patent Database (USPTO).
Keywords: armatures, magnetic, metal, pipe, sensor, signal.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6847207 (William et al.) 25 January 2005 (25-01-2005) - abstract - col. 2, line 37 - col. 8, line 7	1-8
A	US 20110167914 (Earle et al.) 14 July 2011 (14-07-2011) - see entire document	1-8
A	US 5351564 (Kenneth et al.) 4 October 1994 (04-10-1994) - see entire document	1-8

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search
07 August 2017 (07-08-2017)

Date of mailing of the international search report
18 August 2017 (18-08-2017)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
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50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 819-953-2476

Authorized officer
Tung Nguyen (819) 639-8246

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5336998 (Kenneth et al.) 9 August 1994 (09-08-1994) - see entire document	1-8

Box No. II **Observations where certain claims were found unsearchable (Continuation of item 2 of the first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III **Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet (see page 6)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claim Nos.:

4. ☑ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim Nos.:

1-8

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

There are 2 inventions claimed in the international application covered by the claims indicated below:

Group A: Claims 1-8 are directed to an in-line inspection device comprising a body, an instrument apparatus, and first and second magnetic sensor assemblies.

Group B: Claims 9-13 are directed to a method of identifying and characterizing features of a metallic pipe structure comprising the steps of detecting and collecting magnetic flux leakage signals, and providing the signals to a signal processor, wherein using the signal processor to process the provided signals.

It is considered that **the international application does not comply with the requirements of unity of invention** (Rules 13.1, 13.2 and 13.3) since the inventions listed as **Groups A and B** do not relate to a single inventive concept under PCT Rule 13.1 and they lack the same or corresponding technical features under PCT Rule 13.2.

Patent Document Cited in Search Report	**Publication Date**	**Patent Family Member(s)**	**Publication Date**
US6847207B1	25 January 2005 (25-01-2005)	AU2005238857A1	10 November 2005 (10-11-2005)
		AU2005238857B2	18 February 2010 (18-02-2010)
		BRPI0509943A	25 September 2007 (25-09-2007)
		CA2560749A1	10 November 2005 (10-11-2005)
		CN1942762A	04 April 2007 (04-04-2007)
		CN100523801C	05 August 2009 (05-08-2009)
		EP1735612A1	27 December 2006 (27-12-2006)
		EP1735612A4	10 June 2009 (10-06-2009)
		MXPA06011921A	25 January 2007 (25-01-2007)
		NO20064779A	27 December 2006 (27-12-2006)
		RU2006140242A	20 May 2008 (20-05-2008)
		RU2364860C2	20 August 2009 (20-08-2009)
		WO2005106451A1	10 November 2005 (10-11-2005)
US2011167914A1	14 July 2011 (14-07-2011)	AU2009263848A1	30 December 2009 (30-12-2009)
		AU2009263848B2	13 November 2014 (13-11-2014)
		CA2729223A1	30 December 2009 (30-12-2009)
		CN102159944A	17 August 2011 (17-08-2011)
		CN102159944B	01 April 2015 (01-04-2015)
		EP2294399A2	16 March 2011 (16-03-2011)
		EP2294399A4	21 September 2016 (21-09-2016)
		MX2011000174A	20 June 2011 (20-06-2011)
		RU2010153150A	10 August 2012 (10-08-2012)
		RU2014119256A	20 November 2015 (20-11-2015)
		WO2009156862A2	30 December 2009 (30-12-2009)
		WO2009156862A3	11 March 2010 (11-03-2010)
US5351564A	04 October 1994 (04-10-1994)	CA2074120A1	20 January 1993 (20-01-1993)
		CA2074120C	17 September 1996 (17-09-1996)
		DE69200649D1	15 December 1994 (15-12-1994)
		DE69200649T2	09 March 1995 (09-03-1995)
		EP0523880A1	20 January 1993 (20-01-1993)
		EP0523880B1	09 November 1994 (09-11-1994)
		ES2066559T3	01 March 1995 (01-03-1995)
		GB9115668D0	04 September 1991 (04-09-1991)
		GB2257788A	20 January 1993 (20-01-1993)
		HK1006996A1	26 March 1999 (26-03-1999)
		JPH05188040A	27 July 1993 (27-07-1993)
		JPH0814574B2	14 February 1996 (14-02-1996)
US5336998A	09 August 1994 (09-08-1994)	None	