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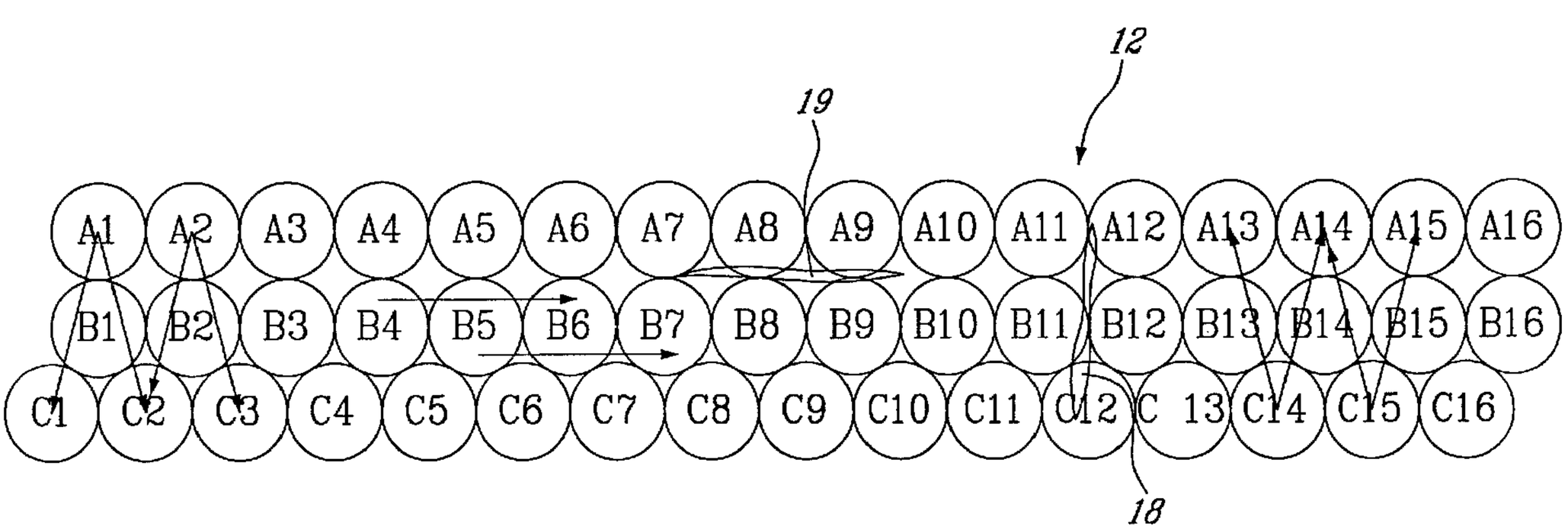
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In an eddy current testing probe, efficiency is improved by reusing coils in different measurement configurations in order to provide a higher density of inspection coverage.

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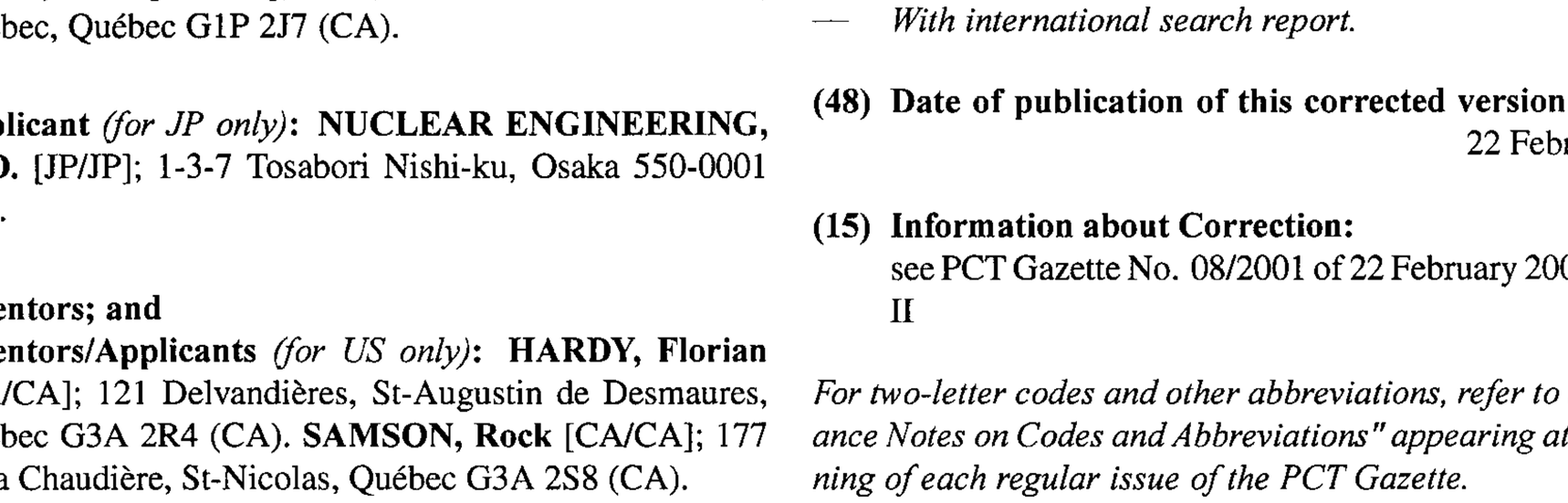
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(54) Title: EDDY CURRENT TESTING WITH COMPACT CONFIGURATION



(57) Abstract: In an eddy current testing probe, efficiency is improved by reusing coils in different measurement configurations in order to provide a higher density of inspection coverage.

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EDDY CURRENT TESTING WITH COMPACT CONFIGURATION

Field of the Invention

The present invention relates to non-destructive testing of conductive materials, namely eddy-current testing. More particularly, the invention relates to methods of using eddy current testing (ECT) probes and to the probes themselves, for example of the type suitable for inspecting heat exchanger tubes.

Background of the Invention

ECT probes are well known in the art, and have various configurations depending on the nature of the material being tested. Some ECT probes are adapted for testing planar surfaces, others for testing tubes. In the case of tubes, both the interior and the exterior may be tested, and the probes are suitably adapted accordingly. ECT probes, in the case of heat exchanger tube inspection probes for inspecting the insides of heat exchanger tubes, have a probe head with coils for inducing and detecting eddy currents in the conductive material being tested. Coils may be configured in arrangements known as "bracelets" of coils, namely series of coils on the circumferential surface of the probe head. A bracelet may be provided as circumferential bands consisting of many coils.

The instrumentation for ECT consists of the probe including the probe head having the coils, signal generator and receiver equipment, the cabling connecting the probe to the signal generator and receiver equipment, and the signal analyzer equipment for analyzing the data and providing an indication of faults in the material being tested. The probe and cabling is typically subjected to extreme industrial environments which place considerable physical stress on the equipment. In the case of tube inspection, the cabling includes often a flexible shaft or tube for inserting the probe into the heat exchanger tubes, and the electrical signal conductors must therefore be durable, reliable and as thin as possible to fit inside the flexible shaft, and also to lessen the burden of cable manipulation from the signal processing equipment and the probe.

A common ECT technique to inspect tubes is to use a bobbin coil. This type of probe examines an entire cross-section of the tube at once. The difficulty is to detect small volume flaws, long axial flaws, and circumferential flaws, anywhere on either the inside or outside of the tube, and especially where the tubes are expanded.

An improved technique to the detect flaws described above is the use of probes that use one or a few small rotating coil, scanning the surface of the tube. The small coil or coils only look at a small portion of the tube surface at any given time, increasing sensitivity. Because of the mechanical rotation, such probes are typically slow.

The use of an array of coils, such as a bracelet, ensures that only small surface areas are inspected with each coil, resulting in sensitivity similar to that of the rotating probes, but without requiring mechanical rotation. Array probes, when coupled with adequate data acquisition systems provide excellent sensitivity at much greater speeds than rotating probes.

Summary of the Invention

It is an object of the present invention to provide an ECT probe which overcomes many of the drawbacks associated with known ECT probes.

More particularly, it is an object of the present invention to provide an ECT probe which uses an arrangement of coils in different measurement configurations so as to involve coil reuse. By “coil reuse”, it is meant that at least one coil from one measurement configuration is also used in another measurement configuration with at least some different coils. According to this aspect of the invention a coil may be used during one measurement as a transmit coil, and during a subsequent measurement as a receive coil. Likewise, one of two coils in a differential mode configuration during one measurement may be used in a subsequent measurement in a differential mode configuration with a different other coil, or as an absolute coil. Preferably, an array of closely arranged coils is provided and the coils are used in different measurement configurations, so as to detect faults in the surface of the material being tested in a greater number of positions (i.e. a higher density of inspection coverage), and possibly directions.

Preferably, the number of conductors connecting the probe coils to the instrumentation is reduced by selectively connecting coils to conductors at the probe end (or routing coil signals onto conductors). Preferably, such selective connection is done using a multiplexer switch controlled by a selection signal. Using solid state switches high selection rates are possible, and high speed scanning is possible.

Preferably, coils not being used in a measurement are disconnected or isolated using devices, such as separate solid state switches.

According to a broad aspect of the invention, there is provided a method of detecting faults in a conductive material to be tested using eddy currents, the method comprising:

a) providing a probe head having an arrangement of coils arranged on a surface of the probe to induce eddy currents in the conductive material to be tested, wherein the arrangement allows the probe to cover an area transverse to a direction of displacement of the probe head during inspection;

b) selectively exciting one of the coils with an AC source to induce an eddy current in the material;

c) measuring eddy current flow in the conductive material to be tested using at least one of said coils;

d) repeating steps b) and c) to cover the area transverse to the direction of displacement in different measurement configurations in which at least one of:

i. one of the coils used as a receiver coil is reused as a driven coil;

ii. the excited one of the coils is reused as a receiver coil;

iii. one of two or more coils used as receiver coils in a differential mode is used as a receiver coil with a different other receiver coil.

Brief Description of the Drawings

The invention will be better understood by way of the following detailed description of a preferred embodiment with reference to the appended drawings, in which:

Fig. 1 is a schematic block diagram of the ECT probe system according to the preferred embodiment;

Fig. 2 is a diagram illustrating the layout of coils according to the preferred embodiment including an illustration of a first axial or longitudinal fault or crack in the surface of the material being inspected, as well as a second tangential or lateral fault or crack;

Fig. 3 is a perspective view of a probe head adapted for inspecting boiler tubes, the probe head having two rows of coils;

Fig. 4 is a perspective view of a probe head similar to Fig. 3, except with one row;

Fig. 5 is a perspective view of a probe head similar to Fig. 3, except with three rows;

Fig. 6 is a perspective view of a probe head similar to Fig. 5, except with the last row staggered with respect to the second row;

Fig. 7 is a perspective view of a probe head similar to Fig. 5, except that the middle row has larger coils than the first and third rows;

Fig. 8 is a block diagram of a switching circuit connecting transmit coils to a single transmit conductor and receiver coils to a single receiver conductor;

Fig. 9 is a block diagram of a switching circuit connecting a row of coils to a single transmit conductor and also to a single receive conductor;

Fig. 10 is a block diagram of a switching circuit connecting a middle row of coils to a single transmit conductor and to two receive conductors, and also top and bottom rows of coils to top and bottom row receiver conductors;

Fig. 11 is a block diagram of a signal processor computing a pseudo-differential signal from a stored receiver coil signal and a subsequently obtained receiver coil signal;

Fig. 12 is a signal diagram illustrating the transmit signal, the first stored receiver coil signal, the subsequently obtained receiver coil signal, and the calculated pseudo-differential signal; and

Fig. 13 is a plan view of an arrangement of coils according to an alternative embodiment.

Detailed Description of the Preferred Embodiment and Other Embodiments

In the preferred embodiment, a number of advantageous features provided according to the invention are combined into a single ECT probe system. In the preferred embodiment, the probe is a heat exchanger tube inspection probe, although the invention may be applied to other types of ECT probes as will be apparent to those skilled in the art.

Fig. 1 illustrated a system block diagram of a probe having a configuration according to the invention. The coils are arranged according to Fig. 2 in a bracelet array having three rows of 16 coils designated by reference numeral 12. In the preferred embodiment, the coils 12 are circular coils having a central axis. The filament wires of the coils are small and the coils are mounted in the probe body such that the coils are protected against filament breakage due to shock. It will be appreciated that non-circular core windings may replace coils in certain applications without adversely affecting the induction of eddy currents in the material being tested. In the preferred embodiment, the coils are arranged parallel to the surface, i.e. their axes are perpendicular to a plane of the surface of the material. Each coil 12 can be connected to either the transmit signal conductor 20 or the receiver conductor 22 via the transmit driver multiplexer switching device 14 or the receiver signal multiplexer switching device and amplifier 16, respectively. In the preferred embodiment, the cable bus connecting the probe head to the instrumentation contains separate coax cables for conductors 20 and 22, as well as a 5V DC power line and ground, a transmit coil selector bus 24, and a receiver coil selector bus 26. These conductors are bundled into a protective harness sheath and inserted into a flexible tube shaft of the probe.

The selector buses 24 and 26 are preferably single wire serial bus wires. In the preferred embodiment, the buses 24 and 26 comprise a single toggle or pulse control wire. In the case of a serial bus, it is preferred to provide the probe head with a controller having a serial interface, thus combining buses 24 and 26 into one. When the electronics at the probe head need to be reduced to conserve space, a pulse control may be more suitable. In pulse control, the selector signal acts as a clock signal for a simple digital circuit which outputs a signal on each of the 16 coil select gate signals, sequentially one-by-one.The buses 24 and 26 may alternatively comprise multiple wires to provide a parallel

bus. The parallel bus may be a static control bus in which the logic signals on the wires control the switching devices directly. The wires in buses 24 and 26 may be smaller than the signal conductors 20 and 22 since they carry logic signals or lower frequency AC signals.

As shown in Fig. 2, some of the coils 12 function both as receiver coils and transmitter coils at different times for different measurements. The coils 12 arranged on the circumferential surface of the cylindrical probe to be substantially parallel to the surface of the conductive material being inspected. The transmit coil (or spaced apart transmit coils) induces a current in the material being tested, which current circulates in the material around the center of the transmit coil. The alternating current in the material then induces a current in nearby receiver coils. A crack or fault in the material typically causes different electrical conductivity properties, and detection of faults is possible due to this phenomenon. Current in the material passes around cracks, and consequently, it is easier to detect an elongated crack using current flowing transversely to the crack. Current directed in the direction of a narrow crack will go around the crack with little resistance. For this reason, the detection of the eddy current is done in two different directions, namely axially and circumferentially. To detect an axial crack 18, the receiver coils are selected to be circumferentially adjacent to one another, and the receiver coils are operated preferably in a differential or pseudo-differential mode. To detect a circumferential crack 19, the receiver coils are selected to be axially or longitudinally adjacent.

It is also possible to provide a coil oriented with its axis parallel to the plane of the surface of the material being tested. This alternative embodiment is illustrated in Fig. 13 in plan view, in which a close arrangement of coils at right angles to one another is illustrated. The current induced in the material then flows along a segment extending adjacent the edge of the coil near the surface, and then branches out into two side lobes connecting the ends of the segment. In such a configuration, an obstruction to the current flow in the area of the segment results in a change in impedance in the coil, and the detection of the obstruction is achieved by comparing the impedance of the coil in different orientations. This can be done either by rotating the coil (not shown), or by providing coils in different fixed orientations within substantially the same region

of the probe, as shown in Fig. 13. In this embodiment, elements 16 and 22 as shown in Fig. 1 are not used, and instead the instrumentation generating the transmit AC signal 20 measures the impedance of coils 12 directly.

As can be seen from Fig. 2, the choice of transmit coil and receiver coil from the matrix of coils 12 is freely selected by selector signals 22 and 24. In the preferred embodiment, the receiver coil is a single coil instead of a receiver coil pair. Therefore, the receiver coil signal is read and stored for a first of two receiver coils, and then the selector signal 24 is used to select the other of the two receive coils whose signal is read. Instead of using two differentially connected receiver coils, the invention allows each of two coils to be read separately in time, and then a pseudo-differential signal to be obtained by processing at the instrumentation. Pseudo-differential signal detection has been found to be satisfactory. Alternatively, the switching device 16 could be made to connect two coils simultaneously in differential mode to its amplifier. The number of coils switches may be doubled or may remain the same depending on the coil arrangement geometry and system flexibility. It is also possible to have separate output signals for two receiver coils, and to connect such output signals in a simultaneous differential mode at the instrumentation.

According to the invention, the instrumentation controls the coil selector signals to measure eddy currents using a particular measurement configuration for a brief period of time before electronically changing the selected coils to a new measurement configuration. All desired measurement configurations are thus employed to take measurements of the surface of the material being tested within a relatively short period of time. This period of time is sufficiently short, compared to the probe travel speed and defect sizes, so that one set of measurements are made at substantially the same axial location on the tube. Rotation of the probe head is thus not required. Both circumferential and axial cracks are detected because the measurement configurations cover both directions of receiver coils. Because the coils cover a sufficiently small area, any significant crack will not be missed. Because of the reuse of coils, a higher density of detection is provided than with conventional coil bracelet systems.

In the preferred embodiment shown in Fig. 2, the middle row contains the coils which can be driven or excited to transmit and also selectively connected to

receive. The outer row A is aligned in the axial direction of the probe with row B, while row C is offset and close packed with respect to the middle row B. When row A transmits, row C receives, and vice versa, as shown by the arrows. In the mode for detecting axial cracks or faults, a driven coil from row A emits while a pair of coils in row C receive, or a driven coil from row C emits while a pair of coils in row A receive. In this arrangement, the receiver coils are spaced from the transmit coil by one coil. Likewise, in the circumferential mode, a transmit coil is selected from row B and a receiver coil is taken as the second coil over on the same row, as shown by the arrows. Of course, two receiver coils, one from each side, may be read simultaneously. Each coil in row B may be used to transmit and cover with the greatest detail the surface of the material being inspected. It will be appreciated that a differential pair of coils can also be used for detecting circumferential cracks 19, and in fact the number of coil detection configurations is very large.

In the preferred embodiment, there are multiple receive conductors 22, and more than one coil is excited to transmit at the same time. It is important that excited coils be separated by a good distance to avoid inductive influence between them. However, depending on the capacity of instrumentation to process multiple signals and the dimensions of the probe, it is desirable to excite as many non-interfering coils as possible to measure eddy currents as quickly as possible.

It will be appreciated that various probe head configurations are possible according to the present invention. In the embodiment of Fig. 3, a probe head is shown having two rows of coils wherein the second row is staggered with respect to the first row. The second row is connected by a multiplexer switch to the transmit conductor 20 only, and is thus dedicated to transmission. The first row is connected by a multiplexer switch to a single receiver conductor 22, and is thus dedicated to receiving. The circuit block diagram for this embodiment is illustrated in Fig. 8.

In the embodiment of Fig. 4, a single row of coils is provided which is connected by multiplexer 14' to conductor 20 and by multiplexer 16' to conductor 22. This embodiment illustrates a simpler configuration involving both coil reuse

and the use of a single conductor 20 and 22 for all coils. The circuit block diagram for this embodiment is illustrated in Fig. 9.

The embodiment of Fig. 5 makes use of three rows of coils 12, in which the transmit multiplexer 14' is connected to the middle row, and the receiver multiplexer and amplifier 16 comprises a first multiplexer 16a for the first top row of coils, second and third multiplexers 16b and 16c for the middle row, and a fourth multiplexer 16d for the bottom row. This allows for a measurement configuration consisting of a central transmit coil surrounded by four receiver coils. Each coil in the middle row is used as the transmit coil, one after the other, to test the entire inside circumference of the tube. The circuit block diagram for this embodiment is illustrated in Fig. 9.

In the embodiment of Fig. 6, the last row is staggered and is used for differential detection of axial cracks. Two receiver multiplexers are thus connected to the last row for outputting two receiver signals on conductors 22 and 22'. The transmit signal is connected to either the first or the second row of coils. In the preferred embodiment, a coil in the first row transmits while two coils in the third row receive signals for differential detection of axial cracks. This places a separation of one coil between the transmit coil and the receive coils. In the circumferential mode, the transmit coil is selected to be from the first row and subsequently from the second row, while the corresponding receiver coil is taken from the same row, again with one coil between the transmit and receiver coils.

In the embodiment of Fig. 7, the middle row is reserved for transmission, and the coils in the middle row are larger than the receive coils in the top and bottom rows. For each transmit coil, there are four surrounding receiver coils, one in each corner, differential measurements can be taken between any two adjacent pairs of receiver coils. As previously described, the differential measurement can be achieved either by connecting the two coils differentially and measuring the difference signal, or by buffering or storing the signal from one coil and then subtracting the signal from the other coil by the stored signal. In this embodiment, receiver coils are reused, and thus the transmitted coils are arranged closer to one another to provide better coverage.

In the embodiment of Fig. 11, a pseudo-differential mode is provided by buffering the signal from a first one of a pair of receiver coils being used in a differential configuration, and thereafter measuring the signal from a second one of the pair of receiver coils. The difference between the two signals is subtracted to obtain the pseudo-differential signal. As shown in Fig. 12, the transmit signal is a sine wave having a predetermined frequency. The first signal is buffered beginning from a predetermine phase reference with respect to the transmit signal. The second signal is likewise referenced with respect to the phase of the transmit signal, and the two receiver signals acquired one after the other are subtracted to yield the pseudo-differential signal.

It will be appreciated that many variants and alternative configurations are possible within the scope of the present invention, as defined in the appended claims.

CLAIMS

1. A method of detecting faults in a conductive material to be tested using eddy currents, the method comprising the steps of:

a) providing a probe head having an arrangement of coils arranged on a surface of the probe to induce eddy currents in the conductive material to be tested, wherein the arrangement allows the probe to cover an area transverse to a direction of displacement of the probe head during inspection;

b) selectively exciting one of the coils with an AC source to induce an eddy current in the material, wherein coils excited to transmit are spaced from a receiver coil by one coil not used in the present measurement of the eddy current flow;

c) measuring eddy current flow in the conductive material to be tested using at least one of said coils;

d) repeating steps b) and c) to cover the area transverse to the direction of displacement in different measurement configurations in which at least one of alternatives i, ii, iii, iv, and v is used:

i. one of the coils used as said receiver coil is reused as a driven coil;

ii. the excited one of the coils is reused as said receiver coil;

iii. one of two or more coils used as receiver coils in a differential mode is used as a receiver coil with a different other receiver coil;

iv. said arrangement of coils is connectable to a single transmit signal conductor, wherein said step b) further comprises switching the excited coil to the transmit signal conductor; and

v. said arrangement of coils is connectable to one or more receiver conductors, wherein said step c) further comprises switching one of the at least one of the coils to one of said one or more receiver conductors.

2. The method as claimed in claim 1, wherein said coils excited to transmit are spaced from said receiver coil in a same row in said arrangement of coils by one coil not used in the present measurement.

3. The method as claimed in claim 1, wherein the probe head is cylindrically shaped and three rows of bracelets of coils are arranged on the probe head to be substantially parallel to a surface of the material to be tested.

4. The method as claimed in claim 3 using a central transmit coil in a middle of said rows surrounded by four receiver coils, each of the four receiver coils being arranged in either a top of said rows or a bottom of said rows.

5. The method as claimed in claim 3 wherein a coil in a first of said rows transmits while two coils in a third of said rows receive signals for differential detection of axial cracks to thereby place a separation of one coil between said transmit coil and said receive coils, and wherein the third of said rows is staggered with respect to the first and second rows.

6. The method as claimed in claim 1, wherein the probe head is cylindrical having an axis and both axial and circumferential measurement configurations with respect to the axis are used, wherein to detect an axial crack, the receiver coils are selected to be circumferentially adjacent to one another, and wherein to detect a circumferential crack the receiver coils are selected to be axially adjacent.

7. The method as claimed in claim 1, wherein the probe head comprises a transmit multiplexer switching device for connecting the excited coil to the transmit signal conductor.

8. The method as claimed in claim 1, wherein the coils are arranged to be substantially parallel to a surface of the material to be tested, and said eddy current induced by the excited coil in the material to be tested is measured by at least one receiver coil, the probe head comprising a receiver multiplexer switch for connecting one of the at least one receiver coil to the receiver conductor, and said step c) comprises transmitting a selector signal to the receiver multiplexer switch.

9. The method as claimed in claim 1, wherein the probe head is cylindrically shaped and said arrangement of coils comprises either one or two rows of coils arranged on the probe head to be substantially parallel to a surface of the material to be tested.

10. The method as claimed in claim 8, wherein only one receiver conductor is provided, and said step c) is carried out twice to obtain sequentially the measurement of eddy current flow in the conductive material to be tested between the excited one of the coils and each of two receiver coils.

11. The method as claimed in claim 8, wherein said step c) comprises amplifying at the probe head a signal from the one of the at least one receiver coil after the receiver multiplexer switch.

12. The method as claimed in claim 8, wherein the selector signal is a toggle signal causing the receive multiplexer switch to connect to a next coil in a series of the arrangement of coils.

13. The method as claimed in claim 1, wherein the coils are arranged in planes perpendicular to a surface of the material to be tested, and said step (c) comprises measuring an impedance of the same excited coil.

14. The method as claimed in claim 1, wherein the probe head is cylindrically shaped and adapted to be inserted into a heat exchanger tube.

15. The method as claimed in claim 14, wherein the coils are arranged to be substantially parallel to a surface of the material to be tested, and in said step c) the eddy current induced by the excited coil in the material to be tested is measured by at least one receiver coil, and the arrangement of coils comprises at least two circumferential bracelets of coils arranged in rows.

16. The method as claimed in any one of claims 1, 3 or 15, wherein a high switching frequency of connections of the driven and the receiver coils is carried out relative to the movement of the probe head, such that a scanning of the conductive surface where the coils are located takes place.

17. The method as claimed in claim 1, wherein step c) further comprises reading and storing eddy current flow in the conductive material to be tested at a first of two receiver coils and then reading and storing eddy current flow at the other of said two receiver coils and the method further comprises the step:

e) processing the stored eddy current flow of said two receiver coils to obtain a pseudo-differential measurement based on the readings of said two coils made separately in time.

18. An eddy current testing probe for detecting faults in a conductive material to be tested using eddy currents, the probe comprising:

a probe head having an arrangement of coils arranged on a surface of the probe to induce eddy currents in the conductive material to be tested, wherein the arrangement allows the probe to cover an area transverse to a direction of displacement of the probe head during inspection; and

an AC source and eddy current detector equipment connected over a length of cable to said coils to induce an eddy current in the material;

characterized in that the probe further comprises:

a controller for connecting said equipment to said coils in different measurement configurations in which at least one of alternatives i, ii, iii, iv and v is used:

i. one of the coils used as a receiver coil is reused as a driven coil;

ii. the excited one of the coils is reused as a receiver coil;

iii. one of two or more coils used as receiver coils in a differential mode is used as a receiver coil with a different other receiver coil;

vi. said arrangement of coils is connectable to a single transmit signal conductor, wherein said inducing an eddy current further comprises switching the excited coil to the transmit signal conductor; and

iv. said arrangement of coils is connectable to one or more receiver conductors, wherein measuring eddy current flow comprises switching one of the at least one of the coils to one of said one or more receiver conductors; and

wherein coils excited to transmit are spaced from a receiver coil by one coil not used in the present measurement of the eddy current flow.

19. The testing probe as claimed in claim 18, wherein said coils excited to transmit are spaced from said receiver coil in a same row in said arrangement of coils by one coil not used in the present measurement.

20. The testing probe as claimed in claim 18, wherein the probe head is cylindrically shaped and three rows of bracelets of coils are arranged on the probe head to be substantially parallel to a surface of the material to be tested.

21. The testing probe as claimed in claim 20 using a central transmit coil in a middle of said rows surrounded by four receiver coils, each of the four receiver coils being arranged in either a top of said rows or a bottom of said rows.

22. The testing probe as claimed in claim 20 wherein a coil in a first of said rows transmits while two coils in a third of said rows receive signals for differential detection of axial cracks to thereby place a separation of one coil between said transmit coil and said receive coils, and wherein the third of said rows is staggered with respect to the first and second rows.

23. The testing probe as claimed in claim 18, wherein the probe head is cylindrical having an axis and both axial and circumferential measurement configurations with respect to the axis are used, wherein to detect an axial crack, the receiver coils are selected to be circumferentially adjacent to one another, and wherein to detect a circumferential crack the receiver coils are selected to be axially adjacent.

24. The testing probe as claimed in claim 18, wherein the probe head comprises a transmit multiplexer switching device for connecting the excited coil to the transmit signal conductor.

25. The testing probe as claimed in claim 18, wherein the coils are arranged to be substantially parallel to a surface of the material to be tested, and said eddy current induced by the excited coil in the material to be tested is measured by at least one receiver coil, the probe head comprising a receiver multiplexer switch for connecting one of the at least one receiver coil to the receiver conductor, and measuring eddy current flow comprises transmitting a selector signal to the receiver multiplexer switch.

26. The testing probe as claimed in claim 18, wherein the probe head is cylindrically shaped and said arrangement of coils comprises either one or two rows of coils arranged on the probe head to be substantially parallel to a surface of the material to be tested.

27. The testing probe as claimed in claim 25, wherein only one receiver conductor is provided, and said measuring eddy current flow is carried out twice to obtain sequentially the measurement of eddy current flow in the conductive material to be tested between the excited one of the coils and each of two receiver coils.

28. The testing probe as claimed in claim 25, wherein said measuring eddy current flow comprises amplifying at the probe head a signal from the one of the at least one receiver coil after the receiver multiplexer switch.

29. The testing probe as claimed in claim 25, wherein the selector signal is a toggle signal causing the receive multiplexer switch to connect to a next coil in a series of the arrangement of coils.

30. The testing probe as claimed in claim 18, wherein the coils are arranged in planes perpendicular to a surface of the material to be tested, and measuring eddy current flow comprises measuring an impedance of the same excited coil.

31. The testing probe as claimed in claim 18, wherein the probe head is cylindrically shaped and adapted to be inserted into a heat exchanger tube.

32. The testing probe as claimed in claim 31, wherein the coils are arranged to be substantially parallel to a surface of the material to be tested, and the eddy current induced by the excited coil in the material to be tested is measured by at least one receiver coil, and the arrangement of coils comprises at least two circumferential bracelets of coils arranged in rows.

33. The testing probe as claimed in any one of claims 18, 21 or 32, wherein a high switching frequency of connections of the driven and the receiver coils is carried out relative to the movement of the probe head, such that a scanning of the conductive surface where the coils are located takes place.

34. The testing probe as claimed in claim 18, wherein measuring eddy current flow further comprises reading and storing eddy current flow in the conductive material to be tested at a first of two receiver coils and then reading and storing eddy current flow at the other of said two receiver coils and the controller is further configured for: processing the stored eddy current flow of said two receiver coils to obtain a pseudo-differential measurement based on the readings of said two coils made separately in time.

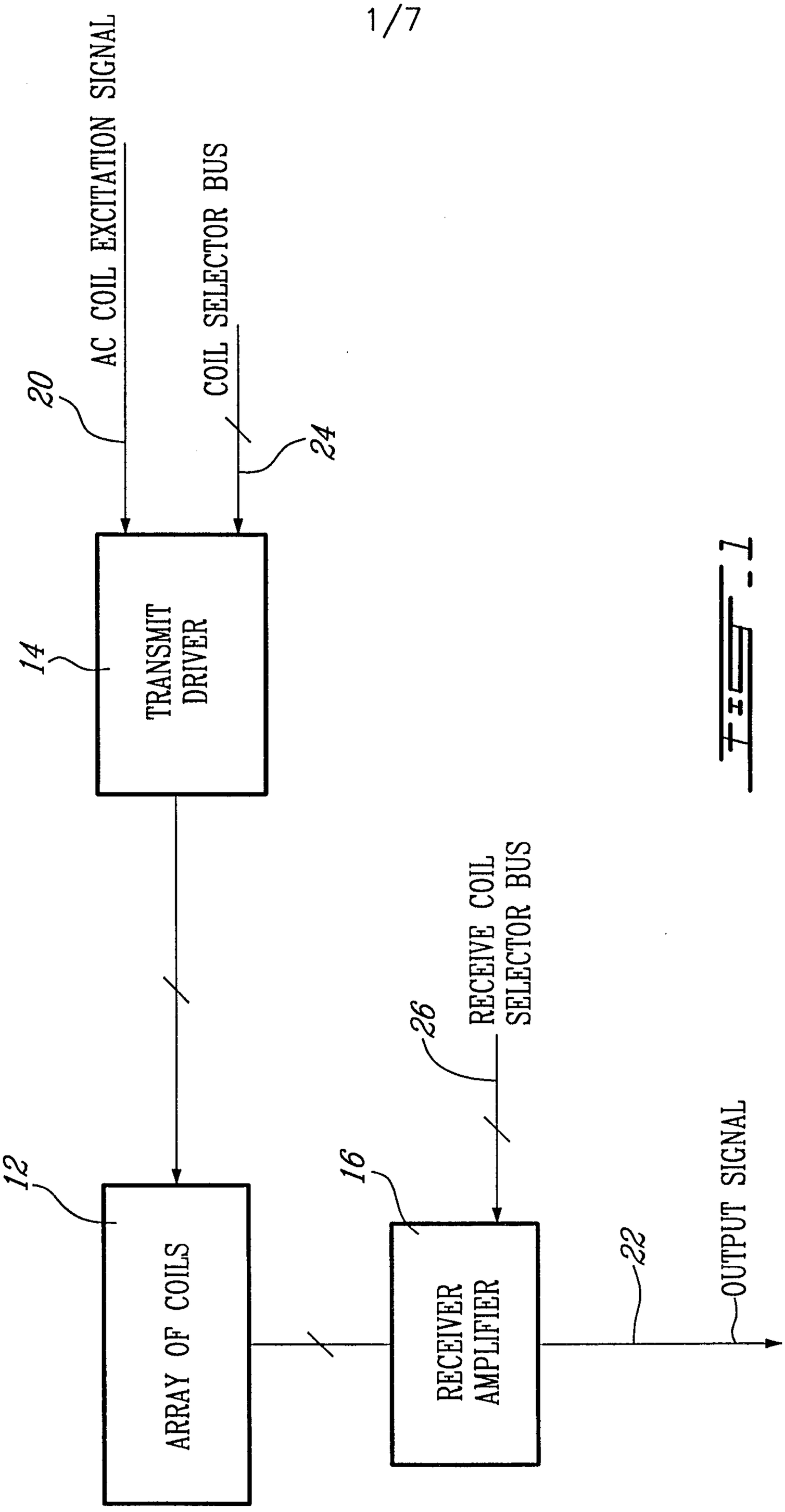

AC COIL EXCITATION SIGNAL
COIL SELECTOR BUS
20
24
TRANSMIT DRIVER
14
12
ARRAY OF COILS
16
RECEIVE COIL SELECTOR BUS
26
RECEIVER AMPLIFIER
22
OUTPUT SIGNAL

Fig. 1

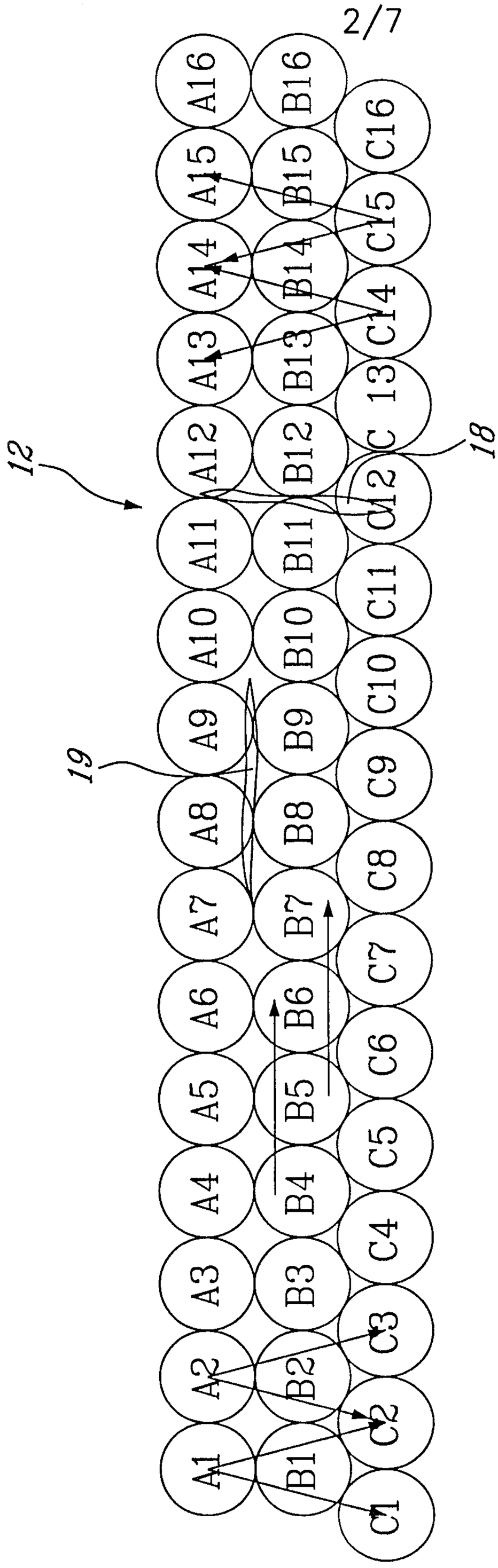

12
18
19
A16
B16
C16
A15
B15
C15
A14
B14
C14
A13
B13
C13
A12
B12
C12
A11
B11
C11
A10
B10
C10
A9
B9
C9
A8
B8
C8
A7
B7
C7
A6
B6
C6
A5
B5
C5
A4
B4
C4
A3
B3
C3
A2
B2
C2
A1
B1
C1

Fig. 2

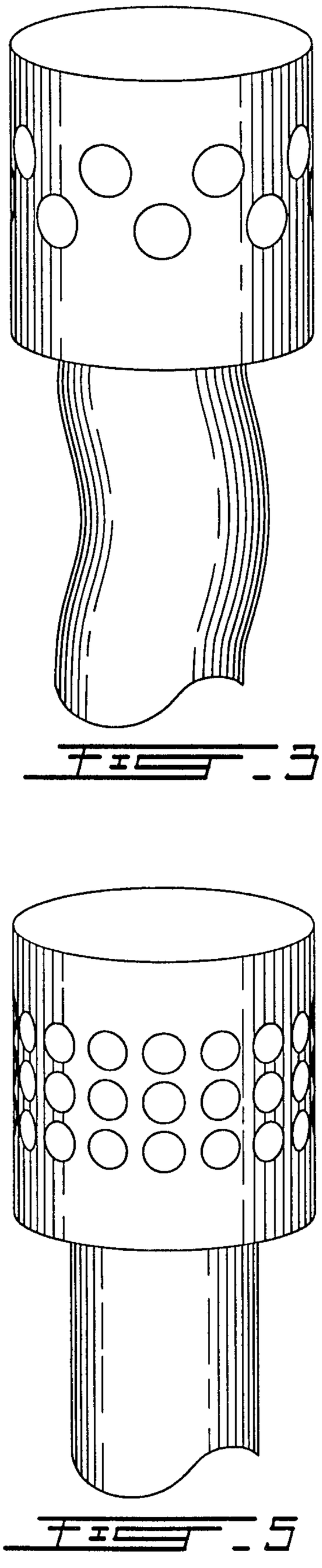


FIG_3

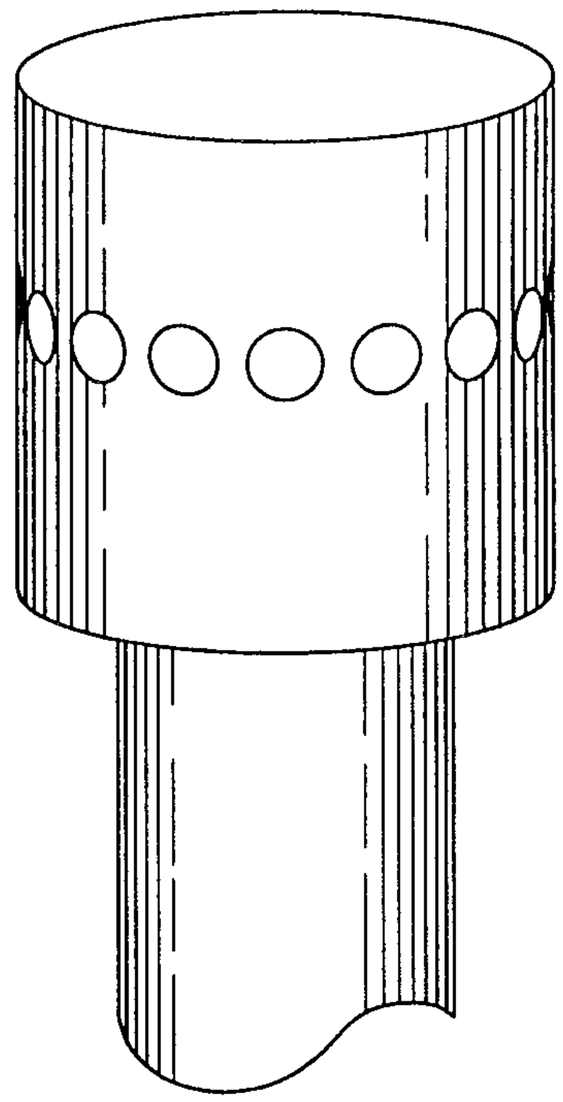


FIG_4

FIG_5

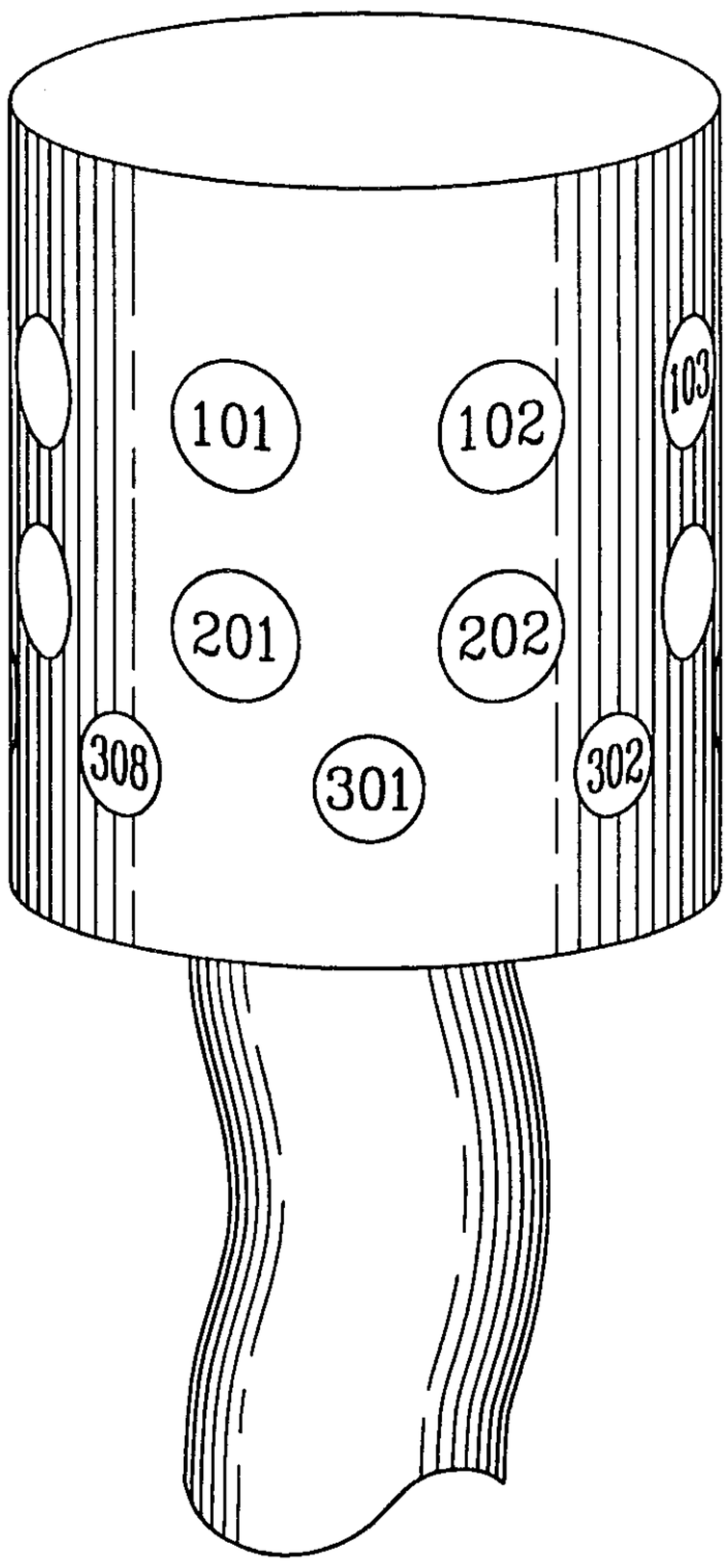


Fig. 6

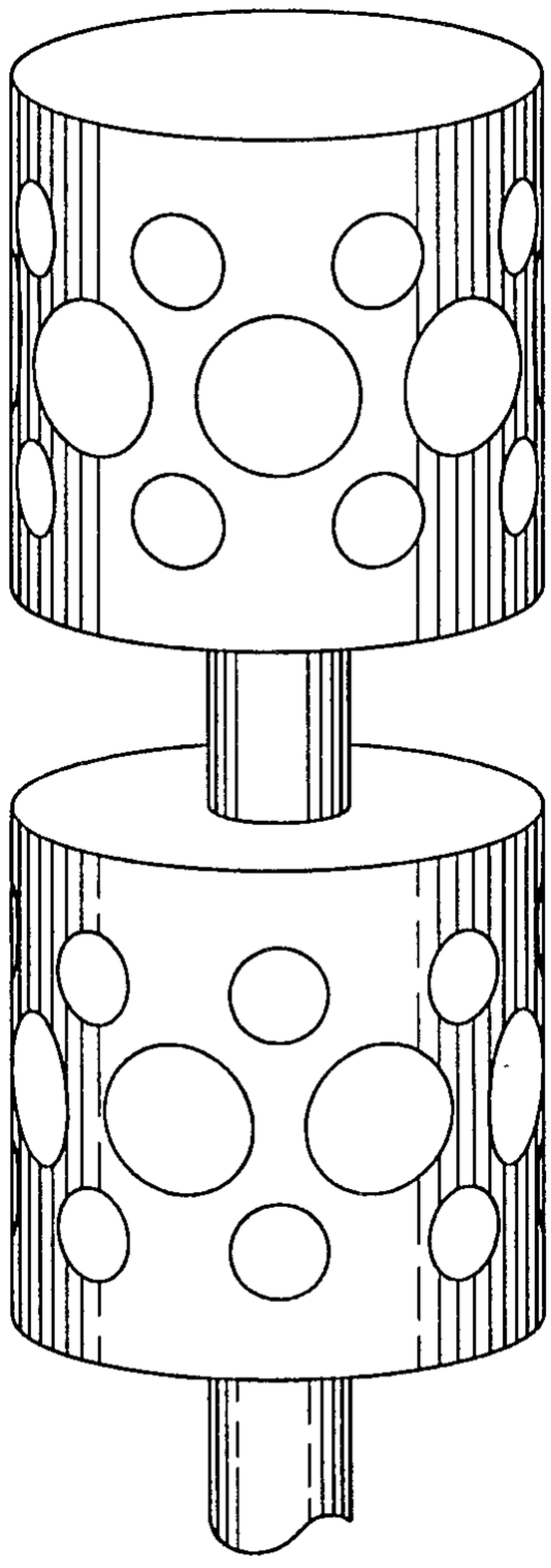
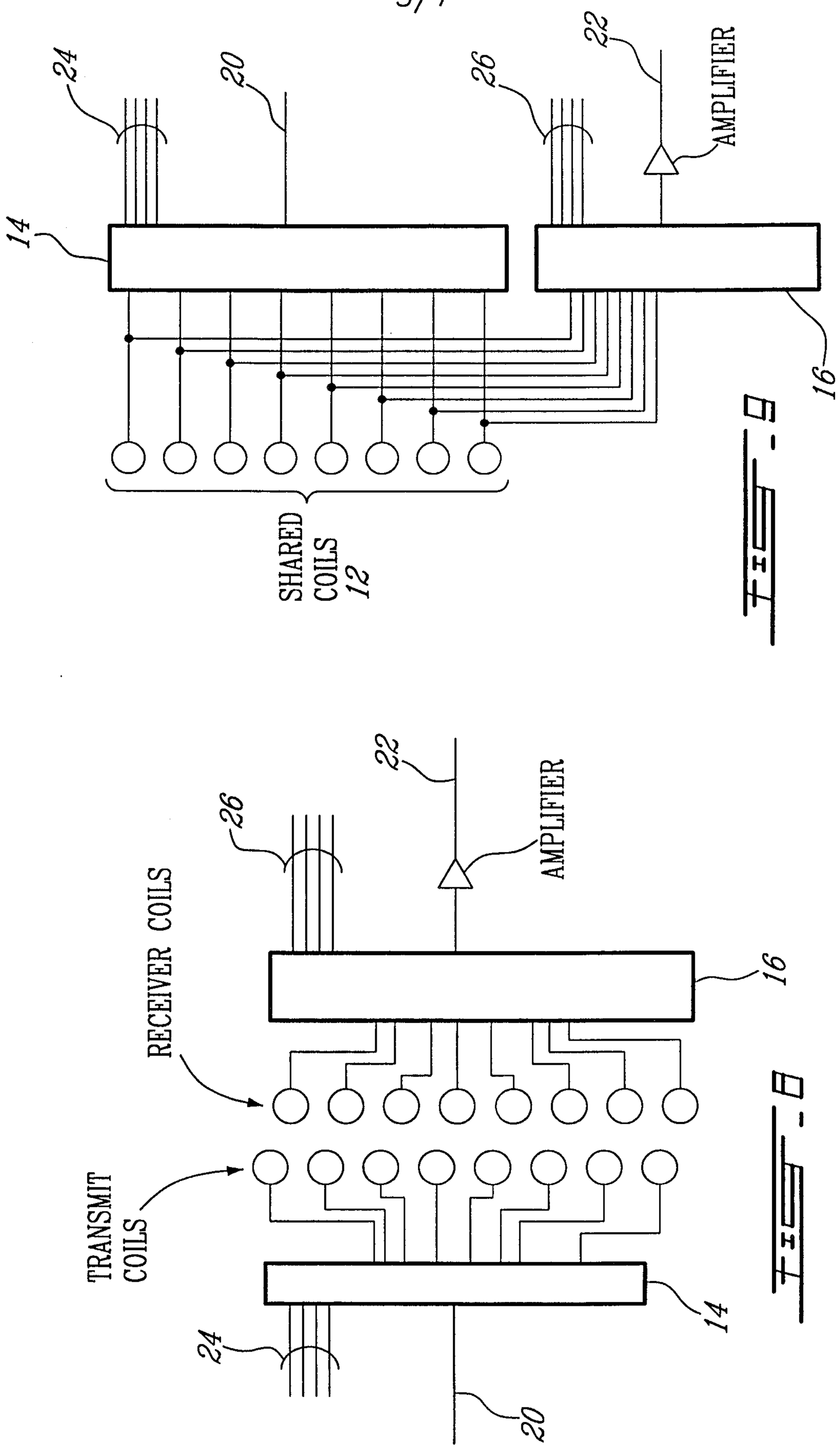


Fig. 7


24
20
26
22
AMPLIFIER
14
16
SHARED
COILS
12
FIG - 9
22
AMPLIFIER
26
RECEIVER COILS
16
FIG - 8
TRANSMIT
COILS
24
20
14

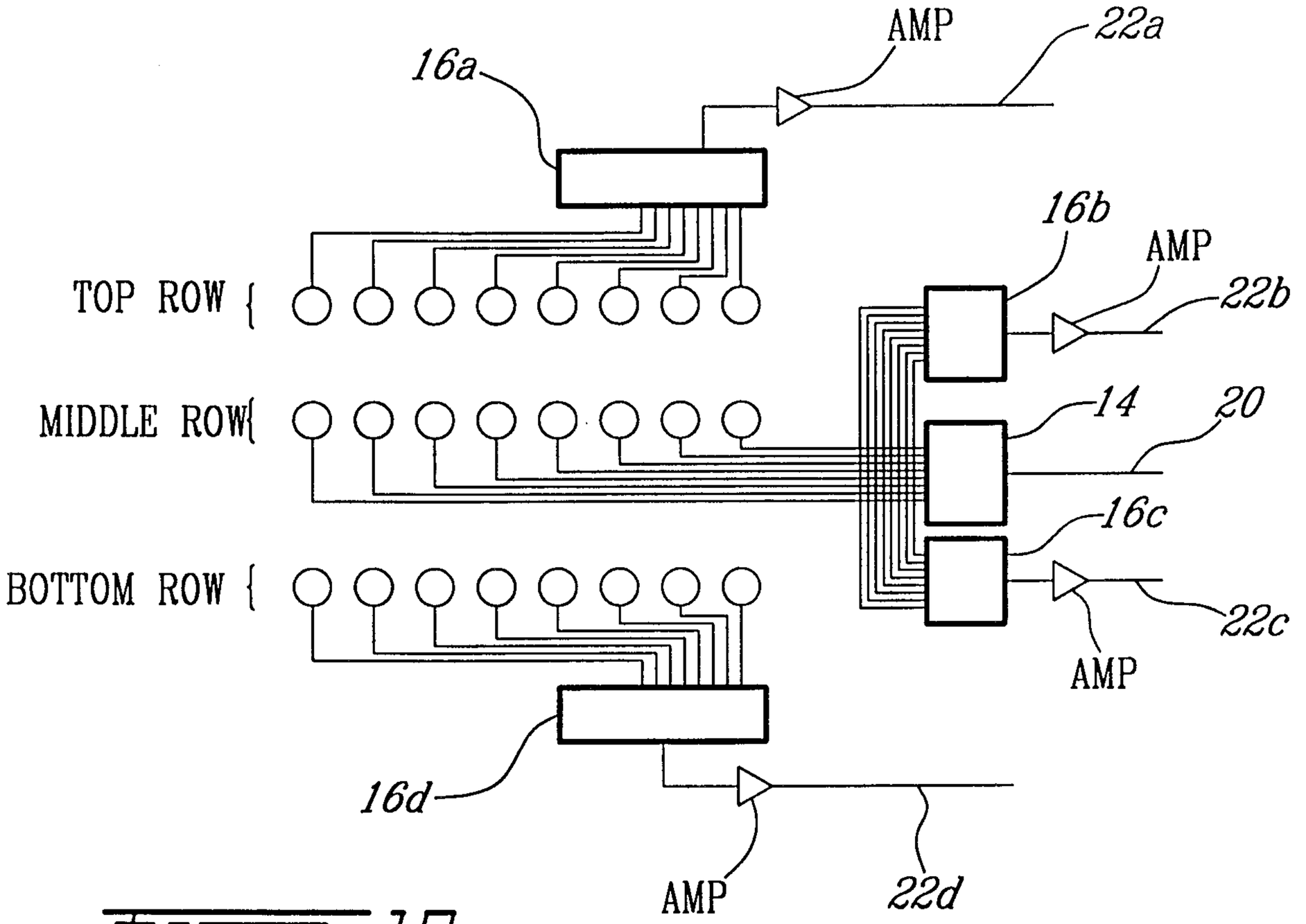

AMP
22a
16a
16b
AMP
22b
TOP ROW
MIDDLE ROW
14
20
16c
BOTTOM ROW
22c
AMP
16d
AMP
22d

Fig_10

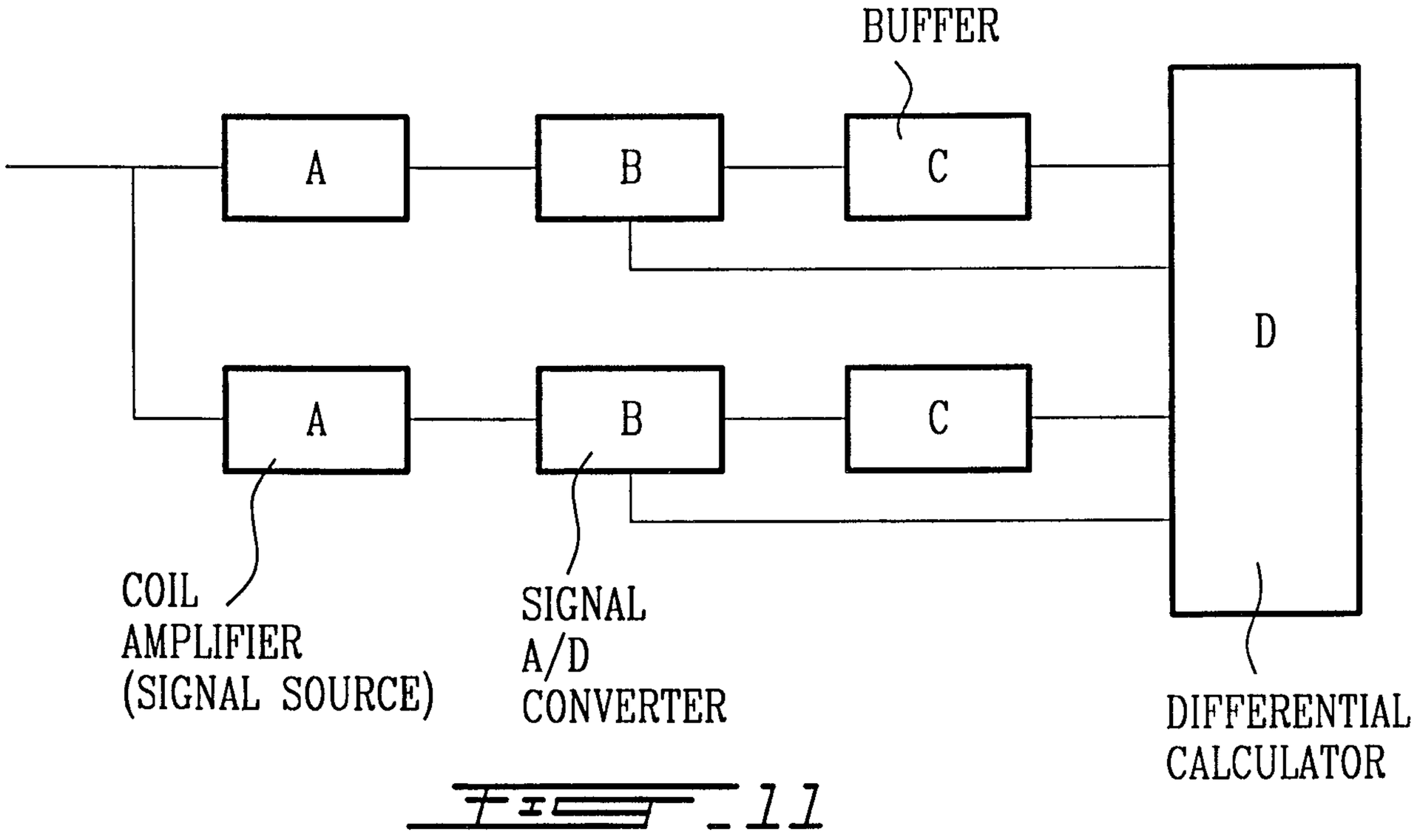

BUFFER
A
B
C
D
A
B
C
COIL
AMPLIFIER
(SIGNAL SOURCE)
SIGNAL
A/D
CONVERTER
DIFFERENTIAL
CALCULATOR

Fig_11

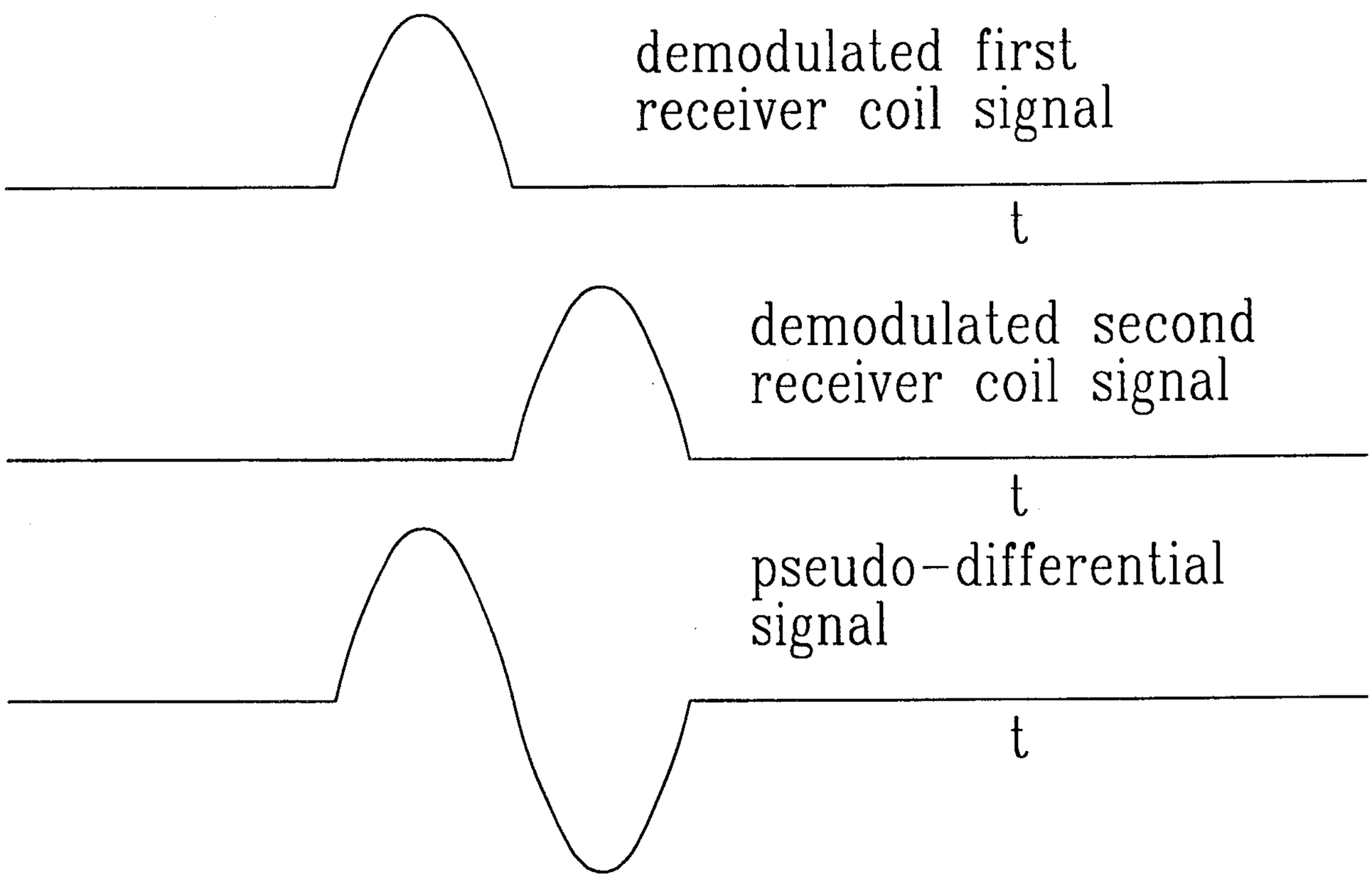

demodulated first receiver coil signal
t
demodulated second receiver coil signal
t
pseudo-differential signal
t

Fig. 12

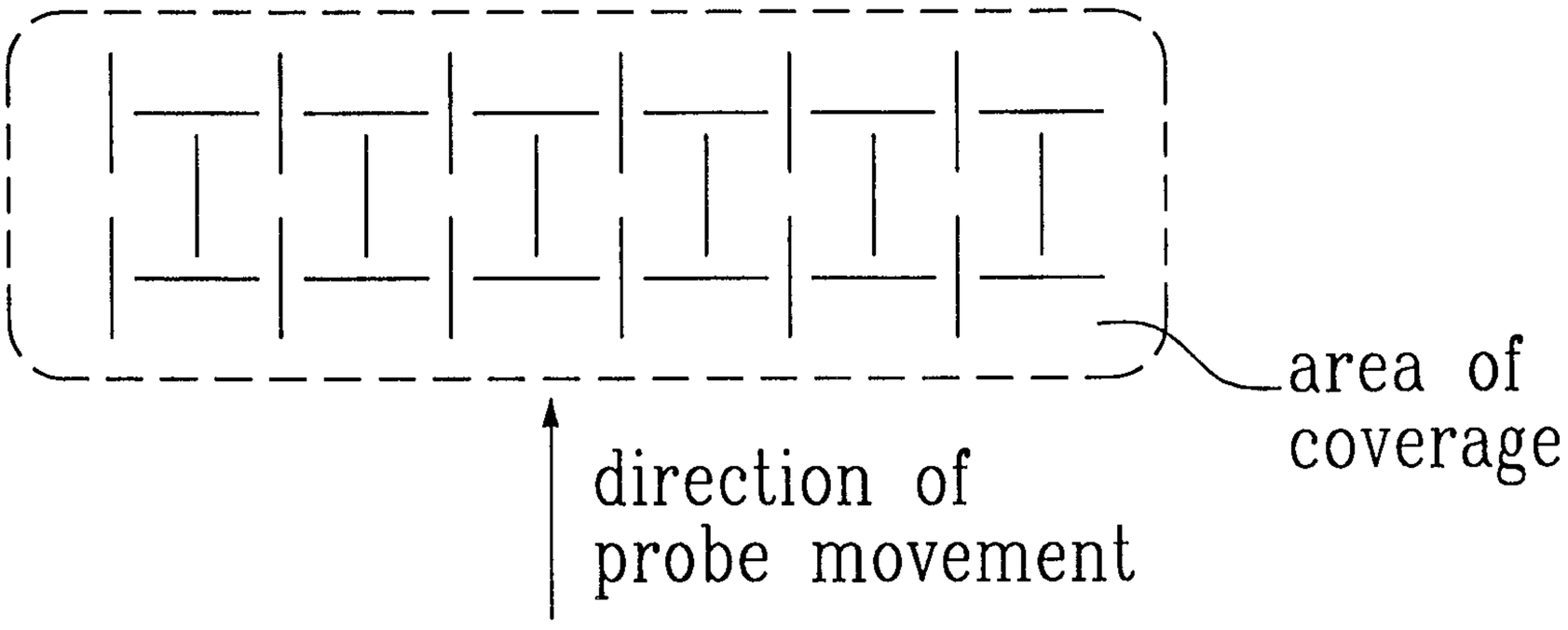
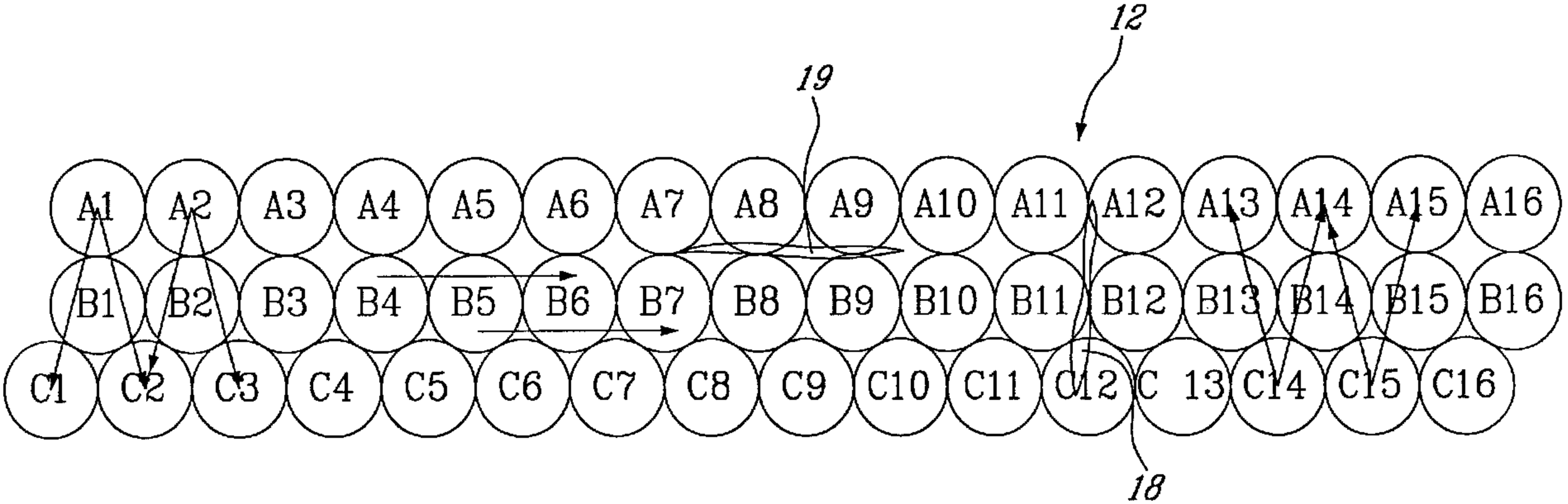

area of coverage
direction of probe movement

Fig. 13


12
19
A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16
B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12 B13 B14 B15 B16
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C 13 C14 C15 C16
18