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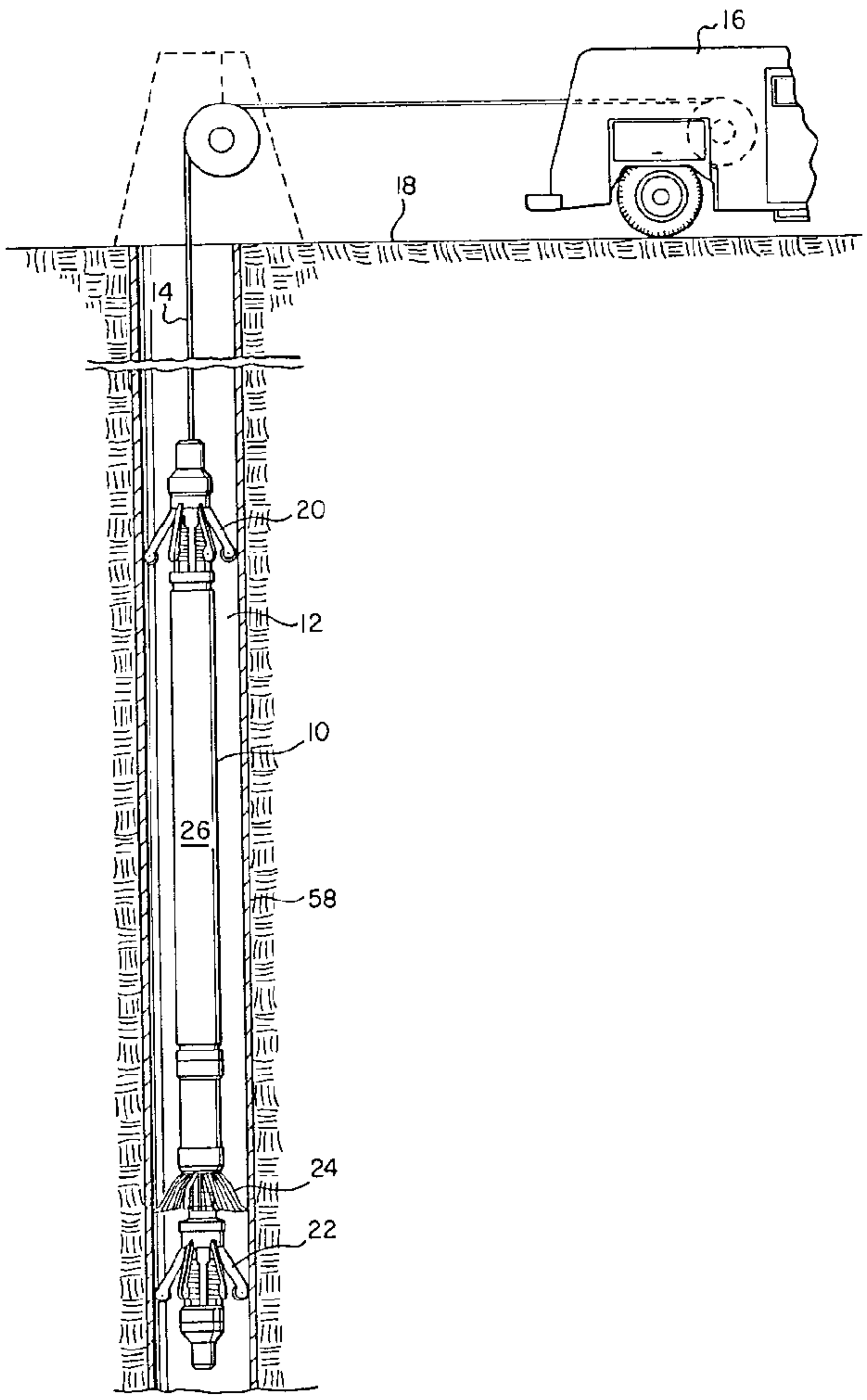
(54) **SYSTEME DE MESURE DES DIMENSIONS INTERNES D'UN TUBE, A L'INTERIEUR D'UN PUITS DE FORAGE, ET METHODE CONNEXE**

(54) **METHOD AND SYSTEM FOR MEASUREMENT OF INTERNAL TUBE DIMENSIONS WITHIN A WELLBORE**



(57) A caliper logging sonde is provided having a plurality of sensing fingers each of which is pivotally mounted to the sonde and movable with respect to the sonde in response to variations in the internal dimensions of a wellbore tube

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through which the sonde passes. An electrical signal which is proportional to variations in the internal dimensions of a wellbore tube is determined at regular time intervals at a series of points around the circumference of the wellbore tube. A maximum and minimum dimension for each point around the circumference of the wellbore tube during a selected time interval is temporarily stored and thereafter transmitted to the surface at regular intervals. A high density array of sensors is provided by utilizing a transducer plate having a large number of cylindrical apertures disposed around the circumference thereof. Thimble members, each having an internal chamber and an elongate body narrower than the cylindrical aperture are fixedly inserted into one end of each of the detector plate apertures while an associated electrical coil is inserted into each aperture from the other end, surrounding the elongate body. Movable magnetic rods within the internal chamber of each thimble are then variably positioned in response to movement of the sensing fingers and the variable inductance of each electrical coil is then utilized to produce an electrical signal proportional to variations in the internal dimensions of the tube under measurement.

ABSTRACT OF THE DISCLOSURE

A caliper logging sonde is provided having a plurality of sensing fingers each of which is pivotally mounted to the sonde and movable with respect to the sonde in response to variations in the internal dimensions of a wellbore tube through which the sonde passes. An electrical signal which is proportional to variations in the internal dimensions of a wellbore tube is determined at regular time intervals at a series of points around the circumference of the wellbore tube. A maximum and minimum dimension for each point around the circumference of the wellbore tube during a selected time interval is temporarily stored and thereafter transmitted to the surface at regular intervals. A high density array of sensors is provided by utilizing a transducer plate having a large number of cylindrical apertures disposed around the circumference thereof. Thimble members, each having an internal chamber and an elongate body narrower than the cylindrical aperture are fixedly inserted into one end of each of the detector plate apertures while an associated electrical coil is inserted into each aperture from the other end, surrounding the elongate body. Movable magnetic rods within the internal chamber of each thimble are then variably positioned in response to movement of the sensing fingers and the variable inductance of each electrical coil is then utilized to produce an electrical signal proportional to variations in the internal dimensions of the tube under measurement.

Docket No. 0140D-029

BACKGROUND OF THE INVENTION

1. Field of the Invention:

This invention relates in general to methods and systems for accurately measuring the internal dimensions of a tube within a borehole and in particular to a method and system for measuring and storing maximum and minimum variations in internal dimensions of a tube within a borehole over a predetermined time interval. Still more particularly, the present invention relates to a system for providing highly accurate measurement of borehole tube internal dimensions utilizing a large number of closely spaced detectors.

2. Description of the Prior Art:

The modern petrochemical industry utilizes a large number of tubes which are designated primarily for the circulation of fluids within a wellbore. Notable examples of such tubes are those utilized for well drilling and fluid circulation in an oil well. In actual practice, it is often necessary to measure the ovalization or corrosion of either the internal or external surfaces of these tubes to ensure that tubing which is about to fail is replaced. Such measurements are often carried out in atmospheres which may deleterious or difficult to reach, for example at the bottom of an oil well in the case of tubing strings. In order to carry out these measurements, provisions must be made for a reliable and accurate measurement which operates in a simple and straightforward manner.

Early systems for measuring the shape of a cylindrical tube within a wellbore were primarily impression-taking devices of a mechanical type which may produce electrical signals as a result of mechanical contact between the measuring device and a dimension of the tubing. Typically such devices utilizing an engraving stylus on a substrate for the purpose of marking a curve which corresponds to ovalization of a cylinder or to surface defects within the cylinder. These devices are complicated by reason of the fact that they require high precision mechanical transmission systems and the fact that a mechanical marking operation impairs the sensitivity of the measurement over time. Moreover, such devices do not immediately deliver usable information since the device must be removed to the surface of a wellbore for analyzation after the measurements have been taken.

Electromechanical devices utilizing multiple feeler arms have been proposed which overcome this mechanical device problem. One example is set forth in U.S. Patent No. 4,186,494, *Peruchon Edouard et al.*, issued February 5, 1980. The transducers set forth within the above-referenced United States patent are quite bulky and only a limited number of fingers may be placed around a sonde owing to the space necessary for corresponding transducers within the sonde.

More recently, United States Patent No. 4,559,709, issued to *Beseme et al.*, December 24, 1985, discloses a technique whereby multiple sensing fingers are provided, each movable with respect to a sonde. A mobile member attached to each sensing finger and movable in response to movement of the finger is placed within an electric coil and is utilized to vary the inductance of that coil in response to variations in the internal dimensions of a tube. Thereafter, the device may be periodically interrogated from the surface, utilizing a signal transmitted over a conductive cable, and the output of each transducer is then transmitted to the surface, providing an indication of defects or irregularities in the internal dimensions of a tube within a borehole.

While each of these systems represents an adequate method for measuring the internal dimensions of a tubular member within a borehole, several shortfalls have been experienced with these devices. For example, the *Beseme et al.* device transmits the output of each transducer to the surface in response to an interrogation from the surface and thus defects which are located physically between two points within the tube at which an interrogation takes place will not be noted utilizing a tool of this type. Additionally, the transducers described therein, while an improvement over *Peruchon Edouard et al.*, still require a substantial amount of space and therefore preclude the provision of a large number of sensing figures which might be utilized to provide a highly accurate indication of irregularities within the internal dimensions of a tubing member within a borehole.

It should therefore be apparent that a need exists for a method and system which permits highly accurate measurements of the internal dimensions of a tube within a borehole utilizing a large number of sensing transducers disposed circumferentially about a measurement tool.

SUMMARY OF THE INVENTION

It is therefore one object of the present invention to provide an improved method and system for accurately measuring the internal dimensions of a tube within a borehole.

It is another object of the present invention to provide an improved method and system for measuring and storing maximum and minimum variations in internal dimensions of a tube within a borehole over a predetermined period of time.

It is yet another object of the present invention to provide an improved system which may be utilized to measure, in a highly accurate manner, the variations of internal dimension of a tube within a borehole utilizing a large number of closely spaced detectors.

In accordance with one aspect of the present invention there is provided an apparatus for measuring the internal dimensions of a tube within a wellbore, said apparatus comprising: an elongate sonde adapted to be suspended within the wellbore by an electrical conductor and movable within a tube to be measured within said wellbore; a plurality of sensing fingers mounted on said elongate sonde and movable with respect to said elongate sonde in response to variations in said internal dimensions of said tube, during movement of said elongate sonde within said tube; detection means disposed within said elongate sonde for producing an electrical signal in response to the position of each of said plurality of sensing fingers at each of a plurality of time instants; comparator means coupled to said detection means for comparing each electrical signal produced in response to the position of each of said plurality of sensing fingers with all other electrical signals produced during each of a plurality of time intervals, each of said plurality of time intervals comprising a said plurality of time instants, in order to determine a maximum electrical signal and a minimum electrical signal for each of said plurality of sensing fingers which occurs during each of said plurality of time intervals; buffer means coupled to said detector means for temporarily storing said maximum electrical signal and said minimum electrical signal for each of said plurality of sensing fingers during each of a plurality of time intervals.

In accordance with another aspect of the present invention there is provided a method for detecting variations in the internal dimensions of a tube within a borehole, said method comprising the steps of: suspending a measurement device in a borehole utilizing an electrical conductor and moving said measurement device within a tube to be measured; repeatedly measuring said internal dimensions of said tube at a plurality of points around the circumference of said tube at each of a plurality of time instants; comparing each of said measured internal dimensions of said tube at said plurality of points around the circumference of said tube with all other measurements during each of a plurality of time intervals, each of said plurality of time intervals comprising a said plurality of time instants, in order to determine maximum and minimum internal dimension which occurs during each of said plurality of time intervals; storing within said measurement device a maximum and minimum internal dimension at each of said plurality of points around the circumference of said tube during each of a plurality of time intervals.

In accordance with yet another aspect of the present invention there is provided an apparatus for measuring the internal dimensions of a tube within a wellbore, said apparatus comprising: an elongate sonde adapted to be suspended within said wellbore by an electrical conductor and movable within a tube to be measured within said wellbore; a plurality of sensing fingers mounted on said elongate sonde and movable with respect to said elongate sonde in response to variations in said internal dimensions of said tube, during movement of said elongate sonde within said tube; a transducer plate mounted within said elongate sonde having a plurality of cylindrical apertures disposed generally about the circumference thereof, each of said plurality of cylindrical apertures having a first end and a second end; a plurality of thimble members, each of said plurality of thimble members having an internal chamber and an elongate body having an external dimension smaller than an internal dimension of each of said plurality of cylindrical apertures, each of said thimble members sized to be fixedly inserted within an associated cylindrical aperture from a first end thereof; a plurality of electrical coils, each sized to be inserted within a second end of an associated cylindrical aperture around said elongate body of an inserted thimble member; means for retaining each of said plurality of electrical coils within an associated cylindrical aperture; a plurality of movable members, each coupled to an associated sensing finger and movable within a said internal chamber of an associated thimble member in response to movement of said associated sensing finger; detection means coupled to each of said plurality of electrical coils for producing an electrical signal in response to variations in position of each of said plurality of movable members at each of a plurality of time instants; comparator means coupled to said detection means for comparing each electrical signal produced in response to variations in position of each of said plurality of movable members with all other electrical signals produced during each of a plurality of time intervals, each of said plurality of time intervals comprising a said plurality of time instants, in order to determine a maximum electrical

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signal and a minimum electrical signal for each of said plurality of movable members which occurs during each of said plurality of time intervals; and buffer means coupled to said detector means for temporarily storing said maximum electrical signal and said minimum electrical signal for each of said plurality of movable members during each of said plurality of time intervals.

In an exemplary embodiment of the present invention, a caliper logging sonde is provided having a plurality of sensing fingers each of which is pivotally mounted to the sonde and movable with respect to the sonde in response to variations in the internal dimensions of a wellbore tube through which the sonde passes. An electrical signal which is proportional to variations in the internal dimensions of a wellbore tube is determined at regular time intervals at a series of points around the circumference of the wellbore tube. A maximum and minimum dimension for each point around the circumference of the wellbore tube during a selected time interval is temporarily stored and thereafter transmitted to the surface at regular intervals. A high density

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array of sensors is provided by utilizing a transducer plate having a large number of cylindrical apertures disposed around the circumference thereof. Thimble members, each having an internal chamber and an elongate body narrower than the cylindrical aperture are fixedly inserted into one end of each of the detector plate apertures while an associated electrical coil is inserted into each aperture from the other end, surrounding the elongate body. Movable magnetic rods within the internal chamber of each thimble are then variably positioned in response to movement of the sensing fingers and the variable inductance of each electrical coil is then utilized to produce an electrical signal proportional to variations in the internal dimensions of the tube under measurement.

Additional objectives, features and advantages will be apparent in the written description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a partially schematic view of a caliper logging sonde within a borehole which has been constructed in accordance with the method and system of the present invention;

Figures 2a and **2b**, when viewed together, form a partial cut-away view of one sensing finger and an associated transducer in the caliper logging sonde of **Figure 1**;

Figure 3 is a plan view of a transducer plate within the caliper logging sonde of **Figure 1**;

Figure 4 is an exploded view illustrating the assembly of one transducer within the caliper logging sonde of **Figure 1**; and

Figure 5 is a high level block diagram of the electronic assemblies which may be utilized to implement the caliper logging sonde of **Figure 1**.

DETAILED DESCRIPTION OF THE INVENTION

With reference now to the figures and in particular with reference to **Figure 1**, there is depicted a partially schematic view of a caliper logging sonde **10** within a borehole **12** which has been constructed in accordance with the method and system of the present invention. As illustrated, caliper logging sonde **10** is supported by conductive cable **14** which is utilized to electrically couple caliper logging sonde **10** to a surface electronics system (not shown) generally disposed within truck **16** on surface **18** above borehole **12**.

As illustrated, caliper logging sonde **10** preferably includes a plurality of upper centering arms **20**, and a plurality of lower centering arms **22** which are utilized to centralize caliper logging sonde **10** within borehole **12** in a manner well known in the art. A plurality of sensing fingers **24** are provided and are utilized, in a manner which will be explained in greater detail herein, to detect ovalization and/or defects within the internal dimensions of tube **58** (see figure 1) which is suspended within borehole **12** in a manner well known in the art. Additionally, caliper logging sonde **10** preferably includes an electronics section **26** which serves to house the various electronic assemblies which are utilized in conjunction with sensing fingers **24** to provide an electrical signal which is representative of defects and/or ovalization in the internal dimensions of tube **58**.

Referring now to **Figures 2a** and **2b**, these figures, when viewed together, form a partially cut-away view of one sensing finger **28** and an associated transducer **60** within caliper logging sonde **10** of **Figure 1**. As illustrated, sensing finger **28** is preferably pivotally mounted to caliper logging sonde **10** in a manner such that sensing finger **28** may be moved with respect to caliper logging sonde **10** in response to variations in the internal dimensions of tube **58** (see figure 1). As illustrated, variations in the position of sensing finger **28** will result in a longitudinal movement of sliding block **30**.

Sliding block **30**, as illustrated within **Figures 2a** and **2b**, is mechanically coupled to transmission rod **32**. Transmission rod **32** is centered within spring **34**, which is utilized to urge sensing finger **28** away from caliper logging sonde **10**, in order to urge sensing finger **28** into contact with the internal dimensions of tube **58** (see figure 1).

At the upper end of transmission rod **32** is a transducer rod **36** which is urged into contact with the upper end of transmission rod **32** by means of spring **38**. As illustrated, the upper end of transducer rod **36** comprises a magnetic rod **40** which is inserted within an internal chamber of thimble member **42**. Thimble member **42** is preferably constructed of a nonmagnetic material, such as titanium, and is inserted into cylindrical aperture **44** within transducer plate **52**, in a manner which will be explained in greater detail herein.

As illustrated, thimble member **42** preferably includes an elongate body portion which is narrower in diameter than the internal dimensions of cylindrical aperture **44** so that electrical coil **46** may be inserted into cylindrical aperture **44** from the upper surface thereof, surrounding the elongate body portion of thimble member **42**. A threaded stud **48** is provided on the closed end of thimble member **42** and a nut **50** may then be utilized to fixedly retain coil **46** within cylindrical aperture **44** in the manner illustrated.

Thus, as those skilled in the art will appreciate upon reference to the foregoing, movement of sensing finger **28** toward and away from caliper logging sonde **10** will be translated into longitudinal movement, via transmission rod **32**, which is then utilized to urge transducer rod **36** into and out of internal chamber **56** of thimble member **42**. By urging magnetic rod **40** on the end of transducer rod **36** into and out of the internal chamber within thimble member **42**, the effective inductance of coil **46** is altered, resulting in an electrical signal which varies in response to variations in the internal dimension of tube **58** (see figure 1) at each of a plurality of points around the circumference of caliper logging sonde **10**.

With reference now to **Figure 3**, there is depicted a plan view of transducer plate **52**. As illustrated, transducer plate **52** preferably includes a large number of cylindrical apertures **44**. When constructing a caliper logging sonde in the manner disclosed within the present application, it is possible to produce a highly dense array of transducers, resulting in a much more accurate ability to detect defects, pitting or the like within the internal dimensions of tube **58** (see figure 1). In the depicted embodiment of the present invention forty cylindrical apertures **44** are provided within transducer plate **52**. Each cylindrical aperture includes an upper and lower end and are preferably provided by simply drilling the cylindrical apertures within a transducer plate provided utilizing a nonmagnetic material, such as titanium.

Referring now to **Figure 4**, there is illustrated an exploded view depicting the assembly of one transducer within caliper logging sonde **10** of **Figure 1**. As illustrated, transducer plate **52** includes a plurality of cylindrical apertures, a single one of which, **44**, is depicted for purposes of illustration. Thimble member **42**, which includes a threaded stud **48** and an internal chamber **56** is then inserted into cylindrical aperture **44** from one side thereof and fixedly mounted within cylindrical aperture **44**. Those skilled in the art will appreciate that this may be accomplished utilizing welding, brazing, or any other suitable technique.

As illustrated, thimble member **42** preferably includes an elongate body portion having an external diameter which is substantially smaller than the internal diameter of cylindrical aperture **44**. Thus, coil **46** may be inserted into cylindrical aperture **44** from the other end thereof, surrounding the elongate body portion of thimble member **42**. As depicted in **Figure 2a**, a nut **50** may then be utilized to secure electrical coil **46** within cylindrical aperture **44**, surrounding the elongate body portion of thimble member **42**.

In this manner, it is possible to construct a transducer plate such as transducer plate **52** which includes a large number of densely located transducers, resulting in the ability of caliper logging sonde **10** to detect defects within the internal dimensions of tube **58** (see figure 1) within a radial accuracy of nine degrees. However, those skilled in the art will appreciate that by disposing a third cylindrical array of apertures within transducer plate **52** it is possible to include an even more dense array of transducers, such as sixty transducers. In this manner, defects or pitting within the internal dimensions of tube **58** (see figure 1) may be detected within an accuracy of six degrees.

Referring now to **Figure 5**, there is depicted a high level block diagram of the electronic assemblies which may be utilized to implement caliper logging sonde **10** of **Figure 1**. As illustrated, a plurality of sensors **62** are depicted. As illustrated schematically within block **62**, each sensor preferably comprises a variable inductor which varies in inductance in response to variations in the position of magnetic rod **40** within the internal chamber of thimble member **42** (see **Figure 2a**). A resistor is also preferably coupled in series with each coil and a current source **64** is then periodically applied to each sensor. The application of current to a sensor formed of a series connected variable inductor and resistor will result in an initial high voltage which will then decay exponentially approaching the voltage which will result from the applied current flowing strictly through the series resistor.

Thereafter, as set forth within the aforementioned United States Patent No. 4,559,709, the current source may be removed, resulting in a so-called "fly back" reaction as a result of the inductance of the variable inductor within each sensor. A large negative voltage will be generated and that voltage will decay back to zero as the current from the inductor decays.

Thus, as those skilled in the art will appreciate, the time which this current takes to decay to a specified level or the amount of current present at a specified time may be utilized to determine the variable inductance of each individual sensor at a particular time instant. By repetitively and sequentially coupling current source **64** to sensors **62**, variations in the internal dimensions of tube **58** may be and accurately rapidly determined. However, as those skilled in the art will appreciate, the bandwidth required to transmit a large number of such readings to the surface from caliper logging sonde **10** is generally not available.

Therefore, in accordance with an important feature of the present invention, the internal dimensions of tube **58** at a plurality of points around the circumference of caliper logging sonde **10** are determined in rapid succession and coupled, via multiplex **66** to analog-to-digital converter **70**. This is accomplished, in manner well known in the art, utilizing data input control **68**. Thereafter, the output of analog-to-digital converter **70** is coupled to maximum/minimum comparator **72**.

In accordance with an important feature of the present invention, each measurement of a sensor at each point around the circumference of caliper logging sonde **10** is measured at a plurality of time instants and the maximum and minimum measurement obtained during an interval of multiple instants thereby is stored within buffer **74**. Thus, by utilizing a digital comparator, such as the one schematically depicted at reference numeral **72**, the maximum and minimum measurement during designated time intervals for each sensor around the circumference of caliper logging sonde **10** may be determined and temporarily stored.

Data input control **68** preferably stores each maximum and minimum within buffer **74**, which, in the depicted embodiment of the present invention, is capable of storing eighty data words. That is, the maximum valve and minimum value for each of the forty sensors within sensor **62**. Thereafter, in response to a command polling signal from the surface, which is received via Universal Asynchronous Receiver/Transmitter **78** (UART) and decoded at command register **80** data output control **76** is utilized to transfer the contents of buffer **74** to the surface via Universal Asynchronous Receiver/Transmitter **78**.

Additionally, as those skilled in the art will appreciate, Universal Asynchronous Receiver/Transmitter **78** (UART) may be utilized to generate commands to motor **82** which may be utilized, in a manner similar to that typically utilized in tools of this type, to retract sensing fingers **24** during insertion of caliper logging sonde **10** within borehole **12**.

Thus, upon reference to the foregoing those skilled in the art will appreciate that caliper logging sonde **10** of the present invention may be utilized to repeatedly measure variations in the internal dimensions of borehole tubing at a plurality of time instants and the maximum and minimum value detected at each of a plurality of points around the circumference of the sonde during selected intervals may be stored within a temporary buffer. Thereafter, a polling command from the surface may be utilized to upload the contents of buffer **74** to the surface, resulting in a tool which is capable of detecting pitting and/or corrosion in the internal dimensions of borehole tubing at any point between polling commands.

Additionally, the novel construction of transducer plate **52** may be utilized to provide a highly dense array of transducers such that defects within the internal dimensions of borehole tubing may be detected at a large number of points around the circumference of caliper logging sonde **10**. It should thus be apparent that caliper logging sonde **10** may be utilized to perform highly accurate and very thorough surveys of the internal dimensions of a borehole tube with a high degree of assurance that all defects within the internal dimensions of that tube will be noted within the resultant log.

While the invention has been shown in only one of its forms, it is not thus limited but is susceptible to various changes and modifications without departing from the spirit thereof.

What is claimed is:

1. An apparatus for measuring the internal dimensions of a tube within a wellbore, said apparatus comprising:

an elongate sonde adapted to be suspended within the wellbore by an electrical conductor and movable within a tube to be measured within said wellbore;

a plurality of sensing fingers mounted on said elongate sonde and movable with respect to said elongate sonde in response to variations in said internal dimensions of said tube, during movement of said elongate sonde within said tube;

detection means disposed within said elongate sonde for producing an electrical signal in response to the position of each of said plurality of sensing fingers at each of a plurality of time instants;

comparator means coupled to said detection means for comparing each electrical signal produced in response to the position of each of said plurality of sensing fingers with all other electrical signals produced during each of a plurality of time intervals, each of said plurality of time intervals comprising a said plurality of time instants, in order to determine a maximum electrical signal and a minimum electrical signal for each of said plurality of sensing fingers which occurs during each of said plurality of time intervals;

buffer means coupled to said detector means for temporarily storing said maximum electrical signal and said minimum electrical signal for each of said plurality of sensing fingers during each of a plurality of time intervals.

2. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 1, further including a plurality of variable inductors, each of said plurality of variable inductors associated with one of said plurality of sensing fingers wherein movement of a particular one of said plurality of sensing fingers will result in a variation of inductance for an associated variable inductor.

3. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 2, wherein said detection means comprises means for detecting variations of inductance of each of said plurality of variable inductors in response to movement of said plurality of sensing fingers at each of a plurality of time instants.

4. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 2, wherein each of said plurality of variable inductors comprises an electrical coil and a movable element extending into said electrical coil and movable therein in response to movement of an associated one of said plurality of sensing fingers.

5. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 4, wherein each of said movable elements comprises a magnetic rod.

6. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 1, further including means for centering said elongate sonde within said tube.

7. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 1, wherein said plurality of sensing fingers comprises forty sensing fingers.

8. A method for rapidly and accurately detecting defects in a tube within a borehole by detecting variations in the internal dimensions of the tube, said method comprising the steps of:

suspending a measurement device in a borehole utilizing an electrical conductor and moving said measurement device within a tube to be measured;

repeatedly measuring said internal dimensions of said tube at a plurality of points around the circumference of said tube at each of a plurality of time instants;

comparing each of said measured internal dimensions of said tube with all other measurements during each of a plurality of time intervals, each of said plurality of time intervals comprising a said plurality of time instants, in order to determine maximum and minimum internal dimension which occurs during each of said plurality of time intervals;

storing within said measurement device a maximum and minimum internal dimension at each of said plurality of points during each of a plurality of time intervals;

transmitting to an external computer said maximum and minimum internal dimensions; and

analyzing at the external computer the maximum and minimum internal dimension to determine defects in the tube.

9. An apparatus for measuring the internal dimensions of a tube within a wellbore, said apparatus comprising:

an elongate sonde adapted to be suspended within said wellbore by an electrical conductor and movable within a tube to be measured within said wellbore;

a plurality of sensing fingers mounted on said elongate sonde and movable with respect to said elongate sonde in response to variations in said internal dimensions of said tube, during movement of said elongate sonde within said tube;

a transducer plate mounted within said elongate sonde having a plurality of cylindrical apertures disposed generally about the circumference thereof, each of said plurality of cylindrical apertures having a first end and a second end;

a plurality of thimble members, each of said plurality of thimble members having an internal chamber and an elongate body having an external dimension smaller than an internal dimension of each of said plurality of cylindrical apertures, each of said thimble members sized to be fixedly inserted within an associated cylindrical aperture from a first end thereof;

a plurality of electrical coils, each sized to be inserted within a second end of an associated cylindrical aperture around said elongate body of an inserted thimble member;

means for retaining each of said plurality of electrical coils within an associated cylindrical aperture;

a plurality of movable members, each coupled to an associated sensing finger and movable within a said internal chamber of an associated thimble member in response to movement of said associated sensing finger;

detection means coupled to each of said plurality of electrical coils for producing an electrical signal in response to variations in position of each of said plurality of movable members at each of a plurality of time instants;

comparator means coupled to said detection means for comparing each electrical signal produced in response to variations in position of each of said plurality of movable members with all other electrical signals produced during each of a plurality of time intervals, each of said plurality of time intervals comprising a said plurality of time instants, in order to determine a maximum electrical signal and a minimum electrical signal for each of said plurality of movable members which occurs during each of said plurality of time intervals; and

buffer means coupled to said detector means for temporarily storing said maximum electrical signal and said minimum electrical signal for each of said plurality of movable members during each of said plurality of time intervals.

10. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 9, further including transmission means coupled to said buffer means for transmitting said stored maximum electrical signal and said stored minimum electrical signal for each of said plurality of movable members via said electrical conductor during each of said plurality of time intervals.

11. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 9, wherein each of said thimble members is constructed of a nonmagnetic material.

12. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 9, wherein each of said plurality of movable members comprises a magnetic rod.

13. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 9, further including means for centering said elongate sonde within said tube.

14. The apparatus for measuring the internal dimensions of a tube within a wellbore according to Claim 9, wherein said plurality of sensing fingers comprises forty sensing fingers.

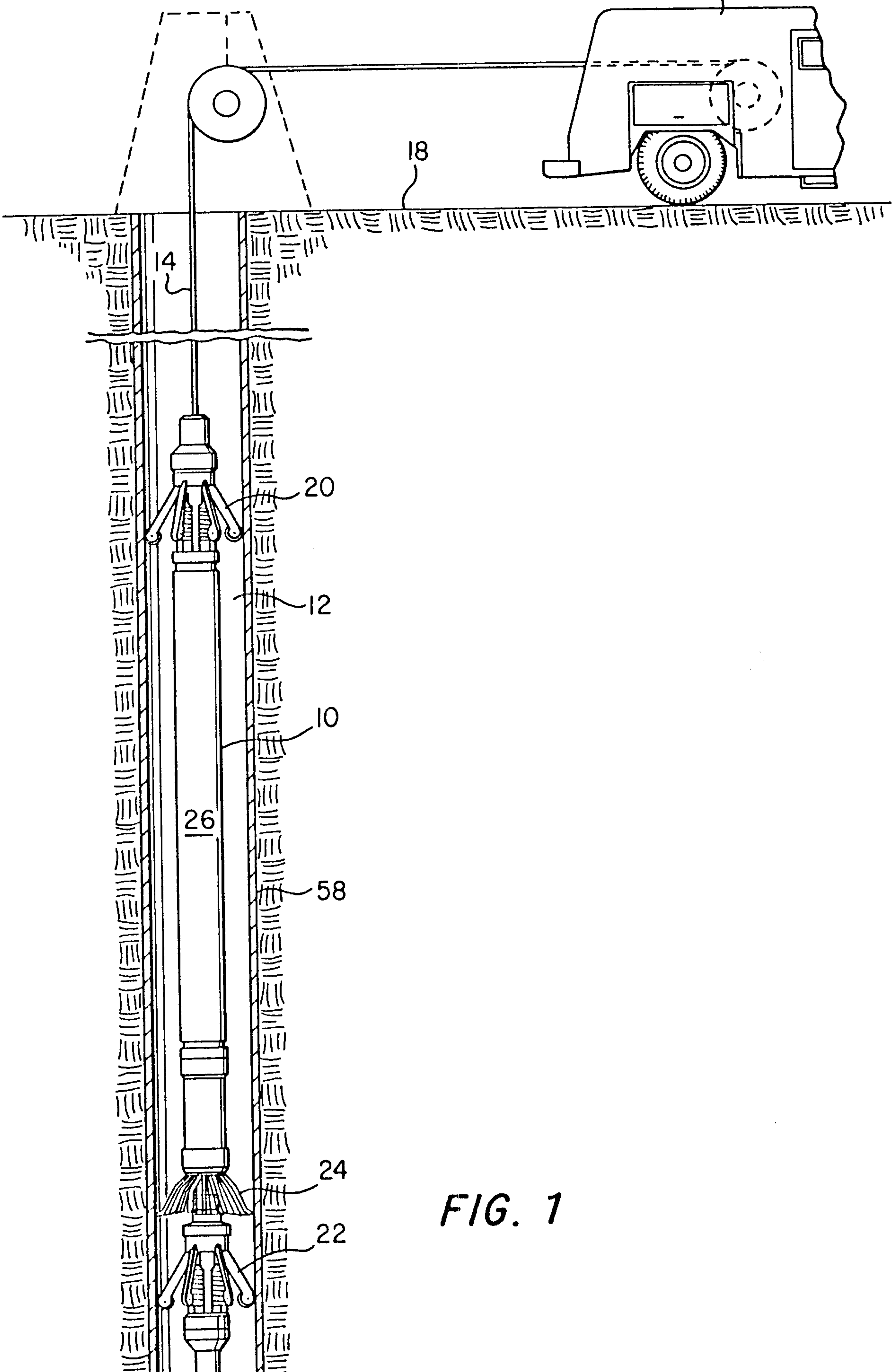

FIG. 1

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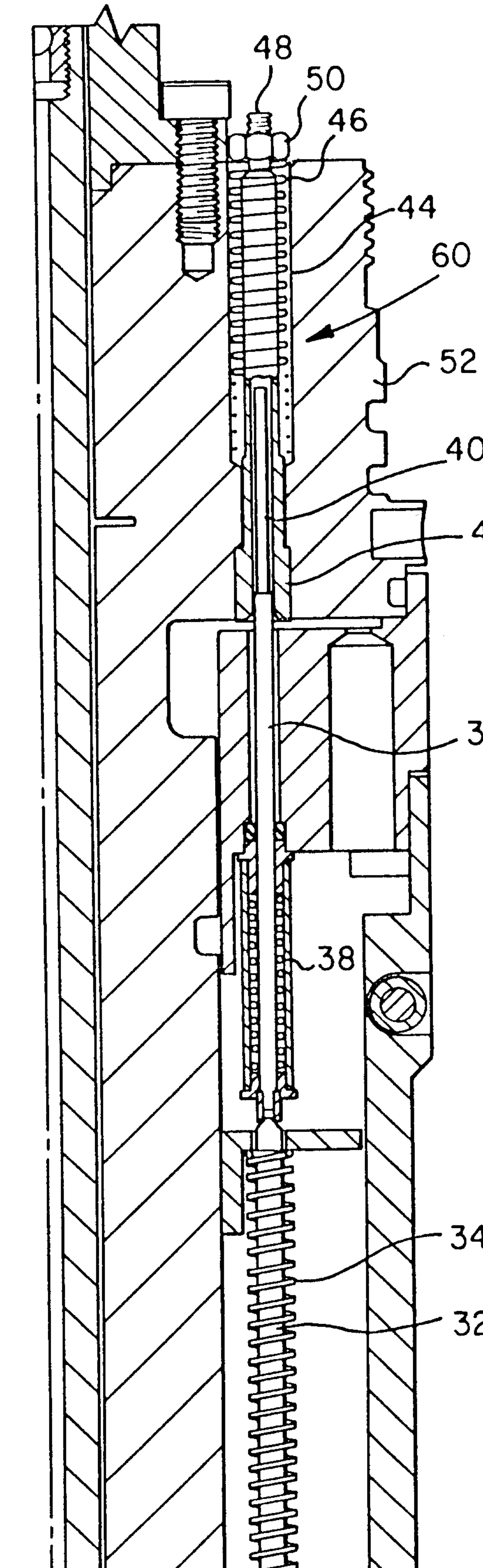
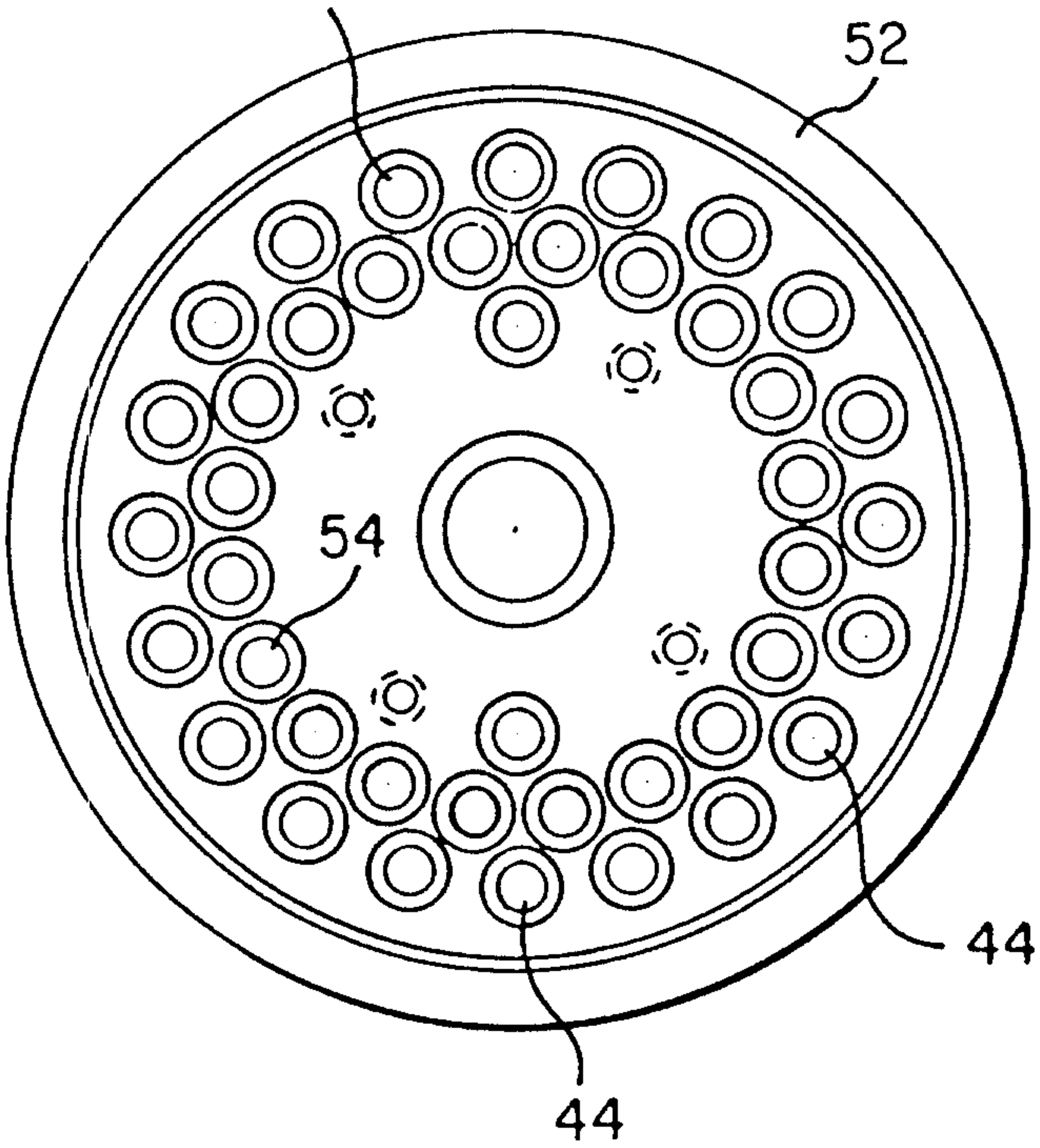


FIG. 2A

FIG. 3



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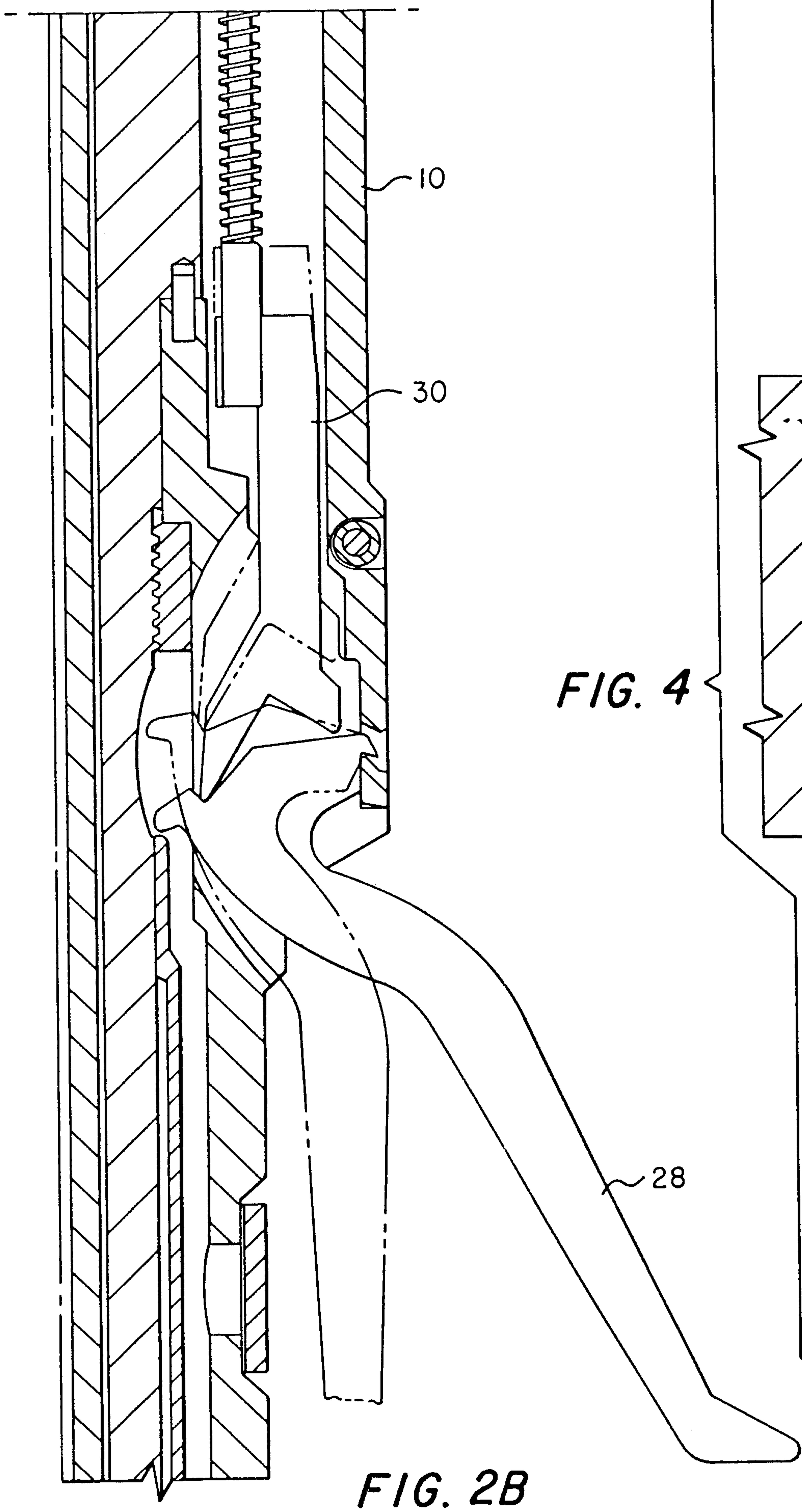

FIG. 2B

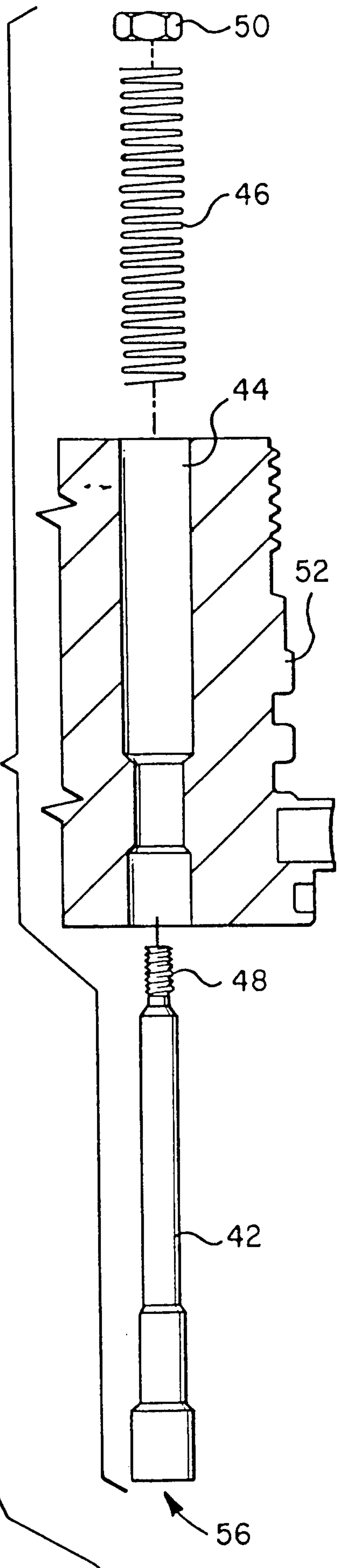

FIG. 4

Kirby, Eades, Gale, Baker

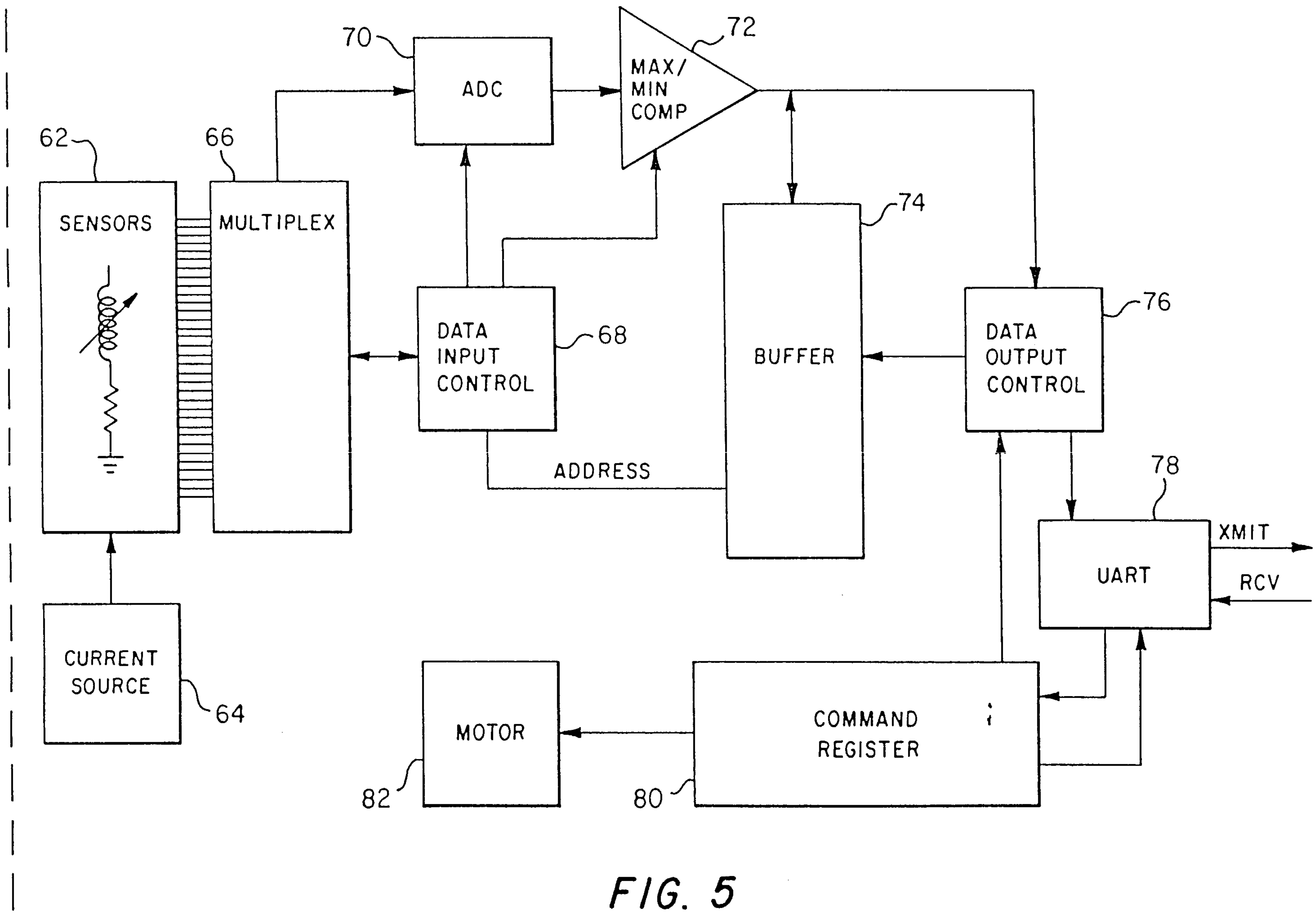
62
SENSORS
66
MULTIPLEX
70
ADC
72
MAX/
MIN
COMP
74
BUFFER
68
DATA
INPUT
CONTROL
ADDRESS
76
DATA
OUTPUT
CONTROL
78
UART
XMIT
RCV
CURRENT
SOURCE
64
MOTOR
82
COMMAND
REGISTER
80

FIG. 5