United States Patent

Clavin et al.

[15] **3,705,506**

[45] **Dec. 12, 1972**

[54] AUTOMATIC POSITIONING DEVICE

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[52] **U.S. Cl.** **72/21**, 72/380, 72/466

[51] **Int. Cl.**.....**B21d 9/00**, B21d 11/22

[58] **Field of Search**.....72/369, 380, 398, 430, 465, 72/466, 21; 254/134.5; 340/21, 196; 324/34; 191/2; 180/98

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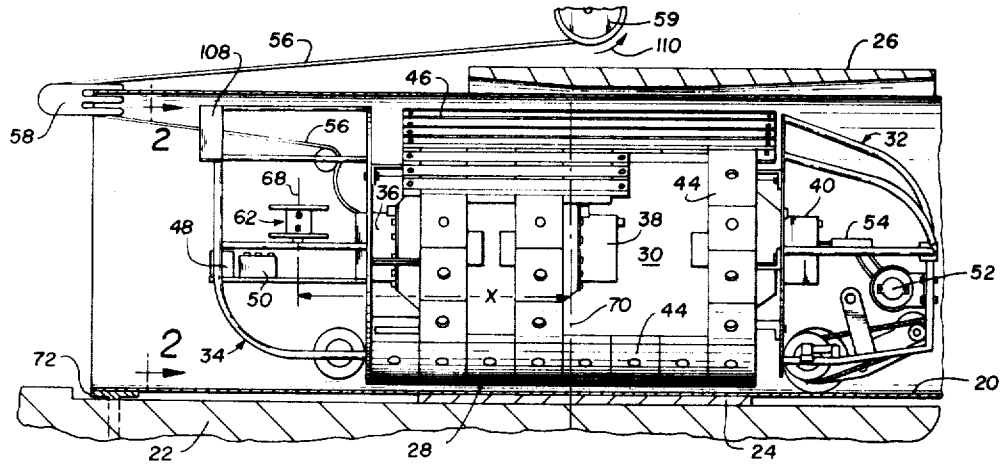
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[57] **ABSTRACT**

A method and apparatus for rapidly positioning a movable device longitudinally inside a tubular structure, such as a pipe, wherein a sensing means attached to said movable device functions to position said movable device responsive to a changing magnetic field generated by an establishing means positioned at a preselected location exterior to said pipe. When said movable device is required to be sequentially positioned longitudinally at a series of locations in one direction inside said pipe, the method and apparatus automatically re-positions said movable device at each location in the desired sequence. This abstract is neither intended to define the invention of the application which, of course, is measured by the claims, nor is it intended to be limiting as to the scope of the invention in any way.

20 Claims, 17 Drawing Figures



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SHEET 1 OF 5

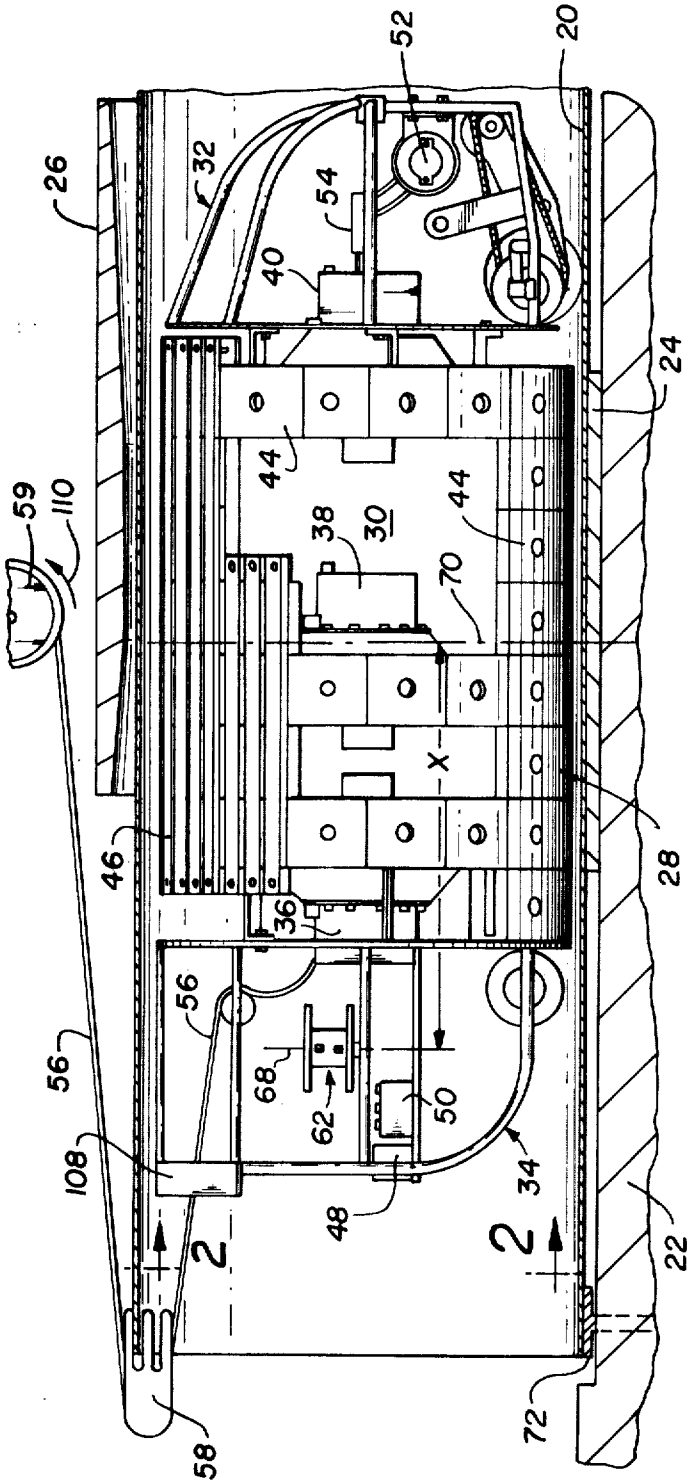


Fig. 1

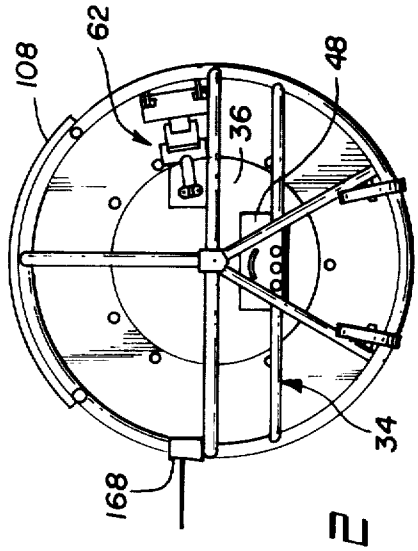


Fig. 2

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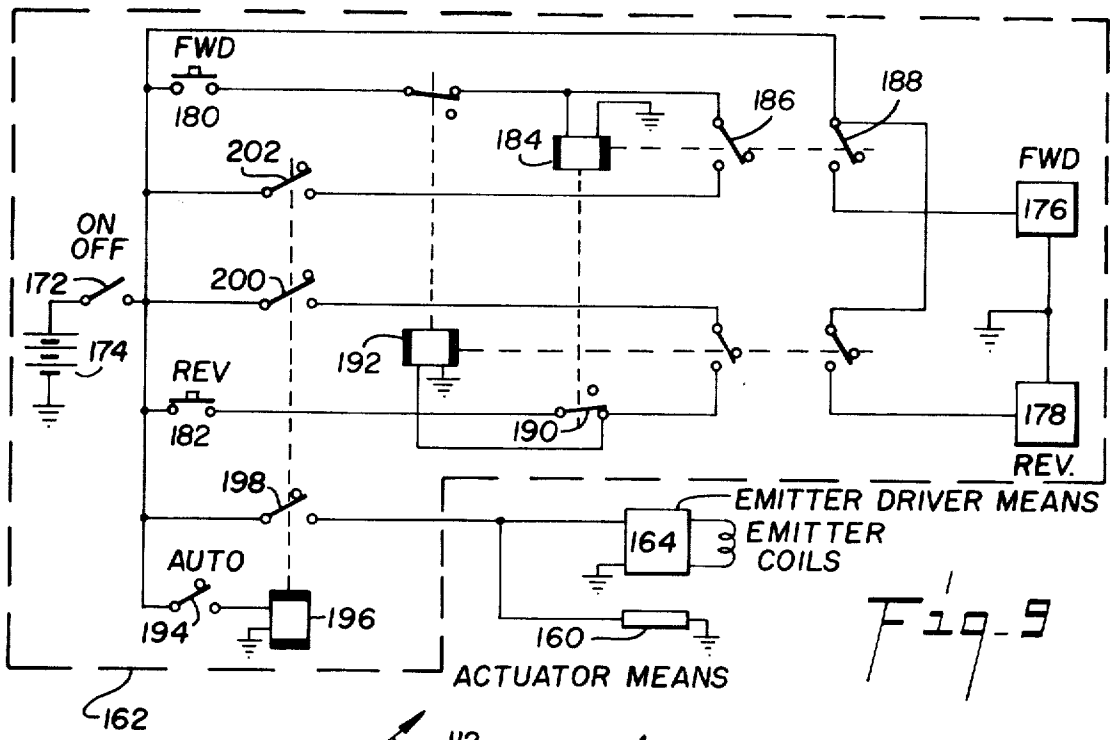


Fig. 9

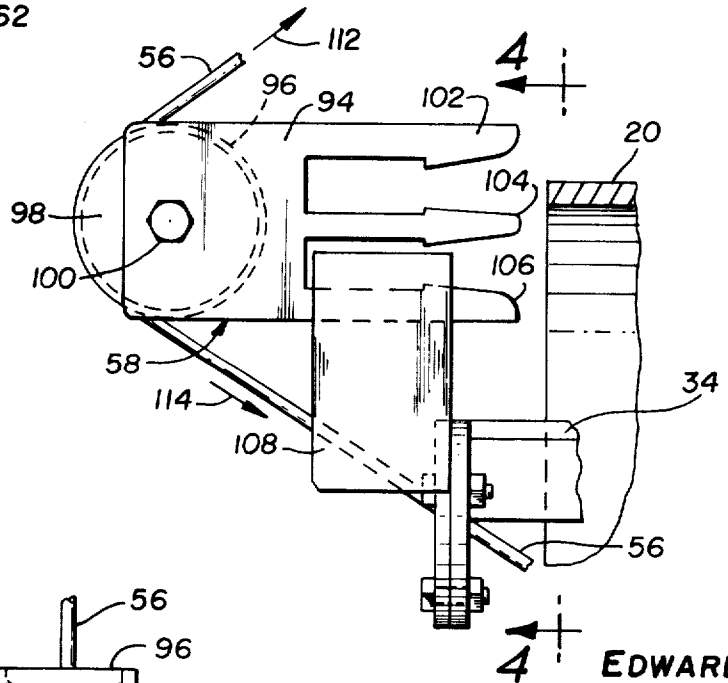


Fig. 3

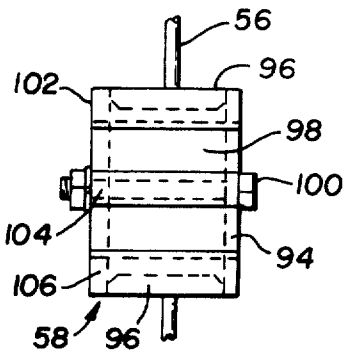
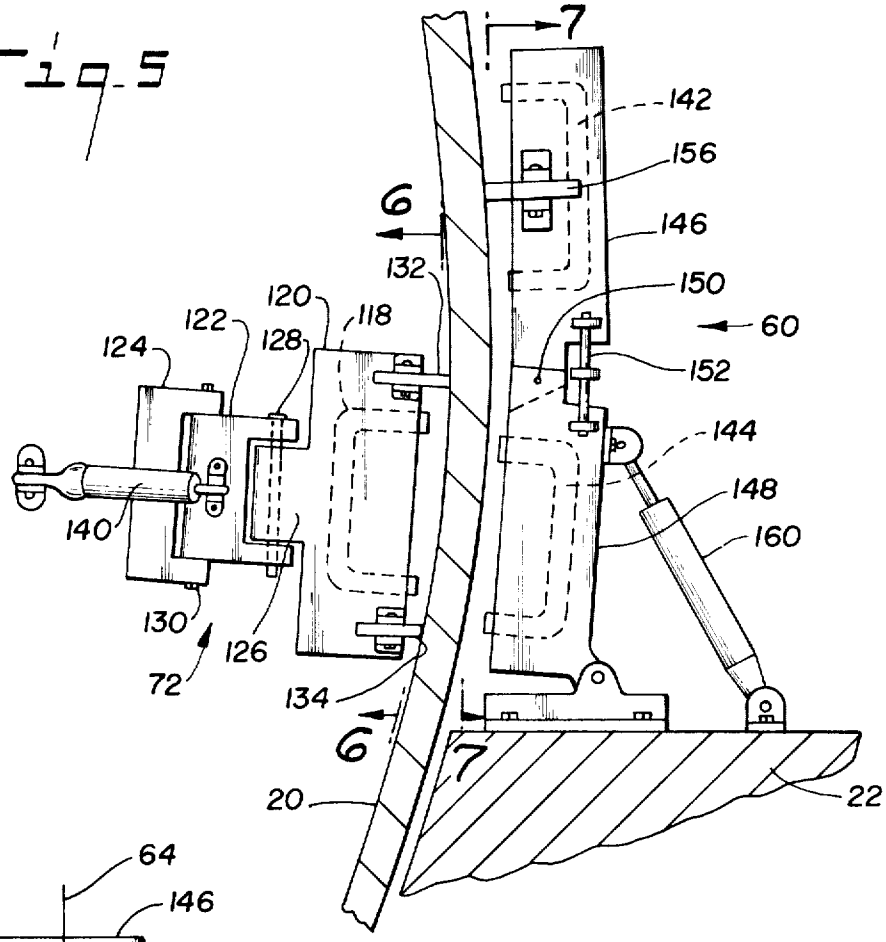


Fig. 4

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Fig. 5



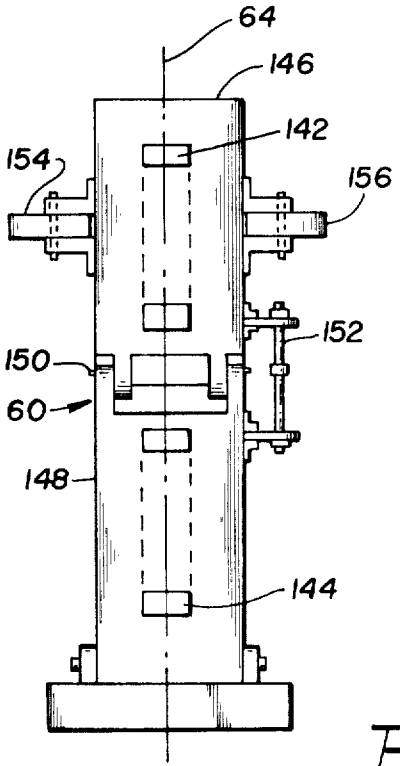


Fig. 7

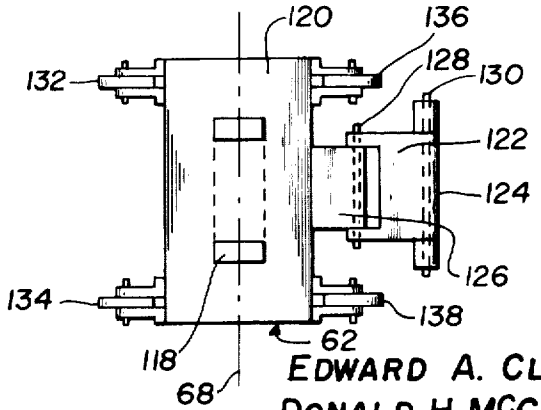
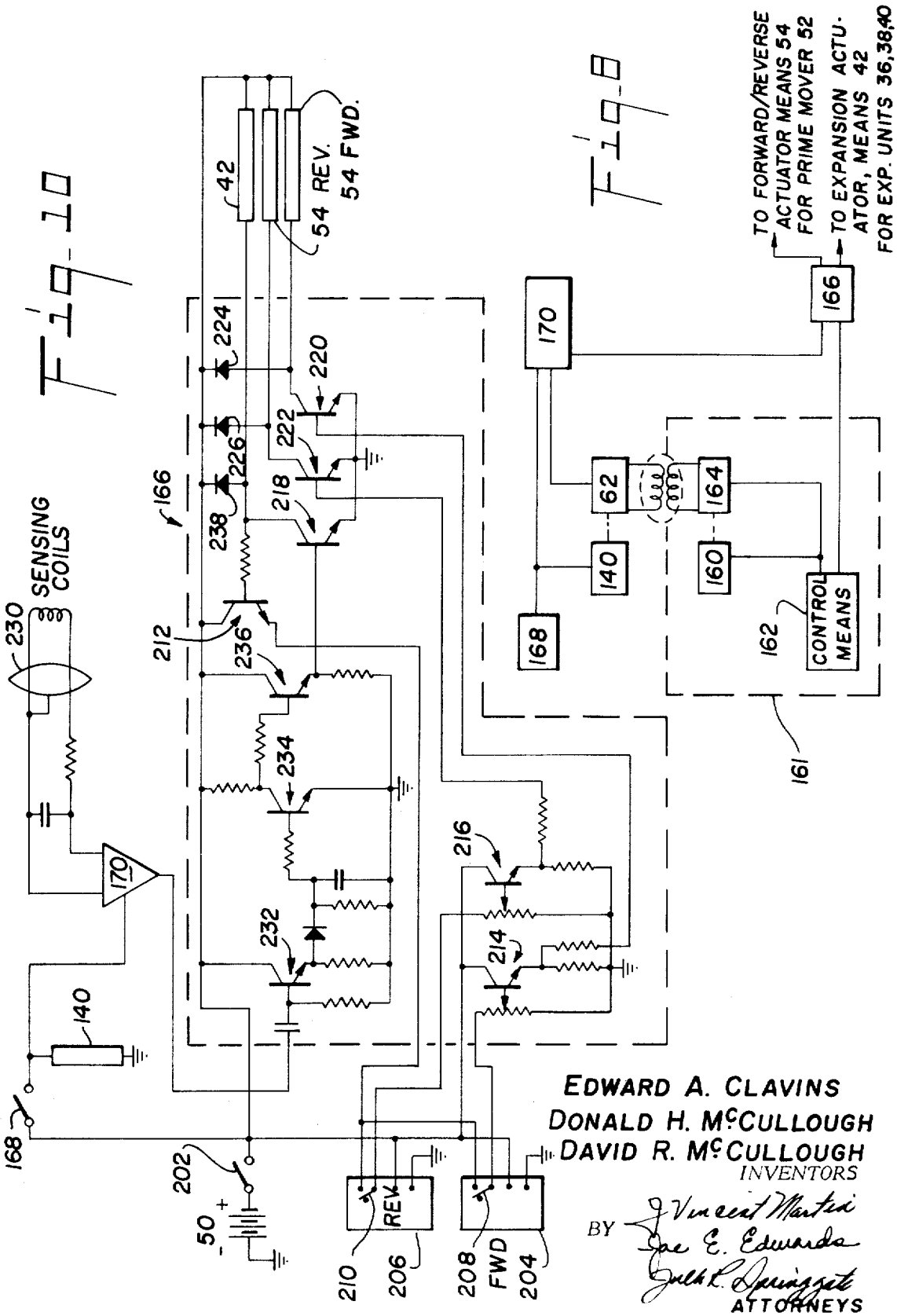


Fig. 6

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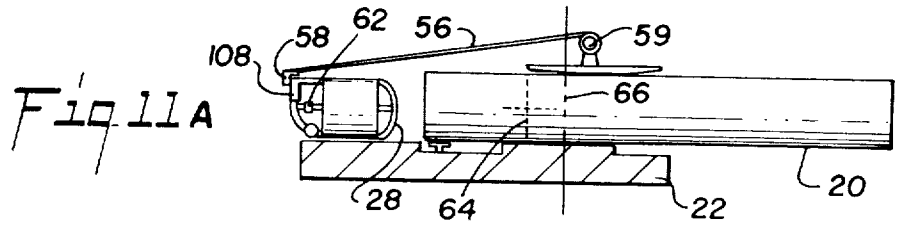


Fig. 11A

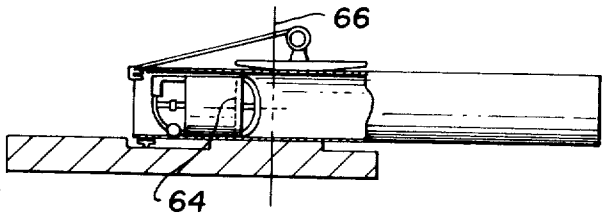


Fig. 11B

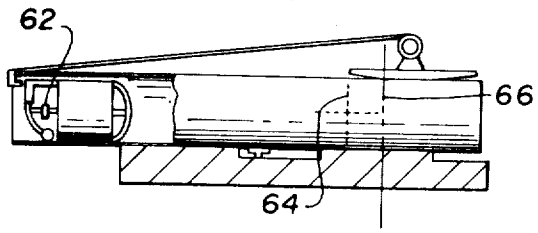


Fig. 11C

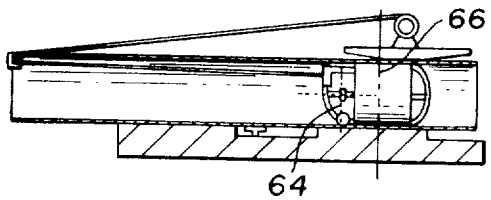


Fig. 11D

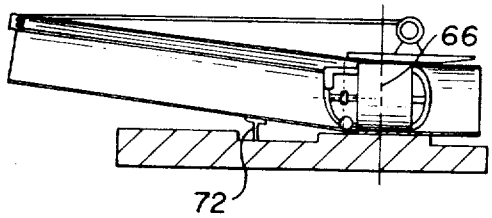


Fig. 11E

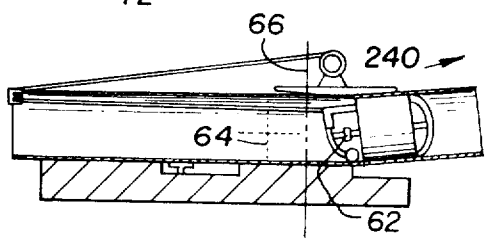


Fig. 11F

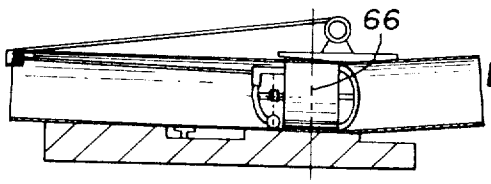


Fig. 11G

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AUTOMATIC POSITIONING DEVICE

BACKGROUND OF THE INVENTION

In the construction, bending and installation of pipe, a plurality of types of movable devices (usually self-propelled) are often employed to accomplish desired functions. Such movable devices are generally required to move longitudinally inside the pipe and stop at a desired location to perform a desired function.

One such movable device is the pipe supporting mandrel for pipe bending machines disclosed in U.S. Pat. No. 3,109,477. Such mandrel is constructed so that it may easily move longitudinally within the pipe to a desired location and, having reached such location, may be expanded against the interior surface of the pipe to support the pipe during the bending operation. Once the bending operation at that location is complete, the mandrel may be contracted and moved longitudinally to the next desired location.

At the present time the most common apparatus for positioning movable devices, such as the pipe supporting mandrel, longitudinally inside a pipe involves manual controls extending out the end of the pipe and, as such, is both difficult to handle and time consuming.

SUMMARY OF THE INVENTION

The present invention relates to an improved method and apparatus of positioning a movable device at a desired location along one side of a partition with respect to an element located on the other side of said partition. Additionally, the present invention has application to a process in which it is desired that said movable device be positioned at a series of desired locations in one direction along the partition.

The apparatus of the present invention employs an electromagnetic means attached in a desired fixed relationship to an element on one side of the partition. Such electromagnetic means establishes a periodically changing magnetic field and is positioned in a close spaced relationship to the partition so that said partition is within said changing magnetic field. A sensing means employing the phenomenon of electromagnetic induction is attached in a desired fixed relationship to the movable device on the other side of the partition. Said sensing means generates an electromagnetic voltage signal responsive to the changing magnetic field it senses, which electrical signal functions to position said establishing means and said sensing and generating means —and consequently said movable device and said element — in a desired relationship with each other.

More specifically, the present invention has particular application to and is herein described with reference to the positioning of a pipe supporting mandrel longitudinally inside a pipe with respect to an external pipe bending machine. During the pipe bending process the apparatus of the present invention automatically positions the mandrel at a series of longitudinal locations in one direction inside the pipe as the pipe is moved in the pipe bending machine to successive locations for successive bends.

It is an object, therefore, of this invention to provide an improved method and apparatus for positioning elements on opposite sides of a partition in a desired relationship to each other.

It is an additional object of this invention to provide an improved method and apparatus for the positioning of a movable device longitudinally inside a pipe.

Another object is an improved method and apparatus for the positioning of a movable device longitudinally inside a pipe in which the positioning of said movable device is accomplished without employing any measurements inside the pipe.

Still another object is when a movable device is to perform functions at a plurality of sequential locations in one direction longitudinally along the inside of the pipe, the method and apparatus will automatically reposition such movable device at such locations.

Still another object of this invention is to provide an improved method and apparatus for the positioning of a movable device longitudinally inside a pipe in which a sensing means, attached to the movable device moving longitudinally inside the pipe, will detect a changing magnetic field generated by an establishing means positioned exterior to the pipe, and will function responsive to said field to position longitudinally said device.

A still further object is to provide an improved pipe supporting mandrel which will automatically position and set itself to support the pipe each time the pipe is moved in one direction for a subsequent bend, which position of the mandrel is the desired internal support position for bending with respect to the external bending machine.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention itself both as to organization and method of operation, as well as additional objects and advantages, is more fully explained in the following description when read in connection with the accompanying drawings in which:

FIG. 1 is a side view of an improved pipe supporting mandrel of the present invention in its contracted position within a pipe shown in section positioned in a schematically illustrated pipe bending machine.

FIG. 2 is an end view of a mandrel taken on line 2—2 in FIG. 1.

FIG. 3 is a side view of a removably secured guide means supporting the hose to the improved mandrel of the present invention.

FIG. 4 is a view of such removably secured guide means taken on line 4—4 in FIG. 3.

FIG. 5 is a sectional view of a pipe showing the sensing means and establishing means of the present invention in contact therewith, and showing the general arrangement of the mechanical portions thereof.

FIG. 6 is a view of the sensing means taken on line 6—6 of FIG. 6.

FIG. 7 is a view of the establishing means taken on line 7—7 of FIG. 5.

FIG. 8 is a block diagram of the electrical and related components of this invention.

FIG. 9 is a schematic diagram of the electrical components located exterior to the pipe.

FIG. 10 is a schematic diagram of the electrical components located on the mandrel.

FIGS. 11(A) through 11(G) are a series of schematic side views of certain parts of a pipe bending machine, a pipe, and an improved mandrel according to this invention, illustrating the operation of the improved mandrel in conjunction with a pipe bending machine.

DESCRIPTION OF THE PREFERRED EMBODIMENT: GENERALLY

FIG. **1** is a side view of a pipe supporting mandrel, such as is disclosed in U.S. Pat. No. 3,109,477, showing it in a contracted position within a fragment of a pipe **20**, such pipe in turn being illustrated schematically within certain parts of a pipe bending machine. The pipe bending machine, broadly designated by the numeral **22**, is a conventional apparatus provided with a transversely arcuate support **24** for the pipe **20** together with a transversly concave but longitudinally convex bending die **26** in diametrically opposed relationship to the support **24**. The pipe **20** is positioned longitudinally in the pipe bending machine by ordinary means; proper positioning of the pipe **20** is not difficult because the exterior of such pipe is visible with respect to the components of the bending machine.

The pipe supporting mandrel, broadly designated by the numeral **28**, is in the nature of an elongated flexible body **30** provided with spiderlike framework **32** and **34** at its ends. In the following explanation, the end of the mandrel having the framework **32** is the "forward" end of the mandrel and the end of the mandrel having the framework **34** is the "rear" end of the mandrel (longitudinal movement of the mandrel toward the forward end is referred to as the "forward" direction and longitudinal movement toward the rear end is referred to as the "reverse" direction). Body **30** includes three identical longitudinally spaced expansion units or assemblies **36**, **38** and **40**. The details of such expansion units are not shown, but each such unit is constructed of ordinary means and functions to expand pneumatically by compressed air a plurality of radially reciprocal plungers (not shown). Expansion actuator means **42** (shown schematically in FIG. **10**), a standard device such as a fluid piston, functions pursuant to an electrical signal to pass and interrupt the flow of compressed air to the expansion units **36**, **38** and **40**. The plungers function to expand and hold the shoes **44** and the extending flexible strips **46** in firm engagement with the interior wall of the pipe **20**, thereby providing support for the pipe during the bending process.

Attached to the framework **34** of the mandrel is a container **48** in which are located certain of the electrical components and a DC battery **50** to power such electrical components.

Forward and reverse movement of the mandrel is provided by a drive of ordinary means. U.S. Pat. No. 3,109,477 describes in detail the construction of such a drive means, including a fluid driven prime mover. The mandrel **28** described herein utilizes such a fluid driven prime mover **52** which is attached to the framework **32** and which operates on compressed air. Also attached to the framework **32** is the forward/reverse actuator means **54** which functions to control the flow of the compressed air to the fluid driven prime mover **52** to drive such prime mover in either the forward or reverse direction and to shut off the flow to stop the prime mover.

The operations of the prime mover **52**, on the one hand, and the expansion units **36**, **38** and **40**, on the other, are mutually exclusive; therefore, the same source of compressed air can easily be used for both. The compressed air is supplied to the expansion units and prime mover of the mandrel through a hose **56** which extends through a removably secured guide means **58** to a spring loaded revolving storage wheel **59** and source of compressed air located exteriorally of the pipe **20** remote from the mandrel.

The revolving storage wheel **59** is shown schematically above the bending die **26** in close proximity to the bending machine **22**. Such location allows easy access to the wheel by the operator of the bending machine and removes the wheel from the longitudinal path of the mandrel while outside the pipe. However, since the mandrel's prime mover preferably has compressed air supplied to it both while inside and outside of the pipe, the guide means **58** ensures that the hose **56** has free passage at all times from the storage wheel **59** to the mandrel. Such guide means **58** is attached to the end of the pipe (as shown in FIG. **1**) when the mandrel is in the pipe and attached to the mandrel itself when such mandrel is outside the pipe.

A means to establish a periodically changing magnetic field of desired frequency and magnetic intensity is placed in close spaced relationship to the exterior surface of the wall of the pipe at a desired relationship with respect to the pipe bending machine to generate a magnetic field which will flow into the wall of the pipe. In the preferred embodiment of this invention, such establishing means **60** (where shown) includes at least one electromagnet comprised of a U-shaped core of ferromagnetic material, such as cold rolled steel, around which is coiled a conductor capable of carrying electric current. The magnetic field is created when electric current is driven through such coiled conductor.

If the material comprising the wall of the pipe has a permeability of magnetism approximately equal to that of free space (such as a plastic pipe), then the magnetic flux of the field will extend relatively undisturbed through such wall into the free space interior of the pipe. If, however, the permeability of magnetism of the wall of the pipe is much greater than that of free space (such as a ferromagnetic metallic pipe), the effect of the magnetic flux generated by the electromagnet is to align the spinning electrons in such wall so that they themselves become sources of magnetic flux and the original flux distribution is disrupted. Most of the magnetic lines emanating from the positive pole of the electromagnet are then passed into the metallic wall of the pipe, travel through such wall to a location therein adjacent to the negative pole of the electromagnet, and pass back to the negative pole of the electromagnet. The pipe wall acts as a shield with respect to the interior free space region of the pipe. It has been found, however, that even when the pipe wall has a high permeability of magnetism, the parameters to be discussed below can be varied so that some portion of the magnetic flux emitted by the electromagnet passes through the wall of the pipe and travels through the free space interior of the pipe prior to being drawn back through the wall of the pipe to the negative pole of the electromagnet.

Certain parameters, some of which may be controlled by the operator of the bending machine, affect the amount of magnetic flux which will pass into the free space interior of the pipe. The permeability of magnetism of the wall of the pipe is of course a principal parameter, but one which cannot be controlled by the operator. However, the operator can control the

magnetic intensity of the magnetic field being established and, therefore, affect the ability of the magnetic flux to penetrate the wall of the pipe. The spaced relationship between the poles of the electromagnet and the exterior surface of the pipe is another easily varied parameter. If the poles are in direct contact with the wall of the pipe, the pipe acts as a "keeper" and almost all of the magnetic flux flows through the pipe from the positive to the negative terminal of the electromagnet. On the other hand, as the poles are moved away from the exterior surface of the pipe, the free space region causes the reluctance to increase dramatically. And at some point the magnitude of the reluctance will be such that the magnetic field will not supply sufficient magnetic flux to the pipe to penetrate into the interior free space region.

If a longer vertical magnetic field is desired on the interior of the pipe, a plurality of electromagnets may be utilized in the establishing means. Since a pipe supporting mandrel may on occasion "walk" up one or the other of the interior walls of the pipe, the preferred embodiment of this invention utilizes two identical U-shaped electromagnets. Each U-shaped electromagnet is mounted so that its ends are vertically aligned, and the two electromagnets themselves are vertically aligned with respect to each other. The positive pole of the first electromagnet is placed adjacent to but in spaced relationship with the negative pole of the second electromagnet. The spaced distance between such positive and negative poles now becomes an additional parameter which may be varied by the operator to affect the amount of magnetic flux penetrating the pipe wall.

A means to sense the periodically changing magnetic field emitted by the establishing means and existing in the free-space interior of the pipe is mounted on the mandrel at a desired location. In the preferred embodiment of this invention, such sensing means **62** is comprised of a conductor capable of carrying electric current coiled around a ferromagnetic core. Such coiled conductor and core are attached to the movable mandrel **28** in close spaced relationship with the interior surface of the pipe **20**. As such coil and core move into the magnetic field generated by the establishing means, the change in flux through such coil generates an electric current through the conductor and causes a difference of voltage potential between its ends.

It has been found that the coiled conductor on the core does not have induced therein a sufficient voltage potential simply by being moved longitudinally through a magnetic field generated by a direct current flowing through the establishing electromagnet. And upon cessation of relative movement between the conductor and the electromagnet, no voltage potential is induced. Therefore, an alternating current (rather than a direct current) is preferably driven through the establishing electromagnet to increase the rate of change of magnetic flux at every point in the magnetic field. In the preferred embodiment of the establishing means a sixty cycle per second square-wave alternating current signal is driven through the coiled conductor in the electromagnets.

Experimentation has revealed that the frequency of the current signal driven through the electromagnets has a marked effect on the accuracy of the sensing means. The higher the frequency of the alternating current, the greater the propensity of the magnetic field to propagate. An alternating current with a frequency of say 10,000 cycles per second generates a magnetic field which flows through the walls of the pipe along the entire length of the pipe; the pipe acts as an antenna and the sensing means will detect changing magnetic fluxes at every point inside the pipe. As the frequency of the alternating current is reduced, the range of the magnetic field decreases. In the preferred embodiment of the establishing means according to this invention, the 60 cycles per second signal generates a magnetic field which penetrates the wall only a few inches longitudinally along the pipeline in either direction from the electromagnets. Even with this low frequency, however, there will be magnetic fluxes emanating from both ends of a ferromagnetic pipe due to the pipe itself tending to act as a magnet. But these magnetic fluxes do not adversely affect the accuracy of the sensing means inside the pipe so long as such sensing means is more than a few inches away from the ends of the pipe.

To utilize properly the pipe supporting mandrel **28** in the pipe bending process, it is preferred that for each bend of the pipe the vertical centerline of the mandrel be approximately coincidental with a traverse vertical plane through the bending die **26** of the pipe bending machine representative of the center of that portion of the die which imparts bend to the pipe. This is because the segment of the pipe which is to be bent and which is to be supported is aligned with said traverse vertical plane of the bending die.

In the preferred embodiment, establishing means **60** is mounted exteriorally of the pipe **20** so that the vertical centerline **64** (FIGS. **7** and **11**) of its vertically aligned U-shaped electromagnets is a known distance X longitudinally from the desired traverse vertical plane **66** (FIG. **11**) of the bending die **26**. Sensing means **62** is mounted on the mandrel **28** so that the vertical centerline **68** (FIGS. **1** and **8**) of its sensing coil is located longitudinally the same distance X from the vertical centerline **70** (FIG. **1**) of the mandrel **28**. Sensing means **62** is mounted in the same longitudinal direction from the vertical centerline **70** of the mandrel as establishing means **60** is mounted from the vertical plane **66** through the bending die. Additionally, sensing means **62** is mounted so as to coincide approximately in latitude with the establishing means **60**.

Proper positioning of the mandrel **28** with respect to the bending machine **22** is accomplished by causing the movement and the expansion of the mandrel **28** to be responsive to the electromagnetic voltage signals generated by the sensing means **62** responsive to the changing magnetic field of the establishing means **60**.

When the mandrel **28** has been properly positioned according to this invention and the shoes **44** and strips **46** are tightly engaged against the inner surface of the pipe **20**, the pipe is firmly and adequately supported for bending. Bending may be accomplished through the use of hydraulic means which forces upward a traversly concave shoe **72** against the bottom exterior of the pipe **20** and bends the pipe against the bending die **26**. When the desired bend has been imparted to the pipe **20**, the arcuate support **24** and bending die **26** are loosened and the hydraulic means is retracted, thereby allowing the end of the pipe supported by the concave

shoe 72 to resume a horizontal position. The pipe may then be repositioned longitudinally in the pipe bending machine for the next bend. The mandrel 28 is then repositioned according to this invention within the pipe in order to provide the necessary support at the location of the next bend.

DESCRIPTION OF REMOVABLY SECURED GUIDE MEANS

FIGS. 1, 2, 3(A) and 3(B) show a practical construction of such a guide means according to this invention. The removably secured guide means 58 includes a body 94 containing a cylindrical cavity 96 in which a pulley 98 is pivotally mounted by a bolted pin 100. The hose 56 travels through the cavity 96 and around the pulley 98.

Connected to the body 94 are three flanges 102, 104 and 106, which function to support removably the guide means 58 to either the wall of the pipe 20 or to the mandrel 28. The wall of the pipe is engaged between flanges 102 and 104 and an arcuate plate 108 on the rear framework 34 of the mandrel 28 is engaged between flanges 104 and 106. The radius of plate 108 is preferred to be approximately equal to the radius of the pipe 20. Arcuate plate 108 is preferred to be attached to the upper framework 34 in such a location so that when the mandrel 28 moves inside the pipe 20, the removably secured guide means 58 engages the pipe 20 between flanges 102 and 104 and plate 108 is pulled from between flanges 104 and 106.

The space between flanges 102 and 104 should be slightly greater than the thickness of the wall of the pipe 20 to accommodate the curvature of pipe 20. Likewise, the thickness of the cavity between the lower two flanges 104 and 106 should be slightly greater than the thickness of the arcuate plate 108 to accommodate the curvature of plate 108. The ends of the flanges are rounded to facilitate entry of the pipe and the arcuate plate into said spaces and to allow for slight misalignment.

The storage wheel 59 functions not only to store the hose 56, but also to exert continuously force on the hose in the direction designated by the arrow 110 in FIG. 1. Since the other end of the hose 56 is attached to the mandrel 28, there are forces acting continuously on the removably secured guide means 58 in the directions of the arrows 112 and 114 shown in FIG. 3. The spaced relationship of the pipe 20, arcuate plate 108 and flanges 102, 104 and 106 in conjunction with the pressures exerted by the hose 56, cause the removably secured guide means 58 to be secured to the arcuate plate 108 of the mandrel whenever the rear of the mandrel is exterior to the pipe 20 and to be secured to the pipe 20 whenever the rear of the mandrel is within the pipe 20.

DESCRIPTION OF ESTABLISHING MEANS AND SENSING MEANS

FIGS. 1, 6 and 8 illustrate a preferred embodiment of the physical construction of the sensing means and establishing mans according to this invention. The sensing means, broadly designated as 62, is attached to the framework 34 of the mandrel 28. Such sensing means 62 is comprised of a ferromagnetic core 118 and an electrical current carrying conductor (not shown) coiled therearound. Such core and conductor are securely molded into or otherwise held by a body 120, preferably non-magnetic, in such a manner that the long axis of the U-shaped core is vertically aligned.

The body 120 is pivotally connected to a yoke 122, which in turn is pivotally connected to a plate 124 secured to the framework 34 of the mandrel. The body 120 has a bored flange 126 which loosely fits between two bored flanges on the yoke 122. A pin 128 is disposed through the two flanges on the yoke 122 and the bored flange 126. The diameter of the pin 128 is somewhat less than the diameter of the bore in the flange 126 so as to provide a "sloppy fit," which aids in the engaging of the body 120 against the inner surface of the pipe 20 by allowing for slight misalignments.

The plate 124 has two bored flanges which fit over the ends of a bore in the yoke 122. A pin 130 through such flanges pivotally secures the yoke to the plate. The plate is secured to the framework of the mandrel by ordinary means such as bolting or welding.

As particularly revealed in FIG. 8, adjustably attached to the body 120 are four wheels 132, 134, 136 and 138. Each wheel is pinned between two lugs and the lugs are adjustably attached to the body 120. The four adjustable wheels function to keep the ends of the core 118 from scraping the inside of the pipe and, in conjunction with the sloppy fit between the body and the yoke, to provide a constant close spaced relationship between the ends of the core 118 and the inner surface of the pipe 20 as the body 120 moves longitudinally along the inside of the pipe.

An actuator means 140 is pivotally connected to the framework 34 and to the yoke 122 by ordinary means, such as pins and lugs. Such actuator means 140, which may be a fluid piston, functions to move plate 120 into position with the four wheels in engagement with the inner surface of the pipe 20 when expanded and to withdraw the sensing means 62 safely within the confines of the framework 34 when retracted. In the preferred embodiment of this invention, such actuator means 140 operates on compressed air supplied from the hose 56; the flow of the compressed air into the fluid piston chamber is controlled by a spring-loaded reciprocally moving magnetic device driven by a solenoid pursuant to a supplied electrical signal as hereinafter explained.

Attached to the bending machine exterior to the pipe is the establishing means, generally designated by the number 60. Such establishing means includes electromagnets 142 and 144, each of which is positioned so that its positive and negative poles are vertically aligned. Each electromagnet 142 and 144 is molded into or attached to a body 146 and 148, respectively, which bodies 146 and 148 are pivotally connected to each other by means such as pin 150 secured in bored flanges attached to each body. The pivotal connection is provided so that the angle between the surfaces of such bodies may be varied in accordance with the varying circumferences of the pipes being bent. The proper angle is maintained through the use of a jackscrew 152 which is attached to the two bodies by suitable means, such as welded lugs. Body 148 is pivotally connected by suitable means to a portion of the bending machine 22. The two wheels 154 and 156 are adjustably mounted on body 146 as shown. The wheels function to space

the electromagnets **142** and **144** a constant distance from the exterior surface of the pipe **20** and to allow the pipe **20** to move easily with respect to the emitting means **60**.

An actuator means **160** pivotally connected to the body **148** and the bending machine function to hold the wheels **154** and **156** firmly against the outer surface of the pipe **20** when expanded and to draw the establishing means **60** back safely away from the pipe when retracted. Such actuator means **160** may be any suitable device, such as a fluid operated piston similar to that described for the sensing means. The actuator means **160** is attached to the body **148** and the bending machine **22**.

ELECTRICAL AND RELATED COMPONENTS

FIG. **8** is a block diagram of the preferred arrangement of the electrical and related components for positioning a movable pipe supporting mandrel inside a pipe according to this invention. These components which are preferably located exteriorly of the pipe are shown within the dashed lines **161**. The remainder of the components shown in FIG. **8** are preferably mounted on the mandrel.

Control means **162** functions to transmit energizing signals to the actuator means **160**, the driver means **164** for the establishing means **60**, and the correlation means **166**. Control means **162** is preferably attached to the pipe bending machine at an easily accessible location.

Pursuant to an energizing signal received from control means **162**, actuator means **160** functions as previously described to move and hold the establishing means **60** in spaced relation to the exterior surface of the pipe **20**. Pursuant to an energizing signal from the control means **162**, driver means **164** functions to produce and drive through the electromagnets in the establishing means **60** an alternating current signal of preselected frequency, thereby producing the desired changing magnetic field.

Switch **168** functions to energize actuator means **140** and amplifying means **170**. In the preferred embodiment of the invention, switch **168** is a "whisker" switch attached to the rear framework **34** of the mandrel **28** in such a manner that it is physically turned on when the rear of the mandrel enters the pipe and stays on continually while the mandrel is inside the pipe.

Actuator means **140** functions as previously described to move and hold the sensing means **62** in spaced relation to the inside of the pipe **20**. Amplifying means **170** functions to amplify by a preselected gain the voltage signal generated by the sensing means **62**.

Correlation means **166** functions to correlate the signals received from control means **162** and signals, if any, received from amplifying means **170**. Control means **162** transmits only two sets of functional signals to the correlation means **166**: enable or disable forward movement of the mandrel and enable or disable reverse movement of the mandrel. So long as no signal of preselected desired magnitude is being received from amplifying means **170**, correlation means **166** will function responsive to the signals received from the control means **162** to energize and deenergize the forward/reverse actuator means **54** for the prime mover. However, whenever a voltage signal of preselected desired magnitude is received from amplifying means **170**, the correlation means **166** will de-energize the forward/reverse actuator means **54** and energize the expansion actuator means **42** for the expansion units **36**, **38** and **40** (regardless of any signal which might be simultaneously received from the control means **162**). The correlation means **166** and amplifier means **170** are preferably contained in the container **48** attached to the framework **34** of the mandrel **28**.

EXTERIOR ELECTRICAL COMPONENTS

FIG. **9** is a schematic diagram of a practical arrangement of the electrical components located exteriorly of the pipe, that is, control means **162**, actuator means **160** and driver means **164**. The components comprising a preferred control means **162** are shown within the dashed lines.

On/off switch **172**, functions to apply a power voltage source **174**, such as a **12** volt DC battery, across the rest of the circuitry in the control means **162**.

One of the functions of the control means **162** is to transmit the operator's signals to the mandrel so that the mandrel can be caused to move in a forward or reverse direction or to cease movement. This could well be accomplished through the use of electrical wires feeding from the pipe bending machine to the container **48** on the framework **34** of the mandrel. Such wires could be secured to the hose **56** which feeds to the mandrel. However, in the preferred embodiment of this invention, such signals are transmitted from the control means **162** to the mandrel via radio waves through the use of transmitting means and receiving means.

Forward transmitting means **176** and reverse transmitting means **178** are standard devices, each of which functions to generate, pursuant to an energizing signal, a constant output signal of preselected frequency. In the preferred embodiment, for example, forward transmitting means **176** generates while energized a UHF signal with a frequency of 275 megacycles and reverse transmitting means **178** generates while energized a UHF signal with a frequency of 285 megacycles.

The operator energizes and de-energizes the forward and reverse transmitting means **176** and **178** through the use of push-button switches **180** and **182** respectively, each of which is an ordinary device which functions to pass the DC voltage only while physically depressed. When push-button switch **180** supplies voltage to the input of relay **184**, such relay functions to close switches **186** and **188** and to open switch **190**. The closing of switch **188** applies voltage across and energizes forward transmitting means **176**. The opening of switch **190** precludes the activating of relay **192**. The reverse push-button switch **182** and its attendant circuitry functions similarly. It is observed that relay **184** and relay **192** are mutually exclusive.

Switch **194** energizes those components utilized to position the mandrel longitudinally inside the pipe. The closing of switch **194** activates relay **196**, which functions to close switches **198**, **200** and **202**. The closing of switch **198** activates actuator means **160** and driver means **164**. Driver means **164** is a standard inverter device which functions to transform the constant DC voltage signal to an AC voltage signal. For example, the output of said means **164** may be a 120 volt, 60 cycle

per second, square-wave signal with 500 watts of power. Such signal is driven through the conductor coiled around the two electromagnets in the establishing means **60**.

The closing of switch **202** creates a potential additional current path to relay **184**. Now when relay **184** is activated by push-button switch **180** and switch **186** closes, relay **184** becomes "locked-in" due to the current flowing through such additional current path. Even if the operator is no longer depressing push-button switch **180**, relay **184** and forward transmitting means **176** remain activated until switch **194** is opened. Switching means **200** and the circuitry attendant to relay **192** functions similarly.

ELECTRICAL COMPONENTS LOCATED ON THE MANDREL

FIG. **10** is a schematic diagram of a practical arrangement of the electrical components in those portions of the preferred embodiment located on the mandrel. The voltage source for such electrical components is the DC battery **50** attached to the framework **34** of the mandrel. On/off switch **202**, an ordinary device mounted on the framework **34** of the mandrel, functions to apply such DC voltage to and enable all of the electrical components shown in FIG. **10** and located on the mandrel except the actuator means **140** for the sensing means **62** and amplifying means **170**.

As previously stated, in the preferred embodiment of the invention signals to control the direction of movement of the mandrel are transmitted to the mandrel via radio waves. The forward receiving means **204** and reverse receiving means **206** are standard devices, each of which functions to receive the radio wave signals generated by the forward and reverse transmitting means **176** and **178**, respectively, and to close a switch **208** and **210**, respectively, encompassed therein. The closing of switch **208** in forward receiving means **204** provides a current path from the output of transistor **212** to the base of transistor **214**. Likewise, the closing of switch **210** provides a similar current path to the base of transistor **216**. In the normal state of operation, transistor **218** is turned off; transistor **212** is thereby turned on and the voltage from voltage source **50** issues from its emitter.

The receipt of the preselected UHF signal by forward receiving means **204** closes switch **208** and applies a bias current on the base of transistor **214**, thereby turning it on. The current output of transistor **214** turns on power transistor **220**, which produces the driving current necessary to energize the forward solenoid in the forward/reverse actuator means **54**. Similarly, the receipt of the preselected UHF signal by reverse receiving means **206** causes transistor **216** to turn on power transistor **222**, which generates the driving current necessary to energize the reverse solenoid in the forward/reverse actuator means **54**. Transistors **214**, **216** and **212** are standard devices such as TI **731**. Power transistors **218**, **220** and **222** are standard devices such as TI **2N 3054**. When no preselected signal is being received by either receiving means **204** or **206**, actuator means **54** is not energized and therefore the mandrel does not move in either direction.

Diodes **224** and **226** function to protect the rest of the circuitry from the effects of the forward and reverse solenoids in the forward/reverse actuator means **54** being de-energized by shorting the large mangitudes of current and voltage created by the collapsing magnetic fields attendant to the de-energizing of such solenoids.

Switch **168** is the previously discussed "whisker" switch mounted on the framework **34** at the rear of the mandrel in such a position that it contacts the wall of the pipe and closes when the rear of the mandrel moves inside the pipe. Such whisker switch **168** functions to enable the actuator means **140** for the sensing means **62** and the amplifying means **170** only while the mandrel is inside the pipe. This ensures that commonly occurring extraneous signals containing sixty cycles per second fundamental frequency or harmonics thereof do not cause the mandrel to expand outside the pipe. Once inside the pipe, the sensing means **62** is shielded from such extraneous signals by the pipe itself if the pipe is made of ferromagnetic material. If, however, the pipe is made of non-magnetic material, a power frequency of perhaps 400 cycles per second may be utilized in the emitter driver means **164** to diminish the effects of the commonly occurring 60 cycles per second signal; additionally, the gain of the amplifying means **170** and the output of the establishing means **60** should be adjusted so as to minimize the effect of such extraneous signals.

When actuator means **140** has moved sensing means **62** into its desired spaced relationship with the inner wall of the pipe and amplifying means **170** has been energized, the portions of the preferred apparatus of the invention located on the mandrel are disposed to position said mandrel longitudinally within the pipe. The voltage signals induced in the coils of sensing means **62** as a result of the changing magnetic flux sensed by such coils are transmitted via a shielded electrical cable **230** through an R-C circuit to the input of amplifying means **170**, a standard operational amplifier such as a National Semiconductor **LM201**, which functions to amplify by a preselected gain such voltage signal.

The amplified AC signal, if any, emitted from amplifying means **170** is coupled to the input of the correlation means **166**. Such signal is initially coupled to transistor **232** which functions as a buffer amplifier to isolate the previous circuitry and present a constant impedance to the remainder of the circuitry. The AC output of transistor **232** is driven through a diode and an R-C circuit which function to rectify the AC signal to a DC signal. The rectified DC voltage signal is amplified by transistor **234** and coupled to the base of transistor **236** which functions as another buffer amplifier. Transistors **232**, **234** and **236** are standard devices such as TI **731** transistors.

The amplified voltage signal emitted by transistor **236** turns on power transistor **218**, which generates the driving current necessary to energize the solenoid in the expansion actuator means **42**. When the driving current is emitted from the collector of transistor **218**, the base of transistor **212** goes to zero voltage and such transistor turns off. There is no longer any base current bias on transistors **214** and **216** and, accordingly, irrespective of the signals received by receiving means **204** and **206**, the forward/reverse actuator means **54** cannot be energized. Diode **238** serves to protect the circuitry from the effects of the de-energizing of the solenoid in the expansion actuator means **42**.

Thus, correlation means **166** functions to obey the command signals received from receiving means **204** or **206** only when no signal of preselected magnitude is being received from amplifying means **170**. However, when a signal of preselected magnitude is received from amplifying means **170**, correlation means **166** de-energizes the forward/reverse actuator means **54** and energizes the expanding actuator means **42**. The mandrel remains motionless and expanded so long as such signal of preselected magnitude is emitted from amplifying means **170**. Upon the loss of such signal, correlation means **166** again operates responsive to the signals, if any, being received from receiving means **204** or **206**.

PREFERRED METHOD OF OPERATION

FIGS. **11**(A) through **12**(G) are a series of schematic side views of certain parts of a pipe bending machine, a pipe supporting mandrel and a pipe. Such series of views show the steps in the method of automatically positioning such mandrel longitudinally in the pipe according to this invention. FIG. **11**(A) reveals the mandrel **28** resting on its storage pad, which comprises a part of the pipe bending machine **22**. The hose **56** for transporting compressed air to the mandrel is connected from the storage wheel **59** through the removably secured guide means **58** to the mandrel **28**. As previously explained, the removably secured guide means **58** is attached to the arcuate plate **108** on the framework **34** of the mandrel. A pipe **20** is placed by ordinary means within the confines of the pipe bending machine. The vertical plane **66** (represented by a dashed line) through the bending die is the location in which that portion of the pipe to be bent is to be positioned. The location of the establishing means (not shown) on the pipe bending machine is indicated by the vertical dotted line **64** and the intersecting horizontal dotted line.

The operator energizes the electrical portions of the invention located on the mandrel by closing switch **202** (shown in FIG. **10**). The electrical portions of the apparatus attached to the pipe bending machine are energized by closing switch **172** (shown in FIG. **9**). The operator depresses forward push-button switch **180** and the mandrel is moved forward into the pipe.

As the rear framework **34** of the mandrel enters the pipe, whisker switch **168** is closed. Sensing means **62** is thereby moved into communication with the wall of the pipe and amplifying means **170** is enabled. As the removable secured guide means **58** comes into contact with the wall of the pipe, such means **58** slides off the plate **108** on the framework **34** of the mandrel and slides onto the end of the pipe.

Once the mandrel has been moved inside the pipe to a desired approximate location, the operator releases forward push-button switch **180** and thereby stops the movement of the mandrel. It is not important how far the mandrel is moved into the pipe so long as the operator is aware of which side of the plane, represented by the vertical centerline **64** of establishing means **60**, sensing means **62** is located. FIG. **11**(B) shows the mandrel stopped just inside the end of the pipe.

The pipe is then positioned by ordinary means so that the portion desired to be bent is aligned with the vertical plane **66**. FIG. **11**(C) reveals a situation in which it is desired that the end of the pipe furthest from the mandrel be bent. As the pipe **20** is moved through the pipe bending machine, the mandrel **28** of course moves with it. Therefore, the operator of the pipe bending machine is aware that sensing means **62** attached to the mandrel is located with respect to the vertical centerline **64** of the establishing means **60** such that the mandrel must be moved in the forward direction to align such sensing and establishing means.

Switch **194** (FIG. **9**) is closed by the operator, thereby activating driver means **164** and actuator means **160**. Establishing means **60** is thus placed in a desired close spaced relationship with the exterior surface of the pipe and the changing magnetic field is generated along a vertical plane coincidental with the vertical centerline **64** of the establishing means. The operator depresses forward push-button switch **180**, which becomes "locked-in," and the mandrel moves in a forward direction (even if the operator ceases to depress the forward push-button means) until sensing means **62** senses the changing magnetic field emitted by establishing means **60** and generates a voltage signal which, when amplified by amplifying means **170**, reaches or exceeds the preselected voltage magnitude necessary to cause correlation means **166** to de-energize the forward solenoid in forward/reverse actuator means **54** and energize expansion actuator means **42**. Thus the mandrel is properly positioned and expanded inside the pipe as shown in FIG. **11**(D). As shown in FIG. **11**(E), the pipe supporting machine bends the pipe by raising the end of the pipe not being held between the shoes of the pipe bending machine.

Generally, however, it is desired that a series of sequential bends be imparted to the pipe. The method and apparatus of positioning the mandrel inside the pipe according to this invention allows the automatic positioning of such mandrel during these sequential bends. The operator determines the longitudinal relationship the vertical centerline of sensing means **62** will have with respect to the vertical centerline **64** of establishing means **60** (not shown) as the pipe commences to move to its new positions. This determination is made so that the mandrel will travel in the correct direction. At some point in time prior to moving the pipe to its new position, the operator correctly adjusts control means **162**. As shown in FIG. **11**(F), the normal method of sequentially bending pipe is to retract the bending shoes of the bending machine and move the pipe approximately 18 inches in the direction designated by the arrow **240**. Thus, the operator knows that the mandrel should move in a reverse direction to align properly the centerline of sensing means **62** with the centerline **64** of establishing means (not shown). Therefore, at some point in time prior to moving the pipe, the operator opens switch **194** and thereby "unlocks" forward relay **184**. The operator then again closes switch **194** and depresses the reverse push-button switch **182** (reverse relay **192** then becomes "locked-in").

As the pipe is moved in the direction designated by arrow **240**, the mandrel and its attendant sensing means **62** are also moved in such direction. As soon as sensing means **62** moves from within the changing magnetic field generated by establishing means **60** sufficiently to decrease its amplified voltage signal below the preselected magnitude, correlation means **166** de-ener-

gizes the expansion actuator means **42** and, pursuant to the signal being received continuously from reverse receiving means **206**, energizes the reverse solenoid in forward/reverse actuator means **54** and moves the mandrel in the reverse direction. FIG. **11**(F) shows in exaggeration the relative position of sensing means **62** on the mandrel with respect to the centerline **64** of establishing means **60** (not shown) as the pipe is moved in the direction denoted by the arrow **240** in preparation for the next bend. The mandrel moves in the reverse direction until the voltage induced in the sensing means **62**, as amplified by amplifier **170** and acted upon by the correlation means **166**, causes the mandrel to stop and to expand at the proper longitudinal position, FIG. **12**(G). Throughout the series of sequential moves of the pipe in the direction denoted by the arrow **240**, the method and apparatus according to this invention automatically positions the mandrel without any additional commands or instructions being transmitted by the operator. The automatic operation of the mandrel is, of course, not limited to movement of the mandrel in the direction denoted by arrow **240**. Rather, the circuitry controlling the automatic operation of the mandrel can be employed to move the mandrel automatically in one of either the forward or reverse directions.

The invention has been shown and defined with reference to a particular embodiment. However, many variations and modifications of the invention will now be apparent to those having skill in the art. For instance, the invention is not limited to use with a tubular structure, but may be used to position elements on opposite sides of a partition. Additionally the circuitry and physical components included in the invention may be arranged and constructed in a myriad of different forms. Therefore, it is felt that the foregoing disclosure and description of the invention are only illustrative and explanatory, and various changes in the circuitry and components, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. A method of positioning a movable mandrel longitudinally along the interior of a pipe at a desired location with respect to an element located exteriorly of said pipe, including the steps of

establishing a periodically changing magnetic field at a desired location at one of the exterior of said pipe and the interior of said pipe, the means establishing said changing magnetic field being mounted in a desired fixed relationship to one of the said element and the said mandrel, respectively, and being located in a sufficiently close spaced relationship with the wall of said pipe so that said wall is within said changing magnetic field,

sensing said changing magnetic field at the other of the exterior of said pipe and the interior of said pipe and generating an electromagnetic voltage signal responsive thereto, said means for sensing and generating being mounted in a desired fixed relationship to the second of said element and said mandrel, and

moving said mandrel and the one of said establishing means and said sensing and generating means mounted in fixed relationship thereto longitudinally along the interior of said pipe to position said establishing means and said sensing and generating means in a desired relationship to each other, said mandrel and said element thereby being positioned in a desired relationship to each other.

2. A method according to claim **1**, wherein said step of establishing a changing magnetic field at a desired location includes

driving an alternating current electrical signal of preselected frequency through a current carrying conductor coiled around a ferromagnetic core.

3. A method according to claim **1**, including the step of

performing a desired function responsive to a desired magnitude of said generated electromagnetic voltage signal.

4. A method according to claim **3**, wherein said step of performing a desired function includes

stopping said movement of said mandrel so that said establishing means and said sensing and generating means are positioned in a desired relationship to each other and said mandrel and said element are likewise positioned in a desired relationship to each other.

5. A method according to claim **1**, including the steps of

stopping said mandrel responsive to a desired magnitude of said generated electromagnetic voltage signal so that said establishing means and said sensing and generating means are positioned in a desired close spaced relationship to each other and said mandrel is likewise positioned in a desired location with respect to said element, and

performing an additional desired function responsive to a desired magnitude of said generated electromagnetic voltage signal.

6. A method of automatically positioning a movable pipe supporting mandrel at a series of locations longitudinally along the interior of a pipe positioned in a pipe bending machine during the pipe bending process, including the steps of

a. positioning said pipe with said mandrel therein in a first desired location in said pipe bending machine so that said pipe is in the proper location for the first bend,

b. establishing a periodically changing magnetic field in a desired location exteriorly of said pipe, the means establishing such changing magnetic field being mounted in a desired fixed relationship to said pipe bending machine and being located in a sufficiently close spaced relationship with the wall of said pipe that said wall is within said changing magnetic field,

c. moving said mandrel in a first direction so that said sensing and generating means moves toward said establishing means to position said establishing means and said sensing and generating means in a desired relationship to each other,

d. sensing said changing magnetic field at the interior of said pipe and generating an electromagnetic voltage signal responsive thereto, the means for sensing and generating being mounted in a desired fixed relationship to said mandrel, the desired

fixed relationship of said establishing mean with said pipe bending machine and the desired fixed relationship of said sensing and generating means with said mandrel being such that when said establishing means and said sensing and generating means are in a desired relationship to each other, said mandrel and said pipe bending machine are in a desired relationship to each other,

e. stopping said mandrel responsive to a desired magnitude of said generated electromagnetic voltage signal so that said establishing means and said sensing and generating means are positioned in a desired close spaced relationship to each other and said mandrel is positioned in a desired relationship to said pipe bending machine, and

f. actuating said mandrel responsive to a desired magnitude of said generated electromagnetic voltage signal to support the interior of said wall of said pipe during the first bend in the pipe bending process.

7. A method according to claim 6, including the steps of

g. bending said pipe,

h. moving said pipe with said mandrel therein to a second desired location in said pipe bending machine so that said pipe is in the proper location for the second bend,

i. deactuating said mandrel responsive to the reduction of said generated electromagnetic voltage signal below said desired magnitude so that said mandrel no longer is supporting said interior of said wall of said pipe,

j. moving said mandrel in the one of the first and second directions so that said sensing and generating means moves toward said establishing means to reposition said sensing and generating means and said establishing means in a desired relationship to each other, and

repeating the above steps d,e,f,g,h,i, and j, throughout the pipe bending process.

8. A method according to claim 6, wherein said step of establishing a changing magnetic field at a desired location exteriorly to the pipe includes

driving an alternating current electrical signal of preselected frequency through a current carrying conductor coiled around a ferromagnetic core.

9. An apparatus for positioning a movable mandrel longitudinally along the interior of a pipe at a desired location with respect to an element located exteriorly of said pipe, comprising

means for establishing a periodically changing magnetic field at a desired location at one of the exterior of said pipe and the interior of said pipe, said establishing means being mounted in a desired fixed relationship to one of the said element and the said mandrel, respectively, and being located in a sufficiently close spaced relationship with the wall of said pipe so that said wall is within said changing magnetic field,

means for sensing said changing magnetic field at the other of the exterior of said pipe and the interior of said pipe and generating an electromagnetic voltage signal responsive thereto, said sensing and generating means being mounted in a desired fixed relationship to the second of said element and said mandrel, respectively, and

means for moving said mandrel and the one of said establishing means and said sensing and generating means mounted in fixed relationship thereto longitudinally along the interior of said pipe so that said establishing means and said sensing and generating means are positioned in a desired relationship to each other and said mandrel and said element are thereby positioned in a desired relationship to each other.

10. An apparatus according to claim 9, wherein said means for establishing said changing magnetic field includes

a ferromagnetic core,

means for conducting electrical current coiled around said ferromagnetic core, and

means for driving an alternating current electrical signal of preselected frequency through said conductor means.

11. An apparatus according to claim 9, including

means for performing a desired function responsive to a desired magnitude of said generated electromagnetic voltage signal.

12. An apparatus according to claim 9, including

means for stopping said movement of said mandrel so that said establishing means and said sensing and generating means are positioned in a desired relationship to each other and said mandrel and said element are thereby positioned in a desired relationship to each other, and

means for performing a desired function responsive to a desired magnitude of said generated electromagnetic voltage signal.

13. An apparatus for automatically positioning a movable pipe supporting mandrel at a series of locations longitudinally along the interior of a pipe held in a pipe bending machine during the pipe bending process, comprising

a pipe supporting mandrel,

means for establishing a periodically changing magnetic field at a desired location at the exterior of said pipe,

means for holding said establishing means in a close spaced relationship with the exterior surface of said wall of said pipe so that said wall will be within said changing magnetic field, said holding means being mounted in a desired fixed relationship to said pipe bending machine,

means for moving said mandrel in one of a first and second longitudinal directions within the pipe,

means on said mandrel for supporting the interior of said pipe during the bending of said pipe,

means for sensing at the interior of said pipe said changing magnetic field and generating an electromagnetic voltage signal responsive thereto,

means for holding said sensing means in a desired spaced relationship with the interior of the wall of said pipe, said holding means for said sensing means being mounted in a desired fixed relationship to said mandrel, and

means for disengaging said moving means and for engaging said supporting means responsive to a desired magnitude of said generated electromagnetic voltage signal.

14. An apparatus according to claim 22, wherein said means for holding said sensing means in a desired rela-

tionship with the interior of the wall of said pipe includes

means for mounting said sensing means, said mounting means being movably secured to said mandrel,

at least one adjustably positioned wheel secured to said mounting means, and

means for retaining said wheel in contact with the interior of the wall of said pipe.

15. An apparatus according to claim **13**, wherein said means for holding said establishing means in close spaced relationship with the exterior of the wall of said pipe includes

means for mounting said establishing means,

said mounting means being movably secured to an element exterior to said pipe,

at least one adjustably positioned wheel secured to said mounting means, and

means for retaining said wheel against the exterior of the wall of said pipe.

16. An apparatus according to claim **13**, wherein said establishing means includes

a ferromagnetic core,

means for conducting electrical current coiled around said ferromagnetic core, and

means for driving an alternating current electrical signal of preselected frequency through said conductor means.

17. An apparatus according to claim **13**, wherein said sensing means includes

a ferromagnetic core, and

means for conducting electrical current coiled around said ferromagnetic core.

18. An apparatus according to claim **13**, wherein said moving means for said mandrel includes

a fluid driven prime mover,

means for supplying fluid to said fluid driven prime mover, and

means for controlling the flow of said fluid to said fluid driven prime mover to drive said prime mover in one of the first and second directions and to stop said prime mover.

19. An apparatus according to claim **18**, wherein said means for supplying fluid to said prime mover includes

a spring loaded revolving storage wheel located exteriorly of said pipe,

a hose for transporting said fluid, and

means for guiding said hose from said storage wheel to said mandrel, said guide means being adapted to be supported on said mandrel when said mandrel is outside said pipe and supported on the end of said pipe when said mandrel is within said pipe, said hose extending from said storage wheel through said removably secured guide means to said means for controlling the flow to said fluid driven prime mover.

20. An apparatus according to claim **19**, wherein said removably secured guide means includes

a body having at one end two parallel flanges with a cavity there-between,

a pulley secured in said cavity between said flanges so that it may freely rotate about its axis,

three parallel flanges formed at the other end of said body, said three flanges being formed in parallel planes and forming upper and lower cavities, and

said three flanges being spaced so that the wall of said pipe may be received in said upper cavity and said arcuate plate may be received in said lower cavity for supporting said guide means.

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