United States Patent

Jakobsen

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[54] **APPARATUS FOR CONTROLLING EQUIPMENT ON A CRAWLER DISPLACEABLE INSIDE A PIPE**

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[73] Assignee: **Picker-Andrex X-Ray A/S**, Copenhagen, Denmark

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[30] **Foreign Application Priority Data**

Oct. 1, 1969 Denmark.....5227/69

[52] **U.S. Cl.**.....**250/52**, 250/65 R, 250/83.3 D

[51] **Int. Cl.**.....**G03b 41/16**

[58] **Field of Search**.....250/65, 52, 53, 83.3 D, 106 VC, 250/106 S

[56] **References Cited**

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Assistant Examiner—C. E. Church
Attorney—Sughrue, Rothwell, Mion, Zinn & Macpeak

[57] **ABSTRACT**

Means for controlling the operation of a crawler adapted to move inside a pipeline and comprising a radiation source, e.g., an X-ray tube, for the inspection of welds in the pipe line. The operation is controlled by means of an AC-supplied electromagnet to be arranged on the outside of the pipe at a certain distance from the weld to be examined. The magnetic field from the electro-magnet is detected by a detector mounted on the crawler and comprising three coils spaced apart in the direction of movement of the crawler. The signals from the three coils are supplied to a logical unit generating control signals for the operation (start, stop, exposure etc.) of the crawler in response to the coil signals. Means may be incorporated for transforming the coil signals into binary DC-signals.

5 Claims, 10 Drawing Figures

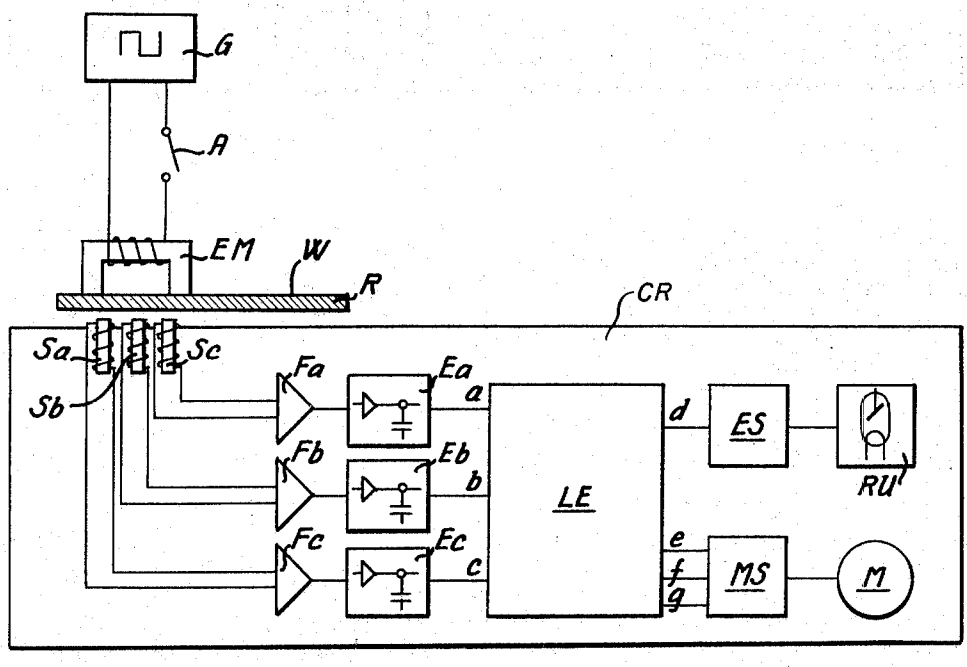


FIG. 1.

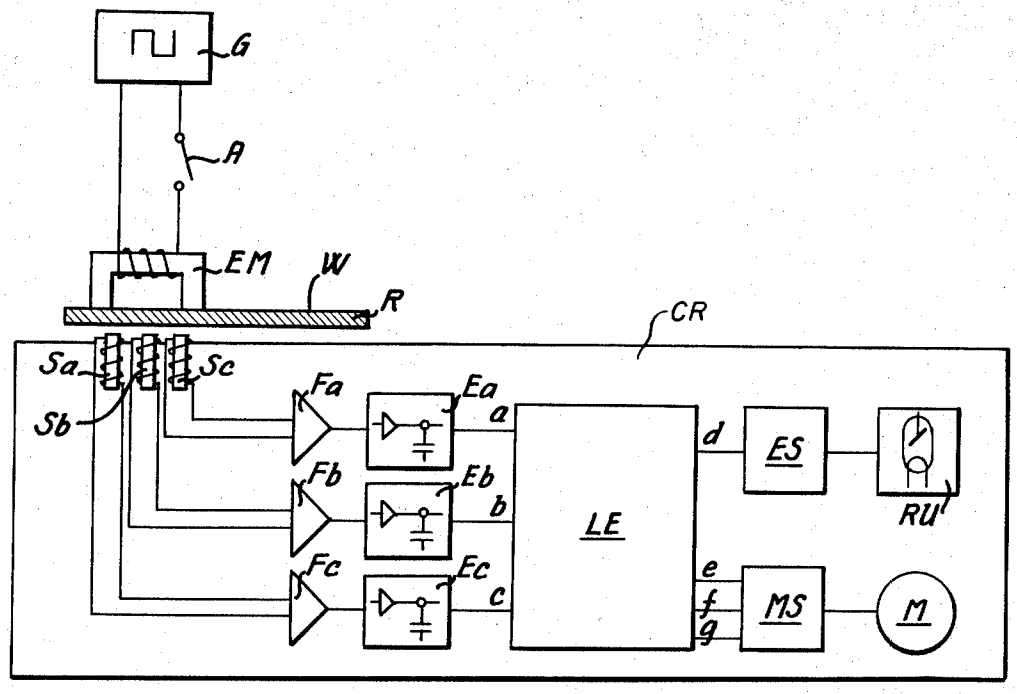


FIG. 2A.

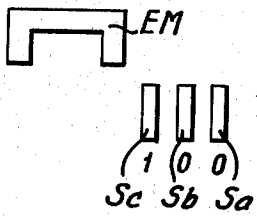


FIG. 2B.

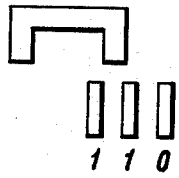


FIG. 2C.

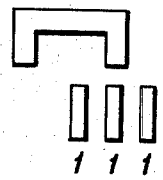


FIG. 2D.

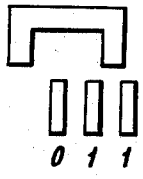


FIG. 2E.

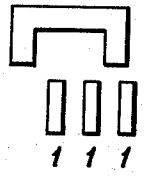


FIG. 2F.

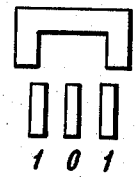


FIG. 3A.

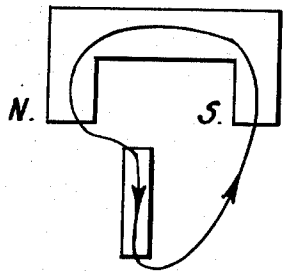


FIG. 3B.

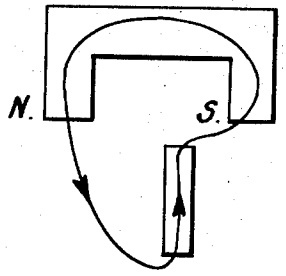
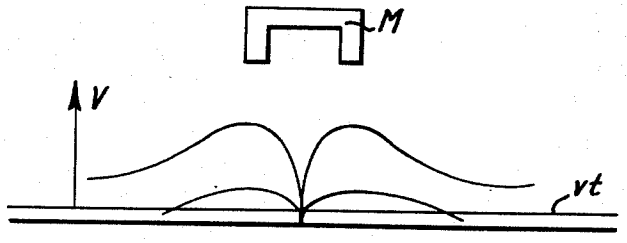


FIG. 4.



APPARATUS FOR CONTROLLING EQUIPMENT ON A CRAWLER DISPLACEABLE INSIDE A PIPE

The present invention relates to an apparatus for controlling equipment which is mounted on a motor-driven crawler which is displaceable inside a pipe, preferably of a magnetic material, said apparatus comprising an AC current-supplied magnet intended to be arranged on the outside of the pipe, and a detector which is mounted on the crawler and is sensitive to magnetic fields and connected to a control circuit. Such an apparatus is employed, by way of example, when laying and checking long pipelines which consist of pipe sections which are welded together, where the need for placing an apparatus inside the pipeline at a quite specific spot exists. Thus, the quality of the weld between the individual pipe sections is often checked by mounting a strip of film around the welded area on the outside of the pipe and by transmitting X-rays or other rays through the weld from the inside of the pipe, which process renders it necessary to conduct an irradiation source which, for instance, may be X-ray equipment or an isotope rod, into the pipe to the welding seam. To this end, the irradiation source is mounted on a motorized trolley, a crawler, which is able to run selfpowered any distance into a pipeline and the stopping of which takes place by the detector reacting to the magnetic field from the magnet arranged on the outside of the pipe and thereby activating the control circuit.

In a known apparatus of this kind, the detector is constituted by two aligned coils provided with iron cores and spaced some distance apart in the longitudinal direction of the pipe, which coils are series-connected in opposition. When such a detector passes an AC current-supplied electromagnet which is transversely mounted on the outside of the pipe, it will generate an AC voltage, the amplitude of which gradually increases as the detector approaches the magnet, to subsequently decrease to a minimum when the detector is situated just opposite the magnet, from which minimum the voltage again increases rather rapidly to a new maximum during the continued movement of the detector, to finally again gradually decrease towards zero as the detector moves away from the magnet. It is the relatively sharp minimum between the two maxima which is used as the criterion for stopping. However, the crawler should not only be capable of being stopped at any desired position, but it should also be possible to start its movement again both in the forward and backward direction, and it should also be possible to activate the irradiation source when the crawler has reached the site of operation. In the said known apparatus, the necessary information for carrying out these functions is transmitted in that the AC generator feeding the magnet can be set to a number of different frequencies, each corresponding to a separate function, and in that the control circuits, on the receiving side, are equipped with corresponding band pass filters. An additional detector coil may be provided, which serves solely for the transmission of control signals. Since it is possible for great variations to occur in the factors, e.g., the wall thickness and material properties of the pipe, determining the strength of the signal produced by the detector, the connected amplifiers have to be able to operate reliable within a wide range of input signal

levels and, under favorable conditions for transmitting signals, there exists a certain risk of one of the selective amplifiers reacting to harmonics from one of the other signal channels.

The apparatus according to the invention is characterized in that the detector comprises three coils provided with iron cores and spaced apart in the longitudinal direction of the crawler, and in that the control circuit comprises a logical unit which is adapted to produce a plurality of different output signals each corresponding to a separate combination of coil signals. By this a dependable transmission of all the information necessary for effecting the desired control functions is obtained by employing a single signal frequency which, for instance, may be a mains frequency of 50 c/s.

It is possible to obtain high sensitivity to the control signals combined with low sensitivity to noise by means of an embodiment, in which in the signal channels between the coils and the logical unit amplifiers are inserted which are adapted to produce an output signal when, and only when the input signal exceeds a predetermined threshold value, which amplifiers are followed by rectifiers which supply DC voltage signals to the logical unit.

The best operating conditions for the logical unit can be obtained by the apparatus comprising limitors which are connected with or contained in the amplifiers in such a manner that the DC voltage supplied by each rectifier acquires one or the other of two values, depending upon whether the input signal to the amplifier in question does or does not exceed the said threshold value. The unit is then supplied with signals of a purely binary kind with the two values each representing its binary digit 0 and 1, respectively.

The three detector coils provide $2^3 = 8$ different combination possibilities. In an embodiment which is expedient in practice the three signal channels are each connected to a separate input of the logical unit and this logical unit has four outputs which are each activated by a separate combination of the three input signals and of which the three are connected to a motor control unit which is adapted, by activation of the three outputs, to bring about the forward run, return run and stopping, respectively, of the crawler, while the fourth output is connected to an exposure control circuit of the irradiation source. In this embodiment four of the eight combinations are employed for initiating the control functions, by way of example, according to the following schedule:

forward run:	1 0 0	
return run:	0 0 1	
stop:	1 0 1	
exposure:	0 0 0	(repetition of the signal 0 0 0 a given number of times after the stop condition has been reached)

When the apparatus comprises smoothing circuits, the time constants introduced by them are going to delay the reaction of the control circuit to the detector signals. This delay only is of practical importance insofar as the stopping function is concerned, and since just before the stopping combination 1-0-1, the signal combination 1-1-1 occurs, so that it is only the center channel which has to change condition by stopping and since, moreover, none of the combinations used have

the digit 1 in the center channel, it is possible to reduce the delay in the stopping function to a value that is, in practice, insignificant, by an embodiment in which the center signal channel has a smoothing circuit with a smaller time constant than the other two signal channels, without there existing any risk of pulsations in the center channel giving rise to malfunction.

The operational reliability under varying external conditions mentioned above is most easily achieved when at least the center coil, in a manner known per se, is constructed and mounted in such a way that the signal produced during the passage of the magnet displays a sharp minimum in a specific position relatively to the magnet. The requirement of a clearly marked minimum can be met by several different ways of constructing and arranging the detector coils; but an embodiment in which the coils are mounted in such a way that they are substantially at right angles to the wall of the pipe, is both simple and supplies a particularly sharp minimum.

In the following, the invention is explained in greater detail with reference to the drawings, in which:

FIG. 1 is a block diagram of an embodiment of the apparatus according to the invention,

FIGS. 2A–F are schematic diagrams showing the signal combinations formed when the detector moves, from the right, into the stopping position relatively to the magnet,

FIGS. 3A and B schematicly show the course of magnetic lines of force when a detector coil is placed immediately to the left and immediately to the right, respectively, at the stopping position, and

FIG. 4 is a graph showing signal voltages produced by a detector coil as a function of the position of the coil relatively to the magnet.

In FIG. 1, R denotes the wall of a pipeline containing a welding seam W, which is to be checked by means of transirradiation with X-rays. EM is an electromagnet which is placed on the outside of the pipe in a predetermined position relatively to the welding seam W. The magnet EM is supplied with alternating current from a square wave generator G via a circuit comprising a switch A. The X-ray equipment RU used for the irradiation is mounted on a crawler, not shown, which is capable of running inside the pipeline and which is driven by an electromotor M.

Furthermore, on the crawler CR, a detector is mounted comprising three coils Sa, Sb and Sc that are provided with iron cores and the axes of which lie in a common radial plane in the pipeline spaced apart some distance from and parallel to each other. The coils may, for instance, be embedded in a rod-shaped block, not shown, of a suitable insulating material, Each coil is connected to the input of an amplifier Fa, Fb and Fc, respectively, the outputs of which are connected to rectifiers Ea, Eb and Ec, respectively, which comprise smoothing circuits. The output of each rectifier is connected to a separate input to a logical unit LE which has four outputs, of which one, *d*, is connected to an exposure control circuit ES, which controls the functioning of the X-ray equipment RU, and the others, *e*, *f* and *g*, are connected to a motor control circuit MS, which controls the functioning of the motor M.

If one visualizes the crawler running past the electromagnet EM placed on the outside of the pipe, and the switch A being closed so that this magnet produces a magnetic alternating field, an alternating voltage will be generated in each detector coil, the amplitude of which varies with the position of the crawler generally as shown in FIG. 4. In FIG. 3, a single magnetic line of force is shown, corresponding to a specific polarization of the electromagnet, in two different positions of the coil core immediately next to the center position and on different sides of the center or symmetry position relatively to the magnet. It will be seen that the line of force has the opposite direction in the two positions and that consequently, there has to be an intermediate position in which the field is zero in the longitudinal direction of the core. This condition results in the signal voltage curve acquiring a very sharp minimum as shown in FIG. 4, in which the upper curve represents a strong signal which is received when the wall of the pipe is thin or consists of material which, in a magnetic respect, is of poor conductivity, while the lower curve displays a weak signal corresponding to a thick pipe wall or to a pipe wall which, in a magnetic respect, is of good conductivity.

The amplifiers Fa–Fc comprise biasing circuits which have the effect of the amplifiers only beginning to function for producing an amplified output signal when the input signal exceeds a predetermined threshold value Vt, which is represented by a horizontal line in FIG. 4. Moreover, the amplifiers comprise limitors which cause all output signals to have the same amplitude. These output signals are rectified and smoothed in the circuits Ea–Ec, so that the signals which are supplied to the logical unit LE are in the form of DC voltages which possess one or the other of two values, depending upon whether the coil voltage is below or above the threshold value Vt. The two values may be regarded as binary digits and are designated by 0 and 1, respectively.

The three signal channels can supply eight different combinations of input signals to the three inputs *a*, *b* and *c* of the logical unit LE, and this unit is adapted in such a way that it only reacts to four of these combinations. The reaction consists in the unit LE activating one of its four outputs *d*, *e*, *f* and *g* characteristic of the combination in question, for starting the control functions, as appears from the following schedule:

Input *a*	*b*	*c*	Output	Control Function
0	0	0	*d*	exposure
0	0	1	*e*	return run
0	1	1		
0	1	0		
1	0	0	*f*	forward run
1	0	1	*g*	stop
1	1	1		
1	1	0		

The exposure control circuit ES is so arranged that it does not bring about an exposure until the combination 0 0 0 has been obtained immediately in succession a predetermined number of times after the stop condition has been obtained.

Such a succession is obtained, when it is desired to make an exposure, by supplying an arbitrary one of the

other signals a predetermined number of times immediately in succession.

When the signal 000 has been received the predetermined number of times the exposure control circuit ES brings the X-ray equipment RU into operation and causes it to emit a predetermined dosis of X-rays, whereupon it switches off the supply voltage to the X-ray tube.

The motor control circuit MS is arranged in such a way that it, on activation of the output e of the unit LE, causes the motor M to run in a rotation direction corresponding to a return run, and on activation the output *f*, causes the motor to run in the opposite rotational direction and on activation of the output *g*, brings the crawler to a halt by interrupting the supply of current to the motor and by activating a brake, not shown.

In FIG. 2, the output voltages are shown which are generated in the three signal channels when the detector moves from the right, that is to say in the return run direction, below the electromagnet EM. In FIG. 2A, the detector has come so close to the magnet that the voltage in the left-hand coil Sc, but not in the two others, Sb and Sc, has exceeded the threshold value. The emitted signal combination 1 0 0 corresponds to the return run and does not result in any changes occurring in the logical unit LE. The following conditions shown in FIGS. 2B–2E correspond to unused signal combinations which do not affect the logical unit, and not until the detector reaches the position shown in FIG. 2F, the signal combination 1 0 1 occurs which is used for stopping the crawler.

When the crawler has been brought to a halt at the desired position opposite the welding seam W, the switch A is opened, whereby the signal combination 0 0 0 occurs for the first time after the stopping. Then the stop signal, or any one of the other signals, is repeated a predetermined number of times by activating the switch a corresponding number of times. This causes the logical unit LE to activate its output d and thereby brings the X-ray equipment RU into action as described above. After the exposure is terminated, the crawler may be set in motion again by placing the magnet so in relation to the three coils Sc, Sb and Sa that its position corresponds to the desired direction of movement as shown, e.g., in FIG. 2A and by closing the switch A. The logical unit is preferably arranged in such a way that an established starting condition is maintained until a stopping signal is detected, so that it is possible to move the magnet immediately after the starting to the position at which it is desired to stop the crawler again.

The smoothing circuits in the signal channels bring about relatively long time constants which reduce the rate at which the apparatus reacts to the control signals. As mentioned earlier, the reaction rate is only of importance to the stopping function, as it affects the precision with which the crawler can be brought to a stop and since the detector, immediately prior to the stopping position, supplies the signal combination 1 1 1, as appears from FIG. 2E, it will be seen that it is only the center channel which has to change its condition, viz. from 1 to 0, in order to produce the stopping signal. In other words, it is only the time constant in the center channel which decisively affects the stopping accuracy and this time constant is therefore, preferably made considerably shorter than those of the other two channels. The short time constant results in the signal in the center channel comprising a certain pulsation voltage; but even if this should be strong enough for an 0-signal of the logical unit being read as a 1-signal, this will not affect the condition of this unit since none of the signal combinations employed has 1 in the center position.

Besides the increased stopping accuracy, the short time constant in the center channel also results in other advantages. When restarting after stopping, it can happen that inaccurate placing of the magnet supplies either 1 1 0 or 0 1 1 instead of the desired 1 0 0 or 0 0 1. In this case, the logical unit is not going to react, but when the supply current to the magnet is switched off again, the center channel will be discharged, with the result that the correct starting signal is established.

In addition, by means of a shorter time constant in the center channel than in the side channels, a convenient possibility of carrying out a re-exposure is obtained, in that such a re-exposure may be carried out by the magnet being placed either as shown in FIG. 2C or as shown in FIG. 2E, after which the switch A is closed. On account of the difference in the time constant, the first logical condition is 0 1 0, which does not cause the crawler to move. The next condition is 1 1 1, which does not produce any reaction in the logical unit either. When the switch A is now reopened, the condition 1 0 1 is obtained first which constitutes the stopping signal and thereupon, subsequent to discharging the side channels, the condition 0 0 0, after which exposure can be obtained by supplying signals as described above.

The details of the apparatus shown and described can be modified in many ways within the scope of the invention. It is thus possible to employ a radioisotope as irradiation source instead of the X-ray equipment RU, which isotope normally lies enveloped by a protective cover that is impervious to the rays, for which cover the isotope can be pushed out by means of a servomechanism when an exposure has to be made.

What is claimed is:

1. A remote controlled inspection device for inspecting a pipe line from the interior thereof by means of radiation comprising a control device adapted to be arranged on the outside of the pipe line at a position adjacent to the area of the pipe line to be inspected, said device comprising an electro-magnet and an AC-current source for supplying an AC-current to the electromagnet, a movable crawler adapted to be placed in the pipe line, driving means on the crawler for moving said crawler in the longitudinal direction of the pipe line, radiation means on said crawler, detector means on said crawler including three coils having iron cores spaced apart in the direction of movement of the crawler and arranged so that when the crawler passes the electro-magnet a signal is induced in each coil having an amplitude dependent on the relative position of the coil and the electro-magnet in the longitudinal direction of the pipe line, logic unit means on said crawler having inputs for receiving signals derived from said three coils, and outputs connected to the driving means and the radiation means to selectively activate the driving means and the radiation means in dependence on the combination of signals received from said three coils.

2. A device as claimed in claim 1, wherein the cores of the coils are arranged with their axes substantially at right angles to the wall of the pipe line when the crawler is in the pipe line.

3. A device as claimed in claim 1, wherein three outputs of the logic unit means are connected to the driving means to bring about forward run, return run and stopping, respectively, when activated, and one output is connected to the radiation means to bring about an exposure when activated.

4. A device as claimed in claim 1, further comprising three signal channels, each extending from one of the coils to one of the inputs of the logic unit means, an amplifier in each of said channels to supply an output signal only when the input signal to the amplifier exceeds a predetermined threshold value, and a rectifier means in each of said channels intermediate said amplifier and said logic unit means.

5. A device as claimed in claim 4, further comprising a smoothing circuit in each of said channels with the smoothing circuit in the channel corresponding to the center coil having a lower time constant than the two other smoothing circuits.

* * * * *