A crawler type pipeline x-ray machine which has a self-contained power unit comprising a gasoline engine and electrical generator. An x-ray tube is powered from the electrical generator. A plurality of sets of hinged arms with wheels serve to centralize the unit inside of the pipe. On one set of three arms electrical motors are provided with locking gears. The crawler is free to rotate about its longitudinal axis as it moves along the pipe. Means are provided to ensure that the gasoline intake means to the engine is always dipped into the pool of gasoline at the bottom of the cylindrical gasoline tank as the crawler rotates.

A control circuit provides means for driving the crawler forward, and, in response to the indication of a star wheel, to stop the crawler after a predetermined time delay, so that the x-ray unit will be at the position of the weld. When the crawler is stopped, the x-ray tube is supplied with power. This is done in two stages whereby the initial surge of current to the x-ray transformer is reduced.

A single sensor of gamma rays is mounted on the axis of the crawler so that the crawler can rotate within the pipe and still have the sensor in a uniformly sensitive position to the gamma rays provided by a source of radioactivity placed on the outside of the pipe. Only a single sensor is required and the circuit provides flexibility of control for the crawler to stop when radiation is detected, to stay stopped so long as radiation is present, and to move forward or backward when the radiation is removed. The control system provides means for skipping, in sequence, certain of the welds that are detected by the star wheel.
PIPELINE CRAWLER TYPE X-RAY MACHINE

CROSS REFERENCE TO RELATED APPLICATION


BACKGROUND OF THE INVENTION

This invention is in the field of portable x-ray equipment. More particularly it is in the field of a self-contained, self-powered crawler type x-ray pipeline device.

In the construction of large diameter long high pressure pipelines for the transmission of liquids or gases, the sections of pipe are joined by electrical welds. Before a weld is certified as satisfactory it must be x-rayed. Normally this is done by placing a photographic film on the outside of the pipe over a joint, and diametrically opposite, using a masked x-ray tube, so as to direct the x-rays through the pipe along a diameter. This will record on the film a shadow of a portion of the weld to determine if there are any flaws.

It has long been desired to have a crawler-type machine which would have an x-ray tube that has a 360° emission of x-rays, that can be placed on the axis of the pipe and record the entire weld on a strip of film which is secured circumferentially around the outside of the weld over the joint. This has always been a problem because of the necessity for carrying a power supply for the x-ray tube. In the prior art batteries have been used. But these are bulky and expensive, and offer great difficulties in handling.

In the prior art devices of this type, use has been made of a plurality of sensors placed at different positions on the crawler, so as to accomplish several different operations, all of which are accomplished in this invention by a single sensor.

It is a primary object of this invention to provide a self-powered crawler type x-ray machine that can crawl along the inside of a pipe and can be directed from outside of the pipe to stop at any point.

It is a further object of this invention to provide means so that the crawler can be stopped at a weld by contact with the internal bead of the weld, so that the x-ray unit will be in position to take a photograph of the weld.

It is a further object of this invention to provide a simple and foolproof control system for a self-contained, self-powered x-ray crawler device for use in pipelines.

It is a still further object of this invention to provide a simple control means, utilizing a gamma ray sensor, by means of which the crawler can be stopped at any point in its progress through the inside of the pipeline, and can be made to reverse the direction of motion of the crawler after each stoppage by activation of the sensor.

SUMMARY OF THE INVENTION

These and other objects are realized and the limitations of the prior art are overcome in this invention by the use of a self-powered means for driving the crawler along the pipe, and, when the crawler is stopped, to power an x-ray tube which is positioned on the axis of the pipe and has a 360° flux of x-rays, and to record the condition of the weld on a strip of film placed on the outside of the weld. No cables for power or control are needed. Once the crawler is moving inside the pipe, it can be stopped at a joint by means of a joint-finding device. It can also be stopped at any other time by the use of a source of gamma rays placed on the outside of the pipe, cooperating with a gamma ray sensor in the control unit.

The unit is powered by a gasoline generator which drives a single phase alternating current generator. There is a control means that controls this voltage and applies it to motors which drive the crawler along the pipes. When the crawler is stationary, the control means applies power to an x-ray tube. Centralizing arms are used to keep the machine along the axis of the pipe. The drive motors are applied to the wheels on the ends of one set of these centralizing arms. Electric motor driven fan means is provided to circulate air down the pipe so that fresh air is provided for the engine and the products of combustion are driven down the pipe to the opposite ends.

A single gamma ray sensor is placed on the axis of the crawler so that even though the crawler may rotate about its longitudinal axis as it progresses down the pipe, the sensor will be in a constant sensitivity position, within the pipe, along the axis of the pipe, so that it will uniformly respond to a source of gamma rays positioned anywhere around the periphery of the pipe. On activation of the sensor by detection of the gamma rays, a ratchet relay is pulsed. This opens the contact which supplies power to a stop relay, which stops the crawler. On removal of the radioactivity, the deactivation of the sensor, the ratchet switch then moves to the next contact which again activates the motors, but in the reverse direction. A second activation of the sensor will cause the motors to again stop, and then on removal of the activation of the sensor, the motor will start again but in the forward direction. So by placing the source of gamma rays ahead of the crawler in whichever direction it is moving, when it reaches the source of radioactivity it will stop and then when the radioactivity is removed it will start again in the reverse direction. Full control can therefore be had in the motion of the crawler by a single sensor and a simple ratchet type switch means.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects of this invention and a better understanding of the principles and details of the invention will be evident from the following description taken in conjunction with the appended drawings in which:

FIG. 1 represents an overall view of the machine partially inserted into a length of pipe.

FIG. 2 is a schematic layout showing each of the sections of the machine.

FIG. 3 indicates the use of an external source of gamma rays to control the stopping and starting of the machine.

FIG. 4 illustrates an improvement in the gasoline tank system so as to ensure that there will always be gasoline input to the engine irrespective of the rotation of the device about its longitudinal axis.

FIGS. 5 and 6 indicate the construction of a thumper to signal the position of the instrument.
FIG. 7 represents the complete control circuit for the x-ray crawler device.
FIG. 8 represents the power transformer connections.
FIG. 9 illustrates the circuit for supplying power to the x-ray unit.
FIG. 10 illustrates the power supply to the drive motors and the direction reversing switch.
FIG. 11 illustrates the wave shapes of voltage at various points in the control circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and in particular to FIGS. 1 and 2, the numeral 10 indicates generally the crawler device while numeral 12 indicates the pipe in which the instrument will be used.

In normal practice, in the construction of a pipeline, a ditch is prepared into which the pipeline will eventually be placed and covered with earth. However, before that is done the individual lengths of pipe are laid out along the ground at the side of the ditch. Two lengths of pipe are placed in longitudinal, axial-spaced relationship and clamp means are provided (generally inside of the pipe) to hold the two ends in precise longitudinal alignment, so that a welding machine operation or a manual welding operation can be carried out on the outside of the joint. When the joint is partially supported by the welding the internal clamp is removed and placed on the next joint of the pipeline. While the first joint is being finish welded, the next joint is being tuck welded. By this means there can be a plurality of joints being finish welded simultaneously as the construction of the pipeline progresses.

Shortly after the completion of the welding of a section of the pipeline, the joints must be examined by an x-ray to ensure that the welds are all satisfactory. If they are not, then a repair must be made before the pipe is placed in the ditch. When a sufficient length of pipeline has been completed, the joints are then x-rayed.

The crawler is inserted into the beginning end of the pipeline and it starts down the line at a slow, continuous rate. The drive motors being powered by a gasoline driven generator. Means are provided on at least one of the centralizing arms to sense the presence of a weld bead as the crawler goes down the pipe. When this slightly protruding bead is felt by the sensor a switch is opened and the control unit shuts down the drive motor after a predetermined delay so that the center of the x-ray tube will be directly in the plane of the weld, and the x-ray unit is turned on. The film having been placed in its cassette around the weld, is then subjected to the x-ray beam and after a preselected time the x-ray tube is shut off and the crawler moves in a forward direction down the pipe.

If it is decided to stop the machine at any time, a small quantity of radioactive material in a safe is placed on the outside of the pipe and a window opened to direct the gamma rays into the pipe. Then as the crawler comes into position a gamma ray detector or sensor in the control unit can sense the presence of the gamma rays. The control means then stops the machine. The controls are designed so that when the safe is removed and there are no gamma rays detected, the unit will start up in the reverse direction. If it is decided to have the crawler move forward, then the gamma ray source is put on the pipe ahead of it (in the reverse direction) so that it will again stop. Then, on starting, it will reverse and go again in the forward direction. By this means it is possible to repeat a pass across a weld. If for any reason, such as for example, the film was not in place, then as the unit progresses along the pipe and the weld sensor stopped the machine and turned on the x-ray, then at the completion of this operation the unit would again start up. By use of the gamma ray source it would be stopped, backed up to a position on the other side of the weld, and again started forward so that the weld examination could be repeated.

In FIG. 2 the power units is on the right end, or leading end, of the machine. In the far front is an electrically driven fan 20 which provides fresh air for the intake of the engine 14. The engine is directly coupled to the electrical generator 18. The gasoline tank 16 is a cylindrical tank and has, as shown in FIG. 4, an intake pipe 62 which is swiveled at point 60 along the axis of the tank and the axis of the crawler. In case the unit rotates about its axis, the gasoline 64 will always flow to the lowest point, and the pendulum pipe 62, having a weighted end 63, will always seek the lowest point. Thus the pipe 62 will always dip into the gasoline which will be picked up by the pipe 62 and delivered to the engine through swivel 60 and tubing 65.

The gasoline engine is a two-stroke-cycle engine in which the crankcase is entirely closed and the down stroke of the piston serves to compress the gasoline mixture in the crankcase. Means are provided to take this gas mixture by means of tubing 66 (FIG. 4) through a check valve 67 and into the tank 68. By this means a vapor pressure can be built up inside the gasoline tank which will force the gasoline up through the pipe 62 and into the carburetor, even though the gasoline pump may fail, once the system has been operating.

The two parts of the crawler, the power unit and the x-ray unit, are coupled by a flexible coupling 22 so that they can better follow a curve in the pipe. This also facilitates the physical handling of the two separate units which can be quickly decoupled at the point 22. Electrical power is transferred across the coupling 22 by leads 24 from the generator to the housing of the x-ray unit 26, to the control unit 28. From there the power is applied to the drive wheels 44 on the rear set of centralizing arms 22. These wheels are driven by a gear motor 46 which is powered through leads 47 from the control unit. The drive motors can conveniently be permanent magnetic field motors so that they can be reversed in direction simply by reversing the polarity of the voltage applied to the armature. When these motors are running and the crawler is moving there is no power on the x-ray unit. When the weld head sensor indicates the presence of the bead, and thus a joint, the control unit permits the crawler to move a selected distance during a certain selected time delay which will position the active x-ray tube directly in the plane of the weld. The control unit will then stop the drive motors and turn on the x-ray unit.

There are a number of different types of joint sensors. One of the simplest, and which is in common use and is available on the market, is a star wheel. This is a rotating device having a plurality of sharp blades, which slide along the pipe. When a slight protuberance on the inside wall of the pipe, such as might be caused
by the inner bead of the weld is felt by this knife edge, it rotates the star wheel. In so doing, it opens a switch which alerts the control unit that a bead joint has been passed. Consequently, after a selected time delay, the drive motors are stopped. The bead sensors are not illustrated since they are commercial devices and the operation of this instrument is not limited to any one of the various types which are available. The star wheel is fully described in the U.S. Pat. No. 2,532,556, issued Dec. 5, 1950 to C. E. Boucher.

There are three sets of centralizing arms indicated as 32, 34, and 36. These are hinged at their inner end to bands 33, 35, and 37, respectively. There are also compression springs in struts 38, 39, and 40 which are connected between a midpoint of the arm at 23, for example, to another set of bands 41, 42, and 43, respectively. The bands 41, 42, and 43 can be slid along the cylindrical surface to which they are clamped, and by so doing, the angle of the arms 32, 34, and 36 can be adjusted to fit the internal diameter of larger or smaller pipes. The bearings at 21, 23, and 25, for example, are arranged with axle pins which can easily be pulled to quickly and simply dismount each of the arms so that the equipment can be made more compact for shipment, etc.

The centralizing arms are completely symmetrical so that the instrument is positioned on the axis of the pipe, and there is no tendency to maintain any particular orientation about the axis of the pipe. Consequently, as the unit travels down the pipe there may be a tendency for the machine to rotate in one direction or the other. Since the machine is designed to operate in any orientation there is no need for means to maintain a selected orientation.

FIG. 3 illustrates the use of a source of gamma rays in a safe 50 through which there is an opening 51 which can be closed off or opened by means on the outside of the safe not shown. A flux of gamma rays 53 issues from the same and flows through the pipe 12 to a sensor 52 inside of the control unit 28. This can be any selected type of gamma ray detector. When it detects the presence of gamma ray flux 53 it generates a voltage which is amplified by amplifier 54 and goes to a control unit 56. This may be a simple relay means to control the voltage coming from the generator along lead 57 and control the operation of the motor 46 which receives power through the cord 47 and lead 58. Other means are provided, now shown, to control the direction of the motors 46 when the unit is again powered, which occurs when the gamma ray flux 53 is cut off by closing the opening 51 or removing the safe 50. The sensor is positioned on the axis of the instrument and therefore on the axis of the pipe. Thus, no matter how the instrument may rotate, the sensor is always the same distance from the outer surface of the pipe.

FIGS. 5 and 6 illustrate a very simple attachment to the crawler which is simply a metal mass 74 (which can be a heavy bolt and nut) which is attached to a flexible strip of material such as tough rubber 72, which is bolted by masses 73 to a wheel 44. The wheel is journalled on the pin 75 attached to the centralizing arm 34. As the wheel 44 rotates this mass 74 is thrown outwardly against the inside of the pipe and creates a loud thump. This sound is easily heard outside of the pipe over a considerable distance in front of and in back of the crawler. Thus it is possible for a workman walking alongside the pipe to know substantially the precise position of the crawler at all times.

The x-ray unit employs a commercial x-ray tube which is designed to emit a 360° flux of x-rays. This is supplied with a voltage on the anode and the cathode by means of separate transformers which amplify the 110 volts single phase AC of the generator up to a voltage of 100,000 volts. At any time when the anode is positive, above ground 100,000 volts, the cathode will be correspondingly below ground potential at minus 100,000 volts. There is thus an electrical field potential of 200,000 volts to create a strong flux of x-rays. Means are provided to inject sulfur hexafluoride gas under pressure into the tanks which houses the x-ray tube and transformers. This gas is for the purpose of minimizing corona and sparking between conductors at high potential difference in the tank.

Examination of FIG. 2 indicates that it is necessary to carry electrical conductors from the generator past the x-ray unit to the control unit. In order to minimize the shadow cast by these conductors in the x-ray film, a plurality of aluminum wires (or preferably thin strips) are mounted to the inside of the tank over the region of the anode. Means are provided at each end to make electrical connections to these wires. The low density of the aluminum minimizes the shadows.

Refer briefly to FIG. 8. Here is shown an auto transformer 190. The terminals A and C are 110 volt potential and are connected directly to the output of the gasoline engine driven generator on the x-ray unit. There is an terminal B such that the voltage between A and B is 24 volts AC. The winding is continued beyond the terminal C so that as the slider 192 connected to terminal D is moved, it can provide a potential between terminals A and D of from zero to 140 volts.

The control circuit is run at 24 volts AC, the input of the control system being connected to terminals A and B. Referring to FIG. 7, the 24 volt AC power goes to a bridge rectifier 310, where the inputs are at terminals 311 and 312 and the rectifier output is at terminals 314 and 313 respectively. The positive potential is on line 316 and the negative potential on lines 318 and 364. A signal light 319 indicates when it is lighted that power is on the control apparatus.

The box of FIG. 7 encased in the dashed line 320 includes essentially all the parts of the radioactivity sensor and its controls. Going to the right end of this box 320, the input power to the sensor circuit is through a resistor 321 which is in series with a Zenor diode 322 which regulates the voltage on line 324 to a maximum of 20 volts. However, the voltage on line 316 is a pulsating direct current, similar to the curve (a) of FIG. 11. This voltage periodically drops to zero and follows a sinusoidal curve 250 to the next zero crossing and so on.

On line 324 past the Zenor diode 322 this pulsating D.C. is flat-topped at a maximum voltage of 20 volts shown by numeral 254 of curve (b) of FIG. 11. Again as in curve (a) there is a rise in voltage 252 from zero at time T1 to the flat portion 254 at time T2. This voltage stays uniform until time T3 and then it drops to zero along the curve 253, and so on. The voltage shown on curve (b) of FIG. 11 is on line 324. Connected between line 324 and the negative voltage line 318 is a series resistor 325 and capacitor 326. The junction 327 between the two elements 325 and 326 rises with the voltage 252 following the time T1. When this voltage
gets to be 16 volts at junction 327, the unijunction element 328, which is normally a high resistance, between the series resistor 329 and the primary 333 of the transformer 330, drops to a low value of resistance and the current through the primary 330 of the current through the primary 330 of the transformer correspondingly increases. With every pulse of the D. C., therefore there is a breakdown of the unijunction and a pulse of current gas through the primary of the transformer 330. When the voltage drops back to zero the current through the unijunction drops to zero and thereafter no current flows until the potential at points 27 again reaches 16 volts.

This pulse of current through the primary of transformer 330 generates a much higher voltage in a secondary winding 331. This voltage is rectified by the bridge rectifier 332. The output of the bridge rectifier is filtered by shunt capacitor 338 and provides a voltage of approximately 350 volts DC at the terminal 334.

A geiger tube 340 is connected in series with resistors 342 between terminal 334 and line 336, so that when voltage is on the geiger tube and gamma radiation is received by the geiger tube, there will be conduction in the tube and the potential of junction 341 will rise to a high value. This potential is carried by the series capacitor 343 to the grid of the grid controlled rectifier, or SCR, 345. When there is positive voltage on the SCR and the grid reaches a high positive voltage, the SCR will conduct and current will then pass from line 316 through the series diode 350, through the relay coil 348, through the series resistor 346 back to the negative terminal 336. As a result, the armature of relay 348 pulls in and closes the contacts 352 which are normally open.

The purpose of the capacitor 349 is to stabilize the operation of the relay so that there is a fluctuating radiation on the geiger tube 340 the relay will nevertheless stay pulled in, and the contacts 352 will remain continuously closed. This condition persists until the potential on line 316 drops to zero at times T4, T7, etc., of FIG. 11. The contacts 110 between the lines 318 and 336 are normally closed. They are part of a relay "x-ray on." This relay closes when the x-ray is on and the contacts 110 open so as to disable the sensor circuit.

A full explanation is made above of the use of a source of gamma rays, which can be placed on the outside of the pipe, inside of which the x-ray unit is crawling, such that when the geiger tube or other gamma ray sensor 340 receives sufficient radiation from the source on the outside of the pipe, a relay will pull in and a contact will be closed.

The portion of the circuit inside of the dashed box 353 includes the controls for the drive motors, responsive to the receiving of gamma rays by the sensor 340. When the sensor 340 detects the gamma radiation, the relay 348 closes its contact 352. This puts power on the relay 354. Here again the relay 354 is shunted with a capacitor 355 to provide a continued hold-in, and to overcome a possible jittering of the relay. The diode 356 is used to prevent the large capacitor 355 from filtering the line 316, on which it is important that the direct current be pulsating, and drop to zero value each half cycle.

The relay coil 354 operates a rotating arm contact 360 of a ratchet driven stepping 358. There are eight contacts on the relay. When the relay 354 receives current, the arm contact 360 moves one-half space and remains there as long as the relay current continues. When the relay current stops, the arm moves another half step and lands on the first contact. It will be noted that four alternate contacts are tied together by leads 366, while the intermediate four contacts are tied together by a second wire 368. The rotating arm contact 360 is tied to line 364 which is the negative terminal of the 24 volts rectified voltage. The contacts tied together by line 366 go to lead 365, while the intermediate contacts, such as 362, are tied to another lead 363. The lead 365 goes to a relay 372 which is connected through a diode 374 to the positive line 316. Again the relay coil is shunted by a capacitor 373 to prevent jittering of the contacts. When potential is on the line 365, the signal lamp 370 which indicates "reverse" direction of motion is lighted. On the other hand, when the alternate contacts such as 362 have power, the signal light 371, which is marked "forward" is lighted.

The action of the "pulse" relay 354 is therefore as follows:

When gamma radiation is received by the sensor 340, the relay 348 pulls in and closes contact 352. The power is then put onto pulse relay 354. Assume that the rotating arm 360 is on a terminal which calls for a "forward" movement, such as the terminal 367, corresponding to forward motion of the crawler. When the relay 354 operates on closing of contact 352, the rotating arm moves one half position clockwise from terminal 367. This stops the motion of the crawler. This results from the opening of "stop" relay 380. This relay 380 receives power from either set of contacts on switch 58, through diodes 375 or 376.

When the rotating arm 360 is on a set of contacts such as 362, current goes through the diode 376 to terminal 378 through the relay contacts 379, which are normally closed, and through the stop relay 380. On the other hand, when the rotating arm 360 is on the reverse group of contacts, connection is made between the negative terminal through lead 365 through the diode 375 through the relay contact 379 to relay coil 380 and to the positive voltage. In other words, whenever the rotating contact is on one of the eight contacts, the stop relay 380 is pulled in and the contacts 232 in FIG. 10 are pulled in, providing power to the motors. However, as soon as the sensor 340 receives radiation, the relay 348 pulls in, closes contacts 352, and the pulse relay 354 operates, breaking the contact between rotary arm 360 and any one of the contacts on which it happens to be positioned. This opens the stop relay 380 and permits the contact 232 to open, and stop the motors.

So long as radiation is still being received by the sensor 340 and relay 348 continues to receive power, and the contacts 352 are closed, the relay 354 does not operate again until the radiation stops. When the source of gamma rays is manually removed, then the sensor relay 348 drops out, the pulse relay 358 moves another half step and closes the circuit between the rotating arm 360 and another contact. On succeeding closures of contacts the direction of motion of the motors is reversed as will be explained in connection with FIG. 10.

In the operation of the crawler, when it is desired to stop it, the source of radiation is placed on the outside of the pipe, and as the crawler approaches, the radiation is detected by the geiger tube 340, the crawler stops. If it has been moving in the forward direction, when it next starts to move it will move in the reverse
direction. This takes place when the source of radiation is removed. If the radiation source is then positioned behind the crawler so that it moves in the reverse direction, it will then approach the source and again the sensor will receive radiation and it will stop. Then when the source is removed a second time the crawler will move in its original forward direction.

The use of the star wheel is described above, to detect the presence of small projections on the inside of the pipe, such as the beads formed at the welds at each joint of pipe. The star wheel slides along the inside surface of the pipe and when it reaches this projection it makes a 90° rotation, momentarily closing a switch while it does so. After a predetermined delay, this switch closes a relay that starts the x-ray tube, and at the same time opens the stop relay 380 and stops the motors. Let us next consider the dashed block 132, which is a time delay circuit to disable the star wheel control, so that the crawler will not stop on the star wheel indication. In other words, it will cause the crawler to fail to respond to a stop signal from the star wheel whenever it passes a weld. For example, if it is desired that only every other weld be x-rayed, then once the crawler has started moving forward and if the delay time of the block 132 is set to a time longer than the passage of the crawler between one pair of welds, it will ignore the star wheel indication as it passes the first weld and then when the time delay relay pulls in it will then be ready to stop the crawler when the second (or third, or desired) weld bead is passed.

In the circuit of block 132 there is a Zenor regulator tube 394 in series with the Resistor 393, so that the junction 396 has a flattened, pulsating rectified DC voltage of approximately 20 volts. This voltage is applied across a series resistor 397 and capacitor 398. The voltage of the junction 100 between the two will rise according to an exponential curve. When it reaches the value of 16 volts the unjunction element 102 which is in series with two resistors 103 and 104 across the 20 volts pulsating DC, will conduct. This will cause the potential at junction 101 to rise. This junction is connected to the grid of the SCR tube 106 so that when it conducts it will apply power to the "skipping" relay 108. When relay 108 pulls in, it closes the contacts 114 and permits power to be applied to the later sections of the control circuit.

Going to FIG. 9 for a moment, there is an overload circuit breaker 204 in the main power circuit to the x-ray unit, which will be explained in detail later. However, this breaker has a contact 112 FIG. 7 which is normally closed, and provides power up the point of the skip relay contact 114. In the event that the overload breaker 204 on the x-ray unit opens, this breaker contact 112 will open and will kill the operation of the remainder of the control apparatus.

There is a "star hold" relay 126 which is connected across the 24 volts past a switch 118 which is on the star wheel, and which shuts the contacts 116 of the star hold relay 126. After skip relay 108 time delay is run out, skip relay 108 closes and this closes its contacts 114 which puts power up to the point 115. When the star wheel closes contact 118, power then is applied to the star hold relay 126 which closes contact 116. This applies continuous power to the relay 126 irrespective of the fact that the contact 118 on the star wheel contact will cause the relay 126 to pull in and to hold in. This provides power up to point 113. The dashed box 134 comprises a time delay means which continues the forward movement of the crawler for a time such that it will move from a first position, where the star wheel is just crossing the weld, to a position where the x-ray window is now centered on the weld. At that time, the power to the motors is removed and the crawler stops.

Once the star wheel switch 118 is closed and the relay contact 116 is closed, then power is supplied to the point 113. This puts power on the series resistor 136 and Zenor diode 138, which provides a regulated voltage of 20 volts applied between the series resistor 139 and the capacitor 140. The voltage of the junction 141 between these two elements will therefore rise as a function of time and as was discussed briefly before, when it becomes 16 volts the unjunction device 142 will conduct and current will flow through the series resistor 143 through the unjunction 142 and resistor 144. The voltage across the resistor 144 at point 145 is impressed on the grid of the SCR tube 146 and when this reaches the proper voltage, this SCR will conduct and the current will pass through the delay relay 148. After the set delay and the firing of the SCR the relay relay 148 pulls in and closes its contact 150, which applies power then to lead 149.

Delay relay 148 also has a second set of contacts 130 which close after the required delay and apply power to two relays, one of these relays 122 is "x-ray on" and it has a contact 379 in series with the stop relay 380 which insures that the motors are stopped and the crawler is stopped while the x-ray unit is on. At the same time, relay 124 which is called "x-ray start" is pulled in and this closes switch 206 in FIG. 9 which provides power to the x-ray unit, as will be explained later. The x-ray on relay 122 also has a second set of contacts number 110 which are normally closed. When this relay pulls in, it opens the relay contacts 110 and takes power from the sensor circuit to prevent its operation, because of the x-ray flux which will be generated by the x-ray tube. Thus the sensor is deactivated and the drive motors are deactivated whenever the "x-ray on" relay is closed.

With the x-ray tube now having power, the next important thing is to time its operation. Consider the dashed box 166. As in previous timers the closing of relay contact 150 applies power to line 149 and therefore between line 390 and 149, across the series resistors 151 and Zenor diode 152. This provides regulated voltage at junction 153, across the series resistor 154 and capacitor 155. The junction 156 is again connected to a unjunction device 157 which will fire when the junction 156 reaches 16 volts and current will then be carried through the series resistors 158 and 159, raising the potential of point 165 which, when it becomes positive enough, will fire the SCR tube 160. This will cause current to pass from the line 390 through the diode 164 through the "x-ray timer" relay 162. Again this relay 162 is bypassed with a large capacitor 163 to avoid chattering. When the relay 162 pulls in its contact 386, which is normally closed, is opened. This contact, in series with line 384, provides power to all of the delay devices. Consequently when contact 386 is opened, the current in line 391 is dropped to zero, all of the SCR tubes go to zero current and do not reconduct. Consequently, when the SCR tube 160 stops conducting, it
3,904,878

stops current through the relay 162, which falls out again causing the normally closed contacts 386 to close. Everything is recycled to zero, and is ready now to start a new series of operations.

There is another dashed box 168 which is important in the operation of the x-ray unit itself. Refer for a moment to FIG. 9. Here we show the terminals A and D, which, as from FIG. 8, provide a potential variable from zero to 140 volts AC. These go to lines 202 and 203, through the overload circuit breaker 204, through a closing switch, or contacts 206, on the "x-ray start" relay. In other words when this x-ray start relay closes, power is then applied through the switch 206 to a pair of series resistors 208 and 212. Resistor 208 is approximately 5 ohms and 212 is 1 ohm. Resistor 212 is for the purpose of measuring the current flow through the x-ray tube and this is done by placing a rectifier bridge 214 across the resistor, the output of the bridge at terminals 215 and 216, filtered by series resistor 219 and capacitor 218, provides an output voltage at terminals 220 which go to a microammeter (not shown). The reading of the microammeter is a measure of the current passing through the resistor 212, which is therefore a measure of the cathode-to-anode electron current, and therefore of the intensity x-rays.

When the power is applied to the x-ray transformer at points E, F, there is a momentary large surge of charging current, which maybe sufficient to open the circuit breaker 204. It is desirable, therefore, to have a two step application of current. In the first step, power is applied on the closing of contact 206 through the series 5 ohm resistor 208 and the series resistor 212 to the primaries of the cathode and anode transformers, which are connected to terminals E and F. One second after the first application of current, the relay contact 210, which is on a relay called the "x-ray surge" relay 120 is closed. This shorts the resistor 208 and permits the current to rise to its normal value. It is necessary to provide a time delay for the closing of this x-ray surge relay, and that is done in the box 168.

As in the case of box 166 there is a regulator tube 170, a unijunction device 175, and an SCR tube 178, connected in series with the x-ray surge relay 180. The contacts on this relay 180 are indicated by numeral 128, which are in series with an x-ray surge relay, numeral 120. This is a power relay which is controlled by the control relay, x-ray surge, relay 180. The relay 120 has a high current capacity contact 210 which is used to close and short the resistor 208.

There is only one more part of this circuit which needs explanation and this is shown in FIG. 10. The terminals A, C, carry 110 volts AC and are applied to lines 230 and 231 through a series contact 232 which is on the stop relay 380. This contact 232 is normally open. When the relay 380 is pulled in, the contacts 232 close and 110 volts AC is applied to the bridge rectifier 234. The output of the rectifier on terminals 235 and 236 go to a reversing switch 244. The moving contacts 240 and 242 are controlled by the forward-reverse relay 372. As the moving contact arms 240 and 242 move from one set of contacts to the other, the potential applied to the motor terminals G, H, reverses in polarity. The drive motors are provided with permanent magnet field structures, so that simply reversing the potential of the armature will cause a reversal of direction of rotation of the motor.

While we have described the operation of this control system in terms of an alternating current power supply to the crawler system, it is possible to substitute for the AC power supply to the control circuit of FIG. 1 an interrupted, or pulsed, DC power. Therefore, this control circuit could equally well be used on a crawler having a battery power source as well as a generator power source.

While the circuit has been described in terms of various circuit elements such as bridge rectifiers, diodes, relays, unijunction devices, Zenor diodes, and SCR devices, all of these are well known in the art and are described in many textbooks and catalogs and need not be described in further detail.

While the invention has been described with a certain degree of particularity it is manifest that many changes may be made in the details of construction and the arrangement of components. It is understood that the invention is not to be limited to the specific embodiments set forth herein by way of exemplifying the invention, but the invention is to be limited only by the scope of the attached claim or claims, including the full range of equivalency to which each element or step thereof is entitled.

What is claimed:

1. An inside-pipe crawler type x-ray machine, adapted for operation at all angles of rotation about its longitudinal axis, comprising:
   a. a gasoline engine including a gasoline tank, wherein said gasoline tank is cylindrical and coaxial with said crawler and said pipe, and including a pendulous intake pipe swiveled at the axis of said tank, whereby as the crawler rotates about its longitudinal axis, the bottom of said intake pipe will always be dipped into the gasoline in the bottom of said tank;
   b. an alternating current electrical generator driven by said engine;
   c. an x-ray unit supplied with power from said generator;
   d. a plurality of sets of hinged, spring-backed centralizing arms, and a plurality of motors connected to a plurality of driving wheels mounted respectively on one set of said centralizing arms;
   e. a single gamma ray sensing means mounted on the longitudinal axis of said crawler;
   f. control means comprising:
      1. a source of pulsed DC voltage comprising said electrical generator, a transformer and a rectifier;
      2. means powered from said pulsed DC voltage to provide a high voltage DC first potential comprising current control means, step-up transformer means, rectifier means and filter means;
      3. high energy radiation detector means powered by said first potential comprising geiger counter means;
      4. first relay means responsive to said radiation detector means;
      5. second relay means responsive to said first relay means to operate a ratchet driven switch means;
      6. third relay means including circuit reversing means responsive to said ratchet driven switch means for controlling the power to said motor means;
      7. said ratchet switch means including a first set of spaced contacts, and a second set of spaced
contacts interleaved between said first set, so that a progressive movement of a contact arm sequentially contacts each of said two sets, said third relay means controlled by both sets of contacts, said circuit reversing means controlled by only one of said sets of contacts.

2. The crawler type x-ray machine as in claim 1 including control means to reverse the direction of the motors which drive the wheels each time the motors restart after being stopped by the sensor.

3. The crawler type x-ray machine as in claim 2 in which said motors are permanent magnet motors and said control means includes means to reverse the DC potential applied to the motors each time they restart.

4. The crawler type x-ray machine as in claim 1 including means on the end of at least one of said centralizing arms to sense the presence of a pipe joint weld.

5. The crawler type x-ray machine as in claim 4 in which said sensing means is a star wheel, and including switch means responsive to said star wheel and control means responsive to said switch means to stop said crawler at a preselected time after the operation of said switch means.

6. The crawler type x-ray machine as in claim 1 including x-ray control means to supply power to said x-ray machine whenever power is removed from said driving wheels.

7. The crawler type x-ray machine as in claim 6 in which said x-ray control means includes timing means to remove power from said x-ray unit at the end of a preselected time.

8. The crawler type x-ray machine as in claim 7 including control means to start the crawler in the forward direction when the x-ray unit is shut down.

9. The crawler type x-ray machine as in claim 1 including wheels on the ends of each of said centralizing arms, and including a flexible thumper means attached to at least one of said wheels and adapted to strike the inside of the pipe once each rotation of the wheel.

10. The crawler type x-ray machine as in claim 1 including a two-stroke-cycle gasoline engine and tubular means connected between the crankcase of said engine and said gasoline tank and including check valve means to permit gas flow only from said engine to said tank.

11. The crawler type x-ray machine as in claim 1 in which said centralizing means which support said crawler in an axial position in the pipe are symmetrical about the axis of the pipe so as to permit said crawler to rotate as it progresses along said pipe.

12. A crawler type x-ray machine as in claim 1 in which said x-ray unit comprises:
   a. a housing adapted to contain a gas under pressure;
   b. an x-ray tube having a cathode and an anode;
   c. a first transformer means having a first high voltage winding, a first end connected to ground and the second end connected to the cathode;
   d. a second transformer means having a second high voltage winding, a first end connected to said anode and the second end connected to ground; and
   e. means to ensure that when the potential applied to said anode is positive with respect to ground, the potential applied to the cathode is negative with respect to ground.

13. The crawler type x-ray machine as in claim 12 including means to inject sulfur hexafluoride gas under pressure in said housing.

14. The crawler type x-ray machine as in claim 12 including a plurality of aluminum wires supported on insulating means longitudinally of said housing and extending past said x-ray tube, and means to make electrical connection to each end of said wires.

15. The crawler type x-ray machine as in claim 1 comprising two rigid subassemblies connected by a flexible joint along the axis between said two subassemblies.

16. The crawler type x-ray machine as in claim 12 including resistor means in series with said x-ray means, second time delay means, and means responsive to said second time delay means to short circuit said resistor means.

17. The crawler type x-ray machine as in claim 6 including third time delay means and means responsive to said third delay means to remove power from said x-ray means.

18. The crawler type x-ray machine as in claim 1 including means to sequentially disable said means responsive to said switch means to stop said crawler, whereby said crawler can be stopped at every second or third or other selected pipe joint.

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