

WELDING MONITORING SYSTEM

The invention relates to the art of welding with an electric arc and more particularly to a method and apparatus for monitoring and controlling a welding system during the welding process.

INCORPORATION BY REFERENCE

5 The present invention relates to the welding of pipe sections and the monitoring thereof. United States Letters Patent No. 5,676,857 is incorporated by reference herein as background information for its discussion of welding sections of pipe together.

BACKGROUND OF THE INVENTION

10 This invention relates to the field of arc welding and particularly to an apparatus and method of welding two steel plates together by use of a consumable electrode and monitoring the welding parameters during the welding process, and more particularly to an apparatus and method of short circuiting arc welding pipe sections together with a cored electrode and the monitoring of the welding parameters and the determining of the location of the formed weld bead.

15 Pipe systems are used to transport a variety of materials such as oil, gas and water to a desired location. Such pipe systems can extend hundreds and even thousands of miles. In many instances, these pipe systems traverse remote and many times undeveloped locations. In the art of welding the ends of large diameter pipe, it is conventional to machine the ends of each pipe to provide an external bevel and a narrow flat land; bring the machined ends into axle alignment with the lands in close but usually spaced relationship to form a gap between the two ends of the pipe;
20 and then to position one or more welding heads around the pipe so as to form a 360° weld. The weld bead is usually made in several steps. First, a root pass is made where at least the inner edges or lands of the pipes are fused and the gap between the lands filled with weld metal. Thereafter, several filler passes are made wherein the space formed by the bevel is filled so that the weld metal is at least flush with the outer surface of the pipe. The root pass is a very important part of the welding
25 operation. Once the root pass is completed, the alignment of the pipes is assured. Thus, during the root pass, a 100% sound weld bead must be laid. Soundness of the weld bead means the complete fusion of both the lands clear through to the inner surface of the pipes and the complete filling of the



gap between the lands with the weld metal. Depositing of the weld metal in the gap is difficult because the weld bead must be made by moving the weld heads around the pipe such that the welding position varies from downhand welding, vertical up or down welding, to overhead weld as the root pass is formed around the pipe. Furthermore, weld metal formed during the root pass should fill the gap between the pipe sections, but should not be allowed to pass through the gap and accumulate on the interior surface of the pipe. The weld bead should also form a relatively smooth surface with respect to the interior of the pipe which has very little, if any, protrusion into the interior of the pipe. Excessive protrusion of the weld bead in the pipe can: 1) create problems with apparatuses running inside the pipes to detect the soundness of the pipe system, and 2) cause unwanted fluid mixing and turbulence as the fluids are transported through the pipe system.

A welding apparatus which creates an acceptable root bead is disclosed in United States Letters Patent No. 5,676,857. This patent discloses two welding bugs which continuously move on a track around the periphery of the pipe and include a special short circuiting power source to apply a root bead between the two ends of a pipe. This patent discloses that by selecting the proper bug speed and welding wire speed, only a slight burn through each edge of the bevel occurs and a small flat weld is formed on the interior of the pipe. The Lincoln Electric Company has found that the welding apparatus disclosed in United States Letters Patent No. 5,676,857 can be modified for use with a flux cored electrode to obtain the desired composition of the weld bead so that composition of the weld metal closely matches the composition of the metal pipe to form a strong and durable weld bead. The welding apparatus can be further modified to ensure that a shielding gas protects the weld bead from the adverse effects of the environment by using a self shielding flux system which forms a shielding gas during welding.

Pipe systems are typically designed to be hundreds of miles in length. Due to the length of such pipe systems, the assembly of the pipe system may be formed in parts along the route of the pipe system. In view of the extensive length of the pipe systems and the importance of properly welding the pipe sections together, a team of welding technicians must be present to inspect the progress and quality of the pipe system and the quality of the weld bead formed between each pipe



section. In remote locations, the costs associated with using a team of technicians can be very costly. Such costs may prevent the pipe line from ever being built. In addition, the team of technicians may be exposed to undesirable conditions when laying the pipe system in remote and/or undeveloped locations. Such undesirable conditions may adversely affect the health of the technicians and/or impair their ability to constantly monitor the quality of the welding process, thus causing delays, increased costs and defective weld beads along the pipe system. In addition to the problems associated with the maintaining of a team of technicians at the welding site, there are inherent problems associated with the determination of the progress of welding along the pipe line and identifying the location of a welding problem or other problem which has occurred along the pipe line. In remote and/or undeveloped locations, it can be very difficult, if not impossible, to ascertain the geographic location of the welder along the pipe system and the location of the weld beads formed by the welder along the pipe line so as to report the progress and/or problems of the welding process.

In view of the problems associated with the welding of pipe sections of large pipe systems, there is a need for a welding monitoring system which monitors the quality of a formed weld bead and the location of such weld bead.

SUMMARY OF THE INVENTION

The present invention relates to a method and apparatus of welding together two steel plates and monitoring the parameters of the welding process and more particularly to a method and apparatus of welding pipe sections together and to monitor one or more welding parameters during the formation of the weld bead between the pipe sections and associating such welding parameters with a location. However, the invention has broader applications and can be used to weld together other long metal workpieces such as track rails, airplane and ship components, bridges, etc..

In accordance with the preferred embodiment of the present invention, there is provided a workpiece having one or more components, a welder designed to produce a weld bead to weld one or more components of the workpiece, a welding monitor to record one or more parameters of the welding process, and a location identifier to determine the location of a formed weld bead. The



monitored welding parameters can include, but are not limited to, voltage and/or current across the electrode, voltage and/or current produced by the power supply, electrode type and/or electrode feed rates, flux type and/or flux feed rates, shielding gas type and/or shielding gas feedrates, welding gas type and/or welding gas feedrates, welding cycle, direction and/or speed of welding head, time of day, ambient temperature and/or conditions, date, type of welding procedure, position of the welding head on the workpiece, interruptions during the welding process, errors (electronic and/or mechanical) during the welding process, the type and/or shape of the workpiece. One or more of these parameters or others can be electronically stored, electronically transferred to another location, printed out and/or displayed on a monitor. The location identifier is designed to determine the location of a particular formed weld bead. This location information or location parameter can then be associated to one or more welding parameters of the formed weld bead. For long workpieces such as pipe lines, railroad tracks, and other large workpieces wherein the welder is moved along the workpiece to perform a welding operation at a plurality of locations, the location identifier determines the position of the welder with respect to a certain reference point and the monitored welding parameters are correlated with or associated with the determined location. The recorded welding parameters and location parameter can be electronically stored, electronically transferred to another location, printed out and/or displayed on a monitor. The recorded data can be immediately analyzed and/or analyzed at a later time to review the welding parameters at a particular location on the workpiece for purposes of quality control.

In accordance with another embodiment, the location identifier is designed to detect two or more signals from a relatively fixed location and to calculate a location parameter based upon the detected signals. The signals are preferably land based and/or global satellite based signals. In one preferred embodiment, the location identifier calculates a location parameter using satellites of the Global Positioning System (GPS). The GPS is a multiple-satellite based radio positioning system in which the GPS satellite transmits data that allows a device to precisely measure the distance from selected ones of the GPS satellites and to thereafter compute position and time parameters to a high degree of accuracy, using known triangulation techniques. The signals provided by the GPS can be



received both globally and continuously. The GPS comprises space and control segments. The space segment, when fully operational, consists of twenty-one operational satellites. These satellites are positioned in a constellation such that typically seven, but a minimum of four, satellites are observable by a device anywhere on or near the earth's surface. Each satellite transmits signals on two frequencies known as L1 (1575.42 MHz) and L2 (1227.6 MHz), using spread spectrum techniques that employ spreading functions. C/A and P pseudo random noise (PRN) codes are transmitted on frequency L1 and/or L2. Both P and C/A codes contain data that enable a receiver to determine the range between a satellite and the device. Superimposed on both the P and C/A codes is the navigation (Nav) message. The Nav message contains GPS system time; a handover word used in connection with the transition from C/A code to P code tracking; ephemeris data for the particular satellites being tracked; and almanac data for all of the satellites in the constellation, including information regarding satellite health, coefficients for the ionospheric delay model for C/A code users, and coefficients used to calculate universal coordinated time (UTC). The control segment comprises a master control station (MCS) and a number of monitor stations. Updated ephemeris and clock data are uploaded to each satellite for re-transmission in each satellite's navigation message. The purpose of the control segment is to ensure that the information transmitted from the satellite is as accurate as possible. A GPS receiver includes an antenna assembly, an RF assembly, and a GPS processor assembly. The antenna assembly receives the L-band GPS signal and transmits the received signal to the RF assembly. The RF assembly mixes the L-band GPS signal down to a convenient IF frequency. Using various known techniques, the PRN code modulating the L-band signal is tracked through code-correlation to measure the time of transmission of the signals from the satellite. The Doppler shift of the received L-band signal is also measured through a carrier tracking loop. The code correlation and carrier tracking function can be performed using either analog or digital processing. The control of the code and carrier tracking loops is provided by the GPS processor assembly. By differencing this measurement with the time of reception as determined by the device's clock, the pseudo range between the device and the satellite being tracked may be determined. This pseudo range includes both the range to the satellite



and the offset of the device's clock from the GPS master time reference. The pseudo range measurements and navigation data from the satellites are used to compute a position and calibrate the device's clock offset, and to provide an indication of GPS time. The RPC processing and memory functions include monitoring channel status and control, signal acquisition and reacquisition, code and carrier tracking loops, computing pseudo range (PR) and delta range (DR) measurements, determining data edge timing, acquisition and storage of almanac and ephemeris data broadcast by the satellites, processor control and timing, address and command decoding, timed interrupt generation, interrupt acknowledgment control, and GPS timing, for example. The navigation processing and memory functions performed by a the GPS receiver include satellite orbit calculations and satellite selection, atmospheric delay correction calculations, navigation solution computation, clock bias and rate estimates, computation of output information, and preprocessing and coordinate conversion of aiding information, for example. When using GPS to determine the location of the formed weld bead on the workpiece, the GPS provides global longitudinal and latitudinal accuracy of about 1-100m.

In accordance with yet another aspect of the present invention, the location parameter and one or more welding parameters are electronically stored and/or printed out for real-time review and/or for later review on-site and/or electronically stored for transmission to a remote location. The ability to record one or more welding parameters and associate such welding parameters with a location parameter enables a technician to periodically monitor the quality of a formed weld bead without having to be present at each welding location. Upon review of the recorded and/or printed data, the technician can determine what weld parameters existed during the formation of a particular weld bead along the workpiece. The technician may review the data hourly, daily, weekly or even monthly, and upon review of such data, determine the quality of a formed weld bead at each location on the workpiece. In addition to or alternatively, the recorded data may be sent electronically via the telephone, Internet, satellite, radio signal, etc. to a remote location for real time and/or delayed monitoring of the welding process at specific locations. When the welding process is performed at a remote location, a satellite may be the only way to form a communication link between the welding



site and remote location. The data storage mechanism, such as a computer, can be designed to store information and, at preselected times during the day, a data link may be formed manually or automatically with a remote location via the satellite. In addition, the data storage unit may be designed to receive signals from a remote location and download, upon command, the information which is electronically stored.

In accordance with still yet another aspect of the present invention, the welding controller for the welder is designed to receive information from a remote location via a telephone, Internet, satellite, radio signal, etc. and/or an on-site technician and thereby use such received information to alter one or more of the welding parameters during the welding process. In one particular embodiment, the weld controller alters one or more welding parameters upon analyzing the location parameter and determining that the welder is at a particular location. In another particular embodiment, a technician and/or control device at a remote location receives data from the welder via the telephone, Internet, satellite, radio signal, etc. and upon determining that the welder is at a particular location, sends updated information to the welding controller via the telephone, Internet, satellite, radio signal, etc. to alter one or more welding parameters.

In accordance with another embodiment of the present invention, the workpiece includes two pipe sections which are positioned together and form a gap between the ends of the two pipe sections and are welded together by a welding system which includes a welding carriage positioned around the gap formed by the two pipe sections, a welding power supply, a welding current circuit which controls one or more welding parameters during the welding process, a location device that determines the location of the welder relative to a fixed location, and a data storage device. The pipe sections are preferably aligned together by the use of clamps at least until a root bead has been applied to the gap between the pipe sections. The welding carriage preferably extends at least 180° around the circumference of the gap and preferably 360° around the circumference of the gap. The welding carriage is designed to slide along a track as it moves around the circumference of the gap, which track is secured about the periphery of the pipe. The welding carriage includes a drive motor to move the welding carriage along the track and around the circumference of the gap at a desired



speed. If an electrode is used during welding, the welding carriage includes a mechanism which controllably moves the consumable electrode toward the gap during the welding process. The mechanism for controlling the movement of the electrode may be integrated with or separate from the mechanism for controllably moving the carriage about the gap during welding. The location device is designed to receive two or more radio signals to calculate a location of the formed weld bead relative to a particular location. The data storage device is designed to store one or more welding parameters during the welding process and a location parameter from the location device.

In accordance with yet another aspect of the present invention, the welding current circuit includes a first circuit for controlling the current flow during the short circuit condition wherein the molten metal at the end of the consumable cored electrode is primarily transferred into the molten metal pool between the gap by surface tension action. The transfer current includes a high current pinch pulse across the shorted melted metal which helps facilitate the transfer of the molten metal from the electrode to the weld pool. The welding current circuit also includes a second circuit to create a melting current. The melting current is a high current pulse which is passed through the arc which preferably has a preselected amount of energy or wattage used to melt a relatively constant volume of metal at the end of the consumable cored electrode when the electrode is spaced from the welding pool. The second circuit of the welding current circuit is preferably designed to provide a high energy boost during the initial portion of the arcing condition. The high current boost preferably has a preselected $I(t)$ area or energy for melting a relatively constant volume of metal on the end of the consumable wire when the wire is spaced from the welding pool. Preferably after the initial high current plasma boost current, the high current is maintained for a preselected period of time and then subsequently decayed over a period of time until the desired amount of energy or wattage is applied to the electrode to melt the desired volume of the electrode. The welding current circuit is also preferably designed to limit the amount of energy directed to the electrode so as to prevent the unnecessary melting of the workpiece during the application of the weld bead and/or to maintain too hot of a weld bead during welding to thereby prevent molten metal from reducing the quality of the welded area. The welding current circuit also preferably includes a circuit to produce



a background current. The background current is a low level current which is maintained just above the level necessary to sustain an arc after the termination of a short circuit condition. The background current is preferably maintained throughout the welding cycle to insure that the arc is not inadvertently extinguished during welding.

5 The primary object of the present invention is the provision of a welding system which monitors one or more welding parameters during the formation of a weld bead on a workpiece and the determined location of the weld bead formed under by welding parameters.

 Another object of the present invention is the provision of a welding system which stores one or more welding parameters during the formation of a weld bead on a workpiece and the determined
10 location of the weld bead formed by such welding parameters.

 Still another object of the present invention is the provision of a welding system which determines the location of a formed weld bead on a workpiece by receiving two or more signals from a relatively fixed location and calculating a position based upon the received signals.

 Yet another object of the present invention is the provision of a welding system which
15 utilizes GPS to determine the location of a formed weld bead.

 Another object of the present invention is the provision of a welding system transmits welding information and corresponding weld bead location information to remote locations.

 Still another object of the present invention is the provision of a welding system which provides access to welding information and corresponding weld bead location information from
20 remote locations.

 Still yet another object of the present invention is the provision of a welding system which allows for real time or delayed quality control review of a welded workpiece.

 Another object of the present invention is the provision of a welding system which provides for cost effective quality control of welding operations in remote and/or undeveloped areas.

25 Still another object of the present invention is the provision of a short circuiting arc welding system and method which forms a high quality weld bead between two metal plates.

 Another objective of the present invention is the provision of a short circuiting arc welding



system and method which accurately tracks a desired current profile during the welding of two metal plates together.

Other objectives and advantages will become apparent from the following description taken together with the accompanied drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram illustrating the welding system of the present invention using a satellite system to determine the location of the formed weld bead along the pipeline; and

Figure 2 is a block diagram of the operation of the welding system.

PREFERRED EMBODIMENTS OF THE INVENTION

Referring now to the drawings wherein the showings are for the purpose of illustrating the preferred embodiments of the invention only and not for the purpose of limiting same, Figure 1 illustrates a welding system 10 for welding pipe sections 20 of a pipe system together and for determining the location of the formed weld bead 30 along the pipe system. The pipe sections 20 are illustrated as being welded by a short circuiting arc welding system 40. The preferred type of short circuiting welding is SURFACE TENSION TRANSFER or STT type of welding. The welding circuit and control arrangement for such type of welding is disclosed in United States Letters Patent Nos. 5,148,001; 5,001,326; 4,972,064; 4,897,523; 4,866,247; and 4,717,807, which patents are incorporated herein.

The welding system 10 for welding pipe sections 20 includes power supply 42 is preferably a D.C. power supply. The power supply preferably includes a motor, such as a gas motor, which powers a generator to produce an AC current. The AC current is then rectified by a rectifier to form a DC current. A phase controller controls the rectifier to produce a substantially uniform DC current. The DC current is then directed into a pulse width modulator. The shapes of the pulse widths are controlled by a shaping circuit to thereby create a desired pulse with the DC current. As can be appreciated, the power supply 42 need not be a rectified output but can be any other appropriate DC source. The DC current from the pulse width modulator is directed across a welding area which includes a consumable cored electrode 50 and pipe section 20.



Referring to the welding of the pipe section 20, the current to electrode 50 alternates between a short circuit condition when the electrode 50 engages pipe sections 20 and an arcing condition where the electrode 50 is spaced from the pipe sections 20. During the arcing condition, an electric arc is created between the pipe and the electrode for purposes of melting and maintaining molten the end of the electrode as it is fed toward pipe sections for a subsequent short circuit condition.

Referring to Figure 1, each pipe section 20 includes an edge 22. Edge 22 is a beveled surface which forms a groove when two pipe sections are positioned closely adjacent to one another. When two pipe sections are positioned next to one another, the pipe edges are spaced apart such that a gap 24 exists between the pipe edges. In accordance with known practice, the pipe edges are positioned and secured together, preferably by clamps, until at least a root bead is applied to the groove between the pipe edges, thereby filling the gap. A pipe ground engages the pipe to complete the arc circuit between electrode 50 and the pipe sections 20. Electrode 50 is unwound from electrode and spool 52 directed toward gap 24 between the two pipe ends by electrode nozzle 44. During the welding cycle, the electrode is fed through electrode nozzle 44 so as to transfer the molten metal at the end of the electrode into the gap between the pipe ends to form a weld bead 30.

Electrode 50 is a consumable cored electrode which includes an outer metal sheath and an electrode core. Preferably the metal electrode sheath is made up of carbon steel, stainless steel or some other type of metal or metal alloy. Preferably the composition of the metal sheath is selected to be similar to the base metal component of the pipe sections 20. The electrode core preferably includes fluxing agents and/or alloy and metals. Fluxing agents may include compounds to create a slag over the weld bead to protect the weld bead until it solidifies, to retain the weld bead in position until it solidifies and/or to shield the weld metal during the formation of the weld bead. The flux may also include components which produce a shielding gas to protect the weld bead from the adverse effects of the environment. Preferably the flux components include fluoride and/or carbonate to generate a shielding gas during welding so as to eliminate the need for external shielding gases during welding. When a self shielding electrode is used, the need for an external shielding gas is eliminated. The slag which forms on the weld bead further shields the weld bead



from the environment, thus resulting in the formation of quality weld beads. The alloying agents are preferably included in the electrode core. The alloying agents are selected such that the alloying agents in combination with the composition of the metal electrode sheath form a weld bead having a composition substantially similar to the metal composition of the pipes 20.

5 A desired current profile to produce low spatter during welding and to prevent the weld bead from passing through the gap and into the interior of the pipe system includes a pinch portion, a plasma boost portion, a plasma portion and a background portion wherein the arc is to be maintained. The plasma boost portion includes a decaying portion referred to as the plasma portion. Following the decaying portion, the welding circuit shifts to the background current level which maintains the plasma or arc. The welding circuit maintains a preselected background current level, thereby
10 preventing the current level through the arc from ever falling below the preselected current low current level and allowing the arc to extinguish. The welding circuit is designed to produce all the melting of the electrode during the plasma boost and plasma portion of the welding cycle. Further melting of electrode 50 does not take place when the background current level occurs since the IR
15 necessary for melting the electrode is not obtainable through an arc maintained only by the background current. Thus, the background current only serves to maintain the arc and the ball of molten metal in the molten state. The amount of molten metal at the end of electrode 50 which is formed by the plasma boost and plasma portion is selected to melt a preselected volume of molten metal at the end of the electrode, and the plasma portion of the current is reduced to the background
20 current once the preselected volume is obtained. The duration of the plasma boost and plasma portion is also selected to prevent unnecessary melting of the metal around pipe ends 22. Such over-melting of the metal can result in the weld metal seeping into the interior of the pipe sections. During the formation of the molten metal ball, the jet forces of the high current repel the melted metal from the welding pool until the preselected amount of molten metal has been melted at the end
25 of the electrode. Once the current is reduced, the molten metal is allowed to form into a ball and the molten metal pool in the gap is allowed to stabilize, thereby allowing for a smooth contact between the substantially spherical ball and the quelled weld metal pool. The desired amount of molten metal



at the end of the electrode is controlled by directing a preselected amount of energy or wattage into the electrode during the plasma portion of the welding cycle. All during the time the molten metal ball is being formed at the end of the electrode, the core components are releasing shielding gases to shield the molten ball and the weld metal in the gap from the atmosphere. The shield gases
5 continue until the molten ball is transferred into the molten metal in the gap. Once the molten metal ball is formed during the plasma boost and the plasma portion of the welding cycle, the molten ball is forced into the molten pool by feeding the electrode into the pool, thereby forming a short circuit condition. When the melted metal ball engages the molten metal pool, it is transferred into the pool by surface tension. This action causes an ultimate necking down of the molten metal extending
10 between the pool and the wire in the electrode, and then a rupture and separation of the ball from the wire occurs. Since there is only a low background current during the separation, little if any spatter occurs. Preferably, the necking of the molten metal ball is monitored such that when the neck rapidly reduces in diameter by electric pits, the current flow during the pinch curve increases more gradually until a detection of an impending fuse is obtained. Once the detection of an impending
15 fuse occurs, the current is reduced to the background current until the molten metal at the end of the electrode transfers into the weld pool.

The welding cycle which is repeated several times per second must be accurately controlled by a welding circuit to reduce spatter during the welding cycle. In the preferred embodiment, the operating frequency of the pulse width modulator controller is 20 KHz with a width of the successive
20 current pulse being determined by a current shape controller. The demanded current for the welding cycle changes 220,000 times each second. Since the highest rate of the welding cycle is generally in the neighborhood of 100 to 400 cycles per second, many update pulses are provided during each welding cycle.

Referring to Figure 1, a welding monitor 60 is provided which monitors one or more welding
25 parameters during the formation of weld bead 30. Preferably welding monitor 60 monitors the current to electrode 50, the feed rate of electrode 50, the total amount of energy to electrode 50 during each weld cycle, and the speed at which the welding head travels around pipe sections 20.



Additional welding parameters may be monitored. Furthermore, data from other sensors and/or inspection instruments may be monitored by welding monitor 60. Welding monitor 60 includes a display to allow a technician to view real-time and/or historical data which is or has been monitored by welding monitor 60. Welding monitor 60 also includes a data entry arrangement 64 to a) allow
5 a technician to alter one or more welding parameters to welder 40, b) display different data on display 62, 3) access historic data, d) activate or deactivate a welding control program or some other operation. Preferably welding monitor 60 includes one or more components of the welding circuit that controls the current to electrode 50.

Welding monitor 60 includes a data storage device to store a portion or all of the monitored
10 information. Preferably, one or more welding parameters are stored on a disk drive or tape. A sufficient number of welding parameters are preferably stored so that the quality of the weld bead 30 formed between the two pipe ends 22 can be reviewed by a technician.

Welding monitor 60 also includes a location circuit to locate the geographic position of formed weld bead 30. The location circuit includes an antenna 66, a GPS reference receiver and a
15 microprocessor for calculating the position of the formed weld bead. Antenna 66 may comprise any of a number of commercially available low-gain antennas. The GPS reference receiver is designed to determine the global latitude and longitude of the formed weld bead welding system by sensing the signals 70 from satellites 80. A memory unit is provided in welding monitor 60 for storing location information supplied by a GPS unit, record the history of travel of the GPS unit, and include
20 information corresponding to the global latitude and longitude information. A clock is provided in welding monitor 60 for supplying time and date information to the tracking circuit. The welding monitor 60 preferably includes a telecommunicating circuit to link to a remote location so as to upload and/or download information to and from the welding monitor. Preferably a telephone system and a satellite transmission unit are included in the welding monitor to provide a data link
25 to a remote location. The operation of the GPS tracking circuit is known in the art and will not be further described.

Referring now to Figure 2, the operation of the welding system will now be briefly described.



The welding circuit includes preset and/or loaded welding parameters. The welding circuit controls the formation of the weld bead 30 on pipe sections 20. Weld monitor 60 monitors and stores various welding parameters during the formation of the weld bead. The welding monitor also monitors and stores information provided by other sensors and inspection instruments used to form the pipe system. The monitored information is stored, preferably on a disk drive. As the weld bead is being formed, the positioning circuit senses signals 70 from GPS satellites 80. Preferably three or more signals are sensed and processed to determine the global longitudinal and latitudinal position of the formed weld bead. The positional information is correlated with the monitored parameters and stored on the disk drive. The stored location and corresponding monitored parameters can be immediately reviewed or later reviewed on-site or at a remote site via telephone, Internet, radio wave or satellite connection. A technician, upon reviewing the recorded data on-site and/or at a remote location can review the stored information to determine the quality of a formed weld bead at a particular location along the pipe system. The technician after reviewing the data can input new welding parameters for future weld bead formation and/or correct a problem with a previously formed weld bead.

The ability of the welding system to provide information on how a particular weld bead is formed and the location of such weld bead along a pipe system, allows a technician to monitor welding operations world-wide and to ensure that quality weld beads are formed. The recorded information can be used to ascertain future failure problems of a weld bead and/or to correct a problem with a previously formed weld bead.

The invention has been described with reference to a preferred embodiment and alternates thereof. It is believed that many modifications and alterations to the embodiments disclosed will readily suggest themselves to one skilled in the art upon reading and understanding the detailed description of the invention. It is intended to include all such modifications and alterations insofar as they come within the scope of the present invention.



L-2041
FOREIGN FILING CLAIMS

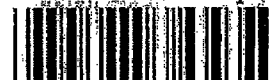
1. A welding system for welding two plates together which comprises:
a) a welding head to supply heat to said plates to form a weld bead therebetween;
b) a welding monitor to monitor at least one welding parameter during the formation of said weld bead; and
5 c) a positioning circuit to sense a plurality of electromagnetic signals originating from a relatively fixed position and to determine the location of said formed weld bead.

2. The welding system as defined in claim 1, wherein said positioning circuit senses a plurality of signals from global satellites and determines a global longitudinal and latitudinal position of said formed weld bead.

3. The welding system as defined in claims 1 or 2, wherein said at least one monitored welding parameter and determined location are electronically recorded.

4. The welding system as defined in claims 1 to 3, wherein said at least one monitored welding parameter and determined location are electronically transmitted to a remote location.

5. The welding system as defined in claims 1 to 4, wherein said monitored welding parameter includes a parameter selected from the group consisting of the amount voltage across the electrode, the amount of current across the electrode, the amount of voltage produced by the power supply, the voltage profile, the amount of current produced by the power supply, the current profile,
5 the amount of power directed to the electrode, the rate of power directed to the electrode, the electrode type, the electrode feed rate, the flux type, the flux feed rate, the shielding gas type, the shielding gas feedrate, the welding gas type, the welding gas feedrate, the welding cycle, the direction of movement of welding head, the rate of speed of welding head, the time of day, the ambient conditions, the date, the type of welding procedure, the type of power supply, the type of
10 welder, the type of welding components, the position of the welding head on the workpiece, the



polarity of the electrode during welding, the interruptions during the welding process, the electronic errors during the welding process, the mechanical errors during the welding process, the type of the workpiece, the shape of the workpiece.

6. The welding system as defined in claims 1 to 5, including a welding circuit having a first circuit to create a transfer current and a second circuit to create a melting current, said second circuit supplying a sufficient amount of current to said electrode to form said weld bead on said two plates.

7. The welding system as defined in claims 1 to 6, including a welding circuit that creates a series of small width current pulses and controls the polarity of the current pulses between a first polarity with said electrode being positive and a second polarity with said electrode being negative, said series of current pulses constituting a welding cycle with a short circuit transfer portion and a plasma arc melting portion, said current pulses in said cycle each having a given electrical polarity of said electrode with respect to said two plates.

8. The welding system as defined in claims 1 to 7, including a welding carriage adapted to move said welding head about the outer peripheral surface of said plates sections and along a gap between said plates.

9. The welding system as defined in claims 1 to 8, including a consumable electrode for forming said weld bead.

10. The welding system as defined in claim 9, wherein said consumable electrode is a cored electrode.

11. The welding system as defined in claims 9 or 10, wherein said electrode being a self-shielding electrode.



12. The welding system as defined in claims 9 to 11, wherein said electrode includes alloying components to form said weld bead having a substantially similar composition as the composition of said plates.

13. The welding system as defined in claims 6 to 12, wherein said second circuit directing a preselected amount of energy to said electrode to melt a relatively constant volume of an electrode during each welding cycle.

14. The welding system as defined in claims 6 to 13, wherein said welding circuit limiting the amount of energy directed to said electrode to prevent molten metal from passing through a gap between said two plates.

15. The welding system as defined in claims 6 to 14, wherein said welding circuit reducing the amount of current to said electrode prior to said molten metal on said electrode forming a short circuit condition with a gap between said two plates.

16. The welding system as defined in claims 6 to 15, wherein said welding circuit creates an alternating current.

17. The welding system as defined in claims 6 to 16, wherein said welding circuit forms part of a STT power supply.

18. The welding system as defined in claims 9 to 17, wherein said electrode is move about the outer peripheral surface of said metal plates and substantially along a gap between the plates.

19. The welding system as defined in claims 8 to 18, wherein said welding carriage continuously moves along said plates sections and wherein the speed of said welding carriage can be varied.



20. The welding system as defined in claims 1 to 19, wherein said two metal plates are two pipe sections.

21. A method of welding two plates together, said method comprising the steps of:

- a) providing an welding head;
- b) moving said welding head toward said plates;
- c) forming a weld bead between said plates;
- d) monitoring at least one welding parameter during the formation of said weld bead; and
- e) determining the position of said formed weld bead relative to a substantially fixed location.

22. The method as defined in claim 21, including the step of electronically saving said at least one welding parameter and said determined position.

23. The method as defined in claims 21 or 22, including the step of transmitting said at least one monitored welding parameter and said determined location to a remote location.

24. The method as defined in claims 21 to 23, wherein said monitored welding parameter includes a parameter selected from the group consisting of the amount voltage across the electrode, the amount of current across the electrode, the amount of voltage produced by the power supply, the voltage profile, the amount of current produced by the power supply, the current profile, the amount of power directed to the electrode, the rate of power directed to the electrode, the electrode type, the electrode feed rate, the flux type, the flux feed rate, the shielding gas type, the shielding gas feedrate, the welding gas type, the welding gas feedrate, the welding cycle, the direction of movement of welding head, the rate of speed of welding head, the time of day, the ambient conditions, the date, the type of welding procedure, the type of power supply, the type of welder, the type of welding components, the position of the welding head on the workpiece, the polarity of the electrode during welding, the interruptions during the welding process, the electronic errors during the welding



process, the mechanical errors during the welding process, the type of the workpiece, the shape of the workpiece.

25. The method as defined in claims 21 to 24, wherein said step of determining the position of said formed weld includes sensing a plurality of signals from global satellites.

26. The method as defined in claims 21 to 25, wherein said step of determining the position of said formed weld includes determining a global longitudinal and a lateral position of said formed weld bead.

27. The method as defined in claims 21 to 26, wherein said two plates are ends of two pipe sections.

28. The method as defined in claims 21 to 27, wherein said weld bead being formed from a consumable electrode.

29. The method as defined in claim 28, wherein said consumable electrode is a self-shielding electrode.

30. The method as defined in claim 28 or 29, wherein said electrode is a cored electrode.

31. The method as defined in claims 28 to 30, wherein said electrode includes alloying components to form said weld bead having a substantially similar composition as the composition of said two plates.

32. The method as defined in claims 21 to 31, including the step of providing a welding carriage which moves said welding head about the outer peripheral surface of said plates.

33. The method as defined in claim 32, wherein the speed of said welding carriage is



varied as said carriage moves about said plates.

34. The method as defined in claims 28 to 33, including the step of melting said electrode by an electric wave, said step of melting directing a preselected energy to said electrode to melt a relatively constant volume of said electrode during each welding cycle.

35. The method as defined in claim 34, wherein said electric wave includes a background current, said background current having a high inductance component and a low level just above the level necessary to sustain an arc after the termination of a short circuit condition which is maintained throughout each welding cycle.

36. The method as defined in claims 28 to 35, including the step of limiting the amount of energy directed to said electrode to prevent molten metal from passing through a gap between said two plates.

37. The method as defined in claims 28 to 36, including the step of reducing the amount of current to said electrode prior to said molten metal on said electrode forming a short circuit condition with a gap between said two plates.

38. The method as defined in claims 34 to 38, wherein said electric wave is an alternating current.

39. The method as defined in claims 34 to 38, wherein said electric wave is formed by a STT power supply.

40. The method as defined in claims 28 to 39, including the step of moving said electrode about the outer peripheral surface of said metal plates and substantially along a gap between the plates.

This Sheet Has Been Replaced

