

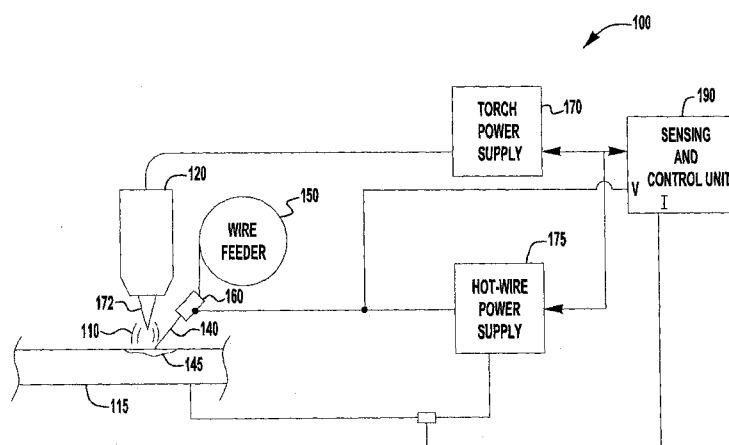
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(54) Title: AUTO STEERING IN A WELD JOINT

**FIG. 1A**

(57) **Abstract:** A method of and system (100) for steering an arc (110) and/or torch head (120) in a weld joint (510) is provided. The system (100) includes a torch head (120) that creates an arc (110) in a weld groove formed in at least one workpiece (115, 115A, 115B). The system (100) also includes a control unit (190) that includes a feedback system that monitors at least one of a voltage of the arc (110), a current of the arc (110), a power output of the torch power supply, and a contact tip to weld distance. The control unit (190) outputs a feedback signal corresponding to the monitoring. The control unit also includes a comparison circuit that compares the feedback signal with at least one predetermined value corresponding to a position of at least one of the arc (110) and the torch head (120) in the weld groove. The control unit (190) further includes an arc steering system that outputs a steering signal based on the comparison.

AUTO STEERING IN A WELD JOINT

[001] The present application is a continuation-in-part of and claims priority to U.S. Patent Application No. 13/438,703, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[002] The invention is related to an arc welding system according to claim 1 and to a method of performing arc welding with arc steering according to claim 9. Certain embodiments relate to arc welding applications. More particularly, certain embodiments relate to steering an arc and/or torch in a weld joint in arc-welding/joining applications.

TECHNICAL BACKGROUND

[003] In related art arc welding systems such as gas-shielded tungsten arc welding (GTAW), gas-shielded metal arc welding (GMAW), plasma arc welding (PAW), etc., weld quality will be adversely affected if the torch head is not properly positioned with respect to the weld groove walls. For example, because ferrous materials of the weld-groove sidewalls can interfere with the arc, the arc of a torch head that is improperly positioned can shift to a sidewall rather than the bottom of the weld. Conversely, if the torch head is positioned too far away from the sidewall, the filler material will not be properly deposited against the sidewall. Further, even a torch head that has been properly positioned at the start of the welding process may need to be readjusted during the welding process. This is because the alignment of the sidewalls of the workpieces may not be straight and true and the relative position of the torch head with respect to the weld groove sidewall could change, i.e., the distance between the welding head and a groove sidewall could get smaller or larger, as the torch head travels the length of the weld groove. In addition, in some cases, the width of the weld groove could also vary along its length due to deviations in machining the weld groove. Accordingly, to account for misalignment and width variations in the weld groove, the position of the torch head and/or the width of the arc oscillation may need to be adjusted in situations where mechanical oscillation, magnetic oscillation

tion and/or ground switching are used. Therefore, even in an "automated" welding process, an operator may need to watch the welding operation and constantly adjust the position of the torch head and/or the width of the arc oscillation.

[004] Further limitations and disadvantages of conventional, traditional, and proposed approaches will become apparent to one of skill in the art, through comparison of such approaches with embodiments of the present invention as set forth in the remainder of the present application with reference to the drawings.

DESCRIPTION OF THE INVENTION

[005] It is an object of the invention to overcome the aforementioned limitations and disadvantages. This problem is solved by an arc welding system with automated arc steering according to claim 1 and by a method of performing arc welding with arc steering according to claim 9. Further embodiments of the invention are subject of the subclaims. Embodiments of the present invention comprise a method and system for steering an arc and/or torch head in a weld joint in a system for arc-welding/joining applications. Some exemplary embodiments of the invention include an automated arc steering system that includes a feedback circuit that receives an indication of a position of an arc and/or torch head in a weld groove. The arc steering system also includes a comparison circuit that compares the arc and/or torch head position indication with a predetermined value. The predetermined value can be a desired voltage and/or current value for the arc and/or torch head for a given point in the weld groove. The arc steering system further includes an arc steering device that positions the arc and/or torch head based on the comparison the arc/torch head position indication with the predetermined value.

[006] In some embodiments, the system includes a torch power supply that is operatively connected to a torch head that creates an arc in a weld groove formed in at least one workpiece. The system also includes a control unit that includes a feedback system that monitors at least one of a voltage of the arc, a current of the arc, a power output of

the torch power supply, and a contact tip to weld distance. The control unit outputs a feedback signal corresponding to the monitoring. The control unit also includes a comparison circuit that compares the feedback signal with at least one predetermined value corresponding to a position of at least one of the arc and the torch head in the weld groove. The control unit further includes an arc steering system that outputs a steering signal based on the comparison. The steering signal is used to control the position of at least one of the arc and the torch head in the weld groove. According to a preferred embodiment of the method said feedback signal is based on said voltage of said arc and said first predetermined value is 9 volts and said second predetermined value is 11 volts.

[007] In some embodiments, the method includes creating an arc in a weld groove formed in at least one workpiece with a torch head. The method also includes monitoring at least one of a voltage of the arc, a current of the arc, a power output of the torch head, and a contact tip to weld distance, and outputting a feedback signal corresponding to the monitoring. The method further includes comparing the feedback signal with at least one predetermined value corresponding to a position of at least one of the arc and the torch head in the weld groove and outputting a steering signal based on the comparison. The method additionally includes controlling the position of at least one of the arc and the torch head in the weld groove based on the steering signal.

[008] These and other features of the claimed invention, as well as details of illustrated embodiments thereof, will be more fully understood from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[009] The above and/or other aspects of the invention will be more apparent by describing in detail exemplary embodiments of the invention with reference to the accompanying drawings, in which:

- [0010] FIGS. 1A and 1B illustrate different views of a functional schematic block diagram of an exemplary embodiment of a system for any of brazing, cladding, building up, filling, hard-facing overlaying, joining, and welding applications;
- [0011] FIGS. 2A-2D illustrate exemplary oscillation patterns that can be produced by the system of Figures 1A and 1B;
- [0012] FIG. 3 illustrates a functional schematic block diagram of an exemplary embodiment of a system for any of brazing, cladding, building up, filling, hard-facing overlaying, joining, and welding applications on a pipe;
- [0013] FIG. 4 illustrates an expanded view of section AA of Figure 3;
- [0014] FIG. 5 illustrates an exemplary weld joint that can be welded using the system of Figure 3; and
- [0015] FIG. 6 illustrates exemplary arc voltage values at various points of an arc sweep in an exemplary weld joint.

DETAILED DESCRIPTION

[0016] Exemplary embodiments of the invention will now be described below by reference to the attached Figures. The described exemplary embodiments are intended to assist the understanding of the invention, and are not intended to limit the scope of the invention in any way. Like reference numerals refer to like elements throughout.

[0017] FIGS. 1A and 1B illustrate different views of an exemplary system **100** for welding/joining applications. For clarity, certain components are not shown in view. The system **100** includes an arc welding system such as a GTAW system. Although a GTAW system is illustrated, the present invention will work with any automated system that uses an arc for brazing, cladding, building up, filling, hard-facing overlaying, joining, and welding applications. As shown in Figure 1A, the system **100** includes a power supply **170** that is operatively connected to tungsten electrode **172**, which is housed in torch head **120**. The

power supply **170** can have an arc starter (not shown) that creates an arc **110** and/or the power supply **170** can be configured to "touch" start the arc **110**. The power supply **170** provides a welding current to workpiece **115** via electrode **172** and arc **110**. The arc **110** heats workpiece **115** to create a weld puddle **145**. In some embodiments, the power supply **170** is a pulsed direct current (DC) power supply, although alternating current (AC) or other types of power supplies are possible as well. Generic arc welding is known and will not be discussed in detail.

[0018] As shown in Figure 1B, the system **100** can also include a magnetic arc oscillation system **130**. The magnetic arc oscillation system **130** includes a magnetic head **137**, magnetic pole **135**, and a power supply **131**. The magnetic pole **135** can be set to have either a positive or negative polarity by head **137**. The polarity on magnetic pole **135** determines where the arc **110** is directed, i.e., either toward the pole **135** or away from it. In some embodiments, the magnetic arc oscillator system **130** can also change the intensity of the magnetic field to control the amount of deflection of the arc **110**. The magnetic arc oscillation system **130** can be configured to oscillate the arc **110** to produce a sweeping motion (an "arc sweep") as shown by arrow **132**. The arc sweep **132** can be used to improve the weld-bead geometry by producing weaving patterns. For example, the magnetic arc oscillation system **130** can be used on wider weld passes such as the "cap" pass of a weld. This technique provides better sidewall fusion as the amount of heat to weld edges can be controlled. The magnetic arc oscillation system **130** can be used for fillet welds to minimize undercutting. In addition, when joining materials of different thicknesses, the arc oscillation can be controlled to adequately penetrate the thicker workpiece while preventing undercutting of the thinner workpiece. Figures 2A to 2D provide some exemplary arc sweep patterns that can be produced by the magnetic arc oscillation system **130**. Of course, the present invention is not limited to the illustrated arc sweep patterns and any arc sweep pattern that produces the desired weld weave pattern can be used. In addition,

magnetic arc oscillation methods and systems in combination with arc welding systems are disclosed in Application No. 13/438,703, which is incorporated herein by reference, in its entirety. Accordingly, magnetic arc oscillation techniques will not be further discussed.

[0019] As illustrated in Figure 1B, the system **100** can further include a mechanical steering device **180**. The mechanical steering device **180** is operatively connected to torch head **120** via bracket **185**. The bracket **185** can be controlled in order to steer the torch head **120** from one side of the weld groove to the other as shown by arrow **182**. Of course, other steering methods and devices can be used so long as torch head **120** can be moved to the desired location within the weld groove. When used with the magnetic arc oscillation system **130**, the bracket **185** can also be operatively connected to oscillation system **130** such that the relative position of pole **135** with respect to the torch head **120** is constant. Thus, the mechanical steering device **180** can position the torch head **120**/magnetic oscillation system **130** in the weld groove such that they are in the proper position for the magnetic arc oscillation system **130** to produce the desired weld weave pattern. In some embodiments, a mechanical steering device can be used to oscillate the torch head **120** (and arc **110**) similar to the magnetic arc oscillation system **130** to produce weld weave patterns, e.g., as discussed above.

[0020] The system **100** can also include a ground switching circuit **195** that can switch between at least two grounds on the workpieces **115A** and **115B** (see Figure 1B). The ground switching circuit **195** is operatively connected to grounds **196A** and **196B** such that only one ground is active at any given time. The grounds **196A** and **196B** are respectively located on workpieces **115A** and **115B**. The ground switching circuit **195** can be configured to switch the active ground in order to control or direct the direction of the arc **110**. For example, in some embodiments, the ground switching circuit **195** is controlled such that it produces a sweeping action on arc **110** to produce a desired weld weave pattern. In some embodiments, an H-bridge circuit can be used to switch the active ground. General

H-bridge circuits are well known in the art and will not be further discussed. The above illustrative embodiments show one ground on each workpiece. However, any number of strategically placed grounds on each workpiece can be used to produce the desired weld weave pattern.

[0021] One or more of power supply **170**, power supply **175**, magnetic oscillation system **130**, mechanical steering device **180**, wire feeder **150**, and ground switching circuit **195** can be connected to sensing and control unit **190**. In some embodiments, the control unit **190** includes control logic that, based on the welding conditions, automatically steers the torch head **120** in the weld joint via mechanical steering device **180**. The control unit **190** may also accept feedback signals from voltage and current sensors that measure the voltage (V) at contact tube **160** and the current (I) flowing to the system in order to determine the proximity of the arc **110** and/or torch head **120** to the sidewalls of the weld groove. Of course, in some embodiments, other feedback signals can be used such as a power output of the power supply **170**, contact tip to weld distance (CTWD), etc. so long as the feedback can provide an indication of the position of the arc **110** and/or the torch head **120** relative to the side walls. The feedback signals can then be used to automatically steer the torch head **120** and/or arc **110**. For example, based on the welding operation (e.g., GTAW, GMAW, PAW, etc.), the type of materials, the number of weld passes (single-pass/multi-pass welding), etc., the control unit **190** (or some other similar device) may be configured with desired arc voltage and/or current values for the arc **110** for one or more positions of the arc **110** along the arc sweep. For example, Figure 6 illustrates an embodiment where the arc **110** is configured to sweep from one sidewall to the other. The magnetic arc oscillation system is configured to provide a left magnetic field via magnetic pole **135** that deflects the arc **110** to the base of the left sidewall and a right magnetic field that deflects the arc **110** to the base of the right sidewall. When the magnetic field is turned off, the arc **110** will be in a center position under the torch head **120**. Of course, the magnetic arc oscilla-

tion system can be positioned differently based on the welding needs. For example, the torch head **120** can be set up such that it is over one of the sidewalls rather than in the middle. In such a case, the magnetic arc oscillation system will move the arc **110** from one sidewall (magnetic field off) to the other sidewall (magnetic field on). In other embodiments, the intensity of the magnetic field can be changed continuously to direct the arc **110** to any position in the weld groove rather than just discrete values, e.g., left sidewall, right sidewall, center, etc.

[0022] For the embodiment in Figure 6, the arc **110** can have different desired arc voltages based on whether the arc **110** is away from the sidewalls (e.g., in the center magnetic field position), at the right sidewall, or at the left sidewall. That is, in exemplary embodiments of the present invention, the desired or threshold voltage levels for any given moment or position in the welding operation will vary by taking into account different factors, including but not limited to: electrode positioning, groove geometry, etc. For example, in the center magnetic field position, the desired arc voltage feedback can be, e.g., 12-15 volts and in the left and right sidewalls (i.e., left and right magnetic field positions), the desired arc voltage can be, e.g., 9-11 volts. Control of embodiments of the described system can occur in a number of different ways. For example, feedback from monitoring the arc voltage can be utilized at specific intervals during the welding operation, at specific locations during the welding process and/or can be continuous during the welding process (or any combination of these methodologies). For example, in some embodiments, the feedback signal, e.g. the arc voltage, can be monitored while or during the arc **110** is at a specific position along the arc sweep, e.g., when the arc **110** is positioned at the left, right, or center position by magnetic pole **135**. In other embodiments, the feedback signal corresponding to arc **110** is monitored continuously, even during the transition from one arc position to another. In still other embodiments, the feedback signal is measured at a desired frequency, e.g., every N arc sweeps, or intermittently to verify proper operation. In further

exemplary embodiments the feedback signal can be utilized after a duration, for example, every 5 to 20 ms. Of course, other durations and methodologies can be used without departing from the spirit or scope of the present invention.

[0023] Based on the feedback signal, e.g., the arc voltage, and information related to the arc position, e.g., left, right, or center position, the control unit **190** can determine if detected voltage is different from the desired voltage at any given position. For example, embodiments of the present invention can determine if the distance between the torch head **120** and the sidewalls has changed for some reason, e.g., the torch head **120** is drifting, misalignment in the side walls, etc. For example, if the control unit **190** sees that the arc **110** voltage is at 8 volts at the right magnetic field position, 12 volts at the center magnetic field position, and 12 volts at the left magnetic field position, the control unit **190** can determine that the torch head **120** is drifting to the right and that the torch head **120** needs to move to the left. Similarly, based on the feedback signal, the control unit **190** can be set up to determine if the arc sweep width needs to be adjusted because the width of the weld groove has changed for some reason, e.g., misalignment of the workpieces, deliberate design change in the weld groove width, etc. For example, if the control unit **190** sees that the arc **110** voltage is at 8 volts at the left and right magnetic field positions and 12 volts at the center magnetic field position, the control unit **190** can determine that the weld groove has narrowed and that the magnetic field strength or another weld setting needs to be adjusted to ensure proper welding with the narrowed groove walls.

[0024] In some embodiments, the system **100** can be set up such that the appropriate adjustments are made to the torch head **120** position and/or the magnetic field strength based on predetermined values for the feedback signal, e.g., the arc voltage. For example, in some systems, a low arc voltage, e.g., less than 9 volts, can indicate that the arc **110** is too close to a sidewall of the weld groove and that a potential short and/or loss of arc condition exists. Conversely, a high arc voltage, e.g., greater than 11 volts, can indi-

cate the arc **110** is away from a sidewall of the weld groove. In such systems, the control unit **190** can be configured such that: 1) when the arc **110** is in the left or right magnetic field position and the arc voltage is below a predetermined low level, e.g., 9 volts, the control unit **190** determines that the torch head **120** is too close to the sidewall; and 2) when the arc **110** is in the left or right magnetic field position and the arc voltage is greater than a predetermined high level, e.g., 11 volts, the control unit **190** determines that the torch **120** at the corresponding left or right position is too far away from the sidewall. Thus, by comparing the predetermined low and high values to the feedback signal from one or more points on the arc sweep (e.g., arc voltages at the left, right, and center magnetic field positions), the control unit **190** can be configured to appropriately move the torch head **120** within the weld groove using the mechanical steering device **180** and/or change the width of the arc sweep using the magnetic arc oscillation system **130**. That is, the control unit **190** can be configured to steer the torch **120** away from the sidewall if the arc voltage is below the predetermined low level, or if the feedback voltage is too high (e.g., 12-15 volts), the control unit **190** can steer the torch head **120** toward the sidewall. The control unit **190** will know which direction to steer the torch head **120** because it is in communication with magnetic arc oscillation system **130**, which can provide the position of the arc **110**, e.g., left, right, and center.

[0025] In some embodiments, the control unit **190** is operatively connected to the mechanical steering device **180** in order to steer the torch head **120**. The control unit **190** may be preprogrammed with predetermined auto steering values that are based on the materials being welded, the thicknesses of the workpieces **115A** and **115B**, whether the process is GTAW, GMAW, PAW, etc., and/or whether the process is single-pass or multi-pass welding – to name just a few. Alternatively, or in addition to, the control unit **190** may use adaptive controls to determine or “fine-tune” the auto steering values during the weld-

ing process. In some embodiments, the auto steering values may be user settable or adjustable.

[0026] By measuring the voltage and/or current at the torch **120** and automatically steering the torch **120** as discussed above, the present invention automatically corrects for misalignment in workpieces that are to be welded. For example, Figure 3 illustrates another exemplary embodiment of the present invention in which torch head **120** with electrode **172** and magnetic oscillator system **130** are mounted on weld head tractor unit **315**, which moves along guide track **310** in an orbital welding system for welding pipe joint **320** that will connect pipe segments **330A** and **330B**. The components of an exemplary orbital welding system are discussed in co-pending Application No. 13/675,168, which was filed on November 13, 2012, and incorporated by reference herein in its entirety. Accordingly, for brevity, only those components of an orbital welding system relevant to explaining the present invention will be further discussed. The guide track **310** is set up around the entire circumference of pipe segment **330B** such that the radial plane of guide track **310** is perpendicular to the longitudinal axis of the pipe segment **330B**. As illustrated, the pipe joint **320** will take two passes to weld, i.e., weld passes **X_A** and **X_B** on either side of centerline **335**. To accomplish this, the mechanical steering device **180** can position the torch head **120** such that torch head **120** is at the mid-point of weld pass **X_A**. As illustrated in Figure 4, which is an expansion of section AA of Figure 3, the torch **120** is initially positioned at line **410A**, which is at the mid-point of weld pass **X_A**. As the magnetic oscillator **180** and/or the ground switching circuit **195** sweeps the arc **110** from one side to the other to produce weld **420**, the weld **420** will cover approximately one-half of the weld joint. However, as is sometimes the case, the weld joint may not be straight and true, i.e., the weld groove sidewalls may not be perpendicular to the longitudinal axis of the pipe segments **330A** and **330B** (see Figure 4). Accordingly, as the weld tractor head **315** moves down the guide track **310** (see Figure 3), the weld **420** may get too close to the sidewall. This may result in a poor

quality weld and/or arc stability issues near the sidewall. In addition, the coverage of the second weld pass X_B will be adversely affected because the first weld pass X_A will not cover one-half of the weld joint **320** as expected. Thus, in traditional welding systems, an operator manually adjusted for any misalignment issues by re-centering the torch head **120**.

[0027] However, as discussed above, the control unit **190** (or some other similar device) can receive and monitor feedback signals, e.g., arc voltage, in order to determine the position of arc **110** and/or torch head **120** with respect to the sidewall. For example, as discussed above, in some embodiments, control unit **190** can determine that torch head **120** is positioned properly based on a feedback signal corresponding to the arc **110**, e.g., arc voltage. In the exemplary embodiment of Figure 3, if the arc voltage at the left magnetic field position, i.e., left sidewall, is between 9-11 volts and between 12-15 volts for the center magnetic field position and the right magnetic field position, the control unit **190** will determine that the torch head **120** is positioned properly. Because this embodiment requires two weld passes, the right magnetic field position on the first pass X_A will position the arc **110** at the center line **335** of weld joint **320** rather than at the right sidewall. Thus, the desired arc voltage for the right magnetic field position in this embodiment is 12-15 volts rather than the 9-11 volts of the exemplary embodiment of Figure 6.

[0028] If the control unit **190** determines that the feedback signal, e.g., arc voltage, is not within the desired range, then the control unit **190** can automatically move (i.e., steer) torch head **120** such that the torch head will maintain the proper distance from the groove wall. For example, if the voltage of arc **110** is below a predetermined value V_A , e.g., 9 volts, at the left magnetic field position, the control unit **190** can be configured to move torch head **120** to the right to point **410B** using mechanical steering device **180** such that the arc **110** voltage at the left sidewall is at a desired value of V_x , e.g. between 9-11 volts. As the welding proceeds and the arc **110** once again gets too close to the left sidewall and

the arc voltage goes below the predetermined voltage V_A , the control unit **190** can further move torch **120** to the right to point **410C** such that the arc voltage is one again at V_x and so on. In this manner, the control unit **190** will automatically adjust for misalignments in the weld joint **320**.

[0029] In the above embodiment, the control unit **190** was configured for stepwise adjustments, i.e., the arc voltage fell to a value V_A from the desired value of V_x before an adjustment was made. However, the invention is not limited to such stepwise adjustments and the control unit **190** can also be configured to continuously adjust the position of torch head **120** such that the arc voltage is maintained at a desired voltage value. Of course, in some embodiments, the present invention can also use the arc current as the feedback value when adjusting torch head **120**.

[0030] For example, in a constant voltage process, current is utilized as the feedback to determine CTWD. In the case of a constant voltage process, as the electrode gets closer to the wall the current feedback signal at the wall will decrease. Conversely, when the electrode gets further away from the wall the current feedback signal will increase. Of course, the present invention is not limited to using the arc current or the arc voltage as the feedback signal and can use other feedback signals that change based on the proximity of the torch head to the sidewall, e.g., a power output of the power supply, CTWD, etc.

[0031] In some situations, the width of the weld joint may vary due to, e.g., deviations in machining the weld groove. In such situations, the arc **110** and/or torch head **120** may move too close to or not close enough to a sidewall because the arc sweep no longer matches the expected width of the weld joint, i.e., the arc sweep may be too large or too small as the width of the weld joint changes. For example, as illustrated in Figure 5, the system may be set up for the width of weld joint **510** at point A, which will produce weld **520**. However, at point B, the width of weld joint **510** is smaller than at point A and the arc sweep will take the arc **110** and weld **520** too close to the left sidewall. Conversely, at point

C the width of weld joint **510** is larger than at point A and the arc sweep will not take the arc **110** and weld **520** to the right sidewall. In addition, due to the change in the width, the torch head **120** may not be in the proper position, e.g., at the midpoint of the desired weld weave pattern. Accordingly, in prior art systems, an operator may need to manually adjust the width of the arc sweep and/or the location of the torch head to ensure a proper weld. However, in some embodiments of the present invention, the control unit **190** (or some other similar device) may adjust the position of torch head **120** using mechanical steering device **180** and/or the width of the arc sweep using the magnetic oscillation system **130** and/or the ground switching circuit **195**. To accomplish this, the control unit **190** can use the voltage and/or current feedback signals from the torch head **120** to determine whether the arc sweep width is appropriate. For example, if the arc voltage is 9-11 volts at both the left and right magnetic field positions, the control unit **190** determines the arc sweep width is appropriate and that the width of the weld groove has not changed significantly. However, if the right and/or left magnetic field position has an arc voltage that is less than a predetermined value, e.g., 9 volts, the control unit **190** determines that the weld groove width has narrowed at the right and/or left side wall, respectively. Similarly, if the right and/or left magnetic field position has an arc voltage that is greater than a predetermined value, e.g., 11 volts, the control unit **190** determines that the weld groove width has widened at the right and/or left side wall, respectively. Accordingly, based on the feedback signal, e.g., arc voltage, the control unit **190** can determine if the width of the weld joint at any particular point has changed and appropriately adjust the location of torch head **120** using mechanical steering device **180** such that the torch **120** is located at the midpoint of the arc sweep at that point. In addition, the control unit **190** can adjust magnetic arc oscillation system **130** and/or ground switching circuit **195** to produce an appropriate arc sweep width. For example, as the welding progress from point A to point B in Figure 5, the control unit **190** will sense that the width of weld groove has changed from width **X** at point **A** to

width **Y**. That is, the control unit **190** will sense that the arc voltage at the left magnetic field position is below a predetermined value, e.g., 9 volts, indicating that the arc **110** is too close to the sidewall, and that the arc voltage at the right magnetic field position is in the proper range, e.g., 9-11 volts. Because the arc voltage at the right magnetic field position has not changed from that measured at point A, the control unit **190** will determine that the weld groove has narrowed due to the left sidewall and make the appropriate adjustments to the width of the arc sweep and/or the position of the torch head **120**. As the welding process progresses and the torch head **120** reaches point C, the control unit **190** determines that the arc **110** is too far away from the right sidewall because the arc voltage at the right magnetic field position is greater than a predetermined value, e.g., 11 volts, and thus not in the proper range of e.g., 9-11 volts. The control unit **190** can then appropriately adjust the position of torch head **120** and/or the width of the arc sweep for width **Z** at point C. In some embodiments, the control unit **190** may use a mechanical steering device to oscillate the torch head **120** in addition to or as an alternative to magnetic arc oscillation system **180** and/or ground switching circuit **195**. To ensure that the deposition rate is still proper after a change in width, the travel speed of the torch head **120** and/or the feed rate of wire **140** can be appropriately adjusted by control unit **190** (or some other device).

[0032] In some embodiments of the present invention, the control unit **190** (or some other device) may be configured with lookup tables that include the desired feedback values of arc **110** at one or more points along the arc sweep. The desired values can depend on the type of welding process (e.g., GTAW, GMAW, PAW, etc.), the types and/or thicknesses of the materials being welded, the number of weld passes, etc. In some embodiments, the control unit **190** (or some other device) may include equations or other representations of feedback curves that provide the desired feedback values for arc **110** at one or more points along the arc sweep.

[0033] While the invention has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the invention. In the above embodiments, the control logic to steer torch head **120** was located in control unit **190**. However, the control logic may be located in mechanical steering device **180** or in some other device. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

REFERENCE NUMBERS

100	system	196A	ground
110	arc	196B	ground
115	workpiece	310	guide track
115A	workpiece	315	weld head tractor unit
115B	workpiece	320	welding pipe joint
120	torch head	330A	pipe segment
130	oscillation system	330B	pipe segment
131	power supply	335	center line
132	arc sweep	410A	line
135	magnetic pole	410B	point
137	magnetic head	410C	point
140	wire	420	weld
145	weld puddle	510	weld joint
150	wire feeder	520	weld
160	contact tube	X _A	weld pass
170	power supply	X _B	weld pass
172	electrode	I	current
175	power supply	V _x	voltage
180	steering device	V _A	voltage
182	steering arrow	A	point
185	bracket	X	width
190	control unit	Y	width
195	circuit		

We claim:

1. An arc welding system (100) with automated arc steering, said arc welding system (100) comprising:
a torch power supply (170) that is operatively connected to a torch head (120) that creates an arc (110) in a weld groove formed in at least one workpiece (115, 115A, 115B); and
a control unit (190) comprising,
a feedback system that monitors at least one of a voltage of said arc (110) ,
a current of said arc (110), a power output of said torch power supply (170), and a contact tip to weld distance, and outputs a feedback signal corresponding to said monitoring,
a comparison circuit that compares said feedback signal with at least one predetermined value corresponding to a position of at least one of said arc (110) and said torch head (120) in said weld groove; and
an arc steering system that outputs a steering signal based on said comparison,
wherein said steering signal is used to control said position of at least one of said arc (110) and said torch head (120) in said weld groove.
2. The system (100) of claim 1, further comprising a mechanical steering device (180) that is operatively connected to said welding torch (120) and positions said welding torch (120) in said weld groove based on said steering signal,
wherein said at least one predetermined value comprises a first predetermined value and a second predetermined value that correspond to a desired position of said arc (110) or said torch head (130) near a sidewall of said weld groove,

wherein said mechanical steering device (180) positions said torch head (120) farther away from said sidewall when said comparison determines that said feedback signal is below said first predetermined value, and

wherein said mechanical steering device (180) moves said torch head (120) closer to said sidewall when said comparison determines that said feedback signal is above said second predetermined value.

3. The system (100) of claim 1 or 2, further comprising an arc oscillation system (130) that sweeps said arc (110) in a direction that is traverse to a travel direction of said torch head (120), said arc oscillation system (130) controlling a sweep width of said arc (110) in said weld groove based on said steering signal, wherein said at least one predetermined value comprises a first predetermined value and a second predetermined value that correspond to a desired position of said arc (110) when said sweep positions said arc (110) near a sidewall of said weld groove, wherein said arc oscillation system (130) decreases said sweep width of said arc so that said arc (110) is farther away from said sidewall when said comparison determines that said feedback signal is below said first predetermined value, and wherein said arc oscillation system (130) increases said sweep width of said arc (110) so that said arc (110) is closer to said sidewall when said comparison determines that said feedback signal is above said second predetermined value.
4. The system (100) of any of the claims 1 to 3, further comprising:
a wire feeder (150) that feeds a consumable to said arc (110) for deposition into said weld groove; and

a drive unit operatively attached to said torch head (120) or said at least one workpiece (115, 115A, 115B) and configured to move said torch head (120) relative to said at least one workpiece (115, 115A, 115B) in a travel direction along said weld groove,

wherein at least one of a feed speed of said consumable and a travel speed of said torch head (120) relative to said at least one workpiece (115, 115A, 115B) is adjusted based on said increase or said decrease in said sweep width.

5. The system (100) of any of the claims 1 to 4, wherein said arc oscillation system (120) comprises a magnetic arc oscillator that generates a magnetic field to control said sweep width of said arc (110), and/or

wherein said arc oscillation system (120) comprises a ground switching circuit (195) that controls said sweep width of said arc (110).

6. The system (100) of any of the claims 1 to 5, wherein said feedback signal is based on said voltage of said arc (110), and said first predetermined value is 9 volts and said second predetermined value is 11 volts.

7. The system (100) of any of the claims 1 to 6, further comprising:
a magnetic arc oscillator (130) that generates a magnetic field that sweeps said arc (110) in a direction that is traverse to a travel direction of said torch head (120); and
a mechanical steering device (180) that is operatively connected to said welding torch (120),

wherein at least one of a sweep width of said arc (110) and said position of said welding torch (120) in said weld groove is controlled based on said steering signal.

8. The system (100) of any of the claims 1 to 7, wherein said at least one predetermined value comprises,

a first predetermined value corresponding to a desired first position of said arc (110) near a first sidewall of said weld groove,

a second predetermined value corresponding to a desired second position of said arc (110) near a second sidewall of said weld groove, and

a third predetermined value corresponding to a desired third position of said arc (110) that is between said first position and said second position, and

wherein said arc steering system (180) determines whether to control said sweep width of said arc (110), said position of said torch head (120), or both said sweep width and said torch head (120) position based on comparisons of said feedback signal with at least one of said first predetermined value, said second predetermined value, and said third predetermined value.

9. A method of performing arc welding with arc steering, said method comprising:
creating an arc in a weld groove formed in at least one workpiece with a torch head;
monitoring at least one of a voltage of said arc, a current of said arc, a power output of said torch head, and a contact tip to weld distance;
outputting a feedback signal corresponding to said monitoring;
comparing said feedback signal with at least one predetermined value corresponding to a position of at least one of said arc and said torch head in said weld groove;

outputting a steering signal based on said comparison; and
controlling said position of at least one of said arc and said torch head in said weld groove based on said steering signal.

10. The method of claim 9, further comprising:

positioning said welding torch in said weld groove based on said steering signal,

wherein said at least one predetermined value comprises a first predetermined value and comprises a second predetermined value that correspond to a desired position of said arc or said torch head near a sidewall of said weld groove,

wherein said positioning said welding torch comprises moving said torch head farther away from said sidewall when said comparing determines that said feedback signal is below said first predetermined value, and

wherein said positioning said welding torch comprises moving said torch head closer to said sidewall when said comparing determines that said feedback signal is above said second predetermined value.

11. The method of claim 9 or 10, further comprising:

sweeping said arc in a direction that is traverse to a travel direction of said torch head; and

controlling a sweep width of said arc in said weld groove based on said steering signal,

wherein said at least one predetermined value comprises a first predetermined value and a second predetermined value that correspond to a desired position of said arc when said sweeping positions said arc near a sidewall of said weld groove,

wherein said controlling said sweep width comprises decreasing said sweep width of said arc so that said arc is farther away from said sidewall when said comparing determines that said feedback signal is below said first predetermined value, and wherein said controlling said sweep width comprises increasing said sweep width of said arc so that said arc is closer to said sidewall when said comparing determines that said feedback signal is above said second predetermined value.

12. The method of any of the claims 9 to 11, further comprising:
feeding a consumable to said arc for deposition into said weld groove; and
moving said torch head or said at least one workpiece in a travel direction along said weld groove,
wherein at least one of a feed speed of said consumable and a travel speed of said torch head relative to said at least one workpiece is adjusted based on said increase or said decrease in said sweep width.
13. The method of any of the claims 9 to 12, wherein said controlling said sweep width comprises using a magnetic field, and/or

wherein said controlling said sweep width comprises switching a ground on said at least one workpiece.
14. The method of any of the claims 9 to 13, wherein said controlling said position of said arc based on said steering signal comprises, generating a magnetic field that sweeps said arc in a direction that is traverse to a travel direction of said torch head, and controlling of a sweep width of said arc, and

wherein said controlling said position of said torch head based on said steering signal comprises mechanically positioning said welding torch in said weld groove.

15. The method of any of the claims 9 to 14, wherein said at least one predetermined value comprises,

a first predetermined value corresponding to a desired first position of said arc near a first sidewall of said weld groove,

a second predetermined value corresponding to a desired second position of said arc near a second sidewall of said weld groove, and

a third predetermined value corresponding to a desired third position of said arc that is between said first position and said second position, and

wherein controlling said position of at least one of said arc and said torch head comprises determining whether to control said sweep width of said arc, said position of said torch head, or both said sweep width and said torch head position based on comparisons of said feedback signal with said first predetermined value, said second predetermined value, and said third predetermined value.

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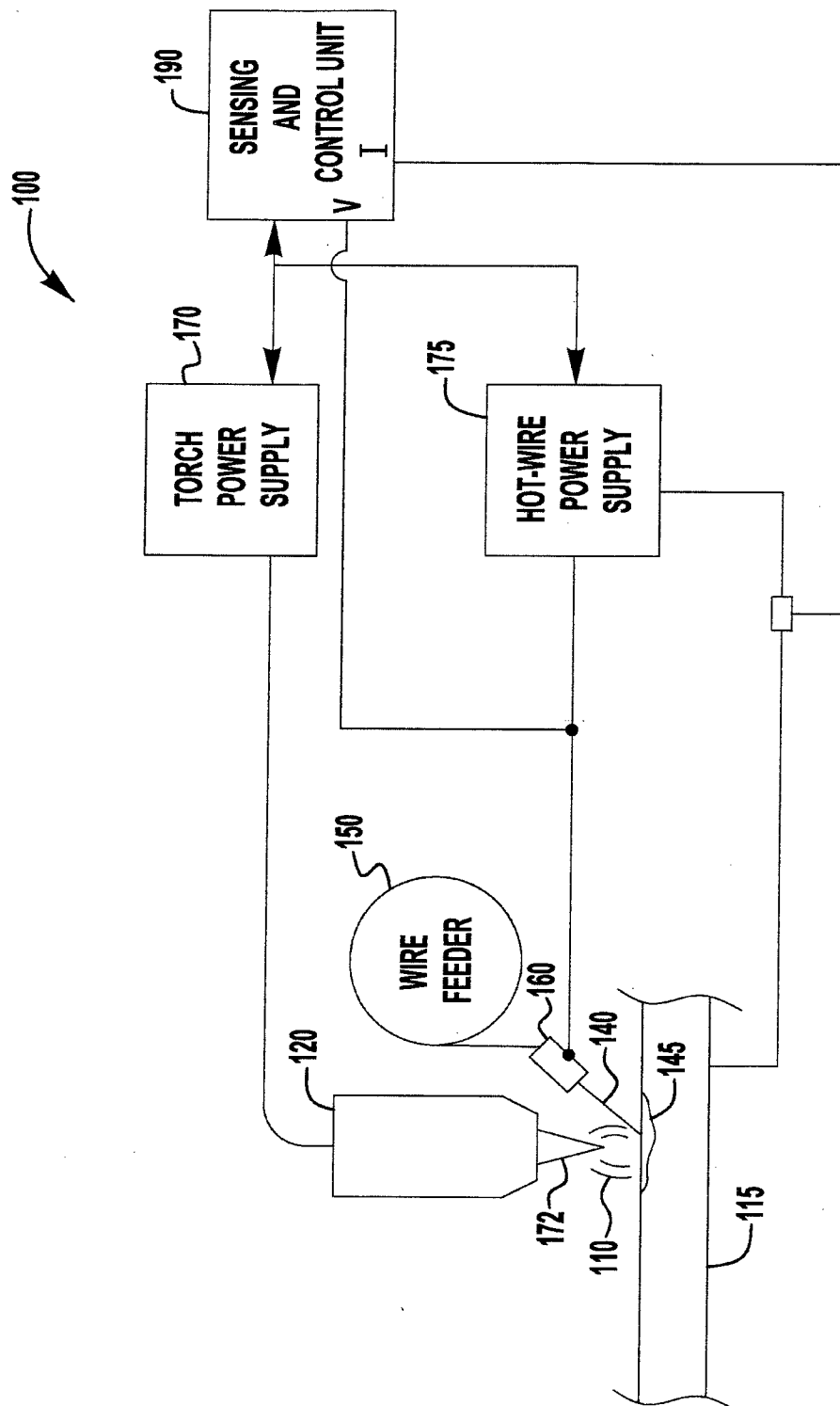


FIG. 1A

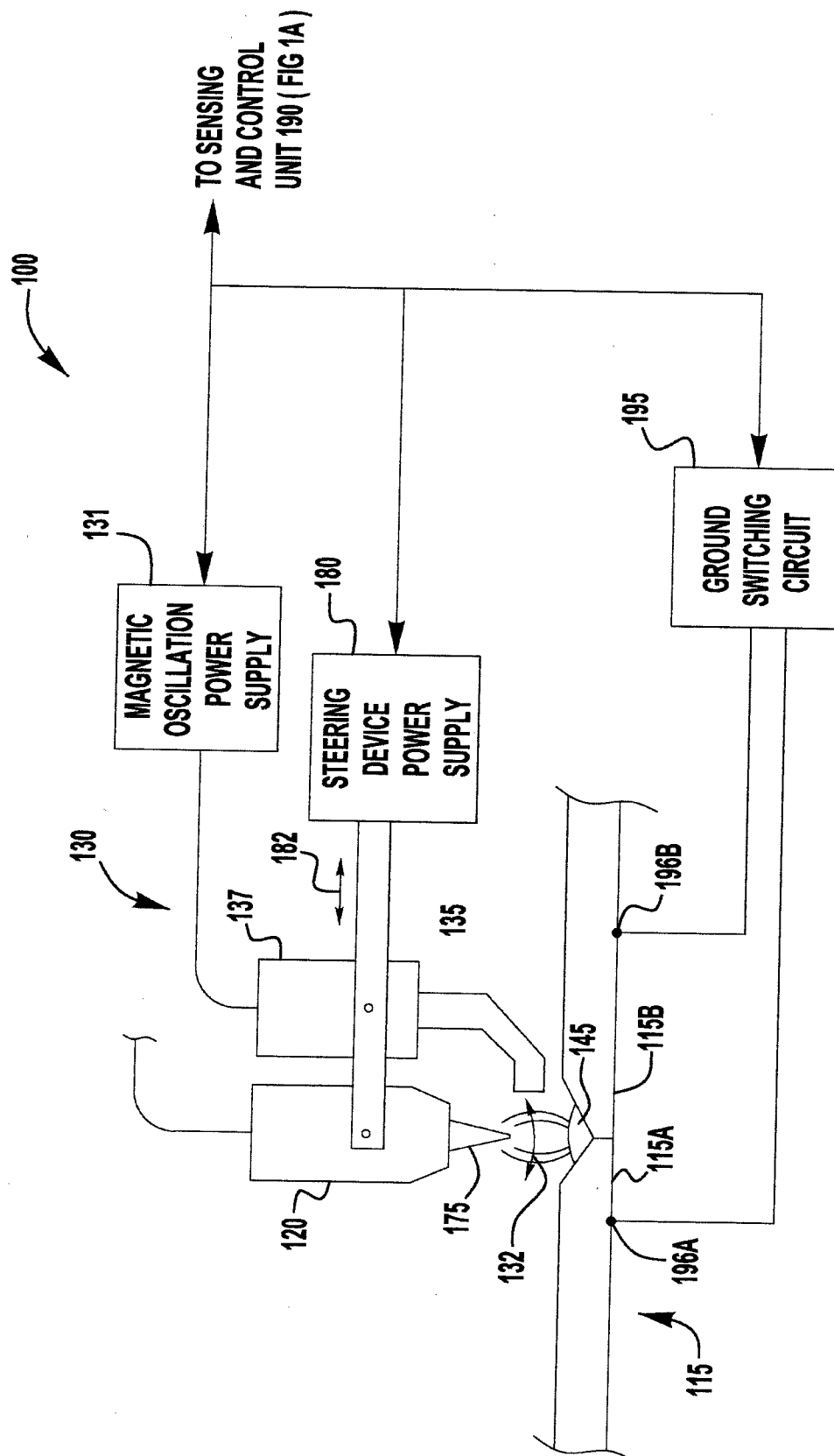


FIG. 1B

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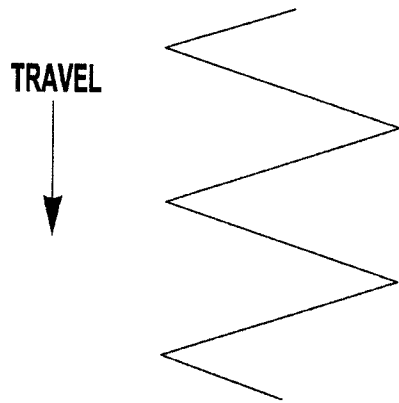


FIG. 2A

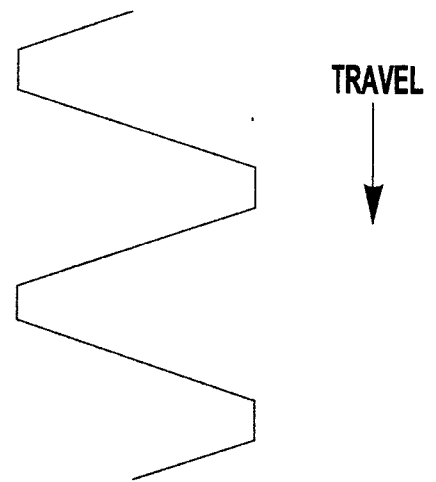


FIG. 2B

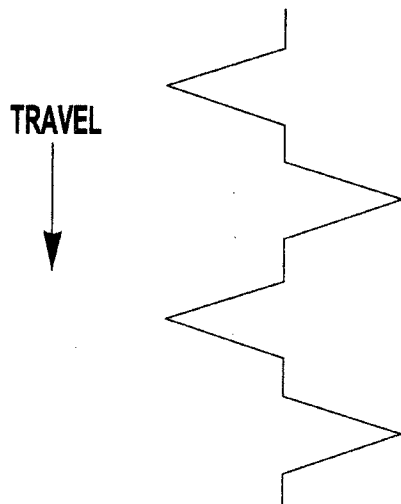


FIG. 2C

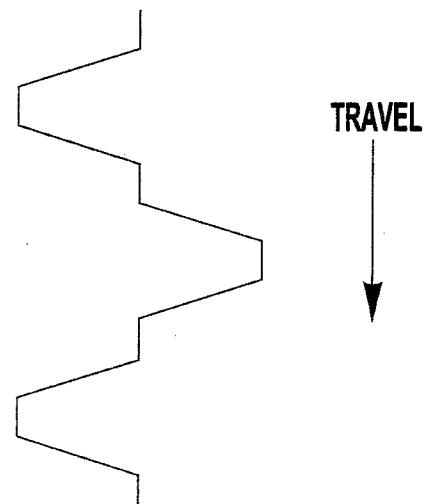


FIG. 2D

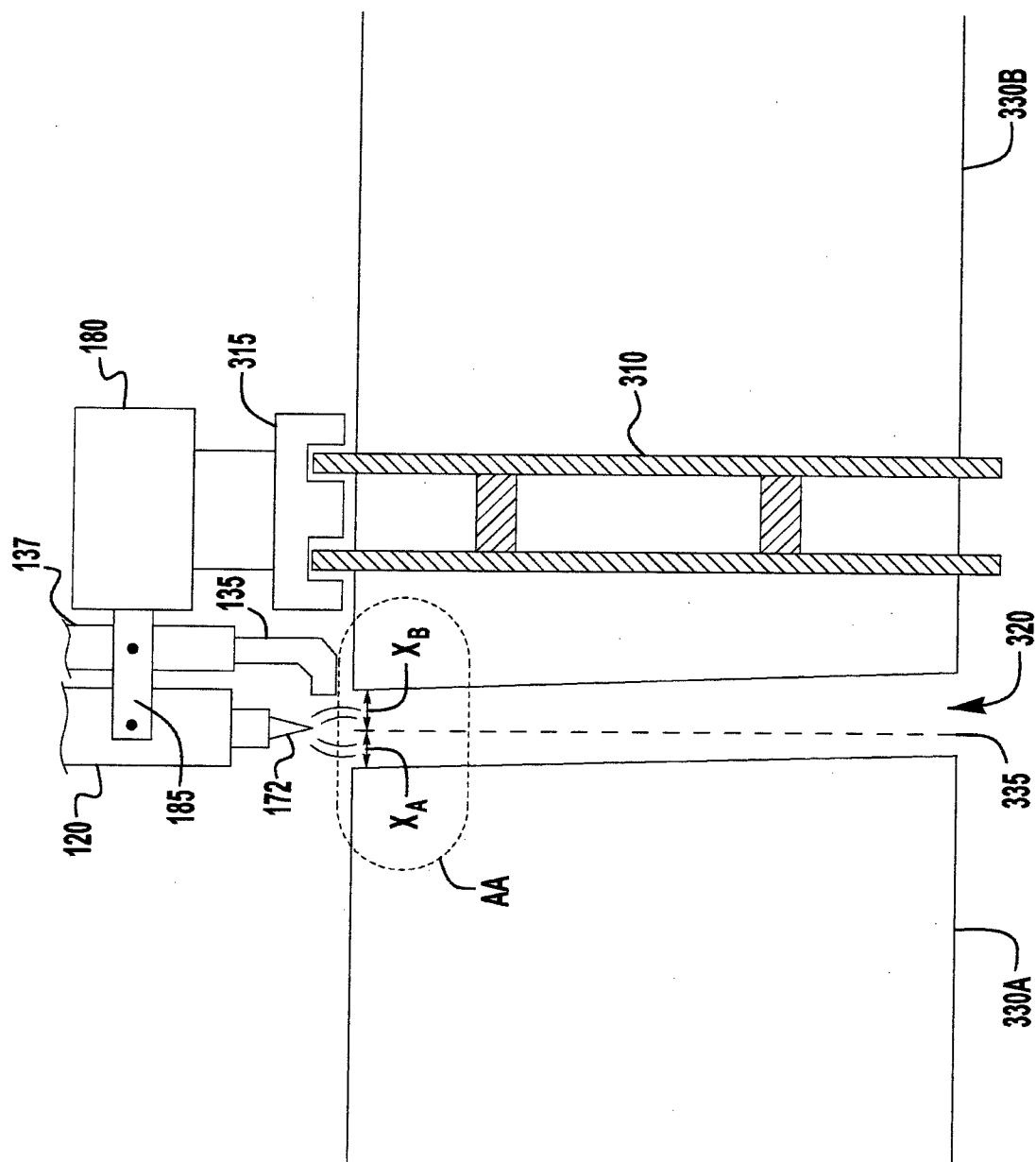
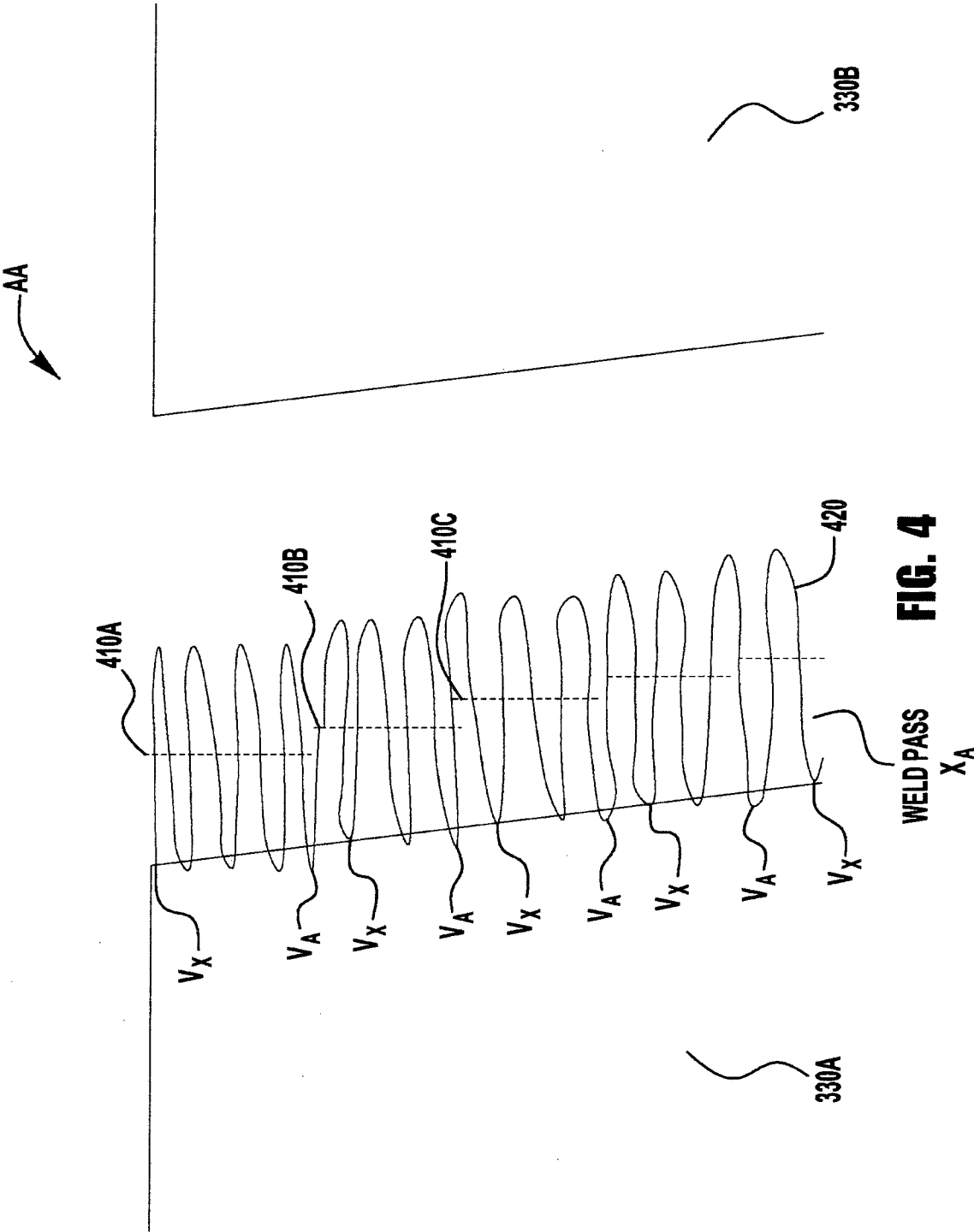


FIG. 3



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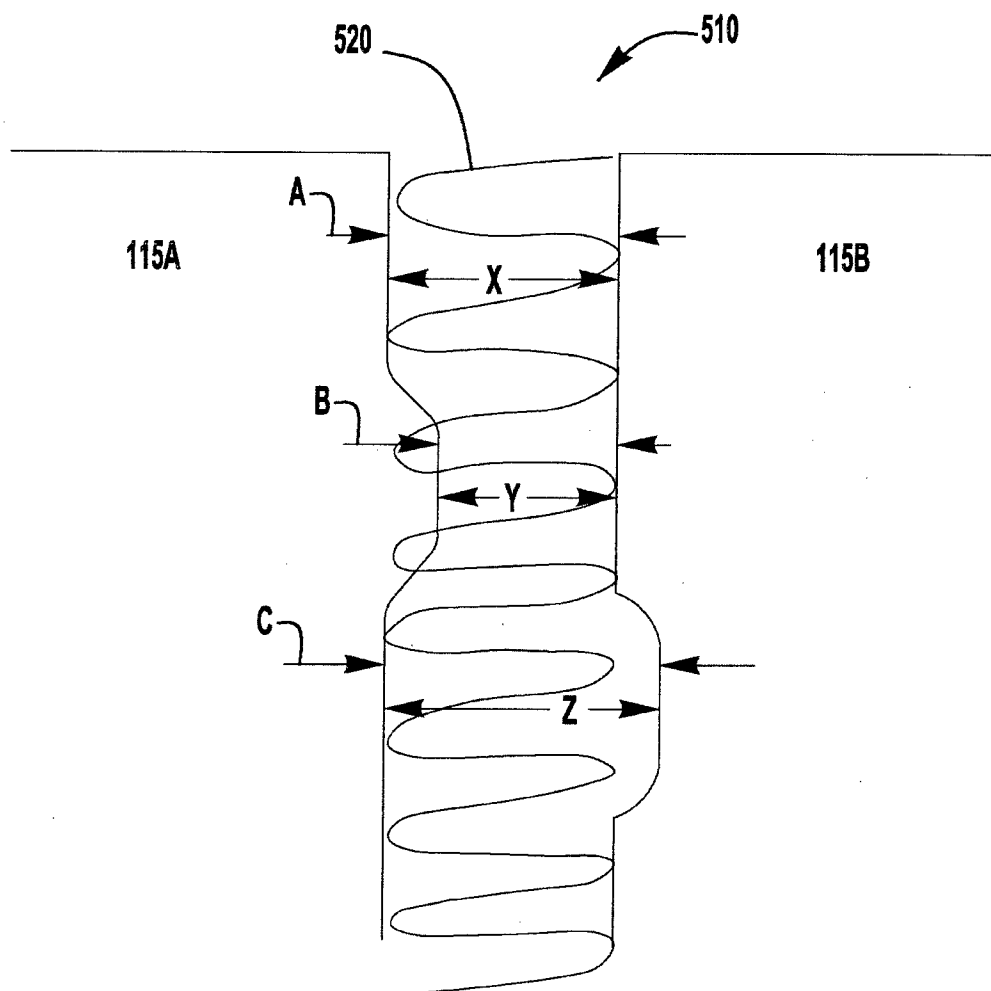


FIG. 5

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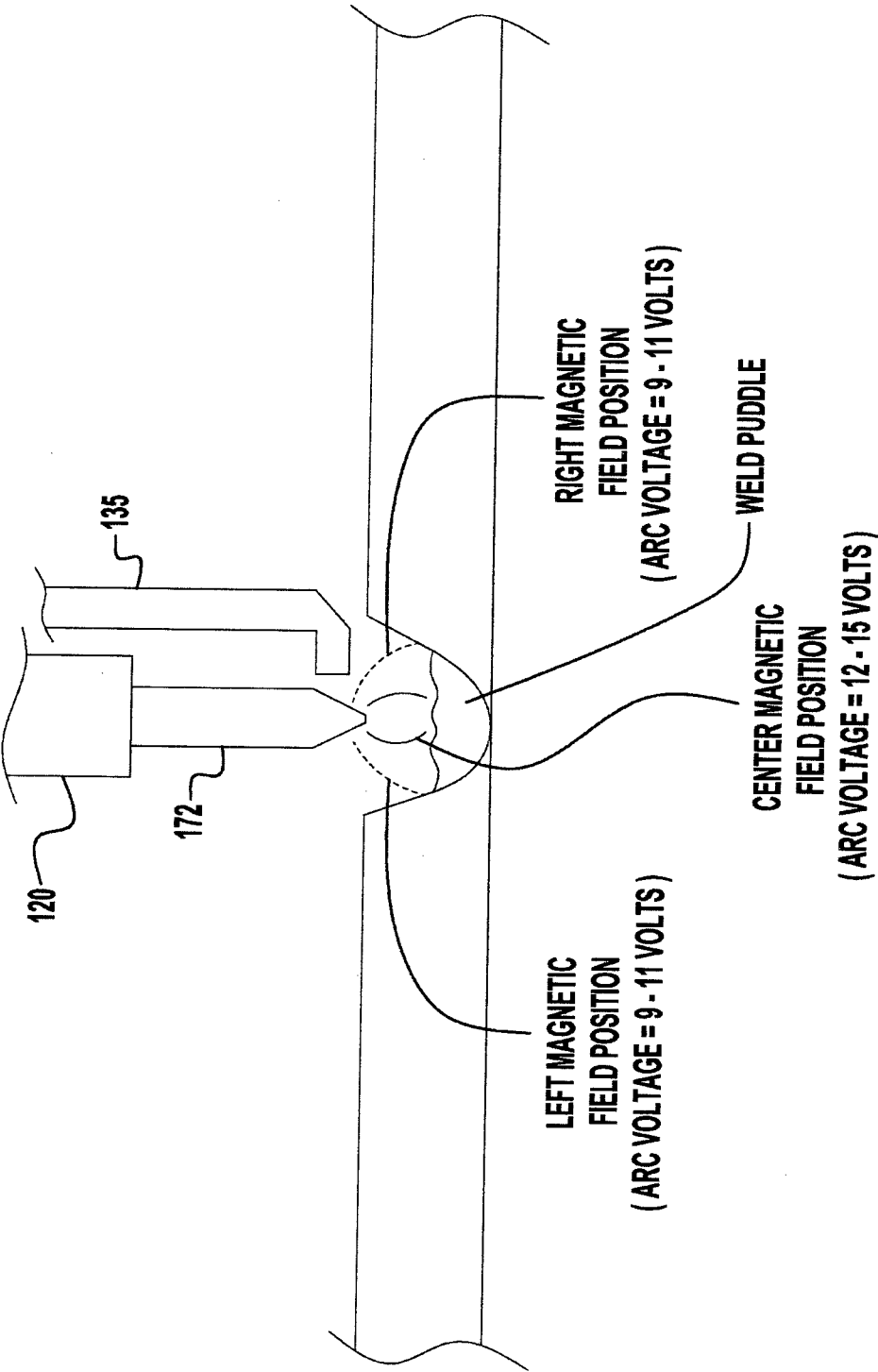


FIG. 6