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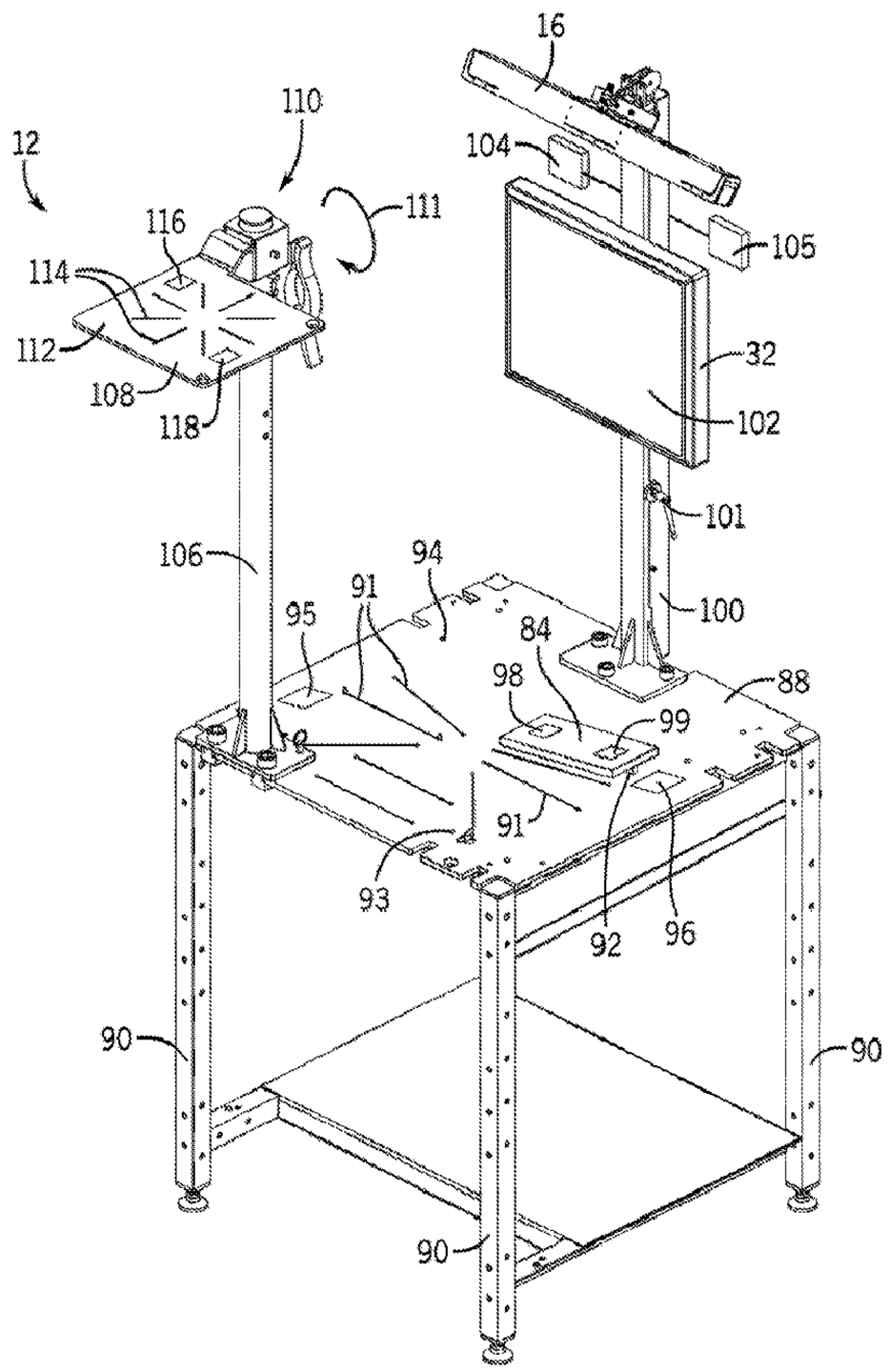
(54) **Titre : DISPOSITIFS D'ETALONNAGE POUR UN SYSTEME DE FORMATION DE SOUDAGE**
(54) **Title: CALIBRATION DEVICES FOR A WELDING TRAINING SYSTEM**



(57) **Abrégé/Abstract:**
A welding training system includes a welding surface, a computer configured to execute a welding training software, and a calibration device. The welding training system also includes a sensor communicatively coupled to the computer and configured to

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(57) **Abrégé(suite)/Abstract(continued):**
sense a position of the calibration device, an orientation of the calibration device, or some combination thereof. The sensor is also configured to provide calibration data to the welding training software to calibrate a location of the welding surface relative to the sensor. The calibration data includes the position of the calibration device, the orientation of the calibration device, or some combination thereof.

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[Continued on next page]

(54) Title: CALIBRATION DEVICES FOR A WELDING TRAINING SYSTEM

(57) Abstract: A welding training system includes a welding surface, a computer configured to execute a welding training software, and a calibration device. The welding training system also includes a sensor communicatively coupled to the computer and configured to sense a position of the calibration device, an orientation of the calibration device, or some combination thereof. The sensor is also configured to provide calibration data to the welding training software to calibrate a location of the welding surface relative to the sensor. The calibration data includes the position of the calibration device, the orientation of the calibration device, or some combination thereof.

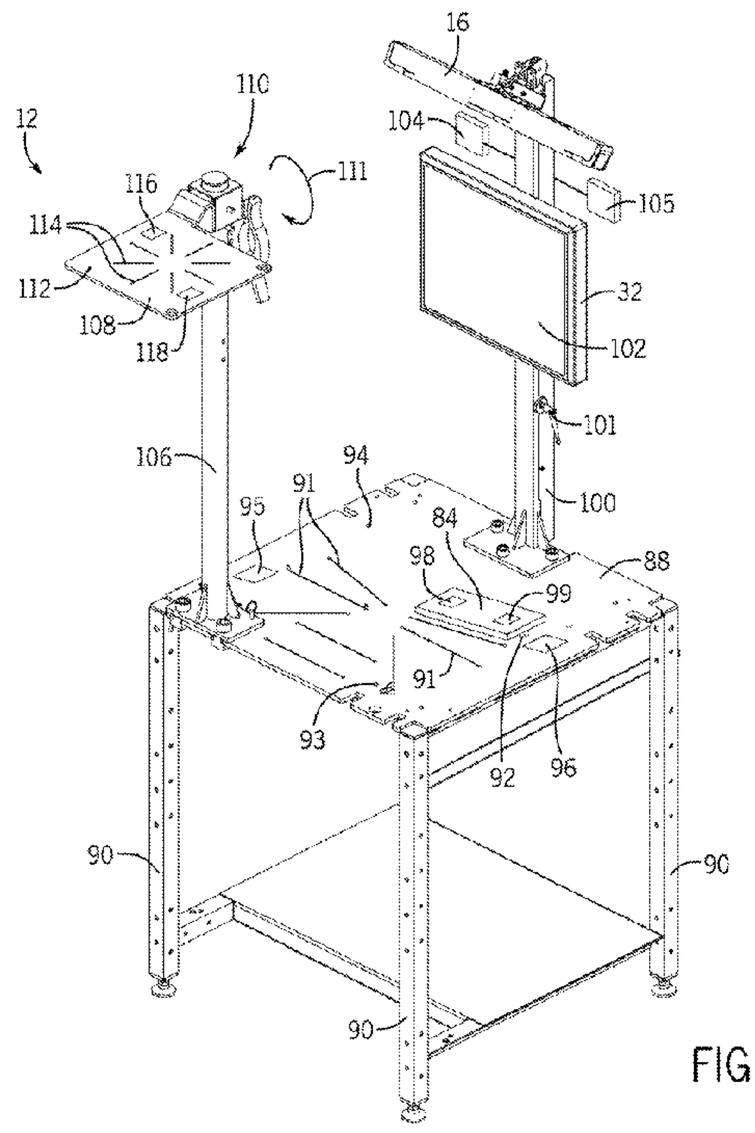

FIG. 4

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CALIBRATION DEVICES FOR A WELDING TRAINING SYSTEM

BACKGROUND

[0001] The invention relates generally to welding and, more particularly, to a welding training system.

[0002] Welding is a process that has increasingly become utilized in various industries and applications. Such processes may be automated in certain contexts, although a large number of applications continue to exist for manual welding operations. In both cases, such welding operations rely on a variety of types of equipment to ensure the supply of welding consumables (e.g., wire feed, shielding gas, etc.) is provided to the weld in appropriate amounts at the desired time.

[0003] In preparation for performing manual welding operations, welding operators may be trained using a welding training system. The welding training system may be designed to train welding operators with the proper techniques for performing various welding operations. Certain welding training systems may use various training methods. As may be appreciated, these training systems may be expensive to acquire and operate. Accordingly, welding training institutions may only acquire a limited number of such training systems. Furthermore, certain welding training systems may not adequately train welding operators to perform high quality welds.

BRIEF DESCRIPTION

[0004] In one embodiment, a welding training system includes a welding surface, a computer configured to execute a welding training software, and a calibration device. The welding training system also includes a sensor communicatively coupled to the computer and configured to sense a position of the calibration device, an orientation of the calibration device, or some combination thereof. The sensor is also configured to provide calibration data to the welding training software to calibrate a location of the welding surface relative to the sensor. The calibration data includes the position

of the calibration device, the orientation of the calibration device, or some combination thereof

[0005] In another embodiment, a welding training system includes a welding surface having a first marker located at a first position, and a second marker located at a second position. The welding training system also includes a computer configured to execute a welding training software. The welding training system includes a sensor configured to sense the first and second markers, to determine a first position of the first marker, to determine a second position of the second marker, to determine a first orientation of the first marker, to determine a second orientation of the second marker, or some combination thereof, and to provide calibration data to the welding training software to calibrate a location of the welding surface relative to the sensor. The calibration data includes the first position of the first marker, the second position of the second marker, the first orientation of the first marker, the second orientation of the second marker, or some combination thereof.

[0006] In another embodiment, a welding training system includes a welding surface and a computer configured to execute a welding training software. The welding training system also includes an emitter configured to emit a visible pattern onto the welding surface. The visible pattern is configured to facilitate alignment of a workpiece with the welding surface.

[0007] In a further embodiment, a welding training system includes a computer configured to execute a welding training software. The welding training system also includes a welding surface having multiple slots. Each slot includes a welding location corresponding to a respective location defined in the welding training software. Moreover, each slot is configured to facilitate alignment of a workpiece with the welding surface.

[0007A] In an aspect of the invention there is provided a welding training system including a computer configured to execute a welding training software; a calibration device communicatively coupled to the computer. The calibration device includes a trigger configured to receive an operator input prior to a simulated weld or a live weld; and a sensor communicatively coupled to the computer and configured to sense a position of the calibration device, an orientation of the calibration device, or some combination thereof, when the trigger receives the operator input prior to the simulated weld or the live weld, and to provide calibration data to the welding training software to calibrate a first location of the calibration device with respect to a welding surface when the trigger receives the operator input prior to the simulated weld or the live weld. The calibration data includes the

position of the calibration device, the orientation of the calibration device, or some combination thereof.

[0007B] In a further aspect of the invention there is provided a method including detecting a position and an orientation of a welding torch positioned at a first location relative to a sensor; receiving a first operator input from the welding torch when the welding torch is positioned at the first location relative to the sensor prior to a simulated weld or a live weld; storing in a non-transitory memory the first location of the welding torch relative to the sensor. Storing the first location is based on receiving the first operator input; receiving a second operator input from the welding torch when the welding torch is positioned at a second location relative to the sensor prior to the simulated weld or the live weld; and storing in the non-transitory memory the second location of the welding torch relative to the sensor. Storing the second location is based on receiving the second operator input.

[0007C] In a further aspect of the invention there is provided a method including detecting a plurality of markers of a welding calibration device *via* an optical sensor; determining a position of the welding calibration device, an orientation of the welding calibration device, or some combination thereof based at least in part on the detected plurality of markers; receiving a first operator input at a first time from the welding calibration device when the welding calibration device is positioned at a first location relative to the optical sensor prior to a simulated weld or a live weld; receiving a second operator input at a second time from the welding calibration device when the welding calibration device is positioned at a second location relative to the optical sensor prior to the simulated weld or the live weld. The first time is different than the second time; and storing calibration data in a non-transitory memory based on receiving the first operator input and the second operator input prior to the simulated weld or the live weld. The calibration data includes the first location and the second location of the welding calibration device relative to the optical sensor prior to the simulated weld or the live weld and at least one of the determined position of the welding calibration device and the orientation of the welding calibration device.

DRAWINGS

[0008] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0009] FIG. 1 is a block diagram of an embodiment of a welding training system in accordance with aspects of the present disclosure;

[0010] FIG. 2 is a block diagram of an embodiment of portions of the welding training system of FIG. 1 in accordance with aspects of the present disclosure;

[0011] FIG. 2A is a schematic diagram of an embodiment of circuitry of the welding torch of FIG. 1 in accordance with aspects of the present disclosure;

[0012] FIG. 3 is a perspective view of an embodiment of the welding torch of FIG. 1 in accordance with aspects of the present disclosure;

[0013] FIG. 4 is a perspective view of an embodiment of the training stand of FIG. 1 in accordance with aspects of the present disclosure;

[0014] FIG. 5 is a perspective view of an embodiment of a calibration device in accordance with aspects of the present disclosure;

[0015] FIG. 6 is a perspective view of an embodiment of a fixture assembly in accordance with aspects of the present disclosure;

[0016] FIG. 7 is a perspective view of a welding wire stickout calibration tool in accordance with aspects of the present disclosure;

[0017] FIG. 8 is a top view of the welding wire stickout calibration tool of FIG. 7 in accordance with aspects of the present disclosure;

[0018] FIG. 9 is an embodiment of a method for calibrating wire stickout from a welding torch in accordance with aspects of the present disclosure;

[0019] FIG. 10 is a perspective view of an embodiment of a welding consumable having physical marks in accordance with aspects of the present disclosure;

[0020] FIG. 11 is a perspective view of an embodiment of welding wire having physical marks in accordance with aspects of the present disclosure;

[0021] FIG. 12 is a perspective view of an embodiment of a vertical arm assembly of the training stand of FIG. 1 in accordance with aspects of the present disclosure;

[0022] FIG. 13 is a perspective view of an embodiment of an overhead welding arm assembly in accordance with aspects of the present disclosure;

[0023] FIG. 14 is a block diagram of an embodiment of welding training software having multiple training modes in accordance with aspects of the present disclosure;

[0024] FIG. 15 is a block diagram of an embodiment of a virtually reality mode of welding training software in accordance with aspects of the present disclosure;

[0025] FIG. 16 is an embodiment of a method for integrating training results data in accordance with aspects of the present disclosure;

[0026] FIG. 17 is an embodiment of a chart illustrating multiple sets of welding training data for a welding operator in accordance with aspects of the present disclosure;

[0027] FIG. 18 is an embodiment of a chart illustrating welding training data for a welder compared to welding training data for a class in accordance with aspects of the present disclosure;

[0028] FIG. 19 is a block diagram of an embodiment of a data storage system for storing certification status data in accordance with aspects of the present disclosure;

[0029] FIG. 20 is an embodiment of a screen illustrating data corresponding to a training weld in accordance with aspects of the present disclosure;

[0030] FIG. 21 is an embodiment of a screen illustrating a discontinuity analysis of a training weld in accordance with aspects of the present disclosure;

[0031] FIG. 22 is a block diagram of an embodiment of a welding instructor screen of welding training software in accordance with aspects of the present disclosure;

[0032] FIG. 23 is an embodiment of a method for weld training using augmented reality in accordance with aspects of the present disclosure; and

[0033] FIG. 24 is an embodiment of another method for weld training using augmented reality in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0034] FIG. 1 is a block diagram of an embodiment of a welding training system 10. The welding training system 10 includes a training stand 12 for providing support for various training devices. For example, the training stand 12 may be configured to support a welding surface, a workpiece, a fixture, one or more training arms, and so forth. The welding training system 10 also includes a welding torch 14 that may be used by a welding operator (e.g., welding student) to perform training operations. As described in greater detail below, the welding torch 14 may be configured with a user interface configured to receive inputs from the welding operator, control circuitry configured to process the inputs, and a communication interface configured to provide the inputs to another device. Furthermore, the welding torch 14 may include one or more display and/or indicators to provide data to the welding operator. Moreover, the welding training system 10 includes a sensing device 16 (e.g., sensor, sensing assembly, and so forth) used to sense a position of one or more welding devices and/or to sense an orientation of one or more welding devices. For example, the sensing device 16 may be used to sense a position and/or an orientation of the training stand 12, the welding torch 14, a welding surface, a workpiece, a fixture, one or more training arms, and so forth. The sensing device 16 may include any suitable sensing device, such as a motion sensing device or a motion tracking device. Furthermore, the sensing device 16 may include one or more cameras, such as one or more infrared cameras, one or more visible spectrum cameras, one or more high dynamic range (HDR) cameras, and so forth.

[0035] The sensing device 16 is communicatively coupled to a computer 18. The sensing device 16 is configured to provide data (e.g., image data, sensed data, six degrees of freedom (6DOF) data, etc.) to the computer 18. Furthermore, the sensing device 16 may be configured to receive data (e.g., configuration data, setup data, commands, register settings, etc.) from the computer 18. The computer 18 includes one or more processors 20, memory devices 22, and storage devices 24. The processor(s) 20 may be used to execute software, such as welding training software, image processing software, sensing device software, and so forth. Moreover, the processor(s) 20 may include one or more microprocessors, such as one or more "general-purpose" microprocessors, one or more special-purpose microprocessors and/or application specific integrated circuits (ASICS), or some combination thereof. For example, the processor(s) 20 may include one or more reduced instruction set (RISC) processors.

[0036] The storage device(s) 24 (e.g., nonvolatile storage) may include ROM, flash memory, a hard drive, or any other suitable optical, magnetic, or solid-state storage medium, or a combination thereof. The storage device(s) 24 may store data (e.g., data corresponding to a training operation, video and/or parameter data corresponding to a training operation, etc.), instructions (e.g., software or firmware for the welding training system, the sensing device 16, etc.), and any other suitable data. As will be appreciated, data that corresponds to a training operation may include a video recording of the training operation, a simulated video, an orientation of the welding torch 14, a position of the welding torch 14, a work angle, a travel angle, a distance between a contact tip of the welding torch 14 and a workpiece, a travel speed, a proximity, a voltage, a current, a traversed path, a discontinuity analysis, welding device settings, and so forth.

[0037] The memory device(s) 22 may include a volatile memory, such as random access memory (RAM), and/or a nonvolatile memory, such as read-only memory (ROM). The memory device(s) 22 may store a variety of information and may be used for various purposes. For example, the memory device(s) 22 may store processor-executable instructions (e.g., firmware or software) for the processor(s) 20 to execute, such as instructions for a welding training simulation and/or for the

sensing device 16. In addition, a variety of control regimes for various welding processes, along with associated settings and parameters may be stored in the storage device(s) 24 and/or memory device(s) 22, along with code configured to provide a specific output (e.g., initiate wire feed, enable gas flow, capture welding current data, detect short circuit parameters, determine amount of spatter, etc.) during operation.

[0038] As illustrated, the welding training system 10 includes a data reporting device 26; however, other embodiments may not include the data reporting device 26. The data reporting device 26 is configured to facilitate electronic communication between the computer 18, the welding torch 14, a welding power supply 28, and/or a wire feeder 30. For example, the data reporting device 26 may be configured to receive torch data from the welding torch 14, provide torch data to the computer 18, provide data to the welding torch 14, receive arc data from the wire feeder 30, provide arc data to the computer 18, and so forth. Furthermore, the data reporting device 26 may be configured to electronically communicate (e.g., either wired or wirelessly) with a device external to the welding training system 10. The welding power supply 28 may be used to provide welding power to a live-arc welding operation, and the wire feeder 30 may be used to provide welding wire to the live-arc welding operation.

[0039] The welding training system 10 includes a display 32 for displaying data and/or screens associated with welding training (e.g., to display data corresponding to a welding training software). For example, the display 32 may provide a graphical user interface to a welding operator (e.g., welding instructor, welding student). The graphical user interface may provide various screens to enable the welding instructor to organize a class, provide assignments to the class, analyze assignments performed by the class, provide assignments to an individual, analyze assignments performed by the individual, add, change, and/or delete parameters for a welding assignment, and so forth. Furthermore, the graphical user interface may provide various screens to enable a welding operator (e.g., welding student) to perform a welding training assignment, view results from prior welding assignments, and so forth. In certain embodiments, the display 32 may be a touch screen display configured to receive touch inputs, and to provide data corresponding to the touch inputs to the computer 18.

[0040] An external display 34 is coupled to the computer 18 to enable an individual located remotely from the welding training system 10 to view data corresponding to the welding training system 10. Furthermore, a network device 36 is coupled to the computer 18 to enable the computer 18 to communicate with other devices connected to the Internet or another network 38 (e.g., for providing test results to another device and/or for receiving test results from another device). For example, the network device 36 may enable the computer 18 to communicate with an external welding training system 40, a production welding system 42, and/or a remote computer 44. As may be appreciated, the welding training system 10 described herein may be used to train welding students in a cost effective manner. Furthermore, the welding training system 10 is configured to integrate real welding with simulated welding in a manner that prepares welding students for high quality production welding.

WELDING TORCH

[0041] FIG. 2 is a block diagram of an embodiment of portions of the welding training system 10 of FIG. 1. As illustrated, the data reporting device 26 includes control circuitry 46 configured to provide data to and/or to receive data from the wire feeder 30, the welding power supply 28, the welding torch 14, and the computer 18. The control circuitry 46 is also configured to provide power to one or more devices, such as the welding torch 14. The data reporting device 26 also includes a communication port 47 (e.g., universal serial bus (USB) port, a high speed serial bus port, etc.) and light emitting diodes (LEDs) 48 that may be used to indicate a status of the data reporting device 26, for example. The data reporting device 26 includes a network interface 49 to facilitate communication between the data reporting device 26 and an external device, such as the computer 18. The network interface 49 may be any suitable device that facilitates wired and/or wireless communication between the data reporting device 26 and the external device. The data reporting device 26 also includes a communication interface 50 to facilitate communication between the data reporting device 26 and the welding torch 14. In certain embodiments, the communication interface 50 may include an RS-232 driver.

[0042] The welding torch 14 includes control circuitry 52 configured to control the operation of the welding torch 14. In the illustrated embodiment, the control circuitry 52 includes one or more processors 54, memory devices 56, and storage devices 58. In other embodiments, the control circuitry 52 may not include the processors 54, the memory devices 56, and/or the storage devices 58. The processor(s) 54 may be used to execute software, such as welding torch software. Moreover, the processor(s) 54 may be similar to the processor(s) 20 described previously. Furthermore, the memory device(s) 56 may be similar to the memory device(s) 22, and the storage device(s) 58 may be similar to the storage device(s) 24.

[0043] The welding torch 14 includes a user interface 60 to enable a welding operator (e.g., welding student, welding instructor, etc.) to interact with the welding torch 14 and/or to provide inputs to the welding torch 14. For example, the user interface 60 may include buttons, switches, touch screens, touchpads, and so forth. The inputs provided to the welding torch 14 by the welding operator may be provided to the computer 18. For example, the inputs provided to the welding torch 14 may be used to control welding training software being executed by the computer 18. As such, the welding operator may use the user interface 60 on the welding torch 14 to navigate the welding training software screens, setup procedures, data analysis, welding courses, make selections within the welding training software, configure the welding training software, and so forth. Thus, the welding operator can use the welding torch 14 to control the welding training software (e.g., the welding operator does not have to put down the welding torch 14 to use a different input device). The welding torch 14 also includes visual indicators 61, such as a display 62 and LEDs 64. The visual indicators 61 may be configured to indicate or display data and/or images corresponding to a weld, welding training, and/or welding training software. For example, the visual indicators 61 may be configured to indicate a welding torch orientation, a welding torch travel speed, a welding torch position, a contact tip to workpiece distance, a proximity of the welding torch 14 in relation to the workpiece, an aim of the welding torch 14 (e.g., at what point the welding torch 14 is directed), training information for the welding operator, and so forth. Moreover, the visual indicators 61 may be configured to provide visual indications before a weld, during a

weld, and/or after a weld. In certain embodiments, the LEDs 64 may illuminate to facilitate their detection by the sensing device 16. In such embodiments, the LEDs 64 may be positioned to enable the sensing device 16 to determine a position and/or an orientation of the welding torch 14 based on a spatial position of the LEDs 64.

[0044] In certain embodiments, the welding torch 14 includes power conversion circuitry 66 configured to receive power from the data reporting device 26 (e.g., or another device), and to convert the received power for powering the welding torch 14. In certain embodiments, the welding torch 14 may receive power that is already converted and/or does not utilize power conversion. Moreover, in some embodiments, the welding torch 14 may be powered by a battery or any suitable powering mechanism. The welding torch 14 also includes a communication interface 68 (e.g., RS-232 driver) to facilitate communication between the welding torch 14 and the data reporting device 26 (or another device). In the illustrated embodiment, the welding torch 14 may communicate with the computer 18 by providing data to the data reporting device 26 using the communication interfaces 50 and 68, then the data reporting device 26 communicates the data to the computer 18. Accordingly, inputs provided to the welding torch 14 may be provided to the computer 18. In certain embodiments, the welding torch 14 may provide inputs to the computer 18 by communicating directly with the computer 18.

[0045] The welding torch 14 includes a trigger 70 configured to mechanically actuate a trigger switch 72 between an open position (as illustrated) and a closed position. The trigger 70 provides a conductor 71 to carry a signal to the control circuitry 52 to indicate whether the trigger switch 72 is in the open position or the closed position. The wire feeder 30, the welding power supply 28, the computer 18, and/or the data reporting device 26 may determine whether there is continuity through the welding torch 14 across a first trigger conductor 74 and a second trigger conductor 76. The trigger switch 72 is electrically coupled between the first trigger conductor 74 and the second trigger conductor 76. Continuity across the first trigger conductor 74 and the second trigger conductor 76 may be determined by applying a voltage across the conductors 74 and 76, applying a current across the conductors 74 and 76, measuring a resistance across the conductors 74 and 76, and so forth. In certain

embodiments, portions of the first trigger conductor 74 and/or portions of the second trigger conductor 76 may be disposed within a connector of the welding torch 14. Furthermore, in certain embodiments, the arrangement of switches and/or conductors within the welding torch 14 may be different than illustrated in FIG. 2.

[0046] The welding power supply 28 may determine whether to enable welding power to flow through the welding torch 14 based on whether there is continuity across the conductors 74 and 76. For example, the welding power supply 28 may enable welding power to flow through the welding torch 14 while there is continuity across the conductors 74 and 76, and the welding power supply 28 may block welding power from flowing through the welding torch 14 while there is an open circuit across the conductors 74 and 76. Furthermore, the wire feeder 30 may provide welding wire to the welding torch 14 while there is continuity across the conductors 74 and 76, and may block welding wire from being provided to the welding torch 14 while there is an open circuit across the conductors 74 and 76. Moreover, the computer 18 may use the continuity across the conductors 74 and 76 and/or the position of the trigger 70 or trigger switch 72 to start and/or stop a welding training operation, a welding training simulation, data recording, and so forth.

[0047] With the trigger switch 72 in the open position, there is an open circuit across the conductors 74 and 76, thus, the open position of the trigger switch 72 blocks electron flow between the conductors 74 and 76. Accordingly, the welding power supply 28 may block welding power from flowing through the welding torch 14 and the wire feeder 30 may block welding wire from being provided to the welding torch 14. Pressing the trigger 70 directs the trigger switch 72 to the closed position where the trigger switch 72 remains as long as the trigger 70 is pressed. With the trigger switch 72 in the closed position, there is continuity between the first trigger conductor 74 and a conductor 77 electrically connected to the trigger switch 72 and a training switch 78.

[0048] The training switch 78 is electrically coupled between the first trigger conductor 74 and the second trigger conductor 76. Moreover, the training switch 78 is electrically controlled by the control circuitry 52 to an open position or to a closed

position. In certain embodiments, the training switch 78 may be any suitable electrically controlled switch, such as a transistor, relay, etc. The control circuitry 52 may selectively control the training switch 78 to the open position or to the closed position. For example, while welding training software of the welding training system 10 is operating in a live-arc mode, the control circuitry 52 may be configured to control the training switch 78 to the closed position to enable a live welding arc while the trigger 70 is pressed. In contrast, while welding training software of the welding training system 10 is operating in any mode other than the live-arc mode (e.g., simulation, virtual reality, augmented reality, etc.), the control circuitry 52 may be configured to control the training switch 78 to the open position to block a live welding arc (by blocking electron flow between the conductors 74 and 76).

[0049] In certain embodiments, the training switch 78 may default to the open position, thereby establishing an open circuit across the conductors 74 and 76. As may be appreciated, while the training switch 78 is in the open position, there will be an open circuit across the conductors 74 and 76 regardless of the position of the trigger switch 72 (e.g., electron flow between the conductors 74 and 76 is blocked by the open position of the training switch 78). However, while the training switch 78 is controlled to the closed position, and the trigger switch 72 is in the closed position, conductivity is established between the conductors 74 and 76 (e.g., electron flow between the conductors 74 and 76 is enabled). Accordingly, the welding power supply 28 may enable welding power to flow through the welding torch 14 only while the training switch 78 is in the closed position and while the trigger switch 72 is in the closed position. For example, welding power may flow from the welding power supply 28, through a weld cable 80, the welding torch 14, a workpiece 82, and return to the welding power supply 28 via a work cable 84 (e.g., electrode-negative, or straight polarity). Conversely, welding power may flow from the welding power supply 28, through the work cable 84, the workpiece 82, the welding torch 14, and return to the welding power supply 28 via the weld cable 80 (e.g., electrode-positive, or reverse polarity).

[0050] As may be appreciated, the training switch 78 may be physically located in any suitable portion of the welding training system 10, such as the data reporting

device 26, the computer 18, and so forth. Furthermore, in certain embodiments, the functionality of the training switch 78 may be replaced by any suitable hardware and/or software in the welding training system 10.

[0051] FIG. 2A is a schematic diagram of an embodiment of circuitry of the welding torch 14 of FIG. 1. In the illustrated embodiment, the trigger switch 72 selectively connects a power supplying conductor (e.g., voltage source, etc.) to the conductor 71. Accordingly, while the trigger switch 72 is open, no voltage is applied to the conductor 71, and while the trigger switch 72 is closed, voltage from the power supplying conductor is supplied to the conductor 71. A trigger enable signal (e.g., TRIGGER_EN) may be provided by the control circuitry 52 to selectively control the training switch 78, and thereby control a feeder enable switch 85. For example, when the trigger enable signal controls the training switch 78 to an open position, no voltage is applied to the feeder enable switch 85 (e.g., via the FEEDER_EN connection), thereby maintaining the feeder enable switch 85 in the open position. Conversely, when the trigger enable signal controls the training switch 78 to a closed position, voltage is applied to the feeder enable switch 85, thereby controlling the feeder enable switch 85 to the closed position. With the feeder enable switch 85 in the closed position, conductivity between the conductors 74 and 76 is established. While one example of welding torch 14 circuitry is provided, any suitable circuitry may be used may be used within the welding torch 14.

[0052] FIG. 3 is a perspective view of an embodiment of the welding torch 14 of FIGS. 1 and 2. As illustrated, the user interface 60 includes multiple buttons 86 which may be used to provide inputs to the welding torch 14. For example, the buttons 86 may enable a welding operator to navigate through welding training software. Furthermore, the welding torch 14 includes the display 62 which may show the welding operator data corresponding to the welding training software, data corresponding to a welding operation, and so forth. As illustrated, the LEDs 64 may be positioned at various locations on the welding torch 14. Accordingly, the LEDs 64 may be illuminated to facilitate detection by the sensing device 16.

CALIBRATION TECHNIQUES

[0053] FIG. 4 is a perspective view of an embodiment of the training stand 12 of FIG. 1. The training stand 12 includes a welding surface 88 on which live welds (e.g., real welds, actual welds) and/or simulated welds may be performed. Legs 90 provide support to the welding surface 88. The welding surface 88 includes slots 91 that may aid a welding operator in positioning and orienting the workpiece 84. In certain embodiments, the position and orientation of the workpiece 84 may be provided to welding training software of the welding training system 10 to calibrate the welding training system 10. For example, a welding operator may provide an indication to the welding training software identifying which slot 91 of the welding surface 88 the workpiece 84 is aligned with. Furthermore, a predefined welding training assignment may direct the welding operator to align the workpiece 84 with a particular slot 91. In certain embodiments, the workpiece 84 may include an extension 92 configured to extend into one or more of the slots 91 for alignment of the workpiece 84 with the one or more slots 91. As may be appreciated, each of the slots 91 may be positioned at a location corresponding to a respective location defined in the welding training software.

[0054] The welding surface 88 includes a first aperture 93 and a second aperture 94. The first and second apertures 93 and 94 may be used together to determine a position and/or an orientation of the welding surface 88. As may be appreciated, at least two apertures are used to determine the position and/or the orientation of the welding surface 88. In certain embodiments, more than two apertures may be used to determine the position and/or the orientation of the welding surface 88. The first and second apertures 93 and 94 may be positioned at any suitable location on the welding surface 88, and may be any suitable size. In certain embodiments, the position and/or orientation of the welding surface 88 relative to the sensing device 16 may be calibrated using the first and second apertures 93 and 94. For example, as described in greater detail below, a calibration device configured to be sensed by the sensing device 16 may be inserted into the first aperture 93, or touched to the first aperture 93. While the calibration device is inserted into, or touching, the first aperture 93, a user input provided to the welding training software (or other calibration software) may

indicate that the calibration device is inserted into the first aperture 93. As a result, the welding training software may establish a correlation between a first data set (e.g., calibration data) received from the sensing device 16 (e.g., position and/or orientation data) at a first time and the location of first aperture 93. The calibration device may next be inserted into the second aperture 94, or touched to the second aperture 94. While the calibration device is inserted into, or touching, the second aperture 94, a user input provided to the welding training software may indicate that the calibration device is inserted into the second aperture 94. As a result, the welding training software may establish a correlation between a second data set (e.g., calibration data) received from the sensing device 16 at a second time and the location of second aperture 94. Thus, the welding training software may be able to calibrate the position and/or orientation of the welding surface 88 relative to the sensing device 16 using the first data set received at the first time and the second data set received at the second time.

[0055] The welding surface 88 also includes a first marker 95 and a second marker 96. The first and second markers 95 and 96 may be used together to determine a position and/or an orientation of the welding surface 88. As may be appreciated, at least two markers are used to determine the position and/or the orientation of the welding surface 88. In certain embodiments, more than two markers may be used to determine the position and/or the orientation of the welding surface 88. The first and second markers 95 and 96 may be formed from any suitable material. Moreover, in certain embodiments, the first and second markers 95 and 96 may be built into the welding surface 88, while in other embodiments, the first and second markers 95 and 96 may be attached to the welding surface 88. For example, the first and second markers 95 and 96 may be attached to the welding surface 88 using an adhesive and/or the first and second markers 95 and 96 may be stickers. The first and second markers 95 and 96 may have any suitable shape, size, and/or color. Furthermore, in certain embodiments, the first and second markers 95 and 96 may be a reflector formed from a reflective material. The first and second markers 95 and 96 may be used by the welding training system 10 to calibrate the position and/or orientation of the welding surface 88 relative to the sensing device 16 without a separate calibration

device. Accordingly, the first and second markers 95 and 96 are configured to be detected by the sensing device 16. In certain embodiments, the first and second markers 95 and 96 may be positioned at predetermined locations on the welding surface 88. Furthermore, the welding training software may be programmed to use the predetermined locations to determine the position and/or the orientation of the welding surface 88. In other embodiments, the location of the first and second markers 95 and 96 may be provided to the welding training software during calibration. With the first and second markers 95 and 96 on the welding surface 88, the sensing device 16 may sense the position and/or orientation of the first and second markers 95 and 96 relative to the sensing device 16. Using this sensed data in conjunction with the location of the first and second markers 95 and 96 on the welding surface 88, the welding training software may be able to calibrate the position and/or orientation of the welding surface 88 relative to the sensing device 16.

[0056] In the illustrated embodiment, the workpiece 84 includes a first marker 98 and a second marker 99. The first and second markers 98 and 99 may be used together to determine a position and/or an orientation of the workpiece 84. As may be appreciated, at least two markers are used to determine the position and/or the orientation of the workpiece 84. In certain embodiments, more than two markers may be used to determine the position and/or the orientation of the workpiece 84. The first and second markers 98 and 99 may be formed from any suitable material. Moreover, in certain embodiments, the first and second markers 98 and 99 may be built into the workpiece 84, while in other embodiments, the first and second markers 98 and 99 may be attached to the workpiece 84. For example, the first and second markers 98 and 99 may be attached to the workpiece 84 using an adhesive and/or the first and second markers 98 and 99 may be stickers. The first and second markers 98 and 99 may have any suitable shape, size, and/or color. Furthermore, in certain embodiments, the first and second markers 98 and 99 may be a reflector formed from a reflective material. The first and second markers 98 and 99 may be used by the welding training system 10 to calibrate the position and/or orientation of the workpiece 84 relative to the sensing device 16 without a separate calibration device. Accordingly, the first and second markers 98 and 99 are configured to be detected by

the sensing device 16. In certain embodiments, the first and second markers 98 and 99 may be positioned at predetermined locations on the workpiece 84. Furthermore, the welding training software may be programmed to use the predetermined locations to determine the position and/or the orientation of the workpiece 84. In other embodiments, the location of the first and second markers 98 and 99 may be provided to the welding training software during calibration. With the first and second markers 98 and 99 on the workpiece 84, the sensing device 16 may sense the position and/or orientation of the first and second markers 98 and 99 relative to the sensing device 16. Using this sensed data in conjunction with the location of the first and second markers 98 and 99 on the workpiece 84, the welding training software may be able to calibrate the position and/or orientation of the workpiece 84 relative to the sensing device 16. While the markers 95, 96, 98, and 99 have been described herein as being detected by the sensing device 16, in certain embodiments, the markers 95, 96, 98, and 99 may indicate locations where a calibration device is to be touched for calibration using the calibration device, as described previously.

[0057] The training stand 12 includes a first arm 100 extending vertically from the welding surface 88 and configured to provide support for the sensing device 16 and the display 32. A knob 101 is attached to the first arm 100 and may be used to adjust an orientation of the sensing device 16 relative to the first arm 100. For example, as the knob 101 is adjusted, mechanical components extending through the first arm 100 may adjust an angle of the sensing device 16. The display 32 includes a cover 102 to protect the display 32 from welding emissions that may occur during a live welding operation. The cover 102 may be made from any suitable material, such as a transparent material, a polymer, and so forth. By using a transparent material, a welding operator may view the display 32 while the cover 102 is positioned in front of the display 32, such as before, during, and/or after a welding operation. A camera 104 may be coupled to the first arm 100 for recording welding operations. In certain embodiments, the camera 104 may be a high dynamic range (HDR) camera. Furthermore, an emitter 105 may be coupled to the first arm 100. The emitter 105 may be used to calibrate the position and/or orientation of the welding surface 88 relative to the sensing device 16. For example, the emitter 105 may be configured to

emit a visible pattern onto the welding surface 88. The visible pattern may be shown onto the welding surface 88. Furthermore, the visible pattern may be detected by the sensing device 16 to calibrate the position and/or the orientation of the welding surface 88 relative to the sensing device 16. For example, based on particular features of the visible pattern alignments and/or orientations may be determined by the sensing device 16 and/or the welding training software. Moreover, the visible pattern emitted by the emitter 105 may be used to facilitate positioning of the workpiece 84 on the welding surface 88.

[0058] The training stand 12 also includes a second arm 106 extending vertically from the welding surface 88 and configured to provide support for an overhead welding plate 108. The second arm 106 may be adjustable to facilitate overhead welding at different heights. Moreover, the second arm 106 may be manufactured in a number of different ways to facilitate overhead welding at different heights. The overhead welding plate 108 is coupled to the second arm 106 using a mounting assembly 110. The mounting assembly 110 facilitates rotation of the overhead welding plate 108 as illustrated by arrow 111. For example, the overhead welding plate 108 may be rotated from extending generally in the horizontal plane (e.g., for overhead welding), as illustrated, to extend generally in the vertical plane (e.g., for vertical welding). The overhead welding plate 108 includes a welding surface 112. The welding surface 112 includes slots 114 that may aid a welding operator in positioning the workpiece 84 on the welding surface 112, similar to the slots 91 on the welding surface 88. In certain embodiments, the position of the workpiece 84 may be provided to welding training software of the welding training system 10 to calibrate the welding training system 10. For example, a welding operator may provide an indication to the welding training software identifying which slot 114 of the welding surface 112 the workpiece 84 is aligned with. Furthermore, a predefined welding training assignment may direct the welding operator to align the workpiece 84 with a particular slot 114. In certain embodiments, the workpiece 84 may include an extension configured to extend into one or more of the slots 114 for alignment of the workpiece 84 with the one or more slots 114. As may be appreciated, each of the

slots 114 may be positioned at a location corresponding to a respective location defined in the welding training software.

[0059] The welding surface 112 also includes a first marker 116 and a second marker 118. The first and second markers 116 and 118 may be used together to determine a position and/or an orientation of the welding surface 112. As may be appreciated, at least two markers are used to determine the position and/or the orientation of the welding surface 112. In certain embodiments, more than two markers may be used to determine the position and/or the orientation of the welding surface 112. The first and second markers 116 and 118 may be formed from any suitable material. Moreover, in certain embodiments, the first and second markers 116 and 118 may be built into the welding surface 112 (or another part of the overhead welding plate 108), while in other embodiments, the first and second markers 116 and 118 may be attached to the welding surface 112 (or another part of the overhead welding plate 108). For example, the first and second markers 116 and 118 may be attached to the welding surface 112 using an adhesive and/or the first and second markers 116 and 118 may be stickers. The first and second markers 116 and 118 may have any suitable shape, size, and/or color. Furthermore, in certain embodiments, the first and second markers 116 and 118 may be a reflector formed from a reflective material. The first and second markers 116 and 118 may be used by the welding training system 10 to calibrate the position and/or orientation of the welding surface 112 relative to the sensing device 16 without a separate calibration device. Accordingly, the first and second markers 116 and 118 are configured to be detected by the sensing device 16. In certain embodiments, the first and second markers 116 and 118 may be positioned at predetermined locations on the welding surface 112. Furthermore, the welding training software may be programmed to use the predetermined locations to determine the position and/or the orientation of the welding surface 112. In other embodiments, the location of the first and second markers 116 and 118 may be provided to the welding training software during calibration. With the first and second markers 116 and 118 on the welding surface 112, the sensing device 16 may sense the position and/or orientation of the first and second markers 116 and 118 relative to the sensing device 16. Using this sensed data

in conjunction with the location of the first and second markers 116 and 118 on the welding surface 112, the welding training software may be able to calibrate the position and/or orientation of the welding surface 112 relative to the sensing device 16. Furthermore, the sensing device 16 may sense and/or track the first and second markers 116 and 118 during a weld to account for any movement of the overhead welding plate 108 that may occur during the weld. While the markers 116 and 118 have been described herein as being detected by the sensing device 16, in certain embodiments, the markers 116 and 118 may indicate locations where a calibration device is to be touched or inserted for calibration using the calibration device, as described previously.

[0060] FIG. 5 is a perspective view of an embodiment of a calibration device 120. The calibration device 120 is shaped like a torch and may be used for calibrating the position and/or orientation of the welding surfaces 88 and 112 relative to the sensing device 16, as described in greater detail above. The calibration device 120 includes a handle 122 and a nozzle 124. The nozzle 124 includes a pointed end 126 that may be used to touch a location for calibration and/or to be inserted into an aperture for calibration. The calibration device 120 also includes a user interface 128 that enables the welding operator to provide input corresponding to a time that the calibration device 120 is touching a location for calibration and/or is being inserted into an aperture for calibration. Moreover, in certain embodiments, the calibration device 120 includes markers 130 configured to be sensed by the sensing device 16. As illustrate, the markers 130 extend from the calibration device 120. However, in other embodiments, the markers 130 may not extend from the calibration device 120. The markers 130 may be any suitable marker configured to be detected by the sensing device 16. Moreover, the markers 130 may be any suitable size, shape, and/or color.

[0061] During calibration, the sensing device 16 may sense a position of the calibration device 120 and/or an orientation of the calibration device 120. The position and/or orientation of the calibration device 120 may be used by the welding training software to determine a position and/or orientation of one or more of the welding surfaces 88 and 112 relative to the sensing device 16, a position and/or orientation of the workpiece 84 relative to the sensing device 16, a position and/or

orientation of a fixture relative to the sensing device 16, and so forth. Thus, the calibration device 120 may facilitate calibration of the welding training system 10.

[0062] FIG. 6 is a perspective view of an embodiment of a fixture assembly 132. The fixture assembly 132 may be positioned on the welding surface 88 and/or the welding surface 112, and may secure the workpiece 84 thereon. In certain embodiments, the fixture assembly 132 may be configured to align with one or more of the slots 92 and 114. In other embodiments, the fixture assembly 132 may be placed at any location on the welding surface 88 and/or the welding surface 122. The fixture assembly 132 also includes a first marker 134 and a second marker 136. The first and second markers 134 and 136 may be used together to determine a position and/or an orientation of the fixture assembly 132. As may be appreciated, at least two markers are used to determine the position and/or the orientation of the fixture assembly 132. The first and second markers 134 and 136 may be formed from any suitable material. Moreover, in certain embodiments, the first and second markers 134 and 136 may be built into the fixture assembly 132, while in other embodiments, the first and second markers 134 and 136 may be attached to the fixture assembly 132. For example, the first and second markers 134 and 136 may be attached to the fixture assembly 132 using an adhesive and/or the first and second markers 134 and 136 may be stickers. The first and second markers 134 and 136 may have any suitable shape, size, and/or color. Furthermore, in certain embodiments, the first and second markers 134 and 136 may be a reflector formed from a reflective material. The first and second markers 134 and 136 may be used by the welding training system 10 to calibrate the position and/or orientation of the fixture assembly 132 relative to the sensing device 16 without a separate calibration device. Accordingly, the first and second markers 134 and 136 are configured to be detected by the sensing device 16. In certain embodiments, the first and second markers 134 and 136 may be positioned at predetermined locations on the fixture assembly 132. Furthermore, the welding training software may be programmed to use the predetermined locations to determine the position and/or the orientation of the fixture assembly 132. In other embodiments, the location of the first and second markers 134 and 136 may be provided to the welding training software during calibration. With the first and second markers 134

and 136 on the fixture assembly 132, the sensing device 16 may sense the position and/or orientation of the first and second markers 134 and 136 relative to the sensing device 16. Using this sensed data in conjunction with the location of the first and second markers 134 and 136 on the fixture assembly 132, the welding training software may be able to calibrate the position and/or orientation of the fixture assembly 132 relative to the sensing device 16. While the first and second markers 134 and 136 have been described herein as being detected by the sensing device 16, in certain embodiments, the first and second markers 134 and 136 may indicate locations where a calibration device is to be touched or inserted for calibration using the calibration device 120, as described previously.

[0063] In the illustrated embodiment, the fixture assembly 132 is configured to secure a lower portion 138 of the workpiece 84 to an upper portion 140 of the workpiece 84 for performing a lap weld. In other embodiments, the fixture assembly 132 may be configured to secure portions of the workpiece 84 for performing a butt weld, a fillet weld, and so forth, to aid a welding operator in performing a weld. The fixture assembly 132 includes vertical arms 142 extending from a base 143. A cross bar 144 extends between the vertical arms 142, and is secured to the vertical arms 142. Adjustment mechanisms 146 (e.g., knobs) may be adjusted to direct locking devices 148 toward the workpiece 84 for securing the workpiece 84 between the locking devices 148 and the base 143 of the fixture assembly 132. Conversely, the adjustment mechanisms 146 may be adjusted to direct the locking devices 148 away from the workpiece 84 for removing the workpiece 84 from being between the locking devices 148 and the base 143. Accordingly, the workpiece 84 may be selectively secured to the fixture assembly 132.

WELDING TRAINING SYSTEM DEVICES

[0064] FIG. 7 is a perspective view of a welding wire stickout calibration tool 150. The tool 150 is configured to calibrate a length of welding wire extending out of a torch nozzle to a selectable length. Accordingly, the tool 150 includes a first handle 152 and a second handle 154. The tool 150 also includes a torch nozzle holder 156 attached to a central portion 157 of the tool 150 and extending outward from the

central portion 157 a selected distance. In the illustrated embodiment, the torch nozzle holder 156 has a generally cylindrical body 158 (e.g., cup shape); however, in other embodiments, the body 158 of the torch nozzle holder 156 may have any suitable shape. Moreover, the torch nozzle holder 156 is configured to receive the torch nozzle through a nozzle inlet 160 such that the torch nozzle extends into the body 158. Furthermore, the torch nozzle holder 156 includes an opening 162 configured to enable welding wire to extend out the end of the torch nozzle holder 156, and to block the torch nozzle from extending through the opening 162. As the torch nozzle extends into the torch nozzle holder 156, the welding wire extends out of the opening 162 of the torch nozzle holder 156 toward a blade assembly 164 of the tool 150. The blade assembly 164 includes one or more sides 165 and 166 configured to contact the welding wire. In certain embodiments, both of sides 165 and 166 include blades to cut opposing sides of the welding wire, while in other embodiments, only one of the sides 165 and 166 includes a blade to cut one side of the welding wire and the other side includes a surface to which the blade is directed toward. For calibrating the length of the welding wire, the welding wire may extend through the opening 162 and into the blade assembly 164. The welding wire may be cut to a selectable length by pressing the first handle 152 and the second handle 154 toward one another, thereby calibrating the length of wire extending from the torch nozzle. The calibration length may be selected using an adjustment mechanism 167 to adjust a distance 168 between the blade assembly 164 and the opening 162 of the torch nozzle holder 156. Thus, using the tool 150, the length of wire extending from the torch nozzle may be calibrated.

[0065] FIG. 8 is a top view of the welding wire stickout calibration tool 150 of FIG. 7. As illustrated, the welding torch 14 may be used with the tool 150. Specifically, a nozzle 170 of the welding torch 14 may be inserted into the torch nozzle holder 156 in a direction 172. Welding wire 174 extending from the welding torch 14 is directed through the nozzle inlet 160, the opening 162, and the blade assembly 164. Accordingly, the first and second handles 152 and 154 may be pressed together to cut the welding wire 174 to the distance 168 (e.g., the calibration length) set by the adjustment mechanism 167.

[0066] FIG. 9 is an embodiment of a method 176 for calibrating wire stickout from the welding torch 14. The tool 150 may be used to calibrate the length of welding wire 174 extending from the nozzle 170 using a variety of methods. In the method 176, the adjustment mechanism 167 of the welding wire stickout calibration tool 150 may be adjusted for a selected welding wire 174 length (block 178). For example, the distance 168 of the torch nozzle holder 156 from the tool 150 may be set to a range of between approximately 0.5 to 2.0 cm, 1.0 to 3.0 cm, and so forth. The welding torch 14 may be inserted into the torch nozzle holder 156 of the tool 150, such that the nozzle 170 of the welding torch 14 abuts the torch nozzle holder 156, and that the welding wire 174 extends through the opening 162 of the torch nozzle holder 156 (block 180). In certain embodiments, the welding wire 174 may be long enough to extend through the blade assembly 164. However, if the welding wire 174 does not extend through the blade assembly 164, a welding operator may actuate the trigger 70 of the welding torch 14 to feed welding wire 174 such that the welding wire 174 extends through the blade assembly 164 (block 182). Accordingly, the welding operator may compress handles 152 and 154 of the tool 150 to cut the welding wire 174 extending through the blade assembly 164 and thereby calibrate the length of the welding wire 174 (block 184).

[0067] FIG. 10 is a perspective view of an embodiment of a welding consumable 186 having physical marks. The welding consumable 186 may be any suitable welding consumable, such as a welding stick, welding rod, or a welding electrode. The welding consumable 186 includes physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204. The physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204 may be any suitable physical mark. For example, the physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204 may include a bar code, an image, a shape, a color, text, a set of data, and so forth. In certain embodiments, the physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204 may be laser etched. Furthermore, in certain embodiments, the physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204 may be visible with the natural eye (e.g., within the visible spectrum), while in other embodiments the physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204 may not be visible with the natural eye (e.g., not within the visible spectrum).

[0068] Each of the physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204 indicates a location on the welding consumable 186 relative to either a first end 206, or a second end 208 of the welding consumable 186. For example, the physical mark 188 may indicate a distance from the first end 206, a distance from the second end 208, or some other location relative to the welding consumable 186. In certain embodiments, the physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204 may indicate a number that corresponds to the first end 206 and/or the second end 208. For example, the physical mark 188 may indicate a number "1" indicating that it is the first physical mark from the first end 206 and/or the physical mark 188 may indicate a number "9" indicating that it is the ninth physical mark from the second end 208. A processing device may use a lookup table to determine a distance from the first end 206 or the second end 208 based on the number indicated by the physical mark.

[0069] A camera-based detection system, which may include the sensing device 16, or another type of system is configured to detect the physical marks 188, 190, 192, 194, 196, 198, 200, 202, and 204 during live arc welding or a welding simulation. Moreover, the camera-based detection system is configured to determine a remaining length of the welding consumable 186, a consumed length of the welding consumable 186, a rate of use of the welding consumable 186, a dipping rate of the welding consumable 186, and so forth, based on the detected physical marks. Accordingly, data corresponding to use of the welding consumable 186 may be tracked by the welding training system 10 for training and/or analysis.

[0070] FIG. 11 is a perspective view of an embodiment of welding wire 210 having physical marks 212, 214, 216, and 218. The physical marks 212, 214, 216, and 218 may be any suitable physical mark. For example, the physical marks 212, 214, 216, and 218 may include a bar code, an image, a shape, text, a set of data, and so forth. In certain embodiments, the physical marks 212, 214, 216, and 218 may be laser etched. Furthermore, in certain embodiments, the physical marks 212, 214, 216, and 218 may be visible with the natural eye (e.g., within the visible spectrum), while in other embodiments the physical marks 212, 214, 216, and 218 may not be visible with the natural eye (e.g., not within the visible spectrum).

[0071] Each of the physical marks 212, 214, 216, and 218 indicates a location on the welding wire 210 relative to either a first end 220, or a second end 222 of the welding wire 210. For example, the physical mark 212 may indicate a distance from the first end 220, a distance from the second end 222, or some other location relative to the welding wire 210. In certain embodiments, the physical marks 212, 214, 216, and 218 may indicate a number that corresponds to the first end 220 and/or the second end 222. For example, the physical mark 212 may indicate a number "1" indicating that it is the first physical mark from the first end 220 and/or the physical mark 212 may indicate a number "4" indicating that it is the fourth physical mark from the second end 222. A processing device may use a lookup table to determine a distance from the first end 220 or the second end 222 based on the number indicated by the physical mark.

[0072] A camera-based detection system, which may include the sensing device 16, or another type of system is configured to detect the physical marks 212, 214, 216, and 218 during live arc welding or a welding simulation. Moreover, the camera-based detection system is configured to determine a remaining length of the welding wire 210, a consumed length of the welding wire 210, a rate of use of the welding wire 210, a dipping rate of the welding wire 210, and so forth, based on the detected physical marks. Accordingly, data corresponding to use of the welding wire 210 may be tracked by the welding training system 10 for training and/or analysis.

[0073] FIG. 12 is a perspective view of an embodiment of a vertical arm assembly 223 of the training stand 12 of FIG. 4. As illustrated, the sensing device 16 is attached to the first arm 100. Furthermore, the sensing device 16 includes cameras 224, and an infrared emitter 226. However, in other embodiments, the sensing device 16 may include any suitable number of cameras, emitters, and/or other sensing devices. A pivot assembly 228 is coupled to the first arm 100 and to the sensing device 16, and enables an angle of the sensing device 16 to be adjusted while the sensing device 16 rotates as illustrated by arrow 229. As may be appreciated, adjusting the angle of the sensing device 16 relative to the first arm 100 changes the field of view of the sensing device 16 (e.g., to change the portion of the welding surface 88 and/or the welding surface 112 sensed by the sensing device 16).

[0074] A cord 230 extends between the knob 101 and the sensing device 16. The cord 230 is routed through a pulley 232 to facilitate rotation of the sensing device 16. Thus, a welding operator may rotate the knob 101 to manually adjust the angle of the sensing device 16. As may be appreciated, the combination of the cord 230 and the pulley 232 is one example of a system for rotating the sensing device 16. It should be noted that any suitable system may be used to facilitate rotation of the sensing device 16. While one embodiment of a knob 101 is illustrated, it may be appreciated that any suitable knob may be used to adjust the angle of the sensing device 16. Furthermore, the angle of the sensing device 16 may be adjusted using a motor 234 coupled to the cord 230. Accordingly, a welding operator may operate the motor 234 to adjust the angle of the sensing device 16. Moreover, in certain embodiments, control circuitry may be coupled to the motor 234 and may control the angle of the sensing device 16 based on a desired field of view of the sensing device 16 and/or based on tracking of an object within the field of view of the sensing device 16.

[0075] FIG. 13 is a perspective view of an embodiment of an overhead welding arm assembly 235. The overhead welding arm assembly 235 illustrates one embodiment of a manufacturing design that enables the second arm 106 to have an adjustable height. Accordingly, as may be appreciated, the second arm 106 may be manufactured to have an adjustable height in a number of ways. As illustrated, the overhead welding assembly 235 includes handles 236 used to vertically raise and/or lower the second arm 106 as illustrated by arrows 238. The overhead welding arm assembly 235 includes a locking device 240 to lock the second arm 106 at a desired height. For example, the locking device 240 may include a button that is pressed to disengage a latch configured to extend into openings 242, thus unlocking the second arm 106 from being secured to side rails 243. With the second arm 106 unlocked from the side rails 243, the handles 236 may be vertically adjusted to a desired height, thereby adjusting the plate 112 to a desired height. As may be appreciated, releasing the button may result in the latch extending into the openings 242 and locking the second arm 106 to the side rails 243. As may be appreciated, the locking device 240 may operate manually as described and/or the locking device 240 may be controlled by a control system (e.g., automatically controlled). Furthermore, the second arm 106

may be vertically raised and/or lowered using the control system. For example, in certain embodiments, the welding training software may control the second arm 106 to move to a desired position automatically. Thus, the plate 112 may be adjusted to a desired height for overhead welding.

MULTI-MODE WELDING TRAINING SOFTWARE

[0076] FIG. 14 is a block diagram of an embodiment of welding training software 244 of the welding training system 10 having multiple training modes. As illustrated, the welding training software 244 may include one or more of a live-arc mode 246 configured to enable training using a live (e.g., actual) welding arc, a simulation mode 248 configured to enable training using a welding simulation, a virtual reality (VR) mode 250 configured to enable training using a VR simulation, and/or an augmented reality mode 252 configured to enable training using augmented reality simulation.

[0077] The welding training software 244 may receive signals from an audio input 254. The audio input 254 may be configured to enable a welding operator to operate the welding training software 244 using audible commands (e.g., voice activation). Furthermore, the welding training software 244 may be configured to provide an audio output 256 and/or a video output 258. For example, the welding training software 244 may provide audible information to a welding operator using the audio output 256. Such audible information may include instructions for configuring (e.g., setting up) the welding training system 10, real-time feedback provided to a welding operator during a welding operation, instructions to a welding operator before performing a welding operation, instructions to a welding operator after performing a welding operation, warnings, and so forth.

[0078] FIG. 15 is a block diagram of an embodiment of the VR mode 250 of the welding training software 244. The VR mode 250 is configured to provide a welding operator with a VR simulation 260. The VR simulation 260 may be displayed to a welding operator through a VR headset, VR glasses, a VR display, or any suitable VR device. The VR simulation 260 may be configured to include a variety of virtual objects, such as the objects illustrated in FIG. 15, that enable interaction between a

welding operator and a selected virtual object of the variety of virtual objects within the VR simulation 260. For example, virtual objects may include a virtual workpiece 262, a virtual welding stand 264, a virtual welding torch 266, virtual wire cutters 268, virtual software configuration 270, virtual training data results 272, and/or a virtual glove 274.

[0079] In certain embodiments, the welding operator may interact with the virtual objects without touching a physical object. For example, the sensing device 16 may detect movement of the welding operator and may result in similar movements occurring in the VR simulation 260 based on the welder operator's movements in the real world. In other embodiments, the welding operator may use a glove or the welding torch 14 to interact with the virtual objects. For example, the glove or the welding torch 14 may be detected by the sensing device 16, and/or the glove or the welding torch 14 may correspond to a virtual object in the VR simulation 260. Furthermore, the welding operator may be able to operate the welding training software 244 within the VR simulation 260 using the virtual software configuration 270 and/or the virtual training data results 272. For example, the welding operator may use their hand, the glove, or the welding torch 14 to select items within the welding training software 244 that are displayed virtually within the VR simulation 260. Moreover, the welding operator may perform other actions such as picking up wire cutters and cutting virtual welding wire extending from the virtual torch 266, all within the VR simulation 260.

[0080] FIG. 16 is an embodiment of a method 276 for integrating training results data. The method 276 includes the welding training software 244 of the computer 18 receiving a first set of welding training data from a storage device (e.g., storage device 24) (block 278). The first set of welding training data may include welding training data corresponding to a first welding training assignment. The method 276 also includes the welding training software 244 receiving a second set of welding training data from the storage device (block 280). In certain embodiments, the first set and/or second set of welding training data may be received from a network storage device. The network storage device may be configured to receive welding training data from and/or to provide welding training data to the welding training system 10

and/or the external welding training system 40. The welding training software 244 may integrate the first and second sets of welding training data into a chart to enable a visual comparison of the first set of welding training data with the second set of welding training data (block 282). As may be appreciated, the chart may be a bar chart, a pie chart, a line chart, a histogram, and so forth. In certain embodiments, integrating the first set of welding training data with the second set of welding training data includes filtering the first set of welding training data and the second set of welding training data to display a subset of the first set of welding training data and a subset of the second set of welding training data. The welding training software 244 may provide the chart to a display device (e.g., the display 32) (block 284). In certain embodiments, providing the chart to the display device includes providing selectable elements on the chart that when selected display data corresponding to a respective selected element of the selectable elements (e.g., selecting wire speed from the chart may change the screen to display the wire speed history for a particular welding training assignment).

[0081] The first set of welding training data and/or the second set of welding training data may include a welding torch orientation, a welding torch travel speed, a welding torch position, a contact tip to workpiece distance, a proximity of the welding torch in relation to the workpiece, an aim of the welding torch, a welding score, a welding grade, and so forth. Moreover, the first set of welding training data and the second set of welding training data may correspond to training performed by one welding operator and/or by a class of welding operators. Furthermore, the first welding training assignment and the second welding training assignment may correspond to training performed by one welding operator and/or by a class of welding operators. In certain embodiments, the first welding training assignment may correspond to training performed by a first welding operator, and the second welding training assignment may correspond to welding performed by a second welding operator. Moreover, the first training assignment and the second training assignment may correspond to the same welding training scenario.

[0082] FIG. 17 is an embodiment of a chart 285 illustrating multiple sets of welding training data for a welding operator. The chart 285 may be produced by the

welding training software 244 and may be provided to the display 32 to be used by a welding instructor to review welding training operators performed by a welding student, and/or may be provided to the display 32 to be used by a welding student to review welding training operations performed by that welding student. The chart 285 illustrates a bar graph comparison between different training assignments of a first set of welding training assignments performed by a welding operator. The first set of welding training assignments includes assignments 286, 288, 290, 292, and 294. The chart 285 also illustrates a bar graph comparison between different training assignments of a second set of welding training assignments performed by the welding operator. The second set of welding training assignments includes assignments 296, 298, 300, 302, and 304. Accordingly, welding training assignments may be compared to one another for analysis, instruction, certification, and/or training purposes. As illustrated, the welding training assignments may be compared to one another using one of any number of criteria, such as a total score, a work angle, a travel angle, a travel speed, a contact to work distance, a proximity, a mode (e.g., live-arc mode, simulation mode, etc.), a completion status (e.g., complete, incomplete, partially complete, etc.), a joint type (e.g., fillet, butt, T, lap, etc.), a welding position (e.g., flat, vertical, overhead, etc.), a type of metal used, a type of filler metal, and so forth.

[0083] FIG. 18 is an embodiment of a chart 305 illustrating welding training data for a welder compared to welding training data for a class. For example, the chart 305 illustrates a score 306 of a welding operator compared to a score 308 (e.g., average, median, or some other score) of a class for a first assignment. Furthermore, a score 310 of the welding operator is compared to a score 312 (e.g., average, median, or some other score) of the class for a second assignment. Moreover, a score 314 of the welding operator is compared to a score 316 (e.g., average, median, or some other score) of the class for a third assignment. As may be appreciated, scores from one or more welding operators may be compared to scores of the entire class. Such a comparison enables a welding instructor to assess the progress of individual welding students as compared to the class of welding students. Furthermore, scores from one or more welding operators may be compared to scores of one or more other welding

operators. In certain embodiments, scores from one class may be compared to scores of another class. Moreover, scores from the first assignment, the second assignment, and/or the third assignment may be selected for comparison.

DATA STORAGE AND ANALYSIS

[0084] FIG. 19 is a block diagram of an embodiment of a data storage system 318 for storing certification status data. The certification status data may be produced as a welding operator completes various assignments in the welding training system 10. For example, a predetermined set of assignments may certify a welding operator for a particular welding device and/or welding process. The data storage system 318 includes control circuitry 320, one or more memory devices 322, and one or more storage devices 324. The control circuitry 320 may include one or more processors, which may be similar to the processor(s) 20. Furthermore, the memory device(s) 322 may be similar to the memory device(s) 22, and the storage device(s) 324 may be similar to the storage device(s) 24. The memory device(s) 322 and/or the storage device(s) 324 may be configured to store certification status data 326 corresponding to a welding training certification of a welding operator.

[0085] The certification status data 326 may include welding training data of the welding operator (e.g., any data that is related to the assignments to certify the welding operator), any data related to an actual certification (e.g., certified, not certified, qualified, not qualified, etc.), a quantity of one or more welds performed by the welding operator, a timestamp for one or more welds performed by the welding operator, welding parameter data for one or more welds performed by the welding operator, a quality ranking of the welding operator, a quality level of the welding operator, a history of training welds performed by the welding operator, a history of production welds performed by the welding operator, a first welding process (e.g., a metal inert gas (MIG) welding process, a tungsten inert gas (TIG) welding process, a stick welding process, etc.) certification status (e.g., the welding operator is certified for the first welding process, the welding operator is not certified for the first welding process), a second welding process certification status (e.g., the welding operator is certified for the second welding process, the welding operator is not certified for the

second welding process), a first welding device (e.g., a wire feeder, a power supply, a model number, etc.) certification status (e.g., the welding operator is certified for the first welding device, the welding operator is not certified for the first welding device), and/or a second welding device certification status (e.g., the welding operator is certified for the second welding device, the welding operator is not certified for the second welding device).

[0086] The control circuitry 320 may be configured to receive a request for the first welding process certification status, the second welding process certification status, the first welding device certification status, and/or the second welding device certification status of the welding operator. Furthermore, the control circuitry 320 may be configured to provide a response to the request. The response to the request may include the first welding process certification status, the second welding process certification status, the first welding device certification status, and/or the second welding device certification status of the welding operator. In certain embodiments, the welding operator may be authorized to use a first welding process, a second welding process, a first welding device, and/or a second welding device based at least partly on the response. Furthermore, in some embodiments, the first welding process, the second welding process, the first welding device, and/or the second welding device of a welding system may be enabled or disabled based at least partly on the response. Moreover, in certain embodiments, the first welding process, the second welding process, the first welding device, and/or the second welding device of a welding system may be enabled or disabled automatically. Thus, a welding operator's certification data may be used to enable and/or disable that welding operator's ability to use a particular welding system, welding device, and/or welding process. For example, a welding operator may have a certification for a first welding process, but not for a second welding process. Accordingly, in certain embodiments, a welding operator may verify their identity at a welding system (e.g., by logging in or some other form of authentication). After the identity of the welding operator is verified, the welding system may check the welding operator's certification status. The welding system may enable the welding operator to perform operations using the first welding process based on the welding operator's certification status, but may block

the welding operator from performing the second welding process based on the welding operator's certification status.

[0087] FIG. 20 is an embodiment of a screen 327 illustrating data corresponding to a training weld. The screen 327 may be produced by the welding training software 244 and may be displayed on the display 32. The screen 327 illustrates parameters that may be graphically displayed to a welding operator before, during, and/or after performing a welding operation. For example, the parameters may include a work angle 328, a travel angle 330, a contact tip to workpiece distance 332, a welding torch travel speed 334, a proximity of the welding torch in relation to the workpiece 336, a welding voltage 337, a welding current 338, a welding torch orientation, a welding torch position, an aim of the welding torch, and so forth.

[0088] As illustrated, graphically illustrated parameters may include an indication 339 of a current value of a parameter (e.g., while performing a welding assignment). Furthermore, a graph 340 may show a history of the value of the parameter, and a score 341 may show an overall percentage that corresponds to how much time during the welding assignment that the welding operator was within a range of acceptable values. In certain embodiments, a video replay 342 of a welding assignment may be provided on the screen 327. The video replay 342 may show live video of a welding operator performing a real weld, live video of the welding operator performing a simulated weld, live video of the welding operator performing a virtual reality weld, live video of the welding operator performing an augmented reality weld, live video of a welding arc, live video of a weld puddle, and/or simulated video of a welding operation.

[0089] In certain embodiments, the welding training system 10 may capture video data during a welding assignment, and store the video data on the storage device 24. Moreover, the welding training software 244 may be configured to retrieve the video data from the storage device 24, to retrieve welding parameter data from the storage device 24, to synchronize the video data with the welding parameter data, and to provide the synchronized video and welding parameter data to the display 32.

[0090] The welding training software 244 may analyze welding parameter data to determine a traversed path 344 that may be shown on the display 32. In some embodiments, a time 346 during a weld may be selected by a welding operator. By selecting the time 346, the welding operator may view the video replay 342 and/or the traversed path 344 in conjunction with the welding parameters as they were at the selected time 346 in order to establish a correlation between the welding parameters, the video replay 342, and/or the traversed path 344. The welding training software 244 may be configured to recreate welding training data based at least partly on welding parameter data, to synchronize the video replay 342 with the recreated welding training data, and to provide the synchronized video replay 342 and recreated welding training data to the display 32. In certain embodiments, the recreated welding training data may be weld puddle data and/or a simulated weld.

[0091] In certain embodiments, the storage device 24 may be configured to store a first data set corresponding to multiple training welds performed by a welding operator, and to store a second data set corresponding to multiple non-training welds performed by the welding operator. Furthermore, the control circuitry 320 may be configured to retrieve at least part of the first data set from the storage device 24, to retrieve at least part of the second data set from the storage device 24, to synchronize the at least part of the first data set with the at least part of the second data set, and to provide the synchronized at least part of the first data set and at least part of the second data set to the display 32.

[0092] FIG. 21 is an embodiment of a screen 347 illustrating a discontinuity analysis 348 of a training weld. The discontinuity analysis 348 includes a listing 350 that may itemize potential issues with a welding operation. The discontinuity analysis 348 provides feedback to the welding operator regarding time periods within the welding operation in which the weld does not meet a predetermined quality threshold. For example, between times 352 and 354, there is a high discontinuity (e.g., the welding quality is poor, the weld has a high probability of failure, the weld is defective). Furthermore, between times 356 and 358, there is a medium discontinuity (e.g., the welding quality is average, the weld has a medium probability of failure, the weld is partially defective). Moreover, between times 360 and 362, there is a high

discontinuity, and between times 364 and 366, there is a low discontinuity (e.g., the welding quality is good, the weld has a low probability of failure, the weld is not defective). With this information a welding operator may be able to quickly analyze the quality of a welding operation.

[0093] FIG. 22 is a block diagram of an embodiment of a welding instructor screen 368 of the welding training software 244. The welding training software 244 is configured to provide training simulations for many different welding configurations. For example, the welding configurations may include a MIG welding process 370, a TIG welding process 372, a stick welding process 374, the live-arc welding mode 346, the simulation welding mode 248, the virtual reality welding mode 250, and/or the augmented reality welding mode 252.

[0094] The welding instructor screen 368 may be configured to enable a welding instructor to restrict training of a welding operator 376 (e.g., to one or more selected welding configurations), to restrict training of a class of welding operators 378 (e.g., to one or more selected welding configurations), and/or to restrict training of a portion of a class of welding operators 380 (e.g., to one or more selected welding configurations). Moreover, the welding instructor screen 368 may be configured to enable the welding instructor to assign selected training assignments to the welding operator 382, to assign selected training assignments to a class of welding operators 384, and/or to assign selected training assignments to a portion of a class of welding operators 386. Furthermore, the welding instructor screen 368 may be configured to enable the welding instructor to automatically advance the welding operator (or a class of welding operators) from a first training assignment to a second training assignment 388. For example, the welding operator may advance from a first training assignment to a second training assignment based at least partly on a quality of performing the first training assignment.

[0095] FIG. 23 is an embodiment of a method 389 for weld training using augmented reality. A welding operator may select a training mode of the welding training software 244 (block 390). The welding training software 244 determines whether the augmented reality mode 252 has been selected (block 392). If the

augmented reality mode 252 has been selected, the welding training software 244 executes an augmented reality simulation. It should be noted that the welding operator may be wearing a welding helmet and/or some other headgear configured to position a display device in front of the welding operator's view. Furthermore, the display device may generally be transparent to enable the welding operator to view actual objects; however, a virtual welding environment may be portrayed on portions of the display device. As part of this augmented reality simulation, the welding training software 244 receives a position and/or an orientation of the welding torch 14, such as from the sensing device 16 (block 394). The welding training software 244 integrates the virtual welding environment with the position and/or the orientation of the welding torch 14 (block 396). Moreover, the welding training software 244 provides the integrated virtual welding environment to the display device (block 398). For example, the welding training software 244 may determine where a weld bead should be positioned within the welding operator's field of view, and the welding training software 244 may display the weld bead on the display device such that the weld bead appears to be on a workpiece. After completion of the weld, the augmented reality simulation may enable the welding operator to erase a portion of the virtual welding environment (e.g., the weld bead) (block 400), and the welding training software 244 returns to block 390.

[0096] If the augmented reality mode 252 has not been selected, the welding training software 244 determines whether the live-arc mode 246 has been selected (block 402). If the live-arc mode 246 has been selected, the welding training software 244 enters the live-arc mode 246 and the welding operator may perform the live-arc weld (block 404). If the live-arc mode 246 has not been selected and/or after executing block 404, the welding training software 244 returns to block 390. Accordingly, the welding training software 244 is configured to enable a welding operator to practice a weld in the augmented reality mode 252, to erase at least a portion of the virtual welding environment from the practice weld, and to perform a live weld in the live-arc mode 246. In certain embodiments, the welding operator may practice the weld in the augmented reality mode 252 consecutively a multiple number of times.

[0097] FIG. 24 is an embodiment of another method 406 for weld training using augmented reality. A welding operator may select a training mode of the welding training software 244 (block 408). The welding training software 244 determines whether the augmented reality mode 252 has been selected (block 410). If the augmented reality mode 252 has been selected, the welding training software 244 executes an augmented reality simulation. It should be noted that the welding operator may be wearing a welding helmet and/or some other headgear configured to position a display device in front of the welding operator's view. Furthermore, the display device may completely block the welding operator's field of vision such that images observed by the welding operator have been captured by a camera and displayed on the display device. As part of this augmented reality simulation, the welding training software 244 receives an image of the welding torch 14, such as from the sensing device 16 (block 412). The welding training software 244 integrates the virtual welding environment with the image of the welding torch 14 (block 414). Moreover, the welding training software 244 provides the integrated virtual welding environment with the image of the welding torch 14 to the display device (block 416). For example, the welding training software 244 may determine where a weld bead should be positioned within the welding operator's field of view and the welding training software 244 displays the weld bead on the display device with the image of the welding torch 14 and other objects in the welding environment. After completion of the weld, the augmented reality simulation may enable the welding operator to erase a portion of the virtual welding environment (e.g., the weld bead) (block 418), and the welding training software 244 returns to block 408.

[0098] If the augmented realty mode 252 has not been selected, the welding training software 244 determines whether the live-arc mode 246 has been selected (block 420). If the live-arc mode 246 has been selected, the welding training software 244 enters the live-arc mode 246 and the welding operator may perform the live-arc weld (block 422). If the live-arc mode 246 has not been selected and/or after executing block 422, the welding training software 244 returns to block 408. Accordingly, the welding training software 244 is configured to enable a welding operator to practice a weld in the augmented reality mode 252, to erase at least a

portion of the virtual welding environment from the practice weld, and to perform a live weld in the live-arc mode 246. In certain embodiments, the welding operator may practice the weld in the augmented reality mode 252 consecutively a multiple number of times.

[0099] As may be appreciated, using the systems, devices, and techniques described herein, a welding training system 10 may be provided for training welding operators. The welding training system 10 may be cost efficient and may enable welding students to receive high quality hands on training.

[00100] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS

What is claimed is:

1. A welding training system comprising:

a computer configured to execute a welding training software;

a calibration device communicatively coupled to the computer, wherein the calibration device comprises a trigger configured to receive an operator input prior to a simulated weld or a live weld; and

a sensor communicatively coupled to the computer and configured to sense a position of the calibration device, an orientation of the calibration device, or some combination thereof, when the trigger receives the operator input prior to the simulated weld or the live weld, and to provide calibration data to the welding training software to calibrate a first location of the calibration device with respect to a welding surface when the trigger receives the operator input prior to the simulated weld or the live weld, wherein the calibration data comprises the position of the calibration device, the orientation of the calibration device, or some combination thereof.

2. The welding training system of claim 1, wherein the calibration data comprises a first data set corresponding to the first location of the calibration device when the trigger receives the operator input prior to the simulated weld or the live weld and the calibration device touches the welding surface at a first surface location, and a second data set corresponding to a second location of the calibration device when the trigger receives the operator input prior to the simulated weld or the live weld and the calibration device touches the welding surface at a second surface location.

3. The welding training system of claim 2, wherein the computer is configured to calibrate welding surface position relative to the sensor, a welding surface orientation relative to the sensor, or any combination thereof, based at least partly on the first data set and the second data set.

4. The welding training system of claim 2, wherein the first surface location of the welding surface comprises a first aperture, and the second surface location of the welding surface comprises a second aperture, and wherein during calibration an end of the calibration device is disposed within the first aperture to produce the first data set, and the end of the calibration device is disposed within the second aperture to produce the second data set.

5. The welding training system of claim 1, wherein the calibration device comprises a handle, and a nozzle having a pointed end.

6. The welding training system of claim 1, comprising the welding surface, wherein the welding surface is a component of a training stand, and the welding surface comprises a plurality of apertures configured to interface with the calibration device to calibrate a welding surface orientation relative to the sensor, a welding surface position relative to the sensor, or any combination thereof.

7. The welding training system of claim 6, comprising a workpiece disposed on the welding surface, wherein the calibration data comprises a first data set corresponding to a first workpiece location of the workpiece touched by the calibration device when the calibration device receives the operator input prior to the simulated weld or the live weld, and a second data set corresponding to a second workpiece location of the workpiece touched by the calibration device when the calibration device receives the operator input prior to the simulated weld or the live weld.

8. The welding training system of claim 7, wherein the computer is configured to calibrate the location of the workpiece relative to the sensor based at least partly on the first data set and the second data set.

9. The welding training system of claim 1, wherein the calibration device comprises a calibration torch.

10. The welding training system of claim 1, wherein the sensor comprises a plurality of cameras.

11. A method comprising:

detecting a position and an orientation of a welding torch positioned at a first location relative to a sensor; receiving a first operator input from the welding torch when the welding torch is positioned at the first location relative to the sensor prior to a simulated weld or a live weld;

storing in a non-transitory memory the first location of the welding torch relative to the sensor, wherein storing the first location is based on receiving the first operator input;

receiving a second operator input from the welding torch when the welding torch is positioned at a second location relative to the sensor prior to the simulated weld or the live weld; and

storing in the non-transitory memory the second location of the welding torch relative to the sensor, wherein storing the second location is based on receiving the second operator input.

12. The method of claim 11, wherein the first operator input comprises a trigger pull.

13. The method of claim 11, wherein an end of the welding torch interfaces with a first surface location of a welding surface at the first location relative to the sensor.

14. The method of claim 13, wherein the first surface location of the welding surface comprises an aperture configured to receive the end of the welding torch.

15. The method of claim 11, comprising determining a position of a welding surface, determining an orientation of a welding surface, or some combination thereof based at least in part on the first location and the second location, wherein the first location corresponds to a first surface location of the welding surface that the welding torch touched while receiving the first operator input, and the second location corresponds to a second surface location of the welding surface that the welding torch touched while receiving the second operator input.

16. A method comprising:

detecting a plurality of markers of a welding calibration device *via* an optical sensor;

determining a position of the welding calibration device, an orientation of the welding calibration device, or some combination thereof based at least in part on the detected plurality of markers;

receiving a first operator input at a first time from the welding calibration device when the welding calibration device is positioned at a first location relative to the optical sensor prior to a simulated weld or a live weld;

receiving a second operator input at a second time from the welding calibration device when the welding calibration device is positioned at a second location relative to the optical sensor prior to the simulated weld or the live weld, wherein the first time is different than the second time; and

storing calibration data in a non-transitory memory based on receiving the first operator input and the second operator input prior to the simulated weld or the live weld, wherein the calibration data comprises the first location and the second location of the welding calibration device relative to the optical sensor prior to the simulated weld or the live weld and at least one of the determined position of the welding calibration device and the orientation of the welding calibration device.

17. The method of claim 16, wherein an end of the welding calibration device interfaces with a first surface location of a welding surface at the first location relative to the optical sensor.

18. The method of claim 17, wherein the first surface location of the welding surface comprises an aperture configured to receive the end of the welding calibration device.

19. The method of claim 16, wherein the optical sensor comprises a plurality of cameras.

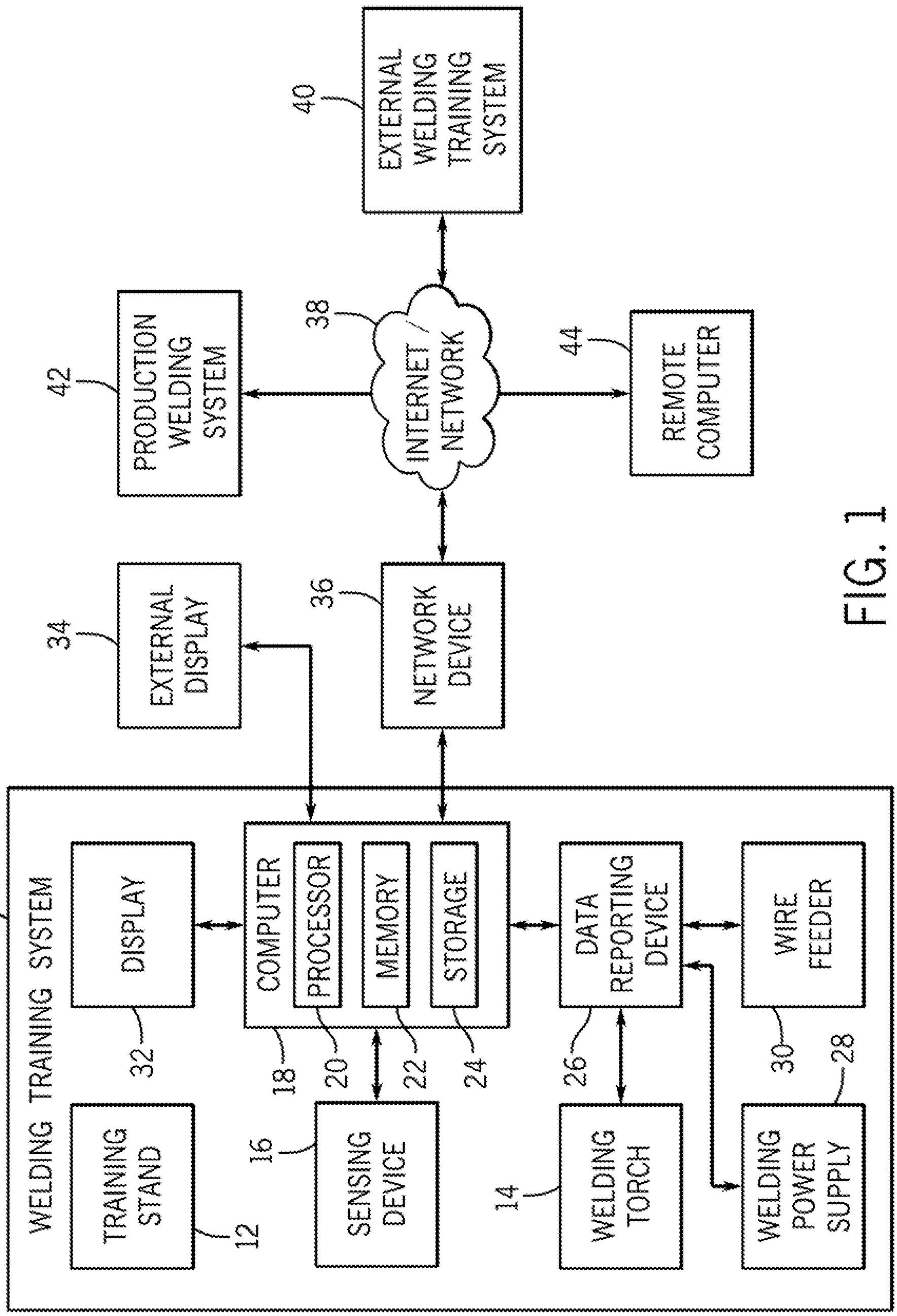
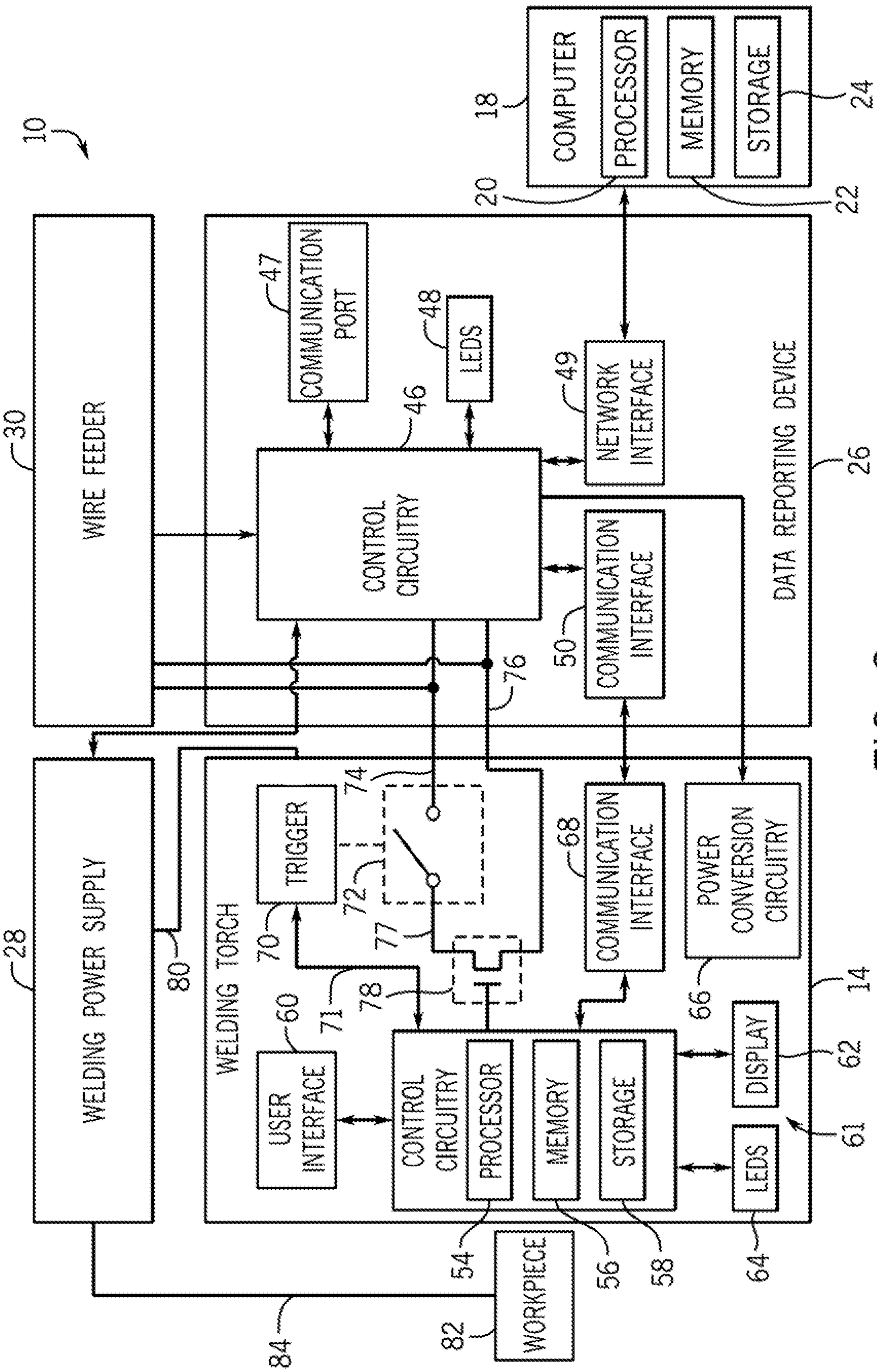

WELDING TRAINING SYSTEM
10
TRAINING STAND
12
DISPLAY
32
COMPUTER
18
PROCESSOR
20
MEMORY
22
STORAGE
24
SENSING DEVICE
16
WELDING TORCH
14
DATA REPORTING DEVICE
26
WIRE FEEDER
30
WELDING POWER SUPPLY
28
EXTERNAL DISPLAY
34
NETWORK DEVICE
36
INTERNET / NETWORK
38
PRODUCTION WELDING SYSTEM
42
REMOTE COMPUTER
44
EXTERNAL WELDING TRAINING SYSTEM
40

FIG. 1


10
COMPUTER
PROCESSOR
MEMORY
STORAGE
18
20
22
24
WIRE FEEDER
30
COMMUNICATION PORT
47
LEDS
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46
49
NETWORK INTERFACE
CONTROL CIRCUITRY
DATA REPORTING DEVICE
26
50
COMMUNICATION INTERFACE
76
WELDING POWER SUPPLY
28
80
WELDING TORCH
TRIGGER
74
72
70
77
68
COMMUNICATION INTERFACE
POWER CONVERSION CIRCUITRY
66
14
60
71
78
USER INTERFACE
73
CONTROL CIRCUITRY
PROCESSOR
MEMORY
STORAGE
DISPLAY
LEDS
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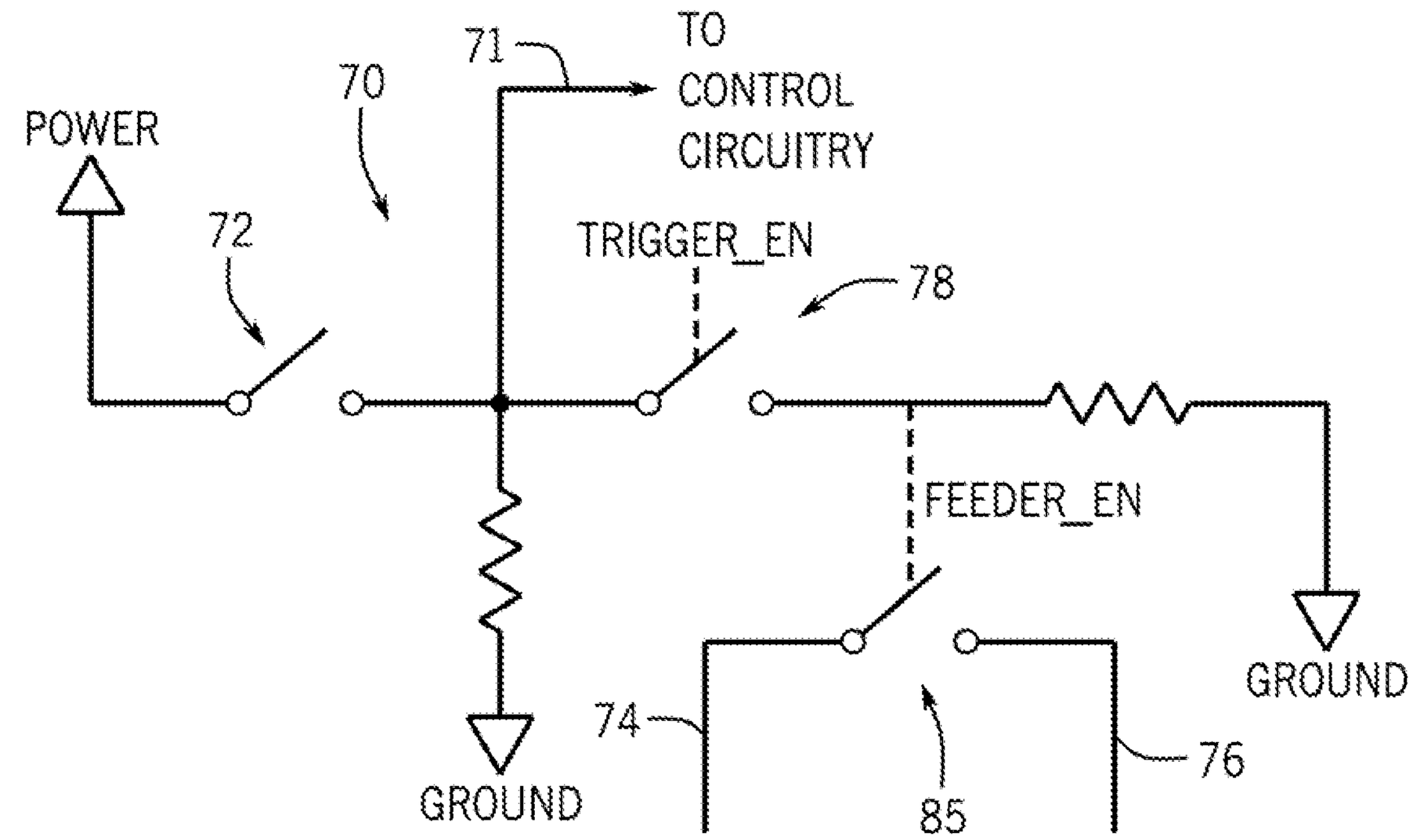
61
64
54
56
58
WORKPIECE
82
84

FIG. 2


POWER
72
70
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TO
CONTROL
CIRCUITRY
TRIGGER_EN
78
FEEDER_EN
GROUND
74
76
85
GROUND

FIG. 2A

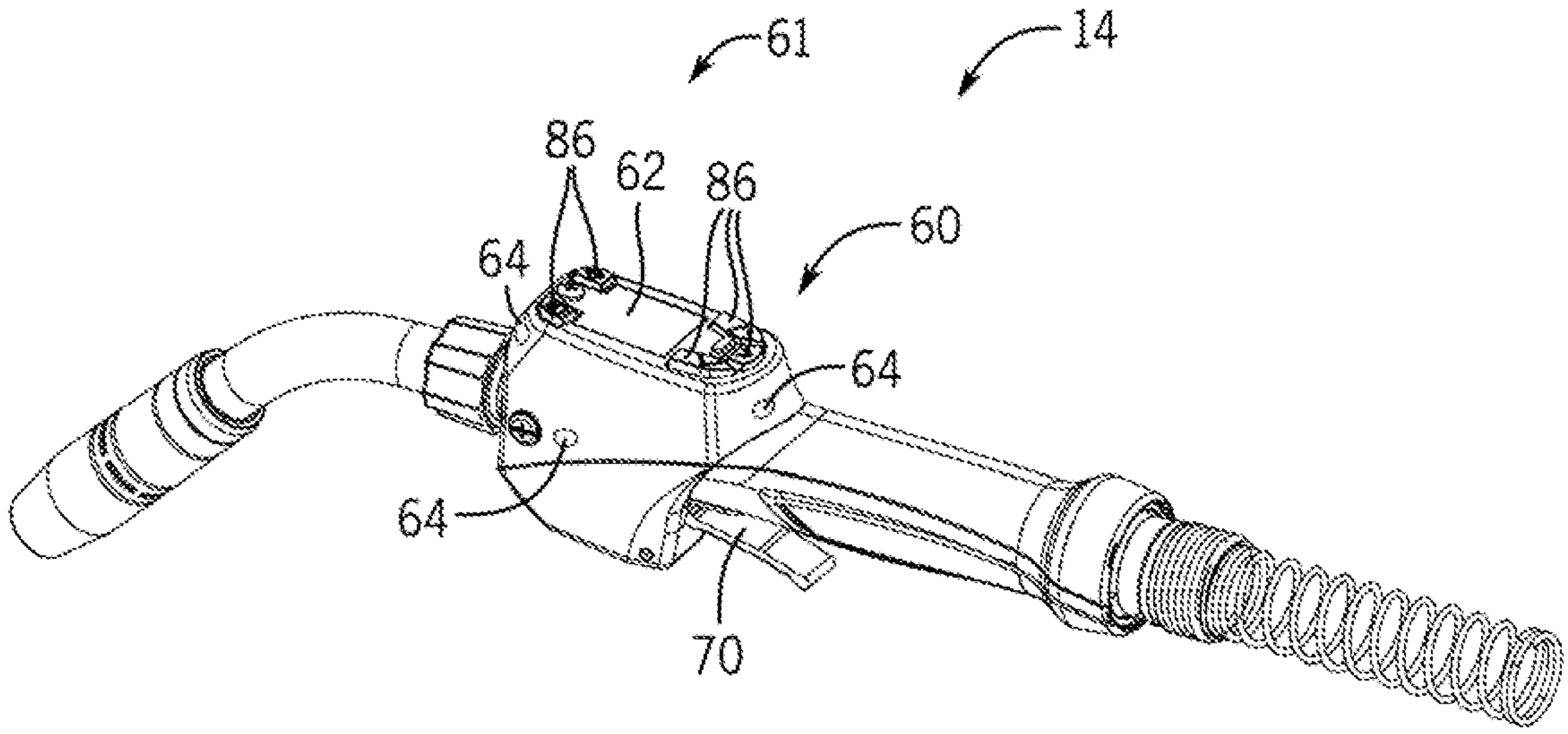
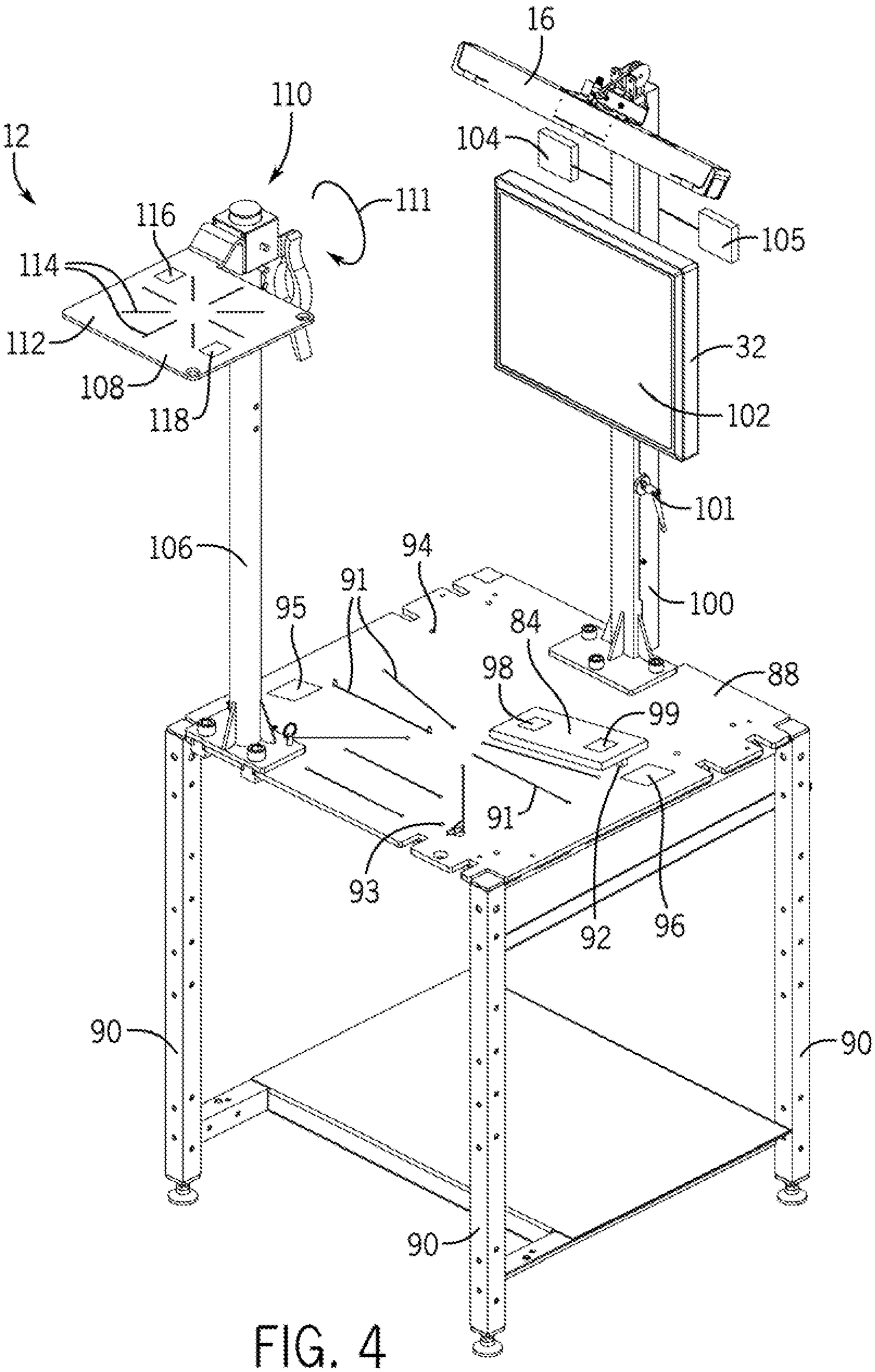

61
14
86
62
86
60
64
64
64
70

FIG. 3


16
110
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111
116
114
112
108
118
104
105
32
102
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100
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93
92
96
90
90
90

FIG. 4

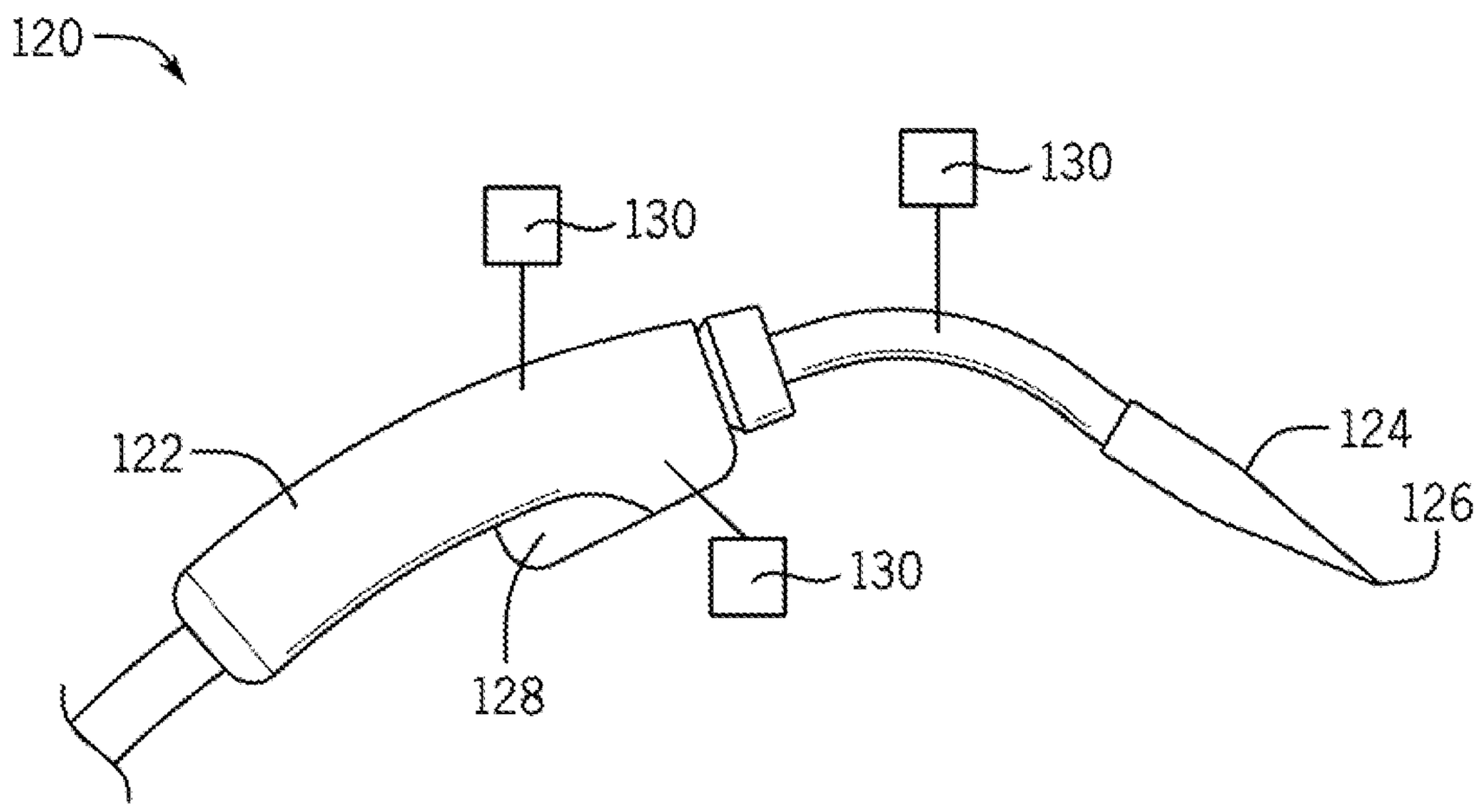


FIG. 5

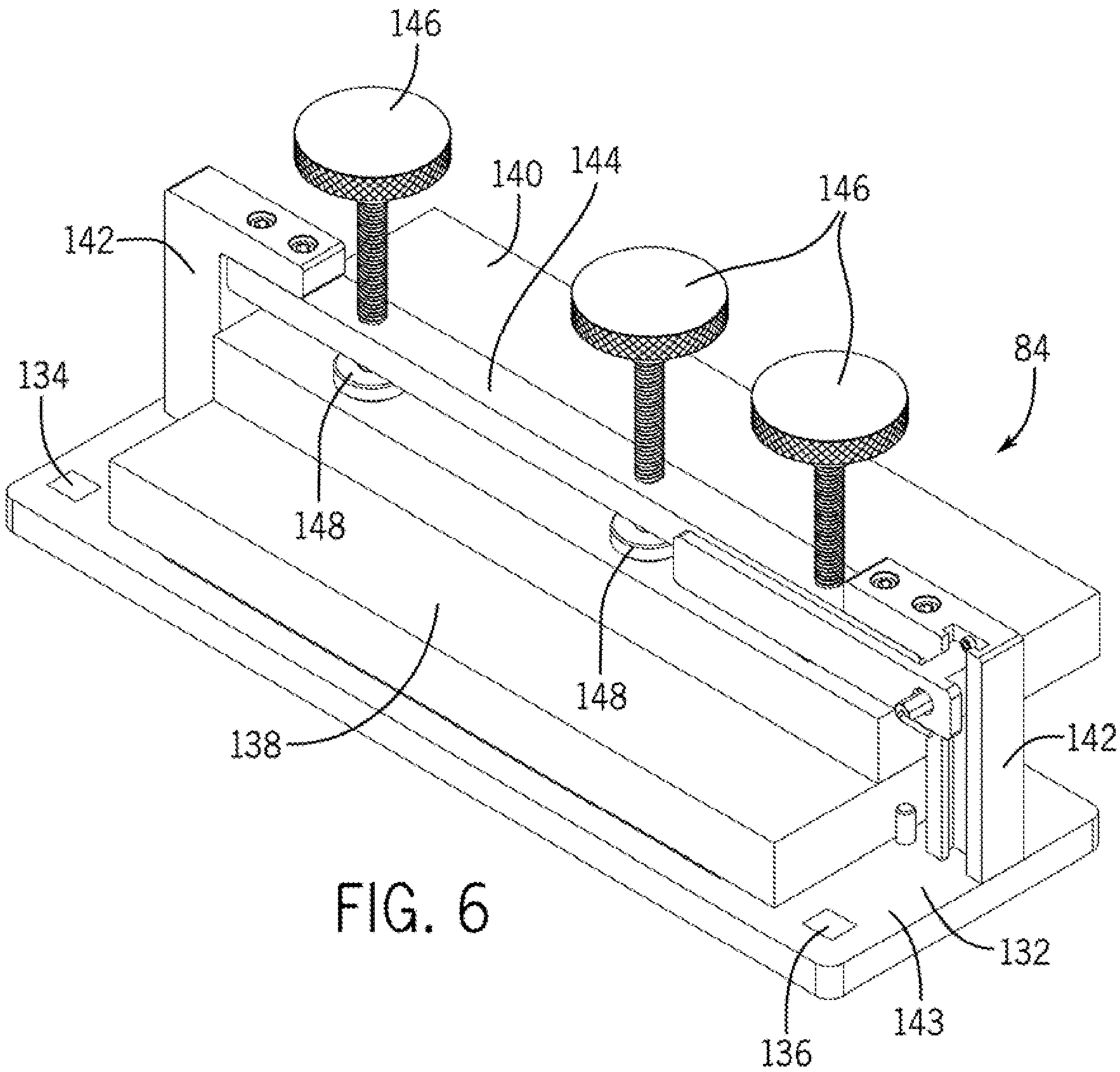


FIG. 6

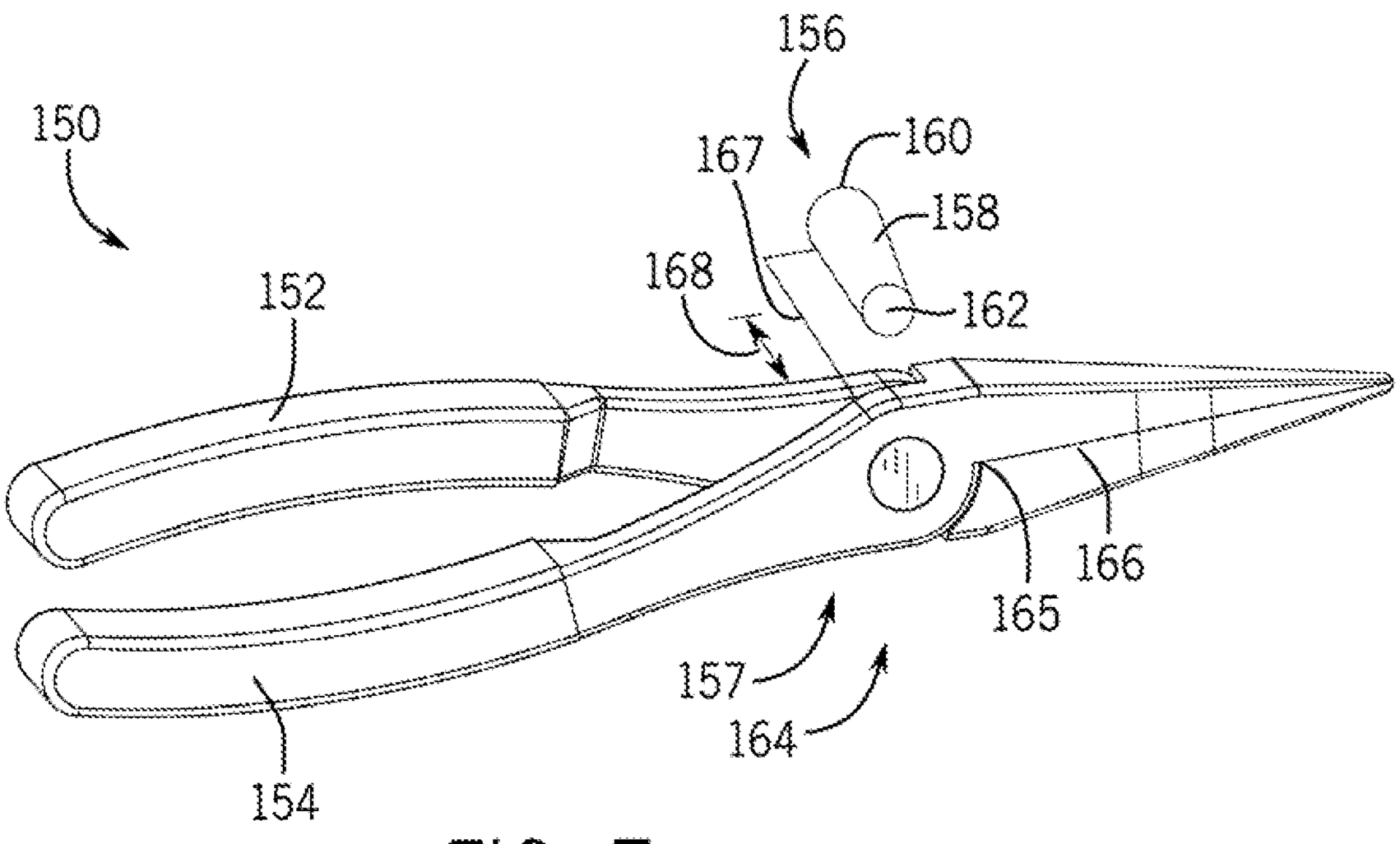

150
152
154
156
157
158
160
162
164
165
166
167
168

FIG. 7

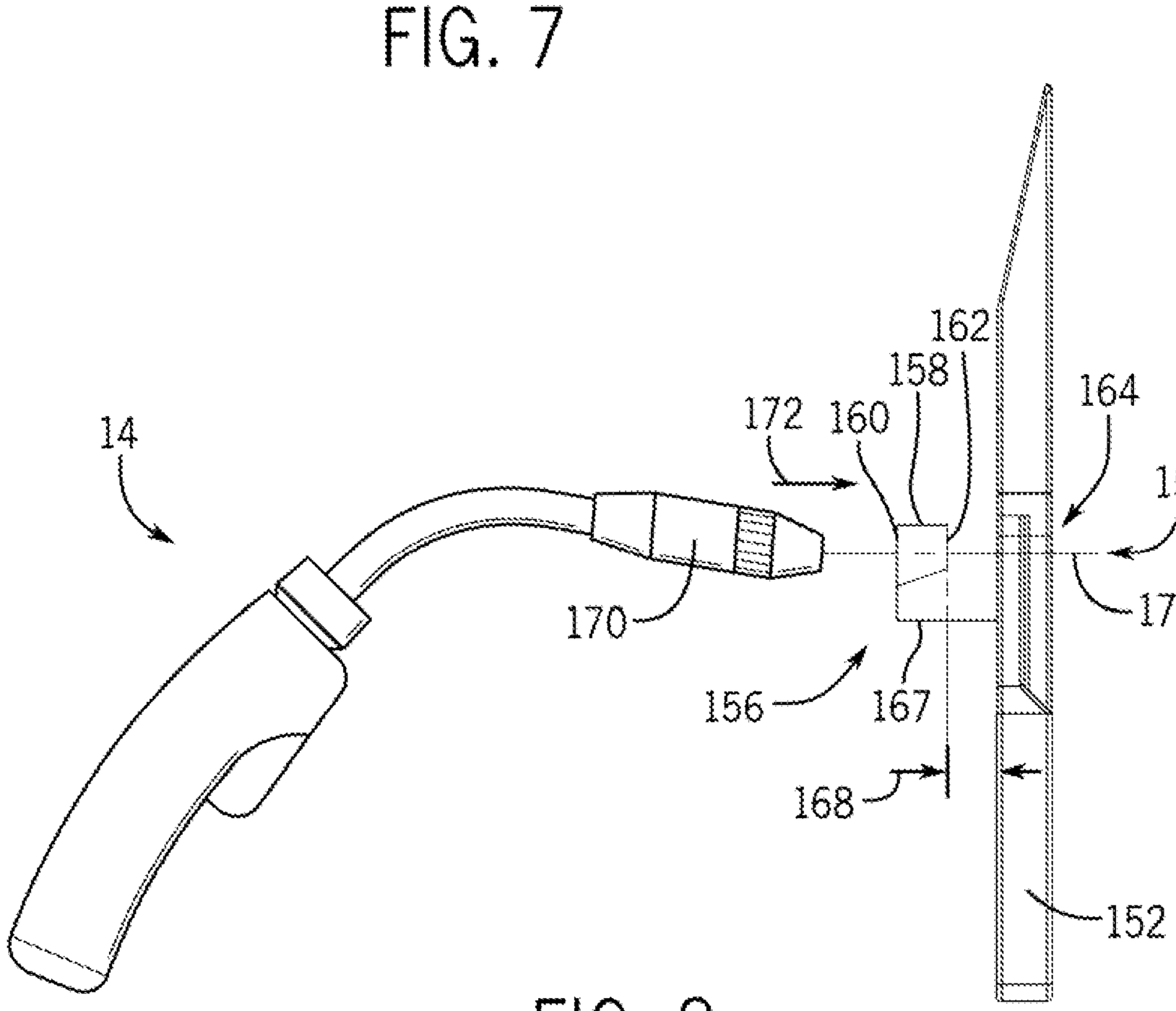

14
152
156
157
158
160
162
164
167
168
170
172
174

FIG. 8

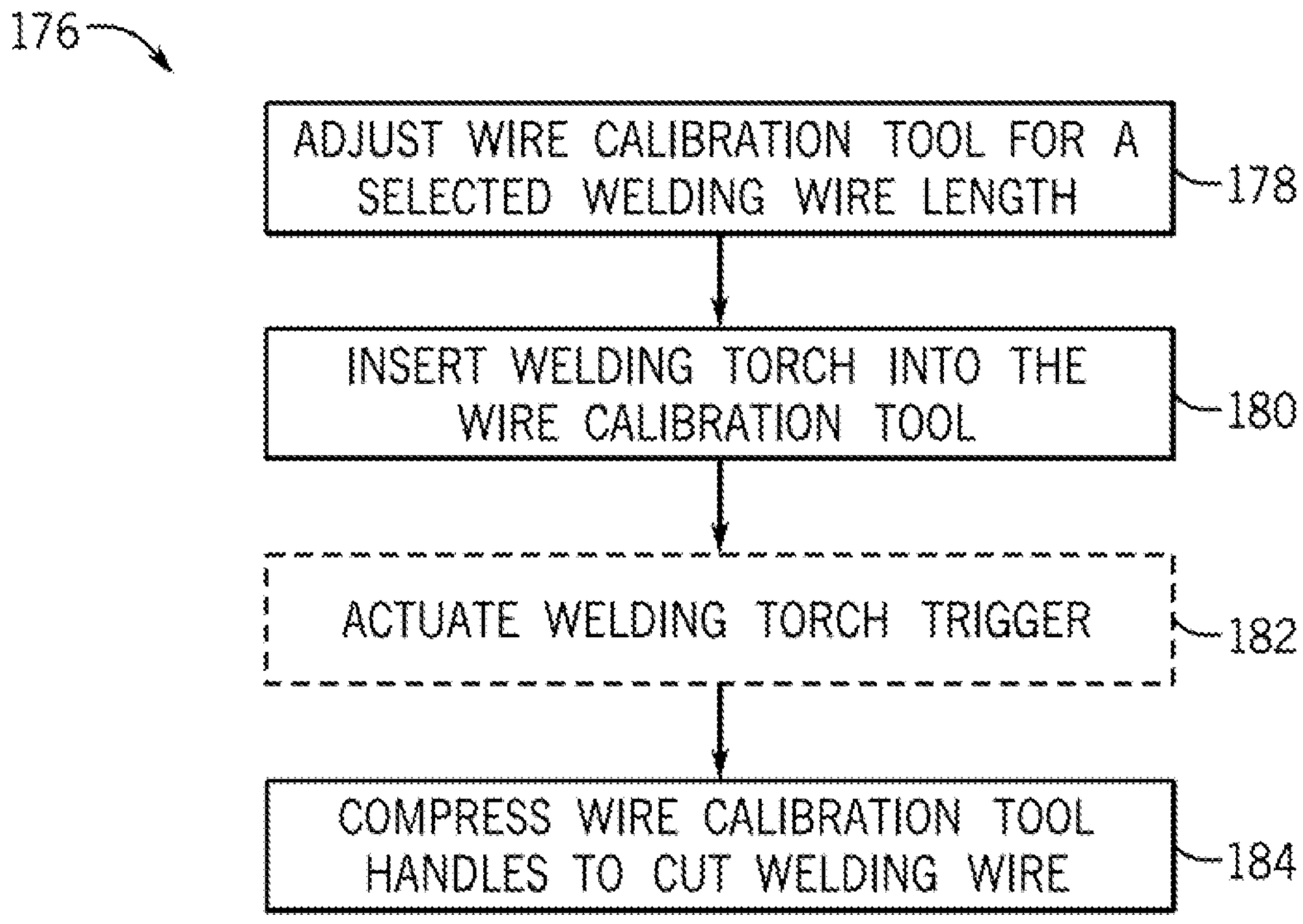

176
ADJUST WIRE CALIBRATION TOOL FOR A SELECTED WELDING WIRE LENGTH
178
INSERT WELDING TORCH INTO THE WIRE CALIBRATION TOOL
180
ACTUATE WELDING TORCH TRIGGER
182
COMPRESS WIRE CALIBRATION TOOL HANDLES TO CUT WELDING WIRE
184

FIG. 9

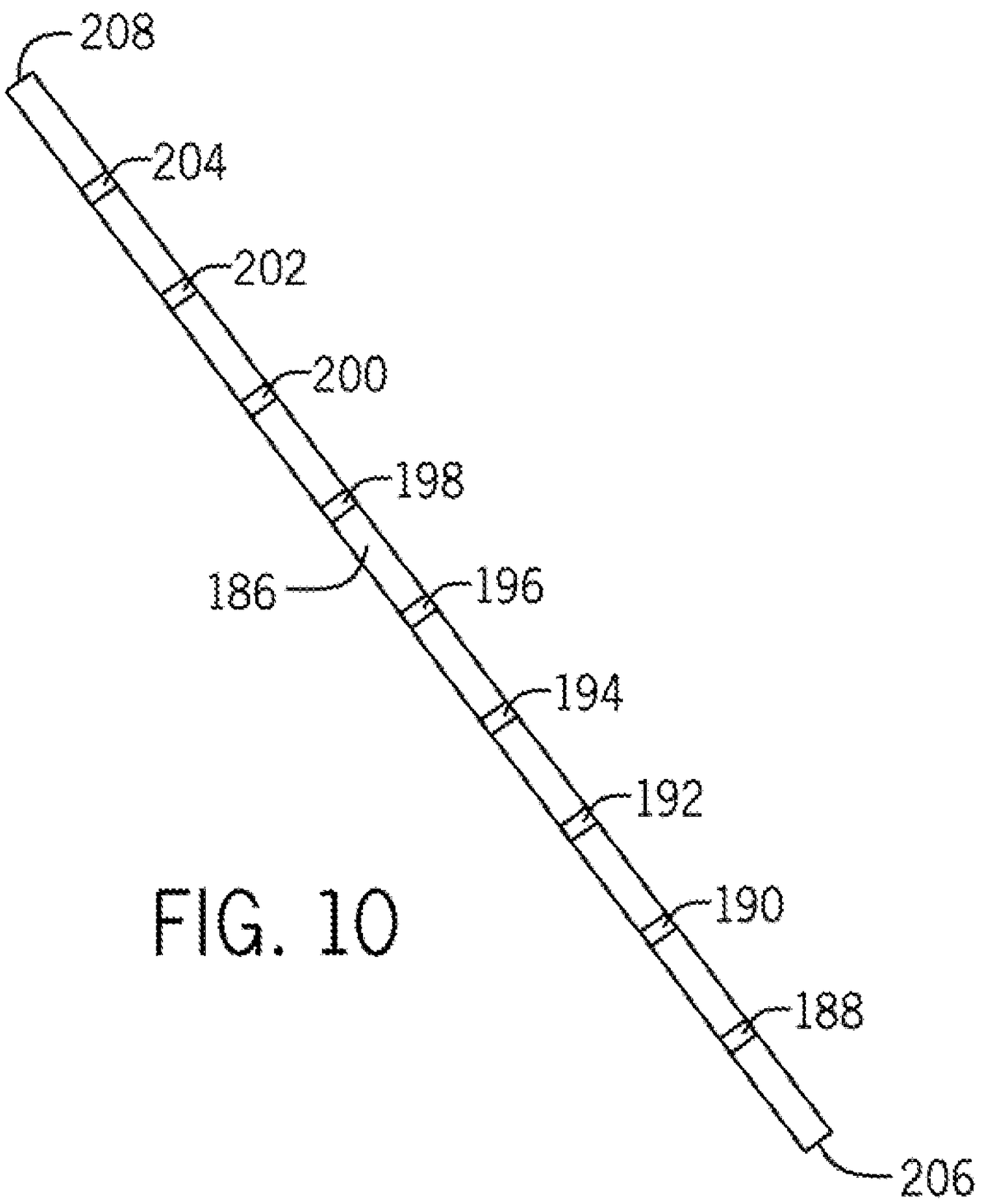

208
204
202
200
198
186
196
194
192
190
188
206

FIG. 10

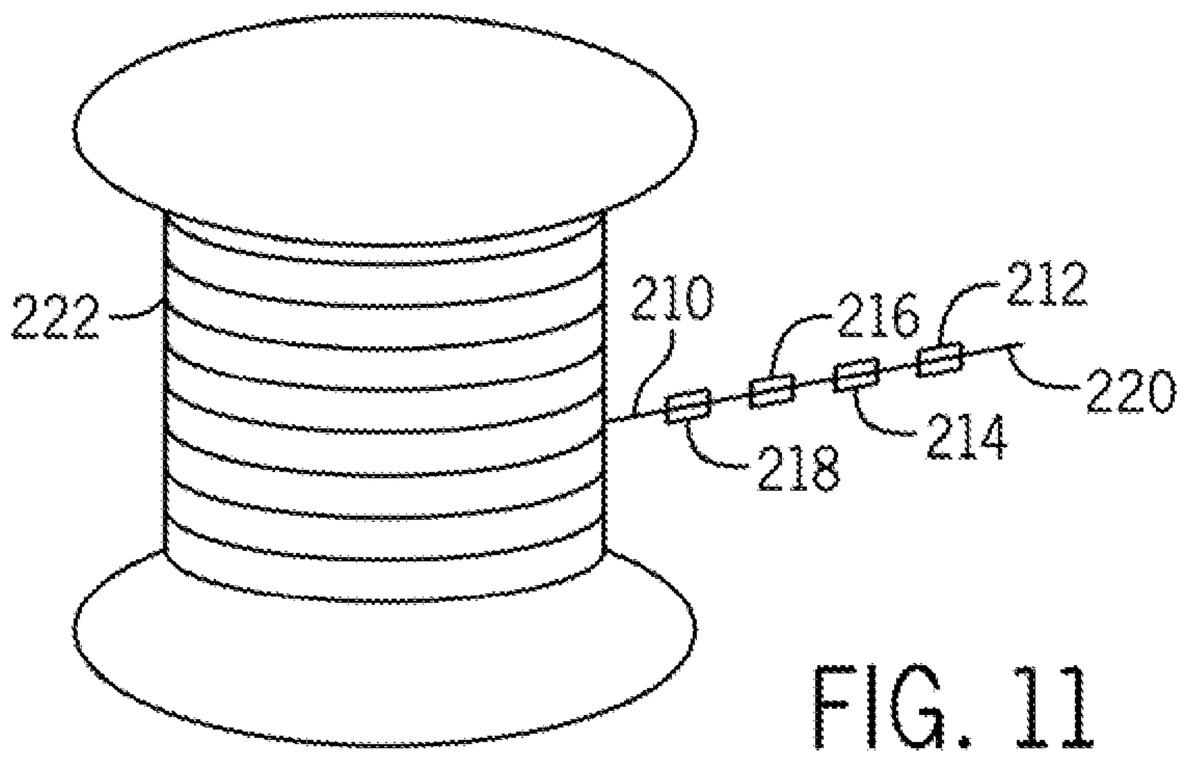

222
210
216
212
220
218
214

FIG. 11

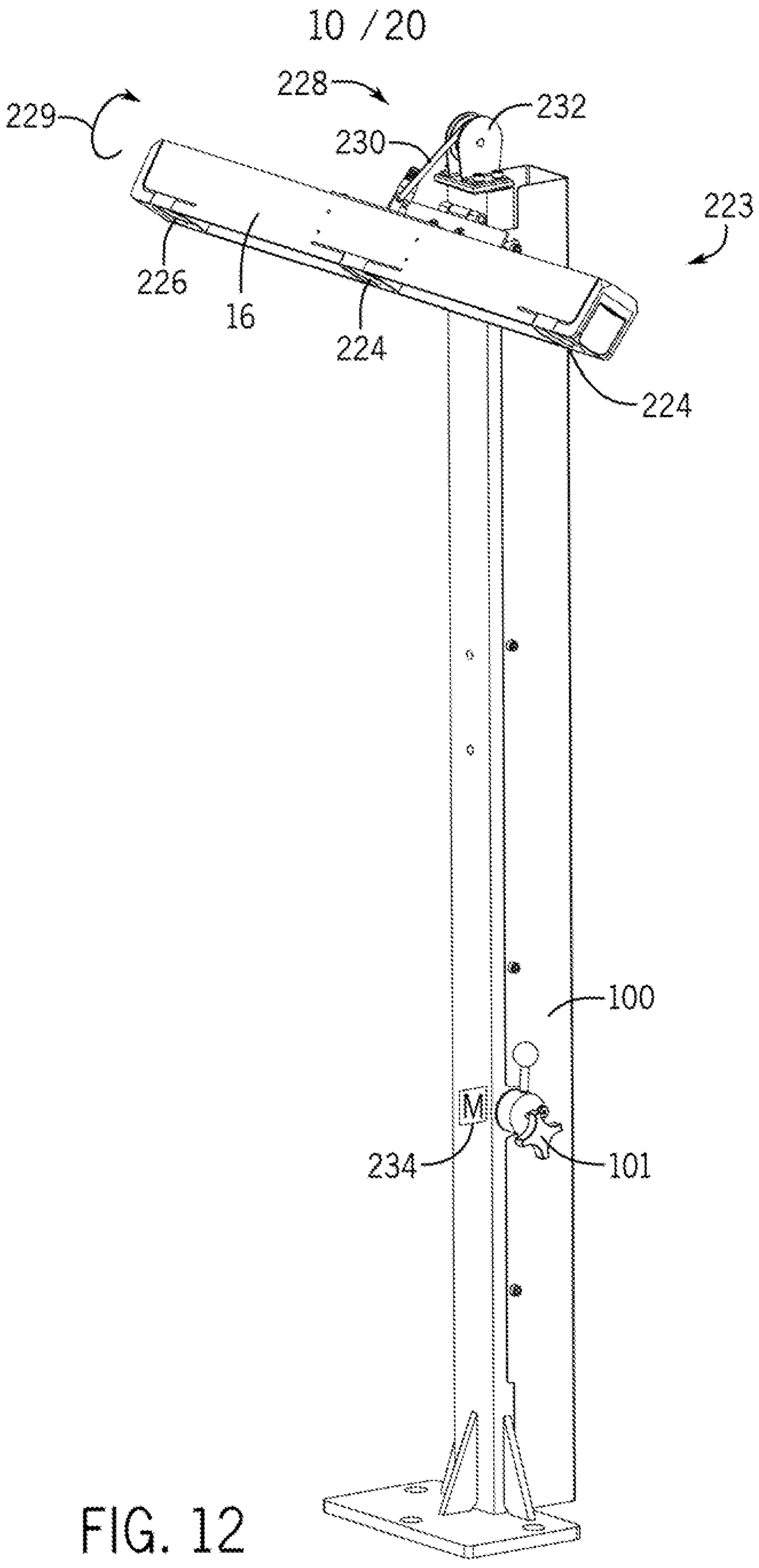


FIG. 12

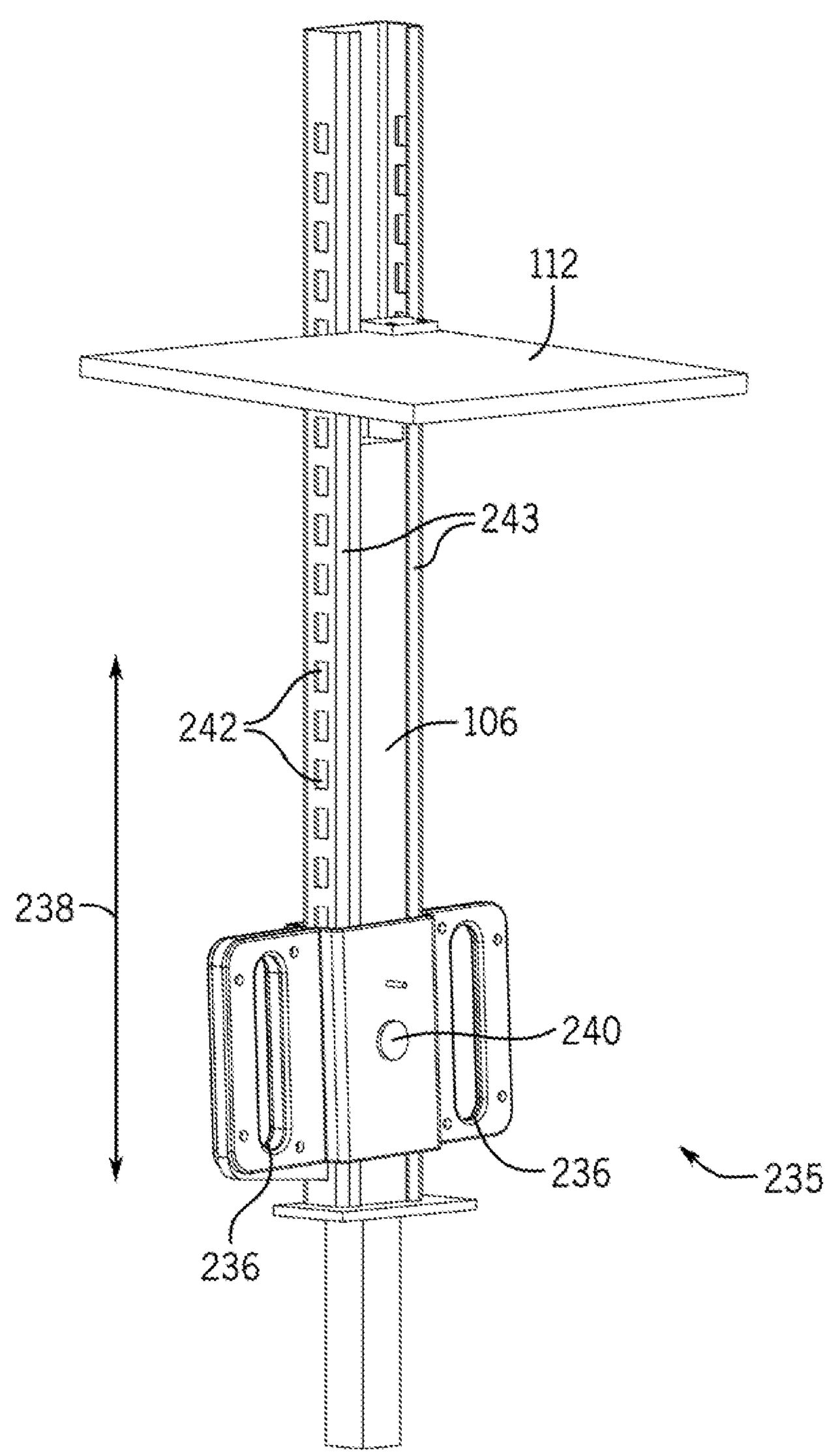


FIG. 13

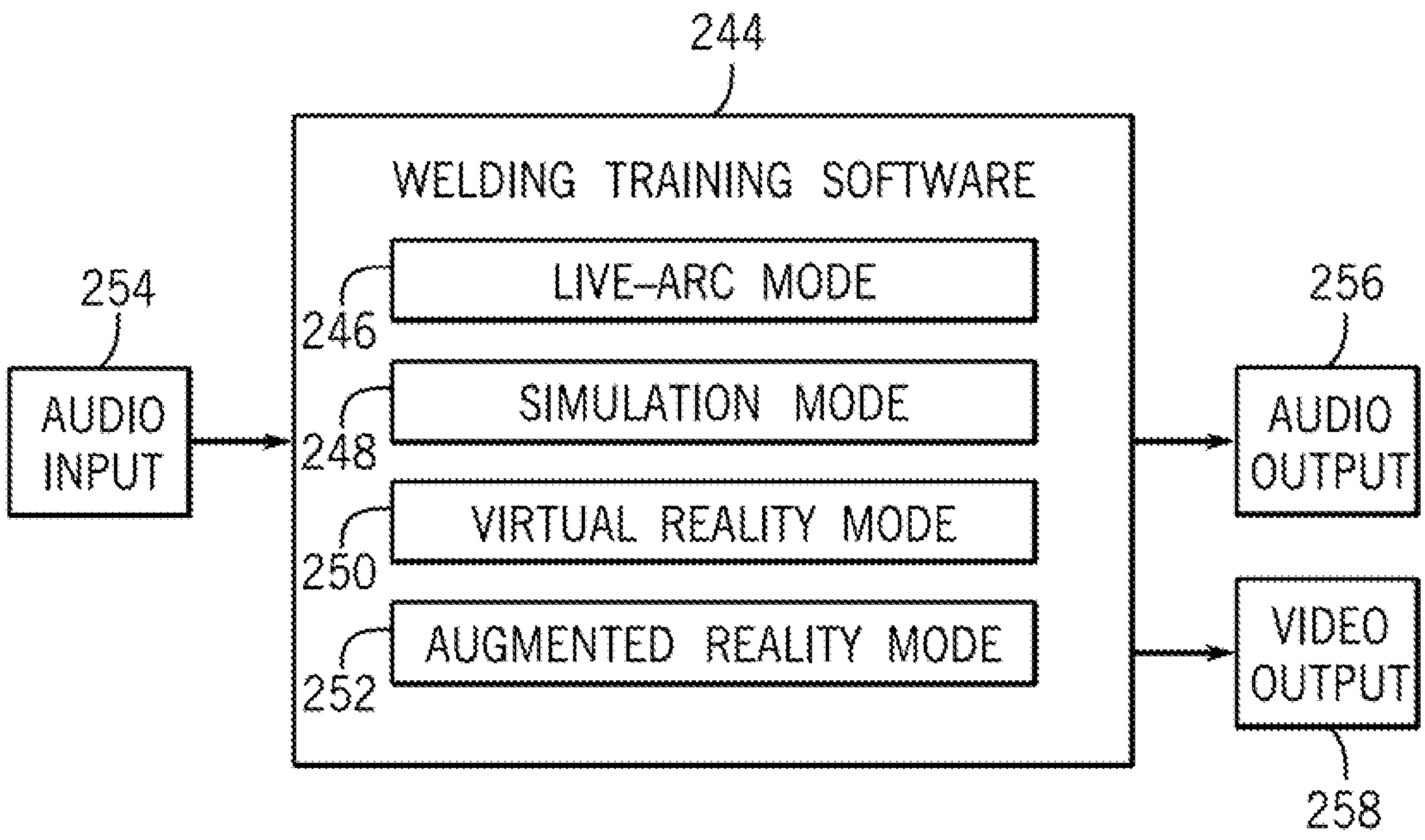

244
WELDING TRAINING SOFTWARE
254
AUDIO INPUT
246
LIVE-ARC MODE
248
SIMULATION MODE
250
VIRTUAL REALITY MODE
252
AUGMENTED REALITY MODE
256
AUDIO OUTPUT
VIDEO OUTPUT
258

FIG. 14

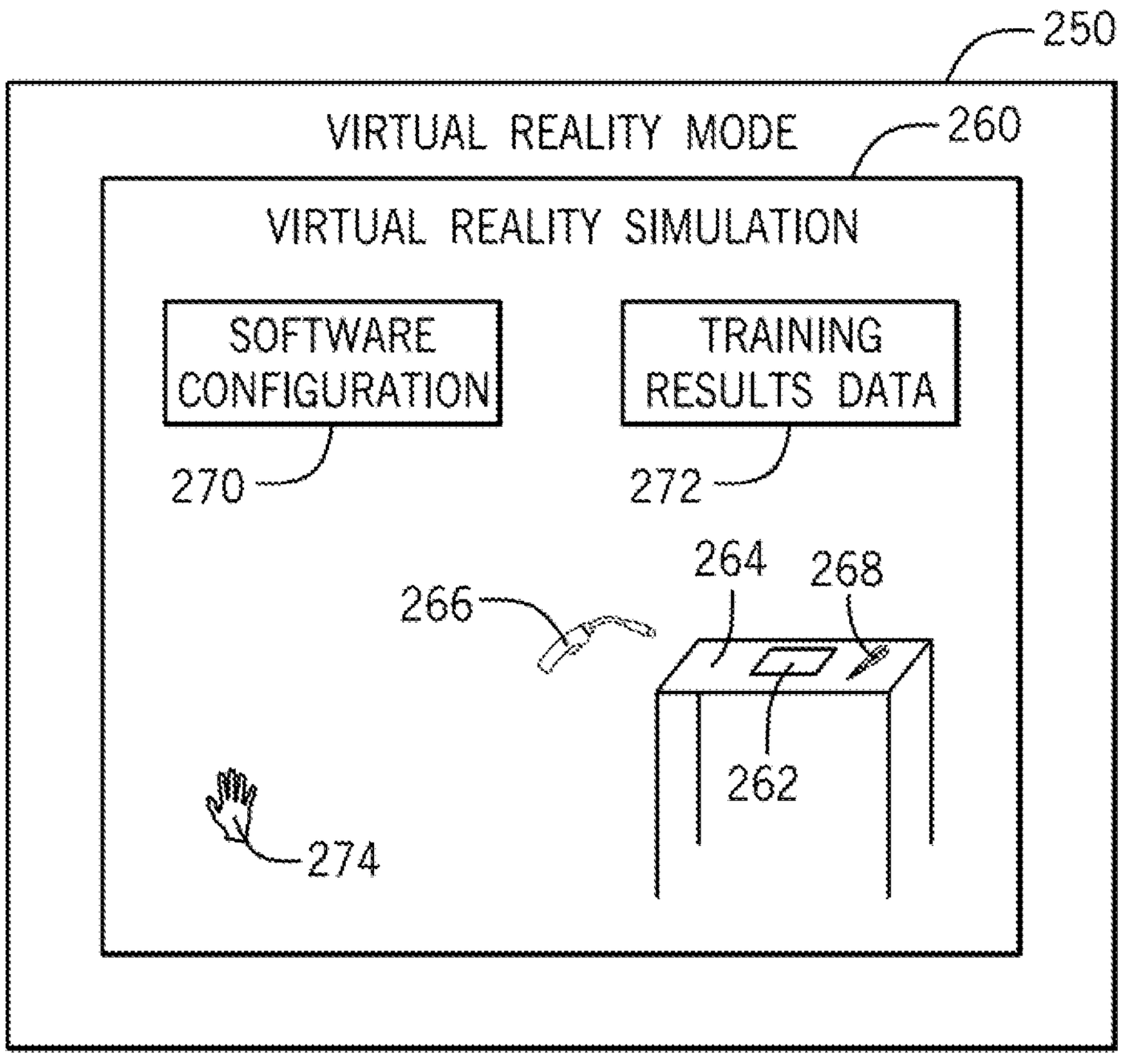

250
VIRTUAL REALITY MODE
260
VIRTUAL REALITY SIMULATION
SOFTWARE CONFIGURATION
270
TRAINING RESULTS DATA
272
264
268
266
262
274

FIG. 15

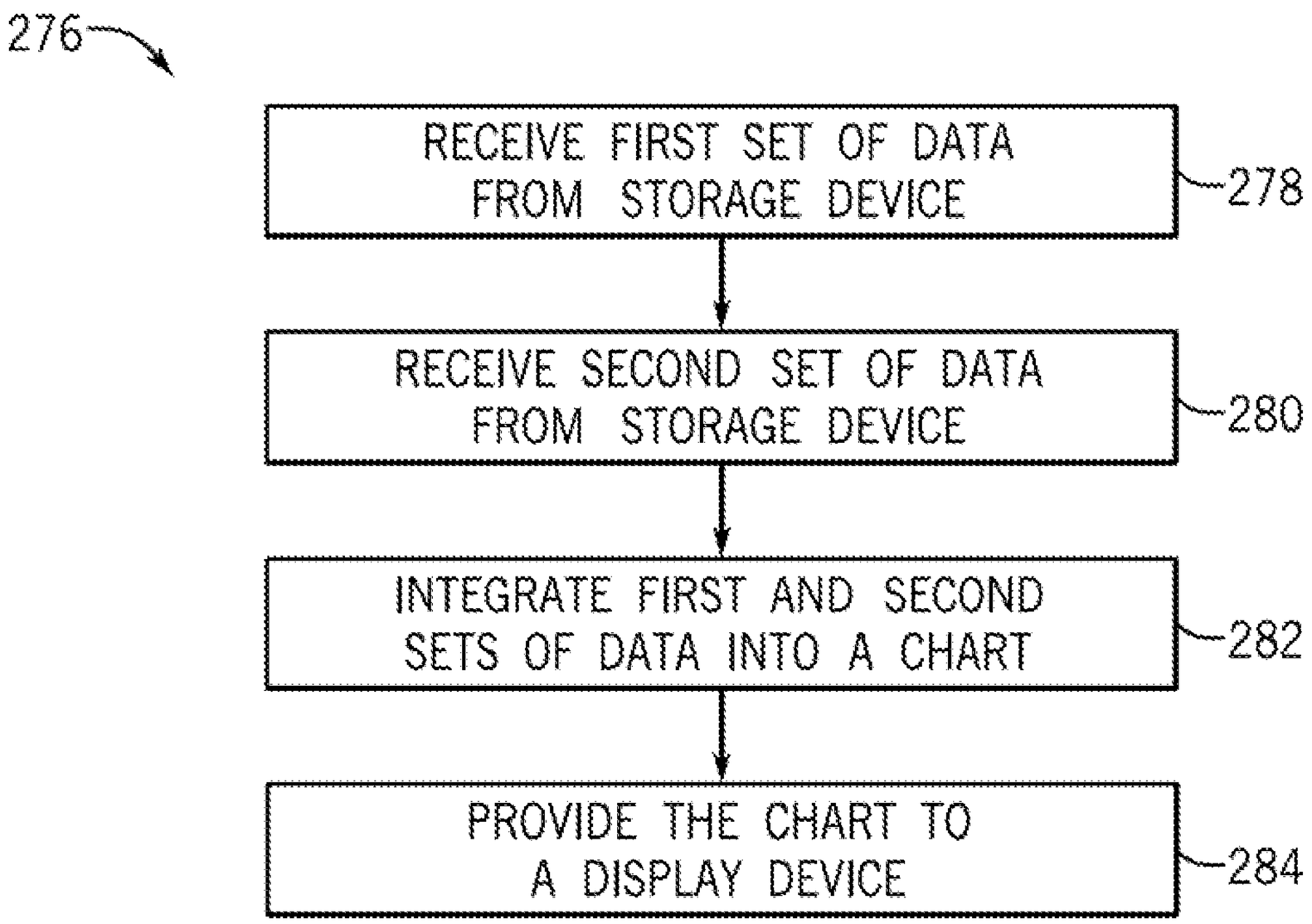

276
RECEIVE FIRST SET OF DATA FROM STORAGE DEVICE
278
RECEIVE SECOND SET OF DATA FROM STORAGE DEVICE
280
INTEGRATE FIRST AND SECOND SETS OF DATA INTO A CHART
282
PROVIDE THE CHART TO A DISPLAY DEVICE
284

FIG. 16

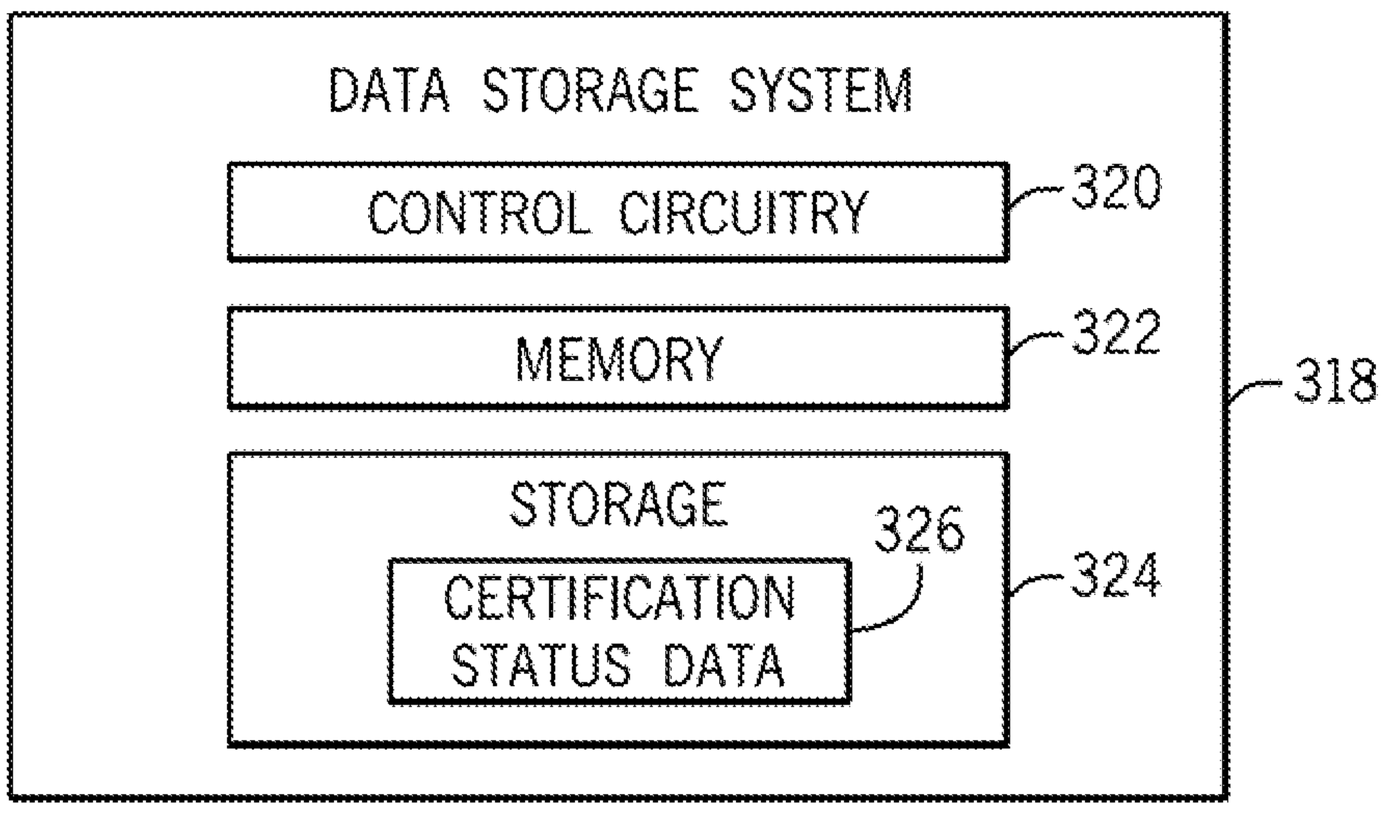

DATA STORAGE SYSTEM
CONTROL CIRCUITRY
320
MEMORY
322
318
STORAGE
326
CERTIFICATION STATUS DATA
324

FIG. 19

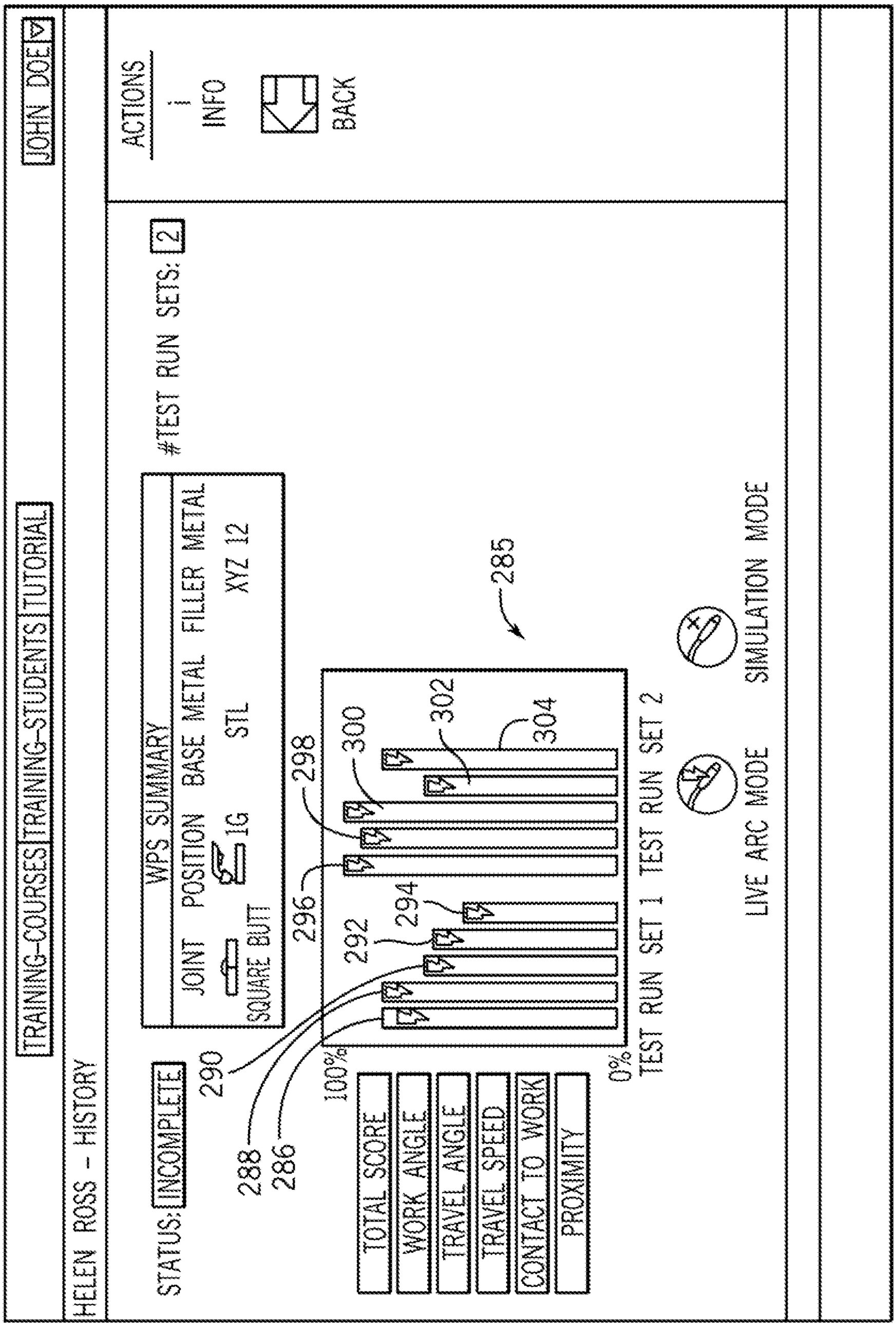

JOHN DOE
ACTIONS
INFO
BACK
TRAINING–COURSES
TRAINING–STUDENTS
TUTORIAL
#TEST RUN SETS: 2
WPS SUMMARY
JOINT
POSITION
BASE METAL
FILLER METAL
XYZ 12
STL
1G
SQUARE BUTT
285
298
300
302
304
296
292
294
290
288
286
100%
0%
TEST RUN SET 1
TEST RUN SET 2
LIVE ARC MODE
SIMULATION MODE
HELEN ROSS – HISTORY
STATUS: INCOMPLETE
TOTAL SCORE
WORK ANGLE
TRAVEL ANGLE
TRAVEL SPEED
CONTACT TO WORK
PROXIMITY

FIG. 17

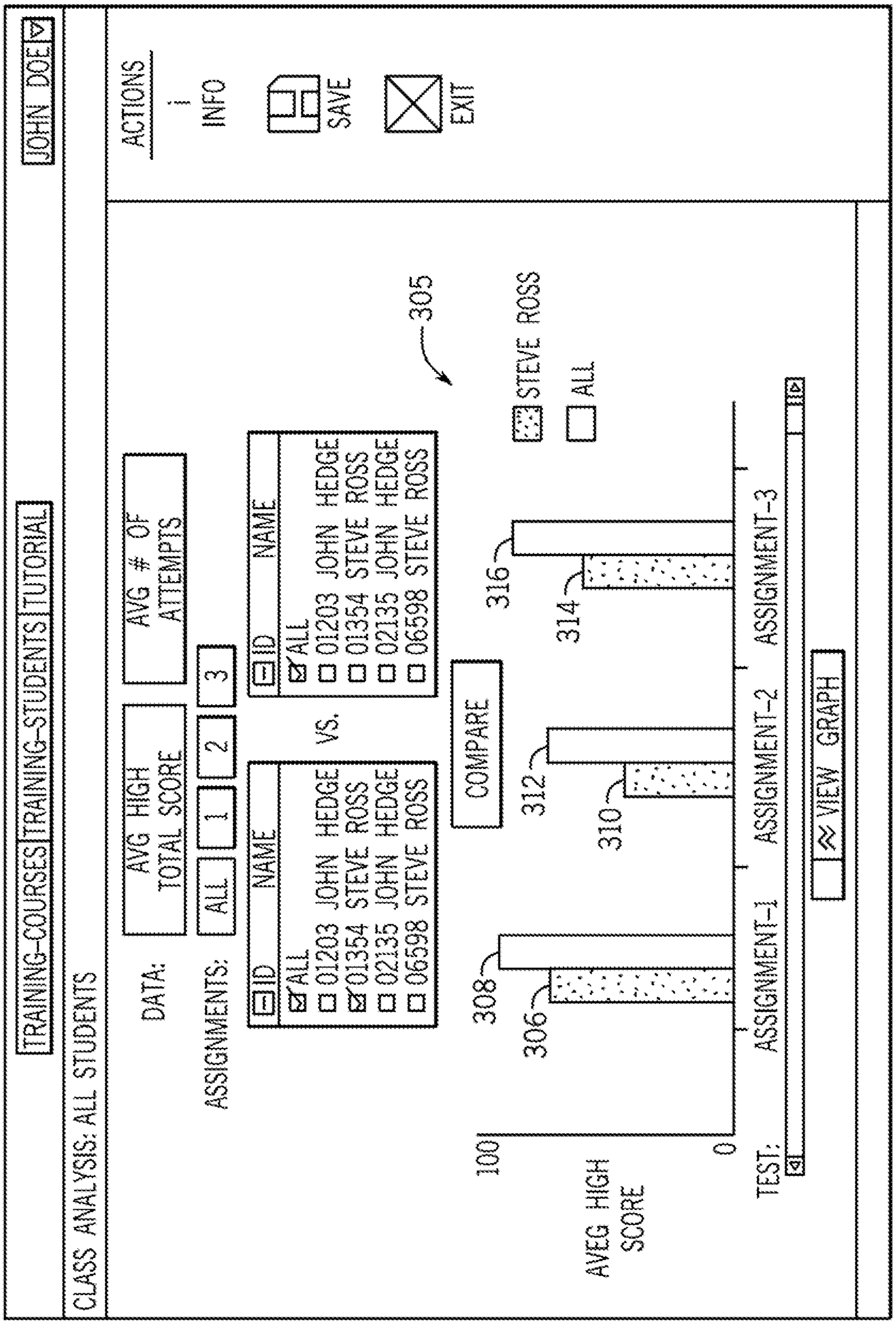

JOHN DOE
ACTIONS
INFO
SAVE
EXIT
TRAINING–COURSES
TRAINING–STUDENTS
TUTORIAL
CLASS ANALYSIS: ALL STUDENTS
DATA:
AVG HIGH TOTAL SCORE
AVG # OF ATTEMPTS
ASSIGNMENTS:
ALL
1
2
3
ID
NAME
ALL
01203 JOHN HEDGE
01354 STEVE ROSS
02135 JOHN HEDGE
06598 STEVE ROSS
305
VS.
STEVE ROSS
ALL
COMPARE
316
314
312
310
308
306
100
0
ASSIGNMENT-1
ASSIGNMENT-2
ASSIGNMENT-3
VIEW GRAPH
AVEG HIGH SCORE
TEST:

FIG. 18

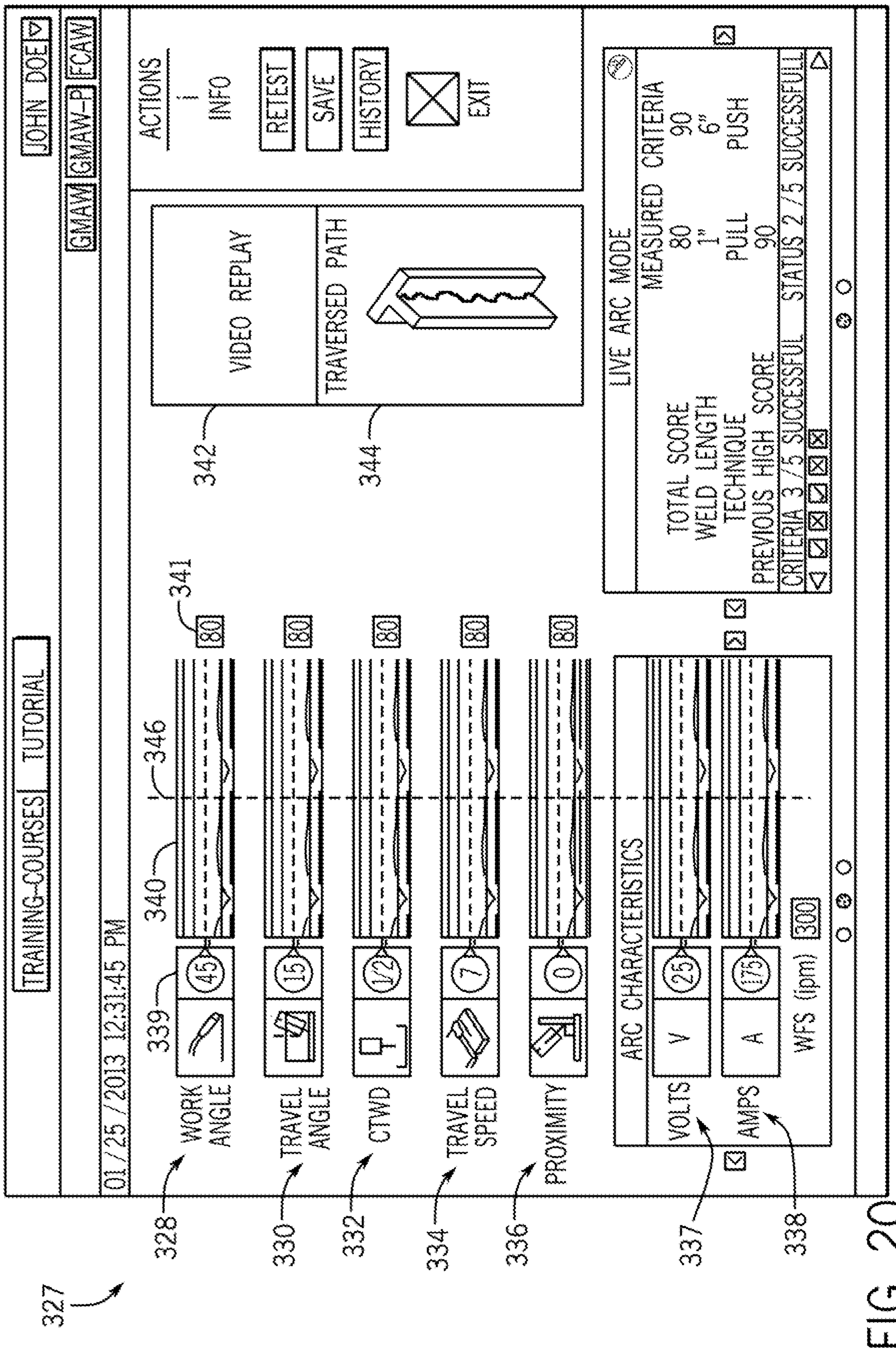

JOHN DOE
GMAW
GMAW-P
FCAW
TRAINING-COURSES
TUTORIAL
01/25/2013 12:31:45 PM
ACTIONS
INFO
RETEST
SAVE
HISTORY
EXIT
VIDEO REPLAY
TRAVERSED PATH
342
344
341
LIVE ARC MODE
MEASURED CRITERIA
TOTAL SCORE 80 90
WELD LENGTH 1" 6"
TECHNIQUE PULL PUSH
PREVIOUS HIGH SCORE 90
CRITERIA 3/5 SUCCESSFUL STATUS 2/5 SUCCESSFUL
339
340
346
ARC CHARACTERISTICS
WFS (ipm) 300
WORK ANGLE
TRAVEL ANGLE
CTWD
TRAVEL SPEED
PROXIMITY
VOLTS
AMPS
328
330
332
334
336
337
338
327

FIG. 20

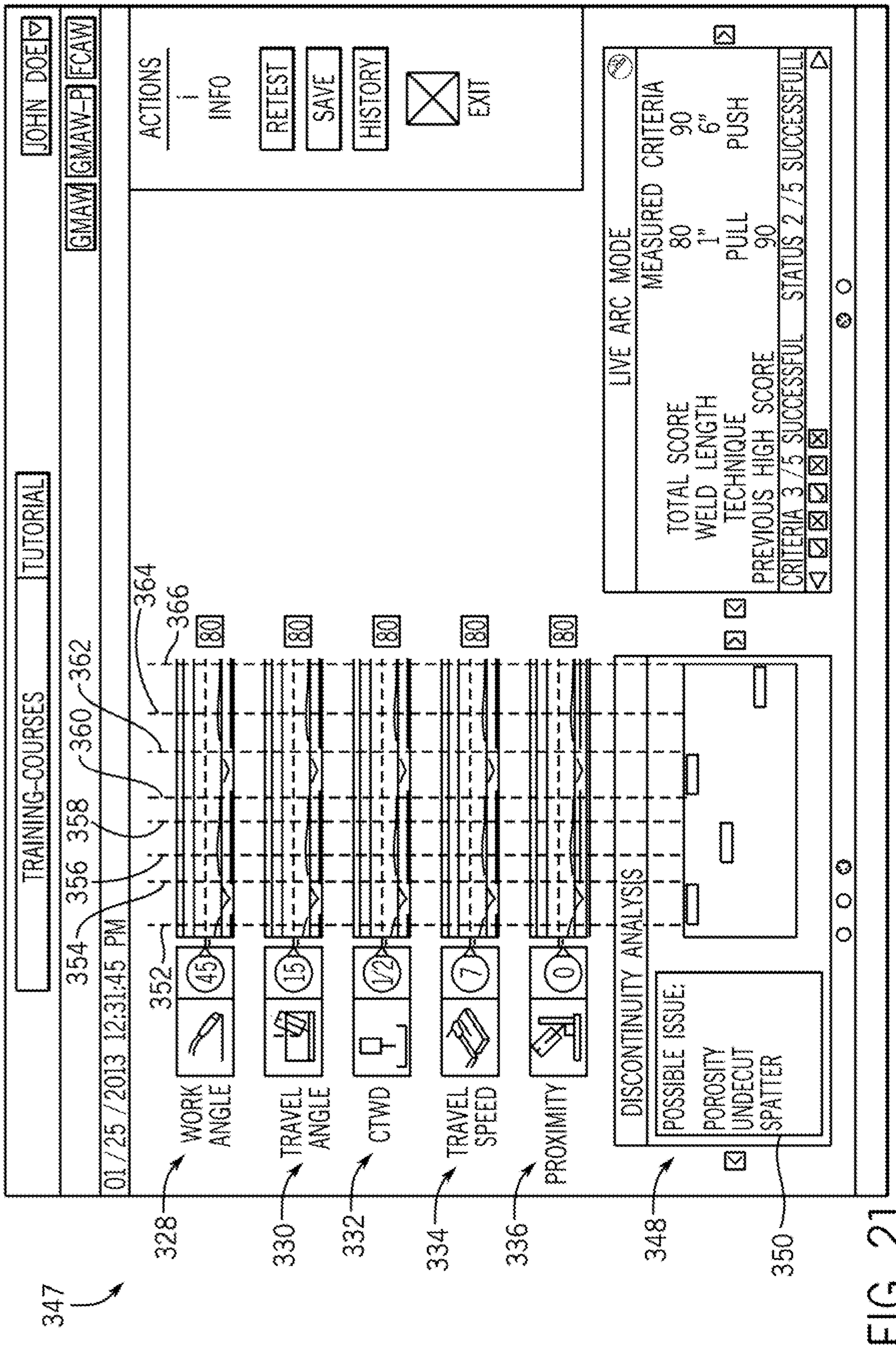

JOHN DOE
GMAW-P
FCAW
ACTIONS
INFO
RETEST
SAVE
HISTORY
EXIT
TUTORIAL
TRAINING-COURSES
01/25/2013 12:31:45 PM
LIVE ARC MODE
MEASURED CRITERIA
TOTAL SCORE 80 90
WELD LENGTH 1" 6"
TECHNIQUE PULL PUSH
PREVIOUS HIGH SCORE 90
CRITERIA 3/5 SUCCESSFUL STATUS 2/5 SUCCESSFULL
362
360
358
356
354
352
364
366
WORK ANGLE
TRAVEL ANGLE
CTWD
TRAVEL SPEED
PROXIMITY
DISCONTINUITY ANALYSIS
POSSIBLE ISSUE:
POROSITY
UNDERCUT
SPATTER
328
330
332
334
336
348
350
347

FIG. 21

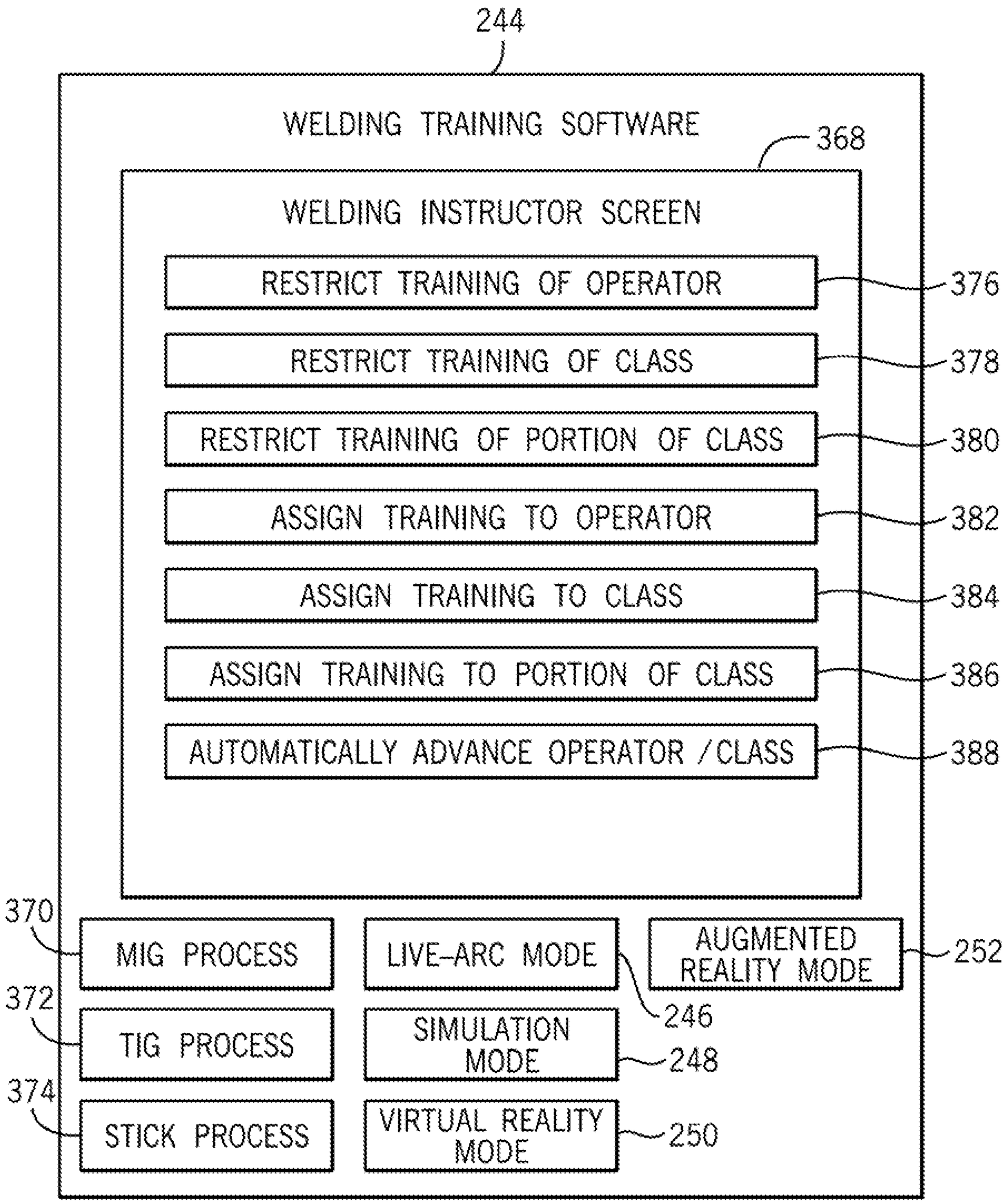

244
WELDING TRAINING SOFTWARE
368
WELDING INSTRUCTOR SCREEN
RESTRICT TRAINING OF OPERATOR
376
RESTRICT TRAINING OF CLASS
378
RESTRICT TRAINING OF PORTION OF CLASS
380
ASSIGN TRAINING TO OPERATOR
382
ASSIGN TRAINING TO CLASS
384
ASSIGN TRAINING TO PORTION OF CLASS
386
AUTOMATICALLY ADVANCE OPERATOR / CLASS
388
370
MIG PROCESS
372
TIG PROCESS
374
STICK PROCESS
LIVE-ARC MODE
246
SIMULATION MODE
248
VIRTUAL REALITY MODE
250
AUGMENTED REALITY MODE
252

FIG. 22

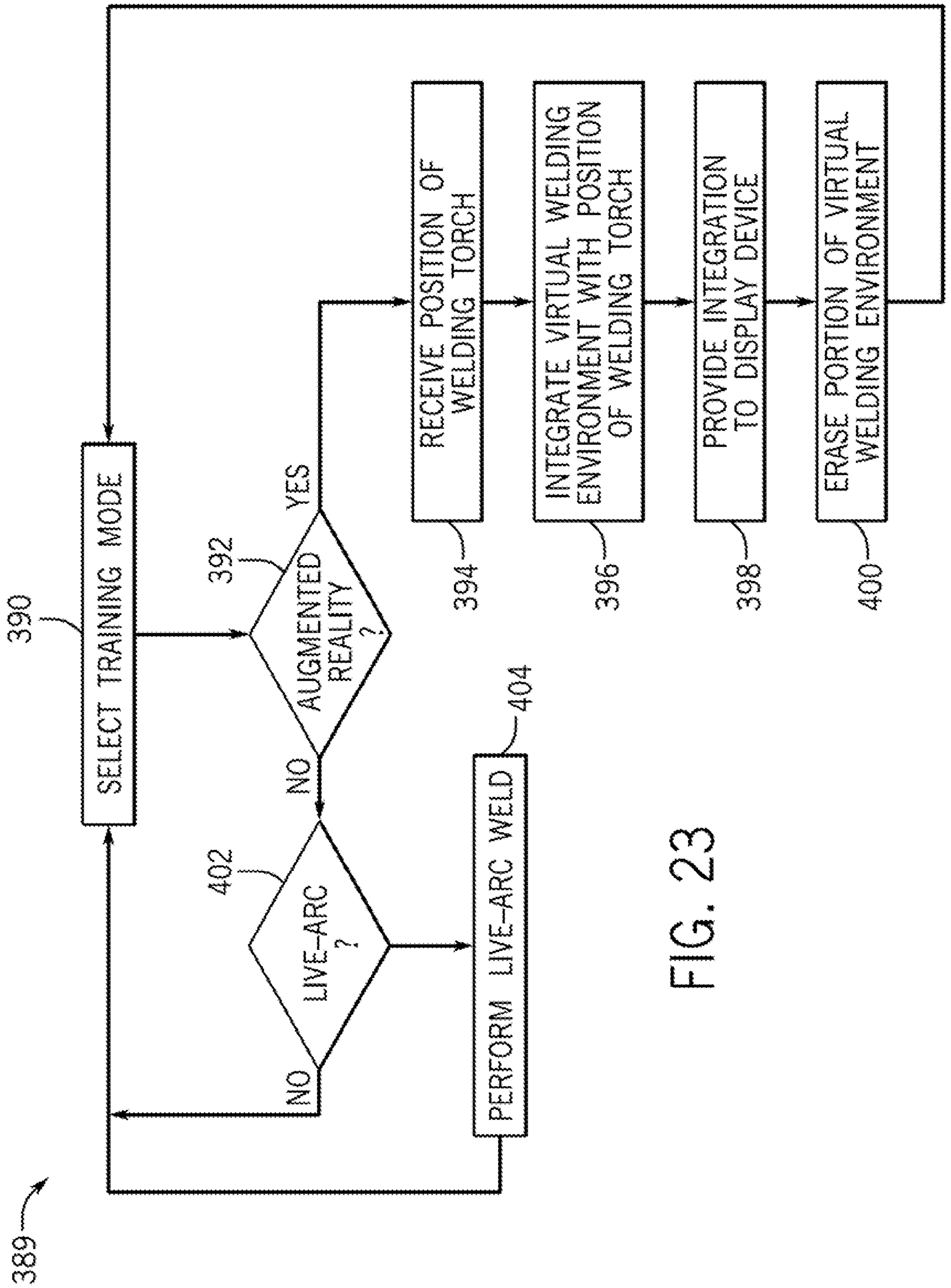

389
390
SELECT TRAINING MODE
392
AUGMENTED REALITY ?
YES
NO
394
RECEIVE POSITION OF WELDING TORCH
396
INTEGRATE VIRTUAL WELDING ENVIRONMENT WITH POSITION OF WELDING TORCH
398
PROVIDE INTEGRATION TO DISPLAY DEVICE
400
ERASE PORTION OF VIRTUAL WELDING ENVIRONMENT
402
LIVE–ARC ?
NO
404
PERFORM LIVE–ARC WELD

FIG. 23

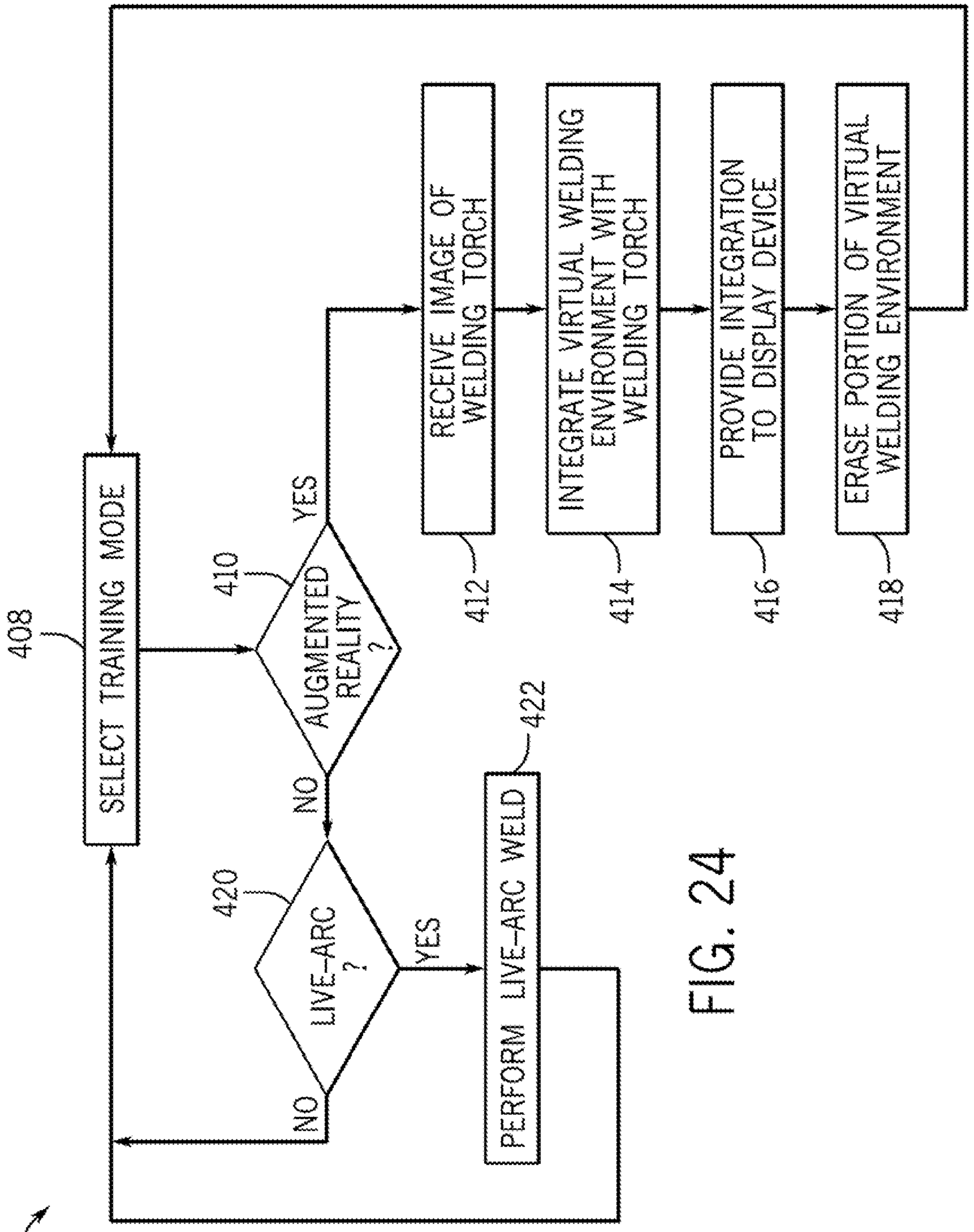
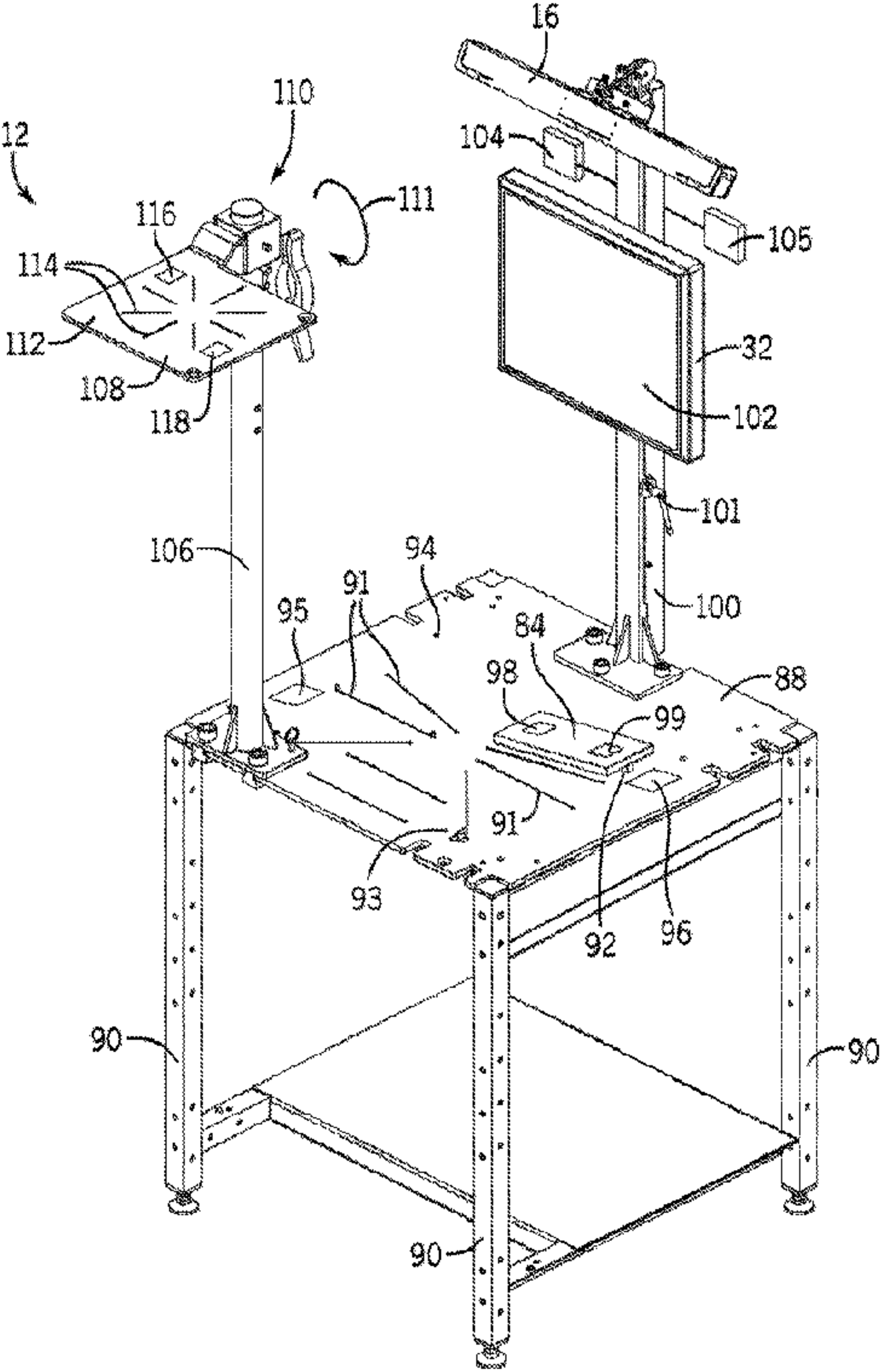

406
408
SELECT TRAINING MODE
410
AUGMENTED REALITY ?
YES
NO
412
RECEIVE IMAGE OF WELDING TORCH
414
INTEGRATE VIRTUAL WELDING ENVIRONMENT WITH WELDING TORCH
416
PROVIDE INTEGRATION TO DISPLAY DEVICE
418
ERASE PORTION OF VIRTUAL WELDING ENVIRONMENT
420
LIVE–ARC ?
YES
NO
422
PERFORM LIVE–ARC WELD

FIG. 24


16
110
12
104
111
116
105
114
32
112
102
108
101
118
106
94
91
100
95
84
98
88
99
91
93
92
96
90
90
90