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Robotic wire termination system

Abstract

A robotic wire termination system for efficiently and accurately connecting a plurality of wires to an electrical connector having a plurality of connector pins with corresponding wire receptacles. The system generally includes a housing, a removable alignment plate, a robotic positioner, a heating device, a touch responsive display, and a control unit. The alignment plate removably holds a selected electrical connector in a specific position and orientation with the connector pins exposed in the housing and the wire receptacles exposed outside. The display provides a visual representation of the connector pins and selections of the connector pins. The control unit receives inputs indicating the pin selections and controls the robotic positioner to sequentially move the heating device along three orthogonal longitudinal axes to a series of heating positions relative to the selected connector pins to provide heat for melting solder to connect wires to the wire receptacles.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
3418544	12/1967	France	N/A	N/A
3608190	12/1970	Steranko	N/A	N/A
4332083	12/1981	Johnson, Jr.	N/A	N/A
4632294	12/1985	Druschel	N/A	N/A
4774760	12/1987	Seaman	N/A	N/A
4842184	12/1988	Miller, Jr.	N/A	N/A
4987283	12/1990	Beinhaur	N/A	N/A
5092035	12/1991	McMichen	N/A	N/A
5145104	12/1991	Apap	N/A	N/A
5163856	12/1991	McGaffigan	N/A	N/A
5269056	12/1992	Yang	N/A	N/A
5634821	12/1996	Crane, Jr.	N/A	N/A
5651178	12/1996	Sasse	N/A	N/A
5782401	12/1997	Hinrichs	N/A	N/A
5808259	12/1997	Spinner	N/A	N/A
6137075	12/1999	Grabkowski	N/A	N/A
6142787	12/1999	Ikesugi	N/A	N/A
6179631	12/2000	Downes	N/A	N/A
6224399	12/2000	Yacoub	N/A	N/A
6266870	12/2000	Wollermann	N/A	N/A
6392888	12/2001	Chen	N/A	N/A
6818839	12/2003	Hosaka	N/A	N/A
6822867	12/2003	Hsieh	N/A	N/A
6887104	12/2004	Lee	N/A	N/A
6945814	12/2004	Snape	N/A	N/A
6974615	12/2004	Hosaka	N/A	N/A
7973239	12/2010	Koyama	N/A	N/A
9190795	12/2014	Johnson	N/A	N/A

9629259	12/2016	Hart	N/A	N/A
9904259	12/2017	Bando	N/A	N/A
10239164	12/2018	Johnson	N/A	N/A
2002/0077003	12/2001	Northey	N/A	N/A
2002/0179692	12/2001	Tung	N/A	N/A
2002/0190107	12/2001	Shah	N/A	N/A
2004/0144834	12/2003	Nomoto	N/A	N/A
2004/0232204	12/2003	Wolf	N/A	N/A
2008/0155823	12/2007	Heinzel	N/A	N/A
2008/0280495	12/2007	Ko	N/A	N/A
2009/0080140	12/2008	Iyer	N/A	N/A
2010/0038358	12/2009	Dingle	N/A	N/A
2011/0113626	12/2010	Ng	N/A	N/A
2011/0124215	12/2010	Yin	N/A	N/A
2011/0308850	12/2010	Ni	N/A	N/A
2014/0201989	12/2013	Paynter	N/A	N/A
2014/0298898	12/2013	Yang	N/A	N/A
2015/0077962	12/2014	Mirpuri	N/A	N/A
2015/0098178	12/2014	Otake	N/A	N/A
2015/0107103	12/2014	Johnson	N/A	N/A
2015/0202706	12/2014	Brosnan	N/A	N/A
2015/0229088	12/2014	Johnson	N/A	N/A
2015/0290736	12/2014	Zhang	N/A	N/A
2016/0207131	12/2015	Endress	N/A	N/A
2017/0100795	12/2016	Wu	N/A	N/A
2018/0272479	12/2017	Hori	N/A	N/A
2019/0123463	12/2018	Lee	N/A	N/A
2020/0036148	12/2019	Huang	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	**Application Date**	**Country**	**CPC**
1499678	12/1977	GB	N/A
56102370	12/1980	JP	N/A
02309581	12/1989	JP	N/A
2012084686	12/2011	JP	N/A
200291242	12/2001	KR	N/A
09921676	12/1998	WO	N/A

OTHER PUBLICATIONS

PCT International Search Report and Written Opinion for PCT/US2015/0271111; Received Jul. 30, 2015. cited by applicant
PCT International Preliminary Report on Patentability and Written Opinion for PCT/US2015/0271111; Received Nov. 2, 2017. cited by applicant

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) The present application is a continuation application of U.S. Application Ser. No. 17/985,298 filed on Nov. 11, 2022, which is a continuation of U.S. application Ser. No. 17/121,034 filed on Dec. 14, 2020 now issued as U.S. Pat. No. 11,502,470, which is a continuation of U.S. application Ser. No. 16/809,378 filed on Mar. 4, 2020 now issued as U.S. Pat. No. 10,868,401. Each of the aforementioned patent applications is herein incorporated by reference in their entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT
(1) Not applicable to this application.
BACKGROUND
Field
(2) Example embodiments in general relate to a robotic wire termination system for accurately and efficiently connecting the ends of a plurality of wires to an electrical connector.
Related Art
(3) Any discussion of the related art throughout the specification should in no way be considered as an admission that such related art is widely known or forms part of common general knowledge in the field.
(4) There are various types of electrical connectors used today including but not limited to fine wire terminations, pinned connectors, terminal blocks, plug and socket connectors, medical connectors, transition devices and custom connectors. Conventional electrical connectors include a plurality of connector pins that are intended to be connected to the ends of a corresponding plurality of wires of a cable, typically by soldering. The ends of the wires are connected and soldered to the connector pins according to a pinout which cross-references the wires to the connector pins. Typically, technicians manually connect each individual wire to a corresponding connector pin on the electrical connector. The number of connector pins on a connector can range from 2 to greater than 100 connector pins each of which receives the end of a corresponding wire.
(5) Medical probes typically have numerous connector pins within an electrical connector to which the ends of a corresponding number of fine wires are to be connected and soldered. For example, modern catheters may contain more than 120 40-gauge wires connecting medical transducers. A skilled technician manually connects the end of each of the fine wires to a corresponding connector pin on the electrical connector utilizing a soldering device (e.g. soldering iron or soldering gun). The technician must identify a fine wire and a corresponding connector pin to which the end of the fine wire will be connected. After identifying the proper connection point, the technician must then position the end of the fine wire adjacent to the connector pin and then heat the solder with the soldering device to melt the solder on both the fine wire and the connector pin. The technician then removes the soldering device, causing the melted solder to solidify thereby physically and electrically connecting the fine wire to the connector pin. The technician must manually repeat this process for each individual fine wire and corresponding connector pin until all of the fine wires are connected to corresponding connector pins.
(6) As can be appreciated, the manual process of locating and soldering a plurality of wires to an electrical connector is labor intensive, time consuming, costly, and creates a significant amount of discarded material. Moreover, the process is prone to error. Errors by technicians soldering wires to electrical connectors are common with error rates approaching 25% with some medical connectors where the wires are very thin and a large number of connections are typically to be made. For example, a technician May mistakenly connect a wire to an incorrect connector pin thereby resulting in a defective electrical connector being produced. Even a single mistake can result in expense and additional time for rework to fix the defect or even the complete loss of the electrical connector. Errors by technicians are compounded by the increasingly smaller wires and larger number and smaller size of connector pins used in electrical connectors today, particularly in the medical industry, where some devices require 100 or more connector pins within a square

centimeter. To make matters worse for technicians, they must often times connect and solder extremely fine wires having a 40-gauge or 50-gauge size, which are more prone to physical damage than heavier gauge wires.

(7) Some wire termination systems have incorporated certain robotic components to automate at least a portion of the wire connection operations in order to help improve accuracy and efficiency. For example, U.S. Pat. No. 10,239,164, which is assigned to the assignee of the present application, discloses several variations of robotic positioners in a robotic wire termination system. However, further improvements are still desirable.

(8) Because of the inherent problems and shortcomings with conventional wire termination systems, there is a need for a new and improved robotic wire termination system for accurately and efficiently connecting a plurality of wires to corresponding connector pins of an electrical connector.

SUMMARY

(9) An example embodiment is directed to a robotic wire termination system for connecting a plurality of wires to an electrical connector. The robotic wire termination system includes a housing, an electrical connector alignment plate ("alignment plate") adapted to removably receive and hold an electrical connector having a plurality of connector pins with a plurality of corresponding wire receptacles, a robotic positioner within the housing, a heating device connected to the robotic positioner, a display adapted to display a graphical representation of the plurality of connector pins, and a control unit in communication with the display and with the robotic positioner.

(10) The control unit is configured to receive an input identifying the selection of a first connector pin of the plurality of connector pins and in response to control the robotic positioner to position the heating device in a first heating position relative to the first connector pin to melt solder in a corresponding first wire receptacle of the plurality of corresponding wire receptacles. The display is adapted to provide a visual indication of the selection of the first connector pin and a visual indication of the heating device being in the first heating position as a visual indication to an operator to insert a wire into the corresponding first wire receptacle to connect the wire to the electrical connector.

(11) The input identifying the selection of the first connector pin comprises a signal resulting from selection of a graphic on the display that is associated with selecting the first connector pin in the graphical representation of the plurality of connector pins on the display. The display can comprises a touch responsive display and the input identifying the selection of the first connector pin can comprise a signal resulting from the display being touched at a position associated with selecting the first connector pin in the graphical representation of the plurality of connector pins on the display.

(12) The visual indication of the selection of the first connector pin comprises a first display attribute of the first connector pin in the graphical representation of the plurality of connector pins on the display such as a first color. The visual indication of the heating device being in the heating position comprises a second display attribute of the first connector pin in the graphical representation of the plurality of connector pins on the display such as a second color.

(13) The control unit can be configured to receive an input indicating completion of a wire connecting operation with respect to the first connector pin and in response to automatically control the robotic positioner to position the heating device to a programmatically determined second heating position relative to a second connector pin to melt solder in a corresponding second wire receptacle of the plurality of corresponding wire receptacles. The input indicating completion of the wire connecting operation can comprises a signal resulting from selection on the display of a graphic comprising a visual indication to proceed to a next connector pin. If the display comprises a touch responsive display, the input indicating completion of the wire connecting operation can comprise a signal resulting from the display being touched at a position associated with selecting

the second connector pin in the graphical representation of the plurality of connector pins on the display.

(14) The heating device can comprise a thermal tip or a nozzle adapted to direct a flow of heated air. If the heating device comprises a thermal tip, the first heating position comprises the thermal tip being in contact with the first connector pin. If the heating device comprises a nozzle, the first heating position comprises the nozzle being in proximity with but not in contact with the first connector pin.

(15) The alignment plate is adapted to be removably received and held in relation to the housing. The housing comprises an alignment plate retainer adapted to removably receive and hold the alignment plate in a specific position and orientation in relation to the housing. The alignment plate retainer comprises an opening. The housing also comprises a retainer that may comprise one or more rotatable clips and that is selectively movable between a first position to engage the alignment plate and a second position to disengage the alignment plate.

(16) The alignment plate is adapted to removably receive and hold an electrical connector having a plurality of connector pins with a plurality of corresponding wire receptacles. The alignment plate comprises a key that enables the electrical connector to be received and held in a specific position and orientation in relation to the alignment plate. The alignment plate also comprises a plurality of openings corresponding to and adapted to receive and hold the plurality of connector pins with the plurality of connector pins exposed through the opening of the alignment plate retainer inside the housing and the plurality of corresponding wire receptacles exposed outside the housing.

(17) The robotic positioner comprises a first positioner movable along a first longitudinal axis, a second positioner movable along a second longitudinal axis substantially orthogonal to the first longitudinal axis, and a third positioner movable in a third longitudinal axis substantially orthogonal to the first longitudinal axis and to the second longitudinal axis. The first longitudinal axis and the second longitudinal axis extend laterally in a plane beneath the plurality of connector pins exposed within the housing, and the third longitudinal axis extends vertically in relation to the plurality of connector pins exposed within the housing. The heating device is connected to the third positioner. Each of the first positioner, the second positioner, and the third positioner is selectively and independently controllable for movement and the control unit is configured to independently control the first positioner, the second positioner, and the third positioner to sequentially position the heating device in a plurality of heating positions with each heating position being associated with a connector pin to melt solder in a corresponding wire receptacle.

(18) There has thus been outlined, rather broadly, some of the embodiments of the robotic wire termination system in order that the detailed description thereof may be better understood, and in order that the present contribution to the art may be better appreciated. There are additional embodiments of the robotic wire termination system that will be described hereinafter and that will form the subject matter of the claims appended hereto. In this respect, before explaining at least one embodiment of the robotic wire termination system in detail, it is to be understood that the robotic wire termination system is not limited in its application to the details of construction or to the arrangements of the components set forth in the following description or illustrated in the drawings. The robotic wire termination system is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of the description and should not be regarded as limiting.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Example embodiments will become more fully understood from the detailed description given herein below and the accompanying drawings, wherein like elements are represented by like

reference characters, which are given by way of illustration only and thus are not limitative of the example embodiments herein.
(2) FIG. **1** is a top perspective view of a robotic wire termination system in accordance with an example embodiment with a housing illustrated partially transparent to reveal internal components.
(3) FIG. **2** is a top plan view of a robotic wire termination system in accordance with an example embodiment.
(4) FIG. **3** is a side view of a robotic wire termination system in accordance with an example embodiment illustrating external connections.
(5) FIG. **4**A is a top perspective view of a robotic wire termination system in accordance with an example embodiment illustrating an electrical connector aligned with an alignment plate in an alignment plate retainer of a housing and with the housing illustrated partially transparent to reveal internal components.
(6) FIG. **4**B is an enlarged view of the area enclosed by dashes in FIG. **4**A.
(7) FIG. **5**A is an exploded top perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating a cable and wires aligned with an electrical connector, an alignment plate, an alignment plate retainer of a housing, and other system components.
(8) FIG. **5**B is an enlarged view of the area enclosed by dashes in FIG. **5**A.
(9) FIG. **6**A is a top perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating an alignment plate aligned with an alignment plate retainer of a housing.
(10) FIG. **6**B is an enlarged view of the area enclosed by dashes in FIG. **6**A.
(11) FIG. **7**A is a top perspective view of an alignment plate of a robotic wire termination system in accordance with an example embodiment.
(12) FIG. **7**B is a side view of an alignment plate of a robotic wire termination system in accordance with an example embodiment.
(13) FIG. **7**C is a bottom perspective view of an alignment plate of a robotic wire termination system in accordance with an example embodiment.
(14) FIG. **8**A is a top perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating an alignment plate in an alignment plate retainer of a housing with a plurality of retainer clips in a first position disengaged from the alignment plate.
(15) FIG. **8**B is a top perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating an alignment plate in an alignment plate retainer of a housing with a plurality of retainer clips in a second position engaged with the alignment plate.
(16) FIG. **8**C is a bottom perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating an alignment plate in an alignment plate retainer of a housing with openings in the bottom of the alignment plate exposed to the interior of the housing.
(17) FIG. **9**A is a top view of an electrical connector for use with a robotic wire termination system in accordance with an example embodiment.
(18) FIG. **9**B is a bottom view of an electrical connector for use with a robotic wire termination system in accordance with an example embodiment.
(19) FIG. **9**C is a top perspective view in cross-section of an electrical connector for use with a robotic wire termination system in accordance with an example embodiment.
(20) FIG. **10**A is a top perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating an electrical connector in an alignment plate in an alignment plate retainer of a housing and a plurality of wires of a cable aligned with wire receptacles of the electrical connector.

(21) FIG. **10**B is a bottom perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating an electrical connector in an alignment plate in an alignment plate retainer of a housing with connector pins of the electrical connector exposed to the interior of the housing.
(22) FIG. **10**C is an enlarged view of the area enclosed by dashes in FIG. **10**B.
(23) FIG. **11**A is a top perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating an electrical connector in an alignment plate in an alignment plate retainer of a housing with a first wire of a cable inserted within a first wire receptacle of the electrical connector.
(24) FIG. **11**B is a top perspective view of a portion of a robotic wire termination system in accordance with an example embodiment illustrating an electrical connector in an alignment plate in an alignment plate retainer of a housing with first and second wires of a cable inserted within first and second wire receptacles of the electrical connector.
(25) FIG. **12**A is a top perspective view of a connector pin of an electrical connector for use with a robotic wire termination system in accordance with an example embodiment illustrating an end of a wire aligned for insertion within a wire receptacle of the connector pin.
(26) FIG. **12**B is a top perspective view in cross-section of a connector pin of an electrical connector for use with a robotic wire termination system in accordance with an example embodiment illustrating an end of a wire aligned for insertion within a wire receptacle of the connector pin.
(27) FIG. **12**C is a top perspective view in cross-section of a connector pin of an electrical connector for use with a robotic wire termination system in accordance with an example embodiment illustrating an end of a wire inserted in a wire receptacle of the connector pin.
(28) FIG. **13**A is a top perspective view of one variation of a heating device of a robotic wire termination system in accordance with an example embodiment.
(29) FIG. **13**B is an enlarged view of the area enclosed by dashes in FIG. **13**A.
(30) FIG. **13**C is a top perspective view of another variation of a heating device of a robotic wire termination system in accordance with an example embodiment.
(31) FIG. **14**A is a top perspective view of a robotic positioner and mounted heating device of a robotic wire termination system in accordance with an example embodiment.
(32) FIG. **14**B is a front view of a robotic positioner and mounted heating device of a robotic wire termination system in accordance with an example embodiment.
(33) FIG. **14**C is a first side view of a robotic positioner and mounted heating device of a robotic wire termination system in accordance with an example embodiment.
(34) FIG. **14**D is a second side view of a robotic positioner and mounted heating device of a robotic wire termination system in accordance with an example embodiment.
(35) FIG. **14**E is a top view of a robotic positioner and mounted heating device of a robotic wire termination system in accordance with an example embodiment.
(36) FIG. **14**F is a bottom view of a robotic positioner and mounted heating device of a robotic wire termination system in accordance with an example embodiment.
(37) FIG. **15**A is a top perspective view of a vertical lift stage of a robotic positioner of a robotic wire termination system in accordance with an example embodiment in a retracted position.
(38) FIG. **15**B is a top perspective view of a vertical lift stage of a robotic positioner of a robotic wire termination system in accordance with an example embodiment in an extended position.
(39) FIG. **16**A is a top plan view of a robotic wire termination system in accordance with an example embodiment with a housing illustrated partially transparent to reveal an internal robotic positioner and heating device in an example starting position relative to the connector pins of an electrical connector.
(40) FIG. **16**B is a top plan view of a robotic wire termination system in accordance with an example embodiment with a housing illustrated partially transparent to reveal an internal robotic

positioner and heating device moved laterally along a first orthogonal longitudinal axis to a first position relative to the connector pins of an electrical connector.
(41) FIG. **16**C is a top plan view of a robotic wire termination system in accordance with an example embodiment with a housing illustrated partially transparent to reveal an internal robotic positioner and heating device moved laterally along a second orthogonal longitudinal axis to a second position relative to the connector pins of an electrical connector.
(42) FIG. **16**D is a side view of a robotic wire termination system in accordance with an example embodiment with a housing illustrated partially transparent to reveal an internal robotic positioner and heating device moved vertically along a third orthogonal longitudinal axis to a heating position relative to a first connector pin of an electrical connector.
(43) FIG. **16**E is an enlarged view of the area enclosed by dashes in FIG. **16**D.
(44) FIG. **16**F is a side view of a robotic wire termination system in accordance with an example embodiment with a housing illustrated partially transparent to reveal an internal robotic positioner and heating device moved vertically along a third orthogonal longitudinal axis away from a heating position relative to a first connector pin of an electrical connector.
(45) FIG. **16**G is a side view of a robotic wire termination system in accordance with an example embodiment with a housing illustrated partially transparent to reveal an internal robotic positioner and heating device moved laterally along a second orthogonal longitudinal axis relative to a third position relative to the connector pins of an electrical connector.
(46) FIG. **16**H is a side view of a robotic wire termination system in accordance with an example embodiment with a housing illustrated partially transparent to reveal an internal robotic positioner and heating device moved vertically along a third orthogonal longitudinal axis to a heating position relative to a second connector pin of an electrical connector.
(47) FIG. **17** is a block diagram of a robotic wire termination system in accordance with an example embodiment illustrating the connections and communications between a control unit and other system components.
(48) FIG. **18** is an example of a first control screen of a display of a robotic wire termination system in accordance with an example embodiment for selecting an electrical connector.
(49) FIG. **19**A is an example of a second control screen of a display of a robotic wire termination system in accordance with an example embodiment for selecting a connector pin of a selected electrical connector and for providing a visual indication of the selected connector pin.
(50) FIG. **19**B is an example of a second control screen of a display of a robotic wire termination system in accordance with an example embodiment for selecting a connector pin of a selected electrical connector and for providing a visual indication of a heating device in a heating positioner relative to the selected connector pin.
(51) FIG. **20** is an example of a third control screen of a display of a robotic wire termination system in accordance with an example embodiment for manually controlling movement of a robotic positioner and heating device with respect to the connector pins of an electrical connector.
(52) FIG. **21** is a flow chart illustrating an example of operation of a robotic wire termination system in accordance with an example embodiment.
DETAILED DESCRIPTION
(53) A. Overview.
(54) As illustrated in FIGS. **1-21** and as described herein, an example robotic wire termination system **10** is configured and adapted to enable an operator to efficiently and accurately connect a plurality of wires **20** of a cable **22** (or other source of wires) to an electrical connector **30** having a plurality of connector pins **34** with corresponding wire receptacles **38** that are preloaded with solder preform **39**. The robotic wire termination system **10** generally includes a housing **40**, an electrical connector alignment plate **70** (“alignment plate”), a heating device **80**, a robotic positioner **90**, a control unit **110**, and a display **120**.
(55) The housing **40** includes an alignment plate retainer **60** for removably receiving and holding

the alignment plate **70** in a specific position and orientation. The alignment plate retainer **60** includes an opening **64** aligned with a corresponding opening in the housing **40**. The alignment plate **70** has an inset portion **75** for removably receiving and holding the electrical connector **30** to which wires **20** are to be connected in a specific position and orientation. The alignment plate **70** also has a plurality of openings **78** that are arranged to correspond with the plurality of connector pins **34** of the electrical connector **30**. With the alignment plate **70** held by the alignment plate retainer **60** and the electrical connector **30** held by the alignment plate **70**, the connector pins **34** of the electrical connector **30** are exposed to the interior **42** of the housing **40** and the corresponding wire receptacles **38** are exposed outside the housing **40**.
(56) The heating device **80**, robotic positioner **90**, and control unit **110** are enclosed within the interior **42** of the housing **40** with the heating device **80** and robotic positioner **90** in communication and under control of the control unit **110**. The heating device **80** is mounted on the robotic positioner **90**. The robotic positioner **90** comprises first, second, and third positioners **92**, **94**, **96**. The first, second, and third positioners **92**, **94**, **96** are independently controllable and movable by the control unit **110** along three mutually orthogonal longitudinal axes to selectively move the heating device **80** to selected coordinates within the 3D space in the interior **42** of the housing **40** corresponding to positions relative to the connector pins **34** exposed in the interior **42** of the housing **40**.
(57) The control unit **110** is configured to receive as inputs a selection of an electrical connector **30** to which wires **20** are to be connected and subsequently selections of one or a plurality of individual connector pins **34** of the selected electrical connector **30** to which individual wires **20** are to be connected. In response, the control unit **110** controls the robotic positioner **90** to move the heating device **80** to a heating position relative to the selected connector pin **34** or to a plurality of heating positions relative to the plurality of selected connector pins **34** in a predetermined sequence or series. The heating device **80** is controlled at each heating position to apply heat to the currently selected connector pin **34** to melt the solder preform and form a connection between the selected connector pin **34** and the corresponding wire **20** of the cable **22** or other source of wires.
(58) The display **120**, which can comprise a touch responsive display, is in communication with the control unit **110** and provides selections made by an operator as inputs to the control unit **110**. The display **120** displays several control screens. One control screen displays icons or graphics for the operator to select a particular electrical connector **30**. Another control screen displays graphics and icons for the operator to selectively control various operations of the system and to select connector pins **34** of the selected electrical connector **30**. These include a visual graphic representation of the connector pins **34**. This control screen also displays visual indications showing a selected connector pin **34**, and showing that the heating device **80** is in the heating position with respect to a selected connector pin **34**. From this information the operator can determine to insert a wire **20** into the corresponding wire receptacle **38** of the connector pin **34** to form a solder connection. Another control screen displays icons and graphics for the operator to manually control movement of the robotic positioner **90** and heating device **80**. Other input devices **108** such as a remote footswitch and/or hand switch also are in communication with the control unit **110** and also can be used by the operator to selectively control various operations of the system.
(59) B. Electrical Connector.
(60) The electrical connector **30** (also referred to as an insulator) with which the robotic wire termination system **10** is intended for use may be comprised of any device at which electrical wires **20** are to be terminated. There are various types of electrical connectors in use including but not limited to fine wire terminations, pinned connectors, terminal blocks, plug and socket connectors, medical connectors, transition devices and custom connectors. The electrical connector **30** also may be intended for various types of industries such as but not limited to the medical industry.
(61) As best illustrated in FIGS. **4**B, **5**B, and **9**A-**9**C, the electrical connector **30** comprises an insulator body or housing **32** formed of an electrically insulating material and a plurality of

connector pins **34** that extend through the insulator body or housing **32**. The connector pins **34** are comprised of an electrically conductive material such as metal. The insulator body or housing **32** electrically insulates one or more of the connector pins **34** from the other connector pins **34** and also provides support for the connector pins **34**. The insulator body or housing **32** may have various shapes (e.g., substantially circular as illustrated in FIGS. **9**A-**9**C), thicknesses, and sizes.
(62) The connector pins **34** are typically configured to extend substantially parallel with one another through the insulator body or housing **32**. The connector pins **34** can be arranged in various shapes and patterns depending on the application for which the electrical connector **30** is intended. The number of connector pins **34** can range from two connector pins **34** to greater than 100 connector pins **34**, again depending on the intended application for the electrical connector **30**.
(63) One or more and typically all of the connector pins **34** have a male connecting end **36** (which sometimes is itself referred to as a pin). The male connecting end **36** typically has a tapered or pointed end that is used to electrically connect the electrical connector **30** to a corresponding electrical socket or the like having a like plurality and arrangement of female receptacles. The male connecting end **36** typically is comprised of a solid pin structure as illustrated in FIG. **9**C. The male connecting ends **36** extend outwardly from a first side of the insulator body or housing **32** as best illustrated in FIGS. **4**B, **5**B, **9**B and **9**C.
(64) One or more and typically all of the connector pins **34** include a corresponding wire receptacle **38** that is positioned opposite of the male connecting ends **36** of the connector pins **34**. The distal ends of wires **20**, such as the distal ends of wires **20** protruding from the end of a cable **22**, are inserted and terminate in the wire receptacles **38** for connection to the electrical connector **30**, typically via a solder connection as illustrated in FIGS. **11**A-**11**B and **12**A-**12**C. The ends of the wires **20** are inserted into the corresponding wire receptacles **38** of the connector pins **34** and soldered, typically according to a pinout, to form a physical and electrical connection between the wires **20** and the electrical connector **30**, and more specifically between the wires **20** and the connector pins **34** of the electrical connector **30**.
(65) In the example electrical connector **30** illustrated in FIGS. **4**B, **5**B, **9**A-**9**C, and **12**A-**12**C, the wire receptacles **38** are comprised of a female connecting end having a substantially tubular structure adapted to receive and terminate the ends of the wires **20**. The wire receptacles **38** alternatively may have a non-tubular structure as long as the wire receptacles **38** allow for the insertion or other termination, and soldering of the wires **20**. The wire receptacles **38** preferably extend outwardly from a second side of the insulator body or housing **32** of the electrical connector **30** which is opposite of the first side. The wire receptacles **38** preferably have an upper opening that may be recessed in, extend past, or be flush with the second side of the insulator body or housing **32** of the electrical connector **30** as best illustrated in FIGS. **4**B, **5**B, **9**A-**9**C, and **11**A-**11**B. Preferably all of the wire receptacles **38** are flush or recessed or extend the same distance with respect to the second side of the electrical connector **30**. However, if desired different wire receptacles **38** can extend outwardly from the second side at different distances (e.g., central located receptacles may extend outwardly further than outer located receptacles, or some receptacles may be flush or recessed and others extend outwardly).
(66) The wire receptacles **38** are preferably prefilled with a solder material **39** prior to a wire connection operation being carried out on the electrical connector **30** with the example robotic wire termination system **10** as described herein. For example, the interior cavities of one or more of the wire receptacles **38** may be at least partially filled with a customized solder preform **39**. The prefilling of the wire receptacles **38** with solder preform **39** allows for the heating device **80** of the example robotic wire termination system **10** to be moved into heating positions relative to individual connector pins **34** and to provide heat to the individual connector pins **34** to connect the wires **20** without an operator having to manually apply solder. It will be appreciated however that the example robotic wire termination system **10** also can be used to connect wires **20** to an electrical connector **30** without the wire receptacles **38** being prefilled with solder preform **39**. For

example, an operator can manually apply solder to a wire **20** and/or wire receptacle **38** as the heating device **80** applies heat to the connector pin **34**. In either case, the example robotic wire termination system **10** provides substantial improvements to wire connection operations.
(67) Various types of solder preform **39** may be utilized such as but not limited to lead solder, lead-free solder, solder balls, solder paste and flux-core solder. The solder preform **39** may be comprised of various fusible metal alloys that have a relatively low melting point capable of physically and electrically connecting the wires **20** to the connector pins **34** of the electrical connector **30**.
(68) C. Cable and Wires.
(69) FIGS. **5**A, **5**B illustrate a typical cable **22** comprising a substantially tubular outer insulation or sheath **24** enclosing a plurality of wires **20** with the distal ends of the wires **20** extending outwardly from the insulation or sheath **24**. However, it can be appreciated that the wires **22** to be connected to the electrical connector **30** do not have to be part of the same insulated cable and instead can be separate of one another without a common sheathing and with or without individual insulation or sheathing. The wires **20** can have various lengths and sizes and can extend outwardly from any insulation by varying distances.
(70) The plurality of wires **20** of the cable **22** is typically soldered to the wire receptacles **38** of the respective connector pins **34** according to a pinout which cross-references the wires **20** to corresponding connector pins **34** to which they are to be connected. The pinout can be a diagram or chart that visually cross-references the specific connector pins **34** and corresponding wires **20** to be connected. The pinout can be color coded, numbered or otherwise coded to assist an operator in positioning and inserting the correct wires **20** into the correct wire receptacles **38** of the corresponding connector pins **34** so that the wires **20** are correctly connected to the electrical connector **30**. Incorrect connection of any wire **20** to a connector pin **34** of the electrical connector **30** can result in time-consuming and expensive rework or even the complete scrapping and loss of the electrical connector **30**.
(71) D. Housing and Housing External Components.
(72) The housing **40** of the example robotic wire termination system **10** may comprise almost any structure that is able to support, hold, and/or contain the various components of the system as described herein. In the example embodiments, the housing **40** has an interior space **42** enclosed by a substantially horizontal top **44**, a substantially horizontal bottom **46**, and four substantially vertical sides **48***a*, **48***b*, **48***c*, and **48***d* that extend between the top **44** and the bottom **46**. The top **44**, bottom, **46**, and sides **48***a*-**48***d* can be arranged to form an enclosure having any shape and interior volume suitable for and consistent with carrying out the functions and objectives described herein. Preferably the housing **40** will be of a size and shape that is suitable for the system to be operated on a support surface of a table, desk, work bench, or the like.
(73) The housing **40** may include various externally accessible components on the exterior surfaces of one or more of the top **44** and sides **48***a*-**48***d*. For example, the housing **40** preferably includes an emergency power kill switch **49**, a plurality of input/output (I/O) ports **50**-**54**, and an electrical socket **55**.
(74) The emergency power kill switch **49** is preferably located on the top **44** or alternatively on a side **48***a*-**48***d* of the housing **40** preferably in a location that is easy and fast for a technician to access. The emergency power kill switch **49** can be wired into the electrical power system of the example robotic wire termination system **10** and can be of a type such that manually actuating it interrupts power to at least the components of the robotic positioner **90** and the heating device **80**. This enables an operator to immediately remove power in the event of an emergency to prevent damage to the system **10**, the electrical connector **30**, and/or the surrounding environment.
(75) The I/O ports **50**-**54** are preferably located on one or more of the sides **48***a*-**48***d*, such as side **48***d* for example, and/or the top **44** of the housing **40**. Preferably the I/O ports **50**-**54** are in locations such that wired connections can be conveniently made between external I/O devices **108** as described herein, other external peripherals, external power sources and the example robotic

wire termination system **10** without interfering with the process of connecting wires **20** to the electrical connector **30** as described further herein.
(76) The I/O ports may comprise, for example, a micro USB port **50** that is electrically connected to the control unit **110** for receiving and providing power from an external power source to the control unit **110**. The I/O ports also may comprise an HDMI port **51** that is connected to the control unit **110** for providing communication between the control unit **110** and the display **120**, and USB ports **52-53** that are connected to the control unit **110** for communicating data between the control unit **110** and I/O devices **108** and other external peripherals such as external storage. The I/O ports also may comprise an Echo® port **54** that is connected to the control unit **110** and that is adapted to receive a corresponding Echo® magnetic connector of a cable to receive and/or communicate data and/or signals between the control unit **110** and I/O devices **108** such as a hand and/or foot switch as described further herein. Echo® is a registered trademark of Onanon Inc. of Milpitas, California and the Echo® magnetic connector is the subject of patents owned by Onanon.
(77) The electrical socket **55** can comprise an alternating current (AC) electrical socket **55** for receiving electrical power from an external power source to power the robotic positioner **90**, the heating device **80**, and other components, such as fans, that require AC power to operate. An on/off power switch (in addition to the emergency power kill switch **49**) that is externally accessible by an operator can be provided in circuit with the electrical socket **55**.
(78) Various components of the example robotic wire termination system **10** enclosed within the housing **40** may produce heat in operation, including for example the heating device **80** and the control unit **110**. To maintain a suitable operating temperature within the housing **40**, one or more fans can be disposed within the housing **40** and one or more vents **56** can be provided in one or more of the sides **48***a*-**48***d*, for example side **48***d*, of the housing **40**.
(79) The housing **40** also comprises an alignment plate retainer **60** which is illustrated in FIGS. **5**A, **6**A-**6**B, **8**C, **10**B-**10**C among others. The alignment plate retainer **60** is preferably disposed on the exterior surface of the top **44** of the housing **40** in a location easily and conveniently accessible by an operator. The alignment plate retainer **60** can be formed in a substantially flat relatively thin plate **61** that is attached to the housing **40** and exposed in the top **44** of the housing **40**. The alignment plate retainer **60** also can comprise an integral part of the top **44** of the housing **40** itself.
(80) The alignment plate retainer **60** is adapted to removably receive, support, and hold the alignment plate **70** in a specific orientation and position in relation to the housing **40** in order to carry out an operation to connect wires **20** to an electrical connector **30** using the example robotic wire termination system **10**. For that purpose, the alignment plate retainer **60** comprises an inset portion **62** and a support surface **63** with an opening **64**. The inset portion **62** comprises a substantially flat horizontal bottom surface, at least part of which comprises the support surface **63**, and a substantially vertical peripheral wall **65** that extends from the bottom surface to the top surface of the plate **61** (or the exterior surface of the top **44** of the housing **40**) and at least partially around the outer periphery of the support surface **63**.
(81) The inset portion **62** preferably has at least a portion that is shaped and dimensioned substantially the same as the alignment plate **70**. This allows the alignment plate **70** to be received and supported in the alignment plate retainer **60**, and more particularly the inset portion **62**, in a specific orientation and position relative to the housing **40**. Further, with the alignment plate **70** received in the inset portion **62**, the peripheral edges **74** of the alignment plate **70** abut against the vertical peripheral walls **65** of the inset portion **62** so that the alignment plate **70** is held in place and prevented from moving laterally within the alignment plate retainer **60** and more specifically the inset portion **62**. In the example embodiments, the inset portion **62** and the alignment plate **70** each have substantially the same rectangular shape. It will be appreciated however that the alignment plate **70** and the inset portion **62** may take many other corresponding shapes consistent with the objective of the alignment plate retainer **60** receiving, supporting, and holding the alignment plate **70** in a specific orientation and position.

(82) In addition, the depth of the inset portion **62** preferably is approximately equal to the thickness of the alignment plate **70**, which is described in more detail below. Accordingly, when the alignment plate **70** is received in the inset portion **62** it is held and supported with its bottom surface **73** supported on the support surface **63** and its top surface **72** substantially flush with the top surface of the plate **61** and/or the exterior surface of the top **44** of the housing **40** as best illustrated in FIGS. **8**A-**8**B, **10**A, and **11**A-**11**B.
(83) An opening **64** is formed in the bottom surface of the inset portion **62**. The opening **64** can be formed substantially centrally in the bottom surface of the inset portion **62** and can have a substantially square or rectangular shape as in the example embodiments. However, it will be appreciated that the opening **64** also can be formed in numerous different shapes and have numerous different placements, provided they are consistent with achieving the functions and objectives described herein.
(84) The support surface **63** comprises at least a portion of the bottom surface of the inset portion **62** that extends around the opening **64**. The support surface **63** engages the bottom surface **73** of the alignment plate **70** at and near its edges **74** and provides support for the alignment plate **70** when the alignment plate **70** is received and held in the inset portion **62** of the alignment plate retainer **60**. The support surface **63** and opening **64** are configured and arranged so that at least the portion of the bottom surface **73** of the alignment plate **70** that contains openings **78** is exposed and accessible from the interior **42** of the housing **40** through the opening **64** when the alignment plate **70** is held and supported in the inset portion **62**.
(85) If the alignment plate retainer **60** is formed in the plate **61** rather than directly in the top **44** of the housing **40**, the top **44** of the housing **40** has an opening to the interior **42** of the housing **40** that preferably is substantially aligned with the opening **64** of the alignment plate retainer **60**. In either case, when the alignment plate **70** is held and supported in the alignment plate retainer **60** and more particularly the inset portion **62**, and an electrical connector **30** is inserted and held in the alignment plate **70** as described below, the plurality of connector pins **34** of the electrical connector **30** are exposed to the interior **42** of the housing **40** through the opening **64** and the corresponding wire terminals **38** are exposed outside the housing **40**.
(86) The housing **40** also comprise a heat shield **67**. The heat shield **67** can be comprised of a substantially flat plate of aluminum or another material that provides suitable insulation against the conductance of heat. The heat shield **67** can be mounted or attached to the housing **40** in any suitable fashion and preferably is positioned between the plate **61** or other structure in which the alignment plate retainer **60** is disposed or formed and the heating device **80**. The heat shield **67** will have an opening **68** that is substantially aligned with the opening **64** in the plate **61** and/or the opening in the top **44** of the housing **40**.
(87) The housing **40** also comprises a retainer **66** that is adapted to engage the alignment plate **70** and prevent it from moving, including vertically, when it is received, held, and supported in the alignment plate retainer **60** and more specifically the inset portion **62**. The retainer **66** is movable between a first position to engage the alignment plate **70** and a second position to disengage from the alignment plate **70**.
(88) The retainer **66** can comprise one or a plurality of substantially flat elongated clips **66***a*-**66***d*. Each of the clips **66***a*-**66***d* has a first proximal end, a second distal end, a top surface and a bottom surface. The clips **66***a*-**66***d* can be attached to the top surface of the plate **61** or the top **44** of the housing **40** at spaced apart locations around the alignment plate retainer **60**. Each clip **66***a*-**66***d* can be rotatably attached at or near its first proximal end to the top surface of the plate **61** or the top **44** of the housing **40** near the alignment plate retainer **60**, and more specifically the inset portion **62**, by a screw, bolt or other suitable fastener. Each clip **66***a*-**66***d* is rotatably movable around the point at which it is attached to the top of the plate **61** or the top **44** of the housing **40** independently of the other clips **66***a*-**66***d*. The clips **66***a*-**66***d* are preferably attached to the top of the plate **61** or the top **44** of the housing **40** so that their respective bottom surfaces are in or near to being in movable

contact with the exterior surface of the plate **61** or the top **44** of the housing **40**. Accordingly, when a clip **66***a*-**66***d* is moved rotationally around its attachment point its bottom surface essentially slides over and approximately flush with the exterior surface of the plate **41** or the top **44** of the housing **40**.
(89) The clips **66***a*-**66***d* are preferably positioned around the alignment plate retainer **60** and each clip is preferably dimensioned lengthwise so that when it is rotationally moved about its attachment point, its second distal end extends at least partly over a portion of the periphery of the inset portion **62** of the alignment plate retainer **60**. Accordingly, when an alignment plate **70** is held and supported in the alignment plate retainer **60** as described above, each rotatable clip **66***a*-**66***d* can be selectively and independently moved rotationally by an operator into a first angular position in which its bottom surface engages at least a portion of the top surface **72** of the alignment plate **70** to hold it in position and prevent it from moving, including vertically. Similarly, each rotatable clip **66***a*-**66***d* can be selectively and independently moved rotationally by an operator into a second angular position wherein it disengages the alignment plate **70**, thus allowing the alignment plate **70** to be easily and quickly removed from the alignment plate retainer **60** and/or another alignment plate **70** to be inserted in the alignment plate retainer **60** as desired.
(90) It will be apparent that in place of one or more clips **66***a*-**66***d* as described above other structures can be used for the retainer **66** provided they are consistent with achieving the functions and objectives of the retainer **66**. Such other structures or devices can be spring-biased or not spring-biased. They can roll rather than slide across the top of the plate **61** or the top **44** of the housing **40**. They can move linearly rather than rotationally. They may or may not be attached and move substantially flush with and/or in contact with the top of the plate **61** or the top **44** of the housing **40**. Fasteners or adhesive elements can be used, provided an operator can operate them to relatively easily and quickly insert and remove alignment plates **70**. In addition, more or fewer clips **66***a*-**66***d* or other structures can be used.
(91) It will be appreciated that because the alignment plate retainer **60** is adapted to removably receive, hold, and support the alignment plate **70**, the example robotic wire termination system **10** can be used to carry out wire connection operations on a plurality of different electrical connectors **30** having different configurations of connector pins **34** without the need to make significant changes to the components or configuration of the system. All that is needed to change the system over from one electrical connector **30** to another is to remove the alignment plate **70** corresponding to the one electrical connector **30** from the alignment plate retainer **60** and seat another alignment plate **70** corresponding to the other electrical connector **30** in the alignment plate retainer **60**.
(92) E. Electrical Connector Alignment Plate (“Alignment Plate”).
(93) The alignment plate **70** of the example robotic wire termination system **10** is best illustrated in FIGS. **6**B, **7**A-**7**C and **8**A-**8**C among others. The alignment plate **70** comprises a substantially flat thin plate having a substantially horizontal top surface **72** and substantially horizontal bottom surface **73**, and a substantially vertical peripheral edge **74** that extends between the top surface **72** and bottom surface **73** around the periphery of the alignment plate **70**.
(94) As described above, the alignment plate **70** is adapted to be removably received, held and supported in the alignment plate retainer **60** of the housing **40** in a specific position and orientation in relation to the housing **40**. Accordingly, the alignment plate **70** is shaped and dimensioned substantially the same as the inset portion **62** of the alignment plate retainer **60**, which in the example embodiments is substantially rectangular. However, as described above, the alignment plate **70** and the inset portion **62** of the alignment plate retainer **60** can have many other corresponding geometric shapes suitable to accomplish the same objectives.
(95) As also described above, the alignment plate **70** preferably has a thickness that is substantially the same as the depth of the inset portion **62** of the alignment plate retainer **60**. As a result, with the alignment plate **70** received and supported in the inset portion **62**, the top surface **72** of the alignment plate **70** is substantially flush with the top surface of the plate **61** (or the exterior surface

of the top **44** of the housing **40**) and the peripheral edges **74** of the alignment plate **70** abut against the vertical peripheral walls **65** of the inset portion **62** further ensuring that the alignment plate **70** is held in place and prevented from moving laterally within the alignment plate retainer **60** and more specifically the inset portion **62**. Holding the alignment plate **70** in a specific position and orientation in relation to the housing **40** enables the robotic positioner **90** of the example robotic wire termination system **10** to precisely and accurately position the heating device **80** in relation to the individual connector pins **34** of an electrical connector **30** mounted in the alignment plate **70** in order to provide heat precisely to each individual connector pin **34** to connect a wire **20**.

(96) The top surface **72** of the alignment plate **70** includes an inset portion **75**. The inset portion **75** is adapted and configured to removably receive and hold an electrical connector **30** to which wires **20** are to be connected.

(97) The inset portion **75** has a substantially flat horizontal bottom surface **76** and a substantially vertical peripheral wall **77** that extends around the periphery of the bottom surface **76** substantially vertically from the bottom surface **76** to the top surface **72** of the alignment plate **70**. A plurality of openings **78** are formed in the bottom surface **76** of the inset **75** and extend through the bottom surface **73** of the alignment plate **70**. The openings **78** are preferably formed to extend substantially parallel to each other and substantially perpendicular to the top surface **72** and the bottom surface **73** of the alignment plate **70**.

(98) The inset portion **75**, including the bottom surface **76** and the peripheral wall **77** are preferably shaped and dimensioned to correspond to the shape and dimensions of a particular electrical connector **30** with which the alignment plate **70** is intended for use, such as the electrical connector **30** illustrated in FIGS. **9**A-**9**C. The number and arrangement of the openings **78** preferably correspond to the number and arrangement of the connector pins **34** of the particular electrical connector **30** with which the alignment plate **70** is intended for use. However, the openings **78** also can be configured in number and arrangement to generically accept the connector pins **34** of a number of different electrical connectors **30** having the same shape and dimensions as the inset portion **75**.

(99) For a particular electrical connector **30** to be inserted in and received by the alignment plate **70**, and more particularly the inset portion **75**, the male connecting ends **36** of the connector pins **34** of the electrical connector **30** must be properly aligned with the openings **78** in the alignment plate **70**. The electrical connector **30** can then be inserted by simply pushing it into the inset portion **75**. The male connecting ends **36** will extend through the openings **78** and outwardly from the bottom surface **73** of the alignment plate **70**. At the same time, the first surface of the insulator body or housing **32** (from which the male connecting ends **36** of the connector pins **34** extend) is supported on the bottom surface **76** of the inset portion **75** and the peripheral side edges of the insulator body or housing **32** abut the vertical peripheral wall **77** of the inset portion **76**. The electrical connector **30** can be easily and quickly removed from the alignment plate **70** by simply pulling it out of the inset portion **75**.

(100) As illustrated in FIGS. **7**A and **9**A-**9**C, the inset portion **75** and the electrical connector **30** also can have one or more keys to ensure the electrical connector **30** can only be received and held in the alignment plate **70** in a specific position and orientation and to prevent the inset portion **75** from receiving and holding the electrical connector **30** in any other position or orientation. For example, the inset portion **75** can have one more flats **71** formed in the vertical peripheral wall **77** and the particular electrical connector **30** can have one or more corresponding flats **31** formed in the peripheral edge of the insulator body or housing **32** so that the electrical connector **30** can only be received in the inset portion **75** with the corresponding flats aligned. Separately, or in addition, the inset portion **75** can have one more inward protrusions or projections **79** formed in the vertical peripheral wall **77** and the particular electrical connector **30** can have one or more corresponding notches or insets **37** formed in the peripheral edge of the insulator body or housing **32** so that the electrical connector **30** can only be received in the inset portion **75** with the protrusion or projection

79 and the corresponding notch **37** aligned.
(101) It should be noted that the inset portion **75** is preferably located on the alignment plate **70** so that when the alignment plate **70** is received and held in the alignment plate retainer **60**, at least the portion of the bottom surface **73** of the alignment plate **70** below the inset portion **75** is exposed to and accessible from the interior **42** of the housing **40** through the opening **64** of the alignment plate retainer **60**. Accordingly, as best illustrated in FIGS. **5**A-**5**B and **10**A-**10**C, when a particular electrical connector **30** with which the alignment plate **70** is intended for use is received and held in the alignment plate **70**, the male connecting ends **36** of the connector pins **34** of the electrical connector **30** extend **9** through the openings **78** in the alignment plate **70**, are exposed to the interior **42** of the housing **40**, and are accessible by the heating device **80** through the opening **64**. At the same time, the corresponding wire receptacles **38** of the connector pins **34** are exposed outside the housing **40** and are accessible to receive the ends of the wires **20** to be connected to the electrical connector **30** as best illustrated in FIGS. **4**B, **5**A-**5**B, **10**A, and **11**A-**11**B.
(102) It will be appreciated that because the alignment plate **70**, and more particularly the inset portion **75**, is adapted and configured to receive and hold a particular electrical connector **30** in a particular position and orientation in relation to the alignment plate **70** and the housing **40**, the robotic positioner **90** can be controlled to precisely and accurately position the heating device **80** to a heating position relative to each individual connector pin **34** of the electrical connector **30** to provide heat to connect a wire **20**.
(103) It also will be appreciated that because the alignment plate **70** is removably received and held in the alignment plate retainer **60**, an operator can select from among a plurality of alignment plates **70** with different inset **75** configurations for use with a plurality of different electrical connectors **30** having different insulator body **32** shapes and sizes, and different numbers and arrangements of connector pins **34**. It is thus a beneficial aspect of the example robotic wire termination system **10** that it readily and easily usable with many different electrical connectors **30** without the need for substantial configuration or hardware changes. Another related beneficial aspect is that an operator can easily and quickly switch over from one electrical connector **30** to another electrical connector **30**, by simply removing one alignment plate **70** from the alignment plate retainer **60** and replacing it with another alignment plate **70**. Production delays due to change-over time are thus greatly reduced.
(104) F. Robotic Positioner.
(105) The robotic positioner **90** of the example robotic wire termination system **10** is illustrated in detail in FIGS. **14**A-**14**F and **15**A-**15**B. The robotic positioner **90** is also illustrated in connection with the housing **40**, alignment plate retainer **60** and alignment plate **70**, heating device **80**, and other system components in FIGS. **1**, **4**A, and **16**A-**16**H.
(106) The robotic positioner **90** is mounted within the housing **40** and is in communication with the control unit **110**. The robotic positioner **90** is controllable by the control unit **110** and is operable to move the heating device **80** in three dimensions (3D) within the housing **40**. More particularly, the robotic positioner **90** is controllable and operable to move the heating device **80** in three dimensions to and between a plurality of positions within the housing **40** in relation to the connector pins **34** of an electrical connector **30**. The positions include a heating position relative to each individual connector pin **34**. Each position corresponds to a unique set of coordinates of a three dimensional coordinate system, such as the X, Y, and Z coordinates of a Cartesian coordinate system.
(107) Because each electrical connector **30** to which wires **20** are to be connected is received and held by a corresponding alignment plate **70** in the alignment plate retainer **60** of the housing **40** in a specific position and orientation relative to the housing **40**, and because the specifications of each such electrical connector **30**, including the number, arrangement, and spacing of connector pins **34** are known, the unique set of coordinates corresponding to the position in 3D space of each connector pin **34** can be determined. The coordinate sets for all of the connector pins **34** of a

particular electrical connector **30** can be grouped and stored together in the control unit **110** or in storage accessible to the control unit **110** with each unique set of coordinates associated with or indexed to a different connector pin **34** and the entire group associated or indexed to the particular electrical connector **30**. As individual connector pins **34** of a particular connector **30** are selected to have wires **20** connected, the control unit **110** can access and use the associated coordinates to control the robotic positioner **90** to move the heating device **80** to a position beneath a selected connector pin **34**, and from there to a heating position relative to the selected connector pin **34**.

(108) As one example, the robotic positioner **90** can be controlled by the control unit **110** to move and position the heating device **80** to a set of coordinates that corresponds to a heating position relative to a first selected connector pin **34**. After the heating device **80** has applied heat to the first selected connector pin **34** for a wire **20** to be connected, the robotic positioner **90** can be controlled to move and position the heating device **80** to another set of coordinates corresponding to a heating position relative to a second selected connector pin **34**. The robotic positioner **90** can be controlled to selectively move the heating device **80** to any set of coordinates, including any set of coordinates corresponding to a heating position relative to any selected connector pin **34** of an electrical connector **30** and this can be done in any order and without regard to the relative locations of the selected connector pins **34** on the electrical connector **30**.

(109) As another example, the robotic positioner **90** can be controlled by the control unit **110** to automatically move and position the heating device **80** to each of a plurality of different sets of coordinates corresponding to a plurality of different heating positions relative to a plurality of different selected connector pins **34** of an electrical connector **30** according to a predetermined sequence or series. After the heating device **80** has applied heat to one connector pin **34** of the sequence or series for a wire **20** to be connected, the robotic positioner **90** can be automatically controlled to move the heating device **80** to a next set of coordinates corresponding to a heating position relative to the next connector pin **34** in the sequence or series. The robotic positioner **90** can be controlled to automatically move the heating device **80** to sets of coordinates corresponding to heating positions relative to connector pins **34** of an electrical connector **30** according to a predetermined sequence or series in any order and without regard to the relative locations of the selected connector pins **34** on the electrical connector **30**. However, for efficiency it may be preferable to move the heating device **80** between adjacent connector pins **34** in a common row, to complete the wire connection operations with respect to the connector pins **34** in that row, and then to reposition the heating device **80** to an adjacent connector pin **34** in an adjacent row and complete the wire connection operations with respect to the connector pins **34** in that row, and so on.

(110) The robotic positioner **90** can be controlled to move and position the heating device **80** to a heating position relative to one or more individually selected connector pins **34** of an electrical connector **30**, or sequentially to each connector pin **34** in a predetermined sequence or series of connector pins **34** of the electrical connector **30** based on manual input from an operator, programmatically, or a combination of both. For example, the control unit **110** can be configured to receive an input indicating completion of a wire connecting operation with respect to an individually selected first connector pin **34** by an operator actuating a switch or making a selection on a display as described below, or otherwise. In response, the control unit **110** can be configured to wait to receive a selection of a second connector pin **34** from the operator and then to automatically control the robotic positioner **90** to move and position the heating device **80** to the heating position relative to the second connector pin **34**.

(111) Similarly, the control unit **110** can be configured to receive an operator input indicating completion of a wire connecting operation with respect to one connector pin **34** in a predetermined sequence or series of connector pins **34** or to proceed from one connector pin **34** in the predetermined sequence or series to the next connector pin **34** in the series. In response, the control unit **110** can be configured to automatically control the robotic positioner **90** to position the heating device **80** to the heating position relative to the next connector pin **34** in the sequence or series.

(112) The control unit **110** also can be configured to control the robotic positioner **90** to **2** move and position the heating device **80** from a heating position relative to one connector pin **34** in a predetermined series of connector pins **34** to a heating position relative to the next connector pin **34** of the predetermined series based on programmatic input. For example, the control unit **110** can be configured to monitor the temperature of the heating device **80** and/or the elapsed time the heating device **80** is in the heating position with respect to the one connector pin **34**, and to automatically control the robotic positioner **90** to move and position the heating device **80** to the heating position relative to the next connector pin **34** in the series when it is determined that the temperature of the heating device **80** has fallen below a predetermined value, and/or or a predetermined time has elapsed with the heating device **80** in the heating position.
(113) The robotic positioner **90** comprises a first positioner **92**, a second positioner **94**, and a third positioner **96**. The first positioner **92**, the second positioner **94**, and the third positioner **96** are each in communication with the control unit **110** and are each selectively and independently controllable and movable by the control unit **110**.
(114) The first positioner **92**, the second positioner **94**, and the third positioner **96** each preferably comprise a linear positioner. In the example embodiments, the first positioner **92** comprises a first drive motor and encoder **93**, a pair of elongated first mounting frames **92***a*, **92***b*, a pair of elongated first drive screws **95***a*, **95***b*, a first set of one or more elongated first guide rails **97***a*, a second set of one or more elongated first guide rails **97***b*, and a pair of first linear stages **99***a*, **99***b*. The second positioner **94** comprises a second drive motor and encoder **100**, an elongated second mounting frame **94***a*, an elongated second drive screw **101**, a set of one or more elongated second guide rails **102**, and a second linear stage **103**. The third positioner **96** comprises a third drive motor and encoder **104** and a vertical stage **105**.
(115) Any suitable linear positioner or positioners may be used for the first positioner **92**, the second positioner **94**, and the third positioner **96**. For example, a number of linear positioners used in connection with 3D printers are suitable for use. More specifically, a stepper motor-driven leadscrew linear stage sold by Newmark Systems, Inc. of Rancho Santa Margarita, California as the “eTrack” linear stage is specified as having positional resolution of 0.04 μm and is suitable for the first positioner **92** and the second positioner **94**. A stepper motor-driven leadscrew vertical lift stage also sold by Newmark Systems, Inc. as the “VS” series is specified as having a positional resolution of 0.03 μm and is suitable for the third positioner **94**.
(116) In general, the first positioner **92**, the second positioner **94**, and the third positioner **96** are preferably arranged and configured in relation to each other so that the first positioner **92** is movable along a first longitudinal axis, the second positioner **94** is movable along a second longitudinal axis substantially orthogonal or perpendicular to the first longitudinal axis, and the third positioner **96** is movable along a third longitudinal axis substantially orthogonal or perpendicular to the first longitudinal axis and to the second longitudinal axis. The first positioner **92**, the second positioner **94**, and the third positioner **96** are each selectively and independently controllable by the control unit **110** for movement along the first, second, and third longitudinal axis respectively.
(117) As used herein, “along” a longitudinal axis in the context of the components and movement of the robotic positioner means and includes not only “on” the longitudinal axis but also “in a direction parallel to” the longitudinal axis. Further, and for purposes of description, the first longitudinal axis can correspond to the X-axis, the second longitudinal axis can correspond to the Y-axis, and the third longitudinal axis can correspond to the Z-axis of a 3D Cartesian coordinate system.
(118) Thus, for example, the first positioner **92** may be movable along the X-axis, the second positioner **94** may be movable along the Y-axis, and the third positioner **96** may be movable along the Z-axis of the 3D Cartesian coordinate system under control of the control unit **110**. Of course it will be appreciated that the axes of the 3D coordinate system can be arbitrarily reassigned to the

first positioner **92**, the second positioner **94**, and the third positioner **96** so that each positioner is movable along a longitudinal axis corresponding to one of the other X, Y, or Z axes of the coordinate system.

(119) In the example embodiments, the first mounting frames **92***a*, **92***b* of the first positioner **92** each comprise a substantially similar elongated plate with end plates at opposite ends. The first drive screw **95***a* is connected to the first drive motor and encoder **93**, and is selectively and rotationally drivable by the first drive motor and encoder **93**. The first drive screw **95***a* extends outward linearly along the first longitudinal axis from the first drive motor and encoder **93** through an opening in the end plate at one end of first mounting frame **92***a* and terminates at the end plate at the opposite end of the first mounting frame **92***a*. The first set of one or more first guide rails **97***a* extend linearly between the end plates substantially along the first longitudinal axis and substantially in parallel with the first drive screw **95***a*, and are supported at their opposite ends by the end plates. The first set of one or more first guide rails **97***a* extend though passages in the first linear stage **99***a* to support the first linear stage **99***a* and guide it for movement substantially along the first longitudinal axis between the end plates. The first drive screw **95***a* extends through a threaded passage of the first linear stage **99***a* so that rotation of the first drive screw **95***a* causes the first linear stage **99***a* to translate and move linearly on the first set of one or more first guide rails **97***a* substantially along the first longitudinal axis between the end plates.

(120) The first mounting frame **92***b* is spaced apart from and is arranged to be substantially co-planar with and to extend substantially parallel to the first mounting frame **92***a*. The first drive screw **95***b* is arranged to extend substantially linearly between the end plates of the first mounting frame **92***b* substantially along the first longitudinal axis and substantially co-planar with and parallel to the first drive screw **95***a*. The opposite ends of the first drive screw **95***b* are supported for rotational by the end plates, for example by hearings or the like. No drive motor is directly connected to the first drive screw **95***b*, but as will be appreciated from the description herein, the first drive motor and encoder **93** are indirectly connected to the first drive screw **95***b*. The second set of one or more first guide rails **97***b* are arranged to extend substantially linearly between the end plates of the first mounting frame **92***b* substantially along the first longitudinal axis, substantially parallel to the first drive screw **95***b*, and substantially co-planar with and parallel to the first set of one or more first guide rails **97***a*, and to have their opposite ends supported by the end plates. The first drive screw **95***b* and the first set of one or more first guide rails **97***a* extend though passages in the first linear stage **99***b* to support the first linear stage **99***b* and to guide it for movement between the end plates substantially along the first longitudinal axis and substantially co-planar with and substantially parallel to the first linear stage **99***a*.

(121) It will be appreciated that in the foregoing arrangement the first positioner **92** has two spaced-apart sides comprising the first mounting frames **92***a*, **92***b* with a space between them. Further, the side with the first drive motor and encoder **93** comprises a driven side, while the other side comprises a follower side. That is, provided the driven side and the follower side are interconnected, as the first drive motor and encoder **93** is selectively operated to rotate the first drive screw **95***a* on the driven side, the first linear stage **99***a* is driven linearly by translation on the first drive screw **95***a* along the first longitudinal axis. At the same time, the first linear stage **99***b* on the follower side follows the movement of the first linear stage **99***a* by translating linearly on the first drive screw **95***b* along the first longitudinal axis. Accordingly, the first linear stage **99***a* of the driven side and the first linear stage **99***b* of the follower side are selectively movable along the first longitudinal axis on opposite sides of the space between them.

(122) The first positioner **92** may be connected to the housing **40** of the example robotic wire termination system **10** either directly or indirectly via the first mounting frames **92***a*, **92***b*. With the first mounting frames **92***a*, **92***b* fixedly connected to the housing **40** (or to some other structure), rotation of the first drive screw **95***a* by the first drive motor and encoder **93** will cause both first linear stages **99***a*, **99***b* to move together along the first longitudinal axis on their respective first

drive screws **95**_a_, **95**_b_ and respective first guide rails **97**_a_, **97**_b_. Thus, the robotic positioner **90** and more particularly the first positioner **92** can be controlled by the control unit **110** to selectively move the first linear stages **99**_a_, **99**_b_ to any coordinate value along the first longitudinal axis within the limits of movement of the first linear stages **99**_a_, **99**_b_. The limits of movement of the first linear stages **99**_a_, **99**_b_ along the first longitudinal axis are determined by the locations of the end plates of the respective first mounting frames **92**_a_, **92**_b_. The first positioner **92** is preferably positioned within the interior **42** of the housing **40** so that within its limits of movement it can move and position the heating device **80** along the first longitudinal axis in the space between the first mounting frames **92**_a_, **92**_b_ so that the heating device **80** can be brought into a heating position relative to every individual connector pin **34** exposed to the interior **42** of the housing **40** through the opening **64** in the alignment plate retainer **60**.

(123) Similarly to the first positioner **92**, the second mounting frame **94**_a_ of the second positioner **94** comprises a substantially elongated plate with end plates at opposite ends. The second drive screw **101** is connected to the second drive motor and encoder **100**, and is selectively and rotationally drivable by the second drive motor and encoder **100**. The second drive screw **101** extends outward linearly along the second longitudinal axis from the second drive motor and encoder **100** through an opening in the end plate at one end of second mounting frame **94**_a_ and terminates at the end plate at the opposite end of the second mounting frame **94**_a_. The set of one or more second guide rails **102** extend linearly between the end plates substantially along the second longitudinal axis and substantially in parallel with the second drive screw **101**, and are supported at their opposite ends by the end plates. The set of one or more second guide rails **102** extend though passages in the second linear stage **103** to support the second linear stage **103** and guide it for movement substantially along the second longitudinal axis between the end plates. The second drive screw **101** extends through a threaded passage of the second linear stage **103** so that rotation of the second drive screw **101** causes the second linear stage **103** to translate and move linearly on the set of one or more second guide rails **102** substantially along the second longitudinal axis between the end plates.

(124) The second mounting frame **94**_a_ extends along the second longitudinal axis substantially orthogonal to the first mounting frames **92**_a_, **92**_b_. Each end plate at an opposite end of the second mounting frame **94**_a_ is connected to a first linear stage **99**_a_, **99**_b_ of the first positioner **92** by a plate, adaptor, or the like and suitable fasteners. With this arrangement, the second positioner **94** is disposed beneath the first positioner **92** within the housing **40** and the second linear stage **103** of the second positioner **94** is selectively movable within the housing **40** in the space between the first mounting frames **92**_a_, **92**_b_ of the first positioner **92**.

(125) With the second positioner **94** connected to the first positioner **92** as described, the second positioner **94** is movable with the first positioner **92** along the first longitudinal axis as the first linear stages **99**_a_, **99**_b_ of the first positioner **92** move in parallel along the first longitudinal axis. However, because the first positioner **92** is not connected to the second linear stage **103** of the second positioner **94**, the first positioner **92** does not move along the second longitudinal axis with the second positioner **94** when the second linear stage **103** moves along the second longitudinal axis.

(126) Rotation of the second drive screw **101** by the second drive motor and encoder **100** causes the second linear stage **103** to translate on the second drive screw **101** and to move linearly along the second longitudinal axis on the second drive screw **101** and the respective second guide rails **102**. Thus, the robotic positioner **90** and more particularly the second positioner **94** can be controlled by the control unit **110** to selectively move the second linear stage **103** to any coordinate value along the second longitudinal axis within the space between the first mounting frames **92**_a_, **92**_b_ of the first positioner **92** and within the limits of movement of the second linear stage **103**. Further, the second positioner **94** is arranged and connected to the first positioner **92** so that within its limits of motion, the second positioner **94** can move and position the heating device **80**

connected to the second linear stage **103** along the second longitudinal axis so that the heating device **80** can be brought into a heating position relative to every individual connector pin **34** exposed to the interior **42** of the housing **40**.

(127) The limits of movement of the second linear stage **103** along the second longitudinal axis traversing the space between the first mounting frames **92***a*, **92***b* are determined by the locations of the edges of the respective first mounting frames **92***a*, **92***b* along the space. Preferably, a range of motion limit indicator **106** is coupled to the second linear stage **103** and is in communication with the control unit **110**. The range of motion limit indicator **106** may be coupled to the second linear stage **103** either directly or indirectly, for example by being connected to a component such as the third positioner **96** which is in turn mounted on and connected to the second linear stage **103**. In either case, when the second linear stage **103** reaches the limits of its allowed motion along the second longitudinal axis, the range of motion limit indicator **106** communicates a signal to the control unit **110**, which is configured to control the second drive motor and encoder **100** to stop further movement of the second linear stage **103**.

(128) More specifically, the range of motion limit indicator **106** comprises a first limit switch **106***a* and a second limit switch **106***b*. The first limit switch **106***a* and the second limit switch **106***b* are spaced-apart and arranged so that when the second linear stage **103** reaches the limit of its range of motion in a first direction along the second longitudinal axis, the first limit switch **106***a* contacts the edge of the first mounting frame **92***a* of the first positioner **92** along the edge of the space. Similarly, when the second linear stage **103** reaches the limit of its range of motion in a second opposite direction along the second longitudinal axis, the second limit switch **106***b* contacts the edge of the first mounting frame **92***b* of the first positioner **92** along the opposite edge of the space. The first limit switch **106***a* and the second limit switch **106***b* are each in communication with the control unit **110**. Thus, when the first limit switch **106***a* contacts the edge of the first mounting frame **92***a* indicating the second linear stage **103** has reached the limit of its range of motion in the first direction, the first limit switch **106***a* communicates a signal to the control unit **110**, which is configured to control the second drive motor and encoder **100** to stop further movement of the second linear stage **103** in the first direction. Similarly, when the second limit switch **106***b* contacts the edge of the first mounting frame **92***b* indicating the second linear stage **103** has reached the limit of its range of motion in the second opposite direction, the second limit switch **106***b* communicates a signal to the control unit **110**, which is configured to control the second drive motor and encoder **100** to stop further movement of the second linear stage **103** in the second direction.

(129) At least in connection with the example embodiments, the first longitudinal axis and the second longitudinal axis extend laterally in relation to the connector pins **34** that are exposed to the interior **42** of the housing **40**. Based on the description above, it will be appreciated that the first positioner **92** is controllable to selectively move the second linear stage **103** of the second positioner **94** laterally to any coordinate value along the first longitudinal axis in the area beneath the connector pins **34** and the second positioner **94** is controllable to selectively move the second linear stage **103** laterally to any coordinate value along the second longitudinal axis in the area beneath the connector pins **34**. Accordingly, with the heating device **80** mounted to the second linear stage **103** of the second positioner **94**, the first positioner **92** and the second positioner **94** are controllable to selectively move the heating device **80** laterally in two orthogonal directions to any set of coordinates corresponding to any position within a substantially horizontal plane that extends laterally beneath the connector pins **34** including positions directly below each individual connector pin **34**.

(130) The third positioner **96** is mounted on and connected to the second positioner **94** and more specifically to the second linear stage **103** of the second positioner **94**. The connection can be made using a suitable plate, adaptor, or the like and suitable fasteners. The third positioner **96** is movable with the second positioner **94** and more specifically with the second linear stage **103** of the second

positioner **94** along the second longitudinal axis. In addition, because the second positioner **94**, and more specifically the second linear stage **103** of the second positioner **94**, is coupled with and movable with the first positioner **92** along the first longitudinal axis, the third positioner **96** is also movable with the first positioner **92** and the second positioner **94** along the first longitudinal axis. Thus, the third positioner **96** is selectively movable with the first positioner **92** and the second positioner **94** to any set of coordinates corresponding to any position within a substantially horizontal plane that extends laterally beneath the connector pins **34** of an electrical connector **30** that are exposed to the interior **42** of the housing **40** as described herein.
(131) The third drive motor and encoder **104** of the third positioner **96** is connected to the vertical stage **105**. The third drive motor and encoder **104** is operable to selectively drive the vertical stage **105** to extend or retract as illustrated in FIGS. **15**A and **15**B. The third positioner **96** is mounted on and connected to the second linear stage **103** of the second positioner **94** such that the vertical stage **105** extends and retracts along a third longitudinal axis that is substantially orthogonal or perpendicular to the first longitudinal axis and the second longitudinal axis as described herein. With the first longitudinal axis and the second longitudinal axis arranged to extend laterally beneath and with respect to the connector pins **34** of an electrical connector **30** that are exposed to the interior **42** of the housing **40** as described herein, the third longitudinal axis thus extends substantially vertically in relation to the connector pins **34**.
(132) The third positioner **96** is controllable to selectively move (extend or retract) the vertical stage **105** to any coordinate value along the third longitudinal axis within its limits of motion. With the first positioner **92**, second positioner **94**, and third positioner **96** arranged and interconnected as described herein, the vertical stage **105** thus can be selectively moved and positioned to any set of coordinates corresponding to any position in three dimensional space in the area beneath the connector pins **34** of an electrical connector **30** that are exposed to the interior **42** of the housing **40** as described herein.
(133) The heating device **80**, which is described in further detail below, is mounted on and connected to a top surface **107** of the vertical stage **105** such that the heat providing element of the heating device **80** extends outwardly and upwardly substantially along the third longitudinal axis from the vertical stage **105**. With the heating device **80** mounted on the vertical stage **105** and the third positioner **96** mounted on the second linear stage **103** of the second positioner **94** as described herein, within the limits of its motion the vertical stage **105** can be selectively extended and retracted to bring the heat providing element of the heating device **80** into a heating position relative to each individual connector pin **34** of an electrical connector **30** that is exposed to the interior **42** of the housing **40** as described herein and to remove the heat providing element from the heating position. As described further herein, the heating position can comprise the heat providing element being in contact with or in proximity with but not in contact with each connector pin **34**.
(134) With the first positioner **92**, second positioner **94**, and third positioner **96** arranged and interconnected as described and with the heating device **80** mounted to the third positioner **96** as described, it will be appreciated that the first positioner **92**, the second positioner **94**, and the third positioner **96** may each be independently controlled by the control unit **110** to sequentially move and position the heating device **80** in a plurality of different heating positions in three dimensional space within the interior **42** of the housing **40** to apply heat to a sequence or series of individual connector pins **34** exposed to the interior **42** of the housing **40** to melt the solder preform **39** in corresponding wire receptacles **38** and enable individual wires **20** to be sequentially connected to the connector pins **34**. It will be further appreciated that each different heating position is associated with and relative to a selected connector pin **34** of an electrical connector **30** that is exposed to the interior **42** of the housing **40** as described herein and corresponds to a unique set of coordinates (e.g., X, Y, Z coordinates of a Cartesian coordinate system) in the three dimensional space within the interior **42** of the housing **40**.
(135) An example sequence is illustrated in FIGS. **16**A-**16**H. In the example sequence, an electrical

connector **30** is held in a an alignment plate **70** in the alignment plate retainer **60** on the top surface **44** of the housing **40** with the connector pins **34** of the electrical connector **30** exposed to the interior **42** of the housing **40** as described herein. As shown in FIG. **16**A, the robotic positioner **90** starts in a zero or starting position. In this position, the heating device **80** is laterally removed from the area beneath the connector pins **34**. A connector pin **34** may be selected to have a wire **20** connected. As described herein, the selection may be made in a number of ways. For example, an operator may manually select an individual connector pin **34**. Alternatively, the connector pin **34** may be automatically selected programmatically, for example as the first selected connector pin **34** of a predetermined sequence or series of connector pins **34** to which wires **20** are to be connected. Regardless of the manner in which the connector pin **34** is selected, as shown in FIG. **16**B in response the robotic positioner **90**, and more specifically the first positioner **92**, is automatically controlled by the control unit **110** to move the heating device **80** laterally along the first longitudinal axis (indicated by the direction of the arrow) to a coordinate value corresponding to a position in the area beneath the connector pins **34**. For example, the coordinate value may correspond to a position directly beneath a row of connector pins **34** that contains the selected connector pin **34**.

(136) Next, as shown in FIG. **16**C, the robotic positioner **90**, and more specifically the second positioner **94**, is automatically controlled by the control unit **110** to move the heating device **80** laterally along the second longitudinal axis (indicated by the direction of the arrow) to a coordinate value corresponding to another position in the area beneath the connector pins **34**. For example, the coordinate value may correspond to a position directly beneath the selected connector pin **34**.

(137) It will be appreciated that while FIGS. **16**B and **16**C show the heating device **80** being moved laterally first along the first longitudinal axis and then along the second longitudinal axis, this is just an example. The heating device may be moved laterally along the first longitudinal axis and the second longitudinal axis in any order.

(138) Next, as shown in FIGS. **16**D and **16**E, the robotic positioner **90**, and more specifically the third positioner **96**, is automatically controlled by the control unit **110** to move the heating device **80** along the third longitudinal axis (indicated by the direction of the arrow) to a coordinate value corresponding to a heating position associated with and relative to the selected connector pin **34**. Depending on the heat providing element of the heating device **80**, which is described further below, the heating position can comprise the heat providing element being in contact with the male connecting end **36** of the selected connector pin **34** (FIG. **16**E) or in proximity to but not in contact with the male connecting end **36**. The heating device **80** is then activated to provide heat to the male connecting end **36** to melt the solder preform **39** in the corresponding wire receptacle **38** of the connector pin **34** to enable a wire **20** to be connected.

(139) After a wire **20** has been connected, another connector pin **34** may be selected. As described herein, another connector pin **34** may be selected in a number of ways. For example, an operator may manually select another connector pin **34** or may select to proceed to the next connector pin in a predetermined sequence or series of connector pins **34**. Alternatively, the connector pin **34** may be automatically or programmatically selected in response to an operator indicating the wire connection procedure with respect to the previously selected connector pin **34** is complete or in response to the control unit **110** detecting a reduction in the temperature of the heating device **80** for example. Regardless of the manner in which another connector pin **34** is selected, as shown in FIG. **16**F in response the robotic positioner **90**, and more particularly the third positioner **96**, is automatically controlled by the control unit **110** to move the heating device **80** along the third longitudinal axis in the opposite direction (indicated by the direction of the arrow) to a coordinate value at which the heating device **80** is removed from the heating position with respect to the previously selected connector pin **34**.

(140) Next, as shown in FIG. **16**G, the robotic positioner **90** and more particularly the first positioner **92** can be automatically controlled to move the heating device **80** laterally along the first

longitudinal axis (indicated by the direction of the arrow) to a coordinate value corresponding to another position in the area beneath the exposed connector pins **34**. For example, the coordinate value may correspond to a position directly beneath the next selected connector pin **34**. It will be appreciated that while FIG. **16**F shows only lateral movement of the heating device **80** along the first longitudinal axis to bring it beneath the next selected connector pin **34**, this is just an example. It may be that the heating device **80** also must be moved laterally along the second longitudinal axis, or along both the first longitudinal axis and the second longitudinal axis as shown in FIGS. **16**B and **16**C, to position it at a set of coordinates corresponding to a position directly beneath the next selected connector pin **34**. As noted in connection with FIGS. **16**B and **16**C, in that case the heating device **80** may be moved laterally along the first longitudinal axis and the second longitudinal axis in any order.

(141) Next, as shown in FIG. **16**H, the robotic positioner **90**, and more specifically the third positioner **96**, is automatically controlled by the control unit **110** to move the heating device **80** along the third longitudinal axis (indicated by the direction of the arrow) to a coordinate value corresponding to a heating position associated with and relative to the next selected connector pin **34** to apply heat. The sequence as illustrated in FIGS. **16**A-**16**H and as described above can continue indefinitely until all connector pins **34** of the electrical connector **30** which are to have wires **20** connected have been selected and wires **20** have been connected.

(142) G. Heating Device.

(143) The heating device **80** of the example robotic wire termination system **10** is utilized to apply heat to the individual connector pins **34** of electrical connectors **30** sufficient to melt solder preform **39** (e.g., approximately 190 degrees F. or greater) into a liquid state to solder connect the wires **20** of cable **22** or another source to the connector pins **34**. Details of alternative example heating devices **80** are illustrated in FIGS. **13**A-**13**C and the heating device **80** is further illustrated in connection with the robotic positioner **90** and other system components in FIGS. **1**, **4**A, **5**A, **14**A-**14**F, **16**A-**16**H, and **17**.

(144) The heating device **80** is preferably constructed as a relatively compact mobile unit that is adapted and configured for attachment to the robotic positioner **90** for movement within the interior **42** of the housing **40**. The heating device **80** comprises a base **81**, a mounting block **82**, one or more heating elements **83**, a heat providing element which in the example embodiments comprises a thermal tip **84** (FIG. **13**A, **13**B) or nozzle **85** (FIG. **13**C), and a temperature measuring device **86**.

(145) The heating elements **83** can be comprised of any device capable of generating heat sufficient to melt solder preform **39** to connect wires **20** to the connector pins **34** of the electrical connector **30**. The heating elements **83** can generate heat via electricity or via other options. In the example robotic wire termination system **10**, the one or more heating elements **83** preferably comprise electronic-type heating elements. For example, the ceramic cartridge-type electronic heating elements employed in 3D printers are suitable. For the purpose of generating heat to melt the solder preform, a single **12**_v_ 40 W heating element of that type is at least minimally sufficient. However, in order to raise the temperature from ambient to and above the melting point of solder more rapidly, the use of at least two such heating elements **83** is preferred. The heating elements **83** are electrically connected to the control unit **60** by wires, are in electrical communication with the control unit **110**, and are controllable by the control unit **110** as described further below.

(146) The heating elements **83** are fixedly attached to and are in physical and thermal contact with the mounting block **82**. The mounting block **82** is preferably constructed of a thermal conducting material, such as a metal. The heating elements **83** are preferably attached to the mounting block **82** in a manner so that they remain in good physical and thermal contact with the mounting block **82** even when the heating device **80** is moved within the interior **42** of the housing **40** with the robotic positioner **90**. Accordingly, while the heating elements **83** may be attached to an external surface of the mounting block **82**, it is more preferred that they be securely held within the mounting block **82**. One way to accomplish this is to divide the mounting block **82** into a separate upper mounting

block **82***a* and lower mounting block **82***b*. Complementary half-rounds can be formed in the mating surfaces of the upper mounting block **82***a* and the lower mounting block **82***b*. The half-rounds engage, surround, and securely hold cylindrical cartridge-type heating elements **83** when the mating surfaces of the upper mounting block **82***a* and the lower mounting block **82**B are brought together or mated. The upper mounting block **82***a* and the lower mounting block **82***b* are suitably connected and held together by screws, bolts or other similar fasteners. By tightening the screws, bolts, or other fasteners the heating elements **83** are engaged and securely held in the half-rounds between and in good physical and thermal contact with the mating surfaces of the upper mounting block **82***a* and the lower mounting block **82***b*.

(147) Although a solid block of material can be used for the mounting block **82**, the described arrangement has the advantage of maximizing the surface contact between the heating elements **83** and the mounting block **82** and therefore maximizing thermal transfer from the heating elements to the mounting block **82**. It also has the advantage that if a heating element **83** must be replaced, it can be easily replaced by simply loosening the screws, bolts, or other fasteners and separating the upper mounting block **82***a* and the lower mounting block **82***b*.

(148) The mounting block **82** preferably includes a threaded receptacle. The threaded receptacle is adapted to receive and securely but removably hold the heat providing element, which is described further below, in threaded engagement. The threaded receptacle enables one heat providing element to be removed from the mounting block **82** and another inserted in its place quickly and easily. Since different electrical connectors **30** may require different types or sizes of heat providing elements to connect wires **20**, the use of the threaded receptacle (alone or together with the use of the removable alignment plate **70**) advantageously reduces down time associated with switching over between different electrical connectors **30**.

(149) The mounting block **82** is fixedly attached, connected or mounted to the top surface of the base **81**, for example by suitable bolts, screws, or similar fasteners. The base **81** in turn is fixedly attached, connected, or mounted to the robotic positioner **90**, also by suitable bolts, screws, or similar fasteners for example. More particularly, and as described further below, the base **81** is connected or mounted to the third positioner **96** of the robotic positioner **90**, and still more particularly to the top surface **107** of the vertical stage **105** of the third positioner **96**. The base **81** is preferably constructed of a material, such as a ceramic, that has substantial resistance to heat and is a good thermal insulator. The base **81** thus resists the conductance and transfer of heat from the heating elements **83** and mounting block **82** to the robotic positioner **90** and other components of the system.

(150) The heat providing element of the heating device **80** may comprise any technology that can selectively provide heat to the connector pins **34** of the electrical connector **30** sufficient to melt solder preform **39** in any suitable manner. In the example embodiments, the heat providing element comprises technology that provides the heat to individual connector pins **34** of an electrical connector **30** either directly or indirectly.

(151) In one alternative, illustrated in FIGS. **13**A and **13**B, the heat providing element comprises the thermal tip **84**. The thermal tip **84** is comprised of a heat conductive material, such as a metal, having a higher melting point than the solder preform **39**. The thermal tip **84** may, for example, comprise a tip similar to a soldering tip of a soldering tool of the type used to solder connect fine structures, such as small wires. The thermal tip has a first end portion that is preferably threaded. The threaded portion is adapted to be inserted in the threaded receptacle of the mounting block **82** and to be securely but removably held in threaded physical engagement with the mounting block **82**. The thermal **17** tip **84** has a second end portion that extends outwardly from the top surface of the mounting block **82** substantially along the third longitudinal axis and in the direction of the connector pins **34**.

(152) The second end portion of the thermal tip **84** preferably comprises a hollow point or tip **87** with a substantially cylindrical interior portion **87***a*. The hollow point or tip **87** is dimensioned and

configured so that the male connecting end **36** of an individual connector pin **34** of the electrical connector **30** can be received in the cylindrical interior portion **87***a* of the hollow point or tip **87** when the heating device **80** is brought into a heating position with respect to the individual connector pin **34** by the robotic positioner **90**. When received in the cylindrical interior portion **87***a*, the male connecting end **36** is surrounded by and in physical and thermal contact with the hollow point or tip **87**. The edge of the hollow point or tip that engages the male connecting end as it is received in the cylindrical interior portion may be beveled in order to help guide the male connecting end into the cylindrical interior portion **87***a*.

(153) The hollow point or tip can **87** be provided with a holding mechanism to help securely but removably hold the male connecting end **36** in the interior portion **87***a*. The holding mechanism can comprise an expansion or spring mechanism **88** that biases the hollow point or tip **87** and helps it engage the male connecting end **36** when it is positioned in the interior portion **87***a*. The expansion or spring mechanism **88** can comprise one or more elongated slots for example. Accordingly, the diameter of the cylindrical interior portion **87***a* can be dimensioned slightly smaller than the male connecting end **36** so that the male connecting end **36** fits snugly within the interior portion **87***a* preferably with substantially the entire external surface of the male connecting end **36** in contact with the surface of the interior portion **87***a* of the hollow point or tip **87**. In addition to helping hold the connector pin **34** securely in place as the heating device is moved into the heating position and heat is applied, this also helps maximize the heat transfer from the thermal tip **84** to the connector pin **34**.

(154) When the heating device **80** is in heating position in relation to an individual connector pin **34** of the electrical connector **30** with the male connecting end **36** of the connector pin **34** in the cylindrical interior portion **87***a* of the hollow point or tip **87** of the thermal tip **84**, and the heating elements **83** are activated, the heat generated transfers from the heating elements **83** through the mounting block **82** to the thermal tip **84**. The thermal tip **84** transfers the heat to the male connecting end **36** and hence to the individual connector pin **34** of the electrical connector **30** directly by conduction.

(155) In another alternative, illustrated in FIG. **13**C, the heat providing element comprises the nozzle **85**. The nozzle **85** comprises an air inlet and an air outlet **89**. The nozzle **85** is comprised of a material, such as a metal, having a higher melting point than the solder preform **39**. The nozzle **85** may, for example, comprise a nozzle of the type used to provide heated air to melt materials in 3D printers. The nozzle **85** has a first end portion that is preferably threaded. The threaded portion is adapted to be inserted in the threaded receptacle of the mounting block **82** and securely but removably held in threaded physical engagement with the mounting block **82**. The nozzle **85** has a second end portion that extends outwardly from the top surface of the mounting block **82** substantially along the third longitudinal axis and in the direction of the connector pins **34**. The second end portion of the nozzle **85** preferably comprises the air outlet **89**.

(156) When the heating device **80** is in heating position in relation to an individual connector pin **34** of the electrical connector **30**, the air outlet **89** of the nozzle **85** is in proximity to but not in physical contact with the male connecting end **36** of the connector pin **34**. When the heating elements **83** are activated, the heat generated transfers from the heating elements **83** through the mounting block **82** to the nozzle **85**. Air is blown through the nozzle **85** from the air inlet to the air outlet **89**. As the air passes through the nozzle **85**, the nozzle **85** transfers the heat to the air to heat the air to a temperature sufficient to melt the solder preform **39**. The air outlet **89** of the nozzle **85** directs the heated air onto the male connecting end **36** of the individual connector pin **34** to melt the solder preform **39** indirectly and without physical contact by convection.

(157) The temperature measuring device **86** can be thermally coupled to the heating elements **83** and the heat providing element of the heating device **80** indirectly through the mounting block **82**. The temperature measuring device **86** also can be directly thermally coupled to the heating elements **83** or to the heat providing element. In embodiments employing convection heating, the

temperature measuring device **86** can be exposed in a flow of heated air to directly measure the temperature of the air. The temperature measuring device **86** measures the temperature of the heat produced by the heating device **80** and provided to the connector pins **34** by the heat providing element. The temperature measuring device **86** is in communication with the control unit **110** and communicates temperature data measurements to the control unit **110**. The control unit **110** is configured to determine from the measured temperature data the amount of heat being provided to the connector pins **34** in response to control the operation of the heating device **80**, for example by activating or deactivating the heating device **80** or increasing or decreasing the level of a drive signal. The temperature measuring device **86** can be comprised of any device capable of measuring high temperatures such as temperatures in excess of the melting point of solder. The temperature measuring device **86** can comprise but is not limited to a thermocouple.
(158) H. Control Unit.
(159) The control unit **110** can be comprised of any type of circuit board or computer suitable for practicing the various aspects of the example robotic wire termination system **10**. Preferably, the control unit **110** comprises a computer or controller with a small footprint, such as a Rasberry Pi, that can be easily enclosed and contained within housing **40**, and that requires little space and little power to operate, yet has sufficient functionality to communicate with and control the operation of the various components of the system as described herein. This helps to make the example robotic wire termination system **10** relatively light, compact, portable, and suitable for desktop or benchtop use.
(160) However, the control unit **110** can be comprised of any conventional computer, controller, or similar electronic device that has sufficient functionality to communicate with and control the operation of the various components of the system as described herein. The control unit **110** can comprise without limitation a personal computer (e.g. APPLE® based computer, an IBM based computer, or compatible thereof) or a tablet computer (e.g. IPAD®). The control unit **110** can also be comprised of various other electronic devices capable of sending and receiving electronic data including but not limited to smartphones, mobile phones, telephones, personal digital assistants (PDAs), mobile electronic devices, handheld wireless devices, two-way radios, smart phones, communicators, video viewing units, television units, television receivers, cable television receivers, pagers, communication devices, and digital satellite receiver units.
(161) The control unit **110** may comprise a conventional computer that can and preferably does include a display screen (or monitor), a disk drive or other storage device, a network interface, one or more conventional I/O interfaces, and optionally a keyboard and a printer. A conventional computer also will include a microprocessor, a memory bus, random access memory (RAM), read only memory (ROM), a peripheral bus, and one or more I/O controllers for a keyboard, mouse, and/or other I/O devices. The microprocessor will typically be a general-purpose digital processor that controls the operation of the computer. The microprocessor can be a single-chip processor or implemented with multiple components. Using instructions retrieved from memory, the microprocessor controls the reception and manipulations of input data and the output and display of data on output devices. The memory bus is utilized by the microprocessor to access the RAM and the ROM. RAM is used by microprocessor as a general storage area and as scratch-pad memory, and can also be used to store input data and processed data. ROM can be used to store instructions or program code followed by microprocessor as well as other data. A peripheral bus is used to access the input, output and storage devices used by the computer. In the described embodiments, these devices can include a display screen, a hard disk drive or other storage device, a network interface, and optionally a printer device. The conventional computer will typically include a keyboard controller that is used to receive input from the keyboard and send decoded symbols for each pressed key to the microprocessor over the bus. The keyboard can be used by a user to input commands and other instructions to the computer system. Other types of user input devices can also be used in conjunction with the example robotic wire termination system **10**. For example,

pointing devices such as a computer mouse, a track ball, a stylus, or a tablet can be used to manipulate a pointer on a display screen of the computer system, and make selections as inputs to the control unit **110**. Hand operated switches, foot operated switches, or other switches can be used to provide signals to the control unit **110** indicating selections by an operator or the occurrence of events. The display screen is typically an output device that displays images of data provided by the microprocessor via the peripheral bus or provided by other components in the computer. However, the display screen can also be touch sensitive and able to generate signals to the control unit **110** indicating selections by an operator and/or the occurrence of events. If used, the printer device when operating as a printer provides an image on a sheet of paper or a similar surface. The hard disk drive or other storage device, such as a solid state disk device, can be utilized to store various types of data. The microprocessor, together with an operating system, operates to execute computer code and produce and use data. The computer code and data may reside on RAM, ROM, hard disk drive or other storage medium such as solid state disk drive. The computer code and data can also reside on a removable program medium and loaded or installed onto computer system when needed. Removable program mediums include, for example, CD-ROM, PC-CARD, USB drives, floppy disk and magnetic tape. The network interface circuit is utilized to send and receive data over a network connected to other computer systems. An interface card or similar device and appropriate software implemented by microprocessor can be utilized to connect the computer system to an existing network and transfer data according to standard protocols.
(162) The control unit **110** is adapted and configured to control the operation of the example robotic wire termination system **10** as described herein. The control unit **110** is in communication with and is configured to control the heating device **80**, the temperature measuring device **86**, the robotic positioner **90**, the display **120**, which is described further below, and various I/O devices **108**, which also are described further below, through the plurality of input/output (I/O) ports **50-54**.
(163) More particularly regarding the robotic positioner **90**, the control unit **110** is in communication with and is configured to control each of the first positioner **92**, the second positioner **94**, and the third positioner **96** separately and independently. Even more particularly, the control unit **110** is in communication with and is configured to control each of the first drive motor and encoder **93** of the first positioner **92**, the second drive motor and encoder **100** of the second positioner **94**, and the third drive motor and encoder **104** of the third positioner **96** separately and independently. The control unit **110** also is in communication with and is configured to receive inputs from the range of motion limit indicator **106** of the second positioner and even more particularly from the first limit switch **106***a* and the second limit switch **106***b* of the range of motion limit indicator **106**.
(164) The control unit **110** can be configured to control the heating device **80** by selectively activating and deactivating the heating elements **83**. When the control unit **110** activates the heat elements **83**, heat is provided to the heat providing element (thermal tip **84** or nozzle **85**) which can provide heat to a selected connector pin **34** to melt solder preform **39** for connecting a wire **20**. When the heat elements **83** are deactivated, heat for melting the solder preform **39** is no longer provided by the heat providing element. The control unit **110** also can be configured to selectively control the heating device **80** to produce a desired amount of heat by selectively controlling the level and/or frequency of one or more drive signals to the heat elements **83**.
(165) The control unit **110** is configured to receive temperature measurements from the temperature measuring device **86** either continuously or periodically. The control unit **110** can receive the temperature measurements either with or without transmitting requests to the temperature measuring device **86**.
(166) The control unit **110** is configured to control the robotic positioner **90** to selectively move and position the heating device **80** in one or more heating positions associated with and relative to one or more corresponding selected individual connector pins **34** of an electrical connector **30** to which wires **20** are to be connected. The control unit **110** controls the robotic positioner **90** by sending

control signals separately and independently to the first drive motor and encoder **93** of the first positioner **92**, the second drive motor and encoder **100** of the second positioner **94**, and the third drive motor and encoder **104** of the third positioner **96** to move the heating device **80** to sets of coordinates in 3D space corresponding to the heating positions relative to the selected connector pins **34**.

(167) The control signals can take various forms, but can comprise for example step counts for stepper motors comprising the drive motors **93**, **100**, **104**. For example, as described above, an electrical connector **30** to which wires **20** are to be connected is received and held in a corresponding alignment plate **70** in the alignment plate retainer **60** of the housing **40** in a specific position and orientation with the connector pins **34** of the electrical connector **30** exposed to the interior **42** of the housing **40**. The coordinates (e.g., X, Y, and Z coordinates of a Cartesian coordinate system) corresponding to the heating position associated with and relative to each such connector pin **34** in 3D space can thus be determined. Similarly, the coordinates of a starting position of the heating device **80** in 3D space can be assigned or determined. From the starting position and heating position coordinates, the distance the heating device **80** must move along each of the first, second, and third longitudinal axes to reach the heating position associated with each selected connector pin **34** can be determined. Those distances can be related to corresponding step counts for the stepper motors comprising the drive motors **93**, **100**, **104** of the corresponding first, second, and third positioners **92**, **94**, **96**. The control unit **110** can thus send the step counts as control signals to the robotic positioner **90** to move and position the heating device **80** in the heating position relative to each and any selected connector pin **34** of the electrical connector **30**.

(168) A set of coordinates corresponding to each heating position of each connector pin **34** of each electrical connector **30** with which the example robotic wire termination system **10** is intended to be used can be stored and later retrieved by the control unit **110** for use, for example in response to receiving as input a selection of an electrical connector **30** from an operator. The coordinates can be stored in any suitable storage, including RAM, EPROM, hard drive, solid state device, etc. Each stored coordinate set can be indexed by or associated with an identifier of the electrical connector **30** to which it applies. The coordinates can be stored as positions in 3D space, distances from an origin, such as a predetermined starting point, step counts, and/or in other forms.

(169) The control unit **110** also is configured to receive various inputs, including inputs identifying selections of one or more connector pins **34** of an electrical connector **30** to which wires **20** are to be connected. The inputs identifying selections of one or more connector pins **34** may include inputs identifying the selection of a single arbitrarily selected connector pin **34** of an electrical connector **30** to which a wire **20** is to be connected, for example in connection with a rework operation. The inputs identifying selections of one or more connector pins **34** also can include inputs identifying the selection of a connector pin **34** of a predetermined set, sequence, or series of connector pins **34** that constitute all or some of the connector pins **34** of an electrical connector **30** to which wires **20** are to be connected.

(170) The control unit **110** is configured to receive the inputs identifying selections of one or more connector pins **34** from the display **120**, from one or more input devices of the I/O devices **108**, or automatically under control of a predetermined program. Inputs received from the display **120** can result from an operator manually interacting with the display **120** as described further below. Inputs received from the I/O devices **108** can result from an operator manually actuating a hand switch and/or a foot switch, also as described further below.

(171) In comparison, inputs received automatically under control of a predetermined program are received by the control unit **110** internally and automatically and may result without any manual intervention or action by an operator. Such inputs, for example, can result from the control unit **110** determining under programmatic control that the heating device **80** has reached a predetermined temperature, and/or that a predetermined time period has elapsed, and/or that some other event or condition exists or has occurred.

(172) The control unit **110** also is configured to control the display **102** to visually display various information. As described further below, the control unit **110** can control the display **120** to visually display information such as an icon or graphic for an operator to select an electrical connector **30**, to visually display a graphic indication of the connector pins **34** of a selected electrical connector **30**, to provide a visual indication of the selection of a connector pin **34**, to provide a visual indication of the heating device **80** being in a heating position with respect to a selected connector pin **34**, to visually display icons or graphics for an operator to select to move the heating device **80** to a next or a previous connector pin **34** in a predetermined series of connector pins **34**, to visually display the measured and target temperatures of the heating device **80**, and to visually display icons or graphics for an operator to selectively increase or decrease the target temperature of the heating device **80**. The control unit **110** also can control the display **120** to visually display other information for controlling the operation of the system, such as an icon or graphic for an operator to select a manual mode of operation of the system, a visual indication of the selected mode of operation of the system (e.g., automatic or manual), an icon or graphic for an operator to stop the system from carrying out a sequence or series of wire connection operations, an icon or graphic for an operator to select to manually engage or disengage the heating device **80** with a selected connector pin **34** and a visual indication of the engagement and disengagement status of the heating device **80**, an icon or graphic for an operator to select to activate and deactivate the heating device **80**, and any other information to enable an operator to control operation of the system.
(173) The control unit **110** is further configured to control the various components of the example robotic wire termination system **10** to take various actions and to perform various operations in response to receiving various inputs. Generally, in response to receiving inputs identifying the selection of one or more connector pins **34** to which wires are to be connected, the control unit **110** is configured to control the robotic positioner **90** to selectively position the heating device **80** to one or more heating positions associated with and relative to the selected connector pins **34** and to provide heat to melt solder preform **39** to enable wires **20** to be connected to the selected connector pins **34**.
(174) More specifically, in response to inputs indicating selection of an electrical connector **30** and an automatic mode of operation, the control unit **110** is configured to control the robotic positioner **90** to sequentially position the heating device **80** in a plurality of heating positions with each heating position being associated with a selected connector pin **34** of a predetermined set of connector pins **34** according to a predetermined sequence or series in order to connect a plurality of wires **20**. The control unit **110** is further configured in response to receiving an input indicating a selection to proceed to the next connector pin **34** to control the robotic positioner **90** to move the heating device **80** from the heating position associated with the currently selected connector pin **34** of the predetermined sequence or series to a heating position associated with the next connector pin **34** in the predetermined sequence or series.
(175) The input indicating a selection to proceed to the next connector pin **34** in a predetermined series can be generated manually by an operator, for example by actuating a hand or foot switch of the I/O devices **108**, or by selecting a displayed icon or graphic on the display **120**, or can be generated automatically under programmatic control. In the latter case, the control unit **110** can monitor the temperature of the heating device **80** by periodically or continuously receiving temperature measurements from the temperature measuring device **86**. When the control unit **110** determines that the heating device **80** is in a heating position relative to a selected connector pin **34** and that the temperature of the heating device **80** has reached a predetermined target value for melting solder preform **39**, it can automatically take an action in response, such as controlling the robotic positioner **90** to move the heating device **80** from the heating position associated with the currently selected connector pin **34** in the predetermined series to a heating position associated with the next selected connector pin **34** in the predetermined series. It can also control the heating device **80** to deactivate the heating elements **83** as the heating device **80** is moved from one heating

position to another. Also under programmatic control, the control unit **110** can factor into the determination whether to take an action a predetermined elapsed time, for example the elapsed time the heating device **80** has been in a heating position and at a predetermined target temperature.
(176) Also more specifically, in response to inputs indicating selection of an electrical connector **30**, a manual mode of operation, and a connector pin **34**, the control unit **110** is configured to control the robotic positioner **90** to position the heating device **80** to the heating position associated with the selected connector pin **34**. If after that the control unit **110** receives an input indicating selection of another connector pin **34**, it controls the robotic positioner **90** to move the heating device **80** from the heating position associated with the currently selected connector pin **34** to a heating position associated with the newly selected connector pin **34**. It can also control the heating device **80** to deactivate the heating elements **83** as the heating device **80** is moved. In the manual mode of operation, the connector pins **34** can be selected arbitrarily and in any order.
(177) In all of the situations described above it is understood that, as described previously, whenever the control unit **110** controls the robotic positioner **90** to move the heating device **80**, it independently and separately controls the first positioner, the second positioner, and the third positioner **92**, **94**, **96** of the robotic positioner **90** as described herein to move the heating device **80** along three substantially orthogonal longitudinal axes. It is also understood that the control unit **110** is further configured to control the heating device **80** at each heating position to provide heat to the selected connector pin **34** to melt solder preform **39** for connecting a wire **20** to the connector pin **34** either in response to input manually initiated by an operator or input automatically received under control of a predetermined program.
(178) I. Display and Input Devices.
(179) The display **120** is in communication with the control unit **110** and is adapted and configured to display various information, including the information described above, under the control of the control unit **110**. The display **120** can comprise a touch sensitive type display which is further adapted and configured to sense or detect an operator physically touching or otherwise selecting a displayed icon, graphic, or other visual indication and in response to generate a corresponding input signal that is received by the control unit **110** and indicates the selection.
(180) The display **120** also can comprise a conventional non-touch responsive monitor or display that is adapted and configured to display a visual pointer that is generated by an input device of the I/O devices **108**, such as a mouse, track ball, or pointer, that is in communication with the control unit **110**. The input device is adapted to be manipulated by an operator to selectively position the visual pointer on the display **120**. The input device also comprises a switch that when actuated generates an input signal that is received by the control unit **110**. When the input device is manipulated to position the visual pointer at a location on the display **120** associated with a displayed icon or graphic, actuation of the switch generates an input signal that is received by the control unit **110** and that indicates the selection of the icon or graphic.
(181) There are many other ways an operator can select icons or graphics on the display **120** and those selections can be indicated to the control unit **110**. In the description herein whenever there is reference to such a selection being made, it is assumed that a resulting input signal indicating the selection is received by the control unit **110**. Further, all suitable ways of making the selection and indicating it to control unit **110** are contemplated, including but not limited to those specifically described above.
(182) When the example robotic wire termination system **10** is powered up, the display **120** can be controlled by the control unit **110** to display a control screen **122** such as shown in FIG. **18**. The control screen **122** can include an icon or graphic, such as a control box **123**, for an operator to select an electrical connector **30** (which also may be called an “insulator”) to which wires **20** are to be connected. The control screen **122** can also display an icon or graphic, such as a control box **124**, for an operator to confirm a selection of an electrical connector **30**. The example robotic wire termination system **10** can be used with a plurality of different electrical connectors **30** each of

which can be identified by a suitable unique identifier. The identifiers can be stored in the system. The control unit **110** can be configured to respond to the operator selecting the control box **123** to retrieve the list of identifiers stored in the system and to cause the display **120** to display the list. The control unit **110** can be configured to respond to the operator selecting a particular identifier from the displayed list by retrieving from system storage the information for the electrical connector **30** corresponding to the selected identifier. Such information will include the information necessary for the control unit **110** to control the robotic positioner **90** to position the heating device **80** to a heating position relative to each individual connector pin **34** of the selected electrical connector **30**. The information can include for example the number, spacing, dimensions, arrangement, and coordinates of the connector pins **34** on the electrical connector **30**, as well as the coordinates of the heating position relative to each connector pin **34**.

(183) The display **120** also can be controlled by the control unit **110** to display a control screen **125** such as shown in FIGS. **19**A and **19**B. The control unit **110** can control the display **120** to display the control screen **125** in response to an operator selecting a particular electrical connector **30** on the control screen **122**. The control screen **125** can include a number of icons, graphics, including control boxes, and visual indications that the operator can select to control the operation of the example robotic wire termination system **10** as described herein.

(184) The control screen **125** can include a graphical representation **126** of the connector pins **34** of the selected electrical connector **30**. Each of the connector pins displayed in the graphical representation **126** corresponds to a connector pin **34** of the selected electrical connector **30**. The connector pins displayed in the graphical representation **126** can be arranged in substantially the same way the actual connector pins **34** are arranged on the electrical connector **30**. For example purposes, FIGS. **19**A and **19**B illustrate the graphical representation of the connector pins **34** of a simple two row electrical connector **30**. It is understood however, that in actual practice the electrical connectors **30** with which the example robotic wire termination system **10** is intended for use can and often will include a substantially greater number of connector pins **34** arranged in substantially more complex arrangements, which need not be regular or symmetrical.

(185) The control screen **125** also can include one or more icons or graphics, such as control boxes **127**, **128** for an operator to select a manual **127** or automatic **128** mode of operation of the system and to provide a visual indication of the selected mode of operation of the system (e.g., automatic or manual) **128**. The control unit **110** can be configured to automatically start the system in automatic mode or can be configured to await a mode selection by the operator.

(186) In automatic mode, the control unit **110** can be configured to control the robotic positioner **90** to automatically move and position the heating device **80** beneath a predetermined first connector pin **34** of the electrical connector **30**. As described herein, the predetermined first connector pin **34** can be the first in a predetermined series of connector pins **34** to which wires **20** are to be connected. In the example illustrated in FIG. **19**A, the predetermined first connector pin **34** corresponds to a pin labeled “1” in the graphic representation **126** of the display **120**.

(187) In manual mode, the control unit **110** can be configured to await an input signal corresponding to a selection of a connector pin **34** to which the heating device **80** is to be moved. The input signal identifying the selected connector pin **34** can comprise a signal that results from an operator selecting (e.g., by touching or by using an input device as described above) a position in the graphical representation **126** associated with the selected connector pin **34**, i.e., the position of the pin displayed in the graphical representation **126** that corresponds to the selected connector pin **34** of the electrical connector **30**.

(188) Any individual connector pin **34** of the electrical connector **30** can be selected arbitrarily, and any number of individual connector pins **34** can be selected individually in any arbitrary order. For example, a connector pin **34** may be selected and a wire connecting operation may be completed with respect to the selected connector pin **34**. Another connector pin **34** may then be selected. This selection results in a signal from the display **120** that is received by the control unit **110** as an input

and that indicates completion of the wire connecting operation with respect to the previously selected connector pin **34**. The control unit **110** can be configured to respond to the input by automatically controlling the robotic positioner **90** to move the heating device **80** to a position beneath the now-selected connector pin **34**. The control unit **110** can be configured to control the robotic positioner **90** to move the heating device from that position into a heating position relative to the now-selected connector pin **34** to carry out a wire connecting operation with respect to that connector pin **34**.

(189) In manual mode, the control unit **110** also can be configured to await input signals corresponding to selections of distances the heating device **80** is to be moved along each of the orthogonal first, second, and third longitudinal axes (e.g., X, Y, and Z axes of a Cartesian coordinate system). In response to an operator selecting manual mode, the display **120** can be controlled by the control unit **110** to display a control screen **150** such as shown in FIG. **20**. The control screen **150** can include icons or graphics, such as control boxes **152**, that an operator can select to control movement of the robotic positioner **90** and in turn the heating device **80** along the first, second, and third longitudinal axes. For example, control boxes **152** can include a first plurality of individual control boxes **153** corresponding to the first longitudinal axis, a second plurality of individual control boxes **154** corresponding to the second longitudinal axis, and a third plurality of individual control boxes **155** corresponding to the third longitudinal axis. Each individual control box can be selected to move the heating device **80** by a predetermined distance from the current position of the heating device **80** along one of the three longitudinal axes, e.g., “X+0.01,” “Y−0.01,” Z+0.001.” In this way, an operator can manually and incrementally move the heating device **80** into any heating position relative to and associated with any connector pin **34** of the electrical connector **30**.

(190) The control screen **125** can also include various other icons or graphics, including control boxes, and visual indications that can be selected by an operator to control other actions and operations of the example robotic wire termination system **10**. The control screen **125** can include control boxes **129**, **130** that can be selected when the system is in automatic mode. The control unit **110** can be configured to respond to selection of the control boxes **129**, **130** to control the robotic positioner **90** to move the heating device **80** to the next or previous connector pin **34** in a predetermined series of connector pins **34**. Thus, for example, selection of the control box **129** after a wire connection operation has been completed with respect to a currently selected connector pin **34** can indicate completion of the wire connecting operation to the control unit **110**. The control unit **110** can be configured so that in response it automatically controls the robotic positioner **90** to reposition the heating device **80** from a position beneath the previously selected connector pin **34** to a programmatically predetermined position beneath the next connector pin **34** in the predetermined series of connector pins **34** to which wires **20** are to be connected. From there, the control unit **110** can control the robotic positioner **90** to position the heating device **80** in the heating position relative to the next connector pin **34** to provide heat for melting solder preform **39** and connecting a wire **20**.

(191) Also in automatic mode, the control boxes **129**, **130** can be selected to skip or return to connector pins **34** in a predetermined series of connector pins **34**. For example, it may be desired for one or more connector pins **34** of an electrical connector **30** to not have wires **20** connected. An operator can simply select control box **129** without carrying out a wire connecting operation. The control unit **110** can be configured to respond to the selection to move the heating device **80** to the next connector pin **34** in the predetermined series. Also for example, it may be discovered that a wire connecting operation with respect to a connector pin **34** had a problem and that rework is required. An operator can select control box **130** without carrying out a wire connecting operation. The control unit **110** can be configured to respond to the selection to move the heating device **80** to the previous connector pin **34** in the predetermined series. The operator can select control boxes **129**, **130** repeatedly without carrying out wire connecting operations to skip forward or backwards

in the predetermined sequence or series of connector pins **34** as desired.

(192) Alternatively or in addition to the above, input devices of the I/O devices **108**, such as a foot switch or hand switch, also can be used by an operator to indicate the completion of a wire connection operation in order to move the heating device **80** to the next connector pin **34** in the series, or to move the heating device **80** to the next connector pin **34** in the series without carrying out a wire connection operation. The input device can be manually actuated by the operator either after a wire connection operation has been completed or when the operator desires to move the heating device **80** to the next connector pin **34** in a predetermined series without carrying out a wire connection operation. Actuation of the input device generates an input signal that is received by the control unit **110** via one or more of the I/O ports **50-54**. The control unit **110** can be configured to respond to the input signal in the same way it responds to the operator selecting the control boxes **129**, **130** on the display **120**.

(193) Regardless of the mode of operation, the display **120** is adapted to provide a visual indication of the currently selected connector pin **34** regardless of whether that selection is made automatically under programmatic control or manually by an operator. As an example, the currently selected connector pin **34** of the electrical connector **30** corresponds to the connector pin labeled “1” in the graphic representation **126** on the control screen **125**. Under control of the control unit **110**, the display **120** provides a visual indication of the selected connector pin **34** by displaying pin “1” with a display attribute that is different from the display attributes of the other connector pins displayed in the graphic representation **126**. Pin “1” is illustrated as having different display attribute(s) from pins “2”-“16” of the graphic representation **126** by vertical hashes as compared to the diagonal hashes shown for pins “2”-“16.” For example, the selected connector pin “1” may be displayed as having a color, e.g., yellow, that is different than the color, e.g., green, of the rest of the pins “2”-“16”. Alternatively or in combination, the connector pin of the graphic representation **126** that corresponds to the currently selected connector pin **34** of the electrical connector **30** can be displayed as blinking, as being brighter, or as having any other display attribute that distinguishes it from the other pins of the graphic representation that correspond to non-selected connector pins **34** of the electrical connector **30**. When another connector pin **34** of the electrical connector **30** is subsequently selected either manually or automatically under programmatic control, the control unit **110** controls the display **120** to display the corresponding connector pin in the graphic representation **126** with the display attribute associated with a selected connector pin, and the connector pin in the graphic representation **126** corresponding to the previously selected connector pin **34** of the electrical connector **30** with the same display attribute as the other pins in the graphic representation **126** corresponding to the other non-selected connector pins **34** of the electrical connector **30**.

(194) The control screen **125** and the control screen **150** also can include icons or graphics **131**, **132** that provide visual indications of the measured and target temperatures of the heating device **80**. The control screen **125** and the control screen **150** also can include icons or graphics, such as control boxes **133** and **134** that an operator can select to activate or deactivate the heating device **80** and to selectively increase or decrease the target temperature of the heating device **80**. The control unit **110** can be configured to respond to the selection of the control box **134** by applying an electrical drive signal to the heating elements **83** to activate the heating device **80** or by removing the electrical drive signal to deactivate the heating device **80**. The control unit **110** also can be configured to respond to the selection of the control box **134** by activating the heating device **80** for a predetermined period of time and then automatically deactivating the heating device **80**. In that case, the operator need only select the control box **134** to activate the heating device **80**.

(195) The control unit **110** can be configured to control the display **120** to display the measured temperature **131** of the heating device **80** as determined by the control unit **110** from the measured temperature data provided by the temperature measuring device **86**. The control boxes **133** can be selected by an operator to increase (+) or decrease (−) the target temperature of the heat the heating

device **80** is to provide to a selected connector **19** pin **34**. Under control of the control unit **110**, the display **120** also displays the selected target temperature **132**. The control unit **110** can be configured to respond to the selection of control boxes **133** by an operator to maintain the electrical drive signal to the heating elements **83** if the measured temperature has not reached the target temperature or to remove the electrical drive signal from the heating elements **83** if the measured **24** temperature exceeds the target temperature. The control unit **110** also can be configured to respond to the selection of control box **133** by increasing or decreasing the level and/or frequency of the electrical drive signal to the heating elements **83** to increase or decrease the temperature of the heat provided by the heating device **80** to the selected connector pin **34**. The control unit **110** can be configured to monitor the temperature provided by the heating device **80** to a selected connector pin **34** via the temperature measuring device **86** and to either deactivate the heating device **80** when the measured temperature reaches the target temperature or to increase or decrease the level and/or frequency of the electrical drive signal to the heating elements **83** as necessary for the measured temperature to reach and maintain the target temperature.

(196) The control screen **125** also can include an icon or graphic, such as a control box **135**, that can be selected by an operator to position the heating device **80** from a position beneath a selected connector pin **34** to a heating position relative to the selected connector pin **34**, and to remove the heating device **80** from the heating position to a position beneath the connector pin **34**. The control unit **110** can be configured to respond to the selection of control box **135** when the heating device **80** is beneath a selected connector pin **34** and not in the heating position by controlling the robotic positioner **90** to move the heating device **80** to the heating position relative to the selected connector pin **34**. Similarly, the control unit **110** can be configured to respond to selection of the control box **135** by an operator when the heating device **80** is in the heating position relative to a selected connector pin **34** by controlling the robotic positioner **90** to move the heating device **80** from the heating position to a position beneath the selected connector pin **34**.

(197) Alternatively or in addition to the above, the operator can also manually actuate an input device of the I/O devices **108**, such as a foot switch and/or a hand switch, to generate an input signal indicating to the control unit **110** to move the heating device **80** into and out of a heating position relative to the selected connector pin **34**. The control unit **110** can be configured to respond to the input signal in the same way it responds to the operator selecting the control box **135** on the display **120**.

(198) It will be appreciated that while movement of the heating device **80** into and out of the heating position relative to a selected connector pin **34** can be initiated manually by an operator as described above, the control unit **110** can also be configured to automatically move the heating device **80** into and out of a heating position without operator intervention, for example in connection with or as a continuation of moving the heating device **80** from one selected connector pin **34** to another.

(199) The display **120** under control of the control unit **110** can also display one or more visual indications of the heating position status of the heating device **80** to show an operator whether the heating device **80** is in or is removed from a heating position relative to a selected connector pin **34**. The control unit **110** can be configured to control the display **120** to display the control box **135** as a visual indication of the heating position status of the heating device **80**, for example by displaying the terms “Engage” and “Disengage” in association with the control box **135**. “Engage” indicates that the heating device **80** is not in a heating position and selection of the control box **135** is required to move the heating device **80** into the heating position. “Disengage” indicates that the heating device **80** is in a heating position and selection of the control box **135** is required to remove the heating device **80** from the heating position. It is noted that although the control box **135** as illustrated in FIGS. **19**A and **19**B provides the visual indication of heating position status using the descriptors “Engage” and “Disengage,” this is for example purposes only and other descriptive terms can be used instead. In addition, it will be recalled that whether the heat providing element of

the heating device **80** is actually in physical engagement with a selected connector pin **34** or in proximity to but not in actual physical engagement with the selected connector pin **34** depends on whether the thermal tip **84** or nozzle **85** is employed as the heat providing element.

(200) The control unit **110** also can be configured to control the display **120** to display the pins in the graphic representation of the connector pins **34** of the electrical connector **30** to provide a visual indication of the heating position status of the heating device **80** relative to the selected connector pin **34**. For description it is assumed again that the currently selected connector pin **34** of the electrical connector **30** corresponds to the connector pin labeled "1" in the graphic representation **126** on the control screen **125**. The control unit **110** can be figured such that when the heating device **80** is in the heating position with respect to the selected connector pin **34**, the control unit **110** controls the display **120** to display pin "1" with one or more display attributes that are different from the one or more display attributes with which pin "1" was previously displayed to indicate the corresponding connector pin **34** has been selected (FIG. **19**A). The display attributes with which pin "1" is displayed to indicate the heating device **80** is in the heating position should also be different from the display attributes with which the other pins "2"-"16" of the graphic representation **126** that correspond to non-selected connector pins **34** of the electrical connector **30** are displayed.

(201) Accordingly, pin "1" is illustrated in FIG. **19**B as being displayed with one or more different display attribute(s) by reverse diagonal hashes as compared to the diagonal hashes shown for pins "2"-"16" and the vertical hashes shown for pin "1" in FIG. **19**A. For example, when the connector pin **34** corresponding to pin "1" has been selected and the heating device **80** is in the heating position relative to the selected connector pin **34**, pin **13** "1" may be displayed as having a particular color, e.g., red, that is different from the color, e.g., yellow, with which pin "1" was displayed when the corresponding connector pin **34** had been selected but the heating device **80** was not in the heating position. Thus, the use of two different display attributes, in this example color, to display the pin in the graphical representation that corresponds to the selected connector pin **34**, provides a visual indication of the heating position status of the heating device **80** with respect to the selected connector pin **34**. As noted previously, other display attributes besides color can also be employed alone or in combination, including without limitation blinking, brightness, etc.

(202) The control screens **125** and **150** can include any number of other icons or graphics, including control boxes, for an operator to control the operations of the example robotic wire termination system **10**. The control screens **125** and **150** can include a control box **136** that an operator can select to return to a home screen, for example the control screen **122**. This control box **136** can be selected by an operator for example when the operator has completed connecting wires **20** to all of the electrical connectors **30** of one type and needs to switch to an electrical connector **30** of another type.

(203) The control screen **125** can also include a control box **137** that an operator can select to stop the system from carrying out a sequence or series of wire connection operations, and a control box **138** that an operator can select to quit further use of the system and shut down. The control screen **150** can include a similar control box **139** that an operator can select to exit manual mode and return to the control screen **122** or **125** for example. The control screen **150** also can include a control box **140** that can be selected to cause the control unit **110** to control the robotic positioner **90** to return the heating device **80** from its current position to its zero or start position, and a control box **141** that can be selected to set the current position of the heating device **80** as its zero or starting position. The control screen **150** also can include a control box **142** that can be selected to cause the control unit **110** to control the robotic positioner **90** to position the heating device **80** with the heat providing device elevated and directly beneath the opening **64** in the alignment plate retainer **60** in the top surface **44** of the housing **40** to facilitate the operator changing or replacing the heat providing device (thermal tip **84** or nozzle **85**) of the heating device **80**.

(204) J. Operation of Preferred Embodiment.

(205) An example of use of the example robotic wire termination system **10** to connect wires **20** to an electrical connector **30** is described with reference to FIG. **21** among others. When the example robotic wire termination system **10** is powered up, the display **120** displays the control screen **122**. The operator selects an electrical connector **30** as indicated in flow chart box **156**. The operator selects an electrical connector **30** by selecting the control box **123** on the control screen **122**. In response, a list of electrical connectors **30** is displayed and the operator selects an electrical connector **30** from the list.

(206) As indicated in flow chart box **157**, the operator then mounts an alignment plate **70** corresponding to the selected electrical connector **30** in the alignment plate retainer **60** on the top surface **44** of the housing **40**. The operator mounts the alignment plate **70** in the alignment plate retainer **60** in a specific position and orientation as determined by the inset portion **62** of the alignment plate retainer **60**. The operator secures the alignment plate **70** in the alignment plate retainer **60** using the retainer **66**.

(207) As indicated in flow chart box **158**, the operator then positions the selected electrical connector **30** in the alignment plate **70**. The operator positions the selected electrical connector in the alignment plate **70** in a specific position and orientation with the keys of the electrical connector **30** and the alignment plate **70** aligned, i.e., with the flats **31**, **71** and/or the notches and protrusions **37**, **79** aligned. With the electrical connector **30** properly positioned in the alignment plate **70**, the male connecting ends **36** of the connector pins **34** are exposed to the interior **42** of the housing **40** and the corresponding wire receptacles **38** of the connector pins **34** are exposed outside the housing **40**.

(208) As indicated in flow chart box **159**, the operator selects a connector pin **34** to which a wire **20** is to be connected. As described herein, the operator can manually select the connector pin **34** by selecting a corresponding pin in the graphic representation **126** of the connector pins **34** on the control screen **125** displayed on display **120**. The operator can also manually select the connector pin **34** by selecting movement control boxes **152** on the control screen **152** displayed on the display **120** to manually move the heating device **80** to the coordinates of a position beneath the selected connector pin **34**. The operator also can select the connector pin **34** by simply allowing the system to power up in automatic mode or by selecting control box **128** on the control screen **125** displayed on the display **120** to place the system in automatic mode. In automatic mode, the system automatically selects the first connector pin **34** on the electrical connector **30**. As indicated in flow chart box **160**, in response to the selection of the connector pin **34**, the system automatically provides a visual indication of the selected connector pin **34** on control screen **125** and moves the heating device **80** to a set of coordinates corresponding to a position beneath the selected connector pin **34**.

(209) The system provides a visual indication of the selected connector pin **34** by displaying the corresponding pin of the graphical representation of connector pins **126** on the control screen **125** with a unique display attribute, e.g., yellow color. The operator can use this visual indication to confirm that the correct connector pin **34** has been selected before proceeding.

(210) As indicated in flow chart box **161**, the operator can then select to move the heating device **80** into the heating position relative to the selected connector pin **34**. The operator can select to move the heating device **80** into the heating position by selecting the control box **135** on control screen **125** or by manually actuating an input device of the I/O devices **108**, e.g., a foot switch or hand switch. In response, the system automatically positions the heating device **80** to a set of coordinates corresponding to the heating position. In the heating position, the heat providing element of the heating device **80** is either in contact with the male connecting end **36** of the selected connector pin **34** or is in proximity to but not in contact with the male connecting end **36** depending on the heat providing element being used.

(211) As indicated in flow chart box **162**, the system provides a visual indication to notify the

operator that the heating device **80** is in the heating position relative to the selected connector pin **34**. The system notifies the operator by displaying the connector pin in the graphical representation **126** of connector pins displayed on the control screen **125** that corresponds to the selected connector pin **34** with another unique display attribute, e.g., red color.

(212) As indicated in flow chart box **163**, the operator can then select to activate the heating device **80** to provide heat to the selected connector pin **34**. The operator can select to activate the heating device **80** by selecting the control box **134** displayed on control screen **125** or by manually actuating an input device of the I/O devices **108**, a foot switch or hand switch. In response, the system activates the heating elements **83** of the heating device **80**. The operator can monitor the measured temperature **131** and the target temperature **132** of the heating device **80** displayed on the control screen **125**. The operator also can adjust the target temperature by selecting the temperature control boxes **133** displayed on the control screen **125**. When the temperature of the heat provided by the heating device **80** to the selected connector pin **34** is sufficient to melt solder preform **39**, the operator inserts the end of a wire **20** in the wire receptacle **38** of the selected connector pin **34** to connect the wire **20** to the electrical connector **30**.

(213) As indicated in flow chart decision box **164** the operator next determines if there are any remaining wires **20** to be connected to the electrical connector **30**. If no wires **20** remain to be connected, then as indicated in flow chart box **165** the operator deactivates the heating device **80** and moves the heating device **80** from the heating position. The operator can deactivate the heating device **80** and move it from the heating position by selecting the control boxes **134** and **135** displayed on control screen **125** or by manually actuating an input device of the I/O devices **108**, e.g., a foot switch or hand switch. Alternatively, the system can automatically deactivate the heating device **80** after a predetermined period of time has elapsed or in response to the operator selecting the control box **135** or actuating an input device to remove the heating device **80** from the heating position. In response to the operator selecting control box **135** or actuating an input device, the system automatically moves the heating device **80** from the heating position to a set of coordinates corresponding to a position beneath the selected connector pin **34**. Then, as indicated in flow chart box **166**, the operator removes the electrical connector **30** with connected wires **20** from the alignment plate **70**.

(214) However, if any wires **20** remain to be connected to the electrical connector **30** then as indicated in flow chart box **167** the operator deactivates the heating device **80** and moves it from the heating position in the same manner as described above with respect to flow chart box **165**. Next, as indicated in flow chart box **168**, the operator selects the next connector pin **34** to which a wire **20** is to be connected. The operator can manually select the next connector pin **34** in the same manner as the previous connector pin **34** by selecting the corresponding pin in the graphic representation **126** displayed on control screen **125**. In automatic mode, the operator can select the control box **129** displayed on the control screen **125** or actuate an input device of the I/O devices **108**, e.g., a footswitch or hand switch, and the system automatically selects the next connector pin **34** in a predetermined sequence or series of connector pins **34**. In response to the selection of the next connector pin **34** by the operator or by the system, the system automatically moves the heating device **80** to a set of coordinates corresponding to a position beneath the selected connector pin **34** as indicated in flow chart box **160**. The foregoing process continues indefinitely until all wires **20** to be connected to the electrical connector **30** have been connected.

(215) As indicated in flow chart box **169**, once all of the wires **20** to be connected to an electrical connector **30** have been connected, the operator can end the process and quit connecting additional wires **20** to additional electrical connectors **30**. For example, the operator can select the control box **138** ("Quit") on the control screen **125** to quit further use of the system and shut down.

(216) Alternatively, the operator can continue to connect additional wires **20** to additional electrical connectors **30** of the same type. The operator can remove the electrical connector **30** to which wires **20** have been connected from the alignment plate **70** and replace it with an electrical connector **30**

of the same type to which wires **20** are to be connected next as described above with respect to flow chart box **158**. Using control screen **125**, the operator can then select the mode of operation by selecting control box **127** or **128** and, if proceeding manually, an individual starting pin by selecting a position in the graphical representation **126** associated with the selected connector pin **34** as previously described. Alternatively or in addition to the above, the operator can also manually actuate an input device of the I/O devices **108**, such as a foot switch and/or a hand switch, to generate an input signal to begin the process of connecting wires **20** to the next electrical connector **30** of the same type in the manner described above in connection with flow chart boxes **159** et seq. The foregoing process can continue indefinitely until all of the electrical connectors **30** of the same type to which wires **20** are to be connected have had wires **20** connected.

(217) Alternatively also, the operator can continue and prepare to connect wires **20** to electrical connectors **30** of a different type. For example, the operator can select the control box **136** ("Home") on control screen **125** or control screen **150** to return to control screen **122**. On control screen **122**, the operator can select control box **123** and then select a type of electrical connector **30** to which wires **20** are to be connected as described above in connection with flow chart box **156**. The operator can then mount an alignment plate **70** corresponding to the selected type of electrical connector **30** in the alignment plate retainer **60** on the housing **40**, position an electrical connector **30** of the selected type in the alignment plate **70**, and continue the process of connecting wires **20** to electrical connectors **30** of the selected type as described above in connection with flow chart boxes **157-159**. The process of selecting different types of electrical connectors **30** and connecting wires **20** to electrical connectors **30** of the selected types can continue indefinitely until all electrical connectors **30** of all types to which wires **20** are to be connected have had the wires **20** connected.

(218) Any and all headings are for convenience only and have no limiting effect. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety to the extent allowed by applicable law and regulations.

(219) The data structures and code described in this detailed description are typically stored on a computer readable storage medium, which may be any device or medium that can store code and/or data for use by a computer system. This includes, but is not limited to, magnetic and optical storage devices such as disk drives, magnetic tape, CDs (compact discs), DVDs (digital video discs), and computer instruction signals embodied in a transmission medium (with or without a carrier wave upon which the signals are modulated). For example, the transmission medium may include a telecommunications network, such as the Internet.

(220) At least one embodiment of the robotic wire termination system is described above with reference to block and flow diagrams of systems, methods, apparatuses, and/or computer program products according to example embodiments of the invention. It will be understood that one or more blocks of the block diagrams and flow diagrams, and combinations of blocks in the block diagrams and flow diagrams, respectively, can be implemented by computer-executable program instructions. Likewise, some blocks of the block diagrams and flow diagrams may not necessarily need to be performed in the order presented, or may not necessarily need to be performed at all, according to some embodiments of the invention. These computer-executable program instructions may be loaded onto a general-purpose computer, a special-purpose computer, a processor, or other programmable data processing apparatus to produce a particular machine, such that the instructions that execute on the computer, processor, or other programmable data processing apparatus create means for implementing one or more functions specified in the flow diagram block or blocks. These computer program instructions may also be stored in a computer-readable memory that can

direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction means that implement one or more functions specified in the flow diagram block or blocks. As an example, embodiments of the invention may provide for a computer program product, comprising a computer usable medium having a computer-readable program code or program instructions embodied therein, the computer-readable program code adapted to be executed to implement one or more functions specified in the flow diagram block or blocks. The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational elements or steps to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions that execute on the computer or other programmable apparatus provide elements or steps for implementing the functions specified in the flow diagram block or blocks. Accordingly, blocks of the block diagrams and flow diagrams support combinations of means for performing the specified functions, combinations of elements or steps for performing the specified functions, and program instruction means for performing the specified functions. It will also be understood that each block of the block diagrams and flow diagrams, and combinations of blocks in the block diagrams and flow diagrams, can be implemented by special-purpose, hardware-based computer systems that perform the specified functions, elements or steps, or combinations of special-purpose hardware and computer instructions.
(221) The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it is therefore desired that the present embodiment be considered in all respects as illustrative and not restrictive. Many modifications and other embodiments of the robotic wire termination system will come to mind to one skilled in the art to which this invention pertains and having the benefit of the teachings presented in the foregoing description and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although methods and materials similar to or equivalent to those described herein can be used in the practice or testing of the robotic wire termination system, suitable methods and materials are described above. Thus, the robotic wire termination system is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

Claims

1. A system, comprising: a holder member adapted to removably receive and hold an electrical connector; a robotic positioner, the robotic positioner comprising a first positioner movable along a first longitudinal axis, a second positioner movable along a second longitudinal axis substantially orthogonal to the first longitudinal axis, and a third positioner movable in a third longitudinal axis substantially orthogonal to the first longitudinal axis and to the second longitudinal axis, wherein each of the first positioner, the second positioner, and the third positioner is selectively and independently controllable for movement; wherein the second positioner is connected to the first positioner, wherein the first positioner moves the second positioner along an axis that is parallel to the first longitudinal axis, wherein the third positioner is connected to the second positioner, and wherein the second positioner moves the third positioner along an axis that is parallel to the second longitudinal axis; a heating device connected to the third positioner of the robotic positioner, wherein the heating device comprises a thermal tip or a nozzle adapted to direct a flow of heated air; and a control unit in communication with the robotic positioner, wherein the control unit is configured to independently control the first positioner, the second positioner, and the third positioner to position the heating device in a plurality of heating positions with each heating position of the plurality of heating positions being associated with a connector pin of a plurality of

connector pins of the electrical connector to melt solder in a corresponding wire receptacle of a plurality of corresponding wire receptacles of the electrical connector; wherein the first longitudinal axis and the second longitudinal axis extend laterally beneath the plurality of connector pins, and the third longitudinal axis extends vertically in relation to the plurality of connector pins.

2. The system of claim 1, wherein the control unit is configured to move and position the heating device to a first set of coordinates that correspond to a first heating position relative to a first selected connector pin of the plurality of connector pins and a second set of coordinates that correspond to a second heating position relative to a second selected connector pin of the plurality of connector pins.

3. The system of claim 1, wherein the control unit is configured to automatically control the first positioner, the second positioner, and the third positioner to position the heating device in the plurality of heating positions.

4. The system of claim 1, wherein the control unit is configured to move and position the heating device based on a manual input from an operator.

5. The system of claim 1, wherein the control unit is configured to move and position the heating device along a common row of the plurality of connector pins.

6. The system of claim 1, wherein the first positioner, the second positioner and the third positioner are each comprised of a linear positioner.

7. The system of claim 1, wherein the first positioner and the second positioner are each comprised of a stepper motor-driven leadscrew linear stage.

8. The system of claim 1, wherein the third positioner is comprised of a stepper motor-driven leadscrew vertical lift stage.

9. The system of claim 1, including a display in communication with the control unit.

10. The system of claim 9, wherein the display is comprised of a touch sensitive type display adapted and configured to sense an operator physically selecting a visual indication on the display and in response to generate a corresponding input signal that is received by the control unit indicating a selection of the visual indication on the display.

11. The system of claim 1, wherein the first positioner includes a first linear stage movable along the first longitudinal axis, wherein the second positioner is connected to the first linear stage of the first positioner, and wherein the first positioner moves the second positioner along an axis that is parallel to the first longitudinal axis.

12. The system of claim 1, wherein the second positioner is connected to the first positioner, wherein the third positioner is connected to the second positioner, wherein the first positioner moves the second positioner along an axis that is parallel to the first longitudinal axis, and wherein the second positioner moves the third positioner along an axis that is parallel to the second longitudinal axis.

13. The system of claim 1, wherein the first positioner includes a first linear stage movable along or parallel to the first longitudinal axis, wherein the second positioner includes a second linear stage movable along or parallel to the second longitudinal axis, wherein the second positioner is connected to the first linear stage of the first positioner, wherein the first positioner moves the second positioner along an axis that is parallel to the first longitudinal axis, wherein the third positioner is connected to the second linear stage of the second positioner, and wherein the second positioner moves the third positioner along an axis that is parallel to the second longitudinal axis.

14. The system of claim 1, wherein the first positioner includes a first guide rail and a first linear stage movably connected to the first guide rail, wherein the first linear stage is movable along or parallel to the first longitudinal axis, wherein the second positioner includes a second guide rail and a second linear stage movably connected to the second guide rail, wherein the second linear stage is movable along or parallel to the second longitudinal axis, wherein the second positioner is connected to the first linear stage of the first positioner, wherein the first positioner moves the

second positioner along an axis that is parallel to the first longitudinal axis, wherein the third positioner is connected to the second linear stage of the second positioner, and wherein the second positioner moves the third positioner along an axis that is parallel to the second longitudinal axis.

15. The system of claim 1, wherein the first positioner includes a first guide rail, a first drive screw and a first linear stage movably connected to the first guide rail and the first drive screw, wherein the first linear stage is movable along or parallel to the first longitudinal axis, wherein the second positioner includes a second guide rail, a second drive screw and a second linear stage movably connected to the second guide rail and the second drive screw, wherein the second linear stage is movable along or parallel to the second longitudinal axis, wherein the second positioner is connected to the first linear stage of the first positioner, wherein the first positioner moves the second positioner along an axis that is parallel to the first longitudinal axis, wherein the third positioner is connected to the second linear stage of the second positioner, and wherein the second positioner moves the third positioner along an axis that is parallel to the second longitudinal axis.

16. A system, comprising: a holder member adapted to removably receive and hold an electrical connector; a robotic positioner, the robotic positioner comprising a first positioner movable along a first longitudinal axis, a second positioner movable along a second longitudinal axis substantially orthogonal to the first longitudinal axis, and a third positioner movable in a third longitudinal axis substantially orthogonal to the first longitudinal axis and to the second longitudinal axis, wherein each of the first positioner, the second positioner, and the third positioner is selectively and independently controllable for movement; wherein the second positioner is connected to the first positioner, wherein the third positioner is connected to the second positioner, wherein the first positioner moves the second positioner along an axis that is parallel to the first longitudinal axis, and wherein the second positioner moves the third positioner along an axis that is parallel to the second longitudinal axis; a heating device connected to the third positioner of the robotic positioner; and a control unit in communication with the robotic positioner, wherein the control unit is configured to independently control the first positioner, the second positioner, and the third positioner to position the heating device in a plurality of heating positions with each heating position of the plurality of heating positions being associated with a connector pin of a plurality of connector pins of the electrical connector to melt solder in a corresponding wire receptacle of a plurality of corresponding wire receptacles of the electrical connector; wherein the first longitudinal axis and the second longitudinal axis extend laterally beneath the plurality of connector pins, and the third longitudinal axis extends vertically in relation to the plurality of connector pins; wherein the control unit is configured to move and position the heating device to a first set of coordinates that correspond to a first heating position relative to a first selected connector pin of the plurality of connector pins and a second set of coordinates that correspond to a second heating position relative to a second selected connector pin of the plurality of connector pins.

17. The system of claim 16, wherein the control unit is configured to automatically control the first positioner, the second positioner, and the third positioner to position the heating device in the plurality of heating positions.

18. The system of claim 16, including a display in communication with the control unit, wherein the display is comprised of a touch sensitive type display adapted and configured to sense an operator physically selecting a visual indication on the display and in response to generate a corresponding input signal that is received by the control unit indicating a selection of the visual indication on the display.

19. A robotic positioner system, comprising: a holder member adapted to removably receive and hold an electrical connector; a first positioner movable along a first longitudinal axis; a second positioner movable along a second longitudinal axis substantially orthogonal to the first longitudinal axis; a third positioner movable in a third longitudinal axis substantially orthogonal to the first longitudinal axis and to the second longitudinal axis; wherein each of the first positioner,

the second positioner, and the third positioner is selectively and independently controllable for movement; wherein the first positioner and the second positioner are each comprised of a linear positioner; wherein the second positioner is connected to the first positioner, wherein the third positioner is connected to the second positioner, wherein the first positioner moves the second positioner along an axis that is parallel to the first longitudinal axis, and wherein the second positioner moves the third positioner along an axis that is parallel to the second longitudinal axis; a heating device connected to the third positioner, wherein the heating device comprises a thermal tip or a nozzle adapted to direct a flow of heated air; and a control unit, wherein the control unit is configured to communicate with and independently control the first positioner, the second positioner, and the third positioner to position the heating device in a plurality of heating positions with each heating position of the plurality of heating positions being associated with a connector pin of a plurality of connector pins of the electrical connector to melt solder in a corresponding wire receptacle of a plurality of corresponding wire receptacles of the electrical connector; wherein the first longitudinal axis and the second longitudinal axis extend laterally beneath the plurality of connector pins, and the third longitudinal axis extends vertically in relation to the plurality of connector pins; wherein the control unit is configured to move and position the heating device to a first set of coordinates that correspond to a first heating position relative to a first selected connector pin of the plurality of connector pins and a second set of coordinates that correspond to a second heating position relative to a second selected connector pin of the plurality of connector pins; wherein the control unit is configured to automatically control the first positioner, the second positioner, and the third positioner to position the heating device in the plurality of heating positions.

20. The robotic positioner system of claim 19, including a display in communication with the control unit, wherein the display is comprised of a touch sensitive type display adapted and configured to sense an operator physically selecting a visual indication on the display and in response to generate a corresponding input signal that is received by the control unit indicating a selection of the visual indication on the display.