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(54) Title: METHOD AND APPARATUS FOR FORMING INTERFACE BETWEEN COAXIAL CABLE AND CONNECTOR

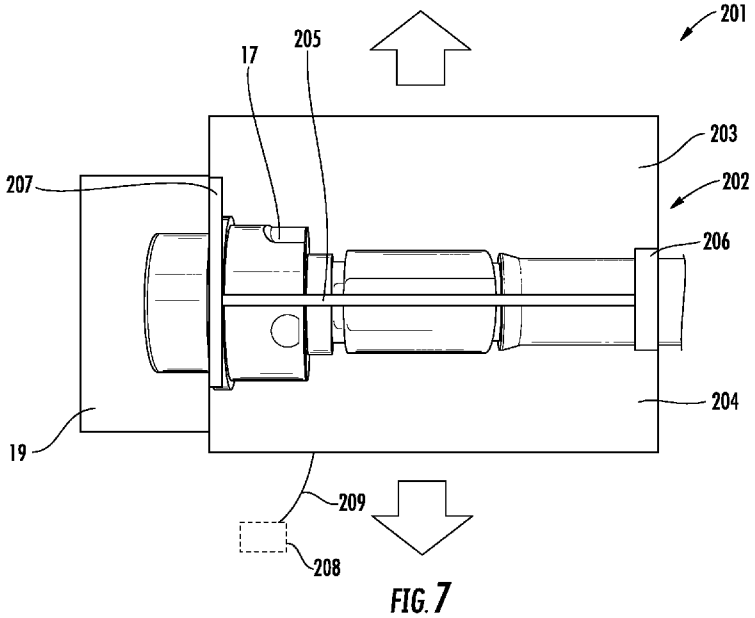

FIG. 7

(57) Abstract: A method of forming a solder joint between a coaxial cable and a coaxial connector includes the steps of: positioning a solder element between an end of an outer conductor of the coaxial cable and a connector body of the connector, wherein the solder element is positioned within a vacuum chamber; melting the solder element to form a solder joint between the outer conductor and the connector body, the solder joint including a lower surface formed by contact with a mounting structure; and applying suction to the melting solder element to reduce the formation of bubbles within the solder joint.

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METHOD AND APPARATUS FOR FORMING INTERFACE BETWEEN COAXIAL CABLE AND CONNECTOR

Related Application

[0001] The present application claims priority from and the benefit of U.S. Provisional Patent Application No. 62/131,105, filed March 10, 2015, the disclosure of which is hereby incorporated herein in its entirety.

Field of the Invention

[0002] invention relates generally to a connector and cable interconnection, and more specifically to a connector and cable interconnection method and apparatus with improved manufacturing efficiency and electrical performance characteristics.

Background of the Invention

[0003] Coaxial connectors are commonly utilized in RF communications systems. A typical coaxial cable includes an inner conductor, an outer conductor, a dielectric layer that separates the inner and outer conductors, and a jacket that covers the outer conductor. Coaxial cable connectors may be applied to terminate coaxial cables, for example, in communication systems requiring a high level of precision and reliability.

[0004] Coaxial connector interfaces provide a connect/disconnect functionality between a cable terminated with a connector bearing the desired connector interface and a corresponding connector with a mating connector interface mounted on an apparatus or on another cable. Typically, one connector will include a structure such as a pin or post connected to an inner conductor and an outer conductor connector body connected to the outer conductor; these are mated with a mating sleeve (for the pin or post of the inner conductor) and another outer conductor connector body of a second connector. Coaxial connector interfaces often utilize a threaded coupling nut or other retainer that draws the connector interface pair into secure electro-mechanical engagement when the coupling nut (which is captured by one of the connectors) is threaded onto the other connector.

[0005] Commonly-owned U.S. Pat. Nos. 5,802,710 and 7,900,344, hereby incorporated by reference in their entireties, disclose a technique for attaching a coaxial connector to a coaxial cable. The connector utilizes an insulating disc retained upon the inner contact and against the dielectric layer and outer conductor of the cable. Induction heating of a solder

preform wrapped around the outer conductor creates a molten solder pool in a cylindrical solder cavity formed between the outer conductor, the insulating disc and the connector body. The insulating disc prevents the molten solder from migrating out of the cavity, fouling the connector bore and/or shorting the outer and inner conductors.

[0006] Commonly-owned U.S. Patent Publication No. 2014/0201989, also incorporated herein by reference in its entirety, illustrates a pedestal with an insulating seat on which the soldering of the outer conductor to the connector body can occur. One issue that can arise with this technique is the formation of air bubbles within the solder; if such bubbles form in locations along the signal path, the electrical performance of the connector interface can be compromised.

Summary

[0007] As a first aspect, embodiments of the invention are directed to a method of forming a solder joint between a coaxial cable and a coaxial connector. The method comprises the steps of: positioning a solder element between an end of an outer conductor of the coaxial cable and a connector body of the connector, wherein the solder element is positioned within a vacuum chamber; melting the solder element to form a solder joint between the outer conductor and the connector body, the solder joint including a lower surface formed by contact with a mounting structure; and applying suction to the melting solder element to reduce the formation of bubbles within the solder joint.

[0008] As a second aspect, embodiments of the invention are directed to a method for attaching a connector to a coaxial cable, comprising the steps of: positioning a solder element between an end of an outer conductor of the coaxial cable and a connector body of the connector; positioning the connector body on a mounting structure; melting the solder element to form a solder joint between the outer conductor and the connector body, the solder joint including a surface formed by contact with the mounting structure, the melting step being performed as the solder element resides in a vacuum chamber; and applying suction to the melting solder element to reduce the formation of bubbles within the solder joint.

[0009] As a third aspect, embodiments of the invention are directed to an apparatus for forming a solder joint between a coaxial cable and a coaxial connector, comprising: a mounting structure with an upper surface configured to receive a connector body and a coaxial cable; a heating element positioned to melt a solder element to form a solder joint between the connector body and the coaxial cable, the upper surface of the mounting

structure positioned to form the lower surface of the solder joint; a vacuum chamber; and a vacuum source attached to the vacuum chamber and positioned to apply suction to the solder joint as it forms between the connector body and the coaxial cable, the solder joint forming in the vacuum chamber.

Brief Description of the Drawings

[0010] **FIG. 1** is a schematic perspective view of a cable-connector assembly apparatus and a cable, wherein electrical interconnections, supporting and enclosure structures are removed for clarity.

[0011] **FIG. 2** is a schematic section view of a connector body seated upon the interface pedestal of the apparatus of **FIG. 1**.

[0012] **FIG. 3** is an enlarged section view of the pedestal and connector body of **FIG. 2** with a cable and solder preform inserted therein for solder interconnection.

[0013] **FIG. 4** is a section view as in **FIG. 3** with the solder preform melted to form a solder joint.

[0014] **FIG. 5** is a front perspective view of an apparatus according to embodiments of the present invention, with the housing and the vacuum source illustrated schematically.

[0015] **FIG. 6** is a side perspective view of the apparatus of **FIG. 5**.

[0016] **FIG. 7** is a schematic front view of an apparatus according to alternative embodiments of the invention.

Detailed Description

[0017] The present invention is described with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments that are pictured and described herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. It will also be appreciated that the embodiments disclosed herein can be combined in any way and/or combination to provide many additional embodiments.

[0018] Unless otherwise defined, all technical and scientific terms that are used in this disclosure have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The terminology used in the above description is for the purpose of describing particular embodiments only and is not intended to be limiting of the

invention. As used in this disclosure, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that when an element (e.g., a device, circuit, etc.) is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present.

[0019] Referring now to the figures, an apparatus **21** for soldering a connector body onto a coaxial cable such as is described in U.S. Patent Publication No. 2014/0201989, *supra*, is shown in **FIG. 1**. The apparatus includes a pedestal **19** mounted on a base **21**, a clamp **41** for holding a cable **1** in place, and an inductive heating element **37** for heating solder used to attach the connector body to the outer conductor of the cable **1**. **FIG. 2** shows a connector body **17** in place on the pedestal **19**, with a step in the connector body **17** resting on a shoulder **25** of the pedestal **19**. A cap **29**, formed of a dielectric, thermally insulative material, is mounted on the upper end of the pedestal **19** to provide thermal insulation to components of the cable **1** during soldering. As a result, the pedestal **19** and cap **29** act as a mounting structure for the connector body **17**. The pedestal **19** includes an inner conductor cavity **39** in its upper surface that is configured to receive the inner contact **11** of the cable **1** during soldering.

[0020] As shown in **FIG. 3**, a solder preform **15** or other solder element circumscribes the end of the outer conductor **5** of the cable **1**. The connector body **17** is positioned on the pedestal **19**, with the solder cavity **27** of the connector body **17** (formed by the inner surface of the connector body **17**, the upper surface of the cap **29**, and the outer conductor **5**) located above the pedestal **19**. The cable **1** with the solder preform **15** in place is lowered into the cavity **27** and onto the pedestal **19**, with the inner contact **11** of the cable **1** received in the inner conductor cavity **39**, and the end of the outer conductor **5** and the solder preform **15** abutting the cap **29**. The clamp **41** is applied to the connector body **17** to secure it in place. Heat is applied to the end of the cable **1** via the heating element **37**, such that the solder preform **15** melts, flows downwardly within the solder cavity **27** between the inner surface of the connector body **17**, the upper surface of the cap **29**, and the outer conductor **5**, and freezes, thereby forming a solder joint **18** between the outer conductor **5** and the connector body **17** (**FIG. 4**).

[0021] As described above, and as shown in **FIG. 4**, in many instances the flowing solder from the solder preform will create bubbles **22** that remain in the frozen solder joint **18**. Such bubbles **22** can adversely impact the electrical performance of the interface between the outer conductor **5** and the connector body **17**, particularly if the bubbles **22** are located in the electrical signal path.

[0022] Referring now to **FIGS. 5** and **6**, an apparatus for forming solder joints between coaxial connectors and coaxial cables is shown therein and designated broadly at **101**. The apparatus **101** includes the components discussed above in connection with apparatus **1**. However, the apparatus **101** is contained within an airtight housing **102** that enables a vacuum to be generated within the housing **102**. As can be seen in **FIGS. 5** and **6**, the housing **102** includes a front wall **103**, a rear wall **104**, side walls **105, 106**, a floor **107** and a ceiling **108**.

[0023] A vacuum source **110** is located externally from the housing **102**. Access to the interior of the housing **102** is available via a port **112** through which a hose **114** is routed. The port **112** is vacuum-sealed around the hose **114**.

[0024] Also, as described above, the cable to be soldered is lowered into the pedestal **19** from above, and is clamped into place with the clamp **41**. The clamp **41** also includes a gasket, O-ring or the like that forms a vacuum seal with the connector body **17** and/or the cable. The clamp **41** also includes a seal with the ceiling **108**. As such, the interior of the housing **102** can be vacuum-sealed.

[0025] In operation, the cable with the connector body **17** is lowered onto the pedestal **19** as described above. The clamp **41** clamps the connector body **17**, thereby forming a seal. The vacuum source **110** is activated, which draws a vacuum within the housing **102**. The heating element **37** is activated, which causes the solder preform **15** to melt; once melted, the solder is allowed to freeze to form the solder joint **18**. However, because the vacuum is present within the interior of the housing **102**, the tendency for bubbles to form in the molten solder is reduced or eliminated, which in turn reduces or eliminates voids in the solder joint **18** that can negatively impact electrical performance.

[0026] The timing of the application of the vacuum may vary. In some embodiments, the vacuum may be activated prior to the application of heat via the heating element and maintained until the solder fully freezes. In other embodiments, the vacuum may be activated after the application of heat and maintained until freezing, and in other instances the vacuum may be deactivated prior to complete freezing of the solder joint **18**.

[0027] Another apparatus directed to reducing the formation of voids in the solder joint is shown in **FIG. 7** and designated broadly at **201**. The apparatus **201** employs the components of the apparatus **1**, but also includes a small vacuum chamber **202** within which the connector body **17** resides during soldering. As shown in **FIG. 7**, the vacuum chamber **202** includes two halves **203, 204** that separate in a manner similar to a reciprocating mold. The meeting edges of the halves **203, 204** include a vacuum seal **205**. The halves **203, 204** also include a vacuum seal **206** that forms around the cable and a seal **207** that forms with the pedestal **19**. A vacuum source **208** is attached via a hose **209** to the half **204**.

[0028] When a cable with a connector body **17** is mounted on the pedestal **19**, the halves **203, 204** close around it to provide an airtight cavity in which soldering can occur, with the seals **205, 206, 207** preventing leakage at the interfaces between components. As described above, the vacuum source **208** can be activated to before or during the melting of the solder preform **15** to reduce or eliminate the formation of voids in the solder joint **18**.

[0029] Those skilled in this art will appreciate that concepts discussed above may be applied to other soldering operations. For example, surface mount and direct launch bulkhead connectors for antennas and filters may be suitable for use with these concepts. Other variations may also be apparent.

[0030] The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

That Which is Claimed is:

1. A method of forming a solder joint between a coaxial cable and a coaxial connector, comprising the steps of:

positioning a solder element between an end of an outer conductor of the coaxial cable and a connector body of the connector, wherein the solder element is positioned within a vacuum chamber;

melting the solder element to form a solder joint between the outer conductor and the connector body, the solder joint including a lower surface formed by contact with a mounting structure; and

applying suction to the melting solder element to reduce the formation of bubbles within the solder joint.

2. The method defined in Claim 1, wherein the melting step comprises applying heat to the solder element with a heating element located inside the vacuum chamber.

3. The method defined in Claim 2, wherein the mounting structure is located within the vacuum chamber.

4. The method defined in Claim 1, wherein the melting step comprises applying heat to the solder element with a heating element located in a wall of the vacuum chamber.

5. The method defined in Claim 4, wherein the vacuum chamber is configured to form a seal with the coaxial cable.

6. The method defined in Claim 4, wherein the mounting structure is located outside of the vacuum chamber.

7. The method defined in Claim 1, wherein the solder element is a solder preform mounted on the outer conductor of the cable.

8. The method defined in Claim 1, wherein the mounting structure is an interface pedestal.

9. The method defined in Claim 1, wherein the coaxial cable further comprises an inner conductor, and wherein an inner contact is mounted onto the inner conductor prior to the positioning step, and wherein the mounting structure includes a cavity for receiving the inner contact.

10. A method for attaching a connector to a coaxial cable, comprising the steps of:

positioning a solder element between an end of an outer conductor of the coaxial cable and a connector body of the connector;

positioning the connector body on a mounting structure;

melting the solder element to form a solder joint between the outer conductor and the connector body, the solder joint including a surface formed by contact with the mounting structure, the melting step being performed as the solder element resides in a vacuum chamber; and

applying suction to the melting solder element to reduce the formation of bubbles within the solder joint.

11. The method defined in Claim 10, wherein the melting step comprises applying heat to the solder element with a heating element located inside the vacuum chamber.

12. The method defined in Claim 11, wherein the mounting structure is located within the vacuum chamber.

13. The method defined in Claim 10, wherein the melting step comprises applying heat to the solder element with a heating element located in a wall of the vacuum chamber.

14. The method defined in Claim 13, wherein the vacuum chamber is configured to form a seal with the coaxial cable.

15. The method defined in Claim 13, wherein the mounting structure is located outside of the vacuum chamber.

16. The method defined in Claim 10, wherein the solder element is a solder preform mounted on the outer conductor of the cable.

17. The method defined in Claim 10, wherein the mounting structure is an interface pedestal.

18. The method defined in Claim 10, wherein the coaxial cable further comprises an inner conductor, and wherein an inner contact is mounted onto the inner conductor prior to the second positioning step, and wherein the mounting structure includes a cavity for receiving the inner contact.

19. An apparatus for forming a solder joint between a coaxial cable and a coaxial connector, comprising:

a mounting structure with an upper surface configured to receive a connector body and a coaxial cable;

a heating element positioned to melt a solder element to form a solder joint between the connector body and the coaxial cable, the upper surface of the mounting structure positioned to form the lower surface of the solder joint;

a vacuum chamber; and

a vacuum source attached to the vacuum chamber and positioned to apply suction to the solder joint as it forms between the connector body and the coaxial cable, the solder joint forming in the vacuum chamber.

20. The apparatus defined in Claim 19, wherein the heating element is located inside the vacuum chamber.

21. The method defined in Claim 20, wherein the mounting structure is located within the vacuum chamber.

22. The method defined in Claim 19, wherein the heating element is located in a wall of the vacuum chamber.

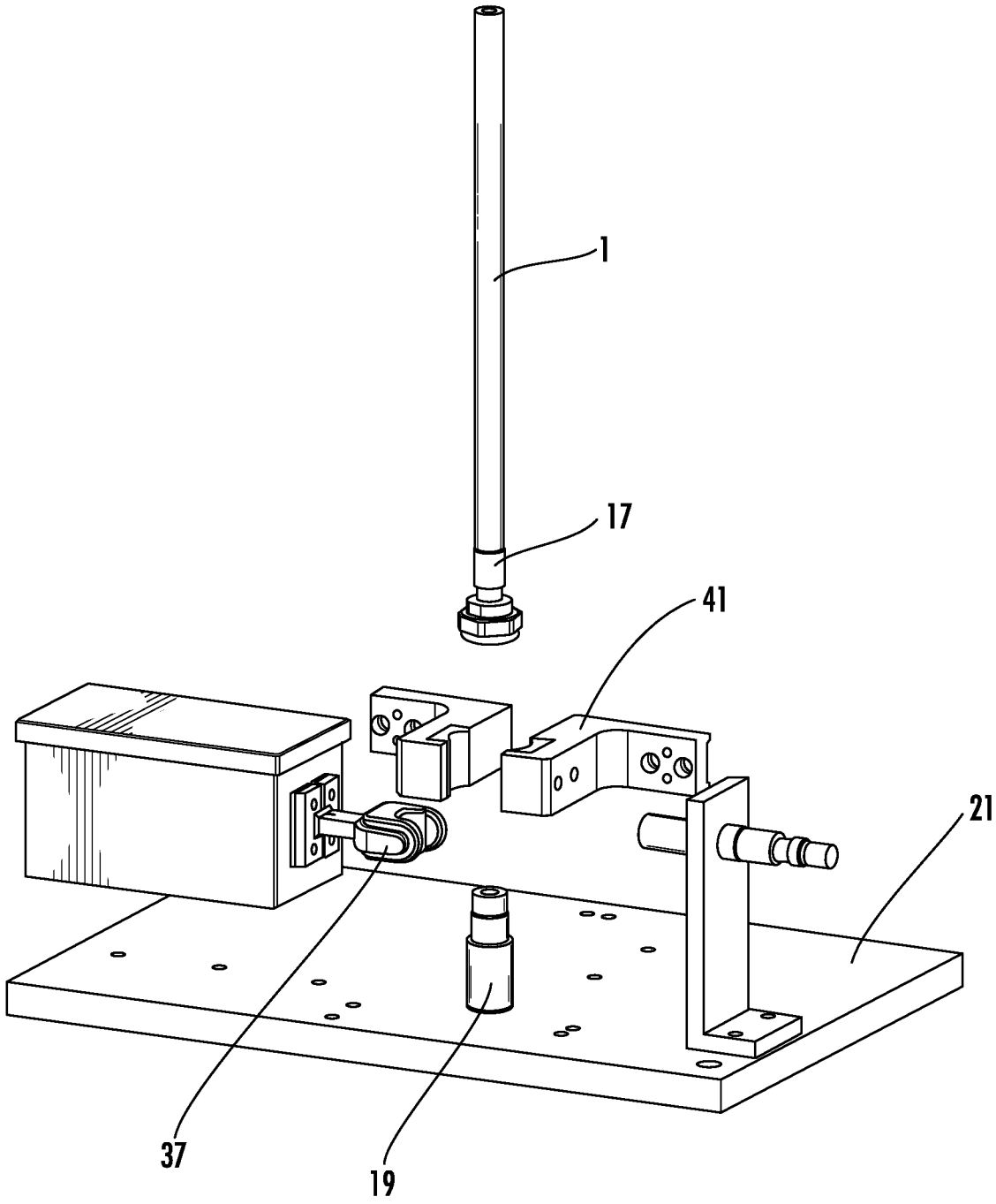

FIG. 1

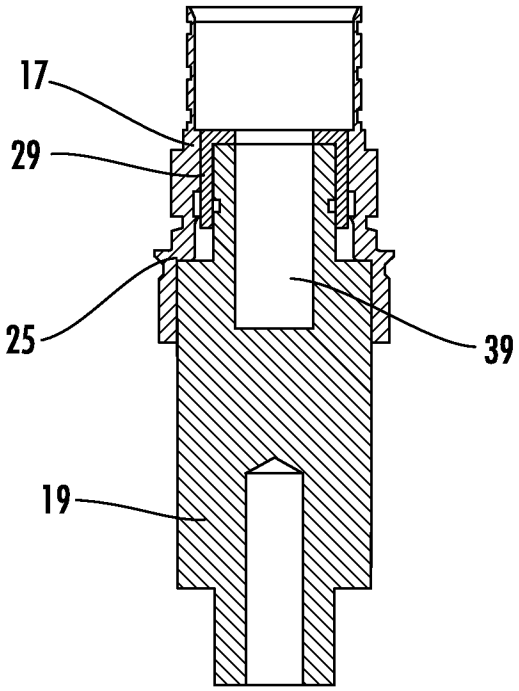

FIG. 2

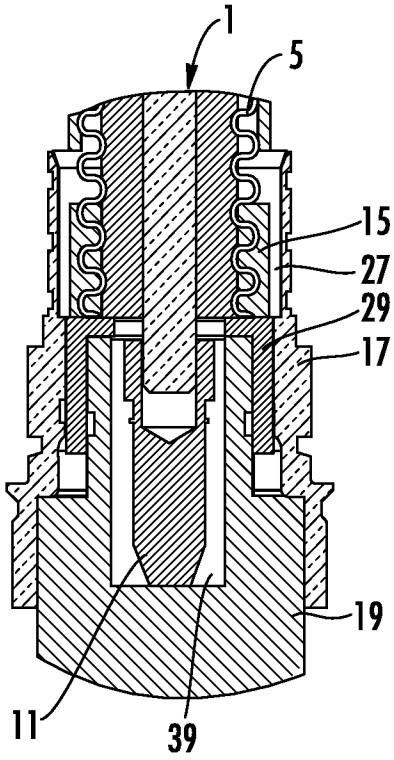

FIG. 3

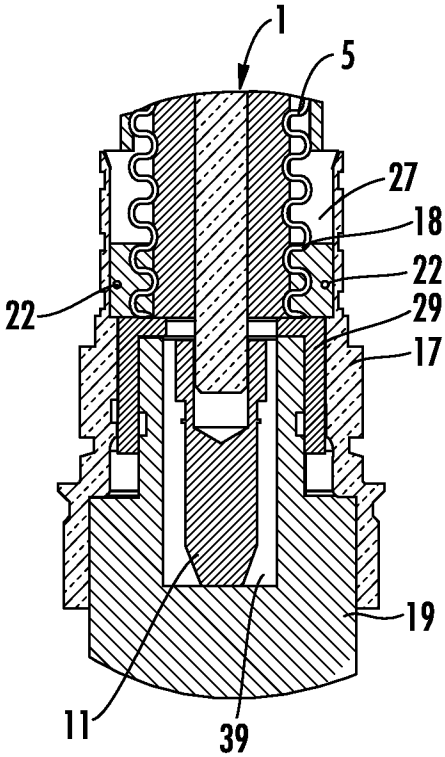

FIG. 4

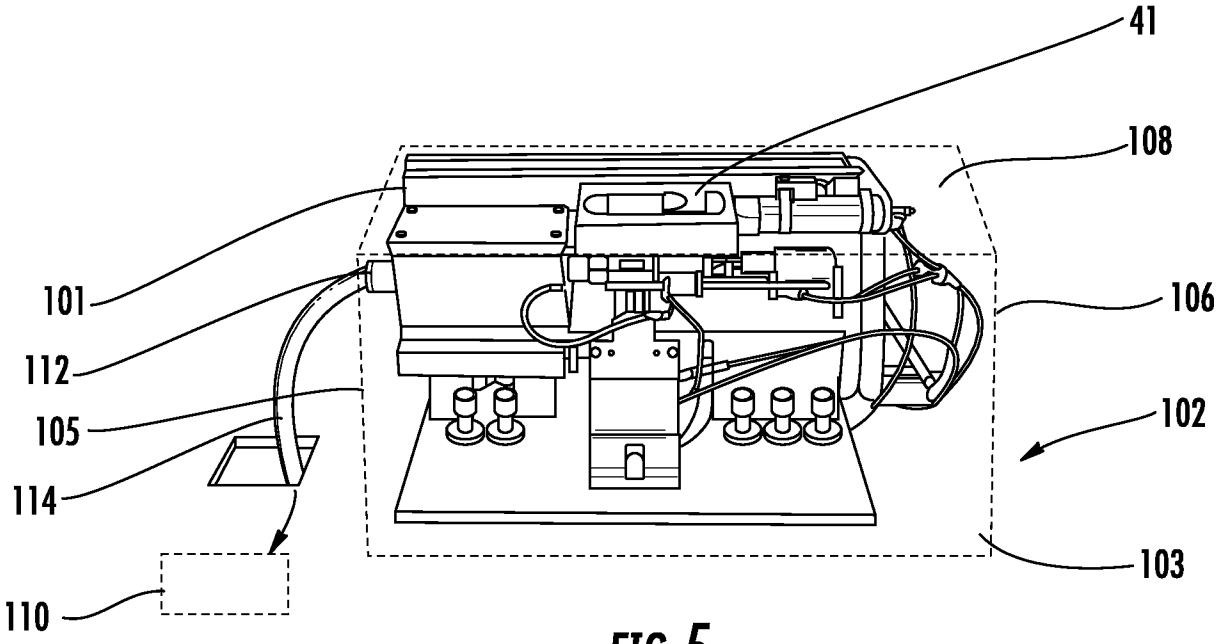

FIG. 5

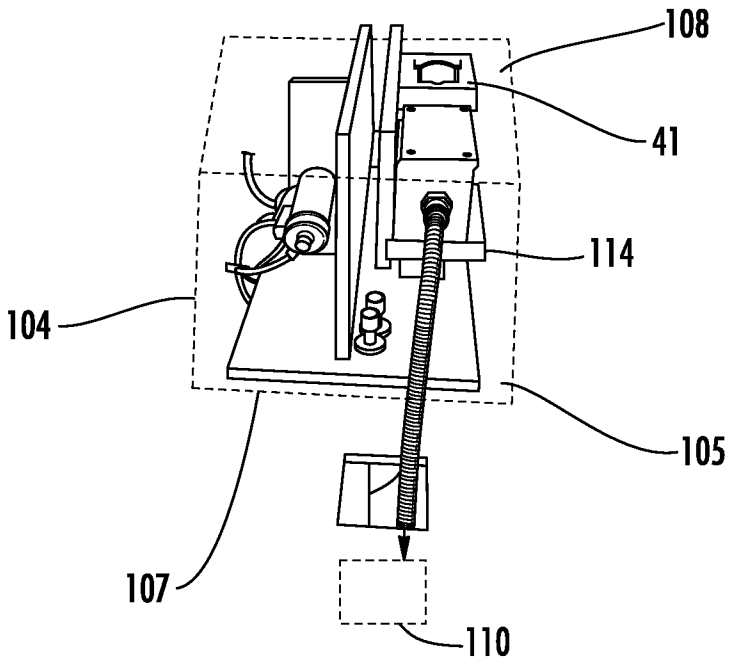

FIG. 6

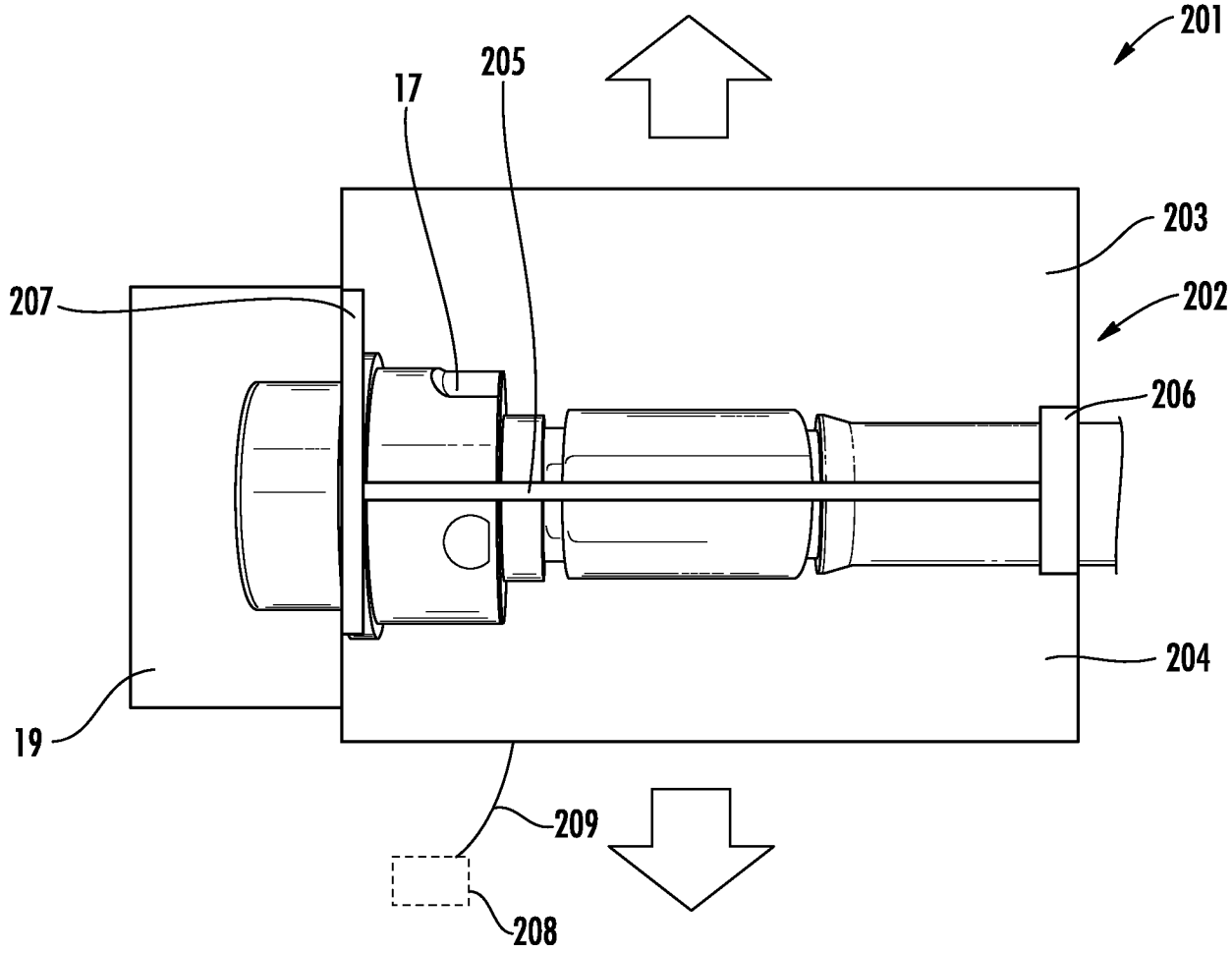

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/021436

A. CLASSIFICATION OF SUBJECT MATTER

H01R 24/38(2011.01)i, H01R 9/05(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01R 24/38; H01R 43/02; A47J 36/02; F16D 1/00; H01R 9/05; H01B 13/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords:coaxial cable, coaxial connector, soldering, vacuum chamber, bubble, heating element

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2014-0201989 A1 (ANDREW LLC.) 24 July 2014 See paragraphs [0024]-[0028], claim 1 and figures 1-2, 6, 10.	1-22
Y	US 2007-0170227 A1 (YASUHIDE OHNO et al.) 26 July 2007 See paragraphs [0013]-[0024] and figure 1.	1-22
A	US 5802710 A (DANIEL E. BUFANDA et al.) 08 September 1998 See column 2, line 63 - column 3, line 48 and figures 1-3.	1-22
A	US 2009-0232594 A1 (RAYMOND H. NG et al.) 17 September 2009 See paragraphs [0019]-[0022], claim 1 and figures 3-4.	1-22
A	KR 10-1450209 B1 (KYUNGSHIN CO., LTD.) 13 October 2014 See paragraphs [0029]-[0040], [0055]-[0062] and figures 1-5.	1-22

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 June 2016 (17.06.2016)	**17 June 2016 (17.06.2016)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2016/021436

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