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(54) ULTRASONIC WELD COAXIAL CONNECTOR

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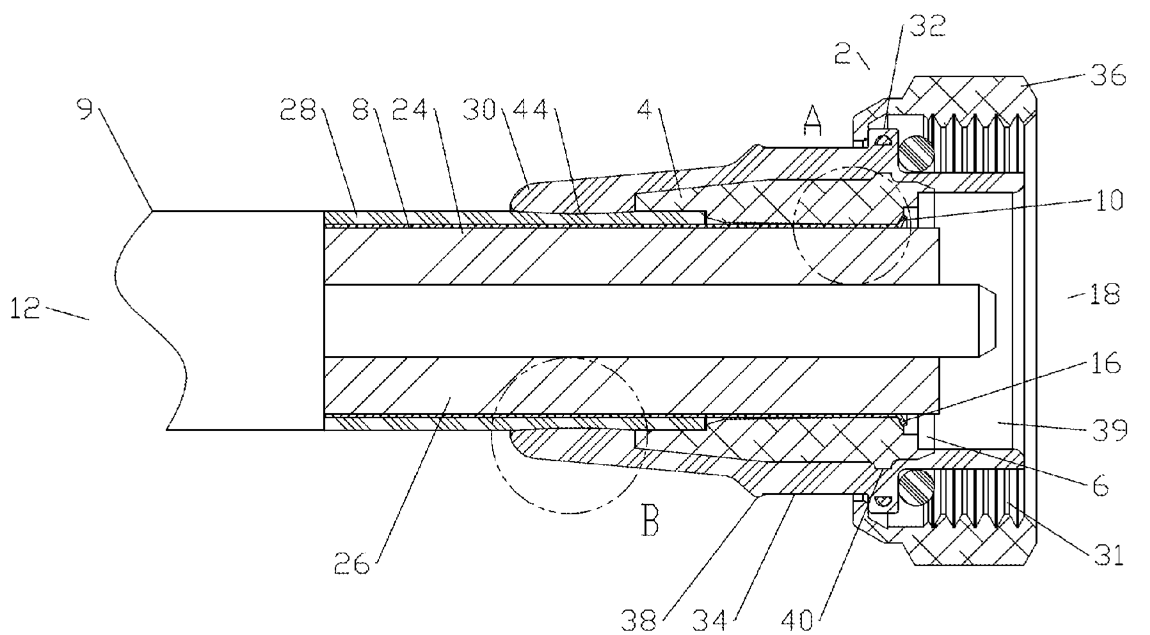
(57) **ABSTRACT**

A coaxial connector for interconnection with a coaxial cable with a solid outer conductor by ultrasonic welding is provided with a monolithic connector body with a bore. An annular flare seat is angled radially outward from the bore toward a connector end of the connector; the annular flare seat open to the connector end of the connector. The flare seat may be provided with an annular flare seat corrugation.



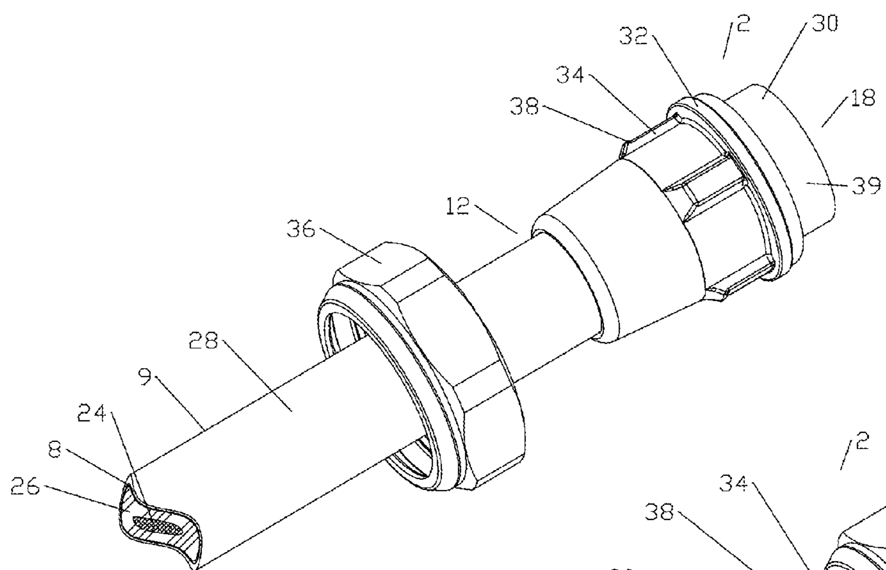


Fig. 1

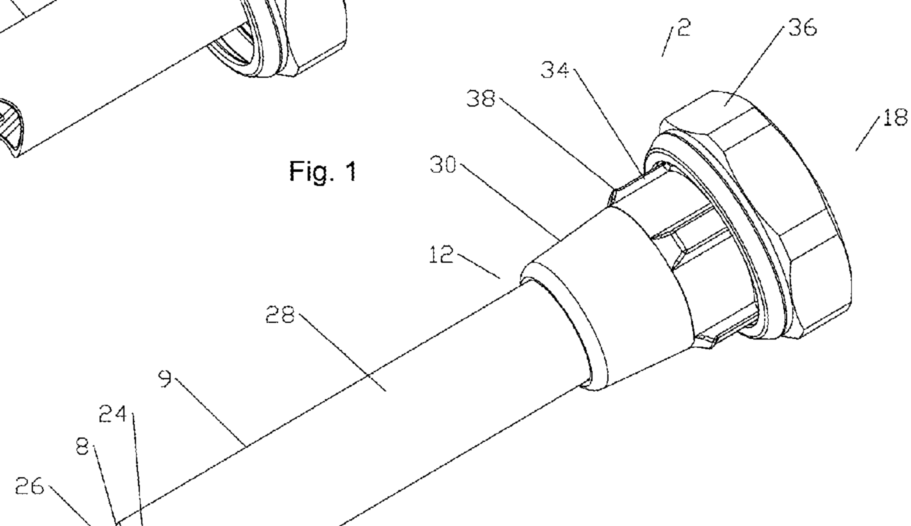


Fig. 2

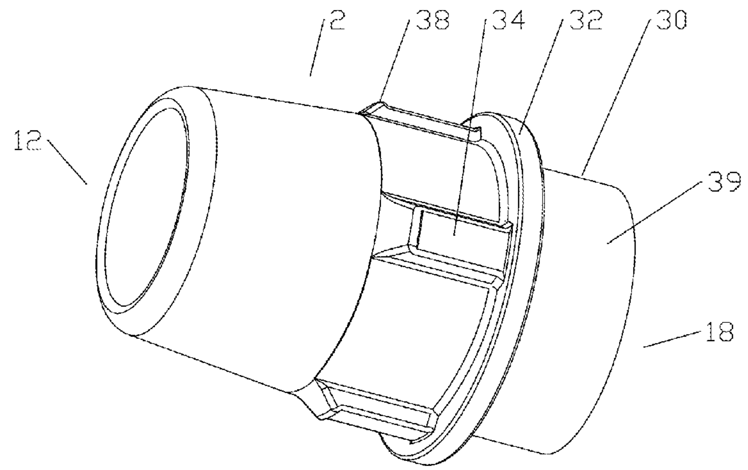
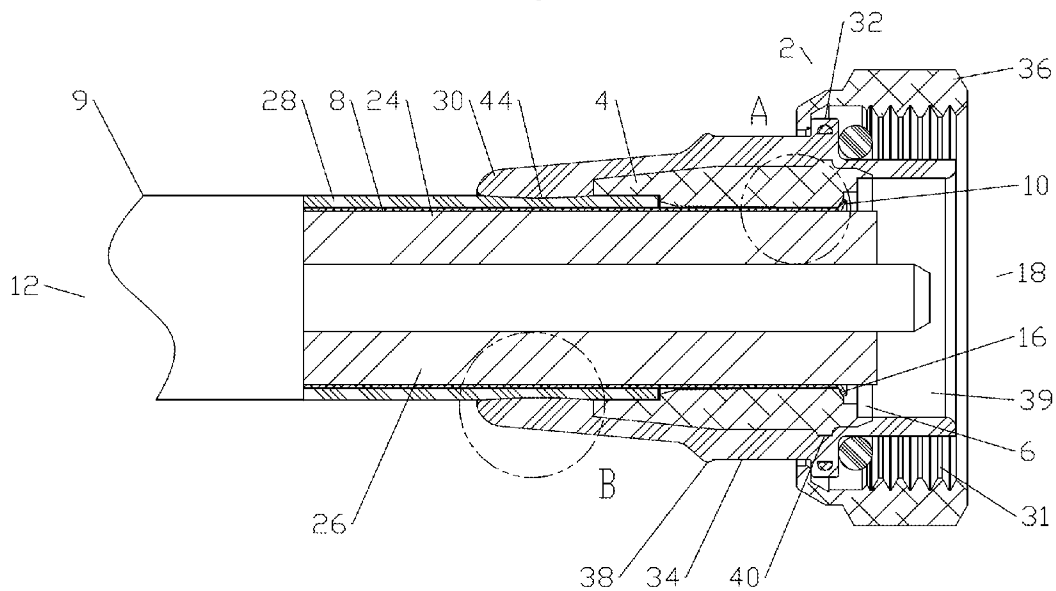

2
38
34
32
30
12
39
18

Fig. 3


32
2
36
9
28
8
24
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4
A
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16
39
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B
31
26
38
34
40

Fig. 4

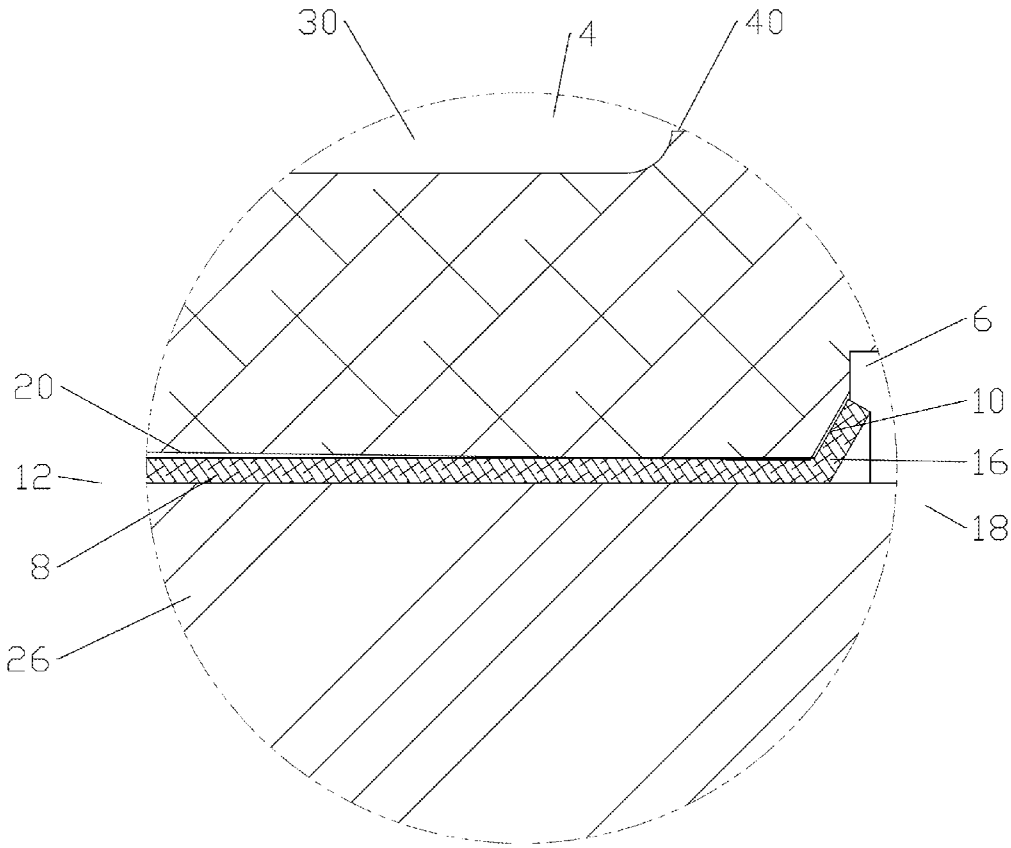

Fig. 5

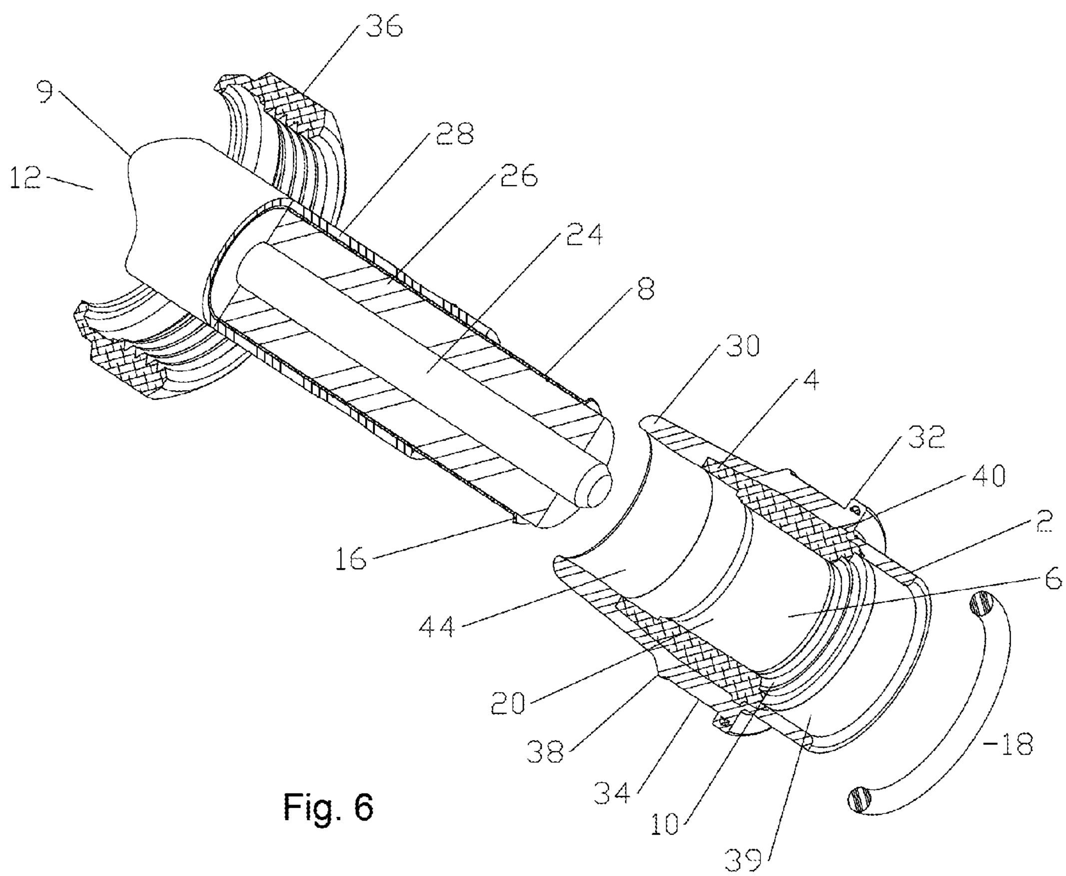

Fig. 6

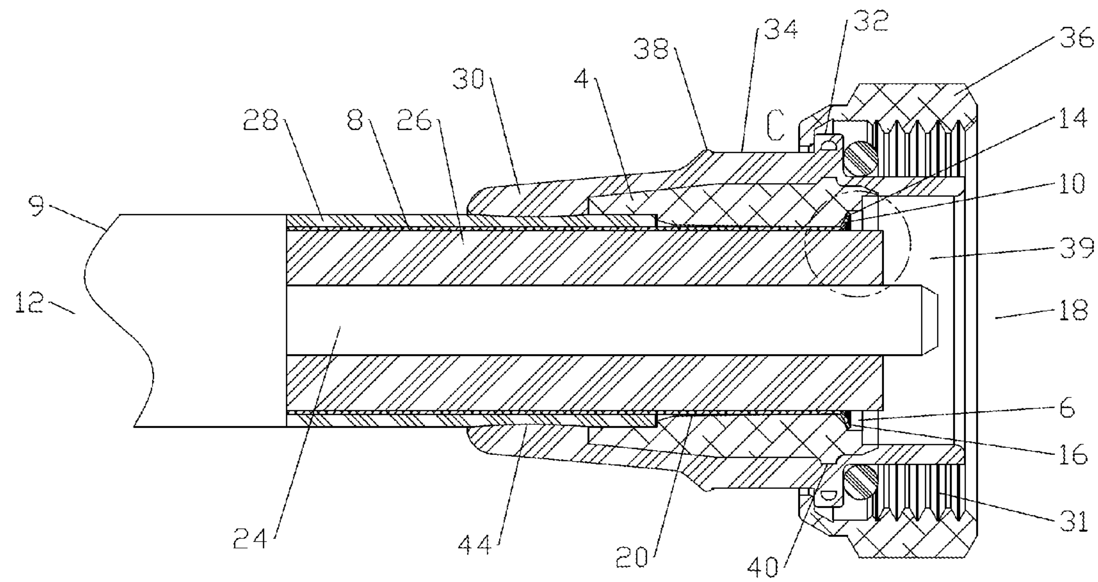

Fig. 7

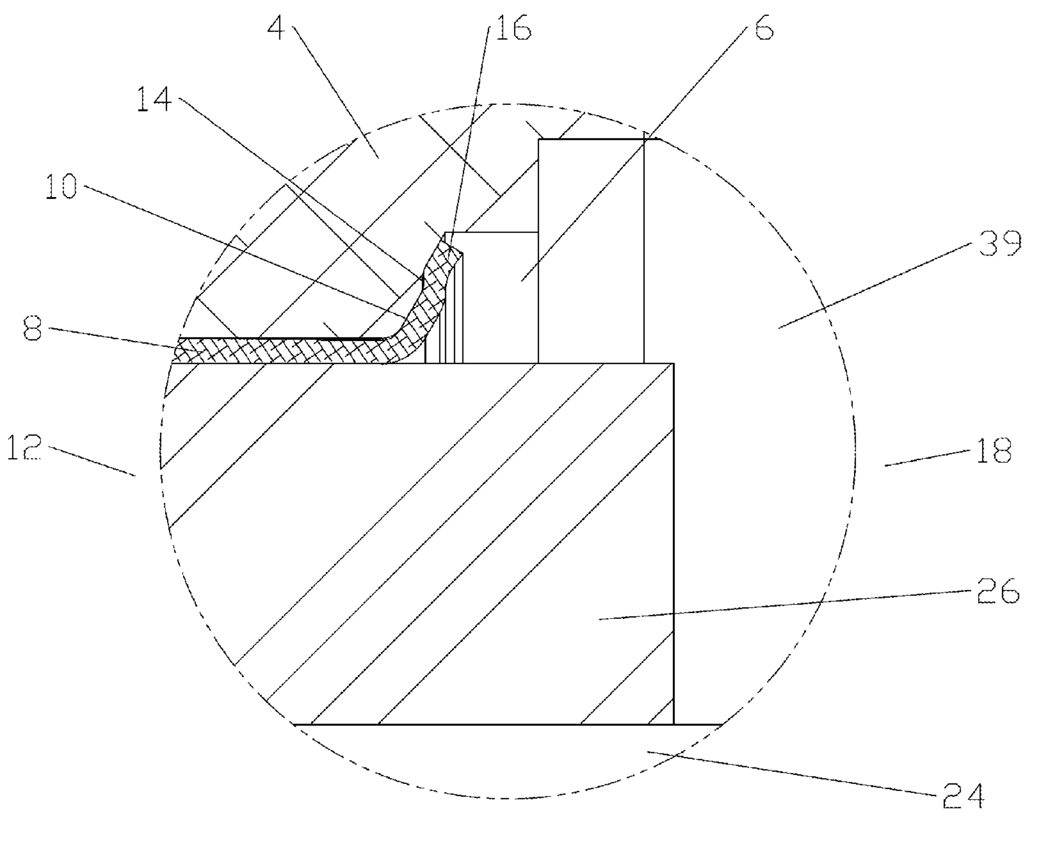

Fig. 8

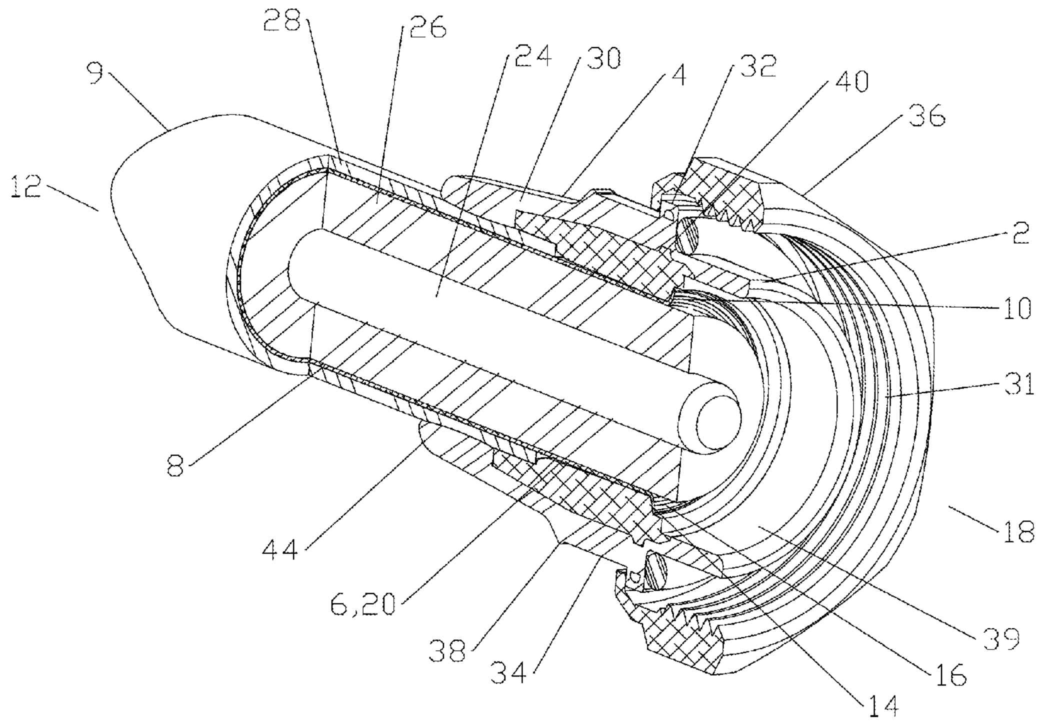

Fig. 9

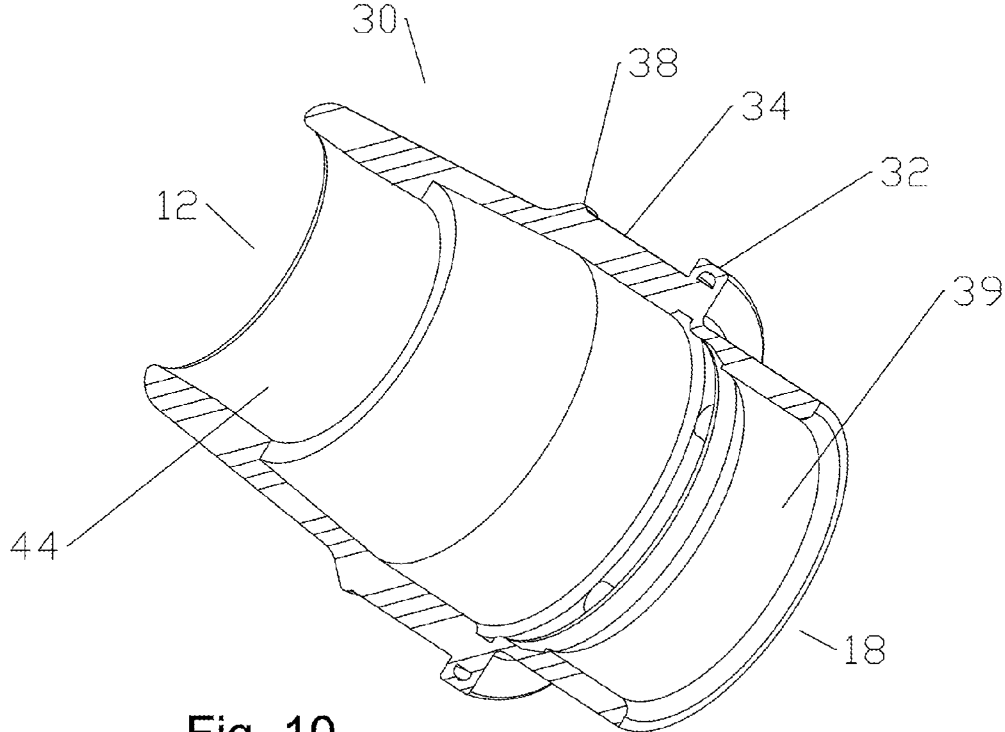

Fig. 10

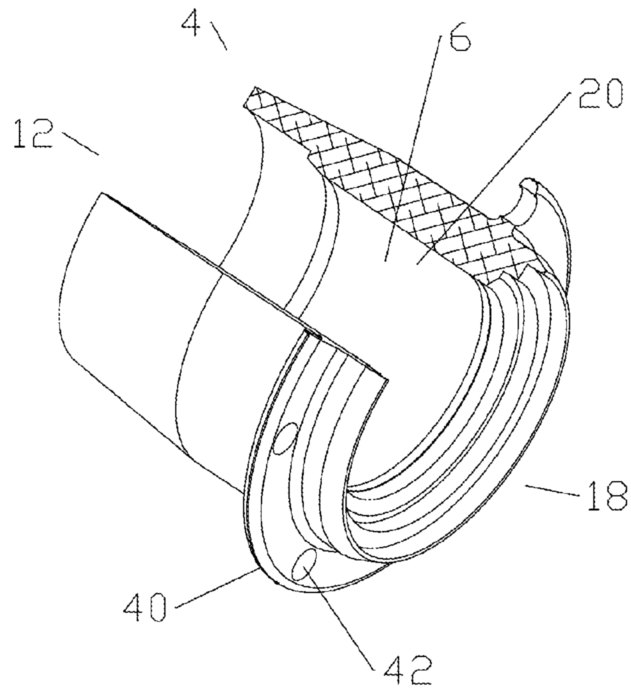

Fig. 11

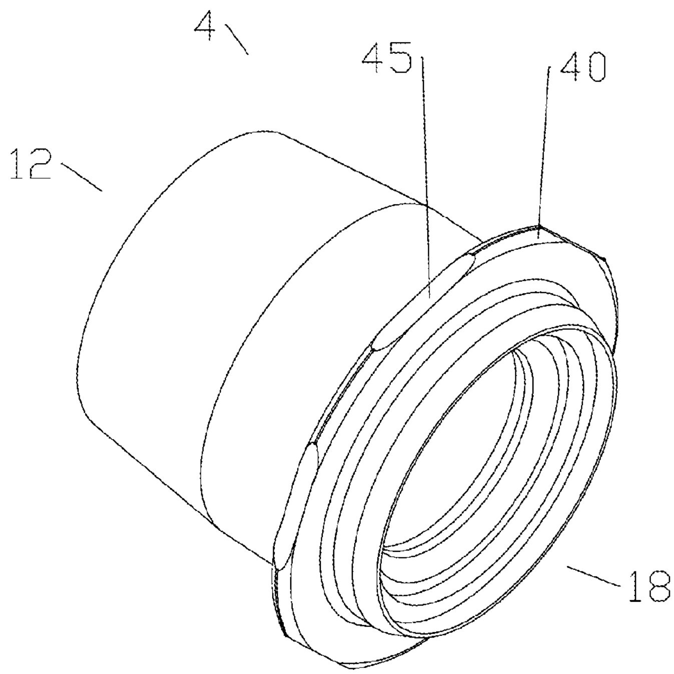

Fig. 12

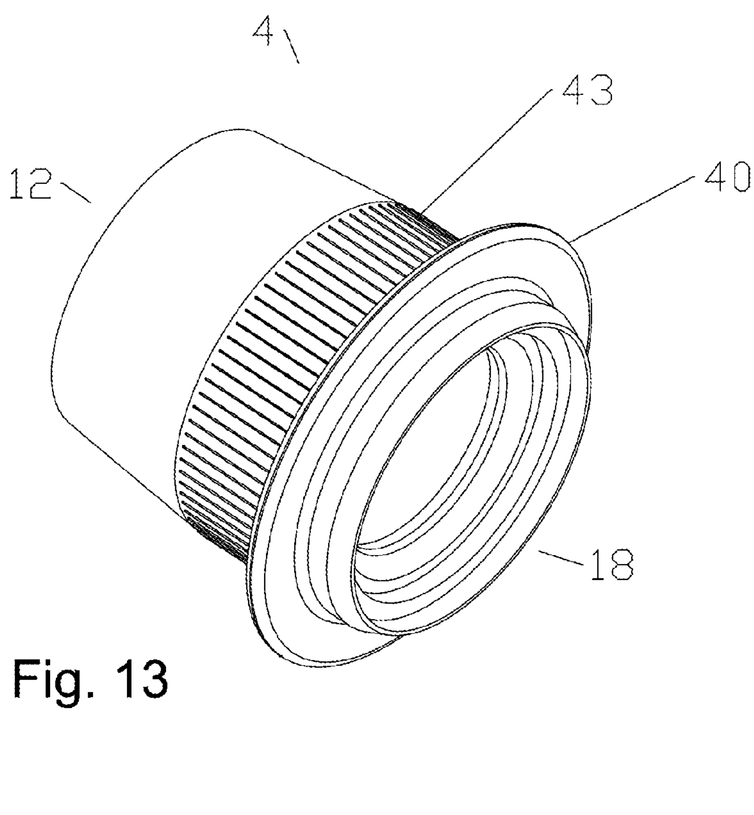

Fig. 13

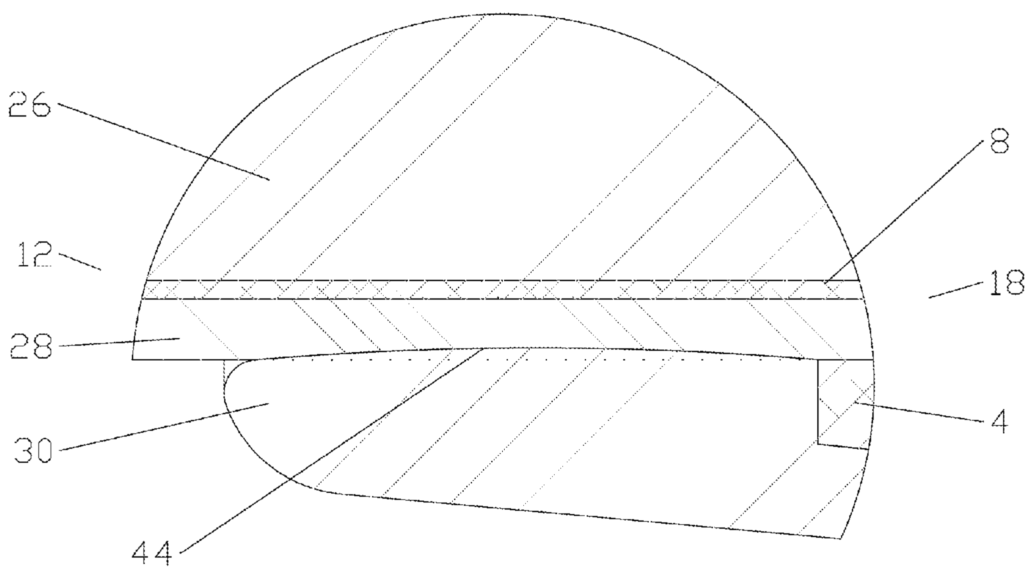

Fig. 14

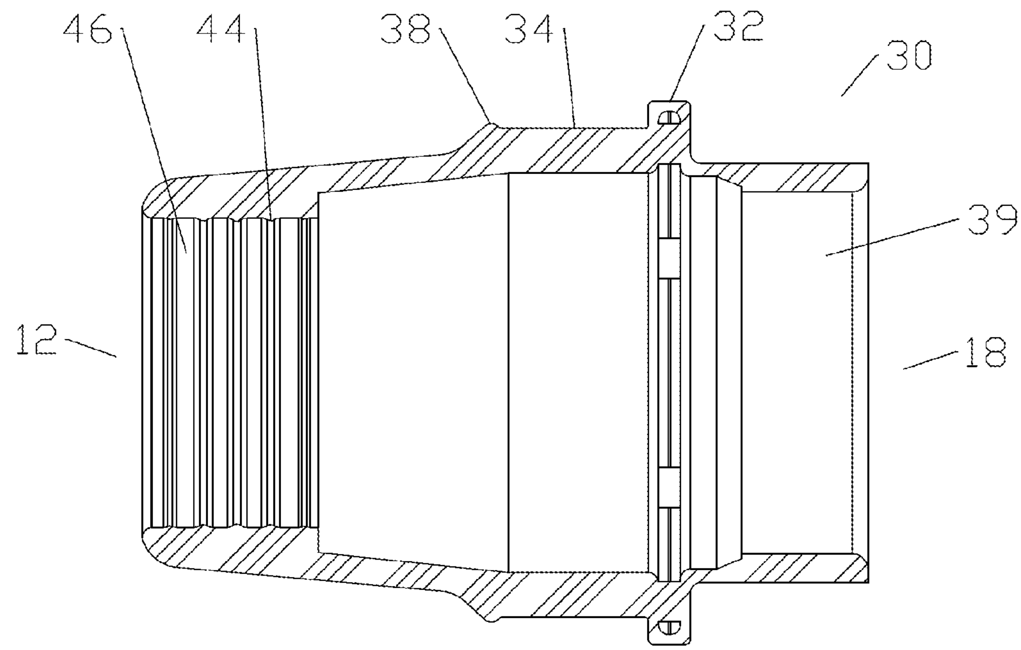

Fig. 15

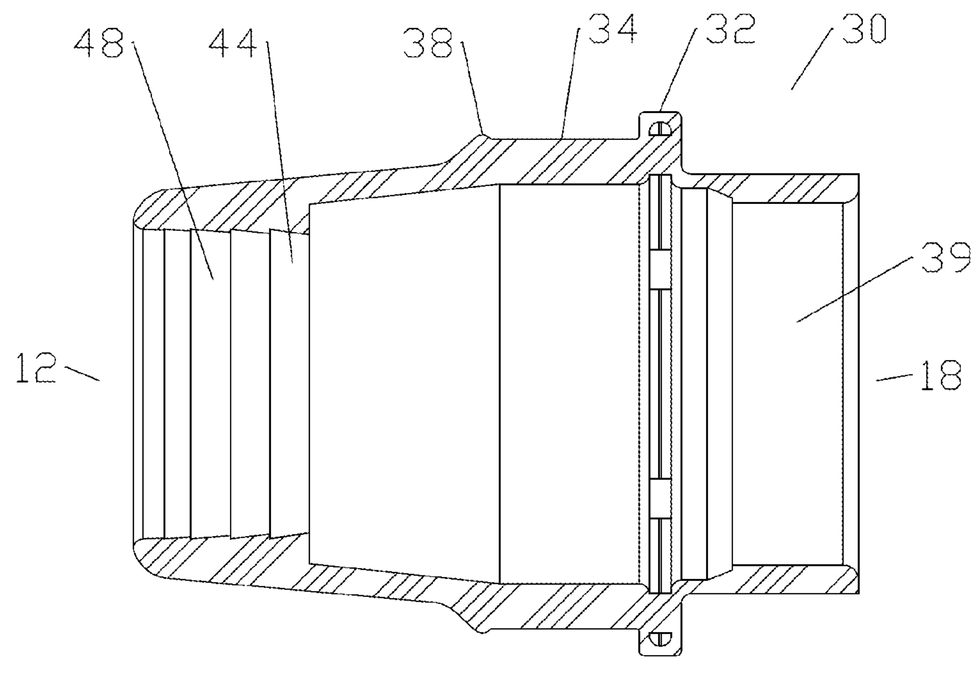

Fig. 16

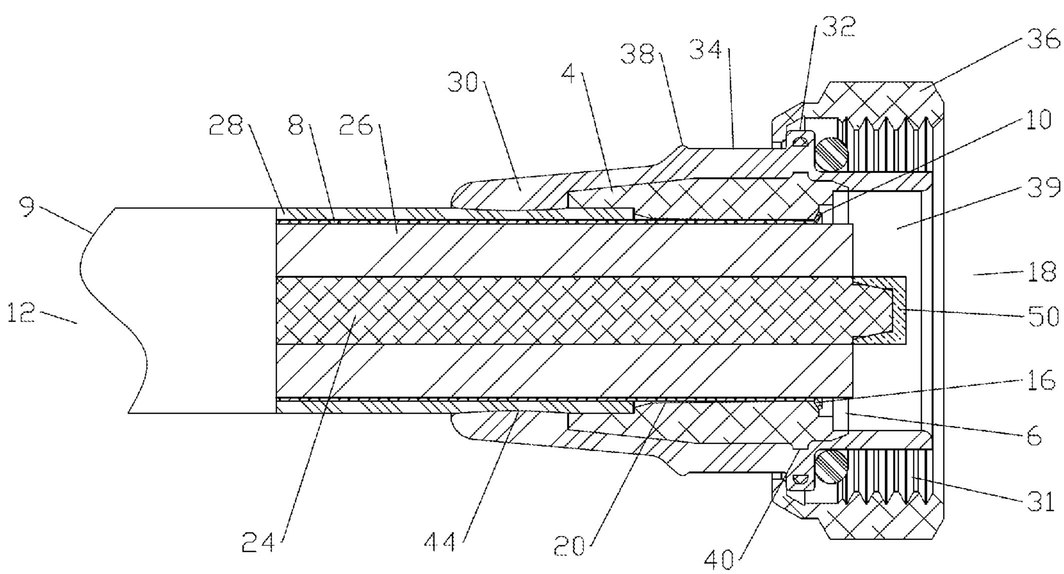

Fig. 17

ULTRASONIC WELD COAXIAL CONNECTOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a division of U.S. Utility patent application Ser. No. 12/980,013, titled "Method of Interconnecting a Coaxial Connector to a Coaxial Cable via Ultrasonic Welding", filed Dec. 28, 2010 by Kendrick Van Swearingen and Nahid Islam, which is a continuation-in-part of commonly owned co-pending U.S. Utility patent application Ser. No. 12/951,558, titled "Laser Weld Coaxial Connector and Interconnection Method", filed Nov. 22, 2010 by Ronald A. Vaccaro, Kendrick Van Swearingen, James P. Fleming, James J. Wlos and Nahid Islam, currently pending and hereby incorporated by reference in its entirety.

BACKGROUND

[0002] 1. Field of the Invention

[0003] This invention relates to electrical cable connectors. More particularly, the invention relates to a coaxial cable connector interconnectable with a coaxial cable via ultrasonic welding.

[0004] 2. Description of Related Art

[0005] Coaxial cable connectors are used, for example, in communication systems requiring a high level of precision and reliability.

[0006] To create a secure mechanical and optimized electrical interconnection between the cable and the connector, it is desirable to have generally uniform, circumferential contact between a leading edge of the coaxial cable outer conductor and the connector body. A flared end of the outer conductor may be clamped against an annular wedge surface of the connector body via a coupling body. Representative of this technology is commonly owned U.S. Pat. No. 6,793,529 issued Sep. 21, 2004 to Buenz. Although this type of connector is typically removable/re-useable, manufacturing and installation is complicated by the multiple separate internal elements required, interconnecting threads and related environmental seals.

[0007] Connectors configured for permanent interconnection via solder and/or adhesive interconnection are also well known in the art. Representative of this technology is commonly owned U.S. Pat. No. 5,802,710 issued Sep. 8, 1998 to Bufanda et al. However, solder and/or adhesive interconnections may be difficult to apply with high levels of quality control, resulting in interconnections that may be less than satisfactory, for example when exposed to vibration and/or corrosion over time.

[0008] Competition in the coaxial cable connector market has focused attention on improving electrical performance and long term reliability of the cable to connector interconnection. Further, reduction of overall costs, including materials, training and installation costs, is a significant factor for commercial success.

[0009] Therefore, it is an object of the invention to provide a coaxial connector and method of interconnection that overcomes deficiencies in the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention, where like reference numbers in the drawing figures refer to the same feature or element and may not be described in detail for every drawing figure in which they appear and, together with a general description of the invention given above, and the detailed description of the embodiments given below, serve to explain the principles of the invention.

[0011] FIG. **1** is a schematic external isometric view of an exemplary embodiment of a coaxial connector installed upon a coaxial cable with a coupling nut spaced away from the connector along the cable for connector-to-cable interconnection.

[0012] FIG. **2** is a schematic isometric view of the coaxial connector of FIG. **1** installed upon a coaxial cable, with the coupling nut seated upon the coaxial connector.

[0013] FIG. **3** is a schematic isometric view of the coaxial connector of FIG. **1**.

[0014] FIG. **4** is a schematic partial cross section side view of the connector of FIG. **2**.

[0015] FIG. **5** is an enlarged view of area A of FIG. **4**.

[0016] FIG. **6** is a schematic exploded isometric partial cut-away view of the connector and cable of FIG. **1**.

[0017] FIG. **7** is a schematic cross section side view of an alternative embodiment of a coaxial connector with a corrugated flare seat.

[0018] FIG. **8** is an enlarged view of area C of FIG. **7**.

[0019] FIG. **9** is a schematic partial cut-away isometric view of the connector of FIG. **7**.

[0020] FIG. **10** is a schematic isometric cut-away view of the overbody of FIG. **5**.

[0021] FIG. **11** is a schematic isometric partial cut-away view of the connector body of FIG. **5**.

[0022] FIG. **12** is a schematic isometric view of an alternative connector body with notches on a flange of the connector body.

[0023] FIG. **13** is a schematic isometric view of an alternative connector body with longitudinal knurls on the connector body outer diameter.

[0024] FIG. **14** is an enlarged view of area B of FIG. **4**.

[0025] FIG. **15** is a schematic cross section side view of an alternative overbody with corrugation on an inner diameter of the cable end.

[0026] FIG. **16** is a schematic cross section side view of an alternative overbody with a stepped surface on an inner diameter of the cable end.

[0027] FIG. **17** is a schematic cross section side view of a coaxial connector embodiment with an inner conductor end cap.

DETAILED DESCRIPTION

[0028] Aluminum has been applied as a cost-effective alternative to copper for the conductors in coaxial cables. However, aluminum oxide surface coatings quickly form upon air-exposed aluminum surfaces. These aluminum oxide surface coatings may degrade traditional mechanical, solder and/or conductive adhesive interconnections.

[0029] The inventors have recognized that increasing acceptance of coaxial cable with solid outer conductors of aluminum and/or aluminum alloy enables connectors configured for interconnection via ultrasonic welding between the outer conductor and a connector body which may also be cost effectively provided, for example, formed from aluminum and/or aluminum alloy.

[0030] An ultrasonic weld may be formed by applying ultrasonic vibrations under pressure in a join zone between two parts desired to be welded together, resulting in local heat sufficient to plasticize adjacent surfaces that are then held in contact with one another until the interflowed surfaces cool, completing the weld. An ultrasonic weld may be applied with high precision via a sonotrode and/or simultaneous sonotrode ends to a point and/or extended surface. Where a point ultrasonic weld is applied, successive overlapping point welds may be applied to generate a continuous ultrasonic weld.

[0031] Exemplary embodiments of an ultrasonic weldable coaxial connector **2** are demonstrated in FIGS. **1-17**. As best shown in FIG. **4**, a unitary connector body **4** is provided with a bore **6** dimensioned to receive the outer conductor **8** of a coaxial cable **9** therein. As best shown in FIG. **5**, a flare seat **10** angled radially outward from the bore **6** toward a connector end **18** of the connector body **4** is open to the connector end of the coaxial connector **2** providing a mating surface to which a leading end flare **16** of the outer conductor **8** may be ultrasonically welded by the sonotrode of an ultrasonic welder.

[0032] One skilled in the art will appreciate that connector end **18** and cable end **12** are applied herein as identifiers for respective ends of both the connector and also of discrete elements of the connector described herein, to identify same and their respective interconnecting surfaces according to their alignment along a longitudinal axis of the connector between a connector end **18** and a cable end **12**.

[0033] Prior to interconnection via ultrasonic welding, the leading end of the coaxial cable **9** may be prepared, as best shown in FIG. **6**, by cutting the coaxial cable **9** so that the inner conductor **24** extends from the outer conductor **8**. Also, dielectric material **26** between the inner conductor **24** and outer conductor **8** may be stripped back and a length of the outer jacket **28** removed to expose desired lengths of each. The cable end **12** is inserted through the bore **6** and an annular flare operation performed on a leading edge of the outer conductor **8**; the resulting leading end flare **16** may be angled to correspond to the angle of the flare seat **10** with respect to a longitudinal axis of the coaxial connector **2**. By performing the flare operation against the flare seat **10**, the resulting leading end flare **16** can be formed with a direct correspondence to the flare seat **10** angle.

[0034] The flare seat **10** may alternatively be formed with surface features, such as a flare seat corrugation **14**, demonstrated for example in FIGS. **7-9** as an annular corrugation. Surface features provide increased surface area along which the ultrasonic weld may be applied, increasing the strength of the resulting interconnection, without requiring a corresponding increased diameter of the leading end flare **16** which may have a negative impact on an impedance discontinuity characteristic of the resulting coaxial connector interconnection. Further surface features may include, for example, annular or radial knurls or other protrusion configurations.

[0035] Ultrasonic welding may be performed, for example, utilizing torsional vibration. In torsional vibration ultrasonic-type friction welding, a torsional vibration is applied to the interconnection via a sonotrode applied to the cable end **12** of the leading end flare **16**, while the coaxial connector **2** and flare seat **10** therewithin are held static. The torsional vibration generates a friction heat which plasticizes the contact surfaces between the leading end flare **16** and the flare seat **10**. Where torsional vibration ultrasonic-type friction welding is utilized, a suitable frequency and torsional vibration displacement, for example between 20 and 40 KHz and 20-35 microns, may be applied.

[0036] Because the localized abrasion of the ultrasonic welding process can break up any aluminum oxide surface coatings in the immediate weld area, no additional care may be required with respect to removing or otherwise managing the presence of aluminum oxide on the interconnection surfaces.

[0037] An overbody **30**, as shown for example in FIG. **10**, may be applied to the connector body **4** as an overmolding of polymeric material. The overbody **30** increases cable to connector torsion and pull resistance. The overbody **30** may also provide connection interface structure at the connector end **18** and further reinforcing support at the cable end **12**, enabling significant reductions in the size of the connector body **4**, thereby reducing overall material costs.

[0038] Depending upon the applied connection interface **31**, demonstrated in the exemplary embodiments herein as a standard 7/16 DIN interface, the overbody **30** may be provided with an overbody flange **32** and longitudinal support ridges **34** for a coupling nut **36**. The coupling nut **36** is retained upon the support ridges **34** at the connector end **18** by an overbody flange **32** and at the cable end **12** by a retention spur **38** provided on at least one of the support ridges **34**. The retention spur **38** may be angled toward the connector end **18**, allowing the coupling nut **36** to be placed over the cable **9** initially spaced away from the coaxial connector **2** during interconnection (see FIG. **1**), but then allowing the coupling nut **36** to be passed over the retention spur **38** and onto the support ridges **34** from the cable end **12**, to be thereafter retained upon the support ridges **34** by the retention spur(s) **38** (see FIG. **2**) in close proximity to the connector interface **31** for connector to connector mating. The support ridges **34** reduce polymeric material requirements of the overbody **30** while providing lateral strength to the connector/interconnection **2** as well as alignment and retention of the coupling nut **36**.

[0039] The overbody **30** may also extend from the connector end **18** of the connector body **4** to provide portions of the selected connector interface **31**, such as an alignment cylinder **39** of the 7/16 DIN interface, further reducing metal material requirements of the connector body **4**.

[0040] The overbody flange **32** may be securely keyed to a connector body flange **40** of the connector body **4** and thereby with the connector body **4** via one or more interlock apertures **42** such as holes, longitudinal knurls **43**, grooves, notches **45** or the like provided in the connector body flange **40** and/or outer diameter of the connector body **4**, as demonstrated in FIGS. **11-13**. Thereby, as the polymeric material of the overbody **30** flows into the interlock apertures **42** during overmolding, upon curing the overbody **30** is permanently coupled to and rotationally interlocked with the connector body **4**.

[0041] As best shown in FIG. **14**, the cable end **12** of the overbody **30** may be dimensioned with an inner diameter friction surface **44** proximate that of the coaxial cable outer jacket **28**, enabling polymeric friction welding between the overbody **30** and the outer jacket **28**, as the connector body **4** and outer conductor are rotated with respect to each other, thereby eliminating the need for environmental seals at the cable end **12** of the connector/cable interconnection. During friction welding, the coaxial connector **2** is rotated with respect to the cable **9**. Friction between the friction surface **44** and the outer diameter of the outer jacket **28** heats the respective surfaces to a point where they begin to soften and intermingle, sealing them against one another. The outer jacket **28**

and/or the inner diameter of the overbody **30** may be provided as a series of spaced apart annular peaks of a contour pattern such as a corrugation **46**, as shown for example in FIG. **15**, or a stepped surface **48**, as shown for example in FIG. **16**, to provide enhanced friction, allow voids for excess friction weld material flow and to add key locking for additional strength. Alternatively, the overbody **30** may be sealed against the outer jacket **28** with an adhesive/sealant or may be overmolded upon the connector body **4** after interconnection with the outer conductor **8**, the heat of the injected polymeric material bonding the overbody **30** with and/or sealing against the outer jacket **28**.

[0042] The inner conductor **24** extending from the prepared end of the coaxial cable **9** may be selected to pass through to the connector end **18** as a portion of the selected connection interface **31**, for example as shown in FIG. **4**. If the selected coaxial cable **9** has an inner conductor **24** that has a larger diameter than the inner conductor portion of the selected connector interface **31**, the inner conductor **24** may be ground at the connector end **18** to the required diameter.

[0043] Although a direct pass through inner conductor **24** advantageously eliminates interconnections, for example with the spring basket interconnection with a traditional coaxial connector inner contact, such may introduce electrical performance degradation such as PIM. Where the inner conductor **24** is also aluminum material some applications may require a non-aluminum material connection point at the inner contact/inner conductor of the connection interface **31**. As shown for example in FIG. **17**, a center cap **50**, for example formed from a metal such as brass or other desired metal, may be applied to the end of the inner conductor **24**, also by friction or ultrasonic welding. To apply the center cap **50**, the end of the inner conductor **24** is ground to provide a pin corresponding to the selected socket geometry of the center cap **50**. To allow material inter-flow during welding attachment, the socket geometry of the center cap **50** and or the end of the inner conductor **24** may be formed to provide material gaps.

[0044] One skilled in the art will appreciate that the connector and interconnection method disclosed has significant material cost efficiencies and provides a permanently sealed interconnection with reduced size and/or weight requirements.

Table of Parts	
2	coaxial connector
4	connector body
6	bore
8	outer conductor
9	cable
10	flare seat
12	cable end
14	flare seat corrugation
16	leading end flare
18	connector end
20	bore sidewall
24	inner conductor
26	dielectric material
28	outer jacket
30	overbody
31	connection interface
32	overbody flange
34	support ridge
36	coupling nut
38	retention spur
39	alignment cylinder
40	connector body flange
42	interlock aperture
43	longitudinal knurl
44	friction surface
45	notch
46	corrugation
48	stepped surface
50	center cap

[0045] Where in the foregoing description reference has been made to materials, ratios, integers or components having known equivalents then such equivalents are herein incorporated as if individually set forth.

[0046] While the present invention has been illustrated by the description of the embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative apparatus, methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departure from the spirit or scope of applicant's general inventive concept. Further, it is to be appreciated that improvements and/or modifications may be made thereto without departing from the scope or spirit of the present invention as defined by the following claims.

We claim:

1. A coaxial connector for interconnection with a coaxial cable with a solid outer conductor, comprising:

a monolithic connector body with a bore;

an annular flare seat angled radially outward from the bore toward a connector end of the connector; the annular flare seat open to the connector end of the connector.

2. The connector of claim **1**, wherein the flare seat is provided with an annular flare seat corrugation.

3. The connector of claim **1**, wherein a diameter of the bore proximate the flare seat decreases to an interference fit with an outer diameter of the outer conductor.

4. The connector of claim **1**, further including an overbody of polymeric material on an outer diameter of the connector body.

5. The connector of claim **4**, wherein the overbody includes an alignment cylinder of a connector interface at a connector end of the connector.

6. The connector of claim **4**, wherein the overbody includes a plurality of longitudinal support ridges extending from an outer diameter of the overbody to less than an inner diameter of a coupling nut dimensioned to seat upon the support ridges.

7. The connector of claim **6**, wherein the coupling nut is retained on the support ridges between a flange of the overbody and an outward extending retention spur proximate a cable end of at least one of the support ridges.

8. The connector of claim **4**, wherein the overbody extends from the cable end of the connector body, an inner diameter of the overbody extending from the cable end of the connector body provided as a friction surface with an interference fit upon an outer diameter of a jacket of the coaxial cable.

9. The connector of claim **8**, wherein the friction surface is provided as a series of spaced apart annular peaks of a contour pattern of the inner diameter of the overbody.

10. The connector of claim **4**, further including a rotational interlock between the overbody and the connector body.

11. The connector of claim **10**, wherein the rotational interlock is a plurality of interlock apertures provided in a connector body flange protruding from an outer diameter of the connector body.

* * * * *