US 20050127668A1

(19) United States
(12) Patent Application Publication
Mobley et al.
(10) Pub. No.: US 2005/0127668 A1
(43) Pub. Date: Jun. 16, 2005

(54) GAS IMPERMEABLE TUBE JOINT AND METHOD OF FORMING SAME

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(21) Appl. No.: 10/732,841

(22) Filed: Dec. 10, 2003

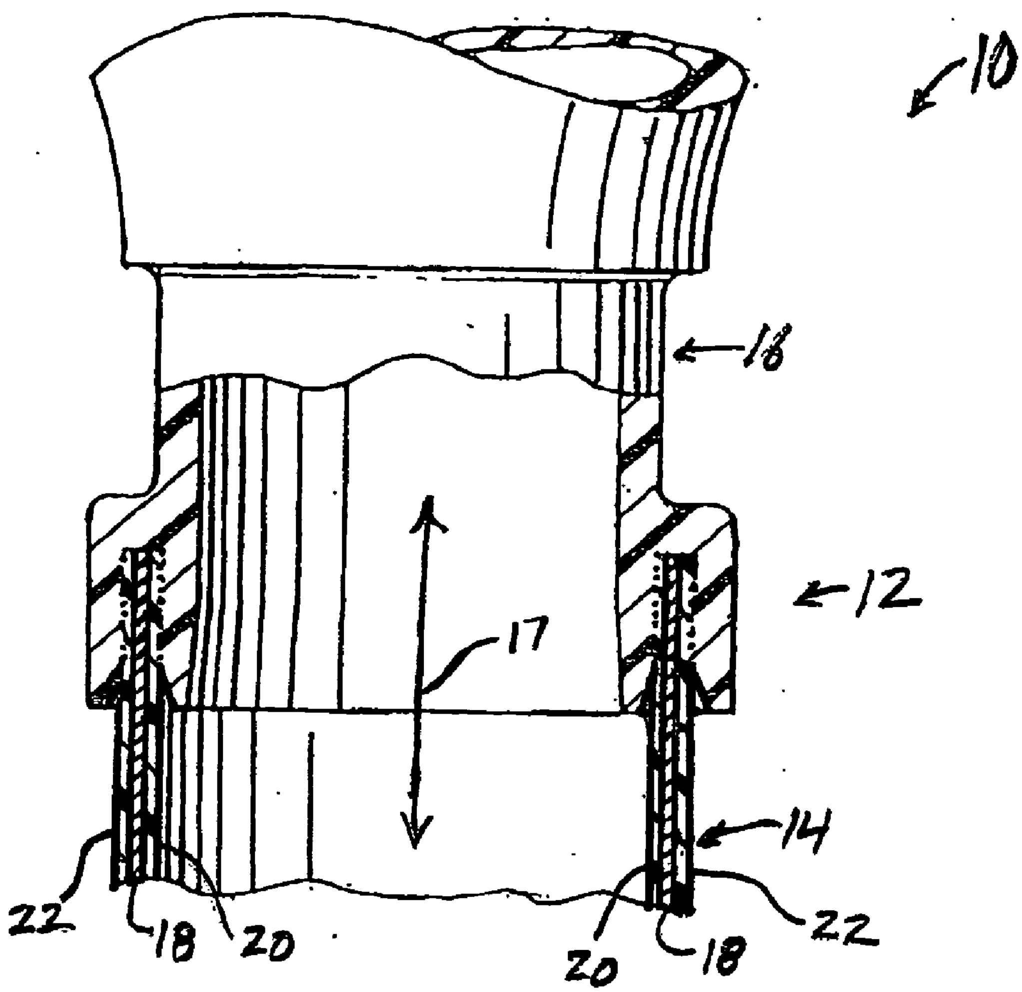
Publication Classification

(51) Int. Cl.7 .... F16L 13/02

(52) U.S. Cl. 285/288.1

(57) ABSTRACT

A method of forming a gas impermeable joint in a fluid system includes: providing a tube having a metallic barrier layer disposed between an inner plastic layer and an outer plastic layer; forcing at least one of the inner plastic layer and the outer plastic layer into contact with a plastic surface of a component; and welding the at least one of the inner plastic layer and the outer plastic layer with the plastic surface to form the gas impermeable joint. The welding may include: spin welding, hot plate welding, vibration welding, and ultrasonic welding. The metallic barrier layer extends substantially to the component, thus improving the gas impermeability of the joint between the tube and the component.



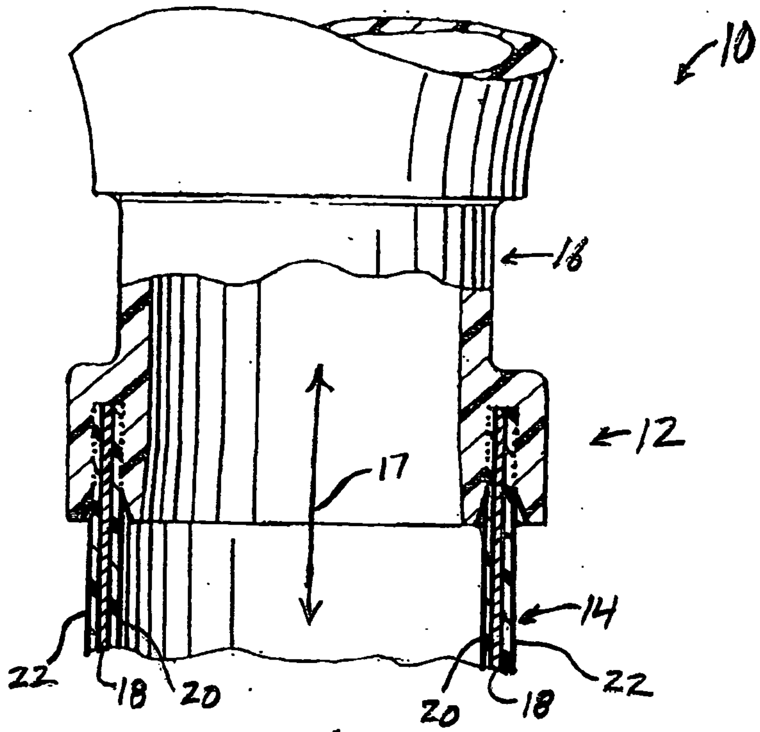


Fig. 1

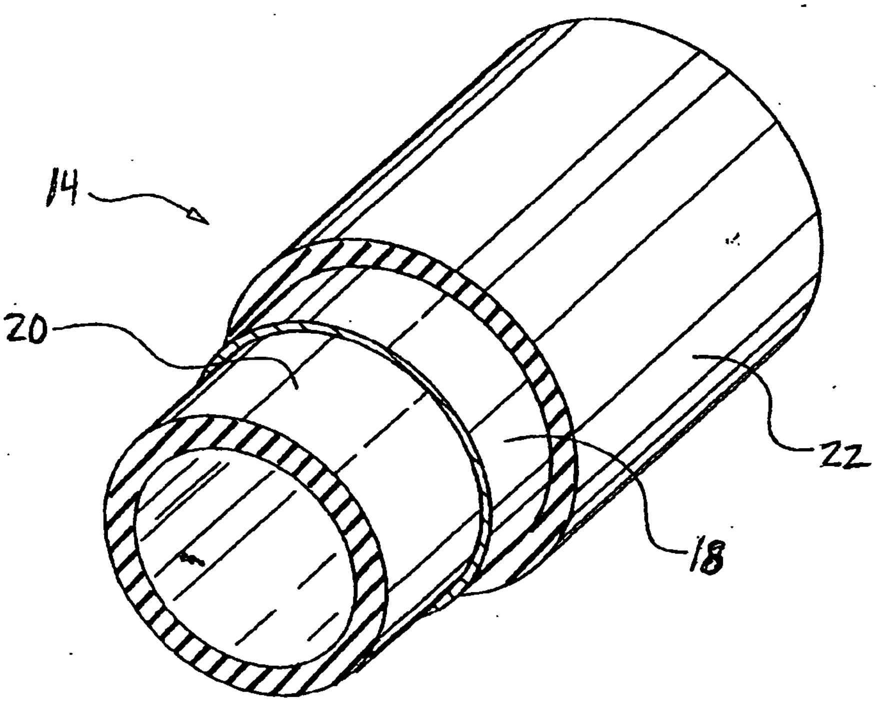
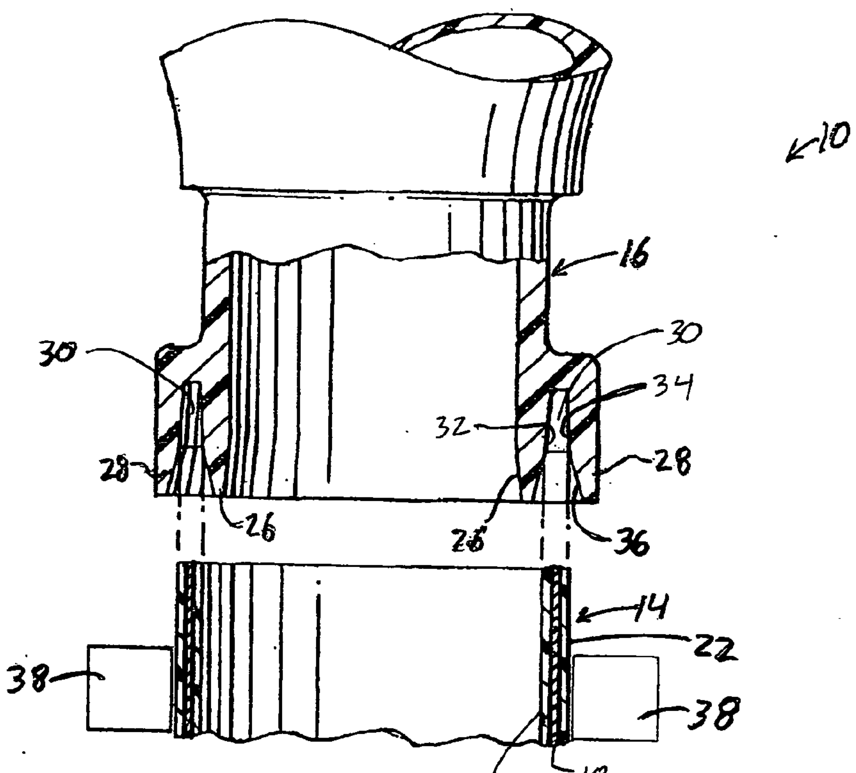


Fig. 2


10
16
30
30
34
32
28
28
26
26
36
14
22
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38
20
18

Fig. 3

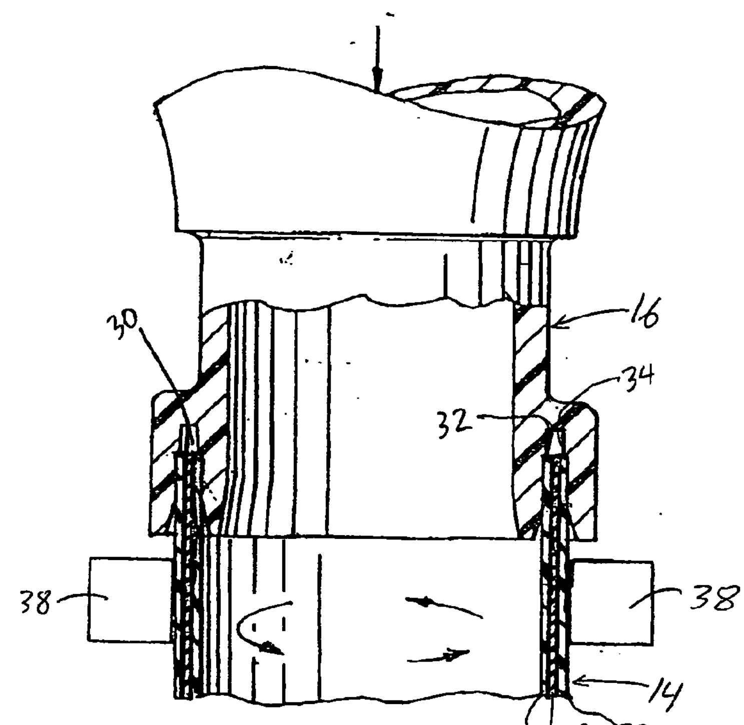
16
30
34
32
38
38
14
20
18
22

Fig. 4

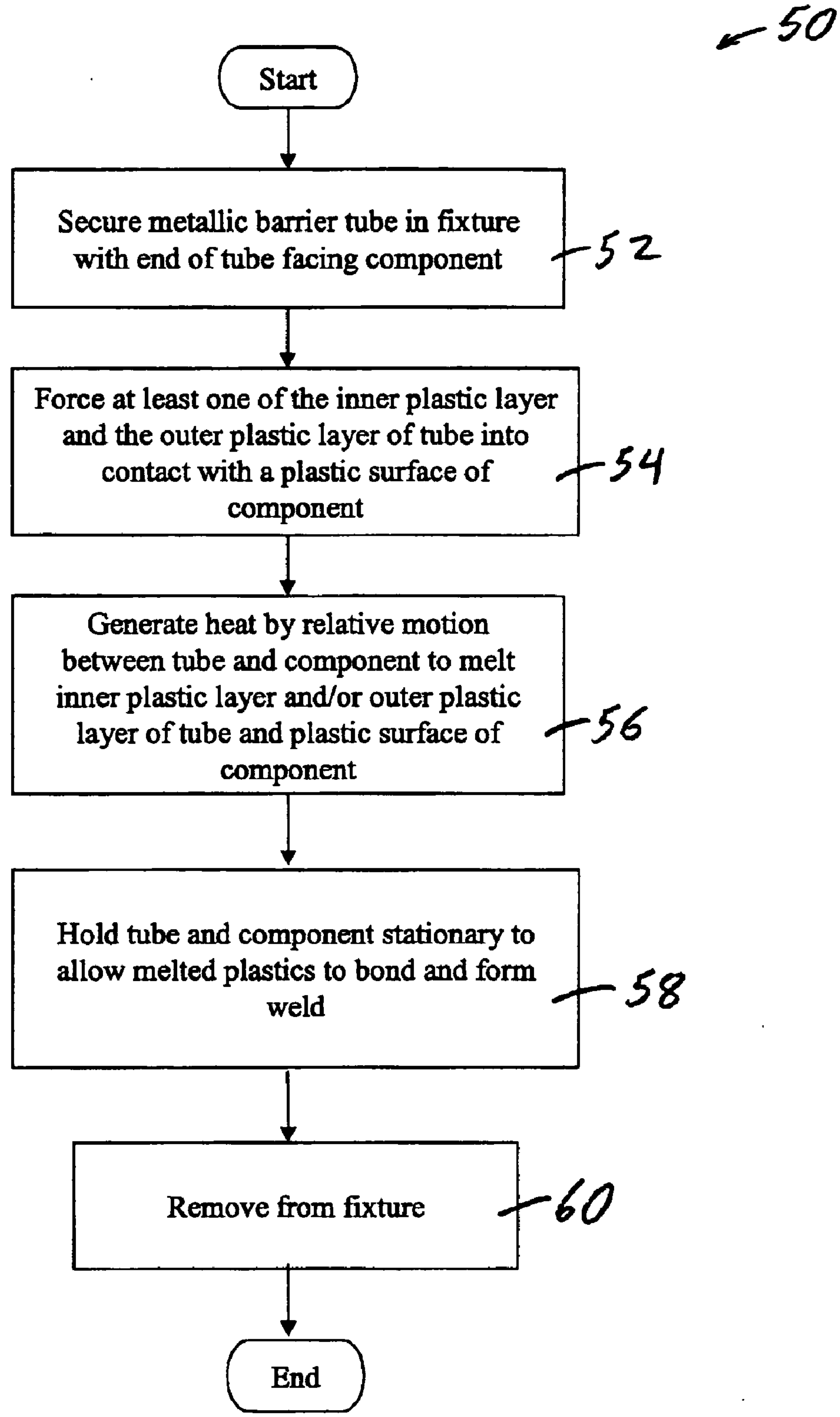
50
Start
Secure metallic barrier tube in fixture with end of tube facing component
52
Force at least one of the inner plastic layer and the outer plastic layer of tube into contact with a plastic surface of component
54
Generate heat by relative motion between tube and component to melt inner plastic layer and/or outer plastic layer of tube and plastic surface of component
56
Hold tube and component stationary to allow melted plastics to bond and form weld
58
Remove from fixture
60
End

Fig. 5

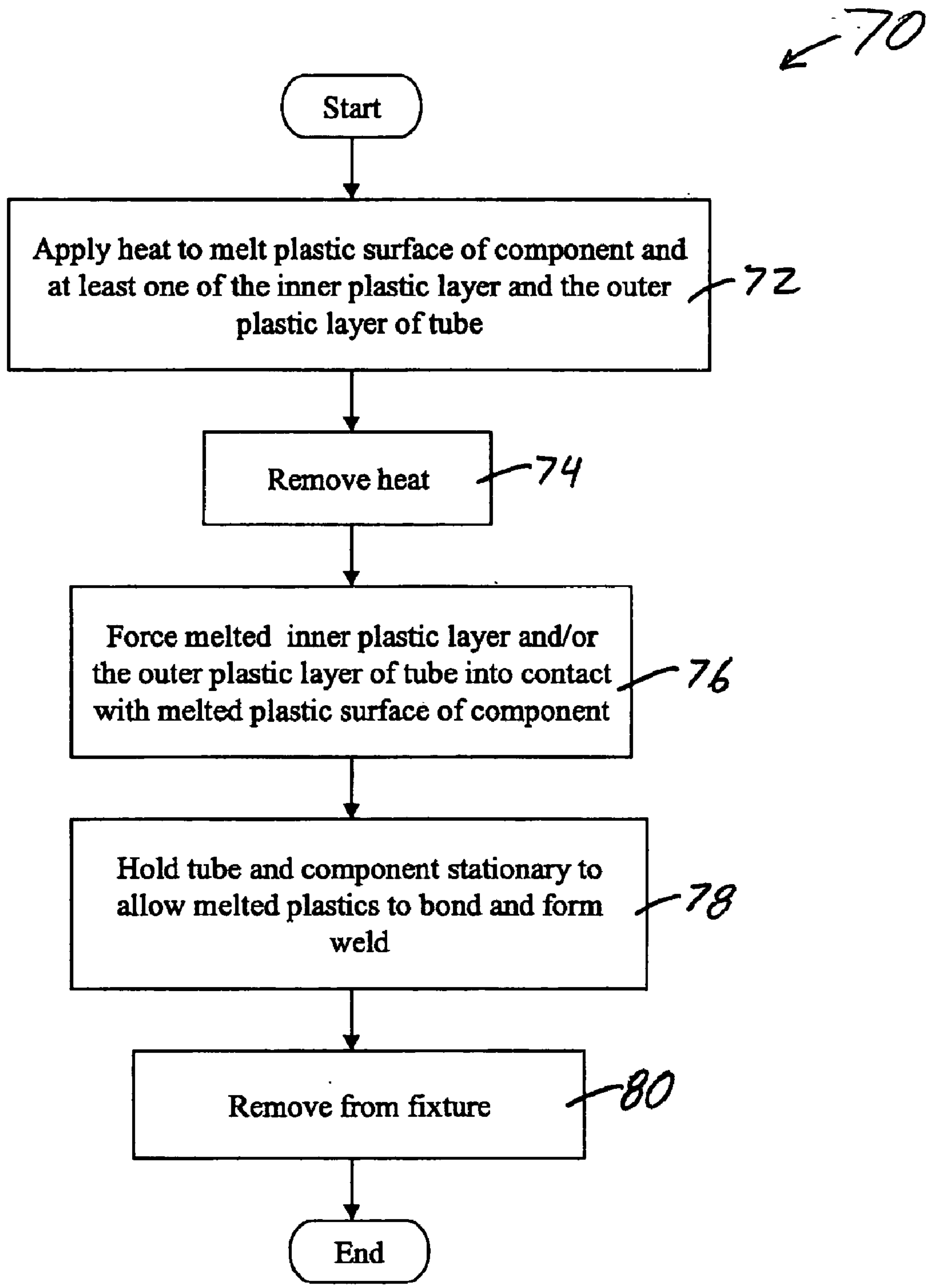
70
Start
Apply heat to melt plastic surface of component and at least one of the inner plastic layer and the outer plastic layer of tube
72
Remove heat
74
Force melted inner plastic layer and/or the outer plastic layer of tube into contact with melted plastic surface of component
76
Hold tube and component stationary to allow melted plastics to bond and form weld
78
Remove from fixture
80
End

Fig. 6

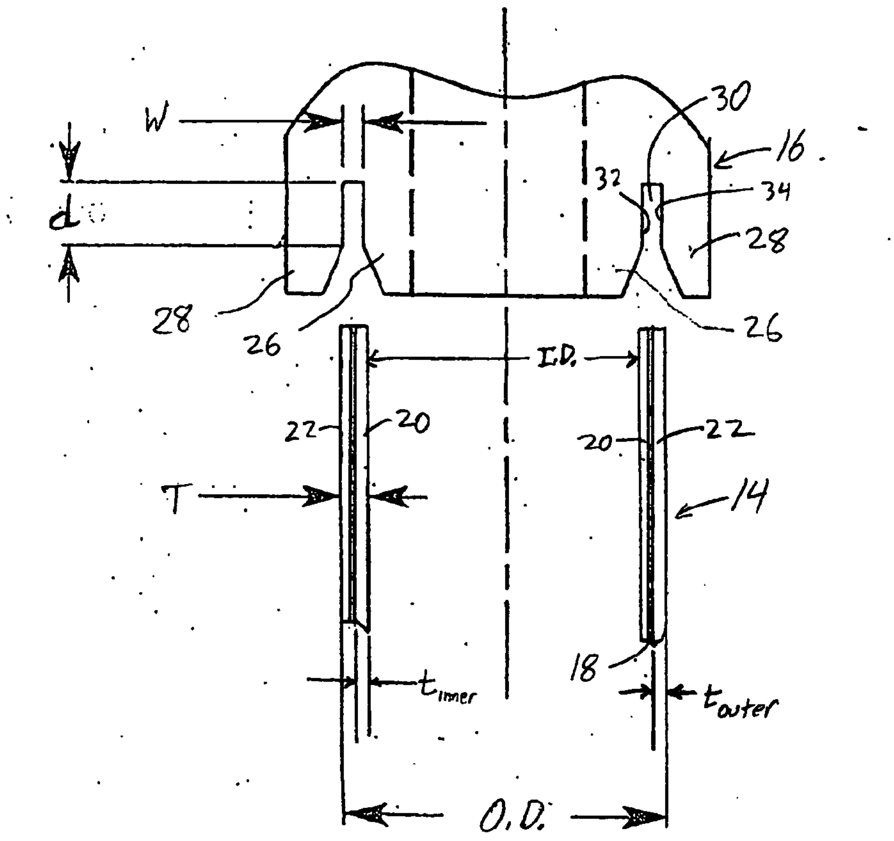

Fig. 7

NOMINAL

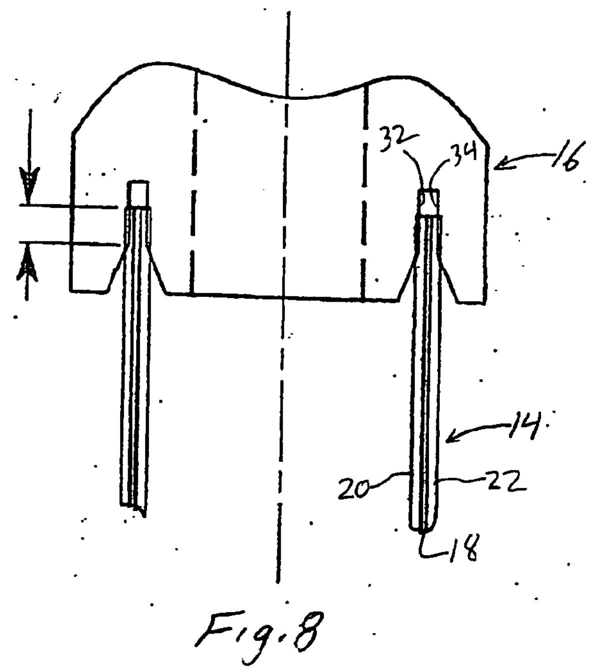

Fig. 8

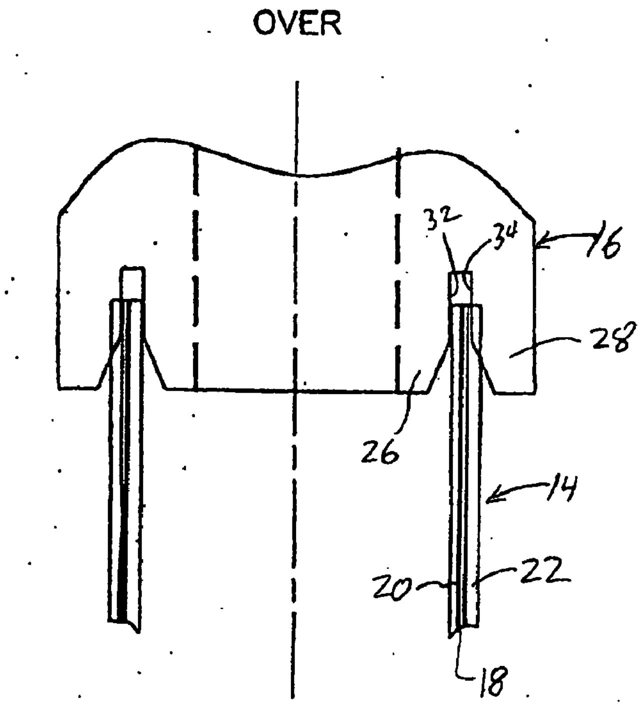

Fig. 9

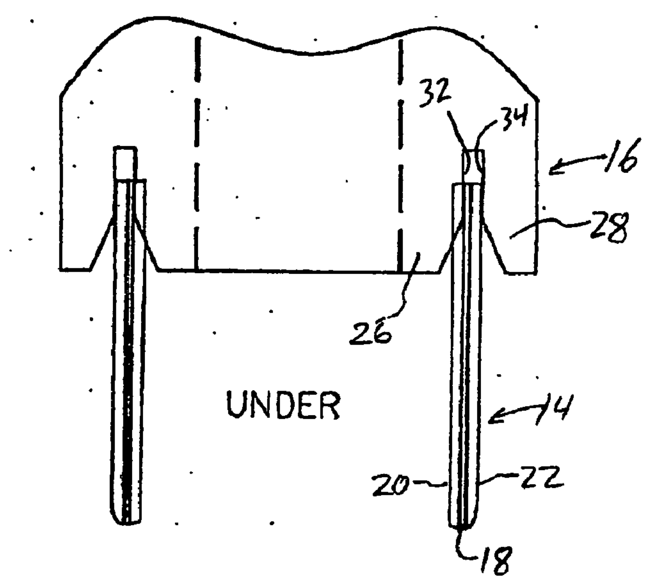

Fig. 10

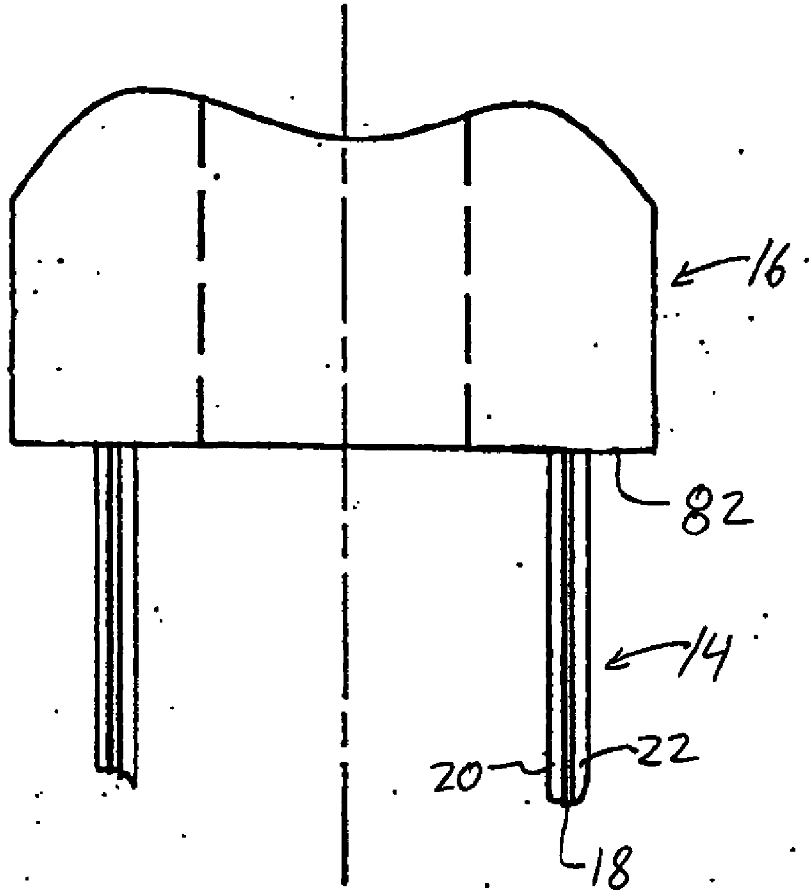

Fig. 11

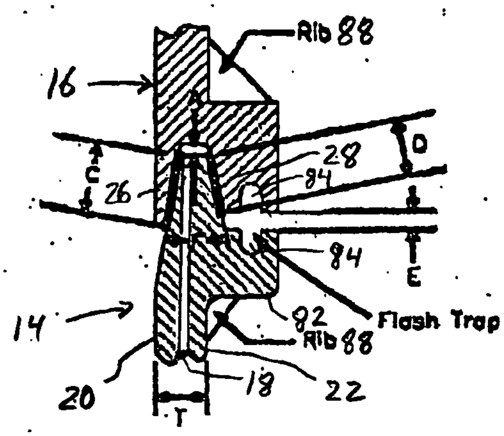

Fig. 12

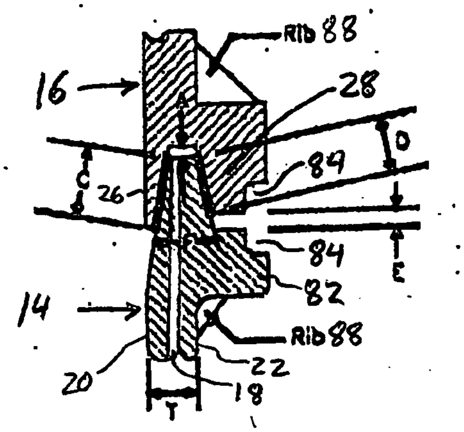

Fig. 13

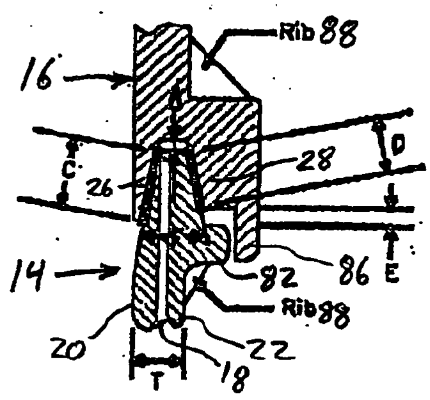

Fig. 14

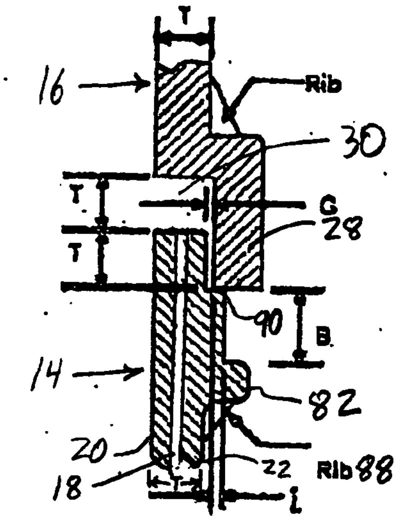

Fig. 15

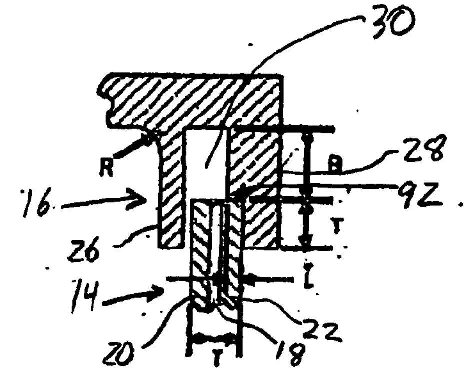

Fig. 16

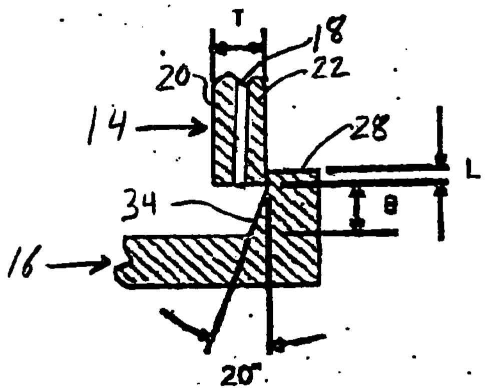

Fig. 17

GAS IMPERMEABLE TUBE JOINT AND METHOD OF FORMING SAME

BACKGROUND

[0001] This invention relates to the joining of tubes to other components in fluid systems. More specifically, this invention relates to gas impermeable tube joints and methods for forming gas impermeable tube joints in fluid systems.

[0002] In general, fluid systems serve to contain a fluid (e.g., a liquid, vapor, gas) as it is transported from one location to another. Fluid systems typically include a number of components interconnected by one or more tubes, which transport the fluid between the components. The components and tubes are connected together by joints, which allow the fluid to flow between the components and tubes while preventing leakage of the fluid from the system.

[0003] For certain fluid systems, it is important to prevent the infiltration or escape of the fluid in its gaseous state. One such fluid system, for example, is a fuel fill system in a motor vehicle, through which fuel is delivered to a storage tank. The escape of fuel vapor from fuel fill systems can be hazardous to the environment, and as a result, the U.S. Environmental Protection Agency prescribes limits to the amount of fuel vapor that may escape from the filler pipe. Another example of such a fluid system, is a radiant heating system found in homes and businesses. Often times hoses in a radiant heating system supply water or other heating fluid to heat exchangers located in floors, ceilings, roofs, and concrete or asphalt slabs. The hoses may be embedded in the surfaces to be heated. A significant problem with such hoses is that they are subject to gas infiltration and exfiltration. Oxygen is particularly troublesome because it is able to penetrate all known plastic films, at least to some small degree. Once oxygen has gained entry to such a heating system, it deteriorates the hoses and corrodes the pumping system. These are only a few examples of systems requiring gas impermeable tube joints and there are myriad fluid systems for which the prevention of the infiltration or escape of gas is critical to operation.

[0004] One way to reduce the infiltration or escape of gas in a fluid system is through the use of tubes having metallic barrier layers. For example, U.S. Pat. No. 6,074,717 to Little et al., describes a flexible hose that has an aluminum barrier layer for preventing ingestion of oxygen and other gasses. The aluminum barrier layer is securely bonded between two adhesion tubes which are vulcanized in place against the aluminum. The resulting tube is flexible and substantially gas impermeable. While such tubing is sufficiently gas impermeable to prevent the permeation of gas along the tube, the joints between tubes and components remain an area where the infiltration or escape of gas can occur.

[0005] Typically, the joints in such fluid systems are formed by sliding the tube over a projection on the component, and securing the tube in-place by way of a barb formed on the projection and/or a mechanical fastener (e.g., a hose clamp). Problematically, this method may allow for the permeation of gas through the joint connection. If the tube has a metallic layer, the permeation may be worse because of the relative inflexibility of the tube material and the resulting inability of the tube to form a tight fit with the projection.

[0006] Thus, there is a need for gas impermeable tube joints and methods for forming gas impermeable tube joints in fluid systems.

BRIEF SUMMARY OF THE INVENTION

[0007] The above-described and other drawbacks and deficiencies of the prior art are overcome or alleviated by a method of forming a gas impermeable joint in a fluid system. The method includes: providing a tube having a metallic barrier layer disposed between an inner plastic layer and an outer plastic layer; forcing at least one of the inner plastic layer and the outer plastic layer into contact with a plastic surface of a component; and welding the at least one of the inner plastic layer and the outer plastic layer with the plastic surface to form the gas impermeable joint. The welding may include: spin welding, hot plate welding, vibration welding, and ultrasonic welding.

[0008] In one embodiment, the component includes a recess disposed therein, the recess being dimensioned to receive an end of the tube, and the plastic surface of the component being formed within the recess to contact at least one of the inner plastic layer and the outer plastic layer. In another embodiment, the component includes a cylindrical protrusion, the plastic surface being formed on either the outer circumference or the inner circumference of the cylindrical protrusion.

[0009] The thickness of the inner plastic layer and the outer plastic layer before welding is preferably greater than about 0.6 millimeters, and more preferably greater than about 1 millimeter. The thickness of the inner plastic layer and the outer plastic layer before welding may be between about 0.6 millimeters and 1.5 millimeters, and more preferably between about 1 millimeter and 1.2 millimeters.

[0010] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings wherein like elements are numbered alike, and in which:

[0012] **FIG. 1** is a partial cross-sectional view of a portion of a fluid system including a gas impermeable tube joint in accordance with an embodiment of the present invention;

[0013] **FIG. 2** is a perspective view of a tube having a metallic barrier layer;

[0014] **FIG. 3** is a partial cross-sectional view of an end of the tube separated from the component before welding;

[0015] **FIG. 4** is a partial cross-sectional view of an end of the tube forced onto the component before welding;

[0016] **FIG. 5** is a flow chart depicting a method of forming the gas impermeable joint;

[0017] **FIG. 6** is a flow chart depicting an alternative method of forming the gas impermeable joint;

[0018] **FIG. 7** is a cross-sectional view of the end of the tube separated from the component showing various dimensions of the tube and the component;

[0019] **FIG. 8** is a partial cross-sectional view of an end of the tube forced onto the component before welding in accordance with a first embodiment of the invention;

[0020] **FIG. 9** is a partial cross-sectional view of an end of the tube forced onto the component before welding in accordance with a second embodiment of the invention;

[0021] **FIG. 10** is a partial cross-sectional view of an end of the tube forced onto the component before welding in accordance with a third embodiment of the invention;

[0022] **FIG. 11** is a partial cross-sectional view of an end of the tube forced onto the component before welding in accordance with a fourth embodiment of the invention;

[0023] **FIG. 12** is a cross-sectional view of a first alternative arrangement of the tube and component before welding;

[0024] **FIG. 13** is a cross-sectional view of a second alternative arrangement of the tube and component before welding;

[0025] **FIG. 14** is a cross-sectional view of a third alternative arrangement of the tube and component before welding;

[0026] **FIG. 15** is a cross-sectional view of a fourth alternative arrangement of the tube and component before welding;

[0027] **FIG. 16** is a cross-sectional view of a fifth alternative arrangement of the tube and component before welding; and

[0028] **FIG. 17** is a cross-sectional view of a sixth alternative arrangement of the tube and component before welding.

DETAILED DESCRIPTION

[0029] **FIG. 1** is a partial cross-sectional view of a portion of a fluid system **10** including a gas impermeable tube joint **12**. The fluid system **10** includes a tube **14** having an end coupled to a component **16** via the joint **12**, which allows fluid to be communicated between the tube **14** and the component **16** as indicated by arrow **17**. The component **16** may be any component in the fluid system **10** such as, for example a pump, funnel, tank, heat exchanger, valve, tube-to-tube coupling, flange, quick disconnect coupling, filter, and the like. For example, component **16** may be a funnel used within a fuel fill system in a motor vehicle, as described in commonly owned U.S. patent application Ser. No. ______ to Swane (Attorney Docket No. 02-13), filed concurrently herewith and entitled "Fuel Fill System", which is incorporated by reference herein in its entirety. The component **16** may also be another tube. It will be appreciated that the fluid system **10** may include any number of joints **12** connecting tubes **14** to components **16**.

[0030] Referring to **FIGS. 1 and 2**, the tube **14** is formed by a metallic barrier layer **18** disposed between an inner plastic layer **20** and an outer plastic layer **22**. The metallic barrier layer **18** extends along the entire length of the tube **14**. The joint **12** is formed by welding at least one of the inner plastic layer **20** and the outer plastic layer **22** to a plastic surface formed on the component **16**. As will be discussed in further detail hereinafter, the weld may be performed using spin welding, hot plate welding, vibration welding, ultrasonic welding, and the like. Advantageously, because the weld is formed with the outer and/or inner plastic layers **20, 22** of the tube **14**, the metallic barrier layer **18** extends substantially to the component **16**, thus improving the gas impermeability of the joint **12** between the tube **14** and the component **16**. The joint **12** is also lightweight and corrosion resistant.

[0031] The inner and outer plastic layers **20, 22** of the tube **14** may be formed from any thermoplastic material. For example, the inner and outer plastic layers **20, 22** may be formed from polyethylene, polypropylene, acetals, nylons, fluoropolymers, rubbers, and combinations, composites, or multiple layers of any of the foregoing. The metallic layer **18** may be formed from any metal in sufficient quantity to prevent permeation of gas into or out of the system **10**. Preferably, the metallic layer **14** is formed from a malleable metal such as aluminum, steel, tin, copper, brass, or combinations or alloys formed from one or more of the foregoing.

[0032] One example of a tube **14** that may be used with the present invention is described in U.S. Pat. No. 6,074,717, which is incorporated by reference herein in its entirety. The '717 patent describes a tube wherein the inner plastic layer **20** is formed by a first tube, the metallic barrier **18** is formed by an aluminum foil bonded exteriorly about the first tube, and the outer plastic layer **22** is formed by a second tube bonded exteriorly about the aluminum foil. The aluminum foil may be between about 0.0005 and 0.030 inches thick. The first tube and the second tube (i.e., inner and outer plastic layers **20, 22**) each comprise about 20 percent by weight of ethylene propylene diene polymethylene (EPDM) rubber and from about 2 to 9 percent by weight of polybutadiene-maleic anhydride adduct resin. The formulation preferably includes about 2-8 percent by weight of active peroxide as a curing agent. The peroxide cure is performed in any conventional manner at a temperature of about 325° F., and provides a strong bond between the aluminum metallic barrier layer **18** and the inner and outer layers **20, 22**. Suitable conventional black and non-black filler ingredients, and paraffinic or naphthenic plasticizers may be added to the mixture as desired. In addition, one or more reinforcement layers (not shown) may be added to the outer surface of the outer plastic layer **22**. The reinforcement layer may be fabricated from, for example, rayon, polyester, polyvinyl acetate, wire, aramid, or any other suitable material. The reinforcement layer may also include a cover selected from any of numerous thermosetting elastomeric compounds such as natural rubber, styrene butadiene, polychloroprene, acrylonitrile butadiene, chlorosulfonated monomer, or chlorinated polyehtelene. Where the outer plastic layer **22** is used to form the weld, a portion of the reinforcement layer will be removed to expose the outer plastic layer **22** for welding.

[0033] Referring to **FIG. 3**, the tube **14** and component **16** are shown separated, before welding. In the embodiment shown, the component **16** includes a generally cylindrical inner protrusion **26** and a coaxial, generally cylindrical outer protrusion **28**. An annular recess **30** is formed between an outer surface **32** of the inner protrusion **26** and an inner surface **34** of the outer protrusion **28**. The annular recess **30** is dimensioned to receive an end of the tube **14**, as shown in **FIG. 4**. The inner and outer surfaces **32, 34** may be angled relative to each other such that the end of the tube **14** becomes wedged within the recess **30** when forced therein. A relief cut **36** may be provided at the inlet end of the annular recess **30** to ease insertion of the end of the tube **14** into the recess **30**.

[**0034**] The component **16** may be molded from a plastic material such that one or more of the surfaces **32, 34** form the one or more plastic surfaces to which the tube is welded. Alternatively, the plastic surfaces **32** and/or **34** may be formed by inserts secured to the component **16**.

[**0035**] **FIG. 5** is a flow chart depicting a method **50** of forming the gas impermeable joint **12** of **FIG. 1**. Referring to **FIGS. 1-5**, the method **50** can be described. With the tube **14** separated from the component **16**, as shown in **FIG. 3**, the tube **14** is secured in a fixture **38** with the end of the tube **14** facing the component **16** (block **52** of method **50**). The fixture **38** may be a chuck disposed on the outside of the tube **14**, a chuck disposed inside the tube **14**, or a combination of both. Preferably, the inner and outer protrusions **26, 28** of the component **16** are sufficiently rigid such that they need not be held by a chuck. However, where the component is a tube or where the inner and outer protrusions **26, 28** are not rigid, the inner and outer protrusions **26, 28** may also be secured by a separate chuck. Next, the tube **14** is forced onto the component **16** such that at least one of the inner plastic layer **20** and the outer plastic layer **22** come into contact with a plastic surface **32** and/or **34** of the article **16** (block **54**). In the embodiment shown, the outer plastic layer **22** contacts the inner plastic surface **34** and the inner plastic layer **20** contacts the outer plastic surface **32**. The inner and/or outer plastic layers **20, 22** are then moved relative to the plastic surface(s) **32, 34** to create frictional heat (block **56**). The relative motion may be created by spinning, vibration, ultrasound, or any other convenient method which results in melting of the inner and/or outer plastic layers **20, 22** and the plastic surface(s) **32, 34**. After the layers **20, 22** and surfaces **32, 34** have melted, the relative motion is stopped and the tube **14** and component **16** are held stationary to allow the melted plastics to bond and form a weld (block **58**). The joined tube **14** and component **16** are then removed from the fixture **38** (block **60**).

[**0036**] **FIG. 6** is a flow chart depicting an alternative method **70** of forming the gas impermeable joint **12**. Unlike the method **50** of **FIG. 5**, which uses a frictional method of generating heat, the method **70** of **FIG. 6** uses an external source of heat to melt the plastic. In the method **70** of **FIG. 6**, an external source of heat (e.g., a hot plate) is applied to the one or more plastic surface **32** and/or **34** on the article **16** and to the inner and/or outer plastic layers **20, 22** to melt each of these surfaces (block **72** of method **70**). The external source of heat is then removed (block **74**) and the melted inner and/or outer layers **20, 22** are forced against the melted plastic surface(s) **32, 34** of the component **16**. The component **16** and tube **14** are held stationary to allow the melted plastics to bond and form a weld (block **78**), after which the tube **14** and component **16** are removed from the fixture **38** (block **80**). The method **70** of **FIG. 6** may be used instead of the method **50** of **FIG. 5**, for example, where the plastic material used in the inner and/or outer plastic layers **20, 22** has a substantially different melting temperature than that of the plastic surfaces **32, 34** on the article **16**. The method **50** of **FIG. 5** requires that the melting temperature of the materials used in the inner and/or outer plastic layers **20, 22** and the plastic surfaces **32, 34** have a melting temperature that is sufficiently the same (e.g., within 20° F.) so that all of the materials forming the weld are melted by the friction welding process.

[**0037**] **FIG. 7** is a cross-sectional view of the end of the tube **14** separated from the component **16** showing various dimensions of the tube **14** and the component **16**. The outside diameter (O.D.) and inside diameter (I.D.) of the tube **14** are selected based on the particular application of the tube **14** and component **16**. It has been determined that to provide sufficient material to form a weld, the inner and outer plastic layers **20, 22** forming the weld preferably each have a thickness "t" greater than about 0.6 millimeters (about 0.024 inches), and more preferably greater than about 1 millimeter (about 0.039 inches). The maximum thickness "t" of the one or more plastic layers **20, 22** forming the weld is determined based on the requirements of the system **10** (e.g., pressure requirements, temperature requirements, and the like). However, as a practical limit to provide for the flexibility of tube **14**, each plastic layer **20** and/or **22** forming the weld may have a thickness "t" less than about 3 millimeters (about 0.12 inches).

[**0038**] The recess **30** has a depth "d", which is the effective depth of the weld. As a result, the depth "d" of the recess may be used to control the strength of the joint **12** (**FIG. 1**) as needed to meet system **10** requirements.

[**0039**] The width "w" of the recess, as well as the outside diameter of the inner protrusion **26** and the inside diameter of the outer protrusion **28**, may be selected in relation to the dimensions of the tube **14** to determine which of the surfaces **32, 34** and layers **20, 22** form the weld. For example, these various dimensions may be selected such that the inner plastic layer **20** contacts the outer surface **32** of the inner protrusion **26**, and the outer plastic layer **22** contacts the inner surface **34** of the outer protrusion **28**, as shown in **FIG. 8**. As a result, both the inner and outer plastic layers **20, 22** will form the weld with the component **16**. In one example of this embodiment, the depth "d" of the recess may be about four times the total thickness "T" of the tube, with the width "w" of the recess being about 0.01 inch less than the total thickness "T". Preferably, the surfaces **32** and **34** are angled relative to each other to provide an included angle of about 1° to about 3°. Where the surfaces **32** and **34** are angled, the width "w" represents the minimum width of the channel.

[**0040**] **FIG. 9** depicts an embodiment where the weld is formed only between the outer plastic layer **22** and the inner surface **34** of the outer protrusion **28**. In this embodiment, the inner protrusion **26** provides internal support to the tube **14**, but is not welded to the tube **14**. It is contemplated that the component **16** may be formed without the inner protrusion **26**, such that the recess **30** is formed only by the inner surface **34**.

[**0041**] **FIG. 10** depicts an embodiment where the weld is only formed between the inner plastic layer **20** and the outer surface **32** of the inner protrusion **26**. In this embodiment, the outer protrusion **28** provides external support to the tube **14**, but is not welded to the tube **14**. It is contemplated that the component **16** may be formed without the outer protrusion **28**, such that the recess **30** is formed only by the outer surface **32**.

[0042] **FIG. 11** depicts another embodiment where the weld is formed as a butt weld between the tube **14** and the component **16**. In this embodiment, the plastic surface is formed on a face **80** of the component **16**, and the weld is formed between both the inner and outer layers **20**, **22** and the face **80**.

[0043] **FIGS. 12-17** depict various arrangements of the tube **14** and component **16** that may be used in forming the joint **12** of the present invention. These arrangements have been found to be especially well suited for use where the tube **14** and component **16** are joined by spin welding. **FIGS. 12-17** depict the tube **14** and component **16** just before welding, when the tube **14** is forced against the component **16**. In each of **FIGS. 12-14**, the weld is formed on the inner and outer layers **20** and **22** of the tube **14**. Unlike the straight-walled tube **14** used in the embodiment described with reference to **FIGS. 7 and 8**, the end of the tube **14** used in the arrangements of **FIGS. 12-14** is shaped to have an included angle "F" between the contact surface "C" of the inner layer **20** and the contact surface "D" of the outer layer **22**. The included angle "F" is preferably between about 20° to about 40°, and more preferably between about 25° to 30°. The arrangements of **FIGS. 12-14** are also shown to include various shoulders **82** disposed on the tube **14**.

[0044] In **FIGS. 12-14**, the total thickness of the tube **14** is indicated at "T", and the welded surface is indicated by the sum of the contact surface on the inner layer **20**, indicated at "C", and the contact surface on the outer layer **22**, indicated at "D". Preferably, the welded surface (C+D) is equal to about 1.5×T to about 3.5×T, and more preferably between about 1×T to 2×T. As discussed above, the welded surface may be increased or decreased depending on the required strength of the weld, among other variables. The depth of the weld, as indicated at "A", is preferably between about 0.3×T to about 10.0×T, and more preferably between about 0.5×T to about 0.8×T.

[0045] Each of the arrangements in **FIGS. 12-14** includes a shoulder **82** protruding radially outward around the circumference of the outer plastic layer **22** of the tube **14**. With the tube **14** and component **16** forced together prior to welding, the shoulder **82** is preferably separated from the outer protrusion **28** by a distance "E", which is preferably equal to the depth of the weld "A" plus about 0.01 inch. The shoulder **82** prevents the tube **14** from extending within the component **16** substantially beyond the depth of the weld, "A".

[0046] The shoulder **82** may be of various shapes. For example, the shoulder **82** and the outer protrusion **28** may include opposing recesses **84** formed therein, as shown in **FIGS. 12 and 13**, for receiving excess material formed during the weld. **FIG. 14** depicts an arrangement where the outer protrusion **28** includes a lip **86** extending outside the opposing shoulder **82** for aiding in the alignment of the tube **14** and component **16**. As shown in **FIGS. 12-14**, the shoulder **82** and outer protrusion **28** may be supported by ribs **88**.

[0047] **FIGS. 15-17** depict arrangements where the weld is formed along only one of the inner and outer layers **20** and **22** of a straight-walled tube **14**. While **FIGS. 15-17** depict the weld as being formed on the outer layer **22**, it will be appreciated that the weld may alternatively be formed on the inner layer **20**. **FIG. 15** depicts an arrangement where the outer layer **20** is configured with a first shoulder **90** recessed from a distal end of the tube **14** by a distance equal to the thickness "T" of the tube **14**. The distal end of the tube **14** is preferably separated from the end of the recess by a distance equal to the thickness "T" of the tube **14**, and is preferably offset from the outer protrusion **28** by an offset distance "G" of about 0.002 inches. The distal end of the tube **14** aids in the alignment of the tube **14** and component **16** during the welding process. The depth of the weld, as indicated at "B", is the distance between the first shoulder **90** and a shoulder **82** formed on the outer layer **22** of the tube **14**. The depth of the weld "B" may be between about 1×T to about 2×T, and more preferably about 1.5 T, and may be increased or decreased depending on the required strength of the weld. The interference between the tube **14** and the component **16**, indicated at "i", may be between about 0.005 inches to about 0.025 inches, and preferably between about 0.01 inches to about 0.02 inches. The shoulder **82** may be supported by ribs **88**.

[0048] **FIG. 16** depicts an arrangement where the outer protrusion **28** is configured with a first shoulder **92** disposed at a distance from the bottom surface of the channel **30** to establish the depth of the weld "B". The depth of the weld "B" may be between about 1×T to about 2×T, and more preferably about 1.5 T, and may be increased or decreased depending on the required strength of the weld. The first shoulder **92** is preferably offset from a distal end of the outer protrusion **28** by a distance equal to the thickness "T" of the tube **14**, thus allowing the outer protrusion **28** to aid in the alignment of the tube **14** and component **16** during the welding process. The interference between the tube **14** and the component **16**, indicated at "i", may be between about 0.005 inches to about 0.025 inches, and preferably between about 0.01 inches to about 0.02 inches. The inner protrusion **26** is offset from the inner layer of the tube.

[0049] **FIG. 17** depicts an arrangement wherein the inner surface **34** of the outer protrusion **28** is angled by about 20 degrees relative to the outer layer **22**. The angled inner surface **34** of the outer protrusion **28** has a height that establishes the depth of the weld "B". The depth of the weld "B" may be between about 1×T to about 2×T, and more preferably about 1.5×T, and may be increased or decreased depending on the required strength of the weld. The angled inner surface **34** is preferably offset from the distal end of the outer protrusion **28** by a distance "L", which may be between about 0.020 inches to about 0.040 inches, thus allowing the distal end of the outer protrusion **28** to aid in the alignment of the tube **14** and component **16** during the welding process.

[0050] The present invention uses the metallic barrier layer **18** of a tube **14** to improve the gas impermeability of the joint **12** between the tube **14** and a component **16**. Advantageously, because the weld is formed with the outer and/or inner plastic layers **20, 22** of the tube **14**, the metallic barrier layer **18** extends substantially to the component **16**, thus improving the gas impermeability of the joint **12** between the tube **14** and the component **16**. The joint **12** is also lightweight and corrosion resistant.

[0051] A number of embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

1. A method of forming a gas impermeable joint in a fuel fill system, the method comprising:

providing a tube having a metallic barrier layer disposed between an inner plastic layer and an outer plastic layer, the tube and the layers each having a circumference, the outer plastic layer including a shoulder protruding radially outward around at least a portion of its circumference;

forcing at least one of the inner plastic layer and the outer plastic layer into contact with a plastic surface of a funnel portion of the fuel fill system, the funnel portion including an outer protrusion portion surrounding a cylindrical recess, the recess being dimensioned to receive an end of the tube, the plastic surface of the funnel portion being formed within the recess to contact the at least one of the inner plastic layer and the outer plastic layer, the plastic surface of the funnel portion also being formed on the outer protrusion portion to contact the shoulder of the outer plastic layer;

causing at least one of the inner plastic layer and the outer plastic layer to contact the plastic surface formed within the recess;

causing the shoulder of the outer plastic layer to contact the plastic surface formed on the outer protrusion portion, and

welding at least one of the at least one of the inner plastic layer and the outer plastic layer and the shoulder of the outer plastic layer with the plastic surface to form the gas impermeable joint.

2. (canceled)

3. (canceled)

4. The method of claim 1, wherein the plastic surface is formed on an outer circumference of the outer protrusion.

5. The method of claim 1, the plastic surface is formed on an inner circumference of the outer protrusion.

6. The method of claim 1, wherein the thickness of the at least one of the inner plastic layer and the outer plastic layer before welding is greater than about 0.6 millimeters.

7. The method of claim 6, wherein the thickness of the at least one of the inner plastic layer and the outer plastic layer before welding is greater than about 1 millimeter.

8. The method of claim 1, wherein the thickness of the at least one of the inner plastic layer and the outer plastic layer before welding is between about 0.6 millimeters to about 0.3 millimeters.

9. The method of claim 1, wherein the thickness of the at least one of the inner plastic layer and the outer plastic layer before welding is between about 1 millimeters to about 3 millimeters,

10. The method of claim 1, wherein the inner plastic layer is formed by a first tube, the metallic barrier is formed by an aluminum foil bonded exteriorly about the first tube, and the outer plastic layer is formed by a second tube bonded exteriorly about the aluminum foil; the first tube and the second tube each comprising about 20 percent by weight of EPDM rubber and from about 2 to 9 percent by weight of polybutadiene-maleic anhydride adduct resin.

11. The method of claim 1, wherein the tube includes a reinforcement layer bonded exteriorly about the outer plastic layer.

12. A fuel fill system comprising:

a tube having a metallic barrier layer disposed between an inner plastic layer and an outer plastic layer, the tube and the layers each having a circumference, the outer plastic layer including a shoulder protruding radially outward around at least a portion of its circumference; and

a funnel portion in fluid communication with the tube via a joint, the funnel portion including an outer protrusion portion surrounding a cylindrical recess, the recess being dimensioned to receive an end of the tube, a plastic surface of the funnel portion being formed within the recess to contact the at least one of the inner plastic layer and the outer plastic layer, the plastic surface of the funnel portion also being formed on the outer protrusion portion to contact the shoulder of the outer plastic layer, wherein at least one of the inner plastic layer and the outer plastic layer includes a spin weld between it and the plastic surface of the funnel portion to form the joint.

13. (canceled)

14. (canceled)

15. The system of claim 12, wherein the plastic surface is formed on an outer circumference of the outer protrusion.

16. The system of claim 12, wherein the plastic surface is formed on an inner circumference of the outer protrusion.

17. The system of claim 12, wherein the thickness of the at least one of the inner plastic layer and the outer plastic layer before welding is greater than about 0.6 millimeters.

18. The system of claim 17, wherein the thickness of the at least one of the inner plastic layer and the outer plastic layer before welding is greater than about 1 millimeter.

19. The system of claim 12, wherein the thickness of the at least one of the inner plastic layer and the outer plastic layer before welding is between about 0.6 millimeters to about 3 millimeters.

20. The system of claim 19, wherein the thickness of the at least one of the inner plastic layer and the outer plastic layer before welding is between about 1 millimeters to about 3 millimeters.

21. The system of claim 12, wherein the inner plastic layer is formed by a first tube, the metallic barrier is formed by an aluminum foil bonded exteriorly about the first tube, and the outer plastic layer is formed by a second tube bonded exteriorly about the aluminum foil; the first tube and the second tube each comprising about 20 percent by weight of EPDM rubber and from about 2 to 9 percent by weight of polybutadiene-maleic anhydride adduct resin.

22. The system of claim 12, wherein the tube includes a reinforcement layer bonded exteriorly about the outer plastic layer.

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