

WELDING APPARATUS AND METHOD FOR WELDING TUBULAR END PORTIONSBACKGROUND OF THE INVENTION

This invention relates to the joining of thermoplastic tubular parts. More particularly, it relates to a method of welding pairs of tubular end portions without forming a bead at the weld. The method is particularly suitable for weld melt processable fluoropolymers such as perfluoroalkoxy (PFA).

Various means have been known for welding together the ends of thermoplastic pipes, see for example U.S. Patent No. 4,929,293 to Oscar which utilizes the placement of an infrared heating plate in between and confronting the tubular end pieces to be joined. The infrared heating plate is removed and the tube joints are then engaged together to create the weld. Although such a procedure provides a high integrity weld on melt processable fluoropolymers, such a weld may leave a deformation or a bead on the inner and/or outer surfaces of the joined tubular end portions.

In many applications it is unacceptable to have any deformations in the joined tube particularly on the interior surface. In sanitary systems used in the food processing and pharmaceutical industries the standards of the U.S. Code of Regulations, 7 C.F.R. §58.128 require a conduit be smooth, permit laminar flow of fluids and be free of discontinuities that could trap particular matter.

Traditionally, stainless steel tubing and pipe have been used in sanitary systems. However, due to corrosion, expense and other problems, plastic pipe and tubing are now being used in such systems.

Welding apparatuses have been developed to accomplish welding thermoplastic pipe or tubing without any internal beads. See for example Patent No. 5,484,506 to DuPont et al. and Patent No. 5,037,500 to Hilpert both of which disclose the use of radially expandable internal mandrels to allow engagement of the interior surface of the tubular end portions to be joined and then allow the mandrel to be radially retracted and removed from the tubing. This type of removable mandrel has a difficulty in that it requires a feed line extending through to one end of the tubing. Where long sections of tubing are being joined or where valves or other fixtures are being joined there may not be a sufficient exit point for removing the mandrel. Attempts have been made to utilize frangible internal mandrels, see U.S. Patent No. 2,963,394 to Wilkenson. However, these types of devices have unacceptable residue and can damage the internal surface of the tubing when such devices are broken for removal.

Moreover, these welding methods utilize heating of the tubular end portions exclusively by way of conduction. In such heating means it is difficult to focus the heat at the tubular end portion abutting faces. Additionally, such heating by exclusively conduction generates a substantial amount of heat in the welding tool which must be dissipated and which delays the tool from being removed from the tubes joined to perform the next weld. This causes extended cycle time.

SUMMARY OF THE INVENTION

An apparatus for joining a first and second components utilizes a sleeve substantially transparent to infrared radiation, extending around the outer surface of abutted tubular end portions of the components and a mandrel positioned interior of the tubular end portions. An infrared heater provides radiant heat through the sleeve to melt and thus join the abutted tubular

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end portions. The abutted tubular ends may be rotated with respect to the infrared heater to provide uniform melting and bonding of the joint. The device may be configured as a portable unit with a separable weld head connected to a control unit by way of a cable containing electric lines for the heater element, sensor lines for thermocouples in the weld head, and a cooling media line to cool the weld head. Thus, a separate air compressor or fluid pump may be placed in the separate control unit remote from the weld head to expedite the cooling of the weld head and reduce cycling times. The device may also be configured as a bench top unit. Either configuration may be used to join sections of straight pipe or to join fittings to pipe or tubing or to join coils of tubing to other tubing sections or fittings.

Means may be provided to provided axial compression to the abutted tubular end portions. One aspect of the invention includes compression means comprising a rod extending through the abutted tubular end portions with two engagement portions, one engaging each component and providing a compression force to same. This facilitates rotation of the components for even heating by the infrared source.

An advantage and feature of the invention is that the use of the transparent sleeve allows focused radiant energy at the abutted end portions to accomplish the weld with minimal melt of the thermoplastic material. Additionally, the focus of the radiant heat minimizes the heating of the weld head thus minimizing cycle times. Concave mirrors or lenses can focus the infrared radiation for optimal welding performance.

The sleeve engaging the exterior surface of the tubing may in alternate embodiments be formed of various quartz materials,

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glass, ceramic materials, or even sapphire. These non-metallic materials provide distinctive characteristics from the traditional metallic sleeves, for example, in allowing expedited cool down periods after the welding operation.

The transparent sleeve may be split longitudinally for insertion and removal of the tubular end portions or may be a single integral piece which is assembled onto the two tubular end portions to join before they are abutted. After welding the sleeve may be slid off if the components outside diameter permits, may be fractured and removed, or may be left on the joined components.

The mandrel may be of known designs that are radially expandable, see for example U.S. Patent No. 5,037,500 to Bruno Hilbert, may be generally rigid and non-expandable formed of polytetrafluoroethylene (PTFE), or other inert materials, or in one aspect of the invention may be formed of a dissolvable material such as sodium chloride. A fluid such as water may be added to the interior of the tubular end portions to dissolve and remove the dissolvable mandrel after the weld.

The dissolvable mandrel may be partially or totally dissolvable. Additional components or additives that are not dissolvable may be added to alter its heat transfer characteristics, such as its infrared absorption and reflectivity characteristics. Additives may include solid metal, ceramic or plastic components or materials such as carbon. The core may, to a significant extent, be heated by the radiant infrared heat and then further heat the tubing end portions to be joined by conduction.

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An additional advantage and feature of the invention is that the mandrel may be dissolved into a solution and thus may be removed in particular installations which would preclude the use of a mechanically inflatable mandrel.

An additional advantage and feature of the invention is that the dissolvable mandrel is food safe and does not create unacceptable containments within the sanitary system.

An additional advantage and feature of the invention is the use of radiant energy is more efficient than the use of heating primarily by way of conduction. The infrared radiation may be focused thru lenses or may be reflected and/or focused by mirrors.

An additional advantage and feature of the invention is that the use of the radiant heat allows lighter and more compact weld heads facilitating portable, non-bench top applications. Particularly in the portable configuration, the weld head is lighter in weight facilitating the portability feature. Additionally, the less mass in the weld head allows for quicker and more efficient cooling.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of one embodiment of the invention configured as a portable welding apparatus.

FIG. 2 is a side elevational view of a bench top configuration of the invention.

FIG. 3 is a cross-sectional view of a weld head illustrating the invention.

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FIG. 4 is a perspective view of a portable weld head apparatus.

FIG. 5 is a end elevational view of the portable weld head of FIG. 4.

FIG. 6 is a cross-sectional view of the portable weld head apparatus taken at line 6-6 of FIG. 5.

FIG. 7 is a perspective view of a ceramic weld head insert applicable to the device shown in FIGS. 4, 5, and 6.

FIG. 8 is a end view of a sleeve half.

FIG. 9 is a top plan view of the sleeve half shown in FIG. 8.

FIG. 10 is a block diagram of the illustrating portions of the control unit.

FIG. 11 is a side elevational view of a dissolvable mandrel with inserts.

FIG. 12 is an elevational view of operation of one aspect the invention.

FIG. 13 is an elevational view of operation of one aspect the invention.

FIG. 14 is an elevational view of operation of one aspect the invention.

FIG. 15 is an elevational view of operation of one aspect the invention.

FIG. 16 is an elevational view of operation of one aspect the invention.

FIG. 17 is an elevational view of operation of one aspect the invention.

FIG. 18 is an elevational view of operation of one aspect the invention.

FIG. 19 is a perspective view of a bench-top embodiment of the invention.

FIG. 20 is a cross-sectional view of the embodiment of FIG. 19.

FIG. 21 is a perspective view of a further embodiment of the invention.

FIG. 22 is a cross-sectional view of the embodiment of FIG. 21.

FIG. 23 is a perspective view of a rod assembly according to the invention with a section of tubing, a sanitary fitting, and a sleeve on the rod assembly.

FIG. 24 is a cross-sectional view thru the rod assembly of FIG. 23.

FIG. 25 is a cross-sectional view of an embodiment of the invention at the tubular end portions utilizing a lens.

FIG. 26 is a cross-sectional view of an embodiment at the tubular end portions utilizing a lens.

FIG. 27 is a cross-sectional view of an embodiment of the invention.

FIG. 28 is a cross-sectional view taken at line 28-28 of FIG. 22.

FIG. 29 is a cross-sectional view similar to FIG. 28 with a drive wheel to rotate the infrared heating sources.

DETAILED SPECIFICATION

Referring to FIG. 1 a portable thermoplastic tubing welding apparatus is depicted and is generally designated with the numeral 20. Said portable welding apparatus is comprised principally of a hand-held weld head 22, a control unit 24, and a connecting cable 26. Referring to FIG. 2 an alternate bench top thermoplastic tubing welding apparatus is shown and is designated with the numeral 30. The bench top welding apparatus 30 has a base portion 32 which may contain the control unit. The bench top configuration may be utilized for larger tube sizes and where it is not necessary to perform the weld in remote locations. The bench top unit of FIG. 2 shows a pair of tubular end portions 38, 40 which are to be welded together. The tubular end portions may be part of a piece of tubing or pipe or may be part of a fitting, reducer, valve or other piece of equipment to be connected. Both the portable welding apparatus 20 and the bench top configuration 30 utilize an exterior sleeve which encompasses the outer circumferential surface 44 of the tubular end portions. Both have separable portions 48 and 50 which allow access to the receiving portion 52 of the weld heads. The separable portions 48, 50 may be suitably foldable together by way of a hinge or may

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be removable from one another. A securing means 60 such as a latch shown in FIG. 1 may be utilized to secure the separable portions 48 and 50 together.

Referring specifically to FIG. 2 the bench top apparatus 30 has sleeve halves 64, 66 supported by the weld head 70 which is attached to the base portion by support 72 and is further supported by auxiliary support members 76, 78 with respect to support members 80, 82 attached to the base portion.

The sections of tubing or pipe 36 to be joined are further supported away from the weld head by way of support members 83, 84. These support members include tubular gripping members 86, 88 which extend around and clamp to the outer surface 44 of the tube sections 36 by way of the adjustment screws 90. The support members 96, 98 are adjustable axially with respect to the tubular end portions on the base portion 32 by way of the cranks 94. The support members 83, 84 grip the tube sections 36 only at the gripping members 86, 88 and utilize a bias means 102 configured as coiled springs to provide an axially compressive force to the tubular end portions 38, 40.

Referring to FIG. 3 a cross-sectional view of a weld head similar to what may be utilized in the bench top apparatus of FIG. 2 is shown. This weld head is comprised of a pair of separable weld head housing portions 110, 112 which extend around the tubular end portions 38 and 40. The weld head housing may be made of aluminum or other suitable material. The configuration of FIG. 3 utilizes a tubular end portion engagement sleeve comprised of a pair of quartz sleeve halves 116 which are illustrated in isolation in the views of FIGS. 8 and 9.

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Referring again to FIG. 3 the weld head 70 includes cooling passages or openings 122 which may be utilized for circulating a cooling media such as air after a weld has been performed. The housing portions 110, 112 as shown in FIG. 3 each have an inner portion 126 and an outer portion 128 secured together by screws 130 or other suitable means. The housing portions each have an intermediary portion 132 which in a preferred embodiment is a machinable ceramic material with the cooling openings 122 formed therein. The intermediary portion also supports an infrared heating element 136 which in FIG. 3 is depicted as a band inset within a recess 138 of the intermediary portion. The recess 138 is suitably configured to provide an air gap between the element and the sleeve and to direct the infrared radiant heat from the element 136 towards the tubular end portions. The radiant heat will, to varying degrees depending on the quartz material, pass through the quartz sleeve surrounding and embracing the tubular end portions.

The tubular end portions each have an end face 142, 144 which abut against each other and at which point the end portions will be joined. Placed within the end portions is a mandrel 150 comprised of a soluble food safe material such as sodium chloride and potassium chloride. The mandrel 150 engages the inner surface 154 of the tubular end portions and is formed with a smooth finish of 10 micron or better. An ideal formulation for the mandrel is a 50% mixture of potassium chloride and sodium chloride compacted together.

The mandrel 150 has an aperture 160 configured as a bore extending axially through the mandrel. The mandrel with the above formulation is stable at temperatures exceeding 900°F but is water soluble such that it may be removed after the weld is formed.

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Referring to FIG. 11, an alternate embodiment of the soluble mandrel 150 is depicted. The embodiment has components 161 added to affect the heat transfer characteristics of the core. Such inserts may be metal or other materials. The components are shown as embedded at the position where the tubing ends will abut. Such inserts may thus provide additional heating of the end faces by reflecting infrared radiation and by conduction. The inserts will typically be segmented to allow easy removal when the core is dissolved. Moreover, it should be noted that the dissolvable mandrel 150 is also suitable for use with conventional metallic sleeve welding apparatus.

The housing portions 110, 112 also have O-ring grooves 166 for supporting the O-ring halves 168 to provide securing of the tubular end portions within the weld head. The support section 72 of the weld head contains a cooling media hose 172 which can carry a media such as air into the weld head to pass through the cooling passages 122 to exit and exhaust 174. Also contained within the support structure 72 is a power line 176 connecting to the infrared heating element 136 and a sensor line 178 connecting to a thermocouple 180 to monitor the temperature of desired locations in the weld head.

Referring to FIGS. 4, 5, 6 and 7 features of the portable weld head are shown. The portable weld head generally has separable portions 48, 50 connected at the hinge 56 and which may be secured with the latch 60. A hand-grip 186 connects to the lower separable portion 50 and has a bore 188 through which the connecting cable, not shown in this view, will extend to the pertinent elements of the weld head.

Referring particular to FIG. 4, this figure does not include the sleeve halves nor the infrared heating element and thus

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disclose the intermediary portions 190, 192 formed of machinable ceramic material. The intermediary portions provide support for the infrared heating element and also may provide locations 196 for desired sensors as well as the passageways 198 for cooling. FIG. 4 also shows O-ring halves 202, 204 for engaging the tubular end portions.

Referring to FIGS. 6 and 7 further detail of a suitable intermediary portion 192 is shown. FIG. 6 shows the infrared heating element 136 in place and mounted on the intermediary portions 190, 192. Note that the infrared heating element 136 is separated from the quartz sleeve halves 116. The connecting wires for the heating elements are not shown in FIGS. 4, 5, 6 or 7.

Referring to FIGS. 8 and 9, the sleeve 116 is shown. The sleeve may be a suitable quartz such as GE quartz grade #214. Note that alternatives to quartz include sapphire and ceramic materials, glass, particularly tempered glass such as Pyrex® (Pyrex is a trademark of the Corning Corporation of first use), and other rigid transparent materials which are resistant to the temperatures encountered. The utilization of a less transparent non-metallic sleeve than the GE quartz #214 allows heating of the sleeve and provides additional conductive heating of the tubular end portions. The materials substantially transparent to infrared radiation still allowing a quick cool down after the weld due to the generally lower heat capacity of these materials compared to conventional stainless steel.

Referring to FIG. 10 a block schematic diagram of the control unit 24 is shown with its principal portions. Generally the control unit has a control processor 210 which is connected to sensors in the weld head 70 by way of an input/output portion

214 and further receives instructions from a key pad or other data input source portion 218 and may display data or information by way of the display portion 220. The control unit 24 also includes a power supply portion 224 to provide power to the heater element in the weld head. Moreover, a coolant supply portion 228 configured as a fan provides coolant media such as forced air or a liquid coolant to the weld head. The cable 26 connecting the controlled unit 24 to the weld head 22 may utilize a suitable connector 230. The control processor may include programmable features to provide and set welding cycle parameters for specific tube sizes and types as well as recording pertinent data such as welders, inspectors, and welding parameters. This is in addition to monitoring and controlling the sensors and functional elements of the weld head and control unit. These may include but are not limited to the control unit display, the weld head temperature sensors, sensors for detecting appropriate closing and latching of the weld head, electronic latching mechanisms at the weld head and the heating element at the weld head. The control unit through the control processor can provide visual or audio indication at the control unit or at the weld head when the weld head has cooled to permit removal of the weld head from the welded tubular end portions. Moreover, the control unit may control electronic locking of the weld head on the tubing such that it is not inadvertently removed before it has reached the proper temperature.

Referring to FIGS. 12-18 the operation of the invention is illustrated. A conventional mechanical tubing expander No. 15071, model S, manufactured by Rigid, 400 Clark Street, Elyria, OH, designated 260 and shown in FIG. 12 may be utilized as necessary on the tubular end portions 38,40 as shown in FIG. 12 to diametrically expand the tubular end faces 142, 144 for insertion of a mandrel 150 as shown in FIG. 13. The tubular end

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portions 38,40 to be joined are axially aligned and the mandrel 150 is inserted therein such that the end faces 144, 142 are abutting as shown in FIG. 14. Typically the tubular end portions will retract after several seconds so the mandrel must be inserted quickly following the expansion. Smooth sleeve halves 64, 66 are placed over the outer circumferential surface 44 of the tubular end portions and secured thereto as shown in FIG. 15 to form a sleeve assembly 270. As shown in FIG. 16, the weld head 22 is then placed over the sleeve halves 64, 66 and engaged therewith. The heater element of the weld assembly is actuated by way of the control unit to provide heat to the juncture 232 of the tubular end portions. Heat is applied at sufficient temperature for a sufficient period of time to accomplish the weld. A compressive axially force as indicated by the arrows labeled 242, 246 may be utilized to facilitate the weld. Significantly, the heating of the juncture should be limited to only accomplish the weld thereby minimizing cycle time and excessive melting of the tubular end portions. The weld head may be removed before the weld is fully cooled particularly if the sleeve assembly 270 is left thereon as shown in FIG. 17. Utilization of the separable sleeve may facilitate shorter cycle times per weld. When the weld is sufficiently cooled the sleeve may then be removed.

As illustrated in FIG. 18, fluid as represented by the arrow 250 may then be flushed into the welded tubular end portions to dissolve and flush out the mandrel 150. Where an expandable mandrel, or otherwise is utilized it is removed at this point in the process.

The apparatus and process disclosed is particularly suited to tubing such as PFA, although the invention is applicable generally to welding thermoplastics.

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Referring to FIGS. 19 and 20, an additional embodiment of the invention is depicted. This embodiment is a bench top configuration and is comprised principally of a support structure 302, a drive motor 303, a weld head 304, a first tubing support 308, including a first bearing 310, and a second tubing support 314, including a second bearing 316, and a third tubular support 320 with a third tubular bearing 322. Each tubing support has a lower half 323 and a separable upper 324 for insertion of the tubing. Engaged within the tubular supports 308, 316, 320 is a first component 326, configured as a section of tubing, which is secured into the first tubing support and the third tubing support and is rotatably engaged therewith. A second component 330, configured as a sanitary fitting, with a second tubular end portion 332. The first component 326 has a first tubular end portion 329. The first tubular end portion and second tubular end portion meet at an abutment 334. The second component 330 is connected to the second tubing support and second bearing by way of the adaptor 338 configured as a drive hub and through a gasket 340. The drive hub 338 rotates in the second bearing 316. The drive hub 338 is engaged with a drive collar 344. Extending through the first component and second component is a rod assembly 348, including a drive shaft portion 350 which connects to the drive motor 303. The rod assembly has a first engagement portion 354 which is comprised of an end piece 356, a spring 358, and a spring nut 360 which is threadably engaged with a threaded portion 362 of the rod 364. A gasket 366 is positioned intermediate the end piece 368 and the first component 326. The rod assembly also includes spherical centering members 370 which may be made of a rigid plastic. These centering members 370 prevent the rod from marring or scratching the smooth inner surface 372 of the first component 326.

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The weld head 304 comprises a lower half 374 and an upper half 376 which are hingedly connected at the pivot 378. A mirrored reflector 382 surrounds on essentially three sides a nickel cadmium wire 384 which is the infrared radiation source 385. Addition shields 388, contain and focus the infrared energy generated by the heating element 384.

As the motor 303 rotates the rod assembly 348 also rotates by way of the coupling 390, the rod 364 is coupled to the drive collar 344 by pin 345 and thus rotates the adaptor 338 and the second component 330. The rod 364 extends through and attaches to the first engagement portion 354. Axially compressive force is applied to the first component and second component by way of tightening the spring nut 360. This type of embodiment is ideal for welding sections of three quarter inch to two inch PFA tubing and fittings.

A drive insert 392 supports a mandrel 394 and extends to engage with the drive hub 338. The mandrel thus engages the interior surface of both the first tubular end portion and the second tubular end portion. Opposite the mandrel with respect to the tubular end portions is a transparent cylindrical one piece sleeve 396. Such a sleeve may be made of tempered glass such as Pyrex®, quartz or other material which is rigid and substantially transparent to infrared radiation.

In the embodiment of FIGS. 19 and 20, the rod assembly provides a desired axial compression to the abutted first and second tubular end portions 329, 332, which are constrained in the annular space between the mandrel 394 and the outer sleeve 396. The rod assembly also provides the additional function of rotating the first component and second component and correspondingly the abutted tubular end portions such that the

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infrared heat generated by the nickel cadmium wire 384 is uniformly dispersed at the abutment. When the weld head is in a closure position the upper mirrored reflector and heater element 384 is in the position as shown and 384.1 by dashed lines. This placement allows a gap intermediate the upper and lower heater elements 384.1, 384.1 such that there is a gap 397 forming a viewing window through which the operator may observe the abutment and the status of the weld taking place during the heating and rotation of the components. The speed of the motor 303 can be controlled as desired by convention motor speed controls.

The axial compression may be controlled by way of the spring nut 360. An ideal range of axial compression of the spring has been found to be 20-24ft-lbs. for 1/2 to 1" PFA tubing. For 1-1/2" and 2" PFA tubing a suitable spring compression is 54ft-lbs. The spring may be configured to provide increasing axial compression with axial deformation. In welding PFA tubular end portions an elongation of the components occurs when heated and melted of a few thousandths of an inch. Good weld results have been obtained when the axial compressive force increases 10% or more during this elongation.

The embodiment of FIGS. 19 and 20 are ideally suited for welding tubing sections to fittings or to components with fittings. As is apparent in the figure, this embodiment utilizes the end of the first and second components that are opposite the tubular end portions for providing the axial compressive force. In an extended length of tubing or in a smaller size tubing which is not rigid enough to support the axial compression, without significant deformation, an additional configuration as discussed below may be used. An appropriate procedure to weld a PFA tubing

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section to a PFA sanitary fitting using the apparatus of FIGS. 19 and 20 is as follows:

1. Clean outside surface, inside surface, and face of the fitting with isopropyl alcohol, lint-free cleanroom cloth and blow-off with clean, dry, compressed air.
2. Push clean fitting onto the PTFE drive hub 338, make sure gasket is in place between fitting and hub.
3. Clean PTFE mandrel with alcohol and blow off with air, inspect for wear and imperfections.
4. Install PTFE mandrel into fitting until it bottoms out on PTFE drive hub.
5. Push the stainless steel drive insert through PTFE mandrel and drive hub until ball-detent snaps into groove in drive insert.
6. Carefully guide clean Pyrex® sleeve over fitting until it bottoms out on shoulder of fitting.
7. Thoroughly blow-off fitting and rod assembly with air.
8. Lay fitting/hub assembly into groove in the second tubing support on right side of welding tool.
9. Clean PFA tubing inside surface, outside surface and face with alcohol, cloth and blow-off with air.
10. Lay tubing into first and third tubing supports on left side of welding tool and carefully slide tube end into Pyrex® sleeve until face to face with fitting.
11. Insert aluminum drive collar into holes in back of PTFE drive hub, rotate and align drive pin hole with hole in stainless steel drive insert.
12. Close and latch all tubing supports over fitting/rod assembly and PFA tubing.

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13. Slowly install appropriate length drive rod into open end of tubing, through stainless steel drive insert and into drive motor. Care must be taken to avoid scratching inside surface of PFA tubing.
14. Install drive pin through drive, collar, stainless steel insert and drive rod.
15. Install gasket onto front of end piece. Install end piece over threaded portion of rod and into open end of PFA tubing. Install spring into recess in back of end piece. Install spring washer into exposed end of spring and run spring nut up to spring washer.
16. Tighten spring nut until back of spring washer is flush with back of end piece.
17. Start rotation of drive motor and verify fitting and tubing are turning freely. Carefully lower upper half of head down, into position.
18. Set variable power supply at appropriate power setting for product size.
19. Turn-on heater until molten material area has penetrated through wall of tubing all the way to the PTFE mandrel, then turn off heater.
20. Continue to rotate assembly while the welded end portions cool, then stop drive motor, and carefully lift upper half of heater head up and out of the way.
21. Loosen spring nut and pull out drive pin.
22. Slowly remove rod and aluminum drive collar. Care must be taken to avoid scratches in inside surface of PFA tubing.
23. Unlatch all tubing supports and remove welded tubing/fitting assembly, place assembly into core pull-out fixture.

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24. When welded assembly has cooled, pull out drive hub, mandrel and stainless steel drive insert assembly from weld joint with suitable mechanical fixture (for example, a push-pull clamp available from De-Sta-Co, No. TC-640).
25. Inspect PTFE mandrel for cleanliness and wear, if necessary, clean with isopropyl alcohol and re-polish with lint-free cloth, or replace with new insert.
26. Remove Pyrex® sleeve and inspect for cleanliness, if necessary, clean and re-polish with cleanser.
27. Inspect weld joint against.

Referring to FIGS. 21, 22, 23, and 24, an additional embodiment is disclosed in which the axial compression of the tubular end portions is again provided by the rod assembly 348, however, the first engagement portion 354 engages with the interior surface 372 of the first component. This permits attachment of a fitting as the second component 330 to a coil 410 of tubing as shown on the motorized coil stand 411. This particular embodiment is particularly appropriate for 1/4" and 1/2" PFA tubing in that such tubing is flexible such that the first engagement point needs to be relatively close to the abutted end portions than in larger diameter tubing. Such PFA tubing sizes can be coils which are very difficult or impossible to weld with.

Referring to FIGS. 23 and 24, details of the rod assembly 348 are shown in conjunction with the first component 326 and the second component 330 and well as the sleeve 396. This embodiment has a first engagement portion 354 comprising a rubber or elastomeric expander 412, a drive nut 414 to compress the rubber expander, a pair of locked nuts 416 and a thrust washer 418. Adjustment of the first engagement portion is accomplished by

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rotation of the rod 364, such as by a suitable tool engaging the end 422 such as conventional knob nuts. This causes the drive nut 414 to move axially along with rod 364 while the locked nuts 416 remain fixed on the rod, compressing the expander which causes a radially expansion of the elastomeric expander 412.

The rod 364 extends through a bore 426 in the mandrel 394 and extends through and engages with the second engagement portion 432 which comprises an end piece 436 and a drive hub, a cushioning and gripping gasket 438, a spring 442, a thrust washer 444, and a wing nut 446 with a threaded bore 448 which engages the at a threaded portion 450.

After the expander 412 is engaged with the inside surface 372 of the first component 326, and with the mandrel, sleeve, and second component 330 in place, the gasket 438 and end piece 436 with the spring 442, washer 444 and wing nut 446, are assembled onto the rod 364. The wing nut is rotated to compress the spring 446 which provides an axial compression to the abutted end portions 329, 332 which are both restrained radially intermediate the mandrel 394 and the sleeve 396. The sleeve inside diameter may be a few thousands of an inch greater than the outside diameter of the tubular end portions to facilitate assembly and to accommodate the tolerances of the outside diameters of a particular tubing.

Still referring to FIGS. 21 and 22, the rod assembly with the first and second components 326, 330 assemble into the first, second and third tubing supports 308, 314, 320 and is rotatable therein. The rotation of the rod assembly with the attached first and second components is accomplished by a drive linkage 460 comprising drive rods 462, a plate 464 which is fixed relative to the drive rods, a spring 468 and a floating link

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plate 472 which floats on the drive rods 462 and is biased into coupling with the motor 303.

Referring to FIGS. 21, 22, 23, and 24, suitable steps for accomplishing a weld with this particular embodiment are as follows:

1. Mount coiled PFA tubing (first component), centered around coil stands aluminum tube 479. Fish end of PFA tubing down to end of aluminum tube on coil stand and in to the clamps on the welding tool. Snap tube holders (3) on PFA tube at end of the aluminum tube of coil stand 481, slide onto aluminum tube alternating openings on tube holders.
2. Clean PFA tubing inside surface, outside surface, and face with alcohol, cloth and blow-off with air.
3. Blow off rod assembly and insert into PFA tubing, rubber expander first.
4. Screw on (2) temporary nuts (not shown) and lock on to rod, then turn wing nut clockwise to expand rubber inside PFA tube, turn until rubber is compressed and expanded sufficiently to grip PFA tubing.
5. Remove temporary knob nuts.
6. Clean outside surface, inside surface, and face of fitting (second component) with isopropyl alcohol, lint-free cleanroom cloth and blow-off with clean, dry, compressed air.
7. Push clean fitting onto PTFE drive hub, make sure gasket is in place between fitting and hub.
8. Clean PTFE mandrel with alcohol and blow off with air, inspect for wear and imperfections.
9. Install PTFE mandrel into fitting until it bottoms out on PTFE drive hub.

10. Carefully guide clean Pyrex® sleeve over fitting and hub assembly, preferably with air to maintain cleanliness.
11. Thoroughly blow-off fitting and hub assembly and end of PFA tubing with air.
12. Carefully guide the rod through the components and the Pyrex® sleeve over the PFA tubing.
13. Inspect weld zone for dirt, redo steps if any dirt is present.
14. Install spring/washer assembly into backside of hub assembly followed by a knob nut.
15. Screw wing nut on until spring washer is flush with hub.
16. Lay fitting/hub assembly into groove in the second tubing support on right side of welding tool.
17. Close and latch all tubing supports over fitting, hub assembly and PFA tubing.
18. Compress drive linkage by hand and insert it between drive hub and drive motor, square shaft side facing motor. Insert the three drive rods into the hub holes first. Then turn drive linkage by hand until the square shaft drops into motor.
19. Carefully lower top half of heater head down into position.
20. Set variable power supply at appropriate power setting for product size.

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21. Start the two drive motors (one on the coil stand and one on the welder) at the same time and watch the direction the welder drive motor is turning and if the coil stand drive motor is turning in the opposite direction, force it to reverse by stopping it by hand, it will reverse automatically.
22. Turn-on heater.
23. When molten material area has penetrated through wall of tubing all the way to the PTFE insert and is forming a flat up against the PTFE mandrel about 1/4" wide then turn off heater.
24. Continue to rotate assembly for cooling, then stop drive motors, and carefully lift top half heater head up and out of the way.
25. Compress and remove drive linkage assembly.
26. Remove wing nut and spring.
27. Unlatch all tubing support and remove welded tube assembly.
28. Remove drive hub and gasket from end of fitting.
29. Screw on (2) knob nuts on load rod and lock in place, then turn knobs counter clockwise to release rubber expander.
30. Push the rod into PFA tubing to release it's grip.
31. Place welded end into a pullout fixture and extract PTFE mandrel and rod assembly. Set rod assembly aside being careful not to touch PTFE mandrel to anything.
32. Slide Pyrex® sleeve to side of weld and inspect weld joint.

Referring to FIGS. 24, 25, 26, 27, and 28, various embodiments are illustrated using infrared radiation to accomplish the welding process. FIG. 24 is cross-section through a mandrel 394, abutted tubular end portions 329, 332 and sleeve

396. This embodiment adds lenses 470 to the basic configuration as shown in FIGS. 19, 20, 21, and 22. The lenses, although shown in cross-section to be half mooned, extend circumferentially and coaxially around the sleeve 396. The lenses operate to focus the infrared energy provided by the infrared source 472 which is shown comprised of a pair of nickel cadmium heating wires 476 mounted within a glass incasing 480 which utilizes gold plating 482 on the exterior surface. The lens formed of glass or the like may be suitably shaped and configured to have a focal point at various desired locations within the assembly. For example, at a point 485 at the exterior of the abutment 334 or at a point 486 in the middle of the thickness of the tubular wall 488 or at a point 490 at the inside surface of the tubular wall 488 or slightly into the mandrel 394.

Referring specifically FIG. 25, an additional embodiment is shown in which the focusing lens is either adjacent to or integral with the sleeve 396. Referring to FIG. 26, an additional embodiment is shown in which the infrared heating source 472 is an infrared laser with the beam of the laser expanded to provide heating at a slightly expanded region over typical infrared lasers. These lasers appropriately have lenses 492 which provide a heating range that extends circumferentially around the abutment. Multiple lasers 472 may be utilized to provide complete coverage and facilitate even melting and fusion of the abutted tubular end portions.

Referring to FIGS. 27 and 28, cross-sectional views illustrated several aspects of the invention. FIG. 28 has the infrared heating source 472 extending substantially around the sleeve as is shown in the embodiments of FIGS. 19, 20, 21, and 22. Relative to these embodiments the infrared source may be a nickel cadmium wire which extends around the sleeve and two

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sections. The sections open at a hinge point 510. In order to accomplish the even uniform heating of the abutment of the tubular end portions, either the rod assembly, including the components to be welded, is rotated as illustrated by the arrow 514 or the infrared source 472 may be rotated as illustrated by the arrow 516. The rotation of the tubular end portions with respect to the infrared source may be further accomplished as shown in FIG. 28 with a simple gear drive rotating a frame 520 onto which the infrared sources 472 are attached. The infrared sources in this figure illustrate potential configurations of three infrared lasers with defuse beams 524.

Referring to FIGS. 19 and 28, a significant additional advantage of utilizing transparent sleeves is that a view window 550 may be provided in which to monitor the progress of the weld allowing adjustment of parameters during the welding such as the amount of infrared energy being generated, the weld time, and the cooling time.

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, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention.

IN THE CLAIMS:

1. A method of joining a pair of tubular end portions of melt processible fluoropolymers, each of the end portions having an inner surface, an outer surface, and an end surface, the method comprising the steps of:

placing the tubular end portions together in an abutting relation with each other;

embracing a hollow cylindrical sleeve substantially transparent to infrared radiation around the tubular end portions;

engaging the inside surfaces of the tubular end portions with a mandrel; and

providing infrared heating energy to the abutted end portions sufficient to melt and fuse said abutted end portions into a joint.

2. The method of claim 1, further comprising the step of providing axial compression to the two end portions as the heating energy is provided.

3. The method of claim 1 wherein the sleeve is a split longitudinally into a plurality of portions and displacing at least one sleeve portion for embracing the tubular end portions.



4. The method of claim 1, wherein the infrared heating energy is provided by an infrared heating source positioned circumferentially around the sleeve and the method further provides rotational movement of at least one of the abutted tubular end portions and infrared heating source whereby uniform heating is provided to the abutted tubular end portions.
5. The method of claim 1, wherein the hollow cylindrical sleeve is frangible and wherein the joint is allowed to cool and the frangible sleeve is then broken whereby the sleeve is removed from the abutted and joined tubular end portions.
6. The method of claim 1, wherein the joint is allowed to cool and the sleeve is left on the joined abutted tubular sleeve portions.
7. The method of claim 1, further comprising the step of providing axial compression to the two end portions as the heating energy is provided and further increasing the level of axial compression as the heating energy is provided.
8. The method of claim 1, wherein the first end portion is part of a first component and the second end portion is part of a second component, and the method further comprises the step of providing axial compression by way of a rod assembly extending axially through both end portions, the rod assembly having a first engagement portion for engagement with the first component and a second engagement portion for engagement with the second component.



9. The method of claim 8, wherein the first component is an elongate tubing section and wherein the first engagement portion of the rod assembly comprises a radially expandable cylindrical gripping portion and the method further comprises the step of engaging the gripping portion with the inside surface of the first end portion for accomplishing the axial compression.
10. The method of claim 8 wherein the first component has an end opposite the first end portion and the method comprises the step of positioning the engagement portion of the rod assembly against said end for providing a compressive force at the two abutted end portions.
11. The method of claim 10, wherein the rod assembly includes a rod extending axially through the end portions the rod engaged with one of the two engagement portions through a spring, the method further comprising the step of compressing the spring.
12. The method of claim 1 wherein the sleeve is visually transparent, and the method further comprises the step of visually monitoring the process of the melting of the end portions through the sleeve.
13. The method of claim 1, further comprising the step of focusing the infrared energy emitted by the infrared heating source.
14. The method of claim 13 wherein the focusing of the infrared energy is at the abutted tubular end portions to be joined.



15. The method of claim 1 further providing the step of providing infrared heating energy to the mandrel.
16. A method of monitoring the welding of a pair of tubular end portions comprising the steps of:

placing the tubular end portions together in an abutting relation with each other;

embracing a hollow cylindrical sleeve substantially transparent around the tubular end portions;

providing infrared heating energy to the abutted end portions; and

monitoring the progress of the welding by visually observing the abutted end portions through the transparent sleeve.
17. A method of joining a first component having a first tubular end portion to a second component having a second tubular end portion, the end portions comprised of melt processible fluoropolymers, each of the end portions having an inner surface, an outer surface, and an end surface, the method comprising the steps of:

placing the tubular end portions together in an abutting relation with each other;

positioning a hollow cylindrical sleeve around the tubular end portions;



engaging the inside surfaces of the tubular end portions with a cylindrical mandrel;

insertion of a rod assembly axially through the two end portions and through the mandrel, the rod assembly comprising a first engagement portion for engaging the first component and a second engagement portion for engaging the second component;

compressing the abutting tubular end portions with a compressive force provided by the rod assembly; and

providing heating energy to the abutted end portions through the sleeve sufficient to melt and fuse said abutted end portions.

18. The method of claim 17 further comprising the step of heating the abutted tubular end portions by infrared radiation by an infrared source positioned exterior the sleeve and radiating said infrared radiation through the sleeve.
19. The method of claim 18 further providing the step of rotatably moving one of the (a) infrared source or (b) the abutted tubular end portions such that the abutted end portions are evenly heated.
20. The method of claim 17 further comprising the step of varying the axial compressive force provided by the rod assembly.



21. An apparatus for welding a first tubular end portion of a first component and a second tubular end portion of a second component, the end portions abutted together in axial alignment, the apparatus comprising:
- a support structure;
 - a hollow cylindrical sleeve supported by the support structure for extending circumferentially around the abutted end portions, the sleeve comprised of a material substantially transparent to infrared radiation; and
 - an infrared radiation source supported by said support structure and positioned radially outward of the cylindrical sleeve for allowing infrared radiation to pass through said sleeve to melt and fuse the abutted end portions.
22. The apparatus of claim 21, further comprising a mandrel insertable within the abutted tubular end portions to prevent the formation of an internal bead when heating and fusing the tubular end portions.



23. The apparatus of claim 22 further comprising a rod assembly comprising a rod configured and positioned to extend axially within and through the abutted tubular end portions and through the mandrel, the rod assembly having a first engagement portion on said rod for engaging the first component and a second engagement portion on said rod for engaging the second component, at least of said engagement portions moveable toward the other engagement portion whereby the tubular end portions may be put in axial compression.
24. The apparatus of claim 23 further comprising a spring engaging one of said engagement portions to provide the axial compression to the tubular end portions.
25. The apparatus of claim 21, wherein the sleeve is split longitudinally for placement and removal of the sleeve on the tubular end portions to be joined.
26. The apparatus of claim 21 wherein the sleeve is visually transparent.
27. The apparatus of claim 26 wherein the apparatus and infrared source are configured such that there is a line of sight from exterior the apparatus through the sleeve to the abutted tubular end portions whereby the welding may be visually monitored.



28. A rod assembly for providing axial compression to a first component and a second component, each component having a tubular end portion, said end portions in axial alignment, the rod assembly having a rod for extending axially through the pair of abutted tubular end portions, a first engagement portion connecting to said rod and positioned to engage the first component, a second engagement portion connecting to said rod and positioned to engage the second component, a tightening member and bias member adjustably connected to said rod for moving the engagement member towards each other thereby providing axial compression to the pair of abutted tubular end portions.
29. The rod assembly of claim 28 wherein the first engagement portion comprises a radially expandable gripping member.
30. The rod assembly of claim 25 further comprising a mandrel for radially supporting the abutted tubular end portions in their interior, the rod extending through the mandrel, the mandrel positioned intermediate the first engagement portion and the second engagement portion.
31. A sleeve for transferring heat for fusing a pair of tubular end portions in an abutting and axial alignment relation, said sleeve sized for the exterior diameter of said tubular end portions, said sleeve visually transparent and substantially transparent to infrared radiation whereby infrared radiation can be transferred through the sleeve to said abutted tubular end portions.
32. The sleeve of claim 31 wherein said sleeve is comprised of one of the set comprising: tempered glass, quartz, and sapphire.



33. The sleeve of claim 31 wherein the sleeve is split longitudinally into a plurality of sections for allowing placement of tubular end portions with the sleeve and removal therefrom.
34. The sleeve of claim 31, wherein the sleeve is integral.
35. The sleeve of claim 34 wherein the sleeve is frangible whereby the sleeve may be broken for removal of the sleeve after the welding.
36. A welding system for joining a pair of melt processible tubular end portions, the tubular end portions comprising, an end face, an outer surface, and an inner surface, the welding system comprising:
- a weld head comprising:
 - a housing openable for insertion and removal of the tubular end portions to be joined;
 - sleeve supported in the housing, the sleeve for engaging the outer surfaces of the tubular end portions;
 - a heating element positioned exterior the sleeve for providing heat to weld the tubular end portions;
 - a power supply for powering the heating element; and
 - a soluble core insertable into the tubular end portions, the soluble core having an outer surface which conforms to the inner surface of the tubular end portions.

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37. A welding system according to claim 1, wherein the soluble core is comprised of sodium chloride.
38. A welding system according to claim 1 wherein the sleeve is substantially transparent to infrared radiation and the heating element produces infrared radiation to pass through said sleeve.
39. A mandrel for use in welding systems in which abutted tubular end portions are positioned between said mandrel and a sleeve engaging the exterior of the abutted end portions wherein heat passes through the sleeve to melt and fuse the end portions, the mandrel soluble in fluid for removal from the welded end portions.
40. The mandrel of claim 39 wherein the mandrel is comprised of sodium chloride.

