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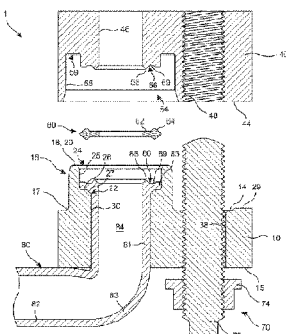
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(54) Title: MANUFACTURING PROCESS FOR FORMING A SHARP FEATURE IN AN AXIAL SEALING FLUID TRANSPORT FITTING



(57) Abstract: A coining apparatus for forming a sealing surface in an end portion of a tube includes an inner portion having a first bead forming surface and an outer portion having a second bead forming surface. The outer portion is arranged concentric to the inner portion with a radial gap formed therebetween. The first bead forming surface and the second bead forming surface each lead towards the gap and are tapered in opposing radial directions.

Description

Title of Invention: MANUFACTURING PROCESS FOR FORMING A SHARP FEATURE IN AN AXIAL SEALING FLUID TRANSPORT FITTING

Technical Field

- [1] The invention relates generally to an apparatus for manufacturing a sealing surface of a block fitting assembly and a method of operating the same, and more particularly, to a punch assembly configured to form a V-shaped bead in a sealing surface of a metal seal assembly of a block fitting assembly and a method of operating the same.

Background Art

- [2] The components of a fluid system are typically joined to each other by fluid lines extending between the components. The connection of each fluid line to each respective component introduces additional points at which a fluid carried by the fluid line may leak out of the refrigerant circuit or at which exterior contaminants may undesirably be introduced into the refrigerant. The lack of a suitable seal at each fluid line connection may lead to damage to the components forming the refrigerant circuit or may reduce an operating efficiency of the refrigerant circuit.
- [3] Such fluid line connections are commonly formed between a male seal fitting block (hereinafter "the male block") and a cooperating female seal fitting block (hereinafter "the female block") forming a block fitting assembly. The male block and the female block may each be associated with one of a pair of components configured to communicate a fluid therethrough. The male block includes a projecting portion and the female block includes a recessed portion configured to receive the projecting portion. The projecting portion and the recessed portion include aligned flow paths that communicate the fluid therebetween, wherein one or both of the aligned flow paths may further receive a tubing segment therein associated with one of the associated components. A primary sealing element is typically compressed between the projecting portion and the recessed portion to prevent the leakage of the fluid from the aligned flow paths and/or tubing segments.
- [4] It is known to utilize a metal sealing assembly in forming such a blocking fitting assembly. A metal sealing assembly includes a sealing element having a metallic portion that is compressed between a first bead projecting axially from the male block and a second bead projecting axially from the female block. Each of the beads may include a V-shaped cross-section in order to minimize the contact area present between the blocks and the metallic portion of the sealing element, thereby facilitating improved deformation of the metallic portion of the sealing element at the positions

where the beads first engage the metallic portion during compression thereof. The deformation of the metallic portion of the sealing element results in a fluid tight seal being formed along the areas of engagement present between the metallic portion and each of the oppositely arranged beads. Examples of such metal sealing assemblies may be found in U.S. Pat. No. 8,468,849, U.S. Pat. No. 9,261,1(94), and U.S. Pat. No. 9,556,993, each of which is hereby incorporated herein by reference in its entirety. Such a metal seal assembly may include the V-shaped beads being formed to include a maximized sharpness, which corresponds to a radius of curvature of each of the point ends of the V-shape having a radius of curvature approaching zero. As the radius of curvature approaches zero, the initial contact surface area of the corresponding bead is minimized, which results in an increase in pressure applied by the correspond bead when first contacting the metallic portion of the sealing element.

- [5] One possible configuration of the metal seal assembly includes one of the tube segments associated with one of the block fittings being formed into a sealing surface having one of the aforementioned V-shaped beads formed therein. For example, one method of forming such a tube segment into a sealing surface may first include feeding the tube through an opening formed through a block until an end portion of the tube extends axially beyond a distal arranged surface of the block. This end portion of the tube is then flanged radially outwardly to engage a surface of the block arranged perpendicular to the axial direction of the tube, wherein this radial outward flaring of the end portion may be accomplished by a suitable punching operation. As a final step, a sealing surface including at least one of the V-shaped beads is machined into the exposed axial end surface of the flanged portion of the tube. The formation of the sealing surface at an axial end portion of the tube results in the sealing surface being positioned to engage an annular sealing element when the illustrated block is operably coupled to a mating block, wherein the mating block includes an oppositely arranged V-shaped bead to cooperate with the V-shaped bead formed in the tube end portion. The tube fed through the block may include a variable thickness or configuration along the length thereof to achieve the desired configuration of the resulting flanged portion and V-shaped bead according to the steps proposed above.

- [6] One disadvantage of the described manufacturing process relates to the manner in which the final machining process for contouring the sealing surface is especially complex and difficult to achieve in comparison to the previously occurring forming (punching) steps. The machining may be performed by a rotating cutting tool that is subject to machine runout during the cutting process. This machine runout can lead to a radial offsetting of the inclined surfaces forming the V-shaped bead, which can in turn lead to a V-shaped bead having a reduced height and a flattened, rather than sharpened, distal surface. The machining process used to create the sealing surface ac-

cordingly requires a high amount of attention and preventative maintenance.

- [7] It has been proposed to utilize a similar punching process to form the sealing surface in the flanged portion to avoid the above-described concerns relating to the rotational machining process. However, it has been discovered that the variable shape of the sealing surface and the manner in which the flanged portion is compressed axially against the corresponding punching tool can result in gases and/or oil present during the manufacturing process being entrapped between the sealing surface of the flanged portion and the engaging surface of the punching tool. This entrapped gas and/or oil can result in surface irregularities forming in the sealing surface that lower the sealing effectiveness thereof due to the resulting surface roughness of the sealing surface.

Disclosure of Invention

Technical Problem

- [8] It would accordingly be desirable to manufacture a sealing surface into a tube segment of a block fitting assembly using a punching or coining operation that avoids the entrapment of gas and/or oil during the deformation of the tube segment into the sealing surface.

Solution to Problem

- [9] Compatible and attuned with the present invention, an apparatus for forming a sealing surface in an end portion of the tube of a block fitting has surprisingly been discovered.
- [10] According to an embodiment of the present invention, a coining apparatus includes an inner portion including an outer circumferential surface. The outer circumferential surface includes a first outer axially extending surface and a first bead forming surface intersecting the first outer axially extending surface. The first bead forming surface is tapered inwardly towards a central axis of the inner portion as the first bead forming surface extends away from the first outer axially extending surface. The inner portion is configured to be movable axially towards the end portion of the tube for forming a first inclined surface of the engaging bead via a deformation of the end portion of the tube by the first bead forming surface. An outer portion includes an inner circumferential surface including an inner axially extending surface and a second bead forming surface intersecting the inner axially extending surface. The second bead forming surface is tapered outwardly away from the central axis of the inner portion as the second bead forming surface extends away from the inner axially extending surface. The outer portion is configured to be movable axially towards the end portion of the tube for forming a second inclined surface of the engaging bead via a deformation of the end portion of the tube by the second bead forming surface. The first outer axially extending surface of the inner portion faces outwardly towards the inner axially

extending surface of the outer portion with a radially extending gap present therebetween.

- [11] A method of coining an engaging bead into an end portion of a tube is also disclosed according to the present invention. The method comprises a step of providing a coining apparatus comprising an inner portion and an outer portion, the inner portion including an outer circumferential surface, the outer circumferential surface including a first outer axially extending surface and a first bead forming surface intersecting the first outer axially extending surface, wherein the first bead forming surface is tapered inwardly towards a central axis of the inner portion as the first bead forming surface extends away from the first outer axially extending surface; the outer portion including an inner circumferential surface including an inner axially extending surface and a second bead forming surface intersecting the inner axially extending surface, wherein the first bead forming surface is tapered outwardly away from the central axis of the inner portion as the second bead forming surface extends away from the inner axially extending surface, wherein the first outer axially extending surface of the inner portion faces outwardly towards the inner axially extending surface of the outer portion with a radially extending gap present therebetween; deforming the end portion of the tube to include a first inclined surface of the engaging bead when the inner portion is moved axially towards the end portion of the tube with the first bead forming surface engaging the end portion of the tube; and deforming the end portion of the tube to include a second inclined surface of the engaging bead when the outer portion is moved axially towards the end portion of the tube with the second bead forming surface engaging the end portion of the tube.

- [12] According to another embodiment of the present invention, a block seal fitting assembly is disclosed. The block seal fitting assembly includes a first block having a first opening formed therethrough, a sealing element, and a tube extending through the first opening of the first block. An end portion of the tube forms a seal engaging surface of the tube configured to sealingly engage the sealing element. The seal engaging surface includes an annular engaging bead projecting axially therefrom with the engaging bead extending around a flow opening formed through the tube at the end portion thereof. At least a portion of the engaging bead is work hardened by a coining process used to form the engaging bead in the end portion of the tube.

Brief Description of Drawings

- [13] The above, as well as other objects and advantages of the invention, will become readily apparent to those skilled in the art from reading the following detailed description of a preferred embodiment of the invention when considered in the light of the accompanying drawings of which:

- [14] Fig. 1 is an exploded cross-sectional elevational view of a block seal fitting assembly according to an embodiment of the present invention;
- [15] Fig. 2 is a cross-sectional elevational view illustrating a lift angle of a first segment of a tube relative to a second segment of the tube when the first segment of the tube is received within a first block;
- [16] Fig. 3 is a bottom plan view of the first block illustrating a range of angular orientations for the second segment of the tube relative to the first segment of the tube;
- [17] Fig. 4 is a cross-sectional elevational view of the block seal fitting assembly of Fig. 1 when the first block and a second block are coupled to each other to compress a sealing element therebetween;
- [18] Fig. 5 is an exploded cross-sectional elevational view showing a tube following a bending thereof and prior to reception within the first block;
- [19] Fig. 6 is a cross-sectional elevational view illustrating a tube end forming apparatus suitable for performing a first deforming step on an end portion of the tube;
- [20] Fig. 7 is a cross-sectional elevational view illustrating a second deforming step performed on the end portion of the tube;
- [21] Fig. 8 is a cross-sectional elevational view illustrating the first block and the tube following the first and second deforming steps of Figs. 6 and 7;
- [22] Fig. 9 is a cross-sectional elevational view illustrating an apparatus for coining a sealing surface into a tube of a block seal fitting assembly according to an embodiment of the present invention;
- [23] Fig. 10 is a perspective view of an inner portion of the apparatus of Fig. 9;
- [24] Fig. 11 illustrates a profile shape of an exemplary relief notch for inclusion in the inner portion of the apparatus of Fig. 9;
- [25] Fig. 12 is an enlarged fragmentary view showing a positioning of the inner portion and an outer portion of the apparatus of Fig. 9 relative to a first block and a tube end portion prior to a deformation of the tube end portion via the apparatus;
- [26] Fig. 13 is an enlarged fragmentary view showing a positioning of the inner portion and the outer portion following reception of the inner portion within the tube and engagement of the outer portion with the tube end portion;
- [27] Fig. 14 is an enlarged fragmentary view showing a positioning of the inner portion and the outer portion following engagement of each of the inner portion and the outer portion with the tube end portion;
- [28] Fig. 15 is a chart showing a preferred gap distance between the inner and outer portions of the apparatus for forming a desired bead based on a temper of the tube being deformed by the inner and outer portions;
- [29] Fig. 16 is a chart showing a preferred gap distance between the inner and outer portions of the apparatus for forming a desired bead based on a viscosity of an oil

utilized during operation of the apparatus that may be disposed between the inner and outer portions and the tube end portion during the deformation of the tube end portion;

- [30] Figs. 17 and 18 illustrate alternative embodiments of the invention which may be formed using the apparatus of Fig. 9 following prior manufacturing steps for forming modified projecting portions of the first block.

Best Mode for Carrying out the Invention

- [31] The following detailed description and appended drawings describe and illustrate various embodiments of the invention. The description and drawings serve to enable one skilled in the art to make and use the invention, and are not intended to limit the scope of the invention in any manner. In respect of the methods disclosed, the steps presented are exemplary in nature, and thus, the order of the steps is not necessary or critical.
- [32] Fig. 1 illustrates a block seal fitting assembly (1) as may be produced using the apparatus and method described hereinafter according to an embodiment of the present invention. The general features of the block assembly (1) relevant to the operation of the disclosed method and apparatus are described herein for context when describing the manufacturing process according to the present invention. The block assembly (1) may be used to couple two different components to each other wherein a fluid associated with the two components enters or exits one of the components with a different flow orientation than when the fluid enters or exits the other of the components. In all cases, the two components may be any two components associated with any type of fluid conveying system, such as an HVAC system, a cooling system, a hydrogen fuel cell system, a steering system, or a braking system of a motor vehicle, as non-limiting examples. The block assembly (1) may be subjected to any type of fluid, including glycol, water, ethanol, methanol, gasoline, diesel, jet fuel, various types of refrigerants or coolants, or combinations thereof, as non-limiting examples.
- [33] The block assembly (1) includes a first block (10), a second block (40), a sealing element (60), a fastener assembly (70), and a tube (80). As shown, the first block (10) forms a male component and the second block (40) forms a female component of the block assembly (1). The first block (10) and the second block (40) are each formed of a rigid material. The rigid material may be a metallic material such as aluminum, steel, and alloys thereof. The tube (80) may be formed from the same materials suitable for forming the blocks (10, 40). In some embodiments, each of the blocks (10, 40) and the tube (80) are formed from a common material, as desired. In some embodiments, the blocks (10, 40) are formed from a different material than the tube (80).
- [34] The first block (10) includes a main body having a substantially planar first mating face (14) and a projecting portion (16) extending substantially perpendicularly from

the first mating face (14). The projecting portion (16) may include a substantially cylindrical outer surface, but other configurations of the outer surface of the projecting (16) may also be utilized such as a hexagonal outer surface configuration, as desired. The projecting portion (16) includes a first end (17) intersecting the first mating face (14) and a second end (18) spaced from the first mating face (14) in an axial direction of the projecting portion (16). The second end (18) of the projecting portion (16) defines a piloting feature (20) of the first block (10) in the form of a peripherally extending rim of the projecting portion (16). The piloting feature (20) may be inwardly tapered to more easily guide the projecting portion (16) into a corresponding portion of the second block (40), as explained hereinbelow.

[35] The piloting feature (20) circumscribes a substantially cylindrical first recess (24) formed in the projecting portion (16). The first recess (24) extends in the axial direction of the projecting portion (16) from the second end (18) thereof toward the first end (17) thereof. The first recess (24) is defined by an inner circumferential surface (25) and a radially extending surface (26) of the projecting portion (16). The inner circumferential surface (25) extends in the axial direction of the boss 16 from the second end (18) thereof to a position intermediate the first end (17) and the second end (18) thereof, but alternative depths of the first recess (24) may be used without departing from the scope of the present invention.

[36] The radially extending surface (26) extends radially inwardly from the inner circumferential surface (25) towards a first opening (30) of the first block (10). The first opening (30) is cylindrical in shape and formed concentrically with respect to the first recess (24) of the projecting portion (16). The first opening (30) also extends in the axial direction of the projecting portion (16), which is perpendicular to the first mating face (14) of the first block (10). The first opening (30) extends through an entirety of the first block (10) and is configured to receive the tube (80) therein. The radially extending surface (26) and an axially extending surface defining the first opening (30) accordingly form an annular shoulder (22) spaced radially inwardly from the inner circumferential surface (25) of the projecting portion (16). The shoulder (22) may further include a chamfer (27) forming a frustoconical surface for connecting the radially extending surface (26) to the surface of the main body defining the first opening (30), as desired.

[37] The first block (10) further includes a first fastener aperture (38) and a leverage feature (29). The first fastener aperture (38) extends through the first block (10) and is spaced laterally from and arranged parallel to the first opening (30). The first fastener aperture (38) may be substantially cylindrical in shape and may be configured to receive a threaded fastener (72) of the fastener assembly (70). The leverage feature (29) may be formed at an end of the first mating face (14) adjacent the first fastener

aperture (38). The leverage feature (29) may take the form of a fulcrum extending away from the first mating face (14) in the axial direction of the first fastener aperture (38). The leverage feature (29) may be substantially heel-like in appearance as the leverage feature (29) extends away from the first mating face (14) of the first block (10).

[38] The tube (80) may include a first segment (81), a second segment (82), and a bend portion (83) connecting the first segment (81) to the second segment (82). A flow opening (84) extends through each of the first segment (81), the bend portion (83), and the second segment (82). The first segment (81) is substantially cylindrical in shape and extends linearly in the axial direction of the first opening (30) while the second segment (82) is substantially cylindrical in shape and extends linearly in a direction arranged at an angle greater than or equal to 0 degrees and equal to or less than 90 degrees relative to the axial direction of the first opening (30) and the first segment (81). The angle formed between the first segment (81) and the second segment (82) is hereinafter referred to as the lift angle of the tube (80). The flow opening (84) includes a substantially circular or elliptical cross-sectional shape along a length of the tube (80) to minimize a drop in pressure of the fluid when traversing the tube (80).

[39] Fig. 1 illustrates the lift angle present between the first segment (81) and the second segment (82) as being about 90 degrees with the second segment (82) extending in a direction away from the fastener assembly (70) of the block assembly (1). However, as shown in Figs. 2 and 3, the second segment (82) may have any number of possible orientations relative to the first segment (81) so long as the second segment (82) does not interfere with a portion of the block assembly (1) such as the threaded fastener (72) or a secondary component disposed adjacent the block assembly (1). The tube (80) may, for example, include no bend at all, wherein an entirety of the tube (80) extends rectilinearly.

[40] For example, Fig. 2 illustrates an alternative lift angle of about 45 degrees present between the first segment (81) and the second segment (82) while also showing a generalized relationship between the first segment (81), the second segment (82), and the bend portion (83) of the tube (80). Regardless of the selected lift angle (except for zero), a central axis A of the first segment (81) always intersects a central axis B of the second segment (82) at a point C disposed within the bend portion (83) of the tube (80). The point C is further disposed exterior to the first opening (30) of the first block (10) and spaced from an outer face (15) of the first block (10) formed opposite the mating face (14) with respect to the axial direction of the first opening (30). The bend portion (83) also extends arcuately when connecting the first segment (81) to the second segment (82). A centerline radius of curvature of the tube (80) along the bend portion (83) is preferably substantially constant when the centerline radius of curvature

connects the central axis A to the central axis B to reduce the drop in pressure of the fluid traversing the flow opening (84). The radius of curvature of the tube (80) along the bend portion (83) thereof is also preferably minimized in order to form a tight bend in the tube (80) for reducing the packaging space occupied by the tube (80) while still forming the bend portion (83) in the tube (80) at a position exterior to the first opening (30). For example, the bend portion (83) of the tube (80) in Fig. 1 includes a minimized radius of curvature in order to minimize an extent to which the second segment (82) projects away from the first block (10) in the axial direction of the first opening (30), which in turn minimizes a profile of the entire block assembly (1) in the axial direction of the first opening (30), while requiring no modification of the structure of the first opening (30) to accommodate the reception of the tube (80) therein.

[41] Fig. 3 shows that the second segment (82) may also have a plurality of different angular orientations relative to the central axis A of the first segment (81) in addition to that shown in Fig. 1. For example, the dashed line in Fig. 3 bounds a range of potential angular orientations of the second segment (82) relative to the central axis A of the first segment (81) for a given lift angle, such as the 90 degree lift angle shown in Fig. 1, while preventing interference between the second segment (82) and the threaded fastener (72) when the threaded fastener (72) is disposed in the first fastener aperture (38) of the first block (10). As should be understood by one skilled in the art, a reduction in the lift angle will result in a greater range of potential angular orientations of the second segment (82) relative to the first segment (81) when the reduction in lift angle reorients the second segment (82) in a manner preventing interference with the threaded fastener (72). As mentioned above, the tube (80) may be purely rectilinear in configuration in the absence of the bend, hence the tube (80) may be described as having only one segment extending axially and rectilinearly.

[42] The tube (80) is shown as including only the two segments (81, 82) separated by the single bend portion (83), but the tube (80) may include additional bends within a portion of the tube (80) extending away from the second segment (82) in order to fluidly couple the block assembly (1) to an adjacent component of the associated fluid system while accommodating the available packaging space provided by the associated fluid system. The remainder of the tube (80) not shown throughout the figures may accordingly include substantially any configuration suitable for communicating a fluid therethrough without departing from the scope of the present invention.

[43] Referring back to Fig. 1, the first segment (81) extends longitudinally from a seal engaging portion (85) of the tube (80) disposed within the recess (24) of the projecting portion (16) to the bend portion (83) thereof. The seal engaging portion (85) is formed by an end portion of the tube (80) extending radially outwardly to cause the seal

engaging portion (85) to be an outwardly extending flange of the tube (80). An underside of the seal engaging portion (85) engages and conforms in shape to the shoulder (22), the radially extending surface (26), and the inner circumferential surface (25) of the projecting portion (16) to prevent the existence of any gaps at the joint therebetween.

- [44] The seal engaging portion (85) of the tube (80) forms a first seal engaging surface (86) having at least one seal engaging bead (88) formed intermediate the inner circumferential surface (25) and the flow opening (84) formed through the tube (80). The engaging bead (88) extends annularly adjacent the first opening (30) and is configured to sealingly engage the sealing element (60). The engaging bead (88) forms an axially extending projection or rib configured to impart a localized compressive stress on a portion of the sealing element (60) disposed within the first recess (24).
- [45] The engaging bead (88) is shown in Fig. 1 as having a substantially V-shaped cross-sectional shape including a pointed edge formed at a distal end of the engaging bead (88). The edge may be formed by a pair of tapering surfaces arranged at an angle relative to each other. A sharpness of the edge of the engaging bead (88) may be selected to impart a desired degree of compressive stress to the portion of the sealing element (60), as explained in greater detail when describing the method of formation of the engaging bead (88) with reference to Figs. 12-14. In some embodiments, an angle formed between the cooperating surfaces forming the pointed edge may be selected to be at least 60 degrees and less than 90 degrees. In other embodiments, the angle may be greater than 90 degrees and less than or equal to 120 degrees.
- [46] In some embodiments, each of the tapered surfaces forming the engaging bead (88) may include equal and opposing angles of inclination relative to the axial direction of the opening (30) and the first segment (81) of the tube (80). For example, each of the opposing tapered surfaces may be arranged at opposing 45 degree angles of inclination such that the total angle of inclination present between the tapered surfaces equals 90 degrees. In other embodiments, it is conceivable one of the opposing tapered surfaces may have a differing angle of inclination than the other of the tapered surfaces, so long as the resulting engaging bead (88) is able to apply an axial force in a desired manner consistent with operation of the block assembly (1). One skilled in the art should appreciate that alternative and additional configurations of the engaging bead (88) may also be used without departing from the scope of the present invention, so long as the engaging bead (88) is suitable for delivering the desired localized compressive stress to the portion of the sealing element (60) disposed within the first recess (24). In some embodiments, the engaging bead (88) may be arranged radially to be disposed intermediate the surfaces defining the opening (30) and the flow opening (84), thereby aligning the pointed edge of the engaging bead (88) with an axially extending portion

of the tube (80) adjacent the first seal engaging surface (86).

- [47] The first seal engaging surface (86) may further include at least one cavity (89) formed therein. The at least one cavity (89) forms a depression in the first seal engaging surface (86) indented in a direction opposing the direction of extension of each of the engaging beads (88) projecting from the first seal engaging surface (86). Fig. 1 illustrates the first seal engaging surface (86) as including a single annular cavity (89) formed adjacent and radially outwardly of the engaging bead (88). The cavity (89) is shown as having a substantially trapezoidal cross-sectional shape, but other shapes may be used without departing from the scope of the present invention. For example, the cavity (89) may have a semi-circular shape, a tapered triangular shape with a relatively small radius of curvature at a distal end thereof, a tapered triangular shape with a relatively large radius of curvature at a distal end thereof, or an oblique angled shape, as non-limiting examples. The cavity (89) is configured to receive at least a portion of the sealing element (60) therein during compression of the sealing element (60) between the first block (10) and the second block (40).
- [48] The first seal engaging surface (86) may include any number of the engaging beads (88) and any number of the cavities (89), as desired. In some embodiments, the first seal engaging surface (86) includes a plurality of the engaging beads (88) interposed in alternating fashion between each of the cavities (89) with respect to the radial direction, as desired. Any suitable configuration of the engaging beads (88) and the cavities (89) may be used without departing from the scope of the present invention.
- [49] The second block (40) includes a main body having a substantially planar second mating face (44). The main body includes a second recess (54) indented axially from the second mating face (44) in a direction perpendicular thereto. The second recess (54) includes an axially extending inner circumferential surface (55) having an inner diameter substantially equal to and slightly greater than an outer diameter of the projecting portion (16) of the first block (10) and a second seal engaging surface (56) extending radially inwardly from the inner circumferential surface (55). An axially extending annular groove (59) is formed at the intersection of the inner circumferential surface (55) and the second seal engaging surface (56). The annular groove (59) is configured to receive the piloting feature (20) of the first block (10) therein.
- [50] The second seal engaging surface (56) extends radially inwardly from the annular groove (59) and terminates at a second opening (46) of the second block (40). The second opening (46) is cylindrical in shape and formed concentrically relative to the annularly extending second recess (54). The second opening (46) extends in the axial direction of the second recess (54), which is arranged perpendicular to the second mating face (44) of the second block (40). The second opening (46) extends through the second block (40) and is configured to convey the fluid therethrough. The second

opening (46) may be configured to receive or otherwise engage a length of tubing or the like (not shown). Alternatively, the second block (40) may form a portion of a component of the associated fluid system and the second opening (46) may communicate the fluid directly to an operational portion of the component, as desired. The second opening (46) of the second block (40) is placed in concentric alignment with the first opening (30) of the first block (10) when the blocks (10, 40) are coupled to each other via the fastener assembly (70).

- [51] The second seal engaging surface (56) includes an engaging bead (58) formed intermediate the inner circumferential surface (55) and the second opening (46). The engaging bead (58) extends annularly adjacent the second opening (46) and is configured to sealingly engage at least a portion of the sealing element (60). The engaging bead (58) forms an axially extending projection or rib configured to impart a localized compressive stress on the portion of the sealing element (60) disposed within the recess (54).
- [52] The engaging bead (58) is shown in Fig. 1 as having a substantially V-shaped cross-sectional shape including a pointed edge formed at a distal end of the engaging bead (58). The edge may be formed by a pair of tapering surfaces arranged at an angle relative to each other. A sharpness of the edge of the engaging bead (58) may be selected to impart a desired degree of compressive stress to the portion of the sealing element (60). An angle formed between the cooperating surfaces may be selected to match the angle formed between the surfaces of the engaging bead (88) of the tube (80). One skilled in the art should appreciate that alternative configurations of the engaging bead (58) may be used without departing from the scope of the present invention so long as the engaging bead (58) is suitable for delivering the desired localized compressive stress to the portion of the sealing element (60) disposed within the second recess (54).
- [53] The second seal engaging surface (56) further includes at least one cavity (69) formed therein. The at least one cavity (69) forms a depression in the second seal engaging surface (56) indented in a direction opposing the direction of projection of each of the engaging beads (58) of the second sealing surface (56). Fig. 1 illustrates the second seal engaging surface (56) as including a single annularly extending cavity (69) formed adjacent and outboard of the engaging bead (58). The cavity (69) is shown as having a substantially trapezoidal cross-sectional shape, but other shapes such as those described with reference to the cavity (89) of the tube (80) may also be used without departing from the scope of the present invention. The cavity (69) is configured to receive at least a portion of the sealing element (60) therein as is explained in greater detail hereinbelow.
- [54] The second seal engaging surface (56) may include any number of the engaging

beads (58) and any number of the cavities (69), as desired. In some embodiments, the second seal engaging surface (56) includes a plurality of the engaging beads (58) interposed in alternating fashion between each of the cavities (69) with respect to the radial direction. The engaging beads (58) and the cavities (69) may be selected to in each case be in radial alignment with corresponding ones of the engaging beads (88) and the cavities (89) of the tube (80), as desired. Any suitable configuration of the engaging beads (58) and the cavities (69) may be used without departing from the scope of the present invention.

- [55] The second block (40) further includes a second fastener aperture (48) spaced apart from and arranged in parallel to the second opening (46). The second fastener aperture (48) is substantially cylindrical in shape and may include a threaded inner surface configured to cooperate with the threads formed on the corresponding threaded fastener (72). As should be understood, the second fastening aperture (48) of the second block (40) is positioned in concentric alignment with the first fastening aperture (38) of the first block (10) during assembly of the block assembly (1).
- [56] The sealing element (60) includes a first seal portion (62) and a second seal portion (64). The first seal portion (62) is a substantially flat annular ring having a substantially rectangular cross-sectional shape. In the embodiment shown, the first seal portion (62) is produced from a metallic material such as aluminum, copper, or alloys thereof. The first seal portion (62) may be further coated with pure tin or tin alloyed with copper, nickel, cobalt, zinc, indium, lead, or antimony, as non-limiting examples.
- [57] The second seal portion (64) extends radially outwardly from the outer peripheral edge of the first seal portion (62). An annular channel is formed in a radial inner portion of the second seal portion (64) to receive the outer edge of the first seal portion (62). The second seal portion (64) is fastened to the first seal portion (62) by any conventional fastening means such as vulcanizing, heat welding, press fitting, an adhesive, or a mechanical means of attachment, for example. In the embodiment shown, the second seal portion (64) is produced from an elastomer. It is understood that the second seal portion (64) may be produced from any conventional material such as nylon, viton, neoprene, PEEK, NBR, HNBR, EPDM, and PTFE, and related series thereof, as non-limiting examples.
- [58] The fastener assembly (70) includes the threaded fastener (72) and a nut (74). The threaded fastener (72) includes an outer surface having threads configured for engagement with the internally threaded surface of the second fastener aperture (48). The threaded fastener (72) may be a threaded stud as shown in Fig. 1. Alternatively, the threaded fastener (72) may be a bolt including a head configured to engage an outer face of one of the blocks (10, 40). The nut (74) is internally threaded and configured to engage the external threads of the threaded fastener (72).

- [59] As shown in Fig. 4, the fastener assembly (70) is configured to urge the first block (10) towards the second block (40) to compress the sealing element (60) between the seal engaging surfaces (56, 86), thereby sealing a flow path formed by the cooperation of the tube (80) and the second opening (46) of the second block (10). First, the threaded fastener (72) is threaded into engagement with the internal threads of the second fastener aperture (48). Next, the nut (74) is rotated relative to the threaded fastener (72) to cause the nut (74) to move axially along the threaded fastener (72) until the nut (74) engages the outer face (15) of the first block (10). Continued rotation of the nut (74) causes a spacing present between the first mating face (14) of the first block (10) and the second mating face (44) of the second block (40) to decrease until the leverage feature (29) of the first block (10) contacts the second mating face (44) of the second block (40). The sealing element (60) is simultaneously compressed to a suitable degree between the first seal engaging surface (86) of the tube (80) and the second seal engaging surface (56) formed by the second block (40). Specifically, the engaging bead (88) and the engaging bead (58) are caused to approach and eventually engage the first seal portion (62) of the sealing element (60) from opposing axial directions, wherein continued urging of the first block (10) towards the second block (40) causes the engaging beads (58), 88 to impinge upon (penetrate) the exposed surfaces of the first seal portion (62) in a manner axially compressing the first seal portion (62) therebetween. The second seal portion (64), which is formed from an elastomer, is compressed between the blocks (10, 40) and is caused to elastically deform to conform to a space surrounding the second seal portion (64), thereby providing additional sealing at a position radially outward of the junction of the beads (58), 88 with the first seal portion (62). One skilled in the art should appreciate that any form of clamping feature suitable for urging the first block (10) towards the second block (40) in the manner described may be used without departing from the scope of the present invention.
- [60] Figs. 5-7 illustrate a method of manufacturing the block assembly (1) prior to formation of the first sealing surface (86), and more specifically, the steps required for forming the tube (80), coupling the tube (80) to the first block (10), and forming the end portion of the first segment (81) of the tube (80) into the seal engaging portion (85) thereof immediately prior to formation of the first sealing surface (86).
- [61] The tube (80) may originally be presented as a length of cylindrical tubing having a substantially constant inner diameter and outer diameter, as desired. In some embodiments, the tube (80) remains rectilinear in shape, and the tube (80) is not subjected to bending. In other embodiments, the tube (80) is bent using any conventional bending process or apparatus to divide the tube (80) into the first segment (81), the second segment (82), and the bend portion (83). The lift angle present between the first

segment (81) and the second segment (82) may be selected in order to accommodate the packaging arrangement of the components adjacent the block assembly (1). If a purely rectilinear tube (80) is utilized, it should be understood that further references to the first segment (81) of the tube (80) hereinafter may alternatively correspond to a portion of the rectilinear tube (80) received through the opening (30) in the same fashion. Although not pictured, the tube (80) may also be provided to include a segment within the opening (30) having a greater thickness than a remainder of the tube (80) extending outside of the opening (30). The tube (80) may also be formed to include an axial stopping feature, such as including a radially outwardly extending bead at a position corresponding to a desired depth of the tube (80) within the opening (30). The tube (80) may be formed to include such features during an initial punching operation similar to those shown and described.

[62] The first segment (81) of the tube (80) is received through the first opening (30) to cause an end portion of the first segment (81) to extend outside of the first opening (30) and into the first recess (24) formed by the projecting portion (16). If a bent tube is used, the second segment (82) may form a stopping feature for establishing an extent of axial insertion of the first segment (81) in the first opening (30) when the second segment (82) contacts the outer face (15) of the first block (10). Alternatively, as mentioned above, the first segment (81) or the bend portion (83) of the tube (80) may be further deformed to provide the stopping feature for establishing the extent of axial insertion of the first segment (81) within the first opening (30) without departing from the scope of the present invention.

[63] Following reception of the first segment (81) in the first opening (30) as shown in Fig. 6, the end portion of the first segment (81) extending outside of the first opening (30) is then deformed radially outwardly to form an outwardly extending flange of the first segment (81). The outward deformation of the end portion of the first segment (81) may require multiple deformation steps. For example, Figs. 6 and 7 show two independent deforming steps for forming the end portion of the first segment (81) into the shape and configuration shown in Fig. 8.

[64] The deforming steps may be performed using a tube end forming apparatus as is known in the art, such as a ram type apparatus including a tool configured for axial reception into or around the end portion of a corresponding tube, wherein a "ramming" of the tool into or around the corresponding tube causes the deformation of the tube.

[65] Figs. 6 and 7 illustrate one exemplary tube end forming apparatus (500) suitable for performing the desired deformation of the end portion of the first segment (81). The apparatus (500) includes a holding structure (502) and one of a pair of ram tools (504, 505). Fig. 6 illustrates a first ram tool (504) suitable for performing the first deforming step while Fig. 7 illustrates a second ram tool (505) having a different structure for

performing the second deforming step. Although described as having a common holding structure (502), it should be apparent that the block assembly (1) may be manufactured via two distinct tooling assemblies with each of the tooling assemblies including an independently provided one of the holding structures (502), as opposed to utilizing two different ram tools (504, 505) with respect to a single holding structure (502). It should also be readily apparent to one skilled in the art that fewer or greater tools may be added to the process for deforming the tube (80) in the manner desired, such as replacing the deforming steps shown with respect to Figs. 6 and 7 with fewer or greater incremental steps for arriving at the same general configuration of the tube (80) as shown in Fig. 8, as is necessary.

[66] The holding structure (502) extends annularly and includes an axially extending tool opening (503) configured to slidably receive either of the ram tools (504, 505). A drive mechanism (not shown) of the apparatus (500) causes the corresponding ram tool (504), 505 to selectively reciprocate within the tool opening (503). The drive mechanism also applies an axial force to the corresponding ram tool (504), 505 suitable for deforming the rigid material forming the tube (80). The holding structure (502) further includes a block opening (508) at an end thereof having a shape and size corresponding to an outer surface of the first block (10). A surface of the holding structure (502) defining the block opening (508) accordingly engages the first block (10) and maintains a position and configuration of the first block (10) during each of the aforementioned deforming steps.

[67] The first ram tool (504) includes a cylindrical and axially extending stem (511), an annular and radially extending surface 512 adjacent an end of the stem (511), and an annular and arcuate surface 513 connecting the stem (511) to the radially extending surface 512. As shown by a comparison of Fig. 6 to Fig. 7, the shape of the first ram tool (504) results in the end portion of the first segment (81) being flared radially outwardly in accordance with the shape of the first ram tool (504) when the first ram tool (504) is axially inserted into the first segment (81).

[68] The second ram tool (505) includes a cylindrical and axially extending stem (521), an annular and radially extending surface 522 extending radially outwardly from a base of the stem (521), and an annular and arcuate surface 523 connecting the stem (521) to the radially extending surface 522. As can be seen by comparison of Fig. 7 to Fig. 8, the shape of the second ram tool (505) results in the end portion of the first segment (81) being further deformed radially outwardly to cause the end portion of the first segment (81) to conform in shape to the corresponding portions of the outer surface of the first block (10) while an axial end of the first segment (81) is arranged substantially planar and perpendicular to the axial direction of the first segment (81).

[69] Referring now to Fig. 9, a method and apparatus for forming the first sealing surface

(86) into the seal engaging portion (85) once the assembly has reached the configuration of Fig. 8 is disclosed. It should be understood that the steps disclosed hereinafter may occur with respect to alternative manufacturing processes utilized in arriving at the configuration of Fig. 8 while remaining within the scope of the present invention. That is, the method of forming a V-shaped bead (88) having a minimized radius of curvature within the first sealing surface (86) as disclosed hereinafter may be applied to the seal engaging portion (85) regardless of the method of forming and flanging the tube (80) into the necessary configuration for use with the disclosed apparatus.

- [70] Fig. 9 illustrates a tube end forming apparatus (600) suitable for performing the desired deformation of the end portion of the tube (80) for forming the first sealing surface (86) therein. The tube end forming apparatus (600) may be described as performing a "coining" operation, wherein the term "coining" is synonymous with forging, stamping, impacting, punching, or drawing, wherein axial force is applied in order to deform a desired surface of the corresponding workpiece.
- [71] The apparatus (600) includes a first ram tool portion (601) and a second ram tool portion (602). The first ram tool portion (601) forms an inner portion of the apparatus (600) while the second ram tool portion (602) forms an outer portion of the apparatus (600). The first ram tool portion (601) may alternatively be referred to as the inner portion (601) of the apparatus (600) while the second ram tool portion (602) may alternatively be referred to as the outer portion (602) of the apparatus (600). The inner portion (601) is received within the outer portion (602) with the portions (601, 602) arranged concentrically relative to each other. The inner portion (601) and the outer portion (602) may each include axially symmetric shapes with respect to the surfaces of the portions (601, 602) configured to engage the seal engaging portion (85) of the tube (80) when deforming the tube (80) as described hereinafter. In the present embodiment, the inner portion (601) is a substantially cylindrically shaped stem while the outer portion (602) is a substantially cylindrically shaped collar.
- [72] The outer portion (602) includes a surface forming portion (605) arranged along a radially inward segment of the outer portion (602) adjacent the inner portion (601) and a holding portion (606) disposed radially outwardly of the surface forming portion (605). The holding portion (606) is configured to surround and hold the block (10) having the tube (80) while the surface forming portion (605) is configured to engage and deform the seal engaging portion (85) of the tube (80) during formation of the first sealing surface (86).
- [73] The inner portion (601) includes an outer circumferential surface 610 including a tapered surface (611) intersecting an end (618) of the inner portion (601) and having a frustoconical shape, an axially extending surface (612) having a cylindrical shape

disposed adjacent the tapered surface (611), a first bead forming surface (613) that is tapered to include a frustoconical shape adjacent the axially extending surface (612), and another axially extending surface (614) having a cylindrical shape disposed adjacent the first bead forming surface (613).

[74] The surface forming portion (605) of the outer portion (602) includes a second bead forming surface (622) facing towards the first bead forming surface (613) of the inner portion (601). That is, the first bead forming surface (613) is inclined to face outwardly away from a central axis of the inner portion (601) while the second bead forming surface (622) is inclined to face inwardly towards the central axis of the inner portion (601). The second bead forming surface (622) is tapered to include a frustoconical shape. The first bead forming surface (613) and the second bead forming surface (622) include opposite tapers to result in the formation of a V-shape via the cooperation of the surfaces (613, 622). That is, the first bead forming surface (613) extends in a first axial direction of the tube (80) when progressing in the radial outward direction thereof while the second bead forming surface (622) extends in an opposing second axial direction of the tube (80) when continuing to progress in the radial outward direction thereof beyond the first bead forming surface (613). The bead forming surfaces (613, 622) may have any desired inclinations relative to the axial direction of the tube (80), as desired, including equal and opposing inclinations. As mentioned above, it is conceivable that the bead forming surfaces (613, 622) may include differing inclinations, as desired, without necessarily departing from the scope of the present invention.

[75] The outer portion (602) includes an inner circumferential surface having an axially extending surface (608) defining an opening (609) for receiving the inner portion (601) therein. The second bead forming surface (622) forms a portion of the inner circumferential surface and tapers radially outwardly away from a central axis of the inner portion (601) as the second bead forming surface (622) extends axially away from an intersection of the second bead forming surface (622) and the axially extending surface (608). The axially extending surface (614) of the inner portion (601) faces towards the axially extending surface (608) of the outer portion (602) and an annular gap (630) is formed therebetween, wherein the gap (630) is present between the inner and outer portions (601, 602) with respect to the radial direction of the apparatus (600). The gap (630) extends axially from an end of each of the bead forming surfaces (613, 622) at the pointed end of the V-shape formed thereby. The gap (630) is fluidly coupled to a space disposed exterior to the apparatus (600), thereby allowing for any substances entering the gap (630) to be vented or otherwise removed from the gap (630). The gap (630) is most easily seen in the enlarged fragmentary views of Figs. 12-14.

[76] The apparatus (600) differs from the apparatus (500) in that the outer portion (602) doubles as the holding structure and one of the ram tools, as opposed to having a

dedicated holding structure (502) that does not directly deform the tube (80). However, it should be readily apparent to one skilled in the art that the structure described as forming the surface forming portion (605) of the outer portion (602) may be adapted for reception within a holding structure such as the holding structure (502) while remaining within the scope of the present invention, wherein the resulting apparatus includes the inner and outer portions (601, 602) moving relative to the holding structure (502) once the corresponding block has been secured by the holding structure (502) during a punching process. For example, Fig. 9 is shown as including a first set of axially extending dashed lines 901 disposed at a first radius from the central axis of the inner portion (601) as well as a second set of axially extending dashed lines 902 disposed at a second radius from the central axis of the inner portion (601). Each of the sets of the dashed lines 901, 902 is representative of a possible division of the outer portion (602) into a distinct holding structure (606) and surface forming portion (605), which are able to move axially independently of one another. Specifically, each set of the dashed lines (901, 902) is representative of the position of a potential cylindrical opening formed within the outer disposed holding structure (606), which in turn slidably receives the surface forming portion (605) therein at a radially inward position, which then further slidably receives the inner portion (601) therein at a central position. It can be seen that the division of the outer portion (602) into the distinct portions (605, 606) at the first set of dashed lines (901) results in the holding structure (606) having substantially the same structure as the holding structure (502). Such a configuration may accordingly result in the ability to utilize an assembly of the surface forming portion (605) disposed inwardly of the first set of the lines 901 and the inner portion (601) as another tool suitable for use with the holding structure (502) utilized in the prior deforming steps, thereby reducing the tooling required in performing the assembly of the blocks.

- [77] Referring now to Fig. 10, the axially extending surface (612) of the inner portion (601) may include a plurality of circumferentially spaced relief notches (640) to allow for excess flow of the tube (80) to be directed to a portion of the resulting tube (80) that does not negatively affect the seal provided by the sealing surface (86). Each of the relief notches (640) is provided to increase a radial distance the gap (630) extends at each of the circumferential positions of one of the relief notches (640). The relief notches (640) are shown as including a rectangular perimeter shape that is indented radially inwardly into the axially extending surface (612), but alternative shapes may be utilized while remaining within the scope of the present invention. For example, each of the relief notches (640) may instead include a tapered trapezoidal shape to facilitate removal of the inner portion (601) from the tube (80) in the absence of excessive friction therebetween as may be produced by purely axially extending

surface engagement. Fig. 11 illustrates one exemplary shape for a trapezoidal shaped relief notch (640) having a first end (641) that is wider circumferentially than a second end (642) thereof, wherein the first end (641) represents the axial end of the relief notch (640) formed at the intersection of the surfaces (611), (612) while the second end (642) represents the axial end of the relief notch (640) formed at the intersection of the surfaces (612), (613). Any number of the relief notches (640) may be utilized, such as two or more, and as many as 100, as a non-limiting example. The relief notches (640) may be provided to include an aspect ratio (width to punch OD) in the range of 1:2 to 1:50.

[78] As shown in the enlarged views of Figs. 12-14, operation of the apparatus (600) includes each of the inner portion (601) and the outer portion (602) being moved axially towards the seal engaging portion (85) of the tube (80) until a compressive load is applied thereto with respect to the axial direction of movement of each of the portions (601, 602). The portions (601, 602) continue to move axially to deform the seal engaging portion (85) into the illustrated shape of the first sealing surface (86) including the engaging bead (88) having the V-shaped cross-section. The first bead forming surface (613) forms a first inclined surface (93) of the engaging bead (88) while the second bead forming surface (622) forms the opposing second inclined surface (94) of the engaging bead (88). The inclined surfaces (93, 94) meet at a pointed end (95) of the engaging bead (88), which preferably includes a minimized radius of curvature corresponding to a maximized sharpness of the pointed end (95). The pointed end (95) of the engaging bead (88) is formed at the position of the radial gap (630). Any oil and/or gas disposed between the apparatus (600) and the seal engaging portion (85) is able to vent through the gap (630) to prevent entrapment along the first sealing surface (86).

[79] Figs. 12-14 illustrate one exemplary sequence wherein the outer portion (602) engages and deforms the seal engaging portion (85) of the tube (80) prior to the inner portion (601) engaging and deforming the seal engaging portion (85). However, another exemplary sequence (not shown) may include the inner portion (601) engaging and deforming the seal engaging portion (85) of the tube (80) prior to the second portion (602) engaging and deforming the sealing engaging portion (85), as desired. The operation of the apparatus (600) may include the portions (601, 602) moving in the axial direction to contact the seal engaging portion (85) of the tube (80) at the described different times to cause the opposing surfaces (93, 94) of the engaging bead (88) to be formed in sequential order, thereby allowing for the material forming the engaging bead (88) to "flow" towards the gap (630) from two opposing radial directions at different instants, thereby aiding in forming a minimized radius of the pointed end (95) of the engaging bead (88).

- [80] The time that elapses between the inner portion (601) and the outer portion (602) engaging and deforming (coining) the tube (80) may vary from 1 millisecond to 10 seconds, as one non-limiting range, regardless of the selected order of engagement of the portions (601, 602) with the tube (80). The inner portion (601) and the outer portion (602) may be semi-rigidly connected to one another to facilitate the slight delay in contact between the different portions (601, 602), wherein the same drive mechanism may be driving the movement of both portions (601, 602) simultaneously. For example, the portions (601, 602) may be mechanically joined via a spring, threaded fastener(s), a wedge, a tapered pin, or other tool or component for prescribing the different timing between the engagement of the portions (601, 602) with the tube (80). Alternatively, each of the portions (601, 602) may be driven by an independent drive mechanism to control the timing of each punch of each of the portions (601, 602), as desired. It should be apparent to one skilled in the art that the same effects of the portions (601, 602) on the tube (80) may be achievable regardless of the mechanism or control method utilized in determining any offset in timing between the strokes of the portions (601, 602), or any order of operation of the strokes of the portions (601, 602), hence any such mechanisms allowing for such an offset are within the scope of the present invention.
- [81] The example shown via comparison of Figs. 12-14 may include the following sequence of events. First, the outer portion (602) begins to move axially towards the first block (10) and the tube (80) with an inner circumferential surface of the holding portion (606) of the outer portion (602) configured to be axially aligned with an outer circumferential surface of the projecting portion (16) of the first block (10) to properly position each feature of the first block (10) and the tube (80) received therein relative to the inner and outer portions (601, 602) of the apparatus (600). The piloting of the projecting portion (16) into the holding portion (606) occurs prior to the engagement of the seal forming portion (605) with the sealing engaging portion (85) of the tube (80).
- [82] Next, as the seal forming portion (605) of the outer portion (602) approaches the seal engaging portion (85) of the tube (80), the inner portion (601) may also be caused to begin moving axially towards the seal engaging portion (85) of the tube (80) in unison with the outer portion (602). As mentioned above, this timing may be achieved by configuring the mechanism coupling the inner and outer portions (601, 602) to prescribe the sequence of the axial movement of each respective portion (601, 602) during a common driving of the assembly of the portions (601, 602) by a common drive mechanism. As shown in Fig. 13, the prescribed timing may include the axially extending surface (612) of the inner portion (601) being received within the flow opening (84) of the tube (80) prior to the seal forming portion (605) making contact with the seal engaging portion (85) of the tube (80) during the simultaneous movement

of the inner and outer portions (601, 602). This reception of the inner portion (601) in the tube (80) may be utilized to stabilize the inner diameter of tube (80) along the flow opening (84) thereof during the deformation of the seal engaging portion (85) via the seal forming portion (605) of the outer portion (602). However, the method may alternatively be practiced absent the axial insertion of the axially extending surface (612) within the flow opening (84) of the tube (80), as desired, without necessarily departing from the scope of the present invention.

[83] The engagement of the seal forming portion (605) with the seal engaging portion (85) of the tube (80) includes the second bead forming surface (622) of the outer portion (602) forming the second inclined surface (94) of the engaging bead (88). Specifically, as the second bead forming surface (622) engages the seal engaging portion (85) and applies an axial load thereto, the seal engaging portion (85) is compressed axially such that material may be caused to flow along the frustoconical surface formed by the second bead forming surface (622) as the shape of the seal engaging portion (85) is reconfigured by the coining process. The inclusion of the gap (630) at the specified position provides a pathway for the compressed material to flow radially inwardly towards the resulting pointed end (95) of the engaging bead (88) due to the open space provided by the gap (630), as opposed to the material flowing in a radial outward direction corresponding to additional compression of the seal engaging portion (85) at a position radially outward of the engaging bead (88). The material forming the tube (80) is accordingly caused to flow in a direction parallel to the inclination of the second bead forming surface (622) that is both radially inward and axially opposite the direction of movement of the second bead forming surface (622) towards the seal engaging portion (85). The described process accordingly allows for the flow of the material forming the engaging bead (88) towards the pointed end (95) thereof, despite the opposing direction of the coining process.

[84] The engagement of the second bead forming surface (622) with the seal engaging portion (85) also allows for any other fluids disposed therebetween, such as any air or oil (or other lubricant) associated with the described manufacturing process, to be similarly displaced towards the gap (630) in the same manner. Specifically, the air, oil, or other fluid may be caused to flow towards the gap (630) while flowing in a direction parallel to the inclination of the second bead forming surface (622) that is both radially inward and axially opposite the direction of movement of the second bead forming surface (622) towards the seal engaging portion (85). The ability of the air, oil, or other fluid to exit the boundary between the second bead forming surface (622) and the seal engaging portion (85) prevents an impingement of the corresponding fluid(s) into the resulting seal engaging surface (86) due to the relatively high compressive loads required for performing the described coining operation. The fluid(s) can flow towards

the gap (630) and then flow axially along the gap (630) away from the seal engaging portion (85). The flow of such fluid(s) occurs prior to the completion of the deformation of the second inclined surface (94) to ensure that the fluid(s) do not negatively affect the resulting configuration of the second inclined surface (94).

[85] As shown in Fig. 13, which includes the outer portion (602) having already formed the second inclined surface (94), the delayed timing of the axial movement of the inner portion (601) may also result in the formation of enlarged flow space 660 that is axially aligned with the first bead forming surface (613) and continuous with the gap (630). The enlarged flow space 660 may provide an additional flow space for the material forming the tube (80) and any additional fluids such as the described air and/or oil to flow during the formation of the second inclined surface (94) of the engaging bead (88).

[86] As shown in Fig. 14, the continued axial movement of the inner portion (601) towards the seal engaging portion (85) eventually results in the first bead forming surface (613) engaging and deforming the seal engaging portion (85) in similar fashion to that described with respect to the second bead forming surface (622), but with a reversed radial direction of flow of any materials disposed at the boundary between the first bead forming surface (613) and the seal engaging portion (85) during the formation of the first inclined surface (93). Specifically, the inclusion of the gap (630) at the specified position provides a pathway for the compressed material of the tube (80) to flow radially outwardly towards the resulting pointed end (95) of the engaging bead (88) due to the open space provided by the gap (630), as opposed to the material flowing in a radial inward direction corresponding to additional compression of the seal engaging portion (85) at a position where the tube (80) engages the axially extending surface (612) of the inner portion (601). The material is accordingly caused to flow in a direction parallel to the inclination of the first bead forming surface (613) that is both radially outward and axially opposite the direction of movement of the first bead forming surface (613) towards the seal engaging portion (85). The described process accordingly allows for the flow of the material forming the engaging bead (88) towards the pointed end (95) thereof, despite the opposing direction of the coining process.

[87] Similarly, any fluid(s) such as air, oil, or other lubricants disposed between the inner portion (601) and the tube (80) may be caused to flow towards the gap (630) while flowing in a direction parallel to the inclination of the first bead forming surface (613) that is both radially outward and axially opposite the direction of movement of the first bead forming surface (613) towards the seal engaging portion (85). The ability of the fluid(s) to exit the boundary between the first bead forming surface (613) and the seal engaging portion (85) prevents an impingement of the fluid(s) into the resulting seal

engaging surface (86) due to the relatively high compressive loads required for performing the described coining operation. The fluid(s) can instead flow towards the gap (630) and then flow axially along the gap (630) away from the seal engaging portion (85). The flow of such fluid(s) occurs prior to the completion of the deformation of the first inclined surface (93) to ensure that the fluid(s) do not negatively affect the resulting configuration of the first inclined surface (93).

- [88] The process of forming the engaging bead (88) also results in the formation of any remaining features present within the seal engaging surface (86), such as one of the cavities (89) described herein. The relief notches (640) formed within the inner portion (601) may also be configured to receive any excess material of the tube (80) therein during either of the coining steps applied with respect to either of the portions (601, 602). The relief notches (640) are provided at positions along the inner portion (601) wherein such excess material will form a circumferential pattern of circumferentially spaced and radially inwardly extending projections around the flow opening (84) adjacent the seal engaging portion (85) of the tube (80), wherein such projections include a relatively small flow profile having a negligible effect on the flow of a corresponding fluid through the block fitting 1.
- [89] The described method may be completed by removing each of the portions (601, 602) from the assembly of the first block (10) and the tube (80) in the opposing axial direction following the formation of the seal engaging surface (86). The first block (10) and the tube (80) are accordingly formed to include the same general configuration as that disclosed in Fig. 1, which allows for the assembly of the first block (10) and the tube (80) to be utilized in the block fitting assembly (1) of Fig. 4.
- [90] As mentioned previously, the described order of the engagement of the bead forming surfaces (613, 622) may be reversed without altering the manner in which the pointed end (95) of the engaging bead (88) is formed. For example, the inner portion (601) may be caused to move axially first such that the inner portion (601) is received within the tube (80) prior to the holding portion (606) of the outer portion (602) guiding the projecting portion (16) therein. The first bead forming surface (613) may form the first inclined surface (93) prior to the second bead forming surface (622) forming the second inclined surface (94). The formation of each surface (93), (94) may include the material forming the tube (80) flowing towards the gap (630) from each respective radial direction for forming an engaging bead (88) having the pointed end (95), and may further include the flow of any entrapped fluid(s) towards the gap (630) in the same manner.
- [91] Additionally, the division of the outer portion (602) into a distinct holding structure (606) and a distinct seal forming portion (605) (moveable relative to the holding structure (606)) may include the formation of the engaging bead (88) in substantially

similar fashion to that shown and described. The holding structure (606) may be caused to move axially prior to the seal forming portion (605) and/or the inner portion (601) to locate the first block (10) and the tube (80). Next, the seal forming portion (605) and the inner portion (601) may be moved axially towards the tube (80) in any of the described sequences for forming the engaging bead (88) in the manner described. Such a process may include the inner portion (601) received within the flow opening (84) of the tube (80) to stabilize the inner diameter of the tube (80) prior to either of the described deformations resulting in either of the inclined surfaces (93, 94).

- [92] As another variation, it is conceivable that some processes may include the simultaneous engagement of both of the bead forming surfaces (613, 622) with the tube engaging portion (85) such that the formation of each of the inclined surfaces (93, 94) includes the simultaneous flow of all corresponding materials and/or fluid(s) towards the gap (630), as desired.
- [93] The use of the apparatus (600) eliminates the need for a separate cutting tool as is traditionally utilized in forming such an engaging bead (88). The replacement of the cutting tool with the described process is able to occur because the described process results in a formation of an engaging bead (88) having a relatively sharp pointed end (95) suitable for use in conjunction with a corresponding sealing element (60) of the block assembly (1). That is, it has been discovered that the formation of the inclined surfaces (93, 94) of the engaging bead (88) via the independently provided first and second bead forming surfaces (613, 622) of the apparatus (600) promotes the deformation of the tube (80) towards the gap (630) in a manner wherein the resulting pointed end (95) has a reduced radius of curvature at the juncture of the inclined surfaces (93, 94) in comparison to a similar coining process utilizing a continuous V-shaped surface (absent a gap) corresponding to the desired shape of the resulting engaging bead (88). This occurs because all intervening fluid(s) are able to be removed from the apex of such a V-shape via the introduction of the gap (630), as opposed to such fluid(s) being trapped at the apex of such a V-shape in a manner preventing the flow of the material forming the tube (80) therein. This also occurs because the described configuration prescribes a desired flow direction of the material forming the tube (80) towards the intersection of each of the bead forming surfaces (613, 622) and each corresponding axially extending surface (608), (614) of one of the portions (601, 602), thereby promoting flow towards the apex of the V-shape for promoting an improved sharpness of the pointed end (95). The resulting configuration of the engaging bead (88) is accordingly advantageously more similar to that formed by such a cutting process while eliminating additional manufacturing steps and tooling assemblies associated with the use of such cutting processes.
- [94] It has also been surprisingly discovered that the process of deforming the tube (80)

via the described coining process results in a work hardening of the material forming the tube (80) in comparison to the use of a cutting process for forming such an engaging bead (88). That is, the compression of the material forming the tube (80) at the seal engaging surface (86) results in a work hardening of the material forming the tube (80) along the seal engaging surface (86), which includes a work hardening of the material forming the tube (80) of at least a portion of the engaging bead (88). The material forming the engaging bead (88) of the tube (80) may be increased in hardness along at least the first inclined surface (93), the second inclined surface (94), and the surface forming the pointed end (95) of the engaging bead (88) connecting the inclined surfaces (93, 94). This increase in hardness is understood to refer to a change in a hardness of the material forming the tube (80) from prior to the deformation of the seal engaging portion (85) of the tube (80) to include the engaging bead (88) to after the deformation of the seal engaging portion (85) of the tube (80) to include the engaging bead (88), and specifically from before and after the formation of each of the respective surfaces (93, 94, 95) formed in the tube (80). A tube (80) having a seal engaging surface (86) and engaging bead (88) formed by the method disclosed herein is accordingly structurally distinct from a tube having an engaging bead formed by a traditional machining process wherein material is cut away or otherwise removed from the seal engaging portion to form the result V-shaped engaging bead into the seal engaging surface. The engaging bead (88) of the present invention is provided to include an increased hardness that cannot be achieved via such a traditional machining process.

[95] The improvement in the hardness of the engaging bead (88) has been discovered to allow for a greater axial impingement (penetration) of the engaging bead (88) into the first seal portion (62) of the sealing element (60), which may be formed from a metallic material, in comparison to a similarly dimensioned engaging bead formed by such a cutting process, when exposed to similar circumstances. That is, a distance the engaging bead (88) is configured to axially penetrate the first seal portion (62) for a given axial load is greater for the punch-formed engaging bead (88) of the present invention than for an engaging bead formed by the described cutting or other machining process of the prior art, despite the ability to machine such a cut engaging bead to include a pointed end having a maximized sharpness (radius of curvature approaching zero). This increased impingement results in an increased sealing effect at the described junction.

[96] The increased hardness of the engaging bead (88) also results in an improvement in the service life of the block fitting assembly (1) due to the manner in which the hardened surfaces can be utilized again following a disassembly and reassembly of the components forming the block fitting assembly (1). That is, the seal engaging surface

(86) is not damaged by the process of engaging the tube (80) to the sealing element (60) as a result of the increased hardness of the tube (80) along the seal engaging surface (86), which facilitates the reengagement of the seal engaging surface (86) to the sealing element (60) (or a replacement sealing element (60)) without compromising the integrity of the seal formed therebetween.

[97] The radial dimension of the gap (630) present between the portions (601, 602) may be selected to impart the desired radius of curvature to the pointed end (95) of the V-shape of the engaging bead (88) while also allowing for the proper venting of the fluid(s) associated with the described manufacturing process. The radial dimension of the gap (630) may also be selected in accordance with a hardness of the material forming the tube (80) and/or the flow characteristics of the material forming the tube (80) during the described coining process.

[98] It has been discovered that a reduction in the dimension of the gap (630) corresponds to a reduction in the radius of curvature at the pointed end (95) of the engaging bead (88). This is implied as the ends of the inclined surfaces (93, 94) intersecting the surface forming the pointed end (95) of the engaging bead (88) are brought closer together via such a reduction in the dimension of the gap (630). It has also been discovered that as the material forming the tube (80) is selected to be relatively softer (referring to the softness of the material prior to deformation thereof), the radius of curvature of the engaging bead (88) is also reduced to correspond to an increasing sharpness thereof. This is believed to occur as a result of the improved ability of the material forming the tube (80) to flow towards the pointed end (95) of the engaging bead (88) in the manner described herein.

[99] Figs. 15 and 16 illustrate the relationships described hereinabove with reference to what is described as a region of "suitable" performance of the engaging bead (88) during use of the tube (80) with the block fitting assembly (1). The suitable performance referenced in the charts of Figs. 15 and 16 corresponds to the formation of the engaging bead (88) to include a pointed end (95) having radius of curvature that is equal to or less than 0.2 mm. Fig. 15 illustrates a suitable range of selections of the dimension of the radial gap (630) for achieving the suitable engaging bead (88) with respect to a variety of different tube tempers corresponding to tubes of differing hardness. In contrast, Fig. 16 illustrates a suitable range of selections of the dimension of the radial gap (630) for achieving the suitable engaging bead (88) with respect to differing viscosities of an oil that may be disposed between the seal engaging portion (85) and the surfaces of the inner and outer portions (601, 602) of the apparatus (600). One non-limiting range of values suitable for the radial dimension of the gap (630) is between and including 0.001 mm and 0.25 mm.

[100] Referring now to Fig. 17, a block assembly (101) according to another embodiment

of the invention is disclosed. The block assembly (101) includes a first block (110) and a tube (180) that are each modified in comparison to the first block (10) and the tube (80) of the block assembly (1). The second block (40), the sealing element (60), and the fastener assembly (70) of the seal fitting assembly (101) are identical to those disclosed with regards to the block assembly (1), hence further description is omitted.

[101] The first block (110) includes an annular projection (116) surrounding and partially defining a first opening (130) of the first block (110). The projection (116) includes a shoulder (122) formed by the cooperation of a radially extending surface (126) of the projection (116) and a surface of the first block (110) defining the first opening (130). The shoulder (122) may further include a chamfer (127) providing an annular frustoconical surface at the intersection of the radially extending surface (126) and the surface defining the first opening (130).

[102] The tube (180) may include a first segment (181), a second segment (182) angled relative to the first segment (181), and a bend portion (183) connecting the first segment (181) to the second segment (182) in similar fashion to the tube (80) of the block assembly (1). However, the tube (180) may alternatively be rectilinear in configuration without modifying the method disclosed hereinafter. The tube (180) is substantially identical to the tube (80) with the exception of a modification of an end portion of the first segment (181) configured to engage the projection (116) of the first block (110). The end portion of the first segment (181) is modified to define each of a seal engaging portion (185) and a piloting feature (192) of the first block (110). The seal engaging portion (185) extends radially outwardly to form a flanged portion of the tube (180) and the piloting portion (192) projects axially from a radial outermost portion of the seal engaging portion (185). The seal engaging portion (185) defines a seal engaging surface (186) of the tube (180) configured to engage the sealing element (60) when the first block (110) and the second block (40) are coupled to each other. The seal engaging surface (186) is disposed radially inwardly from the piloting feature (192) and includes each of the features described hereinabove with reference to the first seal engaging surface (86) of the tube (80) for applying the desired localized compressive forces to the sealing element (60). As shown by comparison of the block assembly (1) of Fig. 1 to the block assembly (101) of Fig. 17, the combination of the projection (116) and the tube (180) forms a male structural feature of the first block (110) having substantially the same shape and configuration as a male structural feature of the first block (10) formed by the combination of the projecting portion (16) and the tube (80).

[103] The block assembly (101) operates in similar fashion to the block assembly (1). The first block (110) is drawn towards the second block (40) via use of the fastener assembly (70) to compress the sealing element (60) between the seal engaging surface

(186) formed by the tube (180) and the seal engaging surface (56) formed by the second block (40).

[104] The block assembly (101) is also manufactured using substantially the same process as described hereinabove with reference to the block assembly (1), except the formation of the piloting feature (192) in addition to the seal engaging portion (185) may require additional deforming and machining processes to be performed on the end portion of the first segment (181) following reception of the first segment (181) within the first opening (130). Furthermore, a greater length of the end portion of the first segment (181) may extend outside of the first opening (130) to accommodate the additional material used to form the piloting feature (192) of the tube (180). The sealing surface (186) may be formed using the apparatus (600) as disclosed hereinabove, wherein the engaging bead(s) of the block assembly (101) are formed by the same process described hereinabove.

[105] Fig. 18 illustrates a first block (210) and a tube (280) of a block seal fitting assembly (201) according to yet another embodiment of the invention, wherein the first block (210) and the tube (280) are once again configured to cooperate with the second block (40), the sealing element (60), and the fastener assembly (70) as previously disclosed with reference to the block assembly (1) of Figs. 1 and 4.

[106] The first block (210) includes a first opening (230) extending axially therethrough. A shoulder (222) is formed at an intersection of a surface defining the first opening (230) and a substantially planar face (214) of the first block (210). The shoulder (222) may further include a chamfer (227) providing an annular frustoconical surface at the intersection of the planar face (214) and the surface defining the first opening (230). The tube (280) may include a first segment (281), a second segment (282) angled relative to the first segment (281), and a bend portion (283) connecting the first segment (281) to the second segment (282) in similar fashion to the tube (180) of the block assembly (101). However, the tube (280) may alternatively be rectilinear in configuration without modifying the method disclosed hereinafter. An end portion of the first segment (281) is deformed radially outwardly to form each of a seal engaging portion (285) having a seal engaging surface (286) and an axially projecting piloting feature (292). The end portion of the first segment (281) is accordingly substantially similar to the end portion of the first segment (181) except for the increased axial length of the end portion of the tube (280) used to form the entirety of a projecting portion of the tube (280) for reception within the second recess (54) of the second block (40).

[107] The tube (280) may once again be formed by substantially the same process as described with reference to the tubes (80, 180). However, as described with reference to the tube (180), the tube (280) may require a greater length of the first segment (281) thereof extended outside of the first opening (230) to accommodate the additional

material used to form the projecting portion of the tube (280). Furthermore, it should be understood that additional deforming and machining steps may be required for forming the additional contours of the end portion of the tube (280), as desired. Again, the apparatus (600) may be used to form the sealing surface (286) in similar fashion to that described herein, and especially with regards to the formation of any engaging bead(s) present within the block assembly (201).

[108] The block assemblies (101, 201) shown in Figs. 17 and 18 are accordingly representative of alternative configurations of the flanged end portion of the tube that may be utilized in conjunction with the described configuration of the second block (40), where each of the alternative configurations maintains the use of a hardened engaging bead formed by the same coining process described herein with regards to the apparatus (600). One skilled in the art should also appreciate that the block assemblies (101, 201) may be adapted or modified to include any of the shown or described features described hereinabove with reference to the block assembly (1), as desired, without departing from the scope of the present invention.

[109] The apparatus (600) is shown and described herein as including two portions (601, 602) that are concentrically arranged to form a single gap (630) corresponding to a single engaging bead (88), but it should be apparent that the general concepts of the invention may be repeated by repeating the disclosed structure with respect to the radial direction to introduce new and additional engaging beads. For example, a third concentric portion may be added with a second gap present between the second portion and the third portion in addition to a first gap present between the first and second portions. Each gap may correspond to the position of one of the pointed ends of one of the engaging beads. This structure can be repeated to form any number of concentrically arranged engaging beads as is desired.

[110] From the foregoing description, one ordinarily skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications to the invention to adapt it to various usages and conditions.

Claims

- [Claim 1] A block seal fitting assembly comprising:
a first block having a first opening formed therethrough;
a sealing element; and
a tube extending through the first opening of the first block, an end portion of the tube forming a seal engaging surface of the tube configured to sealingly engage the sealing element, the seal engaging surface including an annular engaging bead projecting axially therefrom, the engaging bead extending around a flow opening formed through the tube at the end portion thereof, wherein at least a portion of the engaging bead is work hardened by a coining process used to form the engaging bead in the end portion of the tube.
- [Claim 2] The block seal fitting assembly of Claim 1, wherein the coining process includes a compression of the material forming the tube to result in the at least the portion of the engaging bead being work hardened.
- [Claim 3] The block seal fitting assembly of Claim 1, wherein the engaging bead includes a first inclined surface facing towards the flow opening of the tube, a second inclined surface facing away from the flow opening of the tube, and a pointed end having a surface connecting the first inclined surface to the second inclined surface.
- [Claim 4] The block seal fitting assembly of Claim 3, wherein the at least the portion of the engaging bead that is work hardened by the coining process includes at least one of the first inclined surface thereof, the second inclined surface thereof, and the surface at the point end.
- [Claim 5] The block seal fitting assembly of Claim 3, wherein the first inclined surface is formed by a first bead forming surface deforming the end portion of the tube and the second inclined surface is formed by a second bead forming surface deforming the end portion of the tube, and wherein the forming of the first inclined surface includes at least a portion of the tube deforming along the first bead forming surface towards the pointed end of the engaging bead and wherein the forming of the second inclined surface includes at least a portion of the tube deforming along the second bead forming surface towards the pointed end of the engaging bead.
- [Claim 6] The block seal fitting assembly of Claim 3, wherein a radius of curvature of the surface formed at the pointed end of the engaging bead is less than or equal to 0.2 mm.

- [Claim 7] The block seal fitting assembly of Claim 1, wherein the sealing element includes a first seal portion formed from a metallic material, and wherein the engaging bead is configured to at least partially penetrate the first seal portion when the seal engaging surface of the tube is sealingly engaging the sealing element.
- [Claim 8] A coining apparatus for forming an engaging bead in an end portion of a tube, the apparatus comprising:
an inner portion including an outer circumferential surface, the outer circumferential surface including a first outer axially extending surface and a first bead forming surface intersecting the first outer axially extending surface, wherein the first bead forming surface is tapered inwardly towards a central axis of the inner portion as the first bead forming surface extends away from the first outer axially extending surface, and wherein the inner portion is configured to be movable axially towards the end portion of the tube for forming a first inclined surface of the engaging bead via a deformation of the end portion of the tube by the first bead forming surface; and
an outer portion including an inner circumferential surface including an inner axially extending surface and a second bead forming surface intersecting the inner axially extending surface, wherein the second bead forming surface is tapered outwardly away from the central axis of the inner portion as the second bead forming surface extends away from the inner axially extending surface, and wherein the outer portion is configured to be movable axially towards the end portion of the tube for forming a second inclined surface of the engaging bead via a deformation of the end portion of the tube by the second bead forming surface;
wherein the first outer axially extending surface of the inner portion faces outwardly towards the inner axially extending surface of the outer portion with a radially extending gap present therebetween.
- [Claim 9] The coining apparatus of Claim 8, wherein the radially extending gap is configured to vent a fluid disposed between the end portion of the tube and at least one of the first bead forming surface and/or the second bead forming surface.
- [Claim 10] The coining apparatus of Claim 9, wherein the fluid is at least one of air and/or oil.
- [Claim 11] The coining apparatus of Claim 8, wherein the radially extending gap is configured to receive a flow of the end portion of the tube therein when

- at least one of the first bead forming surface and/or the second bead forming surface is deforming the end portion of the tube.
- [Claim 12] The coining apparatus of Claim 11, wherein a pointed end of the engaging bead is formed at a radial position of the radially extending gap.
- [Claim 13] The coining apparatus of Claim 8, wherein an angle present between the first bead forming surface and the second bead forming surface is between 30 degrees and 120 degrees.
- [Claim 14] The coining apparatus of Claim 8, wherein the inner portion further includes a second outer axially extending surface extending from the first bead forming surface, wherein the second outer axially extending surface is configured for reception within a flow opening of the tube when the inner portion moves axially towards the end portion of the tube.
- [Claim 15] The coining apparatus of Claim 14, wherein the second outer axially extending surface includes a radially inwardly indented relief notch formed therein, the relief notch configured to receive a flow of the end portion of the tube therein during deformation thereof.
- [Claim 16] The coining apparatus of Claim 8, wherein the inner axially extending surface and the first outer axially extending surface are each cylindrical in shape and wherein the first bead forming surface and the second bead forming surface are each frustoconical in shape.
- [Claim 17] A method of coining an engaging bead into an end portion of a tube, the method comprising the steps of:
 providing a coining apparatus comprising:
 an inner portion including an outer circumferential surface, the outer circumferential surface including a first outer axially extending surface and a first bead forming surface intersecting the first outer axially extending surface, wherein the first bead forming surface is tapered inwardly towards a central axis of the inner portion as the first bead forming surface extends away from the first outer axially extending surface; and
 an outer portion including an inner circumferential surface including an inner axially extending surface and a second bead forming surface intersecting the inner axially extending surface, wherein the first bead forming surface is tapered outwardly away from the central axis of the inner portion as the second bead forming surface extends away from the inner axially extending surface;

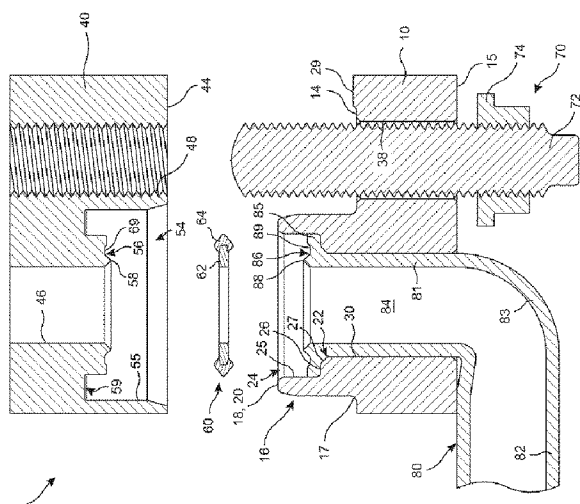
wherein the first outer axially extending surface of the inner portion faces outwardly towards the inner axially extending surface of the outer portion with a radially extending gap present therebetween; deforming the end portion of the tube to include a first inclined surface of the engaging bead when the inner portion is moved axially towards the end portion of the tube with the first bead forming surface engaging the end portion of the tube; and deforming the end portion of the tube to include a second inclined surface of the engaging bead when the outer portion is moved axially towards the end portion of the tube with the second bead forming surface engaging the end portion of the tube.

[Claim 18] The method of Claim 18, further comprising a step of venting a fluid through the radial gap during at least one of the deforming of the end portion of the tube to include the first inclined surface of the engaging bead and/or the deforming of the end portion of the tube to include the second inclined surface of the engaging bead.

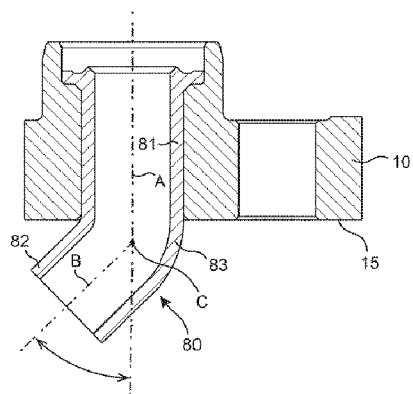
[Claim 19] The method of Claim 18, wherein the end portion of the tube flows towards the radial gap during at least one of the deforming of the end portion of the tube to include the first inclined surface of the engaging bead and/or the deforming of the end portion of the tube to include the second inclined surface of the engaging bead.

[Claim 20] The method of Claim 18, wherein a time offset is present between the steps of deforming the end portion of the tube to include the first inclined surface of the engaging bead and deforming the end portion of the tube to include the second inclined surface of the engaging bead.

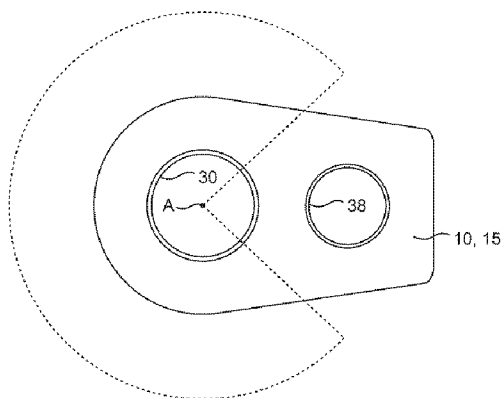
[Fig. 1]



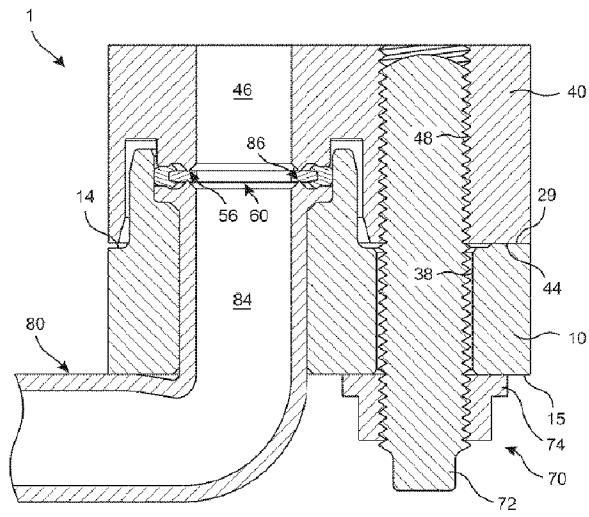
[Fig. 2]



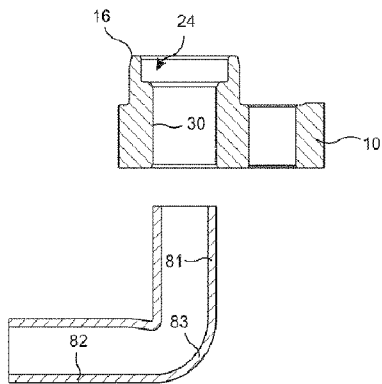
[Fig. 3]



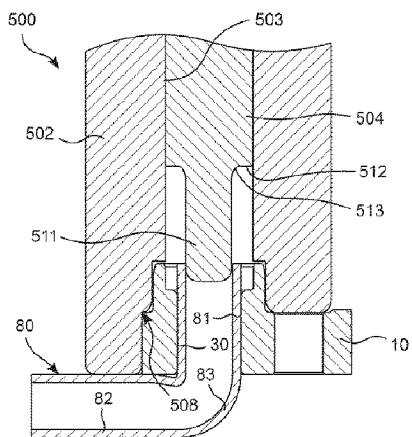
[Fig. 4]



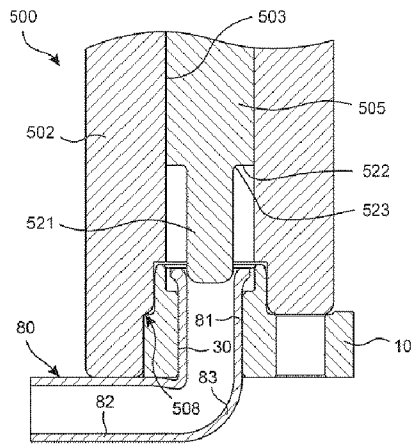
[Fig. 5]



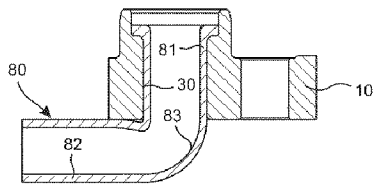
[Fig. 6]



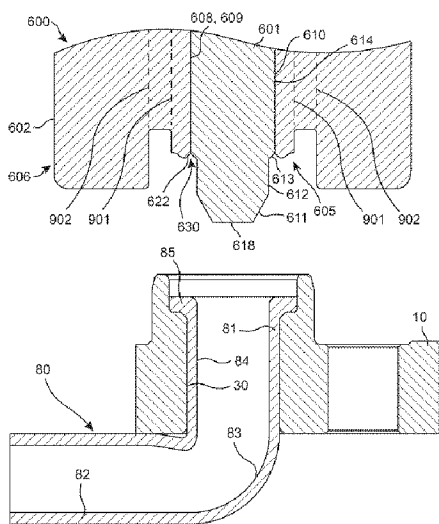
[Fig. 7]



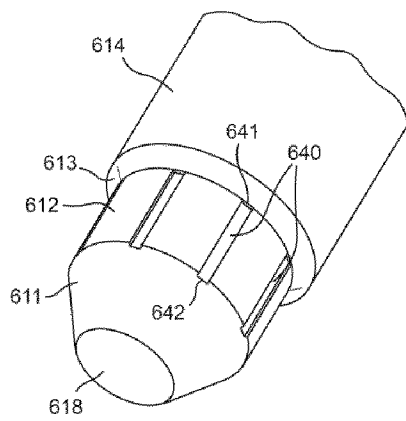
[Fig. 8]



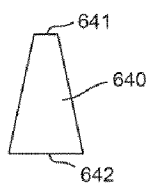
[Fig. 9]



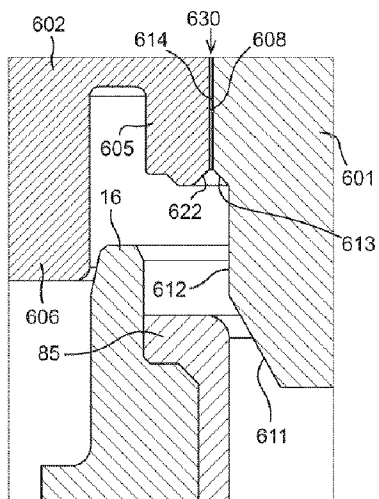
[Fig. 10]



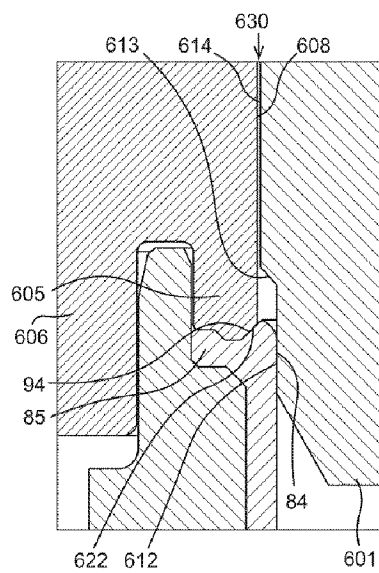
[Fig. 11]



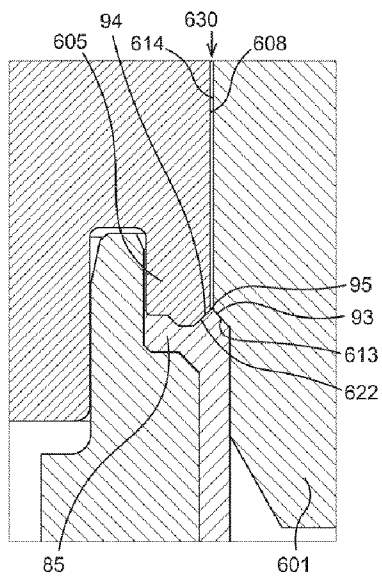
[Fig. 12]



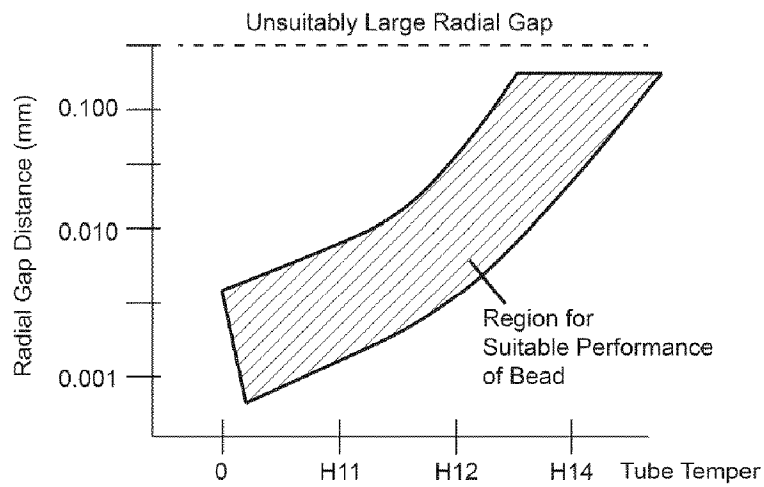
[Fig. 13]



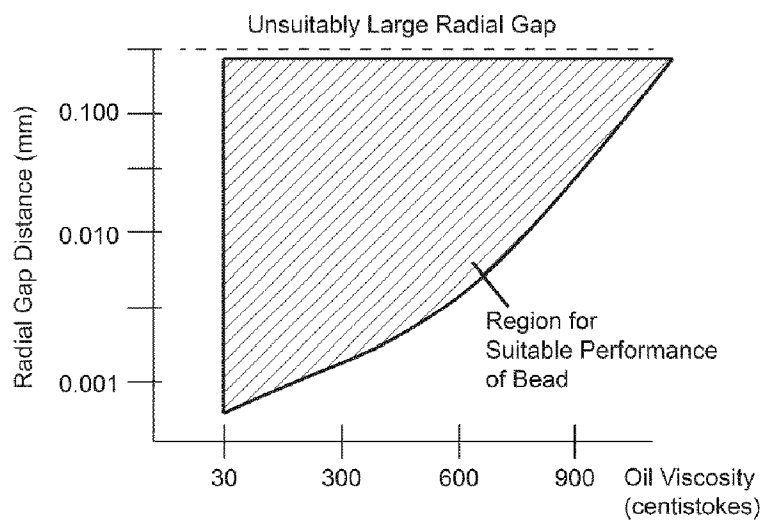
[Fig. 14]



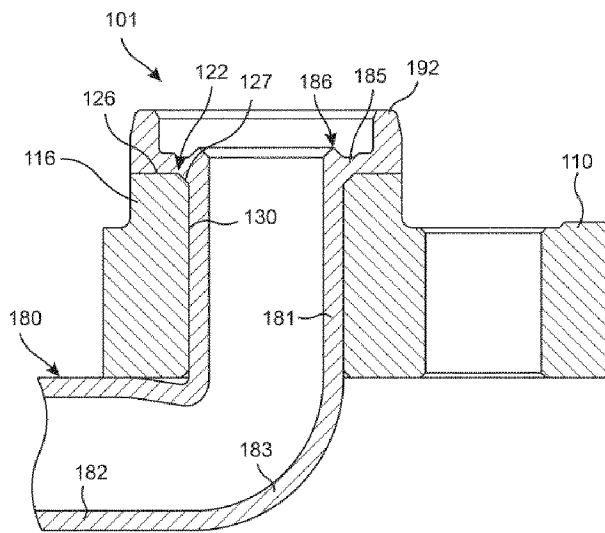
[Fig. 15]



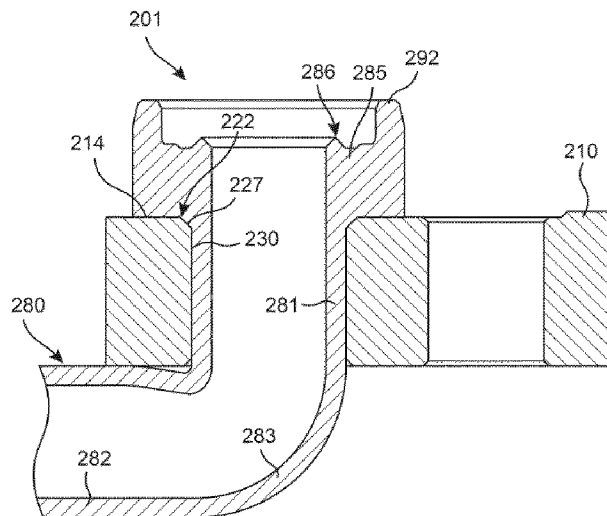
[Fig. 16]



[Fig. 17]



[Fig. 18]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/018391

A. CLASSIFICATION OF SUBJECT MATTER**F16L 33/18(2006.01)i; F16L 17/06(2006.01)i; F16L 1/06(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16L 33/18(2006.01); B21D 22/02(2006.01); B21D 28/32(2006.01); B21D 28/34(2006.01); B60H 1/00(2006.01);
F16L 19/02(2006.01); F16L 19/028(2006.01); F16L 23/02(2006.01); F16L 23/18(2006.01); F16L 41/06(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: fitting, sealing element, seal engaging surface, engaging bead, coining, first inclined surface, second inclined surface, inner portion, outer portion, gap, bead forming surface

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015-0233514 A1 (HALLA VISTEON CLIMATE CONTROL CORP.) 20 August 2015 (2015-08-20) paragraphs [0024]-[0032] and figures 1-3	1-7
A		8-20
Y	EP 0714489 B1 (ITT MANUFACTURING ENTERPRISES, INC.) 15 November 2000 (2000-11-15) paragraphs [0043]-[0045] and figures 1-7	1-7
A	US 2019-0232355 A1 (HA, JIN SANG) 01 August 2019 (2019-08-01) paragraphs [0041], [0053] and figures 5-6	1-20
A	JP 11-033635 A (PACIFIC IND. CO., LTD.) 09 February 1999 (1999-02-09) claim 1 and figure 1	1-20
A	KR 10-2010-0134499 A (HANON SYSTEMS) 23 December 2010 (2010-12-23) figures 1-6	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

07 March 2023

Date of mailing of the international search report

07 March 2023

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/018391**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

Group I: claims 1-7, drawn to a block seal fitting assembly.

Group II: claims 8-20, drawn to a coining apparatus and a method of coining an engaging bead.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2022/018391

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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				EP	2908040	B1	10 March 2021
				KR	10-1586567	B1	02 February 2016
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				CN	109844388	B	19 November 2021
				JP	2020-502434	A	23 January 2020
				JP	6920428	B2	18 August 2021
				KR	10-1757773	B1	14 July 2017
				WO	2018-074836	A1	26 April 2018
JP	11-033635	A	09 February 1999	JP	3517559	B2	12 April 2004
KR	10-2010-0134499	A	23 December 2010	None			