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### MALLEABLE PRESS FITTINGS

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#### Abstract

A method of connecting a pipe to a cast fitting, the method can include casting a body including a first body end and a second body end disposed opposite from the first body end, wherein the body defines an axis extending from the first body end to the second body end, wherein the body includes a first neck disposed proximate to the first body end wherein the body further includes an inner body surface defining a bore extending through the body from the first body end to the second body end, and wherein the body further includes an outer body surface spaced from the inner body surface a predetermined wall thickness.

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## **Background/Summary**

**CROSS-REFERENCE TO RELATED APPLICATIONS [0001]** This application is a continuation of U.S. patent application Ser. No. 17/461,612, filed Aug. 30, 2021, which is a continuation of U.S. patent application Ser. No. 17/165,067, filed Feb. 2, 2021, which is a divisional of U.S. patent application Ser. No. 15/852,462, filed Dec. 22, 2017, which issued into U.S. Pat. No. 11,060,652 on Jul. 13, 2021, which are each hereby incorporated in their entirety by reference.

### **TECHNICAL FIELD**

[0002] This disclosure relates to pipe fittings. More specifically, this disclosure relates to cast pipe fittings that can be press fit onto a pipe.

### **BACKGROUND**

[0003] Pipe fittings are commonly used to connect two pipe lengths together to form a pipe connection, such as when installing a pipe system or pipe infrastructure. Some pipe fittings can be time consuming or difficult to install. For example, some stab-in couplings require a pipe length to be stabbed into a socket. Some other pipe fittings require tightening of numerous bolts positioned around the pipe fitting. The bolts typically must be tightened in a pattern, such as a star pattern, to ensure that pressure from the bolts is evenly distributed over the pipe connection assembly to provide for a reliable and uniform seal. Additionally, many cast pipe fittings can be of poor structural integrity. If the defect in the casting is found early, these poor fittings can be repoured at the foundry. If the defect is not found early, the fitting can fail in use which can be dangerous and costly.

### **SUMMARY**

[0004] It is to be understood that this summary is not an extensive overview of the disclosure. This summary is exemplary and not restrictive, and it is intended to neither identify key or critical elements of the disclosure nor delineate the scope thereof. The sole purpose of this summary is to explain and exemplify certain concepts of the disclosure as an introduction to the following complete and extensive detailed description.

[0005] Disclosed is a cast body for a pipe fitting, the cast body comprising: a first body end and a second body end disposed opposite from the first body end, the body defining an axis extending from the first body end to the second body end, an inner body surface defining a fitting bore extending through the body from the first body end to the second body end; and an outer body surface spaced from the inner body surface at a predetermined wall thickness, wherein at a first location on the axis, the inner body surface is a first distance from the axis, wherein at a second location on the axis that is spaced from the first location and proximate to the first body end, the inner body surface is a second distance from the axis that is greater than the first distance, wherein at the first location, the outer body surface is a third distance from the axis, and wherein at the second location, the outer body surface is a fourth distance from the axis that is less than the third distance.

[0006] Also disclosed is a pipe connection assembly comprising: a fitting comprising: a cast body comprising a first body end and a second body end disposed opposite from the first body end,

wherein the body defines an axis extending from the first body end to the second body end, wherein the body further comprises an inner body surface defining a fitting bore extending through the body from the first body end to the second body end, wherein the body further comprises an outer body surface spaced from the inner body surface a predetermined wall thickness, and wherein a seal cavity is defined in a portion of the fitting bore, wherein at a first location on the axis, the inner body surface is a first distance from the axis and at a second location on the axis that is spaced from the first location, the inner body surface is a second distance from the axis that is greater than the first distance, and wherein at the first location, the outer body surface is a third distance from the axis and at the second location, the outer body surface is a fourth distance from the axis that is less than the third distance; at least one of a seal, a spacer, and a grip ring positioned in the seal cavity; and a pipe length having a pipe end insertable into the fitting bore.

[0007] Also disclosed is a method of connecting a pipe to a cast fitting, the method comprising: casting a body comprising: a first body end and a second body end disposed opposite from the first body end, wherein the body defines an axis extending from the first body end to the second body end, wherein the body comprises a first neck disposed proximate to the first body end, wherein the body further comprises an inner body surface defining a bore extending through the body from the first body end to the second body end, and wherein the body further comprises an outer body surface spaced from the inner body surface a predetermined wall thickness, wherein at a first location on the axis, the inner body surface is a first distance from the axis and at a second location on the axis that is spaced from the first location, the inner body surface is a second distance from the axis that is greater than the first distance, and wherein at the first location, the outer body surface is a third distance from the axis and at the second location, the outer body surface is a fourth distance from the axis that is less than the third distance.

[0008] Also disclosed is an unmachined cast body for a pipe fitting, the cast body comprising a first body end and a second body end disposed opposite from the first body end, the cast body defining an axis extending from the first body end to the second body end, the cast body defining a midpoint between first body end and the second body end, a centerline of the cast body defined at the midpoint perpendicular to the axis, a first distance from the centerline to the first body end being equal to a second distance from the centerline to the second body end, an inner body surface defining a fitting bore extending through the cast body from the first body end to the second body end, and an outer body surface spaced from the inner body surface, the outer body surface defining a first frustoconical shape and a second frustoconical shape, the first frustoconical shape intersecting the second frustoconical shape at the centerline, the outer body surface defining a groove between the centerline and the first body end, the first frustoconical shape extending between the centerline and the groove, the first frustoconical shape tapering inwards towards the axis as the first frustoconical shape extends from the centerline towards the groove, the cast body comprising a neck extending from the groove to the first body end, a portion of the outer body surface defined by the neck defining a cylindrical surface, the second frustoconical shape defined between the centerline and the second body end, the second frustoconical shape tapering inwards towards the axis as the second frustoconical shape extends towards the second body end, and wherein the inner body surface tapers inward toward the axis from the first body end.

[0009] Various implementations described in the present disclosure may include additional systems, methods, features, and advantages, which may not necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims. The features and advantages of such implementations may be realized and obtained by means of the systems, methods, features particularly pointed out in the appended claims. These and other features will become more fully apparent from the following description

## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The features and components of the following figures are illustrated to emphasize the general principles of the present disclosure. The drawings are not necessarily drawn to scale. Corresponding features and components throughout the figures may be designated by matching reference characters for the sake of consistency and clarity.

[0011] FIG. 1 is a perspective view of a cast fitting in which the fitting is a coupling in accordance with one aspect of the present disclosure, the fitting comprising a cast body.

[0012] FIG. 2 is a cross-sectional view of the cast fitting of FIG. 1 taken along line 2-2 shown in FIG. 1.

[0013] FIG. 3 is a cross-sectional view of the cast fitting of FIG. 1 showing portions of the cast fitting that can be machined away to form a machined fitting.

[0014] FIG. 4 is a cross-sectional view of the cast fitting of FIG. 1 after machining portions of the cast fitting to form a machined fitting.

[0015] FIG. 5 is a cross-sectional view of the machined fitting of FIG. 4 in which seal elements have been positioned in a seal cavity defined in the body of the fitting to form a fitting assembly.

[0016] FIG. 6 is a partial cross-section view of the fitting assembly of FIG. 5, also showing a press having a jaw in a first position relative to the fitting assembly.

[0017] FIG. 7 is a partial cross-section view of the fitting assembly of FIG. 5, also showing a press having a jaw in a second position relative to the fitting assembly.

[0018] FIG. 8 is an elevational view of a cast fitting in which the fitting is an elbow in accordance with one aspect of the present disclosure.

[0019] FIG. 9A is a cross-sectional view of the cast fitting of FIG. 8 taken along line 9-9 shown in FIG. 8.

[0020] FIG. 9B is a cross-sectional view of a cast fitting in which the fitting is a street elbow.

[0021] FIG. 9C is a cross-sectional view of a cast fitting in which the fitting is a 45 degree elbow.

[0022] FIG. 10 is a cross-sectional view of the cast fitting of FIG. 8 taken along line 10-10 shown in FIG. 8.

[0023] FIG. 11 is an elevational view of a cast fitting in which the fitting is a tee in accordance with one aspect of the present disclosure.

[0024] FIG. 12 is a cross-sectional view of the cast fitting of FIG. 11 taken along line 12-12 shown in FIG. 11.

[0025] FIG. 13 is a cross-sectional view of the cast fitting of FIG. 11 taken along line 13-13 shown in FIG. 11.

[0026] FIG. 14 is a cross-sectional view of the cast fitting of FIG. 11 taken along line 14-14 shown in FIG. 11.

[0027] FIG. 15 is a cross-sectional view of a cast fitting in which the fitting is a cross in accordance with one aspect of the present disclosure.

[0028] FIG. 16 is a cross-sectional view of a cast fitting in which the fitting is a cap in accordance with one aspect of the present disclosure.

[0029] FIG. 17 is a cross-sectional view of a cast fitting in which the fitting is a flanged adapter in accordance with one aspect of the present disclosure.

[0030] FIG. 18 is a cross-sectional view of a cast fitting in which the fitting is a second adapter in accordance with one aspect of the present disclosure.

[0031] FIG. 19 is a cross-sectional view of a cast fitting in which the fitting is a third adapter in

accordance with one aspect of the present disclosure.

[0032] FIG. **20** is a cross-sectional view of a cast fitting in which the fitting is a reducer in accordance with one aspect of the present disclosure.

[0033] FIG. **21** is a cross-sectional view of a cast fitting in which the fitting is a union in accordance with one aspect of the present disclosure.

[0034] FIG. **22** is a cross-sectional view of a cast fitting in which the fitting is a fourth adapter in accordance with one aspect of the present disclosure.

[0035] FIG. **23** is a cross-sectional view of a cast fitting in which the fitting is a fifth adapter in accordance with one aspect of the present disclosure.

#### DETAILED DESCRIPTION

[0036] The present disclosure can be understood more readily by reference to the following detailed description, examples, drawings, and claims, and the previous and following description. However, before the present devices, systems, and/or methods are disclosed and described, it is to be understood that this disclosure is not limited to the specific devices, systems, and/or methods disclosed unless otherwise specified, and, as such, can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting.

[0037] The following description is provided as an enabling teaching of the present devices, systems, and/or methods in its best, currently known aspect. To this end, those skilled in the relevant art will recognize and appreciate that many changes can be made to the various aspects of the present devices, systems, and/or methods described herein, while still obtaining the beneficial results of the present disclosure. It will also be apparent that some of the desired benefits of the present disclosure can be obtained by selecting some of the features of the present disclosure without utilizing other features. Accordingly, those who work in the art will recognize that many modifications and adaptations to the present disclosure are possible and can even be desirable in certain circumstances and are a part of the present disclosure. Thus, the following description is provided as illustrative of the principles of the present disclosure and not in limitation thereof.

[0038] As used throughout, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “an element” can include two or more such elements unless the context indicates otherwise.

[0039] Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

[0040] For purposes of the current disclosure, a material property or dimension measuring about X or substantially X on a particular measurement scale measures within a range between X plus an industry-standard upper tolerance for the specified measurement and X minus an industry-standard lower tolerance for the specified measurement. Because tolerances can vary between different materials, processes and between different models, the tolerance for a particular measurement of a particular component can fall within a range of tolerances.

[0041] As used herein, the terms “optional” or “optionally” mean that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0042] The word “or” as used herein means any one member of a particular list and also includes any combination of members of that list. Further, one should note that conditional language, such as, among others, “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain aspects include, while other aspects do not include, certain features, elements and/or steps. Thus,

such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more particular aspects or that one or more particular aspects necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular aspect.

[0043] Disclosed are components that can be used to perform the disclosed methods and systems. These and other components are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these components are disclosed that while specific reference of each various individual and collective combinations and permutation of these may not be explicitly disclosed, each is specifically contemplated and described herein, for all methods and systems. This applies to all aspects of this application including, but not limited to, steps in disclosed methods. Thus, if there are a variety of additional steps that can be performed it is understood that each of these additional steps can be performed with any specific aspect or combination of aspects of the disclosed methods.

[0044] Disclosed are malleable press fittings and associated methods, systems, devices, and various apparatus. The malleable press fitting can be a cast fitting comprising a body defining at least one body bore configured to receive a portion of a pipe therein. A body wall of the body can be a tapered wall such that a wall thickness of the body wall varies. The malleable press fitting can be a coupling, an elbow, a union, a nipple, a reducer, a tee, a cross, a cap, an adapter and the like. In one aspect, the malleable press fitting can be a metallic fitting comprising a ferrous material and formed from, for example and without limitation, cast iron, ductile iron, and the like. In other aspects, the malleable press fitting can be a polymeric fitting formed from, for example and without limitation, nylon, ABS, PVC, and the like. It would be understood by one of skill in the art that the disclosed malleable press fittings are described in but a few exemplary embodiments among many. No particular terminology or description should be considered limiting on the disclosure or the scope of any claims issuing therefrom.

[0045] FIG. 1 shows a perspective view of a malleable press cast fitting **100** in which the fitting is a coupling **110**, according to one aspect. The fitting **100** can comprise a cast body **112** having a first body end **112a** and a second body end **112b**. The first body end **112a** can be disposed opposite from the second body end **112b**, and the body **112** can define an axis **101** extending from the first body end **112a** to the second body end **112b**. Unless otherwise stated, all descriptions of radial and axial directions as used herein are relative to the axis **101** of the fitting **100**. The body **112** can comprise a first neck **120a** disposed proximate to the first body end **112a**, a second neck **120b** disposed proximate to the second body end **112b**, and a center portion **114** disposed between the first neck **120a** and the second neck **120b**. The body **112** can define a first shoulder **124a** between the center portion **114** and the first neck **120a** and a second shoulder **124b** between the center portion and the second neck **120b**. Each of the shoulders **124a,b** can extend radially inward from the center portion **114** to the adjacent neck **120a,b** with respect to the axis **101**.

[0046] The cast body **112** can define an inner body surface **140** and an outer body surface **142** spaced from the inner body surface **140** at a predetermined body thickness. In one aspect, the predetermined body thickness can be the thickness of a wall **144** of the fitting. The inner body surface **140** can define a fitting bore **118** extending through the body **112** from the first body end **112a** to the second body end **112b**. The fitting bore **118** can define a first bore opening **116a** (shown in FIG. 2) at the first body end **112a** and a second bore opening **116b** at the second body end **112b**. In the present aspect, the fitting body **112** can define a centerline **124** disposed substantially at a midpoint between the first body end **112a** and the second body end **112b**. The centerline **124** can divide the body **112** into a first portion **126a** defined between the centerline **124** and the first body end **112a** and a second portion **126b** defined between the centerline **124** and the second body end **112b**. In one aspect, the body **112** can be symmetric with respect to the centerline **124** such that the first portion **126a** is substantially a mirror image of the second portion **126b**. Alternatively, in other aspects, the body **112** can be asymmetric with respect to the centerline **124** such that the first

portion **126a** is different than the second portion **126b**.

[0047] FIG. 2 is a cross-sectional view of the malleable press cast fitting **100** of FIG. 1 taken along line 2-2 shown in FIG. 1. In one aspect, the inner body surface **140** can taper or slope from the centerline **124** towards the first body end **112a** and the second body end **112b**. In another aspect, at the centerline **124**, the inner body surface **140** can be a first distance **D1** from the axis **101**, and at the first body end **112a** and/or the second body end **112b**, the inner body surface can be a second distance **D2** from the axis that is greater than the first distance. That is, prior to machining of the casting **146** (i.e., the cast body **112**), the diameter of the first bore opening **116a** and the second bore opening **116b** can be greater than the diameter of the bore **118** at a position between the first bore opening and the second bore opening, such as, for example, at the centerline **124**. In another aspect, at least a portion of the inner body surface can be at an acute angle relative to the axis **101**. For example, at least a portion of the inner body surface extending between the first body end **112a** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the axis **101**. In another example, at least a portion of the inner body surface **140** extending between the second body end **112b** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the axis **101**.

[0048] As illustrated in FIG. 2, the taper or slope of the inner body surface **140** from the centerline **124** towards each of the first body end **112a** and the second body end **112b** can be substantially constant such that at least a portion of the inner body surface is substantially linear in cross-section from the centerline **124** to the first body end **112a** and from the centerline to the second body end **112b**. Thus, in the present aspect, the inner body surface **140** can define a first frustoconical shape that tapers from the first body end **112a** towards the centerline and a second frustoconical shape that tapers from the second body end **112b** towards the centerline. Alternatively, in other aspects, the slope of the inner body surface **140** from the centerline **124** towards each of the first body end **112a** and the second body end **112b** need not be substantially constant such that a portion of the inner body surface from the first body end to the centerline can have a different slope than at least one other portion of the inner body surface **140** from the first body end **112a** to the centerline. Optionally, at least a portion of the taper of the inner body surface **140** can be arcuate when viewed in cross-section. For example, at least a portion of the taper of the inner body surface **140** from the centerline **124** towards either of the first body end **112a** and the second body end **112b** can be arcuate when viewed in cross-section.

[0049] In one aspect, the outer body surface **142** can taper from the centerline **124** towards the first body end **112a** and the second body end **112b**. In another aspect, at the centerline **124**, the outer body surface can be a third distance **D3** from the axis **101**, and at the first body end **112a** and/or the second body end **112b**, the inner body surface can be a fourth distance **D4** from the axis that is less than the third distance. That is, prior to machining of the casting **146** (i.e., the cast body **112**), the outer diameter of the body **112** can be smaller at the first bore opening **116a** and the second bore opening **116b** than at a position between the first bore opening and the second bore opening, such as, for example, at the centerline **124**. In another aspect, at least a portion of the outer body surface can be at an acute angle relative to the axis **101**. For example, at least a portion of the outer body surface extending between the first body end **112a** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more

than about 15 degrees relative to the axis **101**. In another example, at least a portion of the outer body surface **140** extending between the second body end **112b** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the axis **101**.

[0050] As illustrated in FIG. 2, the taper or slope of the outer body surface **142** from the centerline **124** towards each of the first body end **112a** and the second body end **112b** can be substantially constant such that the outer body surface is substantially linear in cross-section from the centerline **124** to the first body end **112a** and from the centerline to the second body end **112b**. Thus, in the present aspect, the outer body surface **142** can define a first frustoconical shape that tapers from the centerline towards the first body end **112a** and a second frustoconical shape that tapers from the centerline towards the second body end **112b**. Alternatively, in other aspects, the slope from the centerline **124** towards each of the first body end **112a** and the second body end **112b** need not be substantially constant such that a portion of the outer body surface **142** from the first body end to the centerline can have a different slope than at least one other portion of the outer body surface from the first body end **112a** to the centerline. Optionally, at least a portion of the taper of the outer body surface **142** from the centerline towards each of the first body end **112a** and the second body end **112b** can be arcuate when viewed in cross-section.

[0051] In one aspect (not shown), the inner body surface **140** can taper or slope from the first body end **112a** and the second body end **112b** towards the centerline. In another aspect, at the centerline **124**, the inner body surface **140** can be a first distance from the axis **101**, and at the first body end **112a** and/or the second body end **112b**, the inner body surface can be a second distance from the axis that is less than the first distance. That is, the diameter of the first bore opening **116a** and the second bore opening **116b** can be less than the diameter of the bore **118** at the centerline **124**. Thus, in the present aspect, the inner body surface **140** can define a first frustoconical shape that tapers from the centerline towards the first body end **112a** and a second frustoconical shape that tapers from the centerline towards the second body end **112b**.

[0052] In another aspect (not shown), the outer body surface **142** can taper from the first body end **112a** and the second body end **112b** towards the centerline **124**. That is, at the centerline **124**, the outer body surface can be a third distance from the axis **101**, and at the first body end **112a** and/or the second body end **112b**, the inner body surface can be a fourth distance from the axis that is greater than the third distance. Thus, the outer diameter of the body **112** can be less at the centerline **124** than the outer diameter of the body at the first body end **112a** and the second body end **112b**. In the present aspect, the outer body surface **140** can define a first frustoconical shape that tapers from the first body end **112a** towards the centerline, and a second frustoconical shape that tapers from the second body end **112b** towards the centerline.

[0053] The inner body surface **140** and/or the outer body surface **142** need not slope for the entire distance from the centerline **124** towards the body ends **112a,b**. In one aspect, at a first location anywhere on the cast body **112**, the inner body surface can be the first distance **D1** from the axis **101** and at a second location on the body that is spaced from the first location, the inner body surface **140** can be the second distance **D2** from the axis that is greater than the first distance, and at the first location, the outer body surface can be the third distance **D3** from the axis **101** and at the second location, the outer body surface **142** can be the fourth distance **D4** from the axis that is less than the third distance. That is, in one aspect, the inner body surface can taper towards the outer body surface, and the outer body surface **142** can taper towards the inner body surface **140** at any predetermined first and second positions on the fitting. In another aspect, the amount of slope of the inner body surface **140** and the amount of slope of the outer body surface **142** can be different at different portions of the fitting **100**. For example, the slope of the inner body surface and the outer body surface relative to the axis **101** can be different at the first portion **126a** of the fitting than the



slope of the inner body surface **140** and the outer body surface **142** relative to the axis at the second portion **126b**.

[0054] In one aspect, the body **112** of the fitting **100** can be a cast body. In another aspect, the distance between the inner body surface **140** and the outer body surface **142** (i.e., the thickness of the fitting wall **144**) can be configured in a manner controlling the solidification of the molten metal during the casting process of the body **112**. In a further aspect, the taper of the inner body surface **140** and the outer body surface **142** can be configured in a manner controlling the solidification of the molten metal and yielding a sound cast fitting that meets a predetermined set of material properties. In a further aspect, during the casting process, the thicker portions of the wall **144** can be configured to form a reservoir of molten metal such that thinner portions of the wall **144** can draw molten metal from the reservoir during the solidification process. This reservoir can provide the additional liquid metal required to feed thinner portions of the wall **144**, thus controlling the solidification of the fitting **100** during the casting process and yielding a sound cast fitting.

[0055] For example, if the inner body surface **140** and/or the outer body surface **142** taper from the centerline **124** towards the first body end **112a** and the second body end **112b**, the wall **144** of the fitting can be relatively thinner adjacent the first body end **112a** and the second body end **112b** than a relatively thicker wall thickness adjacent the centerline. In one aspect, liquid metal can be poured into the mold through a feeder tube in fluid communication with the thicker wall portion of the fitting **100** adjacent the centerline **124**. As liquid metal is poured into the mold, the thinner wall portion can cool quicker than the relatively thicker wall portion adjacent the centerline. Because solid metal takes up less space in the mold than liquid metal, as this liquid metal solidifies in thinner portions of the wall **144** adjacent the first body end **112a** and the second body end **112b**, more liquid metal can be pulled from thicker portions of the wall adjacent the centerline, and thus, solidification of the metal used to form the fitting can be controlled.

[0056] In another example, if the inner body surface **140** and/or the outer body surface **142** taper from the first body end **112a** and the second body end **112b** towards the centerline **124**, the wall **144** of the fitting can be relatively thicker adjacent the first body end **112a** and the second body end **112b** than a relatively thinner wall thickness adjacent the centerline. In one aspect, liquid metal can be poured into the mold through at least one feeder tube in fluid communication with the thicker wall portion of the fitting **100** adjacent the first body end **112a** and the second body end **112b**. As liquid metal is poured into the mold, the thinner wall portion adjacent the centerline **124** can cool more quickly than the relatively thicker wall portion adjacent the first body end and the second body end. Because solid metal takes up less space in the mold than liquid metal, as this liquid metal solidifies in thinner portions of the wall **144** adjacent the centerline **124**, more liquid metal can be pulled from thicker portions of the wall adjacent the first body end **112a** and the second body end **112b**, and thus, solidification of the metal used to form the fitting can be controlled.

[0057] Still with reference to FIG. 2, at least one groove **150** can be defined in the outer body surface **142** of the fitting **100** by a groove surface **152** positioned at least partially in the wall **144** of the fitting. In one aspect, the at least one groove can comprise a plurality of grooves **150**, such that a first groove **150a** is positioned between the centerline **124** and the first body end **112a**, and a second groove **150b** is positioned between the centerline and the second body end **112b**. In another aspect, at least a portion of the groove surface of the first groove can form a portion of the first shoulder **124a**, and at least a portion of the groove surface **152** of the second groove can form a portion of the second shoulder **124b**.

[0058] FIG. 3 is a cross-sectional view of the cast body **112** of FIG. 2 showing portions of the cast body **112** that can be machined off to form the machined fitting **100**, according to one aspect. In this aspect, portions of the tapered inner body surface **140** can be machined away so that, as shown in FIG. 3, a machined wall **200** of the bore **118** can be substantially parallel to the axis **101** of the fitting. In this aspect, a step **206** can be formed that is positioned between the machined wall and

the unmachined portion of the inner body surface **140**. In another aspect, portions of the outer body surface **142** can be machined away so that a machined jaw engagement surface **202** can be formed on the first neck **120a** and the second neck **120b**. In still another aspect, portions of the inner body surface **142** can be machined away so that a seal cavity **204** can be defined in portions of the first neck **120a** and the second neck **120b**. FIG. **4** is a cross-sectional view of the cast body **112** of FIG. **2** after machining to form the machined fitting **100**.

[0059] FIG. **5** is a cross-sectional view of the machined fitting **100** of FIG. **4** with seal elements installed to form a fitting assembly. In one aspect, the seal elements can comprise at least one of a seal **300**, such as an O-ring and the like, a spacer **302** and a grip ring **304**. In use, described more fully below, the seal **300** can form a seal between the fitting **100** and a pipe inserted into the bore **118** of the fitting. The grip ring **304** can have a plurality of teeth configured to engage a portion of the pipe to prevent or restrict inadvertent removal of the pipe from the bore. The spacer **302** can be positioned between the seal **300** and the grip ring **304** to prevent or restrict inadvertent contact between the seal **300** and the grip ring **304**. For example, the seal **300** can be inserted into the seal cavity **204** of the body closest to the centerline **124** of the body **112** and the grip ring **304** can be inserted into the seal cavity closest to the first end **112a** or the second end **112b** of the body **112**. The spacer **302** can be positioned in the seal cavity **204** between the seal and the grip ring.

[0060] FIGS. **6** and **7** illustrate placement and securement of the first portion **126a** of the fitting assembly to a pipe **600**, according to one aspect. In use, an end **602** of the pipe can be inserted into the bore **118** of the fitting **100**. In one aspect, the end of the pipe **600** can be inserted through the first bore opening **116a** until the end **602** contacts the step **206**, which can prevent the pipe **600** from being inserted any further. A press **604** can be positioned around the first portion **126a** so that a jaw **606** of the press **604** is positioned around at least a portion of the jaw engagement surface **202** of the first neck **120a**. In one aspect, a side edge **608** of the jaw **606** can be substantially aligned with a portion of the groove surface **152** of the first groove **150a** (i.e., the portion of the groove surface that forms the first shoulder **124a**) so that the jaw **606** is in a desired position relative to the fitting **100**. With the jaw **606** in the desired position, the jaw **606** can be moved about and between a first position, in which a lower edge **610** of the jaw is spaced from the jaw engagement surface **202** of the fitting (as illustrated in FIG. **6**), and a second position, in which the jaw **606** contacts the jaw engagement surface **202** and urges the jaw engagement surface **202** towards the bore **118** (as illustrated in FIG. **7**).

[0061] In the second position, according to one aspect, the neck **120a** of the fitting **100** can be compressed so that the thickness of the wall **144** of the neck **120a** is less in the second position than the thickness of the wall of the neck **120a** before compression. This can cause a width of the neck to increase in the second position. For example, when compressed by the jaw **606**, portions of the wall **144** of the neck **120a** can be urged outward towards the ends of the fitting **100**. Similarly, when compressed by the jaw, portions of the wall of the neck **120a** can be urged inward towards the centerline **124** and/or into the groove **150a**. In the second position, compression of the neck **120a** can urge the seal **300** into a fluid-tight seal relative to the pipe **600**. Further, in the second position, at least a portion of the body **112** can be urged into contact with the pipe **600**.

[0062] To secure a pipe **600** to the second portion **126b** of the fitting **100**, the end **602** of the pipe **600** can be inserted through the second bore opening **116b** until the end contacts the step **206**, which can prevent the pipe **600** from being inserted any further. The press **604** can be positioned around the second portion **126b** so that the jaw **606** of the press **604** is positioned around at least a portion of the jaw engagement surface **202** of the second neck **120b**. In one aspect, the side edge **608** of the jaw **606** can be substantially aligned with a portion of the groove surface **152** of the second groove **150b** (i.e., the portion of the groove surface that forms the second shoulder **124b**) so that the jaw **606** is in a desired position relative to the fitting. With the jaw **606** in the desired position, the jaw **606** can be moved about and between the first position, in which a lower edge **610** of the jaw **606** is spaced from the jaw engagement surface **202** of the fitting **100**, and the second

position, in which the jaw **606** contacts the jaw engagement surface **202** and urges the jaw engagement surface **202** towards the bore **118**.

[0063] While the above description of the fitting **100** has been made with reference to a coupling **110**, the fitting **100** can comprise an elbow **210** as illustrated in FIGS. **8-10**. In one aspect, the elbow **210** can comprise the cast body **112** having the first body end **112a** and the second body end **112b** disposed opposite from the first body end **112a**. The body **112** can define the axis **101** extending from the first body end **112a** to the second body end **112b**. In one aspect, at least a portion of the axis **101** of the elbow **210** can be an arcuate axis. For example, the portion of the axis **101** adjacent the first body end **112a** can be at an axis angle of about 90 degrees relative to portion of the axis adjacent the second body end **112b**. Unless otherwise stated, all descriptions of radial and axial directions as used herein are relative to the axis **101** of the fitting. The body **112** can comprise the first neck **120a** disposed proximate to the first body end **112a**, the second neck **120b** disposed proximate to the second body end **112b**, and the center portion **114** disposed between the first neck **120a** and the second neck **120b**. The body **112** can define the first shoulder **124a** between the center portion **114** and the first neck **120a** and the second shoulder **124b** between the center portion and the second neck **120b**. Each of the shoulders **124a,b** can extend radially inward from the body **112** to the adjacent neck **120a,b** with respect to the axis **101**.

[0064] The cast body **112** of the elbow **210** can define the inner body surface **140** and the outer body surface **142** spaced from the inner body surface a predetermined body thickness. In one aspect, the predetermined body thickness can be the thickness of the wall **144** of the elbow. The inner body surface **140** can define the fitting bore **118** extending through the body **112** from the first body end **112a** to the second body end **112b**. The fitting bore **118** can define the first bore opening **116a** at the first body end **112a** and the second bore opening **116b** at the second body end **112b**.

[0065] In the present aspect, the cast body **112** can define the centerline **124** disposed substantially at a midpoint between the first body end **112a** and the second body end **112b**. The centerline **124** can divide the body **112** into the first portion **126a** defined between the centerline **124** and the first body end **112a** and the second portion **126b** defined between the centerline **124** and the second body end **112b**.

[0066] FIG. **9a** is a cross-sectional view of the cast body **112** of the elbow **210** of FIG. **8** taken along line **9-9** shown in FIG. **8**. In one aspect, the inner body surface **140** can taper from the centerline **124** towards the first body end **112a** and the second body end **112b**. In another aspect, at the centerline **124**, the inner body surface **140** can be a first distance **D1** from the axis **101**, and at the first body end **112a** and/or the second body end **112b**, the inner body surface can be a second distance **D2** from the axis that is greater than the first distance. That is, prior to machining of the fitting **100**, the diameter of the first bore opening **116a** and the second bore opening **116b** can be greater than the diameter of the bore **118** at a position between the first bore opening and the second bore opening, such as, for example, at the centerline **124**. In another aspect, at least a portion of the inner body surface can be at an acute angle relative to the axis **101**. For example, at least a portion of the inner body surface extending between the first body end **112a** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the axis **101**. In another example, at least a portion of the inner body surface **140** extending between the second body end **112b** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the axis **101**. In one aspect, at least a portion of the taper of the inner body surface **140** from the centerline towards each

of the first body end **112a** and the second body end **112b** can be arcuate when viewed in cross-section.

[0067] In one aspect, the outer body surface **142** can taper or slope from the centerline **124** towards the first body end **112a** and the second body end **112b**. In another aspect, at the centerline **124**, the outer body surface can be a third distance **D3** from the axis **101**, and at the first body end **112a** and/or the second body end **112b**, the inner body surface can be a fourth distance **D4** from the axis that is less than the third distance. That is, prior to machining, the outer diameter of the body **112** can be smaller at the first body end **112a** and the second body end **112b** than at a position between the first body end and the second body end, such as, for example, at the centerline. In another aspect, at least a portion of the outer body surface can be at an acute angle relative to the axis **101**. For example, at least a portion of the outer body surface extending between the first body end **112a** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the axis **101**. In another example, at least a portion of the outer body surface **140** extending between the second body end **112b** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the axis **101**. In one aspect, at least a portion of the taper of the outer body surface **142** from the centerline towards each of the first body end **112a** and the second body end **112b** can be arcuate when viewed in cross-section.

[0068] The first distance **D1** from the inner body surface **140** to the axis **101** and/or the third distance **D3** from the outer body surface **142** to the axis **101** can vary at different points around the circumference of the bore **118** of the elbow **210**. In one aspect, the first distance **D1** from the axis to the inner body surface located on an inside bend **212** of the elbow can be greater than or less than the first distance from the axis **101** to the inner body surface **140** located on an outside bend **214** of the elbow **210**. Optionally, however, the first distance from the axis to the inner body surface located on the inside bend of the elbow can be substantially equal to the first distance from the axis **101** to the inner body surface **140** located on an outside bend of the elbow **210**. In another aspect, the third distance **D3** from the axis to the outer body surface **142** located on an inside bend **212** of the elbow can be greater than or less than the third distance from the axis **101** to the outer body surface located on an outside bend **214** of the elbow **210**. Optionally, however, the third distance from the axis to the outer body surface located on the inside bend of the elbow can be substantially equal to the third distance from the axis **101** to the outer body surface **142** located on an outside bend **214** of the elbow **210**.

[0069] FIG. **10** is a cross-sectional view of the elbow **210** of FIG. **8** taken along line **10-10** shown in FIG. **8**. In one aspect, in cross-section, the shape formed by the inner body surface **140** can be offset from the shape formed by the outer body surface **142**. For example, if the inner body surface **140** and the outer body surface **142** forms circles when viewed in cross-section, the circles can be eccentric circles having different geometric centers. That is, the center of the circle formed by the inner body surface **140** can be offset from the center of the circle formed by the outer body surface **142** by a fifth distance **D5**.

[0070] In use, as described above with regards to the general fitting **100**, portions of the cast body **112** of the elbow **210** can be machined off to form the fitting, according to one aspect. The seal **300**, spacer **302**, and grip ring **304** can be positioned in the seal cavities of the body **112** of the elbow. The jaw **606** can be positioned in the desired position relative to the jaw engagement surface **202** of the elbow **210**, and moved from the first position to the second position to urge the jaw engagement surface **202** towards the bore **118** and secure the elbow **210** to the pipe **600**.

[0071] FIG. 9B is a cross-sectional view of a street elbow **220** similar to the elbow **210** of FIG. 8. According to one aspect, the street elbow can be substantially the same as the elbow **210** except that the second shoulder **124b** and the second groove **150b** are not formed on the second portion **126b** of the street elbow **220**. FIG. 9C is a cross-sectional view of a 45 degree elbow **230** similar to the elbow **210** of FIG. 8 taken along line 9-9. According to one aspect, the 45 degree elbow can be substantially the same as the elbow **210** except that a portion of the axis **101** adjacent the first body end **112a** can be at an axis angle of about 45 degrees relative to a portion of the axis adjacent the second body end **112b**. Of course, other axis angles between the portion of the axis **101** adjacent the first body end relative to the portion of the axis adjacent the second body end **112b** are contemplated. For example, the axis angle can be any angle between 0 and 90 degrees, such as for example and without limitation, 15, 30, 60 and 75 degrees.

[0072] While the above description of the fitting **100** has been made with reference to a coupling **110** and an elbow **210**, the fitting **100** can comprise a tee **310** as illustrated in FIGS. 11-14. In one aspect, the tee **310** can comprise the cast body **112** having the first body end **112a**, the second body end **112b**, and a third body end **112c**. The first body end **112a** can be disposed opposite from the second body end **112b**, and the body **112** can define a first axis **101a** extending from the first body end **112a** to the second body end **112b**. The third body end **112c** can be positioned between the first body end **112a** and the second body end **112b**, and the body **112** can define a second axis **101b** extending transversely from the first axis **101a** to the third body end **112c**. Unless otherwise stated, all descriptions of radial and axial directions as used herein are relative to the axis of the fitting.

[0073] The cast body **112** of the tee **310** can comprise the first neck **120a** disposed proximate to the first body end **112a**, the second neck **120b** disposed proximate to the second body end **112b**, and a third neck **120c** disposed proximate to the third body end **112c**. The center portion **114** can be disposed between the first neck **120a**, the second neck **120b** and the third neck **120c**. The body **112** can define the first shoulder **124a** between the center portion **114** and the first neck **120a**, the second shoulder **124b** between the center portion **114** and the second neck **120b** and a third shoulder **124c** between the center portion **114** and the third neck **120c**. Each of the shoulders **124a,b,c** can extend radially inward from the body **112** to the adjacent neck **120a,b,c** relative to the respective first axis **101a** or second axis **101b**.

[0074] The cast body **112** of the tee **310** can define the inner body surface **140** and the outer body surface **142** spaced from the inner body surface **140** at a predetermined body thickness. In one aspect, the predetermined body thickness can be the thickness of the wall **144** of the tee **310**. The inner body surface **140** can define the fitting bore **118** extending through the body **112** from the first body end **112a** to the second body end **112b** and to the third body end **112c**. The fitting bore can define the first bore opening **116a** at the first body end **112a**, the second bore opening **116b** at the second body end **112b**, and a third bore opening **116c** at the third body end **112c**.

[0075] In the present aspect, the fitting body **112** can define the centerline **124** disposed substantially at a midpoint between the first body end **112a** and the second body end **112b**. The centerline **124** can divide the body **112** into the first portion **126a** defined between the centerline **124** and the first body end **112a** and the second portion **126b** defined between the centerline **124** and the second body end **112b**.

[0076] FIG. 12 is a cross-sectional view of the cast body **112** of the tee **310** of FIG. 11 taken along line 12-12 shown in FIG. 11. In one aspect, the inner body surface **140** can taper or slope from the centerline **124** towards the first body end **112a** and the second body end **112b**. In another aspect, at the centerline **124**, the inner body surface **140** can be a first distance D1 from the first axis **101a**, and at the first body end **112a** and/or the second body end **112b**, the inner body surface can be a second distance D2 from the first axis that is greater than the first distance. That is, prior to machining, the diameter of the first bore opening **116a** and the second bore opening **116b** can be greater than the diameter of the bore **118** at a position between the first bore opening and the second bore opening, such as, for example, at the centerline **124**.

[0077] In another aspect, at least a portion of the inner body surface **140** can be at an acute angle relative to the first axis **101a**. For example, at least a portion of the inner body surface **140** extending between the first body end **112a** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the first axis **101a**. In another example, at least a portion of the inner body surface **140** extending between the second body end **112b** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the first axis **101a**.

[0078] As illustrated in FIG. **12**, the taper or slope of the inner body surface **140** from the centerline **124** towards each of the first body end **112a** and the second body end **112b** can be substantially constant such that at least a portion of the inner body surface **140** is substantially linear in cross-section from the centerline **124** to the first body end **112a** and from the centerline to the second body end **112b**. Thus, in the present aspect, the inner body surface **140** can define a first frustoconical shape that tapers from the first body end **112a** towards the centerline and a second frustoconical shape that tapers from the second body end **112b** towards the centerline.

Alternatively, in other aspects, the slope from the centerline **124** towards each of the first body end **112a** and the second body end **112b** need not be substantially constant such that a portion of the inner body surface **140** from the first body end to the centerline can have a different slope than at least one other portion of the inner body surface from the first body end **112a** to the centerline.

Optionally, at least a portion of the taper from the centerline **124** towards each of the first body end **112a** and the second body end **112b** can be arcuate when viewed in cross-section.

[0079] In one aspect, the outer body surface **142** can taper or slope from the centerline **124** towards the first body end **112a** and the second body end **112b**. In another aspect, at the centerline **124**, the outer body surface **142** can be a third distance **D3** from the first axis **101a**, and at the first body end **112a** and/or the second body end **112b**, the outer body surface **142** can be a fourth distance **D4** from the first axis that is less than the third distance. That is, prior to machining, the outer diameter of the body **112** can be smaller at the first body end **112a** and the second body end **112b** than at a position between the first body end and the second body end, such as, for example, at the centerline **124**.

[0080] In another aspect, at least a portion of the outer body surface **142** can be at an acute angle relative to the first axis **101a**. For example, at least a portion of the outer body surface extending between the first body end **112a** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the first axis **101a**. In another example, at least a portion of the outer body surface **140** extending between the second body end **112b** and the centerline **124** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the first axis **101a**.

[0081] As illustrated in FIG. **12**, the taper or slope of the outer body surface **142** from the centerline **124** towards each of the first body end **112a** and the second body end **112b** can be substantially constant such that at least a portion of the outer body surface is substantially linear in cross-section from the centerline **124** to the first body end **112a** and from the centerline to the second body end **112b**. Thus, in the present aspect, the outer body surface **142** can define a first frustoconical shape

that tapers from the centerline towards the first body end **112a** and a second frustoconical shape that tapers from the centerline towards the second body end **112b**. Alternatively, in other aspects, the taper from the centerline **124** towards each of the first body end **112a** and the second body end **112b** need not be substantially constant such that a portion of the outer body surface **142** from the first body end to the centerline can have a different slope than at least one other portion of the outer body surface from the first body end **112a** to the centerline. Optionally, at least a portion of the taper from the centerline towards each of the first body end **112a** and the second body end **112b** can be arcuate when viewed in cross-section.

[0082] FIG. **13** is a cross-sectional view of the tee **310** of FIG. **11** taken along line **13-13** shown in FIG. **11**. In one aspect, the inner body surface **140** can taper from a plane containing the first axis **101a** towards the third body end **112c**. In another aspect, at the intersection of the first axis **101a** and the centerline **124**, the inner body surface **140** can be a fifth distance **D5** from the second axis **101b**, and at the third body end **112c**, the inner body surface can be a sixth distance **D6** from the second axis that is greater than the fifth distance. That is, prior to machining, the diameter of the third bore opening **116c** can be greater than the diameter of the bore **118** at the intersection of the first axis **101a** and the centerline **124**. In another aspect, at least a portion of the inner body surface can be at an acute angle relative to the second axis **101b**. For example, at least a portion of the inner body surface **140** extending between the third body end **112c** and the plane containing the first axis **101a** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the second axis **101b**.

[0083] As illustrated in FIG. **13**, the taper or slope of the inner body surface **140** towards the third body end **112c** can be substantially constant such that at least a portion of the inner body surface **140** is substantially linear in cross-section. Thus, in the present aspect, the inner body surface **140** can define a first frustoconical shape that tapers from the third body end **112c** towards the first axis **101a**. Alternatively, in other aspects, the taper towards the third body end **112c** need not be substantially constant such that a portion of the inner body surface **140** can have a different slope than at least one other portion of the inner body surface **140** adjacent the third body end **112c**. Optionally, at least a portion of the taper of the inner body surface **140** towards the third body end **112c** can be arcuate when viewed in cross-section.

[0084] In one aspect, the outer body surface **142** of the tee **310** can taper or slope from a plane containing the first axis **101a** towards the third body end **112c**. In another aspect, at the intersection of the first axis **101a** and the centerline **124**, the outer body surface **142** can be a seventh distance **D7** from the second axis **101b**, and at the third body end **112c**, the outer body surface **142** can be an eighth distance **D8** from the second axis that is greater than the seventh distance. Thus, prior to machining, the outer diameter of the body **112** can be greater at the intersection of the first axis **101a** and the centerline **124** than the outer diameter of the body at the third body end **112c**. In another aspect, at least a portion of the outer body surface **142** can be at an acute angle relative to the second axis **101b**. For example, at least a portion of the outer body surface extending between the third body end **112c** and a plane containing the first axis **101a** can be at an angle of less than about 1 degree, about 1 degree, about 2 degrees, about 3 degrees, about 4 degrees, about 5 degrees, about 6 degrees, about 7 degrees, about 8 degrees, about 9 degrees, about 10 degrees, about 11 degrees, about 12 degrees, about 13 degrees, about 14 degrees, about 15 degrees, or more than about 15 degrees relative to the second axis **101b**.

[0085] As illustrated in FIG. **13**, the taper or slope of the outer body surface **142** towards the third body end **112c** can be substantially constant such that at least a portion of the outer body surface **142** is substantially linear in cross-section. Thus, in the present aspect, the outer body surface **142** can define a frustoconical shape that tapers towards the third body end **112c**. Alternatively, in other aspects, the taper towards the third body end **112c** need not be substantially constant such that a

portion of the outer body surface **142** can have a different slope than at least one other portion of the outer body surface **142** adjacent the third body end **112c**. Optionally, at least a portion of the taper of the outer body surface **142** towards the third body end **112c** can be arcuate when viewed in cross-section.

[0086] The fifth distance **D5** from the inner body surface **140** to the second axis **101b** and/or the seventh distance **D7** from the outer body surface **142** to the second axis **101b** can vary at different points around the circumference of the bore **118** of the tee **310**. In one aspect, the fifth distance **D5** from the second axis **101b** to the inner body surface **142** located on an inside bend **212** of the tee can be greater than or less than the fifth distance **D5** from the second axis **101b** to the inner body surface **140** located at other portions of the tee. Optionally, however, the fifth distance **D5** from the second axis **101b** to the inner body surface **140** located on the inside bend of the tee **310** can be substantially equal to the fifth distance **D5** located at other portions of the tee **310**. In another aspect, the seventh distance **D7** from the second axis to the outer body surface located on an inside bend **212** of the tee **310** can be greater than or less than the seventh distance **D7** from the second axis **101b** to the outer body surface **142** located at other portions of the tee. Optionally, however, the seventh distance **D7** from the second axis **101b** to the outer body surface **142** located on the inside bend of the elbow can be substantially equal to the seventh distance **D7** located at other portions of the tee **310**.

[0087] As can be seen in FIG. **13**, in cross-section, the shape formed by the inner body surface **140** can be offset from the shape formed by the outer body surface **142**. For example, if the inner body surface **140** and the outer body surface **142** forms partial circles when viewed in cross-section, the circles can be eccentric circles having different geometric centers. That is, the center of the partial circle formed by the inner body surface can be offset from the center of the partial circle formed by the outer body surface by a ninth distance **D9**.

[0088] FIG. **14** is a cross-sectional view of the cast body **112** of FIG. **11** after portions of the cast body **112** have been machined off to form the machined fitting, according to one aspect and as described above. In use, the seal **300**, spacer **302** and grip ring **304** can be positioned in the seal cavities of the body **112** of the tee **310**. The jaw **606** can be positioned in the desired position relative to the jaw engagement surface **202** of the tee **310** and moved from the first position to the second position to urge the jaw engagement surface **202** towards the bore **118** and secure the tee **310** to a pipe **600**.

[0089] FIGS. **15-23** illustrate the casting **146** cross-sectional profile of various other fittings **100**. FIG. **15** is a cross-sectional profile of the casting **146** of a cross **410**, according to one aspect. In this aspect, the cross **410** can be similar to the tee **310** described above with the addition of a fourth body end **112d** disposed opposite from the third body end **112c**, a fourth neck **120d** disposed proximate to the fourth body end **112d** and the center portion **114** disposed between the first neck **120a**, the second neck **120b**, the third neck **120c** and the fourth neck. The body **112** of the cross **410** can define the fourth shoulder **124d** between the center portion and the fourth neck **120d**, and the bore **118** can define a fourth bore opening **116d** at the fourth body end **112d**. A fourth groove **150d** can be positioned between the centerline **124** and the fourth body end **112d**.

[0090] FIG. **16** is a cross-sectional profile of the casting **146** of a cap **510**, according to one aspect. In this aspect, the cap **510** can be similar to a portion of the coupling **110** described above. The cap **510**, however, can have a covered second bore opening **116b** to prevent fluid from flowing through the bore **118**.

[0091] FIG. **17** is a cross-sectional profile of the casting **146** of a flanged adapter **612**, according to one aspect. In this aspect, the flanged adapter **612** can be similar to a portion of the coupling **110** described above. The flanged adapter **612**, however, can have a flange **614** defining a plurality of mounting holes **616**. The second body end **112b** can be configured to abut a surface (and not necessarily configured to couple to a pipe).

[0092] FIG. **18** is a cross-sectional profile of the casting **146** of a second adapter **710**, according to



one aspect. In this aspect, the fitting **100** does not have the second shoulder **124b** and the second groove **150b** formed on the second portion **126b** of the second adapter. Note also that the first distance **D1**, the second distance **D2**, the third distance **D3** and the fourth distance **D4** can be different at each portion of the second adapter **710**. That is, the amount of taper or slope of the inner body surface **140**, and the amount of taper or slope of the outer body surface **142** can be different at different portions of the second adapter **710**.

[0093] FIG. **19** is a cross-sectional profile of the casting **146** of a third adapter **810**, according to another aspect. In this aspect, the fitting **100** does not have the second shoulder **124b** and the second groove **150b** formed on the second portion **126b** of the third adapter. Note also that the first distance **D1**, the second distance **D2**, the third distance **D3** and the fourth distance **D4** can be different at each portion of the third adapter **810**. That is, the amount of taper or slope of the inner body surface **140**, and the amount of taper or slope of the outer body surface **142** can be different at different portions of the third adapter **810**.

[0094] FIG. **20** is a cross-sectional profile of the casting **146** of a reducer **910**, according to another aspect. In this aspect, the fitting **100** does not have the second shoulder **124b** and the second groove **150b** formed on the second portion **126b** of the reducer. Note also that the first distance **D1**, the second distance **D2**, the third distance **D3** and the fourth distance **D4** can be different at each portion of the reducer **910**. That is, the amount of taper or slope of the inner body surface **140**, and the amount of taper or slope of the outer body surface **142** can be different at different portions of the reducer **910**.

[0095] FIG. **21** is a cross-sectional profile of the casting **146** of two sections of a union **1010**, according to one aspect. In this aspect, a first section **1012** of the union **1010** can be spaced from a second section **1014** of the union **1010**. Each of the first section **1012** and the second section **1014** can have at least one groove **150** defined therein. In one aspect, each of the first section **1012** and the second section **1014** can have the tapered inner body surface **140** and the tapered outer body surface **142**. In another aspect, at least a portion of the slope of the inner body surface **140** of the first section **1012** can be greater than, less than, or substantially the same as the slope of the inner body surface **140** of the second section **1014**. In a further aspect, at least a portion of the slope of the outer body surface **142** of the first section **1012** can be greater than, less than, or substantially the same as the slope of the outer body surface **142** of the second section **1014**. In a further aspect, the amount of taper or slope of the inner body surface **140** and the amount of taper or slope of the outer body surface **142** can be different at different portions of the union **1010**.

[0096] FIG. **22** is a cross-sectional profile of the casting **146** of a fourth adapter **1110**, according to another aspect. In this aspect, the fitting **100** does not have the second shoulder **124b** and the second groove **150b** formed on the second portion **126b** of the fourth adapter. Note also that the first distance **D1**, the second distance **D2**, the third distance **D3** and the fourth distance **D4** can be different at each portion of the fourth adapter **1110**. That is, the amount of taper or slope of the inner body surface **140** and the amount of taper or slope of the outer body surface **142** can be different at different portions of the fourth adapter **1110**.

[0097] FIG. **23** is a cross-sectional profile of the casting **146** of a fifth adapter **1210**, according to another aspect. In this aspect, the fitting **100** does not have the second shoulder **124b** and the second groove **150b** formed on the second portion **126b** of the fifth adapter **1210**. Note also that the first distance **D1**, the second distance **D2**, the third distance **D3** and the fourth distance **D4** can be different at each portion of the fifth adapter **1210**. That is, the amount of taper or slope of the inner body surface **140** and the amount of taper or slope of the outer body surface **142** can be different at different portions of the fifth adapter **1210**.

[0098] One should note that conditional language, such as, among others, “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally

intended to imply that features, elements and/or steps are in any way required for one or more particular embodiments or that one or more particular embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment.

[0099] It should be emphasized that the above-described embodiments are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Any process descriptions or blocks in flow diagrams should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included in which functions may not be included or executed at all, may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the present disclosure. Further, the scope of the present disclosure is intended to cover any and all combinations and sub-combinations of all elements, features, and aspects discussed above. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure.

## Claims

1. A method of connecting a pipe to a cast fitting, the method comprising: casting a body comprising: a first body end and a second body end disposed opposite from the first body end, wherein the body defines an axis extending from the first body end to the second body end, wherein the body comprises a first neck disposed proximate to the first body end wherein the body further comprises an inner body surface defining a bore extending through the body from the first body end to the second body end, and wherein the body further comprises an outer body surface spaced from the inner body surface a predetermined wall thickness, wherein at a first location on the axis, the inner body surface is a first distance from the axis and at a second location on the axis that is spaced from the first location, the inner body surface is a second distance from the axis that is greater than the first distance, and wherein at the first location, the outer body surface is a third distance from the axis and at the second location, the outer body surface is a fourth distance from the axis that is less than the third distance.
2. The method of claim 1, further comprising machining a portion of the inner body surface of the first neck to define a seal cavity in the first neck and machining a portion of the outer body surface of the first neck to form a jaw engagement surface on the first neck.
3. The method of claim 2, further comprising positioning at least one of a seal, a spacer and a grip ring positioned in the seal cavity.
4. The method of claim 3, further comprising providing a press having a jaw positionable around at least a portion of the first neck, wherein the jaw is movable about and between a first jaw position, in which a lower edge of the jaw is spaced from the jaw engagement surface, and a second position, in which the lower edge of the jaw contacts the jaw engagement surface and urges the portion of the body towards the bore.
5. The method of claim 4, further comprising inserting an end of the pipe into the bore; and positioning the jaw around the jaw engagement surface and moving the jaw from the first jaw position to the second jaw position so that at least a portion of the body engages the pipe.
6. The method of claim 1, wherein the body has a centerline disposed substantially at a midpoint

between the first body end and the second body end, and wherein the first location on the axis is at the centerline.

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