

CLOSURES AND VESSELS WITH CLOSURES**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority to and is a continuation-in-part of co-pending U.S. Patent Application Number 16/923,573 filed July 8, 2020 in the name of Mark Donald Goodall and entitled “Closures and Vessels with Closures,” the entire contents of which are hereby incorporated herein by reference.

TECHNICAL FIELD

[0002] Embodiments of the technology relate generally to closures and more particularly to systems for closing vessels.

BACKGROUND

[0003] Conventional technologies underserve various aspects of closing vessels and closures. Need exists for closures that offer improvements relating to usability, comfort, convenience, sealing, material waste, environmental impact, fabrication, and/or economics. Need further exists for closures that can remain attached to an associated vessel after opening. Need further exists for closures and vessels formed of the same material to promote recycling. Need further exists for closures that resist spillage. Need further exists for closures that are conducive to sterilization. Need further exists for closures having forms that are conducive to molding with reduced or manageable undercuts. Need further exists for closures that can seal carbonated beverages and for such closures that are captive. Need further exists for closures and vessel that resist spewing or unwanted pressure-driven overflow. Need further exists for closures that can be conveniently opened, used, closed, toted, opened again, and used again. A technology addressing one or more such needs, or some related deficiency in the art, would benefit the field.

SUMMARY

[0004] A closure can close an outlet (or an inlet) of a vessel, for example a top of a bottle containing a liquid, solid, or other material or combination of materials, or an end of a tube that conveys gas, liquid, sludge, fluid, or other appropriate material or combination of materials. Such material(s) may be intended for human consumption, for example beverages or solid foods or medicines, or nonedible or non-potable, for example industrial or household chemicals, samples, specimens, supplies, and so forth. In some examples, closing the outlet can comprise providing a seal to prevent material from moving out of (or into) the vessel. In some examples, closing the

outlet can comprise providing a seal between two vessels so that material can move between the two vessels, such as by providing a joint between respective ends of two tubes.

[0005] In an aspect of the disclosure, a vessel outlet can comprise a cavity and a closure can comprise a member configured for insertion in the vessel outlet. A portion of the member can be diametrically oversized relative to the cavity. Insertion of the member in the vessel outlet can produce interference between that portion of the member and the cavity. The interference can produce deflection of another portion of the member to result in sealing the vessel outlet.

[0006] In an aspect of the disclosure, a pull ring can support opening the vessel or closing the vessel or toting the vessel or any combination of opening, closing, and toting the vessel.

[0007] In an aspect of the disclosure, a skirt or flared lip can support opening the vessel or closing the vessel or opening and closing the vessel.

[0008] The foregoing discussion about closing vessels is for illustrative purposes only, without being exhaustive. Various aspects of the present disclosure may be more clearly understood and appreciated from a review of the following text and by reference to the associated drawings and the claims that follow. Other aspects, systems, methods, features, advantages, and objects of the present disclosure will become apparent to those with skill in the art upon examination of the following drawings and text. It is intended that all such aspects, systems, methods, features, advantages, and objects are to be included within this description and covered by this paper and by the appended claims.

BRIEF DESCRIPTION OF THE FIGURES

[0009] Figures 1A, 1B, 1C, 1D, 1E, 1F, 1G, 1H, 1I, 1J, 1K, 1L, and 1M, collectively Figure 1, are illustrations of a closure and an associated vessel in accordance with some example embodiments of the disclosure.

[0010] Figures 2A, 2B, 2C, and 2D, collectively Figure 2, are illustrations further describing representative function and features of the closure of Figure 1, with Figure 2D illustrating a representative variation, in accordance with some example embodiments of the disclosure.

[0011] Figures 3A, 3B, 3C, 3D, 3E, 3F, 3G, and 3H, collectively Figure 3, are illustrations further describing representative operation and features of the closure of Figures 1 and 2 with utilization of a finite element analysis (FEA) computer model in accordance with some example embodiments of the disclosure.

[0012] Figures 4A and 4B, collectively Figure 4, are illustrations of other closures in accordance with some example embodiments of the disclosure.

[0013] Figure 5 is an illustration of another closure in accordance with some example embodiments of the disclosure.

[0014] Figure 6 is an illustration of another closure and associated vessel outlet in accordance with some example embodiments of the disclosure.

[0015] Figures 7A, 7B, 7C, 7D, and 7E, collectively Figure 7, are illustrations of other closures in accordance with some example embodiments of the disclosure.

[0016] Figures 8A and 8B, collectively Figure 8, are illustrations of a closure and associated vessel outlet comprising pressure venting channels in accordance with some example embodiments of the disclosure.

[0017] Figure 9 is an illustration of a closure and associated vessel describing an application of pressure venting channels to the vessel illustrated in Figure 1 in accordance with some example embodiments of the disclosure.

[0018] Figure 10 is an illustration of a blow molding preform for fabricating the closure and associated vessel illustrated in Figure 1 in accordance with some example embodiments of the disclosure.

[0019] Figures 11A, 11B, 11C, 11D, 11E, 11F, 11G, 11H, and 11I, collectively Figure 11, are illustrations of another closure and associated vessel that is resealable and provides a pull ring for toting in accordance with some example embodiments of the disclosure.

[0020] Figures 12A, 12B, 12C, and 12D, collectively Figure 12, are illustrations of another closure and associated vessel in accordance with some example embodiments of the disclosure.

[0021] Figure 13 is an illustration of a tubing coupler in accordance with some example embodiments of the disclosure.

[0022] Figures 14A, 14B, 14C, 14D, 14E, 14F, and 14G, collectively Figure 14, are illustrations of another closure and associated vessel in accordance with some example embodiments of the disclosure.

[0023] Figure 15 is an illustration of another closure and associated vessel in accordance with some example embodiments of the disclosure.

[0024] Figures 16A, 16B, 16C, 16D, 16E, 16F, and 16G, collectively Figure 16, are illustrations of two variations of another closure and associated vessel in accordance with some example embodiments of the disclosure.

[0025] Figures 17A, 17B, 17C, 17D, and 17E, collectively Figure 17, are illustrations of another closure and associated vessel in accordance with some example embodiments of the disclosure.

[0026] Many aspects of the disclosure can be better understood with reference to these figures. The elements and features shown in the figures are not necessarily to scale, emphasis being placed upon clearly illustrating principles of example embodiments of the disclosure. Moreover, certain dimensions may be exaggerated to help visually convey such principles. In the figures, reference numerals often designate like or corresponding, but not necessarily identical, elements throughout the several views.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0027] The technology will be discussed more fully hereinafter with reference to the figures, which provide additional information regarding representative or illustrative embodiments of the disclosure. The present technology can be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the technology to those having ordinary skill in the art. Furthermore, all “examples,” “embodiments,” and “exemplary embodiments” provided herein are intended to be non-limiting and among others supported by representations of the disclosure.

[0028] Those of ordinary skill in the art having benefit of this disclosure will be able, without undue experimentation, to combine compatible elements and features that are described at various places in this written description, which includes text and illustrations. That is, the illustrations and specification are organized to facilitate practicing numerous combinations, such as by combining an element of one illustrated embodiment with another element of another illustrated embodiment or by combining a feature disclosed in an early paragraph of the specification with another element disclosed in a later paragraph of the specification.

[0029] This document includes sentences, paragraphs, and passages (some of which might be viewed as lists) disclosing alternative components, elements, features, functionalities, usages, operations, steps, etc. for various embodiments of the disclosure. Unless clearly stated otherwise, all such lists, sentences, paragraphs, passages, and other text are not exhaustive, are not limiting, are provided in the context of describing representative examples and variations, and are among others supported by various embodiments of the disclosure. Accordingly, those of ordinary skill in the art having benefit of this disclosure will appreciate that the disclosure is not constrained by

any such lists, examples, or alternatives. Moreover, the inclusion of lists, examples, embodiments, and the like (where provided as deemed beneficial to the reader) may help guide those of ordinary skill in practicing many more implementations and instances that embody the technology without undue experimentation, all of which are intended to be within the scope of the claims.

[0030] In some instances, a process or method (for example of using, making, or practicing) may be discussed with reference to a particular illustrated embodiment, application, or environment. Those of skill in the art will appreciate that any such references are by example and are provided without limitation. Accordingly, the disclosed processes and methods can be practiced with other appropriate embodiments supported by the present disclosure and in other appropriate applications and environments. Moreover, one of ordinary skill in the art having benefit of this disclosure will be able to practice many variations of the disclosed methods, processes, and technologies as may be appropriate for various applications and embodiments.

[0031] The term “pull ring,” as used herein, generally refers to something that a user pulls as an aid to opening a vessel, such as a ring, a band, a loop, a circle, an oval, a hoop, a handle, a cord or strap, or a member comprising an aperture and intended to be grasped, held, hooked, or otherwise engaged by hand or finger.

[0032] The term “fasten,” as used herein, generally refers to physically coupling something to something else firmly or securely.

[0033] The term “fastener,” as may be used herein, generally refers to an apparatus or system that fastens something to something else, whether releasably, temporarily, or permanently.

[0034] The term “couple,” as may be used herein, generally refers to joining, connecting, or associating something with something else.

[0035] As one of ordinary skill in the art will appreciate, the term “operably coupled,” as may be used herein, encompasses direct coupling and indirect coupling via another, intervening component, element, or module; moreover, a first component may be operably coupled to a second component when the first component comprises the second component.

[0036] As one of ordinary skill in the art will appreciate, the term “approximately,” as may be used herein, provides an industry-accepted tolerance for the corresponding term it modifies. Similarly, the term “substantially,” as may be used herein, provides an industry-accepted tolerance for the corresponding term it modifies. Such industry-accepted tolerances range from less than one percent to twenty percent and correspond to, but are not limited to, component values, process variations, and manufacturing tolerance.

[0037] As appreciated by those of skill in the art, unless clearly specified otherwise, the values provided herein are intended to reflect commercial design practices or nominal manufacturing targets.

[0038] Turning now to Figures 1A, 1B, 1C, 1D, 1E, 1F, 1G, 1H, 1I, 1J, 1K, 1L, and 1M, these figures illustrate an example closure 110 and an example associated vessel 100 according to some embodiments of the disclosure. Figure 1A illustrates a side view of the vessel 100 and closure 110 in a closed configuration with a pull ring 121 on the left side. Figure 1B illustrates another closed-configuration side view, rotated 90 degrees relative to the view of Figure 1A so the pull ring 121 faces out of the page. Figure 1C illustrates a side view taken from the same perspective as the view of Figure 1A but with the vessel 100 in a fully open configuration. Figure 1D illustrates a top view of the vessel 100 and closure 110 in the closed configuration, with the pull ring 121 largely hidden from view by a base 107 of the closure 110. Figure 1E illustrates a magnified view of the closure 100 corresponding to the view of Figure 1B.

[0039] Figures 1F, 1G, 1H, 1I, 1J, 1K, 1L, and 1M describe progressive opening of the vessel 100. Figure 1F illustrates a cross sectional view corresponding to the view of Figure 1A, with the vessel 100 in the closed configuration. Figure 1G illustrates a magnified view of an upper portion of Figure 1F. The magnified view of Figure 1G illustrates closure details, including the base 107 of the closure 110 and a male portion 111 that extends distally relative to the base 107.

[0040] The term “distal,” as used herein with reference to an element of a body, generally refers to the element being situated away from a main or center of the body. The term “proximal,” as used herein with reference to an element of a body, generally refers to the element being situated towards a main or center of the body. For example, in Figure 1F, a first portion of the vessel 100 that is situated above a second portion of the vessel 100 (that is, the first portion is situated more toward closure 110 along an axis 191) can be characterized as distal to the second portion, and the second portion can be characterized as proximal to the first portion. Similarly, in Figure 1G, an area of the male portion 111 of the closure 110 that is disposed farthest from the base 107 of the closure 110 can be characterized as distal to area of the male portion 111 that is closer to the base 107.

[0041] Figure 1H illustrates a cross sectional view with the same perspective as Figure 1F, with the closure 110 in an early stage of opening in which a user (not illustrated) has lifted the pull ring 121, for example using a rotational motion 196, and initiated opening of the vessel. As illustrated, the rotational motion 196 is about a hinge 177, further discussed below. Figure 1I illustrates a magnified view of a portion of Figure 1H that shows example closure details.

[0042] Figure 1J illustrates a cross sectional view taken from the same perspective as Figure 1H, with the closure 110 in a following stage of opening in which the user has pulled upward on the pull ring 121. As illustrated, the user has applied a rotation motion 197, with rotation about an opposite side 195 of the closure 110. In some example embodiments, the rotation motion 197 can be viewed as an extension of the rotational motion 196 illustrated in Figure 1H.

[0043] As illustrated in Figure 1J and further detailed in Figures 1K and 1L (discussed below), the example vessel outlet 106 comprises an example mouth 167, which can be viewed as an embodiment of a female tubular cavity, and an example rim 114. As illustrated, the rim 114 comprises an example of a projecting rim. As illustrated, the rim 114 defines an example aperture. As illustrated in Figure 1J, pulling upwards on the pull ring 121 has sufficiently extracted the male portion 111 of the closure 110 from the vessel outlet 106 to break the seal. As illustrated, in this configuration, the side of the male portion 111 adjacent the pull ring 121 is tilted up relative to the opposite side 195.

[0044] If the vessel 100 is pressurized, for example holding a carbonated beverage, breaking the seal can release the vessel's internal pressure. In the illustrated configuration, the vessel outlet 106 has a curved contour 166 at the mouth 167. More specifically, the contour 166 at and adjacent the illustrated rim 114 is curved when viewed in a cross section taken through the longitudinal axis 191 of the vessel 100. As used herein in reference to a vessel, "rim," "mouth," and "outlet" generally refer to portions or features of the vessel, with the vessel outlet encompassing the mouth and with the mouth encompassing the rim. As used herein, "rim" generally refers to a distal portion or feature of a mouth and "mouth" generally refers to a distal portion or feature of an outlet. The term "aperture," as used herein, refers to an opening, hole, slit, or gap and has sufficient breadth that a wide variety of rims, mouths, and outlets are within the scope of the word "aperture."

[0045] The curved contour 166 in cooperation with sealing features of the male portion 111 of the closure 110 (further discussed below with reference to Figures 2A, 2B, and 2C) can vent pressure gradually during opening. Venting pressure gradually can avoid unwanted overflow or spewing of carbonated beverages that may occur with many conventional designs when pressure drops abruptly. Figure 1K illustrates a magnified cross sectional side view showing the mouth 167 and sealing features of the male portion 111 with the closure 110 in a sealed configuration, prior to breaking the seal. Figure 1L illustrates a magnified cross sectional view showing the mouth 167 and sealing features of the male portion 111 of the closure 110 as the seal is broken during opening. In the illustrated sealing configuration of Figure 1K, in the illustrated cross sectional view, the

male portion 111 forms an enclosed gap 192 adjacent or at the curved contour 166, the vessel outlet 106, or the mouth 167. As illustrated in Figure 1L, a pressure venting path 171 opens through the gap 192 during vessel opening that facilitates gradual release of pressure, thereby avoiding an abrupt pressure drop that can be associated with spewing or unwanted pressure-driven flow from the vessel 100. Such pressure venting can further help avoid uncontrollable cap blow off of a sealed carbonated beverage, for example.

[0046] Figure 1M illustrates a cross sectional view with the same perspective as Figure 1J, with the closure 110 in a fully open configuration in which the user has pulled the pull ring 121 completely across the vessel outlet 106.

[0047] Example features generally associated with opening the vessel 100 will now be discussed in further. As illustrated in Figure 1E, the pull ring 121 extends downward within a channel 173 that extends from the base 107 of the closure 110 along a side 174 of the closure 110. A frangible connection 176 joins the pull ring 121 to the sides of the channel 173. In the illustrated example, the frangible connection 176 comprises two points or locations where the material of the pull ring 121 continues to or fuses with the material of the closure side 174. The pull ring 121 is further joined to the base 107 of the closure 110 by the hinge 177, which is visible in Figures 1D, 1G, 1I, 1J, and 1M. As can be seen in Figure 1G, in the illustrated example, the hinge 177 comprises a cutout area 175 and a thin region 178 that connects the closure base 107 to the pull ring 121.

[0048] When the user lifts the pull ring 121 as discussed above with reference to Figure 1H, the frangible connection 176 severs and the pull ring 121 rotates about the hinge 177 (illustrated as the rotational motion 196). As the pull ring 121 rotates about the hinge 177, the cutout area 175 closes and the thin region 178 flexes as can be seen in Figure 1I.

[0049] Referring now to Figure 1G, the vessel 100 comprises the mouth 167 with the curved contour 166, as discussed above with reference to Figures 1J, 1K, and 1L. In the illustrated example, the curved contour 166 is associated with the vessel 100 comprising a curved-back portion 179 at the mouth 167. Thus, the illustrated mouth 167 can be viewed as curving back in connection with forming the curved contour 166.

[0050] In an example embodiment of the vessel 100 comprising a beverage container, the curved-back portion 179 forms the rim 114 with a three-dimensional contour 112 (see Figure 1M) that contacts the user's lips and mouth comfortably, to provide a comfortable drinking experience. As shown in Figures 1G and 1M, in the illustrated embodiment, the curved back portion 179 forms an open area 118 that is void of vessel material. For certain applications, the void can support

objectives related to cost, weight, and environmental impact associated with materials, for example saving plastic usage, and further can enhance strength and impact resistance of the rim 114. In some other embodiments, the three-dimensional contour 112 illustrated in Figure 1M can alternatively be provided without utilizing the open area 118.

[0051] In some other example embodiments, a different mouth form or configuration, such as without any curving back, can provide an appropriately contoured surface. In some examples, an appropriately curved contour can be produced via machining on a lathe or other material removal process or via a plastic forming process such as injection molding or blow molding.

[0052] Referring to Figure 1G, the illustrated example curved-back portion 179 comprises a circumscribing notch 180 in which a band 181 is partially disposed. In some example embodiments, the band 181 is a component that is attached to the curved-back portion 179 of the vessel 100. In some example embodiments, the band 181 is an integral seamless part of the curved-back portion 179 of the vessel 100. Accordingly, the features illustrated by Figure 1G as part of the band 181 may be directly incorporated into the curved-back portion 179 of the vessel.

[0053] As illustrated by Figure 1G, the band 181 circumscribes the curved-back portion 179 and comprises a projection 182 adjacent the pull ring 121. The pull ring 121 comprises a projection 187 that comprises a notch 183 in which the projection 182 is disposed. The projection 182 and notch 183 form a catch that retains the closure 110 on the vessel 100, with the male portion 111 disposed in the mouth 167 of the vessel 100. When the user lifts the pull ring 121 as discussed above, the notch 183 moves away from (and may open or distort) and releases the projection 182. The catch thus disengages. Accordingly, the user can readily lift the pull ring 121. Additionally, with the illustrated catch mechanism, the user can move the pull ring 121 back to its original location to re-engage the catch and close the vessel 100 with the male portion 111 of the closure 110 disposed in the mouth 167 of the vessel 100. Thus, the mechanism supports repeated opening and closing of the vessel 100, for example so the user can open the vessel 100, take a drink, and then close the vessel 100.

[0054] Referring now to Figures 1I and 1M, another hinge 184 connects the side 174 of the closure 110 to the band 181 on the opposite side 195 of the vessel 100 from the pull ring 121, projection 182, and notch 183. The illustrated example hinge 184 comprises a flexible strip of material 186 that extends between the band 181 and the closure side 174. As illustrated in Figure 1M, the flexible strip of material 186 retains the closure 110 attached to the vessel 100 after the vessel 100 is fully opened.

[0055] In some example embodiments, the band 181, the closure 110, the pull ring 121, and the flexible strip of material 186 comprise a unitary element that may be formed from one material. Thus, the flexible strip of material 186, the band 181, the pull ring 121, and the closure 110 can be viewed as integral portions of one continuous element.

[0056] In some example embodiments, this continuous element is further integral with the vessel 100. The vessel 100, the flexible strip of material 186, the band 181, the pull ring, and the closure 110 can be formed of a common material and may be integral portions of one unitary element. In some example embodiments, the entirety of what is illustrated in Figures 1A, 1B, 1C, 1D, 1E, 1F, 1G, 1H, 1I, 1J, 1K, 1L, and 1M (or in Figure 11) can be formed of a single polymer such as polyethylene terephthalate (PET or PETE), which can include additives or blends with other materials, or from other appropriate polymers or a combination of polymers. In some example embodiments, the entirety of what is illustrated in Figures 1A, 1B, 1C, 1D, 1E, 1F, 1G, 1H, 1I, 1J, 1K, 1L, and 1M (or in Figure 11) can be formed in a molding operation, for example using injection molding or blow molding or insert molding, any of which can be performed in a single pass or in multiple passes in various embodiments. Fabrication will be further discussed below with reference to Figure 10, which illustrates a blow molding preform.

[0057] In some example embodiments without limitation, the closure 110 (or other closures disclosed herein) can comprise PET, polyester, high-density polyethylene (HDPE), fluorine-treated HDPE, low-density polyethylene (LDPE), polycarbonate (PC), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), post-consumer resin (PCR), K-Resin (SBC), bioplastic, etc. or an appropriate combination thereof with or without appropriate additives (for example for enhanced stability, improved mechanical characteristics, visual appeal, or color).

[0058] In some example embodiments without limitation, the vessel 100 (or other vessels disclosed herein) can comprise PET, polyester, HDPE, fluorine-treated HDPE, LDPE, PC, PP, PS, PVC, PCR, SBC, bioplastic, etc. or an appropriate combination thereof with or without appropriate additives (for example for enhanced stability, improved mechanical characteristics, visual appeal, or color) or an inorganic material such as metal, metal alloy, glass, ceramic, etc.

[0059] In some example embodiments, the vessel 100 (or other vessels disclosed herein) is composed of aluminum, glass, or ceramic material, while the closure 100 (or other closures disclosed herein) is composed of a thermoplastic material.

[0060] In some example embodiments, without limitation, the closure 110 and the vessel 100 (or other closures and vessels disclosed herein) can have a common composition that can comprise PET, polyester, HDPE, fluorine-treated HDPE, LDPE, PC, PP, PS, PVC, PCR, SBC,

bioplastic, etc. or an appropriate combination thereof with or without appropriate additives (for example for enhanced stability, improved mechanical characteristics, visual appeal, or color).

[0061] In some example embodiments, without limitation, the closure 110 and the vessel 100 (or other closures and vessels disclosed herein) can have compositions that are sufficiently compatible to support recycling together. For example, polymer resin of the vessel 100 and the closure 110 can both be PET based, with the vessel made of clear PET and the closure 110 made of PET with a colorant additive.

[0062] In some example embodiments, a molding process fabricates the closures 110 and the vessels 100 (or other closures and vessels disclosed herein) in quantity. The resulting products are filled with beverage and sold to consumers who consume the beverage and return the closures 110 and vessels 100 for recycle. Substantially equal numbers of the returned closures 110 and vessels 100 are collectively heated to form a melt comprising substantially equal numbers of melted closures 110 and melted vessels 100. This melt is then molded to create new closures 110 and new vessels 100, which are filled with beverage and sold to consumers so that the cycle can continue.

[0063] Turning now to Figures 2A, 2B, 2C, and 2D these figures illustrate example function and features of the closure 110 of Figure 1 associated with sealing according to some embodiments of the disclosure. Figure 2D illustrates a representative variation that will be discussed following Figures 2A, 2B, and 2C.

[0064] In the example illustrated by Figures 2A, 2B, and 2C, the vessel outlet 106 and the mouth 167 comprise an interior surface 141 that is straight walled and cylindrical. The interior surface 141 thus differs in shape from the curved contour 166 illustrated in Figure 1 while providing corresponding sealing function. Figure 2 illustrates an alternative embodiment and further illustrates representative operating principles in a manner intended to promote readership.

[0065] In the illustrated example of Figures 2A, 2B, and 2C, the vessel outlet 106 comprises a mouth 167 with a distal rim 114. The mouth 167 defines the interior surface 141 and can be viewed as an embodiment of a female tubular cavity.

[0066] The example closure 110 of Figure 2 comprises the base portion 107 and the male portion 111 extending from the base portion 107. The male portion extends circumferentially to define a cavity 161. To close the vessel 100, the male portion 111 is disposed in the female tubular cavity with a shoulder 152 of the base portion 107 adjoining the rim 114 and a circumferential surface 139 of the male portion 111 facing the interior surface 141 of the vessel outlet 106 and mouth 167. As illustrated, the male circumferential surface 139 comprises an oversized portion

142, a tapered portion 143, and an undersized portion 144 that are progressively displaced from the base 107. In the illustrated example, the oversized portion 142 has an outer diameter 145 exceeding an inner diameter 148 of the mouth 167 of the vessel 100. In the illustrated embodiment of Figure 2, the oversized portion 142, the tapered portion 143, and the undersized portion 144 have distinct geometries. However, in some embodiments, the oversized portion 142 and the tapered portion 143 are formed with a continuous taper. In some embodiments, the undersized portion 144 and the tapered portion 143 are formed with a continuous taper. In some embodiments, the oversized portion 142, the tapered portion 143, and the undersized portion 144 are formed with a continuous taper, for example as illustrated in Figure 7E, which is discussed below.

[0067] For embodiments with the mouth 106 tapered outward or having a lead-in (for example with the curved contour 166 illustrated in Figure 1 and discussed above), the outer diameter of the male portion 111 may exceed the female inner diameter at a location displaced a distance 138 from the rim 114, i.e., at a depth within the mouth 167 of the vessel 100. That is, the inner diameter 148 may vary such that the outer diameter 145 of the oversized portion 142 is smaller than the inner diameter 148 at or adjacent to the rim 114 but is but is larger than the inner diameter 148 at a specified distance 138 from the rim 114.

[0068] Referring to the embodiment illustrated in Figures 2A, 2B, and 2C, part of the male tapered portion 143 can have an outer diameter 146 equaling or exceeding the inner diameter 148 of the mouth 167. The undersized male portion 144 can have an outer diameter 146 that is smaller than the inner diameter 148 of the mouth 167. When the male portion 111 is partially inserted in the mouth 167, clearance or an annular space 149 can exist between the undersized male portion 144 and the interior surface 141 as can be seen in Figure 2B. Once the male portion 111 is sufficiently inserted, interference occurs. The interference can cause the undersized male portion 144 to flare out or to diametrically expand as illustrated in Figure 2C and engage the interior surface 141 of the outlet 106. This engagement of the resulting flared-out portion 137 can provide a seal. (See also Figure 2D, in which deflection of the undersized male portion 144 is illustrated by arrows 101 representing force, rather than illustrating example physical deformation of the undersized male portion 144.)

[0069] In some example embodiments, the flaring out or diametrical expansion of the undersized male portion 144 occurs below the threshold of plastic deformation. In some example embodiments, the flaring out or diametrical expansion of the undersized male portion 144 occurs without plastic creep.

[0070] In another example embodiment, the portion identified with reference number “144” and referred to above as “the undersized portion” has an outer diameter 147 that substantially equals or that substantially matches the inner diameter 148 of the mouth 167. In such an embodiment, interference between the oversized portion 142 and the mouth 167 can produce diametrical expansion force or flaring out force of the portion 144, resulting in heightened lateral force to reinforce a seal.

[0071] In another example embodiment, the portion identified with reference number “144” and referred to above as “the undersized portion” has an outer diameter 147 that exceeds the inner diameter 148 of the mouth 167. In such an embodiment, insertion of that portion 144 may entail applying sufficient force to the closure 110 along the axis 191 (see Figure 1D, *inter alia*) to deform that portion 144 and compress its diameter. In such an embodiment, additional interference between the oversized portion 142 and the mouth 167 can produce diametrical expansion force or flaring out force of the portion 144, resulting in heightened lateral force to reinforce a seal.

[0072] While Figures 2A, 2B, and 2C illustrate an example embodiment in which the interior surface 141 of the vessel outlet 106 adjacent the rim 114 is uniform and cylindrical, some other embodiments have additional contours and features. For example and as further discussed below, Figure 6 illustrates a taper applied to an interior surface and Figures 7D and 7E illustrate embodiments in which an interior surface comprises a projection.

[0073] As discussed above, the example closure-sealing features that Figures 2A, 2B, and 2C illustrate can be combined with the example closure-retention features that Figure 1 illustrates. Moreover, the closure 110 illustrated by Figures 2A, 2B, and 2C can be retained on vessels 100 using other closure-retention systems, for example the retention systems illustrated in Figures 11, 12, 14, or 15 or other closure-retention systems disclosed herein in text or known in the art, without limitation.

[0074] Turning now to the embodiment illustrated by Figure 2D, the rim 114 of the vessel 100 is slanted, and the oversized portion 142 extends lengthwise in accordance with the slant. In some embodiments, the slanted rim 114 facilitates pouring fluid out of the vessel 100, for example to avoid unwanted spillage. In some embodiments, the slanted rim 114 can facilitate gradual release of pressure during vessel opening, so as to avoid unwanted spewing as discussed above with reference to Figures 1K and 1L. For example, the slanted rim 114 can facilitate releasing pressure preferentially from a side 198 of the vessel outlet 106 during opening. In various embodiments, the slanted rim 114 can have a steeper or shallower angle than illustrated. For example, in some embodiments, the slanted rim 114 is slanted in a range of approximately 0.5

degrees to approximately 10 degrees. In some example embodiments, the slanted rim 114 is slanted in a range of approximately 0.5 degrees to approximately 30 degrees. Other ranges may be used as may be deemed appropriate for various applications.

[0075] Turning now to Figures 3A, 3B, 3C, 3D, 3E, 3F, 3G, and 3H, these figures further illustrate example operation and example features of the closure 110 of Figures 1 and 2 with utilization of a finite element analysis computer model according to some embodiments of the disclosure.

[0076] Figure 3A illustrates the example closure configuration that was modeled, where certain dimensions are indicated relative to the axis 191 and thus represent radial dimensions. The modeled radial dimension 305 is 17.00 mm. The modeled radial dimension 310 is 15.60 mm. The modeled radial dimension 315 is 14.40 mm. The modeled radial dimension 325 is 15.00 mm. The modeled dimension 330 is 2.00 mm. The modeled dimension 335 is 1.80 mm. The modeled dimension 340 is 7.00 mm. The modeled dimension 349 is 4.60 mm. All these dimensions are non-limiting examples and are among many others supported by the present disclosure.

[0077] Figure 3B illustrates a three-dimensional cutaway representation of the closure 110 as modeled and in a relaxed state, prior to stress and deformation associated with the finite element analysis.

[0078] Figure 3C illustrates an enlarged cross-sectional view of a portion of the example closure configuration modeled, with additional dimensions indicated. This figure illustrates example interference 346 between the oversized portion 142 and the interior surface 141 of the mouth 167, with the interference having an example dimension 345. The example value used in the model for the dimension 345 of the interference 346 was 0.60 mm. Figure 3C further illustrates an annular space 149 between the undersized male portion 144 and the interior surface 141 of the mouth 106, with the annular space 149 having a dimension 350. The example value used in the model for the dimension 350 of the annular space 149 was 0.00 mm. In other words, the model assumed that no annular space existed.

[0079] The model used glass, with a Young's Modulus of 75 GPa, as the material of the vessel 100. The model used HDPE, with a Young's Modulus of 0.8 GPa, as the material of the closure 110. The material selections represent non-limiting example among numerous others supported by the present disclosure.

[0080] Figures 3D and 3E illustrate three-dimensional cutaway views of two representative stages of the closure 110 closing the vessel 100. Figure 3D illustrates a stage of closing in which the male portion 111 is partially inserted into the vessel outlet 106, with the undersized portion 144

extending into the vessel 100. Figure 3E illustrates a later stage of closing in which the male portion 111 is inserted to a level that the oversized portion 142 is disposed in the vessel outlet 106. The resulting interference 346 (see Figure 3C) produces forces and deformation of the closure 110. The forces and deformation cause a distal portion 194 of the undersized portion 144 of the closure 110 to press radially outward against the interior surface 141 of the vessel outlet 106. As further described below with reference to Figure 3H, the resulting force between the distal portion 194 and the interior surface 141 can provide a robust seal and/or a self-energizing seal 312. With the interior surface 141 of the vessel outlet 106 constraining the distal portion 194 from flaring radially outward, the forces cause a proximal portion 199 of the undersized portion 144 to bow radially inward. The bowing inward produces the enclosed gap 192, with the enclosed gap 192 disposed between the self-energizing seal 312 and a secondary seal 313. As illustrated, the forces further cause the base 107 of the closure 110 to bulge outward, so that the outer surface 188 of the base 107 transitions from substantially flat to convex. In some example embodiments, the base 107 of the closure 110 can be thickened or reinforced to reduce this bulging outward, so that the outer surface 188 remains substantially flat or exhibits less convexity.

[0081] Figures 3F and 3G illustrate output of the computer model in which a three-dimensional cutaway view is overlaid with computed displacement data. The model computed radial displacement of the flared out portion 137 of the male portion 111 with the oversized portion 142 inserted into the vessel outlet 106 as illustrated in Figure 3E while allowing the male portion 111 to flare out without constraint. Thus, the model allowed the undersized portion 144 to flare out without constraint by the interior surface 141 of the mouth 167 of the vessel 100. Figure 3G shows computed values of displacement in millimeters, where negative values indicate radially inward displacement and positive values indicate radially outward displacement. As illustrated, the region 371 was displaced -0.48048 mm; the region 372 was displaced -0.6 mm; the region 373 was displaced -0.59445 mm; the region 374 was displaced -0.51043 mm; the region 375 was displaced -0.37512 mm; the region 376 was displaced -0.24032 mm; the region 377 was displaced -0.107 mm; the region 378 was displaced 0.014385 mm; and the region 379 was displaced 0.12427 mm.

[0082] As discussed above, thickening or reinforcing the base 107 can reduce force-induced bulging of the base 107 of the closure 110. It is estimated (separate from the computer model) that this thickening or reinforcement of the base 107 can increase displacement of the region 379 from the 0.12427 mm displacement computed by the computer model to approximately 0.25 mm.

[0083] Figure 3H illustrates a three-dimensional cutaway view of the closure 110 that magnifies the male portion 111 and further illustrates finite element modeling results. As discussed above, Figures 3F and 3G illustrate results of the finite element model allowing the male portion 111 to flare out without constraint by the interior surface 141 of the mouth 167 of the vessel 100. Figure 3H, meanwhile, illustrates modeling results in which the interior surface 141 (shown in Figures 3C, 3D, and 3E) constrains the male portion 111. In particular, Figure 3H illustrates a contact region 169 where the distal portion 194 of the male portion 111 presses against the interior surface 141 as shown in the bottom right area of Figure 3E. The finite element model computes the pressure between the contact region 169 and the interior surface 141 of the mouth 167 of the vessel 100 as 1.6 MPa. Accordingly, a robust seal is provided.

[0084] Turning now to Figures 4A and 4B, two other example embodiments are illustrated. As illustrated, the closure 400 of Figure 4A and the closure 405 of Figure 4B comprise sealing features in keeping with the features illustrated in Figures 2 and 3 and described in associated text. In various embodiments, the closures 400, 405 can comprise other appropriate sealing features and elements supported by the present disclosure.

[0085] Figure 4A illustrates an example closure 400 and example associated vessel outlet 106 according to some embodiments of the disclosure. In the example of Figure 4A, which provides a cross sectional view, the base 107 of the closure 400 arches towards the vessel outlet 106 to provide increased strength while conserving material. This closure form can counteract the bulging outward illustrated Figure 3E and discussed above with reference to that figure.

[0086] In the example embodiment of Figure 4B, the closure 405 comprises a metallic cover 410 in which a plastic element 415 that comprises sealing features is disposed. The metallic cover 410 can enhance structural support so that the plastic element 415 can be made relatively thin.

[0087] Turning now to Figure 5, this figure illustrates another example closure 500 according to some embodiments of the disclosure. In the example of Figure 5, which provides a cross sectional view, the base 107 of the closure 500 comprises an inner groove 505 and an outer groove 506. In a view from below (not shown, orthogonal to the view of Figure 5), the grooves 505, 506 appear as concentric circles, with the inner groove 505 having smaller diameter than the outer groove 506. In operation, the grooves 505, 506 can promote flex of the male portion 111. Accordingly, the grooves 505, 506 can facilitate sealing in appropriate applications, for example in applications warranting the use of materials that may otherwise resist flexing. The grooves 505, 506 can additionally reduce stress on the base 107 that can produce bulging of the outer surface

188 of the base 107, which is illustrated in Figure 3E and discussed above. Thus, the grooves 505, 506 can be utilized for applications in which flatness of the outer surface 188 is desired.

[0088] As illustrated, the male portion 111 of the closure 500 comprises closure features in keeping with the features illustrated in Figure 2 and described in associated text. In various embodiments, the closure 500 can comprise other appropriate closure features and elements supported by the present disclosure.

[0089] Turning now to Figure 6, this figure illustrates another example closure 600 and example associated vessel outlet 106 according to some embodiments of the disclosure. In the example of Figure 6, which provides a cross sectional view, the outlet 106 of the vessel 100 comprises a rim 114 and a first internal surface 602 of a first diameter adjacent the rim 114. The vessel outlet 106 further comprises a second internal surface 604 that is displaced longitudinally from the first internal surface 602 and is of a second diameter. The vessel outlet 106 further comprises a third internal surface 606 that is disposed between the first internal surface 602 and the second internal surface 604. As illustrated, the third internal surface 606 tapers upward in diameter between the first internal surface 602 and the second internal surface and adjoins and connects the first and second internal surfaces 602, 604.

[0090] In the illustrated example, the closure 600 comprises a male portion 111 that comprises a projection 615 oriented diametrically outward. The projection 615 comprises a portion 614 of consistent diameter and a tapered portion 616. The projection 615 is disposed between a first cylindrical surface 612 and a second cylindrical surface 613, with the first cylindrical surface 612 disposed between the projection and the base 107. In the illustrated example, the first and second cylindrical surfaces 612, 613 are of equal diameters. Other embodiments may have different diameters or geometries.

[0091] In operation, when the male portion 111 enters the vessel outlet 106 to a sufficient depth, deflection of the male portion 111 occurs as the tapered portion 616 of the projection 615 contacts and presses against the tapered third surface 606 within the vessel outlet 106. This deflection results in the closure 600 sealing the vessel outlet 106.

[0092] Turning now to Figures 7A, 7B, 7C, 7D, and 7E, additional example embodiments are illustrated. Figure 7A illustrates an example closure 700 and an example associated outlet 106 of a vessel 100 according to some embodiments of the disclosure. In the example of Figure 7A, which provides a cross sectional view, a male portion 111 of the closure 500 comprises a projection 705. In the illustrated embodiment, when viewed in cross sections, the projection 705 comprises

a convex outline. In various embodiments, the projection 705 can be disposed at different locations on the male portion 111, for example as illustrated by Figure 7B and discussed below.

[0093] In operation, the projection 705 can increase lateral force applied to the male portion 111 associated with insertion in the vessel outlet 106. Accordingly, the projection 705 can promote flex of the male portion 111. Thus, the projection 705 can facilitate sealing in appropriate applications, for example in applications calling for materials that may otherwise resist flexing. Additionally, the projection 705 can support or enhance a secondary seal by forming a narrow band of pressure between the male portion 111 and the interior surface 141 of the vessel outlet 106, with the pressure band disposed adjacent the base 107 in the embodiment of Figure 7A.

[0094] As illustrated by Figure 7A, the projection 705 is applied to the male portion 111 of the closure 500 that comprises a profile in keeping with the features illustrated in Figure 2 and described in associated text. In various embodiments, the projection 705 can be applied to other appropriate closure features and elements supported by the present disclosure.

[0095] In the embodiment that Figure 7B illustrates, a projection 710 is disposed distally on the male portion 111. In this location, the projection 710 can promote sealing by forming a narrow band of concentrated pressure to seal against the interior surface 141 of the vessel outlet 106 (illustrated by Figure 7A). In some example embodiments, the projection 710 can comprise an elastomer, for example synthetic rubber or silicone, and can be disposed so as to comprise the contact region 169 illustrated in Figure 3H and discussed above. For example, the elastomer can be fused to a thermoplastic of the male portion during molding or via another appropriate process. In some example embodiments, the projection 710 and the remainder of the male portion 111 are formed of a common material, for example a thermoplastic. In various example embodiments, the projection 710 can comprise a convex outline.

[0096] In the embodiment that Figure 7C illustrates, the male portion 111 comprises the projection 705 and the projection 710, as respectively illustrated by Figures 7A and 7B as discussed above. In this embodiment, the projection 705 can provide one or more effects discussed above with reference to Figure 7A and the projection 710 can provide one or more effects discussed above with reference to Figure 7B.

[0097] In the example embodiment that Figure 7D illustrates, a vessel 701 has an outlet 106 with an interior surface 141 that comprises a projection 702 adjacent the rim 114. As illustrated, the vessel's closure 110 is consistent with the closure 110 illustrated by Figure 2A, 2B, and 2C and the foregoing associated discussion. Thus in some example embodiments, the closure 110 that Figures 2A, 2B, and 2C illustrate can be utilized in the embodiment of Figure 7D. In

operation, the projection 702 can produce or heighten interference between the male portion 111 and the vessel outlet 106. The produced or heightened interference can amplify flaring out of the male portion 111, which is illustrated at Figures 2C and 3E and discussed above, among other places herein. Amplifying flaring out of the male portion 111 can facilitate utilization of materials or dimensions that may be desired for some applications and/or promote seal enhancement. Additionally, in some example embodiments, the projection 702 can provide a secondary seal at or adjacent where the projection 702 presses against the male portion 111.

[0098] In the example embodiment that Figure 7E illustrates, the vessel 701 has an outlet 106 with an interior surface 141 that comprises a projection 702 adjacent the rim 114. The closure 110 of Figure 7E comprises a male portion 111 that is continuously tapered. The continuously tapered male portion 111 illustrated by Figure 7E can comprise an oversized portion 142, a tapered portion 143, and an undersized portion 144 which Figure 2A illustrates as discussed above.

[0099] Turning now to Figures 8A and 8B, these figures illustrate another example closure 110 and associated vessel outlet 106 comprising example pressure venting channels 800 according to some embodiments of the disclosure. As illustrated, the pressure venting channels 800 extend inside the mouth 167 of the vessel 100 a distance 805 from the rim 114. In the illustrated example, that distance 805 is less than the distance 810 that the male portion 111 of the closure 110 extends from the base 107 of the closure 110. With this configuration, the pressure venting channels 800 can avoid interference with sealing. Additionally, in the illustrated example of Figure 8, once the closure 110 is completely inserted into the mouth 167 of the vessel 100, the oversized portion 142 extends beyond (that is, to a greater depth in the vessel outlet 106 than) the pressure venting channels 800.

[00100] In operation as illustrated in Figure 8B, as the closure 110 is removed from the mouth 167, pressure within the vessel 100 gradually escapes through the pressure venting channels 800, thereby avoiding unwanted spewing as may occur with carbonated beverages in conventional pressurized containers.

[00101] The pressure venting channels 800 may have different forms or geometries according to various applications and vessel configurations. In some example embodiments, the pressure venting channels 800 comprise grooves or slots formed in the interior surface of the vessel outlet 106, such as in a range of 0.1 mm to 1.0 mm in depth and in a range of 0.1 mm to 1.0 mm in width, where these ranges are nonlimiting and among others supported by the present disclosure. The pressure venting channels 800 can be spaced at various distances, for example separated by a

distance in a range of 1.0 mm to 10 mm, where this range is nonlimiting and among others supported by the present disclosure.

[00102] Turning now to Figure 9, this figure illustrates an example closure 110 and example associated vessel 100 describing an example application of example pressure venting channels 800 to the vessel 100 illustrated in Figure 1 according to some embodiments of the disclosure. Thus, the pressure venting channels 800 can vent pressure from a variety of vessel and closures configuration, including the embodiment illustrated in Figure 1 and discussed above.

[00103] Turning now to Figure 10, this figure illustrates an example blow molding preform 1000 for fabricating the closure 110 and associated vessel 100 illustrated in Figure 1 according to some embodiments of the disclosure. The preform 1000 extends lengthwise along the axis 191 and comprises the closure 110 and the vessel 100. In operation, a blow molding machine can heat the preform 1000 to soften its plastic material and then inject gas so it expands against a forming mold, thereby producing the vessel 100 and associated closure 110. In some example embodiments, the preform 1000 provides all materials for the features illustrated in Figure 1. Thus, the blow molding operation can produce the entire vessel 100 and closure 110 as an integrated unit. Alternatively, elements can be added following blow molding.

[00104] Turning now to Figures 11A, 11B, 11C, 11D, 11E, 11F, 11G, 11H, and 11I, these figures illustrate another example closure 110 and example associated vessel 100 that is resealable and provides a pull ring 1100 for toting according to some embodiments of the disclosure. Figure 11 illustrates an example pull ring configuration that provides an alternative to the example pull ring configuration illustrated in Figure 1, discussed above. In the example embodiment illustrated by Figure 1 (and other figures), the pull ring 121 extends longitudinally alongside the vessel outlet 106, substantially parallel with the axis 191. As further discussed below, in the example pull ring configuration illustrated by Figure 11, the pull ring 1100 circumscribes the closure 110 and the vessel outlet 106.

[00105] As illustrated in Figures 11A, 11B, and 11C, the pull ring 1100 extends around the sides 174 of the closure 110 and connects with the sides 174 at a frangible connection 176 (visible in Figure 11A). In the illustrated example, the frangible connection 176 comprises six points or locations where the material of the pull ring 1100 continues to or fuses with the material of the closure side 174. At the opposite side of the closure 110 from a hinge 1110, the pull ring 1100 comprises an extension 1105 that creates an aperture 1112 sized to facilitate engagement or reception of a user fingertip. The hinge 1110 comprises a flexible strip of material 1115 that extends between the pull ring 1100 and the closure side 174.

[00106] In some example embodiments, the closure 110, the pull ring 1100, and the flexible strip of material 1115 comprise a unitary element that may be formed from one material. Moreover, in some embodiments, everything illustrated in Figure 11 (Figures 11A, 11B, 11C, 11D, 11E, 11F, 11G, 11H, and 11I) can be one continuous, unitary element.

[00107] To open the vessel 100, the user can place his or her fingertip below the extension 1105 in the aperture 1112. The user can pull up on the pull ring 1100 so that the pull ring 1100 rotates about the hinge 1110, over the closure 110, and across the axis 191, to result in the configuration illustrated in Figure 11D.

[00108] As illustrated in Figure 11E, from the configuration illustrated in Figure 11D, the user can pull outward and upward on the pull ring 1100 so that the projection 182 escapes from the notch 183 as discussed above with reference to Figure 1. As illustrated in Figure 11F, the user can then pull the pull ring 1100 across the vessel 100 to extract the male portion 111 of the closure 110 from the vessel outlet 106 and open the vessel 100 as discussed above with reference to Figure 1.

[00109] As illustrated in Figure 11G and the magnified view of Figure 11H, after taking a drink or otherwise using the vessel 100, the user can pull the pull ring back over the vessel 100 and reengage or reseal the projection 182 back in the notch 183 to close and reseal the vessel 100. With the resulting configuration illustrated in Figure 11I, the user can then use the pull ring 1100 to carry by hand or to suspend the closed vessel 100 during transport. For example, the user can loop a backpack strap or cord through the pull ring 1100 or clip the pull ring 1100 to the user's belt or a bicycle with a carabiner (not illustrated).

[00110] Turning now to Figures 12A, 12B, 12C, and 12D, these figures illustrate another example closure 1200 and example associated vessel 100 according to some embodiments of the disclosure. In this example, the closure 1200 comprises a skirt 1205, in the example form of a flared lip, that retains and releases the closure 1200 in connection with closing and opening the vessel 100 as discussed below.

[00111] Figure 12A illustrates a cross sectional view of the closure 1200 in an open configuration with the skirt 1205 of the closure 1200 raised. Figure 12B illustrates a cross sectional view of the closure 1200 disposed on the vessel 100 with the closure 1200 in the open configuration and the skirt 1205 raised. Figure 12C illustrates a cross sectional view of the closure 1200 in a closed configuration and the skirt 1205 lowered. Figure 12D illustrates a cross sectional view of the closure 1200 disposed on the vessel 100 with the closure in the closed configuration and the skirt 1205 lowered.

[00112] With the closure 1200 in the open configuration illustrated in Figures 12A and 12B and the skirt 1205 raised, an interior surface 1210 of the closure 1200 is smooth and uninterrupted. Accordingly, the closure 1200 can be readily removed from or placed on the vessel 100.

[00113] With the closure 1200 in the closed configuration illustrated in Figures 12C and 12D and the skirt 1205 lowered, a projection 1215 projects from the interior surface 1210 of the closure 1200. As shown in Figure 12D, the projection 1215 projects under and engages a shoulder 1220 of the vessel 100. The projection 1215 and shoulder 1220 thus form a releasable catch that facilitates closing and opening the vessel 100 repeatedly.

[00114] Turning now to Figure 13, this figure illustrates an example tubing coupler 1300 according to some embodiments of the disclosure. As illustrated (in cross section), the example tubing coupler 1300 comprises two male ends 1305 each comprising male portions 111, configured and oriented for insertion in two tubes 1310. Example assembly can comprise placing the two tubes 1310 over the male ends 1305 until the tubing rims 114 butt against shoulders 1315 of the tubing coupler 1300. In some applications, it may be appropriate to retain the tubes 1310 in this position using one or more retainers (not illustrated), such as a clasps, fasteners, nuts and bolts, threads, bands, clips, hooks, buckles, brackets, or other appropriate retaining apparatus.

[00115] In the illustration of Figure 13, the tubes 1310 comprise an example embodiment of a vessel, and the tubing coupler 1300 comprises an embodiment of a closure. The illustrated example tubing coupler 1300 comprises closure features in keeping with the features illustrated in Figure 2 and described in associated text. In various embodiments, the tubing coupler 1300 can incorporate other appropriate closure features and elements supported by the present disclosure.

[00116] Turning now to Figures 14A, 14B, 14C, 14D, 14E, 14F, and 14G, these figures illustrate another example closure 110 and example associated vessel 100 according to some embodiments of the disclosure. The example embodiment of Figure 14 can accommodate the sealing features of the embodiment of Figure 1, which illustrates the male portion 111 sealing against an interior surface 141 as discussed above. The embodiment that Figure 14 illustrates can further accommodate other sealing technologies and means. While Figure 14 will be discussed below with reference to certain corresponding features of Figure 1, the illustrated features of the closure 110 of Figure 14 have applicability beyond the example seal illustrated at Figure 1.

[00117] The closure 110 of Figure 14 comprises a band 1410 that circumscribes the vessel outlet 106. In some example embodiments, the band 1410 can attach to the vessel 110 in keeping with the attachment of the band 181 illustrated in Figure 1 and discussed above. In some example

embodiments, the band 1410 can be seated in a groove formed in or adjacent to the vessel outlet 106 (not illustrated in Figure 14).

[00118] A base 107 of the closure 110 attaches to the band 1410 via a frangible connection that comprises an array of frangible connection points 1425 extending circumferentially and extending between the band 1410 and the closure side 174. The base 107 further attaches to the band 1410 via a hinge 1460. In some example embodiments, the hinge 1460 can comprise the hinge 184 as illustrated in Figure 1 and/or Figure 11 and as discussed above.

[00119] A pull ring 121 attaches to the base 107 via a hinge 177 in accordance with the hinge 177 illustrated in Figure 1 and discussed above. The pull ring 121 operates from the user's perspective like the pull ring 121 illustrated in Figure 1 and discussed above. When the user pulls the pull ring to open the vessel 100, the frangible connection points 1425 sever, the base 107 moves away from the band 140 with the hinge 1460 maintaining an attachment between the base 107 and the band 1410, and the vessel 100 opens.

[00120] In addition to the frangible connection, the base attaches to the band 1410 via a catch that comprises a projection 187 with a notch 183 on the pull ring 121 and a projection 182 (shown in Figure 1) that seats in the notch. As discussed above with reference to Figure 1, when the user pulls the pull ring, the catch releases. In the example embodiment of Figure 14, a second catch provides additional holding security. The second catch comprises a member 1450 that projects from the pull ring 121. The member 1450 extends from the pull ring 121 into an aperture 1455 in the band 1410. In the illustrated example embodiment, the member 1450 and the aperture 1455 have rectangular cross sections and the member 1450 mates with the aperture 1455. The member 1450 is sized and shaped in accordance with the aperture 1455. When the user pulls the pull ring 121 to open the vessel 100, the member 1450 extracts from the aperture 1455 to release the base 107 from the band 1410. Accordingly, the two catches of the embodiment of Figure 11 can help avoid inadvertent vessel opening and help accommodate high pressures.

[00121] Turning now to Figure 15 this figure illustrates another example closure 110 and example associated vessel 100 according to some embodiments of the disclosure. As further discussed below, in the example that Figure 15 illustrates, a threaded retention system retains the closure 110 on the vessel 100. The closure 110 can comprise a bottle cap in some example embodiments and will be referred to as such below, without limitation. The vessel 100 can comprise a drink bottle in some example embodiments and will be referred to as such below, without limitation.

[00122] In the example embodiment of Figure 15, the outlet 106 of the drink bottle 100 comprises male threads 1505, and the bottlecap 110 comprises female threads 1510. That is, the outlet 106 and the bottlecap 110 comprise corresponding threads 1505, 1510, with the outlet 106 configured for insertion into a threaded recess 1520 of the bottlecap 110. In various embodiments, the threads 1505, 1510 may comprise conventional or nonconventional features.

[00123] In the illustrated embodiment of Figure 15, the sealing system illustrated by Figures 2A, 2B, and 2C is incorporated so that the bottlecap 110 seals and further screws on and screws off. In this embodiment, unscrewing the bottlecap 110 progressively extracts the male portion 111 from the mouth 167 of the outlet 106 to open the drink bottle 100, while screwing the bottlecap 110 on progressively inserts the male portion 111 into the outlet 106 for sealing. The male portion 111 and the interior surface 141 of the outlet 106 thus form a seal that can travel up and down the interior surface 141 of the outlet 106. Accordingly, the screw-on bottlecap 110 can achieve sealing without necessarily requiring a strong compressive force between a surface 1525 on the base 107 of the bottlecap 110 and the top face 1530 of an outlet rim 114. The illustrated seal can thus avoid binding or jamming that may occur with conventional screw-on closures on drink bottles and that may cause unscrewing difficulties associated with axial compressive binding. More particularly, as illustrated by example Figure 15, when the drink bottle 100 is fully closed and sealed, a gap 1535 can exist between the rim 114 of the outlet 106 and the base 107 of the bottlecap 110. The gap 1535 can help avoid binding that may be associated with forming a seal between two surfaces using excessive compressive axial forces, i.e. compression along the axis 191 (see Figure 1M).

[00124] In the illustrated example embodiment of Figure 15, a stop 1540 provides the gap 1535 (or may otherwise control force between the rim 114 and the base 107) by impeding, checking, blocking, or obstructing screwing on the bottlecap 110 beyond a predetermined number of rotations or beyond a predetermined axial distance. The illustrated stop 1540 comprises a projection 1545 extending from the bottlecap 110 and a series of progressively larger projections 1550 extending from the drink bottle 100. When a user screws the bottlecap 110 on to predetermined level, the bottlecap projection 1545 encounters and interacts with the progressively larger bottle projections 1550. As the user screws down the bottlecap 110, the bottlecap projection 1545 ratchets past the progressively larger bottle projections 1550. For tactile feedback, the user applies a progressively increasing amount of torque or rotational force to overcome each of the progressively larger bottle projections 1550. Once the largest of the progressively larger bottle projections 1550 is encountered, further rotation is obstructed and the bottlecap 1545 screwing on is complete. Accordingly, a system of projections or lugs can provide screwing impediment or

friction that increases progressively and/or in a stepwise matter to provide controlled resistance that a user can perceive via tactile feedback while screwing on the bottle cap 110, for example.

[00125] In some example embodiments, the stop 145 can comprise at least one shoulder that provides a physical stop point or one or more projections or lugs that prevent overtightening by obstructing rotation past a predetermined point. In some example embodiments, the stop 145 can comprise a series of projections or lugs that ratchet with corresponding grooves (not illustrated) which extend in an axial direction through one or both of the threads 1505, 1510.

[00126] Turning now to Figures 16A, 16B, 16C, 16D, 16E, 16F, and 16G, these figures illustrate two variations of an example closure 110 and example associated vessel 100 according to some embodiments of the disclosure. Figures 16A, 16B, 16C, 16D, and 16E illustrate a first embodiment, and Figures 16E and 16F illustrate a second embodiment, which are discussed in turn below. The embodiment that Figures 16E and 16F illustrate can be viewed as an example of what Figures 16A, 16B, 16C, 16D, and 16E illustrate. In some example embodiments, the closure 110 and vessel 100 can comprise or have a composition of PET, HDPE, PP, PVC, PS, or PC (not an exhaustive list). In some example embodiments, the vessel 100 and closure 110 can be substantially larger than a handheld beverage bottle, such as when implemented for a PCV pipe having a diameter on the order of 60 cm. In some example embodiments, the vessel 100 and closure 110 can be substantially smaller than a handheld beverage bottle, such as when implemented for a medical vial having a diameter on the order of 5 mm.

[00127] Referring now to the first embodiment of Figures 16A, 16B, 16C, 16D and 16E, Figures 16A, 16B, and 16C illustrate progressive closing of the vessel 100 by inserting a male portion 111 of the closure 110 into an outlet 106 of the vessel. Figure 16A illustrates the closure 110 aligned with the outlet 106. Figure 16B illustrates the male portion 111 of the closure 110 partially inserted in the outlet 106. Figure 16C illustrates the vessel 100 sealed by the closure 110. Figures 16D and 16E illustrate detail views of a portion 1650 of the vessel 100 and closure 110 as illustrated by Figure 16C.

[00128] As further discussed below, the illustrated closure 110 and vessel 100 comprise an example sealing system 1600 that produces three seals 1652, 1654, 1656. Figure 16 illustrates an embodiment of the sealing system 1600 generally corresponding to the sealing system embodiments illustrated by Figures 2A, 2B, 2C, 3A, 3B, 3C, 3D, 3E, 3F, 3G, and 3H as discussed above. Like the embodiment of Figures 2 and 3, the sealing system 1600 that Figure 16 illustrates can be applied to a wide variety of vessel and closure configurations, including the configurations disclosed herein in illustrations and/or in text. For example, the disclosed vessel outlets and

closures can be formed of flexible materials, such as the plastics identified herein, supporting the movements and deformations associated with sealing that are discussed below with reference to Figure 16.

[00129] As illustrated in Figure 16A, the male portion 111 of the closure 110 extends from a base 107 of the closure 110 an overall male distance 1614 and forms a cavity 161. In the illustrated example, the base 107 extends radially beyond the male portion 111 to form a shoulder 152 that extends circumferentially with respect to the male portion 111. The example male portion 111 illustrated by Figure 16 comprises a first male portion 142, a second male portion 143, and a third male portion 144. In the illustrated example, as identified in Figure 16B, the third male portion 143 comprises a wall thickness 1684 that is thinned relative to the wall thickness 1682 that the first male portion 142 comprises; and the second male portion 143 comprises a transition between the two wall thicknesses 1682, 1684.

[00130] As illustrated, the first male portion 142 extends from the base 107 a first male distance 1610 and comprises a first outer diameter 145. In the illustrated embodiment of Figures 16A, 16B, 16C, 16D, and 16E, the first male portion 142 is of uniform outer diameter, so the first male portion 142 maintains the first outer diameter 145 over the first male distance 1610. In some example embodiments, the first male portion 142 may extend with varying outer diameter, for instance so that the first male portion 142 comprises the first outer diameter 145 as well as other outer diameters that may be larger or smaller than the first outer diameter 145.

[00131] As illustrated, the second male portion 143 extends from the first male portion 142 (away from the base) and comprises a decreasing outer diameter. In the illustrated embodiment of Figures 16A, 16B, 16C, 16D, and 16E, the decreasing outer diameter comprises a taper. In some example embodiments, the decreasing outer diameter can comprise a step or an abrupt change in diameter. The first male portion 142 and the second male portion 143 collectively extend a second male distance 1612 from the base 107. Thus, the second male portion 143 extends from the first male portion 142 a distance of the second male distance 1612 less the first male distance 1610.

[00132] As illustrated, the third male portion 144 extends from the second male portion 143 (away from the base) and comprises a second outer diameter 147. As illustrated, the second outer diameter 147 of the third male portion 144 is smaller than the first outer diameter 145 of the first male portion 142. The first, second, and third male portions 142, 143, 144 collectively extend the overall male distance 1614 from the base 107. Thus, the third male portion 144 extends from the second male portion 143 a distance of the overall male distance 1614 less the second male distance 1612. In the illustrated embodiment of Figures 16A, 16B, 16C, 16D, and 16E, the third male

portion 144 is of uniform outer diameter, so the third male portion 144 maintains the second outer diameter 145 over its extension from the second male portion 143. In some example embodiments, the third male portion 144 may extend with varying outer diameter, for instance so that the third male portion 144 comprises the second outer diameter 147 as well as other outer diameters that may be larger or smaller than the second outer diameter 147.

[00133] As illustrated in Figure 16A, the outlet 106 of the vessel comprises a first outlet portion 1642, a second outlet portion 1643, and a third outlet portion 1644. In the illustrated example, as identified in Figure 16B, the first outlet portion 1642 comprises a wall thickness 1686 that is thinned relative to the wall thickness 1688 that the third outlet portion 1644 comprises; and the second outlet portion 1643 comprises a transition between the two wall thicknesses 1686, 1688.

[00134] As illustrated, the first outlet portion 1642 extends from a rim 114 a first outlet distance 1616 and comprises a first inner diameter 146. In the illustrated example, the first outlet distance 1616 is less than the first male distance 1610. Thus, the first male portion 142 is longer than the first outlet portion 1642. With this geometry, the male portion 111 can be inserted into the outlet 106 to a depth at which the second male portion 143 engages the second outlet portion 1643 before the rim 114 contacts the shoulder 152 and stops farther insertion. In the illustrated embodiment of Figures 16A, 16B, 16C, 16D, and 16E, the first outlet portion 1642 is of uniform inner diameter, so the first outlet portion 1642 maintains the first inner diameter 146 over the first outlet distance 1616. In some example embodiments, the first outlet portion 1642 may extend with varying inner diameter, for instance so that the first outlet portion 1642 comprises the first inner diameter 146 as well as other inner diameters that may be larger or smaller than the first inner diameter 146.

[00135] As illustrated, the second outlet portion 1643 extends from the first outlet portion 1642 (away from the rim) and comprises a decreasing inner diameter. In the illustrated embodiment of Figures 16A, 16B, 16C, 16D, and 16E, the decreasing inner diameter comprises a taper. In some example embodiments, the decreasing inner diameter can comprise a step or an abrupt change in diameter. The first outlet portion 1642 and the second outlet portion 1643 collectively extend a second outlet distance 1618 from the rim 114. Thus, the second outlet portion 1643 extends from the first outlet portion 1642 a distance of the second outlet distance 1618 less the first outlet distance 1616.

[00136] As illustrated, the third outlet portion 1644 extends from the second outlet portion 1643 (away from the rim) and comprises a second inner diameter 148. As illustrated, the second inner diameter 148 of the third outlet portion 1644 is smaller than the first inner diameter 146 of

the first outlet portion 1642. In the illustrated embodiment of Figures 16A, 16B, 16C, 16D, and 16E, the third outlet portion 1644 is of uniform inner diameter, so the third outlet portion 1644 maintains the second inner diameter 148 as it extends from the second outlet portion 1643. In some example embodiments, the third outlet portion 1644 may extend with varying inner diameter, for instance so that the third outlet portion 1644 comprises the second inner diameter 148 as well as other inner diameters that may be larger or smaller than the second inner diameter 148.

[00137] In the illustrated example embodiment of Figures 16A, 16B, 16C, 16D, and 16E, the first outer diameter 145 of the first male portion 142 of the closure 110 is smaller than the first inner diameter 146 of the first outlet portion 1642 of the outlet 106. In the illustrated example embodiment of Figures 16A, 16B, 16C, 16D, and 16E, the second outer diameter 147 of the third male portion 144 of the closure 110 is smaller than the second inner diameter 148 of the third outlet portion 1644 of the outlet 106. Accordingly, as illustrated in Figure 16B, respective clearances 1622, 1620 can be provided between the first male portion 142 and the first outlet portion 1642 and between the third male portion 144 and the third outlet portion 1644. The clearances 1622, 1620 can facilitate insertion of the male portion 111 in the outlet 106. In some example embodiments, the outer diameters 145, 147 of the male portion 111 and the inner diameters 146, 148 of the outlet 106 are sized so that the outlet 106 readily receives the male portion 111 with a manageable level of interference, for example with radial interference less than 0.1 millimeter. With such a manageable level of interference, a typical user can manually insert the male portion 111, for example to open and shut the vessel 100 during routine usage in a beverage application. In some example embodiments, a greater level of radial interference can be appropriate, for example in connection with machine-implemented insertion in a manufacturing plant. Thus, in example embodiments, there may be clearance or interference between the first male portion 142 and the first outlet portion 1642 and between the third male portion 144 and the third outlet portion 1644.

[00138] The illustrated sealing system 1600 is sufficiently adaptable to accommodate clearance alternatives as may be purposefully selected for various applications. As further discussed below, the configurability of the sealing system 1600 supports tailoring dimensions of the clearances 1620, 1622. Clearance dimensions can, for example, be tailored for compatibility with industry-standard clearances, for high-speed manufacturing that may involve relatively large clearances, for applications in which the respective materials of the closure 110 and the outlet have different thermal expansion properties and/or different stress and strain properties (for instance,

when the closure 110 comprises metal and the vessel 100 comprises thermoplastic or the closure 110 comprises thermoplastic and the vessel 100 comprises metal), etc.

[00139] When the male portion 111 of the closure 110 is inserted past the insertion depth that Figure 16B illustrates, the second male portion 143 of the closure 110 encounters the second outlet portion 1643 of the outlet 106. As force 1675 is applied to the closure 110 as illustrated by Figures 16C, 16D, and 16E, contact occurs between the second male portion 143 and the second outlet portion 1643. In some example embodiments, the force 1675 can be produced by the threaded retention system of the embodiment that Figure 15 illustrates or by the closure-retention systems illustrated by Figures 1, 11, 12, or 14. As further discussed below, the example embodiment of the sealing system 1600 that Figure 16 illustrates comprises mechanical advantage and features that can achieve robust sealing with relatively low force magnitude. When the sealing system 1600 is utilized with the threaded retention system that Figure 15 illustrates, a capability for robust sealing with relatively low force can help avoid binding of the threads 1505, 1510 due to overtightening. In some applications, the force 1675 can be generated by a human hand, for instance in connection with a person drinking from and opening and closing a handheld beverage bottle. The threading pitch of such a hand-operated threading system can be selected to increase or decrease the magnitude of the force 1675 resulting from human operation. Increasing or decreasing the force 1675 (via thread pitch or otherwise) can generally be used to control the level of movements within the sealing system 1600 associated with sealing the vessel 100 (further discussed below). Thus, controlling the force 1675 can facilitate dimensioning features of the sealing system 1600 with tighter or looser clearances 1620, 1622. In some applications, the force 1675 can be generated by a machine, for instance by a machine that connects segments of large-diameter tubing made of PCV or steel in an industrial application in a chemical plant or an oil pipeline. In the configuration that Figures 16C, 16D, and 16E illustrate, space 1690 exists between the rim 114 and the shoulder 152. In some example embodiments, the force 1675 is at a level that advances the closure 110 until the shoulder 152 moves against the rim 114, with the resulting abutment between the shoulder 152 the rim 114 forming a stop against farther insertion. By stopping farther insertion, the stop can further provide control over the force 1675 applied to the sealing system 1600 and thus movements of sealing elements within the system 1600, which are further discussed below.

[00140] As illustrated in the magnified cross sectional views of Figures 16D and 16E, the force 1675 transfers through the closure 110 and the outlet 106 and presses the second outlet portion 1643 and the second male portion 143 together. Where the second outlet portion 1643 and

the second male portion 143 meet, compression between the outer surface 1641 and the interior surface 141 forms a seal 1654. At the seal 1654, in the illustrated example, the interior surface 141 and the outer surface 1641 are inclined at a common angle θ , as illustrated by reference line 1625, and can slide against one another along the reference line 1625 at the angle θ relative to the axis 191 of the closure 110 and the vessel 100. The inclined interface between the second outlet portion 1643 and the second male portion 143 produces a mechanical advantage. Figure 16E illustrates the angle θ at an example 28 degrees. In the cross sectional views of Figures 16D and 16E, the second outlet portion 1643 and the second male portion 143 abut at the inclined reference line 1625 at the angle θ of 28 degrees. The force 1675 produces deformation, with the mechanical advantage essentially amplifying the effect. As illustrated by Figure 16E, the second male portion 143 moves radially inward along the reference line 1625, while the second outlet portion 1643 moves outward along the reference line 1625. More specifically, in the example magnified cross sectional views of Figures 16D and 16E, the outer surface 1641 of the second male portion 143 moves down and to the left along the reference line 1625, while the interior surface 141 of the second outlet portion 1643 moves up and to the right along the reference line 1625. The overlaid arrows 1601, 1603 respectively illustrate example embodiments of these opposing movements along the reference line 1625. The amount of movement can be controlled by selection of the angle θ . Decreasing the angle θ generally produces more sliding movement 1601 of the second male portion 143 and more sliding movement 1603 of the second outlet portion 1643 along the reference line 1625. The movements and associated stresses plastically deform the third male portion 144 and the first outlet portion 1642 as further discussed below. Thus, the angle θ provides control of plastic deformation of the third male portion 144 and the first outlet portion 1642, which are further discussed below. With support of the wall thinning (discussed above with reference to the wall thicknesses 1682, 1684, 1686 and 1688), the third male portion 144 flares outward, and the first outlet portion 1642 bows inward. The amount of wall thinning can be utilized to control the respective levels of plastic deformation of the third male portion 144 and the first outlet portion 1642, thereby controlling their respective flaring outward and bowing inward. Reducing the wall thickness 1686 of the first outlet portion 1642 can, for example, increase contraction of the first outlet portion 1642. And, reducing the thickness 1684 of the third male portion 144 can, for example, increase expansion of the third male portion 144. The wall thicknesses 1684, 1686 can accordingly be selected to accommodate various levels of clearance 1620, 1622, which may vary according to application as discussed above. As further discussed below, deformations produce a seal 1656 and an associated

annular gap 1660 disposed on one side of the seal 1654 and another seal 1652 and associated annular gap 1658 on the opposing side of the seal 1654.

[00141] The motion 1601 of the second male portion 143 along the reference line 1625 produces localized radial contraction and localized radial expansion of the third male portion 144, example embodiments of which Figure 16E graphically illustrates with respective arrows 1621 and 1611. The radial contraction 1621 of the third male portion 144 forms the annular gap 1660 adjacent the seal 1654. The radial expansion 1611 closes the clearance 1620 and forms the seal 1656, with the annular gap 1660 disposed between the seal 1654 and the seal 1656. In the illustrated example, engagement of the third male portion 144 with the third outlet portion 1644 forms the seal 1656. The outer surface 1641 of the male portion 111, the interior surface 141 of the outlet 106, the seal 1654, and the seal 1656 collectively enclose the annular gap 1660 in the illustrated example embodiment. The levels of the radial expansion 1611 and the radial contraction 1621 can be controlled, as discussed above, based on wall thickness 1684, the angle θ , applied force 1675, and material properties to accommodate different levels of clearance 1620. Additionally, the third male portion 144 may be lengthened for more radial expansion 1611 and more radial contraction 1621 or shortened to lessen radial expansion 1611 and radial contraction 1621. Figure 16F and 16G further illustrate an embodiment in which the third male portion 144 is internally tapered to increase radial expansion 1611 and radial contraction 1621.

[00142] The motion 1603 of the second outlet portion 1643 along the reference line 1625 produces localized radial contraction and localized radial expansion of the first outlet portion 1642, example embodiments of which Figure 16E graphically illustrates with respective arrows 1613 and 1623. The radial expansion 1623 of the first outlet portion 1642 forms the annular gap 1658 adjacent the seal 1654. The radial contraction 1613 forms the seal 1652, with the annular gap 1658 disposed between the seal 1654 and the seal 1652. In the illustrated example, engagement of the first outlet portion 1642 with the first male portion 142 forms the seal 1652. The outer surface 1641 of the male portion 111, the interior surface 141 of the outlet 106, the seal 1654, and the seal 1652 collectively enclose the annular gap 1658 in the illustrated example embodiment.

[00143] The levels of the radial expansion 1623 and the radial contraction 1613 can be controlled, as discussed above, based on wall thickness 1686, the angle θ , applied force 1675, and material properties to accommodate different levels of clearance 1622. Additionally, the first outlet portion 1642 may be lengthened for more radial expansion 1623 and more radial contraction 1613 or shortened to lessen radial expansion 1623 and radial contraction 1613. In some example embodiments, radial expansion 1623 and radial contraction 1613 can be increased by externally

tapering the first outlet portion 1642 (not illustrated by Figure 16) so that the wall thickness 1686 is smallest adjacent the rim 114 and gradually increases with extension of the first outlet portion 1642 towards the second outlet section 1643.

[00144] An example embodiment with specific dimensions will now be discussed with reference to Figures 16F and 16G. Figures 16F and 16G illustrate a dimensioned example following Figures 16A, 16B, 16C, 16D, and 16E and the foregoing discussion directed to Figures 16A, 16B, 16C, 16D, and 16E. Figure 16F corresponds generally to Figure 16B as discussed above, and Figure 16G corresponds generally to Figures 16C, 16D, and 16E as discussed above.

[00145] In the illustrated example of Figures 16F and 16G, the closure 110 comprises a male portion 111 that comprises a first male portion 142, a second male portion 143, and a third male portion 144; and the outlet 106 of the vessel 100 comprises a first outlet portion 1642, a second outlet portion 1643, and a third outlet portion 1644. With the closure 110 in a relaxed configuration as illustrated by Figure 16F, the third male portion 144 comprises an outer surface 1694 and an interior surface 1695 that form a taper in cross section view. With increasing extension away from the base 107, the outer surface 1694 extends parallel with an axis 191 of the closure 110 and the vessel 100, while the interior surface 1695 extends radially away from the axis 191. Thus, the outer surface 1694 extends along the axis 191 with a uniform outer diameter, while the interior surface 1695 extends along the axis 191 with a progressively increasing inner diameter.

[00146] In the illustrated example embodiment of Figures 16F and 16G, the closure 110 and the vessel 100 can comprise PET and can be dimensioned in accordance with the following nonlimiting dimensions. The radial dimensions provided in this paragraph represent radii or distances between the axis 191 and the indicated features as illustrated in Figure 16F. In this example, the radial dimension 305 is 17.00 mm. In this example, the radial dimension 310 is 15.60 mm. In this example, the radial dimension 315 is 14.40 mm. In this example, the radial dimension 325 is 15.20 mm. In this example, the radial dimension 1693 is 15.21 mm. In this example, the dimension 330 is 2.00 mm. In this example, the dimension 335 is 2.80 mm. In this example, the dimension 340 is 8.00 mm. In this example, the dimension 349 is 4.60 mm. In this example, the dimension 1612 is 3.40 mm. In this example, the dimension 1610 is 2.80 mm. In this example, the dimension 1691 is 1.60 mm. In this example, the dimension 1692 is 2.00 mm. In the relaxed configuration of Figure 16F, these dimensions provide a radial clearance 1687 of 0.01 mm between the third male portion 144 and the third outlet portion 1644 and a radial clearance 1689 of 0.01 mm between the first male portion 142 and the first outlet portion 1642. All dimensional values in this paragraph are example dimensions that are among many others supported by the present

disclosure. As discussed above with reference to Figures 16A, 16B, 16C, 16D, and 16E, dimensions of features of the sealing system 1600 can be selected to meet application objectives (including but not limited to amounts of the clearances 1620, 1622 and tolerances); and this paragraph provides example dimensional values for such selections, without limitation.

[00147] Figure 16G illustrates a closed configuration in which the closure 110 has closed the vessel 100. In the illustrated configuration, the first male portion 142, the second male portion 143, and the third male portion 144 of the closure 110 are interacting with first outlet portion 1642, the second outlet portion 1643, and the third outlet portion 1644 of the outlet 106 as discussed above with reference to Figures 16A, 16B, 16C, 16D, and 16E. As discussed above with reference to Figures 16A, 16B, 16C, 16D, and 16E, contact, forces, and movement between the second outlet portion 1643 and the second male portion 143 produce stresses that radially contract the first outlet portion 1642 towards the axis 191 and that radially expand the third male portion 1656 away from the axis 191. In an example embodiment, the third male portion can expand approximately 0.25 mm, thereby taking up the radial clearance 1687 of 0.01 mm, and the first outlet portion 1642 can contract approximately 0.25 mm, thereby taking up the radial clearance 1689 of 0.01 mm. Accordingly, seals 1652, 1654, and 1656 are formed as illustrated by Figure 16G. As discussed above with reference to 16A, 16B, 16C, 16D, and 16E, the closed annular gaps 1658 and 1660 are also formed. In the illustrated embodiment of Figures 16F and 16G with the specifications provided in the present paragraph and in the two paragraphs that immediately precede the present paragraph, the sealing system 1600 can seal below the threshold of plastic deformation and can seal free from plastic creep. (Some other embodiments that the specification and figures support may purposefully operate at or above the threshold of plastic deformation as may be deemed appropriate for certain applications and/or may exhibit plastic creep as may be deemed appropriate for certain applications.)

[00148] In some example embodiments, the first male portion 142 of the closure 110 joins the base 107 of the closure 110 at a corner 1677 that is radiused in a range of 0.50 mm to 0.75 mm. In some example embodiments, the first outlet portion 1642 joins the rim 114 of the outlet 106 at a corner 1678 that is radiused in a range of 0.25 mm to 0.35 mm. In some example embodiments, the seal 1652 comprises contact between the corner 1677 so radiused and the corner 1678 so radiused. In some example embodiments, the seal 1652 comprises contact between the corner 1677 and the corner 1678, wherein the corner 1677 comprises a radius in the range of 0.50 mm to 0.75 mm, and wherein the corner 1678 comprises a radius that is below the range of 0.25 mm to 0.35 mm or is sharp relative to a radius in the range of 0.25 mm to 0.35 mm. In some example

embodiments, the seal 1652 comprises contact between the corner 1677 and the corner 1678, wherein the corner 1677 comprises a radius that is below the range of 0.50 mm to 0.75 mm or that is sharp relative to a radius in the range of 0.50 mm to 0.75 mm, and wherein the corner 1678 comprises a radius in the range of 0.25 mm to 0.35 mm. In some example embodiments, the seal 1652 comprises contact between the corner 1678 and the first male portion 142 of the closure 110 at a location that is sufficiently displaced from the corner 1677 to be separated from any radius of the corner 1677.

[00149] Turning now to Figures 17A, 17B, 17C, 17D, and 17E, these figures illustrate another example closure 110 and example associated vessel 100 according to some embodiments of the disclosure. Figures 17A, 17B, 17C, and 17D illustrate progressive closing of the vessel 100 by inserting a male portion 111 of the closure 110 into an outlet 106 of the vessel 100. Figure 17A illustrates the closure 110 aligned with the outlet 106. Figures 17B and 17C illustrate the male portion 111 of the closure 110 inserted with increasing depth into the outlet 106. Figure 17D illustrates the vessel 100 sealed by the closure 110. Figure 17E illustrates a detail view of a portion 1750 of the vessel 100 and closure 110 as illustrated by Figure 16D.

[00150] In the illustrated example embodiment of Figure 17, the male portion 111 comprises an open end 1710 and an outer diameter 147 that is less than or equal to an inner diameter 148 of the outlet 106. As illustrated, the male portion 111 can be readily inserted into the outlet 106 to a depth of a projection 705 on the male portion 111 without interference. In the illustrated example embodiment, the projection 705 projects radially from and extends fully about the male portion 111. The illustrated example projection 705 has an outer diameter 145 that is greater than the inner diameter 148 of the outlet 106. In some example embodiments, the outer diameter 145 of the projection 705 is in an range of 102 percent to 110 percent of the inner diameter 148 of the outlet.

[00151] In the sealed configuration that Figures 17D and 17E illustrate, the male portion 111 of the closure 110 is disposed in the outlet 106 to a depth at which a rim 114 of the outlet 106 is disposed adjacent a shoulder 152 of the closure 110. Disposed in the outlet 106 as illustrated by Figures 17D and 17E, the projection 705 deforms the outlet 106 by exerting force directed radially outward, resulting in radial expansion of the outlet 106 adjacent the projection 705. The outlet 106 exerts an opposing force on the projection 705 that is directed radially inward and transfers through male portion 111. This force directed radially inward produces radial contraction of the male portion 111 at the projection 705. The opposing radial forces form a seal 1754 where the projection 705 engages the outlet 106.

[00152] The radial expansion of the outlet 106 at the projection 705 produces radial contraction of the outlet 106 at the rim 114, forming a seal 1752 between the male portion 111 and the outlet 106 adjacent the rim 114. An annular gap 1758 further forms between the two seals 1752, 1754. The seal 1752, the seal 1754, the outlet 106, and the male portion 111 enclose the annular gap 1758.

[00153] The radial contraction of the male portion 111 at the projection 705 produces radial expansion of the open end 1710 of the male portion 111, forming a seal 1756 between the male portion 111 and the outlet 106 adjacent the open end 1710. An annular gap 1760 further forms between the two seals 1756, 1754. The seal 1754, the seal 1756, the outlet 106, and the male portion 111 enclose the annular gap 1760.

[00154] Useful closure technology has been described. From the description, it will be appreciated that an embodiment of the disclosure overcomes limitations of the prior art. Those skilled in the art will appreciate that the technology is not limited to any specifically discussed application or implementation and that the embodiments described herein are illustrative and not restrictive. Furthermore, the particular features, structures, or characteristics that are set forth may be combined in any suitable manner in one or more embodiments based on this disclosure and ordinary skill. Those of ordinary skill having benefit of this disclosure can make, use, and practice a wide range of embodiments via combining the disclosed features and elements in many permutations without undue experimentation and further by combining the disclosed features and elements with what is well known in the art. This disclosure not only includes the illustrated and described embodiments, but also provides a rich and detailed roadmap for creating many additional embodiments using the various disclosed technologies, elements, features, their equivalents, and what is well known in the art. From the description of the example embodiments, equivalents of the elements shown herein will suggest themselves to those skilled in the art, and ways of constructing other embodiments will appear to practitioners of the art. Therefore, the scope of the technology is to be limited only by the appended claims.

CLAIMS

What is claimed is:

1. An apparatus comprising:
a vessel comprising an outlet that comprises:
a rim; and
a first cavity that extends from the rim and comprises an interior surface comprising an inner diameter; and
a closure comprising:
a base portion; and
a male portion that extends from the base portion to form a second cavity and that comprises:
a first portion that extends circumferentially about the second cavity and has a first outer diameter that is larger than the inner diameter;
a second portion that extends circumferentially about the second cavity and has a second outer diameter that is no larger than the inner diameter; and
a third portion that extends circumferentially about the second cavity, is tapered, and is disposed between the first portion and the second portion,
wherein the first portion is disposed between the third portion and the base portion, and
wherein the closure is dimensioned so that when the male portion is inserted in the first cavity with the base portion adjoining the rim, interference causes the second portion to flare out and engage the interior surface and produce a seal.
2. The apparatus of Claim 1, wherein the inner diameter is larger than the second outer diameter, and
wherein the interior surface comprises a circumferentially extending projection that is disposed adjacent the rim.
3. The apparatus of Claim 1, wherein the male portion is disposed in the first cavity with the base portion adjoining the rim,
wherein as a result of interference, the second portion flares out and engages the interior surface to produce a seal, with the interior surface, the second portion, and the third portion forming an enclosed space that extends circumferentially about the second cavity.
4. The apparatus of Claim 1, wherein the male portion comprises a continuous taper that comprises the first portion, the second portion, and the third portion.

5. The apparatus of Claim 1, wherein the vessel and the closure are formed of a unitary piece of material with a composition comprising a common polymer.
6. The apparatus of Claim 1, wherein the interior surface of the first cavity comprises pressure venting channels adjacent the rim.
7. The apparatus of Claim 1, wherein the rim comprises a curved contour, wherein with the apparatus in a closed configuration with the male portion extending into the first cavity, the apparatus further comprises a seal, wherein the seal comprises an enclosed gap formed between the male portion and the interior surface, and wherein the curved contour and the enclosed gap comprise a pressure venting path.
8. The apparatus of Claim 1, wherein the closure and the vessel are arranged so that the male portion extends into the first cavity, with the first portion, the second portion, and the third portion disposed in the first cavity, wherein the male portion and the interior surface form the seal, a second seal, and an enclosed gap, and wherein the enclosed gap is disposed between the seal and the second seal.
9. An apparatus comprising:
a vessel comprising an outlet that comprises:
a projecting rim defining an aperture; and
a cavity that extends longitudinally from the projecting rim; and
a closure comprising:
a member that extends over the aperture and circumferentially about the projecting rim;
a male portion that extends from the member into the tubular cavity to seal the vessel;
a hinge attaching the member to the projecting rim at a first location; and
a pull tab attaching the member to the projecting rim at a second location that is diametrically opposed to the first location.

10. The apparatus of Claim 9, wherein the apparatus comprises a blow molding preform.
11. The apparatus of Claim 9, wherein the vessel and the closure are composed of a common polymer.
12. The apparatus of Claim 9, wherein the vessel comprises inorganic material and the closure comprises thermoplastic material.
13. The apparatus of Claim 9, wherein the pull tab comprises a catch that engages the projecting rim.
14. The apparatus of Claim 9, wherein the closure comprises a band that circumscribes and engages with the projecting rim, wherein the pull tab comprises a fastener that releasably fastens to the projecting rim with a projection disposed in a groove.
15. The apparatus of Claim 9, wherein the vessel comprises pressure venting channels or a curved contour operable to for venting pressure.
16. The apparatus of Claim 9, wherein the male portion comprises a distally disposed undersized portion, a proximally disposed oversized portion, and a tapered portion disposed between the undersized and oversized portions.
17. An apparatus comprising:
 - a vessel comprising an outlet that comprises:
 - a projecting rim defining an aperture; and
 - a tubular cavity that extends longitudinally from the projecting rim; and
 - a closure comprising:
 - a member that extends over the aperture and circumferentially about the projecting rim;
 - a male portion that extends from the member into the tubular cavity to seal the vessel;
 - a first hinge attaching the member to the projecting rim at a first location;
 - a catch releasably attaching the member to the projecting rim at a second location that is diametrically opposed to the first location;

a band that extends circumferentially about the member and the projecting rim;
and
a second hinge attaching the band to the catch adjacent the second location.

18. The apparatus of Claim 17, further comprising frangible attachments that attach the band to the member.

19. The apparatus of Claim 18, wherein the closure is configured for a user to open the vessel by:
pulling the band adjacent the first location in a first direction to sever the frangible attachments;
pulling the band in a second direction to release the catch; and
pulling the band in a third direction that extracts the male portion from the tubular cavity.

20. The apparatus of Claim 17, wherein the vessel and the closure are formed of a unitary piece of material composed of a common polymer.

21. An apparatus comprising:
a vessel comprising an outlet that comprises:
a rim;
a first outlet portion extending from the rim to a second outlet portion and comprising a first inner diameter;
the second outlet portion extending from the first outlet portion to a third outlet portion and comprising a decreasing inner diameter; and
the third outlet portion extending from the second outlet portion and comprising a second inner diameter that is smaller than the first inner diameter; and
a closure for the vessel comprising:
a base portion; and
a male portion that extends from the base portion, that forms a cavity, and that comprises:
a first male portion extending from the base portion to a second male portion and comprising a first outer diameter;

the second male portion extending from the first male portion to a third male portion and comprising a decreasing outer diameter; and

the third male portion extending from the second male portion and comprising a second outer diameter that is smaller than the first outer diameter,

wherein the first male portion is longer than the first outlet portion.

22. The apparatus of Claim 21, wherein the first inner diameter is no larger than the first outer diameter, and

wherein the second inner diameter is no larger than the second outer diameter.

23. The apparatus of Claim 21, wherein when the male portion is disposed in the outlet with the closure closing the vessel:

at a first location, a first outer surface of the first male portion contacts a first interior surface of the first outlet portion;

at a second location, a second outer surface of the second male portion contacts a second interior surface of the second outlet portion;

at a third location, a third outer surface of the third male portion contacts a third interior surface of the third outlet portion;

at a fourth location that is disposed between the first location and the second location, a first annular gap is formed between the first outer surface of the first male portion and the first interior surface of the first outlet portion; and

at a fifth location that is disposed between the second location and the third location, a second annular gap is formed between the third outer surface of the third male portion and the third interior surface of the third outlet portion.

24. The apparatus of Claim 23, wherein the first location comprises a first seal, the second location comprises a second seal, and the third location comprises a third seal.

25. The apparatus of Claim 23, wherein said contact of the second outer surface with the second interior surface at the second location comprises deformation that comprises:

radial expansion of the third male portion adjacent the third location; and

radial contraction of the first outlet portion adjacent the first location.