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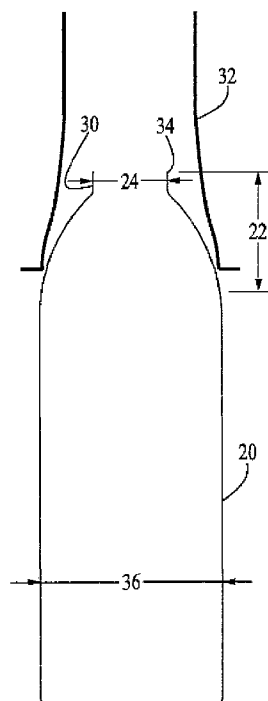
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[Continued on next page]

(54) Title: METHOD OF FORMING A METAL CONTAINER



(57) Abstract: A method of forming a metal container (40) comprises: narrowing a first top section (42) of the container (40) in at least one narrowing step, wherein after narrowing the first top section (42), the first top section (42) has a first top section minimum outer diameter (44); and narrowing a second section (46) of the metal container (40) after narrowing the first top section (42), wherein after narrowing the second section (46), the second section (46) has a second section minimum outer diameter (48); wherein the second section (46) is below the first top section minimum outer diameter (44) and wherein the second section minimum outer diameter (48) is larger than the first top section minimum outer diameter (44). In some embodiments, the second section (46) is below the first top section minimum outer diameter (44). In some embodiments, the second section (46) of the metal container (40) is necked with a necking die (32). In some embodiments, a minimum inner diameter (88) of the working surface of the necking die (92) is greater than the first top section minimum outer diameter (84). In some embodiments, the step of narrowing a second section (86) of the metal container (80) to a second section minimum outer diameter (88) comprises passing the necking die (92) beyond the first top section minimum outer diameter (84).

Fig. 1B



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METHOD OF FORMING A METAL CONTAINER**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This patent application claims priority to U.S. Provisional Patent Application No. 61/495,640, filed June 10, 2011, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Metal containers are mass produced. In order to narrow the tops of the metal containers to accept a closure, often several operations are required using several different necking dies to narrow each metal container a desired amount. Even more narrowing steps and necking dies are required to form a metal container into a bottle or other shape more complex than a standard beverage can. Sometimes, over 20 or 30 necking operations are required to narrow a metal container.

SUMMARY

[0003] A method of forming a metal container comprises: narrowing a first top section of the container in at least one narrowing step, wherein after narrowing the first top section, the first top section has a first top section minimum outer diameter; and narrowing a second section of the metal container after narrowing the first top section, wherein after narrowing the second section, the second section has a second section minimum outer diameter; wherein the second section is below the first top section minimum outer diameter and wherein the second section minimum outer diameter is larger than the first top section minimum outer diameter. In some embodiments, the second section is below the first top section minimum outer diameter.

[0004] In some embodiments, narrowing the second section of the metal container comprises necking with a necking die. As used herein, "necking die" refers to any die that can be used to narrow the diameter of any portion of the container including a top necked

portion, a shaped portion beneath the top necked portion and any other portion of the container. In some embodiments, a minimum inner diameter of the working surface of the necking die is greater than the first top section minimum outer diameter. In some embodiments, the step of narrowing a second section of the metal container to a second section minimum outer diameter comprises passing the necking die beyond the first top section minimum outer diameter.

[0005] In some embodiments, the second section is narrowed 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% or 50% in a single stroke of a necking die.

[0006] In some embodiments, a reduction of about 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% or 50% is possible in a single narrowing step using a single die.

[0007] In some embodiments of the invention, an original diameter of a metal container is narrowed by at least a 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% or 50% using a single necking die without a knockout and/or without first expanding the metal container.

[0008] In some embodiments, at least part of the second section is below the first top section.

[0009] In another embodiment, a method of forming a metal container comprises: narrowing a first top section of the metal container in at least one narrowing step, wherein the first top section has a first top section minimum outer diameter; and narrowing a second section of the metal container to a second section minimum outer diameter after narrowing the first top section, wherein the circumference of the first top section minimum outer diameter does not change when narrowing the second section of the metal container and wherein the second section minimum outer diameter is larger than the first top section minimum outer diameter. In some embodiments, the second section may be completely encompassed within the first top section.

[0010] One embodiment of a method of forming a metal container comprises: narrowing a first top section of the container in at least one narrowing step, wherein after narrowing the first top section, the first top section has a first top section minimum circumference; and narrowing a second section of the metal container after narrowing the first top section, wherein after narrowing the second section, the second section has a second section minimum circumference;

wherein the first top section minimum circumference does not change when narrowing the second section of the metal container and wherein the second section minimum circumference is larger than the first top section minimum circumference. In some embodiments, the second section minimum circumference is below the first top section minimum circumference. In some embodiments, the second section is completely encompassed within the first top section. In some embodiments, at least part of the second section is below the first top section. In some embodiments, narrowing the second section of the metal container comprises necking with a necking die. In some embodiments, necking is performed without the use of a knockout. In some embodiments, a minimum inner circumference of a working surface of the necking die is greater than the first top section minimum outer circumference. In some embodiments, the step of narrowing a second section of the metal container to a second section minimum circumference comprises passing the necking die beyond the first top section minimum circumference. In some embodiments, the second section is narrowed at least 5% in a single stroke of a necking die. In some embodiments, the second section is narrowed at least 10% in a single stroke of a necking die. In some embodiments, the second section is narrowed at least 15% in a single stroke of a necking die.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figure 1A is a cross-sectional side view of a preform metal container.

[0012] Figure 1B is a cross-sectional side view of the preform metal container of Figure 1A after having been narrowed and a necking die.

[0013] Figure 2 is a cross-sectional side view of the preform metal container of Figures 1A and 1B after having been narrowed and while being necked with the necking die of Figure 1B.

[0014] Figure 3 is a cross-sectional side view of the preform metal container of Figures 1A-2 after having been narrowed and while being necked with the necking die of Figures 1B and 2.

[0015] Figure 4 is a partial cross-sectional side view of a metal container having a chimney and a curl before having undergone the step of narrowing a second section of the metal container.

[0016] Figure 5 is a cross-sectional side view of a metal container after having undergone the step of narrowing a first top section of the metal container.

[0017] Figure 6 is a partial cross-sectional side view of a metal container having a curl before having undergone the step of narrowing a second section of the metal container.

[0018] Figure 7 is a partial cross-sectional side view of a necking die, including a working surface, that may be used to narrow a second section of the metal container.

[0019] Figure 8 is a cross-sectional side view of a metal container after having been narrowed and a necking die.

[0020] Figure 9 is a cross-sectional side view of the metal container of Figure 8 after a second section has been narrowed.

[0021] Figure 10 is a top view of the metal container shown in Figure 8.

[0022] Figure 11 is a top view of the metal container shown in Figure 9.

[0023] Figure 12 is a partial cross-sectional view of a metal container after having undergone narrowing of a first top section and of the necking die of Figure 7.

[0024] Figure 13 is a cross-sectional side view of a metal container after having been narrowed.

[0025] Figure 14 is a cross-sectional side view of the metal container of Figure 13 after a second section has been narrowed.

[0026] Figure 15 is a cross-sectional side view of a metal container after having been narrowed and a necking die.

[0027] Figure 16 is a cross-sectional side view of the metal container and necking die of Figure 15 while the container is being necked.

[0028] Figures 17A-17D show an example of a multi-stage necking progression according to one embodiment of the invention.

DESCRIPTION

[0029] For the purposes of this specification, terms such as top, bottom, below, above, under, over, etc. are relative to the position of a finished metal container resting on a flat surface, regardless of the orientation of the metal container during manufacturing or forming steps or processes. A finished metal container is a metal container that will not undergo additional forming steps before it is used by an end consumer. In some embodiments, the top of the container has an opening. When the term “diameter” is used with respect to a necking die, “diameter” refers to an inner diameter. When the term “diameter” is used with respect to a container, “diameter” refers to an outer diameter.

[0030] Referring to Figures 1A-3, a method of forming a metal container 20 comprises: narrowing a first top section 22 of the metal container 20 in at least one narrowing step, wherein after narrowing the first top section 22, the first top section 22 has a first top section

minimum outer diameter 24; and narrowing a second section 26 of the metal container 20 after narrowing the first top section 22, wherein after narrowing the second section 26, the second section 26 has a second section minimum outer diameter 28, wherein the second section 26 is below the first top section minimum outer diameter 24 and wherein the second section minimum outer diameter 28 is larger than the first top section minimum outer diameter 24. Part of the second section 26 is below the first top section 22. In some embodiments, the second section minimum outer diameter 28 is less than the original diameter 36 of the metal container 20. The original diameter 36 is the diameter of the metal container after it has been formed via drawing and ironing or extrusion but before it has been shaped, i.e. what is commonly known in the art as a pre-form metal container. Shaping includes necking and expanding the diameter of the container. In some embodiments, there is no need to pre-stress the metal container 20 by expansion or other means before it is narrowed.

[0031] Figure 1B shows a cross-section of a metal container 20 after having undergone the step of narrowing a first top section 22 of the metal container. Figure 1B also shows a cross-section of a working surface of a necking die 32 before contacting the metal container 20. The metal container 20 shown in Figure 1B is commonly known in the art as a necked pre-form. Figures 2 and 3 show the cross-section of the metal container 20 while the second section 26 is being narrowed by a working surface of the necking die 32. In Figure 2, the working surface of the necking die 32 is in mid-stroke. In Figure 3, the working surface of the necking die 32 is at the end of its stroke. Figures 1B-3 are based on output from finite element modeling. In some embodiments, the stroke of the necking die 32 extends to the bottom of the metal container 20 or proximate to the bottom of the metal container 20.

[0032] The metal comprising the metal container 20 may be any metal known in the art including, but not limited to, aluminum and steel. The metal container 20 may or may not

have a dome. In some embodiments, the metal container 20 is a one-piece metal container having a closed bottom. In some embodiments, the metal container 20 is comprised of multiple pieces of metal seamed together. In some embodiments, a sidewall of the metal container 20 has a uniform thickness from top to near the bottom of the container. In some embodiments, a sidewall of the metal container 20 has a non-uniform thickness. In some embodiments, a sidewall of the metal container 20 is tapered so that the thickness of the sidewall is thinner at the top of the container than the bottom of the container. In some embodiments, the thickness of a sidewall of the metal container 20 varies along the height of the sidewall. In some embodiments, the sidewall is thicker at the top of the container than at a lower sidewall portion of the container.

[0033] Narrowing the first top section 22 of the metal container 20 can be done by any means known in the art, including, but not limited to die necking and spin forming. Necking or spin forming can be performed any way known in the art, including as described in U.S. Patent Nos. 4,512,172; 4,563,887; 4,774,839; 5,355,710 and 7,726,165.

[0034] Narrowing the first top section 22 may be accomplished using traditional means. In some embodiments, several narrowing steps, e.g. 10-30 or more may be required to narrow a first top section and form the containers shown in Figures 1B, 4, 5, 6, 8, 10, 12, 13, 15 and 17A.

[0035] In some embodiments, after narrowing, the first top section 22 includes a chimney 30. The chimney 30 has vertical walls and is a top-most narrowed cylindrical portion of a metal container. In some embodiments, the chimney 30 comprises the first top section minimum outer diameter 24. The chimney 30 may enable the second section 26 to be narrowed more aggressively, i.e. a larger diameter reduction may be taken in a single narrowing step without damaging the metal container, e.g. wrinkling, tearing or collapsing of the metal container. The presence of a chimney 30 in some embodiments helps the opening

of the metal container 20 to maintain its round shape throughout the narrowing process and increases the hoop strength of the opening. However, even when a chimney is present, the opening of the metal container may become out-of-round or oval during subsequent forming operations.

[0036] In some embodiments, the chimney 30 has a curl. Figure 4 shows a partial cross-section of a metal container 110 having a chimney 111 and a curl 112. In some embodiments, the step of narrowing a second section of the metal container after narrowing the first top section occurs after a chimney and/or a curl has been formed in the metal container.

[0037] Some embodiments do not include a chimney. Figure 5 shows a cross-section of a metal container 70 after having undergone the step of narrowing a first top section 72 of the metal container 70. In this embodiment, the metal container 70 does not have a chimney. The first top section minimum outer diameter 74 is at the opening and top edge 76 of the metal container 70. Some embodiments without a chimney include a curl. Figure 6 shows a partial cross-section of a metal container 114 having a curl 116.

[0038] As shown in Figures 2 and 3, narrowing the second section 26 of the metal container 20 can be accomplished using a necking die 32. In some embodiments, after narrowing the first top section 22 a 26 % reduction in diameter of a portion of the metal container 20 in a single stroke of a necking die is possible. In other embodiments, a reduction of diameter of a portion of the metal container 20 of about 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% or 50% is possible in a single stroke of a single die. Some embodiments of the invention can reduce the diameter of a metal container in one necking stroke an amount that would require multiple necking strokes in the prior art. Some embodiments of the invention enable large diameter reductions using a single die to form what is commonly known as a long-necked metal container, significantly reducing the

required number of long-stroke forming operations necessary to form a metal container having a particular shape.

[0039] In some embodiments, the working surface of the necking die 32 has a relief 35 as shown in Figure 7 and as described in U.S. Patent No. 7,726,165. In other embodiments, no relief is necessary. The presence of the relief 35 in the working surface 37 of the necking die 32 enables more aggressive reductions of the metal container 20. In some embodiments, the necking die is comprised of tool steel, carbide, ceramic or any other suitable material known in the art.

[0040] In some embodiments, the land 33, of the working surface 37 of the necking die 32 has a surface roughness average (Ra) ranging from more than or equal to $8\mu\text{in}$ to less than or equal to $32\mu\text{in}$, so long as the surface of the land 33 does not disadvantageously disrupt the aesthetic features of a coating on the metal container in a significantly observable manner, as described in U.S. Patent No. 7,726,165. In other embodiments, the land has an Ra value in the range of $2\mu\text{in}$ to $6\mu\text{in}$. The land 33 is the portion of the working surface 37 of the necking die 32 having the smallest inner diameter, i.e. the minimum inner diameter of the working surface.

[0041] As shown in Figures 2 and 3, in some embodiments, the step of narrowing a second section 26 of the metal container 20 to a second section minimum outer diameter 28 comprises passing a working surface of a necking die 32 beyond the first top section minimum outer diameter 24. In some embodiments, the inner diameter of the land 33 of the working surface of the necking die 32 used in the step of narrowing the second section 26 of the metal container 20 is greater than the first top section minimum outer diameter 24. A knockout does not need to be used when narrowing the second section 26. A knockout provides a surface for releasing a metal container from a necking die. In some embodiments, a pilot is used to control a top edge of a metal container. A pilot is a centering tool that

controls movement of the top edge 34. In some embodiments of the invention, after narrowing the first top section 22, the original diameter of a portion of the metal container 20 is narrowed by at least 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% or 50% using a single necking die without a knockout and/or without first expanding the metal container.

[0042] In another embodiment, a method of forming a metal container 20 comprises: narrowing a first top section 22 of the metal container 20 in at least one narrowing step, wherein after narrowing the first top section 22, the first top section 22 has a first top section minimum circumference; and narrowing a second section 26 of the metal container after narrowing the first top section 22, wherein after narrowing the second section 26, the second section 26 has a second section minimum circumference wherein the first top section minimum circumference does not change when narrowing the second section 26 of the metal container 20 and wherein the second section minimum circumference is larger than the first top section minimum circumference. The circumference is the length of the outer perimeter of the metal container lying in a plane parallel to a flat surface upon which the metal container is resting on its bottom as measured by a tape measure. In some embodiments, the second section may be completely encompassed within the first top section.

[0043] Figure 8 shows a cross-section of a metal container after the first top section 152 has been narrowed but before the second section has been narrowed using the necking die 160. Figure 9 shows the metal container 150 after the second section 156 has been narrowed. The second section 156 is completely encompassed within the first top section 152. Figures 10 and 11 are top down views of the container in Figures 8 and 9, respectively. The minimum circumference 154 of the first top section 152 does not change when the second section 156 is narrowed. The minimum circumference of the second section resides in a plane 158 and is larger than the first top section minimum circumference 154.

[0044] Figure 12 shows certain dimensions of a metal container after having undergone narrowing of the first top section and immediately prior to the step of narrowing the second section. Figure 12 also shows a working surface 37 of a necking die 32 immediately prior to making contact with the metal container. Figure 7 shows certain dimensions of the working surface 37 of the necking die 32, which may be used to perform the step of narrowing the second section of the metal container. A land 33 and undercut 35 are also shown.

Example 1

[0045] In a first example, the dimensions shown in Figures 7 and 12 are:

$$A = 2.305", \quad B = 0.990", \quad C = 1.710", \quad D = 2.418"$$

$$R_{11} = 1.995", \quad R_{12} = 1.995", \quad R_{13} = 0.105"$$

$$R_{21} = 0.050", \quad R_{22} = 1.500", \quad R_{23} = 2.000"$$

$$\theta_{11} = 0^\circ, \quad \theta_{12} = 46.6144^\circ$$

$$\theta_{21} = 85.00^\circ, \quad \theta_{22} = 18.996^\circ, \quad \theta_{23} = 23.996^\circ$$

$$H_{11} = 1.5262", \quad H_{12} = 0.125"$$

$$H_{21} = 1.4234", \quad H_{22} = 0.040"$$

$$L_{21} = 0.0854", \quad L_{22} = 0.0000"$$

[0046] Throughout this specification, quotation marks after a number designate inches, "A", "B", "C" and "D" represent diameters, "R" represents a radius and "H" represents height.

[0047] In this first example, the original starting metal container 20 before the first narrowing step was a 59 mm diameter pre-form, after narrowing the first top section 22, the

second section 26 of the metal container 20 was narrowed 26% using a single working surface of the necking die 32 and a single necking stroke. C represents the minimum diameter of the working surface of the necking die 32. In this example, the necking die 32 travelled 3.5 inches down the metal container 20.

[0048] In this first example, the metal container was comprised of aluminum 3104 alloy, H19 temper and 0.0100" thick sidewall prior to the first necking step. The dimensions in this example were used as input in finite element modeling. The dimensions of Figure 12 in this first example result in a metal container having the shape shown in Figure 1B. After being necked with the working surface of the necking die shown in Figure 7 having the dimensions in this example, the resulting metal container would have the shape of the metal container shown in Figure 3.

Example 2

[0049] Figure 13 shows a second example of a metal container 40 after having undergone the step of narrowing a first top section 42 of the metal container. The metal container 40 shown in Figure 13 is commonly known in the art as a necked pre-form. Figure 14 shows the metal container 40 after the second section 46 has been narrowed. The first top section 42, first top section minimum outer diameter 44, second section 46 of the metal container 40, second section minimum outer diameter 48, chimney 50 and top edge 54 are also shown in Figures 13 and 14.

[0050] Referring again to Figures 7 and 12, the specific dimensions associated with the metal container shown in Figures 13 and 14 are:

$$A = 2.086, B = 1.218, C = 1.822", D = 2.288"$$

$$R_{11} = 1.500, R_{12} = 1.500, R_{13} = 0.070$$

$$R_{21} = 0.100", \quad R_{22} = 5.000", \quad R_{23} = 4.000"$$

$$\theta_{11} = 0, \quad \theta_{12} = 48.5640$$

$$H_{11} = 1.1770, \quad H_{12} = 0.125$$

$$\theta_{21} = 90.00^\circ, \quad \theta_{22} = 9.862^\circ, \quad \theta_{23} = 9.862^\circ$$

$$L_{21} = 0.0000", \quad L_{22} = 0.0000"$$

$$H_{21} = 1.6415", \quad H_{22} = 0.040"$$

[0051] In this example, the original circumference of the metal container 40 corresponding to diameter A was 6.563" as measured with a tape measure. The circumference of the metal container 40 at the first top section minimum outer diameter 44 was 3.875" as measured with a tape measure. The second section minimum circumference of the metal container 40 shown in Figure 14 was 5.781" as measured with a tape measure. The metal container shown in Figures 13 and 14 is comprised of aluminum 3104 alloy, H19 temper and 0.0088" thick sidewall prior to the first necking step. After narrowing the first top section 42, a portion of the second section 46 of the metal container 40 was narrowed approximately 12.7% using a single necking die and a single necking stroke. The original starting metal container before the first narrowing step was a 53 mm diameter pre-form. The metal container shown in Figures 13 and 14 was actually produced using the methods described herein.

Example 3

[0052] Figure 15 shows a third example of a metal container 80 after having undergone the step of narrowing a first top section 82 of the metal container and a working surface of a necking die 92 before contacting the metal container. The metal container 80 shown in

Figure 15 is commonly known in the art as a necked pre-form. Figure 16 shows the metal container 80 while the second section 86 is being narrowed by the working surface of the necking die 92. In Figure 16, the necking die 92 is at the end of its stroke. The first top section 82, first top section minimum outer diameter 84, second section 86 of the metal container 80, second section minimum outer diameter 88, chimney 90, top edge 94 and original diameter 96 are also shown in Figures 15 and 16.

[0053] Referring again to Figures 7 and 12, the specific dimensions associated with the metal container shown in Figures 15 and 16 are:

$$A = 2.305", B = 0.990", C = 1.937", D = 2.430"$$

$$R_{11} = 1.995", \quad R_{12} = 1.995", \quad R_{13} = 0.105"$$

$$R_{21} = 0.050", \quad R_{22} = 3.050", \quad R_{23} = 1.000"$$

$$\theta_{11} = 0^\circ, \quad \theta_{12} = 46.6144^\circ$$

$$\theta_{21} = 85.00^\circ, \quad \theta_{22} = 12.573^\circ, \quad \theta_{23} = 17.573^\circ$$

$$H_{11} = 1.5262", \quad H_{12} = 0.125"$$

$$H_{21} = 1.2228", \quad H_{22} = 0.040"$$

$$L_{21} = 0.2210", \quad L_{22} = 0.0000"$$

[0054] The metal container shown in Figures 15 and 16 is comprised of aluminum 3104 alloy, H19 temper and 0.0100" thick sidewall prior to the first necking step. After the first top section 82 was narrowed, a portion of the diameter of the second section 86 of the metal container 80 was narrowed approximately 16% using a single necking die and a single

necking stroke. The original starting metal container before the first narrowing step was a 59 mm diameter pre-form. Figures 15 and 16 were produced using finite element modeling.

Example 4

[0055] Figures 17A-17D show an example of a multi-stage necking progression according to one embodiment of the invention, which includes additional narrowing steps after a second section 132 of a metal container 130 is narrowed. In this fourth example, after the first top section 134 was narrowed, a portion of the diameter of the second section 132 is narrowed so that the diameter is reduced 26% from the original diameter 144 in a single necking stroke using a single necking die, resulting in the container shown in Figure 17B. The second section 132 is narrowed a second time via die necking, reducing the diameter of the metal container a total of 36% from the original diameter 144 in a portion of the second section 132, as shown in Figure 17C. The second section 132 is narrowed a third time via die necking reducing the diameter of the metal container 130 a total of 40% from the original diameter 144 in a portion of the second section 132, as shown in Figure 17D. Figures 17A - 17D also show a first top section 134, first top section minimum outer diameter 136, chimney 140, and a top edge 142. A second section minimum outer diameter 138 can be seen in Figure 17B. Figures 17A-17D were produced based on output from finite element modeling.

[0056] Referring again to Figures 7 and 12, data ranges in which it is currently thought would yield a metal container according to some embodiments of the invention when the metal container before the first narrowing step comprises a 45 mm - 87 mm diameter pre-form, including, but not limited to, 45 mm (112), 53 mm (202), 59 mm (205), 60 mm (206), 63 mm (207.5), 68 mm (211), 73 mm (214), 76 mm (300), 87 mm (307) diameter pre-forms, include but are not limited to:

$$1.772'' \leq A \leq 3.438''$$

$$0.500'' \leq B \leq A$$

$$0.7 * A \leq C \leq A$$

$$R_{11} \geq 0.125''$$

$$R_{11} \leq R_{12} \leq \infty$$

$$0.100'' \leq R_{13} \leq 5.000''$$

$$0.100'' \leq R_{23} \leq 10.000''$$

$$10^\circ \leq \theta_{11} \leq 60^\circ$$

$$\theta_{11} \leq \theta_{12} \leq 90^\circ$$

$$0 < H_{12} < 3.000''$$

$$0 \leq H_{22} \leq 8.000''$$

[0057] In some embodiments of the invention, the following data ranges are applicable:

45mm ≤ A ≤ 87mm; 45mm ≤ A ≤ 76mm; 45mm ≤ A ≤ 68mm; 54mm ≤ A ≤ 87mm; 54mm ≤ A ≤ 68mm;

76mm ≤ A ≤ 87mm; or 53mm ≤ A ≤ 68mm

18mm ≤ B ≤ 28mm; 2.0'' ≤ B ≤ 3.0''; 2.5'' ≤ B ≤ 3.0''; 18mm ≤ B ≤ 43mm; 25.4mm ≤ B ≤ 38mm; or

26mm ≤ B ≤ 33mm

$R_{11} \geq 0.125'', 0.250'', 0.400'', 0.500'', 1.000''$ or $5.000''$

$0.100'' \leq R_{13} \leq 0.500''$; $0.100'' \leq R_{13} \leq 5.000''$; $0.250'' \leq R_{13} \leq 2.50''$; $0.250'' \leq R_{13} \leq 0.500''$;
 $0.250'' \leq R_{13} \leq 0.750''$; $0.500'' \leq R_{13} \leq 1.00''$; $0.750'' \leq R_{13} \leq 5.000''$; or $0.750'' \leq R_{13} \leq 2.50''$

$0.100'' \leq R_{23} \leq 0.500''$; $0.100'' \leq R_{23} \leq 5.000''$; $0.250'' \leq R_{23} \leq 2.50''$; $0.250'' \leq R_{23} \leq 0.500''$; $0.250'' \leq R_{23} \leq 0.750''$; $0.500'' \leq R_{23} \leq 1.00''$; $0.750'' \leq R_{23} \leq 5.000''$; or $0.750'' \leq R_{23} \leq 2.50''$

$0 < H_{12} < 3.000''$; $0.010'' < H_{12} < 1.00''$; $0.010'' < H_{12} < 5.0''$; $0.010'' < H_{12} < 10.0''$; $0.025'' < H_{12} < 0.250''$; $0.025'' < H_{12} < 1.00''$; $0.050'' < H_{12} < 1.00''$; or $0.010'' < H_{12} < 0.05''$

$0 \leq H_{22} \leq 3.000''$; $0.010 \leq H_{22} \leq 1.00''$; $0.010'' \leq H_{22} \leq 5.0''$; $0.010'' \leq H_{22} \leq 10.0''$; $0.025'' \leq H_{22} \leq 0.250''$; $0.025'' \leq H_{22} \leq 1.00''$; $0.050'' \leq H_{22} \leq 1.00''$; or $0.010 \leq H_{22} \leq 0.05''$

[0058] Ranges of functional dimensions likely depend on many factors including, but not limited to: the type of metal comprising the metal container, including the specific alloy used, the thickness and temper of the metal and the size of the metal container.

[0059] Embodiments of the invention are also applicable to other types and sizes of metal containers. For example, some embodiments of the invention may be used to form metal beverage, aerosol and/or food containers.

[0060] While various embodiments of the present disclosure have been described in detail, it is apparent that modifications and adaptations of those embodiments will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present disclosure.

[0061] All features disclosed in the specification, including the claims, abstracts, and drawings, and all the steps in any method or process disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. Each feature disclosed in the specification, including the claims, abstract, and drawings, can be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0062] Any element in a claim that does not explicitly state "means" for performing a specified function or "step" for performing a specified function should not be interpreted as a "means or step for" clause as specified in 35 U.S.C. § 112.

CLAIMS

1. A method of forming a metal container comprising:
narrowing a first top section of the container in at least one narrowing step, wherein after
narrowing the first top section, the first top section has a first top section minimum
outer diameter; and

narrowing a second section of the metal container after narrowing the first top section,
wherein after narrowing the second section, the second section has a second section
minimum outer diameter;

wherein the second section is below the first top section minimum outer diameter;

wherein the second section minimum outer diameter is larger than the first top section
minimum diameter.
2. The method of claim 1 wherein narrowing the second section of the metal container
comprises necking with a necking die.
3. The method of claim 2 wherein necking is performed without the use of a knockout.
4. The method of claim 2 wherein a minimum inner diameter of a working surface of the
necking die is greater than the first top section minimum outer diameter.
5. The method of claim 2 wherein the step of narrowing a second section of the metal
container to a second section minimum outer diameter comprises passing the
necking die beyond the first top section minimum outer diameter.
6. The method of claim 1 wherein the second section is narrowed at least 5% in a single
stroke of a necking die.
7. The method of claim 1 wherein the second section is narrowed at least 10% in a single
stroke of a necking die.

8. The method of claim 1 wherein the second section is narrowed at least 15% in a single stroke of a necking die.
9. The method of claim 1 wherein at least part of the second section is below the first top section.
10. A method of forming a metal container comprising:
narrowing a first top section of the container in at least one narrowing step, wherein after narrowing the first top section, the first top section has a first top section minimum circumference; and
narrowing a second section of the metal container after narrowing the first top section, wherein after narrowing the second section, the second section has a second section minimum circumference;
wherein the first top section minimum circumference does not change when narrowing the second section of the metal container and wherein the second section minimum circumference is larger than the first top section minimum circumference.
11. The method of claim 10 wherein the second section minimum circumference is below the first top section minimum circumference.
12. The method of claim 10 wherein the second section is completely encompassed within the first top section.
13. The method of claim 10 wherein at least part of the second section is below the first top section.
14. The method of claim 10 wherein narrowing the second section of the metal container comprises necking with a necking die.
15. The method of claim 14 wherein necking is performed without the use of a knockout.

16. The method of claim 14 wherein a minimum circumference of a working surface of the necking die is greater than the first top section minimum circumference.
17. The method of claim 14 wherein the step of narrowing a second section of the metal container to a second section minimum circumference comprises passing the necking die beyond the first top section minimum circumference.
18. The method of claim 10 wherein the second section is narrowed at least 5% in a single stroke of a necking die.
19. The method of claim 10 wherein the second section is narrowed at least 10% in a single stroke of a necking die.
20. The method of claim 10 wherein the second section is narrowed at least 15% in a single stroke of a necking die.

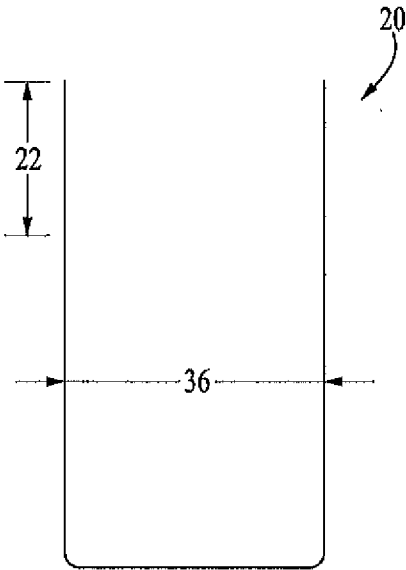


FIG. 1A

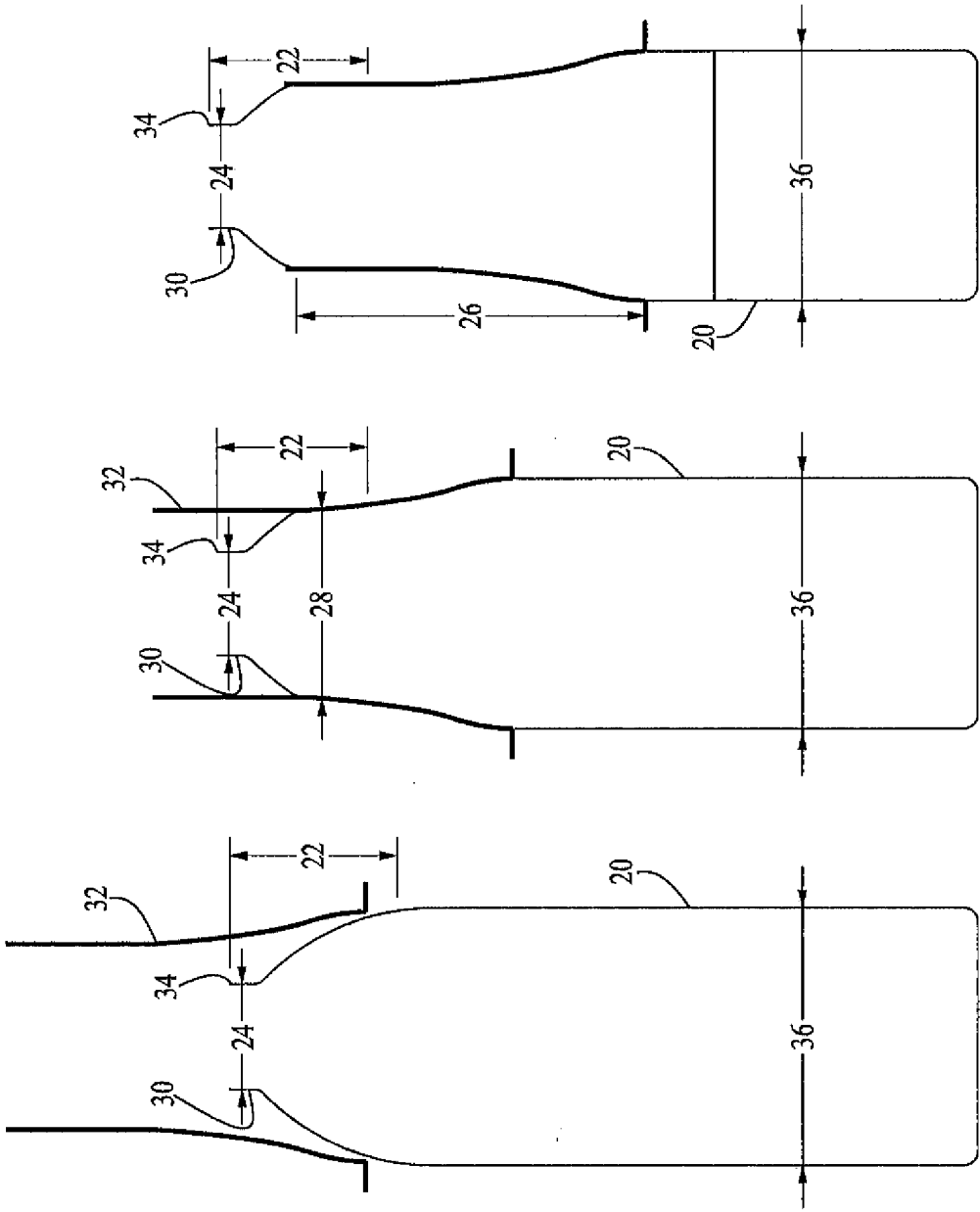


FIG. 3

FIG. 2

FIG. 1B

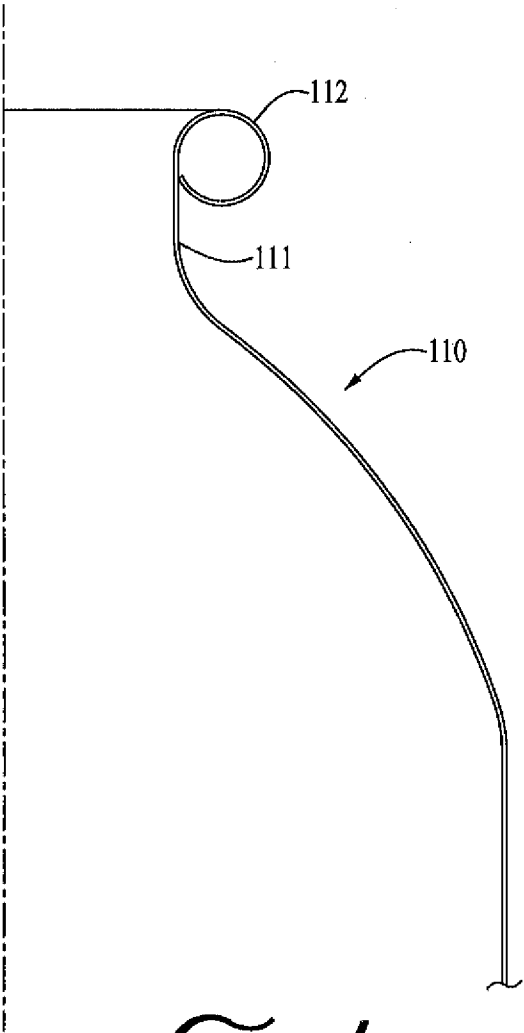


FIG. 4

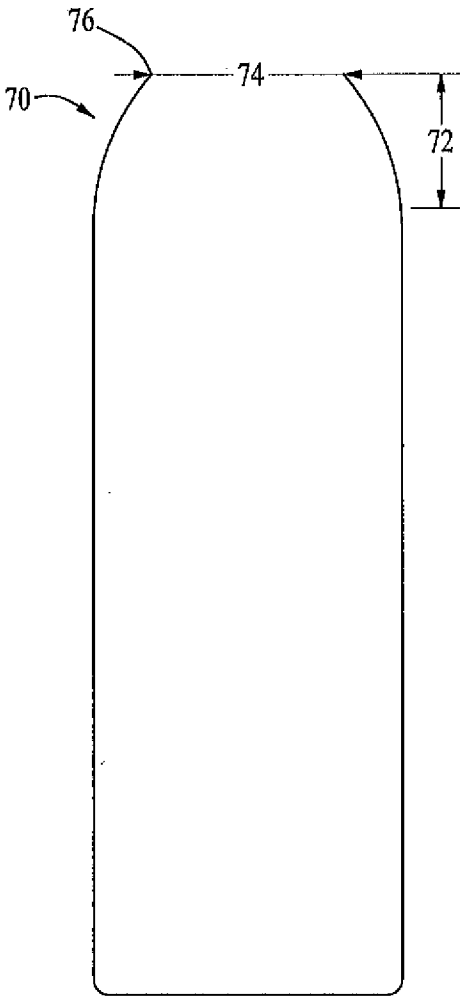


Fig. 5

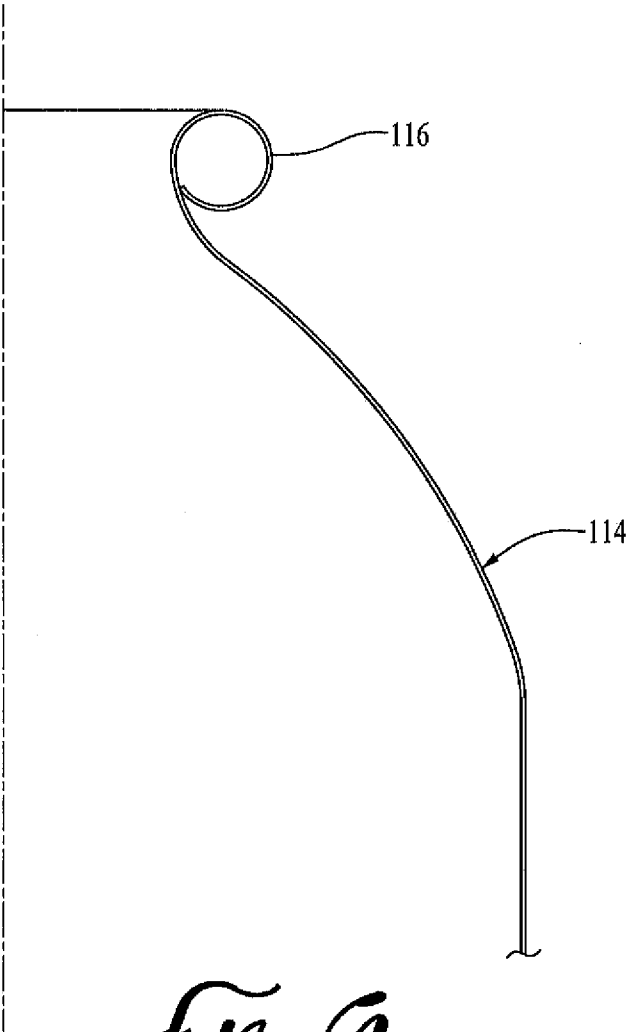
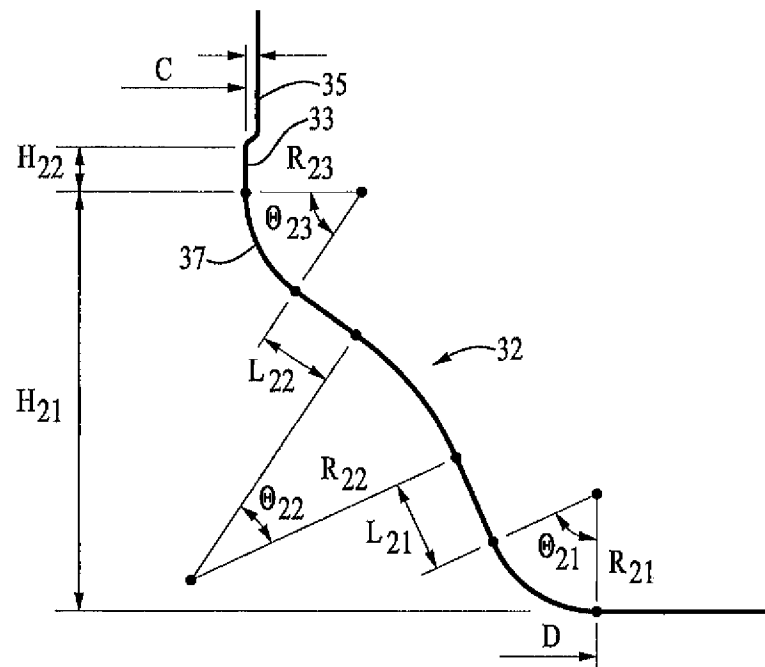


Fig. 6

6/11

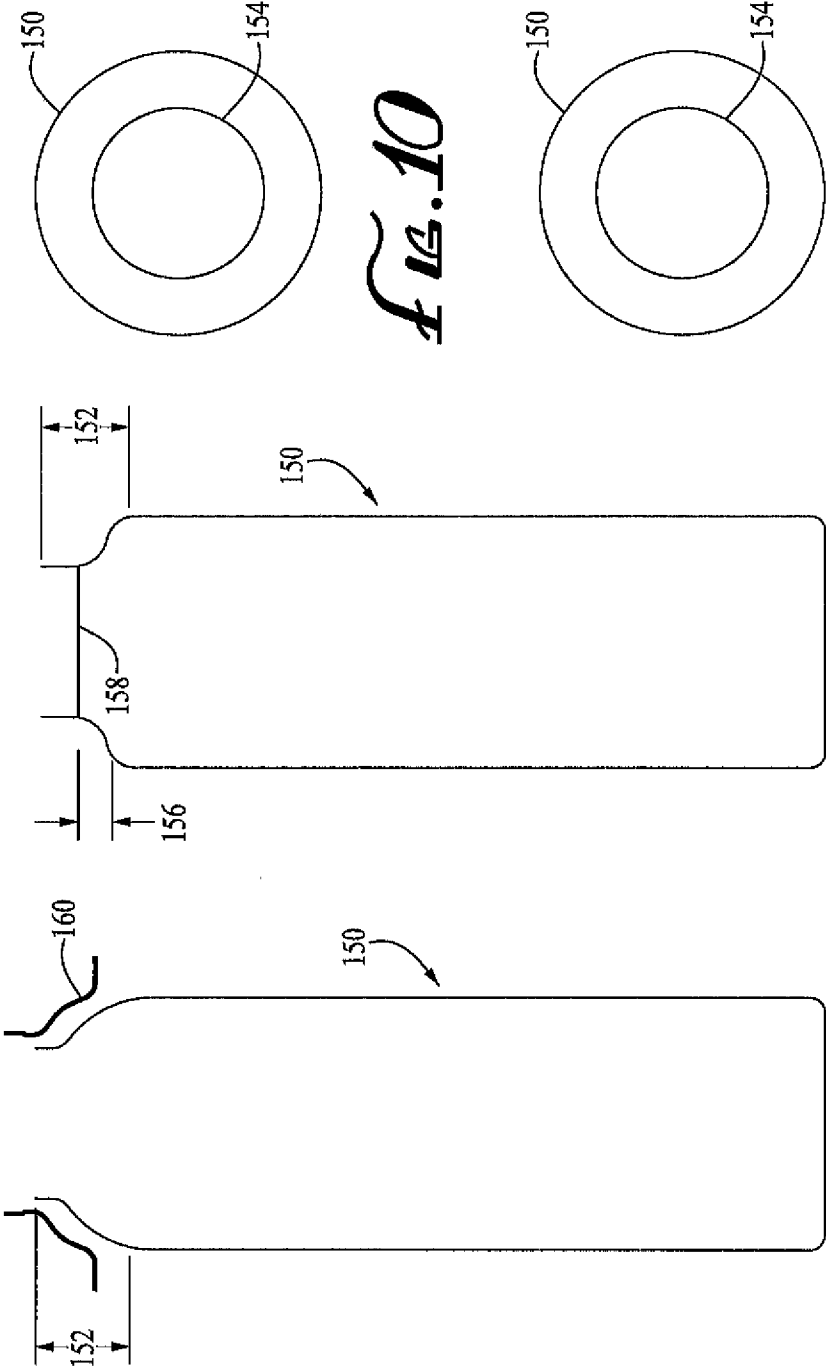


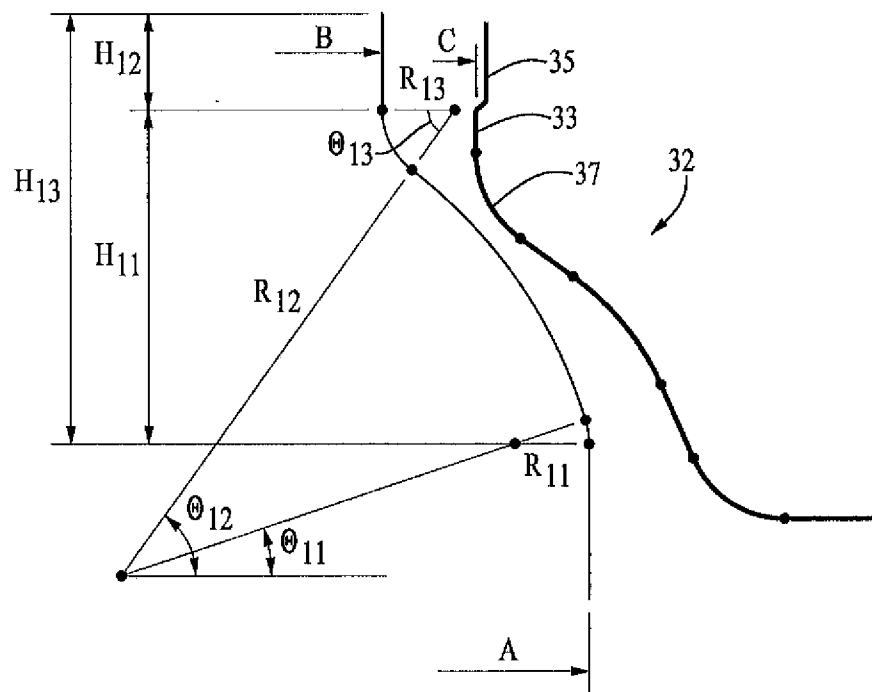
$$D - C = 2 * [(R_{21} + R_{22}) \sin(\theta_{21}) + L_{21} \cos(\theta_{21}) + L_{22} \sin(\theta_{23}) + R_{23} - (R_{22} + R_{23}) \cos(\theta_{23})]$$

$$H_{21} = [R_{21} - (R_{21} + R_{22}) \cos(\theta_{21}) + L_{21} \sin(\theta_{21}) + L_{22} \cos(\theta_{23}) + (R_{22} + R_{23}) \sin(\theta_{23})]$$

$$\theta_{23} = 90 - \theta_{21} + \theta_{22}$$

Fig. 7





$$A - B = 2 * [(R_{11} + R_{13}) + (R_{12} - R_{11}) * \cos(\Theta_{11}) - (R_{12} + R_{13}) * \cos(\Theta_{12})]$$

$$H_{11} = (R_{11} - R_{12}) * \sin(\Theta_{11}) + (R_{12} + R_{13}) * \sin(\Theta_{12})$$

$$H_{13} = H_{11} + H_{12}$$

Fig. 12

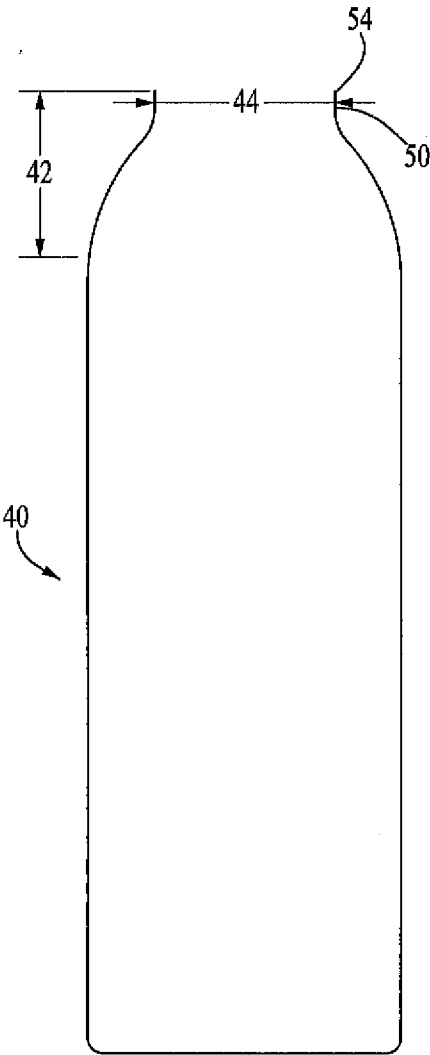


FIG. 13

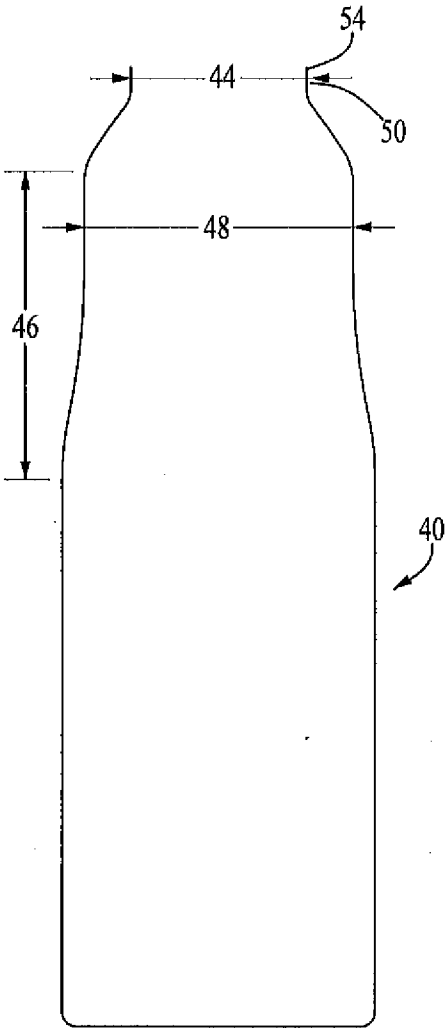


FIG. 14

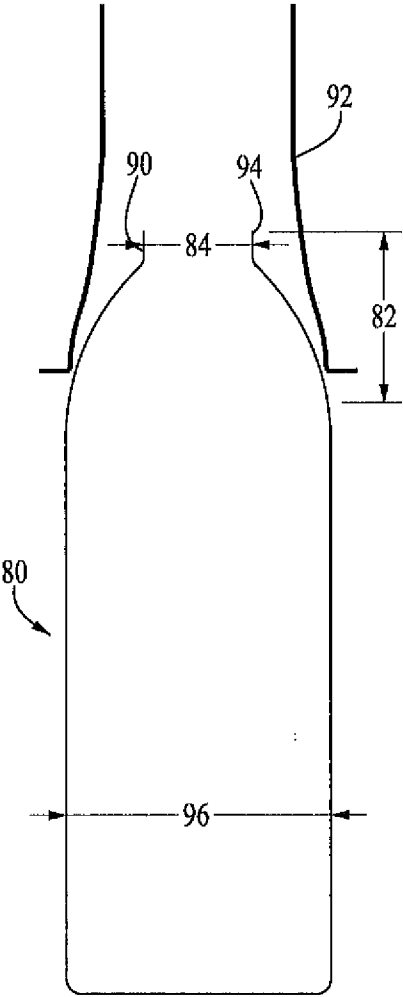


Fig. 15

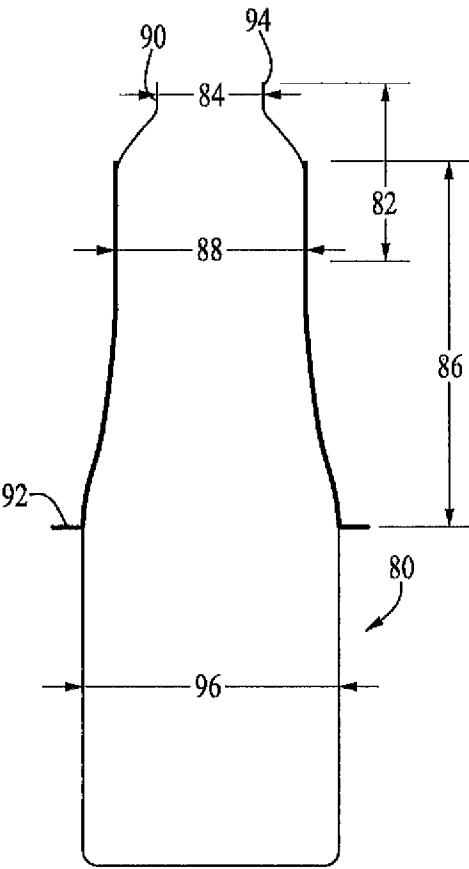
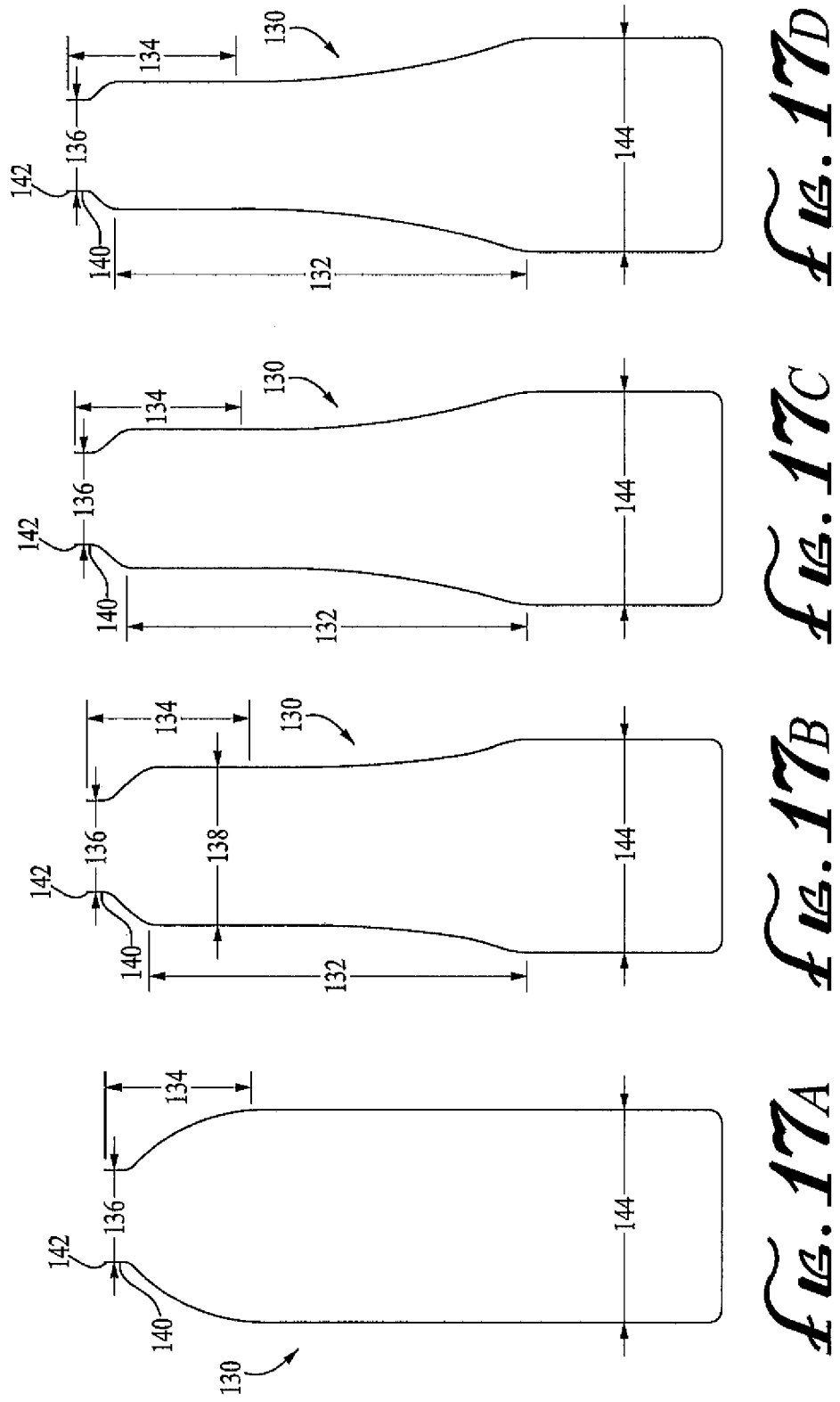


Fig. 16



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/041235

A. CLASSIFICATION OF SUBJECT MATTER INV. B21D41/04 B21D51/16 B21D51/40 B21D51/26 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B21D		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 61 193730 A (TAKEUCHI PRESS) 28 August 1986 (1986-08-28) abstract; figures 1,2,4,6,7 -----	1-20
X	JP 61 193729 A (TAKEUCHI PRESS) 28 August 1986 (1986-08-28) abstract; figures 1,2b,3 -----	1-20
X	FR 2 372 090 A2 (CEBAL [FR]) 23 June 1978 (1978-06-23) figures 1,3,4-6 -----	1-5,9-17
A		6-8, 18-20
X	FR 2 606 686 A1 (CEBAL [FR]) 20 May 1988 (1988-05-20) abstract; figures 3,6 -----	1-4,9-16
A		5-8, 17-20
	----- -/-	
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 23 July 2012		Date of mailing of the international search report 03/08/2012
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Cano Palmero, A

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2012/041235

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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