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Carmichael

[11] **3,727,783**

[45] **Apr. 17, 1973**

[54] **NONEVERTING BOTTOM FOR THERMOPLASTIC BOTTLES**

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[52] **U.S. Cl.** ....**215/1 C,** 99/171 B, 220/70

[51] **Int. Cl.** **B65d 1/02**

[58] **Field of Search** ....215/1 R, 1 C; 220/3, 220/60, 70; 150/.5; 99/171 B

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Assistant Examiner—Stephen Marcus
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[57] **ABSTRACT**

A generally cylindrical thermoplastic bottle for bottling liquids under pressure such as beer, soda and aerosols, having a noneverting bottom under conditions of bottling and use wherein the bottom comprises at least three lobes around the bottom perimeter of the bottom on which the bottle stands, strap sections located between each lobe and a generally circular and axially aligned, recessed section defining a re-entrant cylinder of the base. To further improve eversion resistance, the bottom of the bottle can include a reinforcing ring attached to the re-entrant cylinder.

8 Claims, 12 Drawing Figures

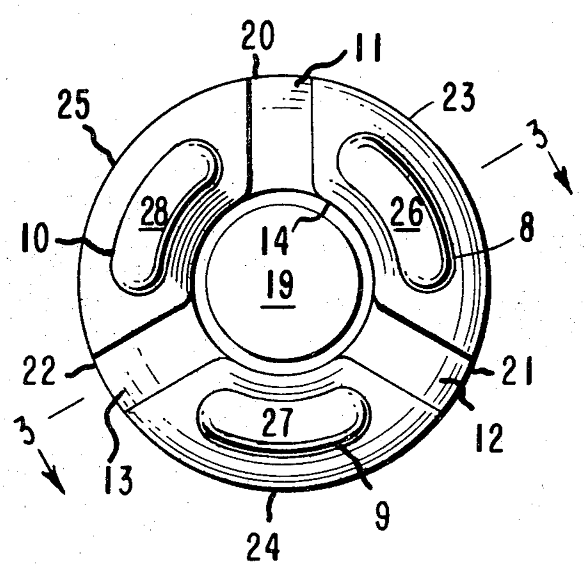

FIG.1

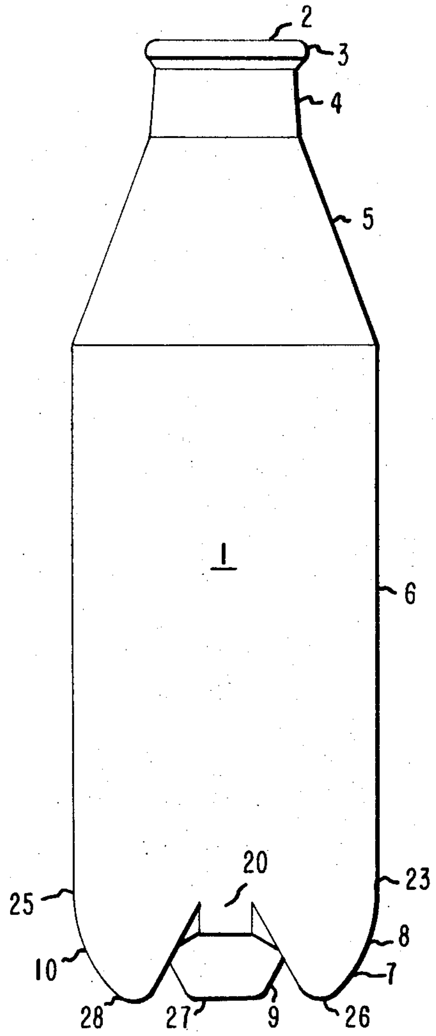

FIG.3

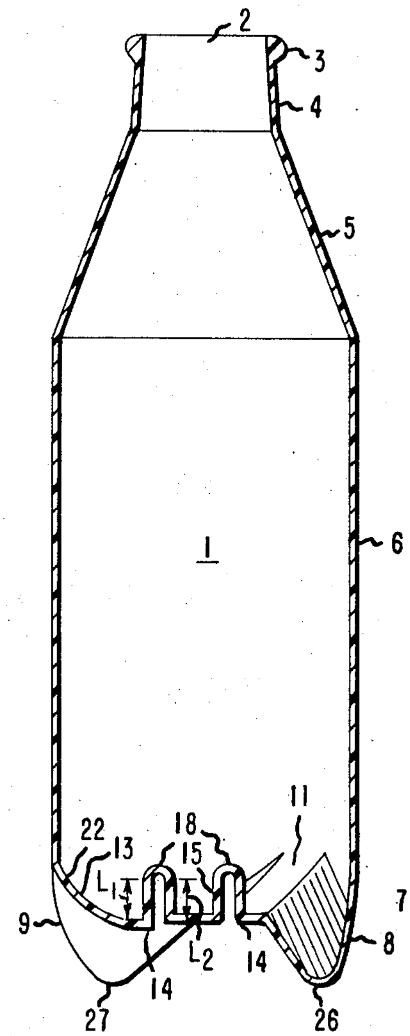

FIG.2

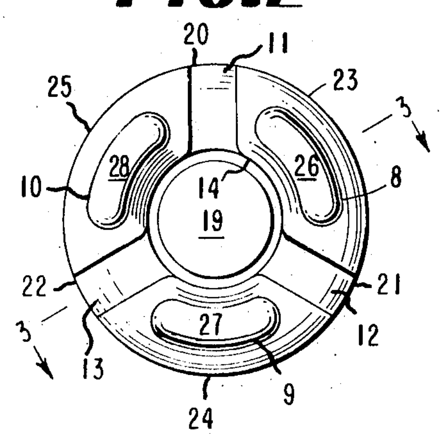

FIG.4

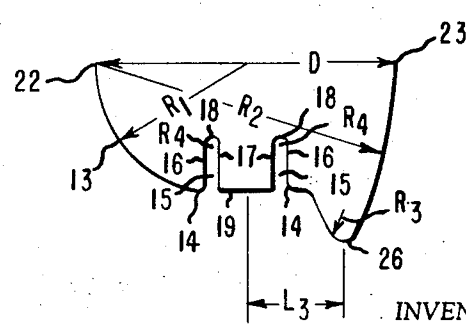

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FIG.5

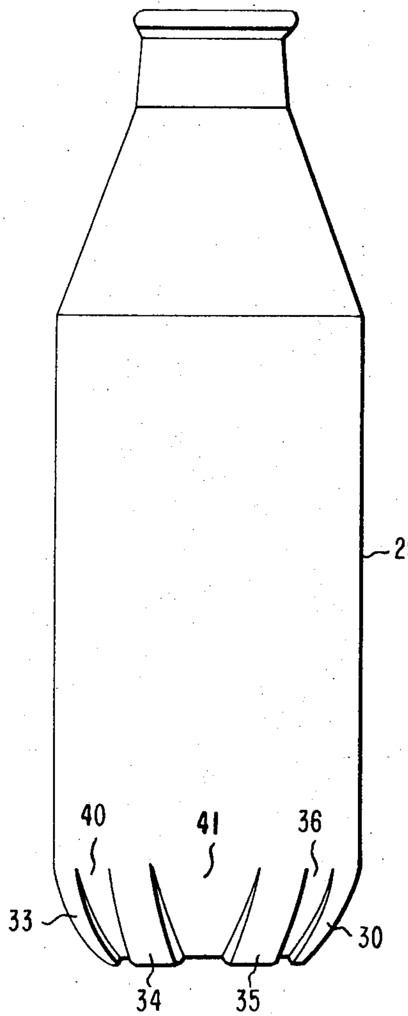

FIG.7

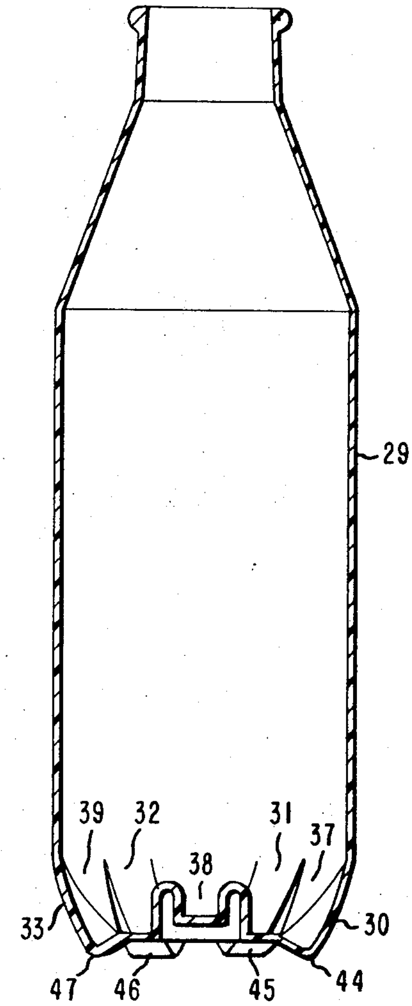

FIG.6

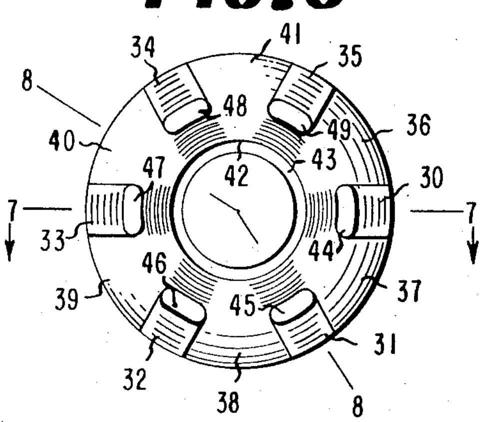

FIG.8

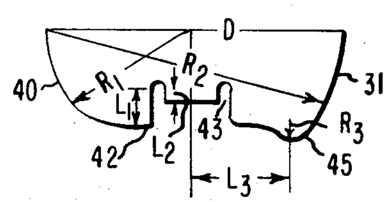

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FIG. 9

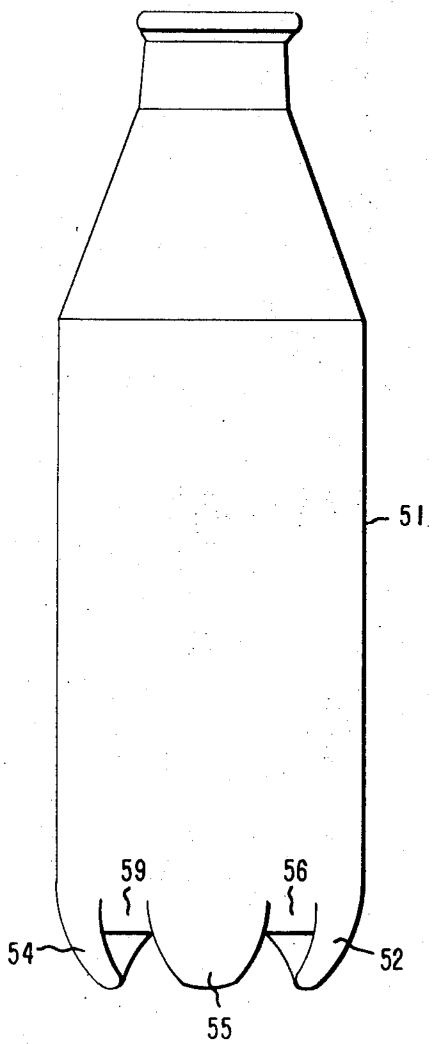


FIG. 11

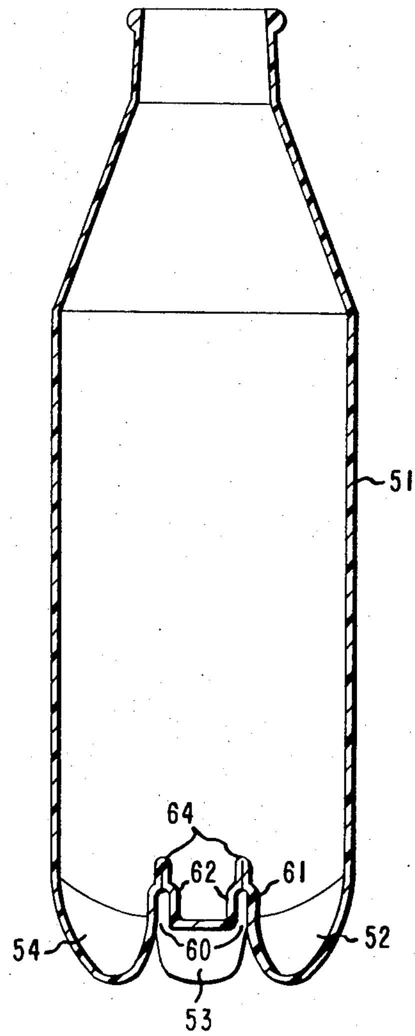


FIG. 10

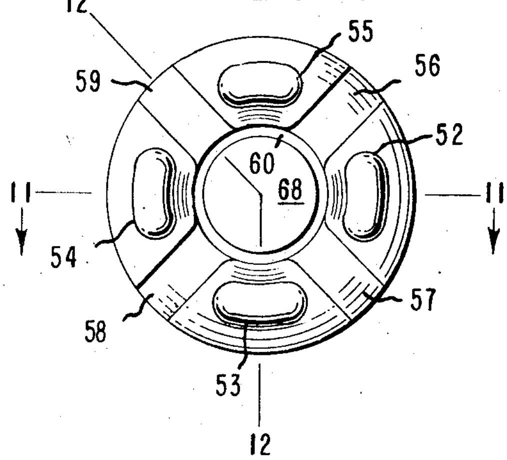
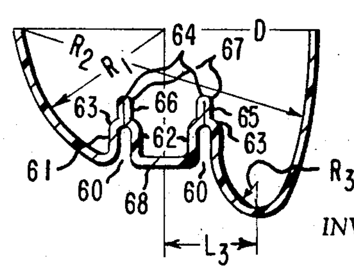


FIG. 12



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NONEVERTING BOTTOM FOR THERMOPLASTIC BOTTLES

BACKGROUND OF THE INVENTION

This invention relates to the art of manufacturing thermoplastic bottles useful in bottling liquids under pressure such as sodas, beer and aerosols and is particularly concerned with providing a bottle having a bottom that will not evert during use.

It is known that thermoplastic bottles can be used to bottle beverages for consumer use. If the bottle is used to contain carbonated beverages such as soda or beer, the bottle must be designed to constrain the autogenous pressure in the bottle while remaining dimensionally stable in shape and volume.

Thermoplastics, however, by nature will deform at moderate temperatures under relatively small loads and therefore, when formed into plastic bottles and used in bottling liquids under pressure, they will deform in normal use. For example, at a temperature of about 50°C. and under an autogenous pressure of about 100 psig, i.e., about the highest pressure typically found in a soda or beer bottle, plastic bottles have a tendency to deform into the shape of a sphere. One way of significantly reducing this tendency is to make the shell of the bottle very thick. While functional, this is not economical and, furthermore, tends to make the bottle so rigid that it fractures in normal use. It has been found, however, that by making a thin-shelled bottle and molecularly orienting the polymer, the yield stress in the side walls can be improved sufficiently to resist this tendency to deform. However, it is very difficult to molecularly orient the polymer in the bottom of the bottle. Therefore, the bottom retains this tendency to deform, i.e., evert.

In general, the bottom of a bottle is conventionally rather flat, permitting the bottle to stand upright. In unpressurized applications, this is not a severe requirement and flat-bottomed bottles can be used successfully. In pressurized applications, however, a flat bottom is inherently a poor shape to hold rigid and the bottom tends to evert into the shape of hemisphere, increasing the volume of the bottle, distorting the bottom shape and eliminating the possibility of the bottle being able to stand on a flat surface. Therefore, the low stress capabilities of the plastic coupled with high temperatures for extended time periods under sufficient internal pressure, will cause the plastic to creep or deform so that shape and volume change excessively even though the contents, i.e., gas and the liquid, are successfully contained within the bottle.

Therefore, it is desirable to find a way of making a plastic bottle useful in bottling liquids under pressure having a bottom that will not evert and will, at the same time, maintain a base sufficient for the bottle to stand on when used to bottle liquids under pressure.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a thermoplastic bottle having a noneverting bottom when subjected to temperatures up to about 50°C. and autogenous pressures up to about 100 psig. The bottle is a generally cylindrical, biaxially oriented, thermoplastic bottle having a shell thickness at the right cylinder section of at least about 20 mils and at least about 30 mils in the bottom section. The bottle is preferably prepared

from a polymer having a modulus of elasticity at yield of 180,000 psi; a tensile strength of at least 5,000 psi; a Poisson's Ratio of 0.35 to 0.4; and a deformation constant equal to the slope of the log (reciprocal of the strain rate) versus strain having a value of at least about 0.65.

The bottom of the bottle consists essentially of at least three lobes around the bottom perimeter of the bottle on which the bottle stands, strap sections located between each lobe, an axially aligned re-entrant cylinder and a generally circular and axially aligned recessed disc-like section with a smooth transition of material between the lobes, straps, re-entrant cylinder and recessed sections of the base. In the following description, D = the outside diameter of the bottle taken perpendicular to the major axis of the bottle, i.e., an imaginary line running from top center to the bottom center, where the bottom section of the bottle meets the generally cylindrical section of the bottle.

The strap sections each begin at the generally cylindrical section of the bottle and extend downward toward the central axis of the bottle with a radius of about 0.45 to 0.70 D, including about 75° to 90° of arc wherein the width of each strap is determined by the following formula:

$$w=\frac{\pi F R}{N\left[\frac{(C_1)\,Syp}{P\frac{R}{t}}-(1-F)\right]}$$

where:

- w = average width of an individual strap,
- N = number of straps,
- R = outside radius of the generally cylindrical section of the bottle taken where the bottom meets the generally cylindrical section and is equal to $D/2$,
- P = autogenous design pressure,
- Syp = yield stress of the thermoplastic,
- C_1 = 0.75–0.95 (design stress factor),
- F = fraction of the total load on the lobes of the bottle to be carried by the straps,
- t = shell thickness of a strap, and
- π = 3.14.

The lobes fit in between the strap sections and each lobe starts at the generally cylindrical section extending downward with a radius of about 0.2–1.5 D measured from the plane between the generally cylindrical section and the bottom section of the bottle including about 20° to 40° of arc and is connected to a toroidal knuckle having a radius of about 0.03 to 0.1 D including about 90° to 150° of arc directed down and inward toward the central axis of the bottle wherein the toroidal knuckle forms the standing surface of the bottle and the center of curvature of the toroidal knuckle is located a distance of about 0.3 to 0.4 D away from the central axis of the bottle.

The inward extending portions of the lobes and strap sections, in uniform circumferential spacing, then meet around the base of a re-entrant cylinder which is axially aligned and recessed in the bottom of the bottle. The re-entrant cylinder is defined by two concentric walls each having a length of about 0.05 to 0.22 D wherein one wall is connected to the lobes and strap sections and the other wall is connected to a recessed central disc and the two walls are interconnected with a toroidal knuckle having a radius of about 0.02 to 0.04 D including about 180° of arc. The wall lengths need not be the same.

In an alternate embodiment, a reinforcing ring is attached to the re-entrant cylinder adding an increased amount of eversion resistance to the bottom of the bottle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view of a three-lobed plastic bottle made according to the present invention.

FIG. 2 is a bottom view of the bottle shown in FIG. 1.

FIG. 3 is a cross section of the bottle shown in FIG. 1 taken along the line 3—3 of FIG. 2.

FIG. 4 is a schematic showing the curves in the bottom of the bottle taken along line 3—3 of FIG. 2.

FIG. 5 is a front view of a six-lobed plastic bottle made according to the present invention.

FIG. 6 is a bottom view of the six-lobed bottle shown in FIG. 5.

FIG. 7 is a cross section of the bottle shown in FIG. 5 taken along line 7—7 of FIG. 6.

FIG. 8 is a schematic showing the curves in the bottom of the bottle taken along line 8—8 of FIG. 6.

FIG. 9 is a front view of a four-lobed plastic bottle made according to the present invention incorporating the alternate embodiments of (a) a re-entrant cylinder and (b) a reinforcing ring in the bottom of the bottle.

FIG. 10 is a bottom view of the bottle shown in FIG. 9.

FIG. 11 is a cross section of the bottle shown in FIG. 9 taken along line 11—11 of FIG. 10.

FIG. 12 is a schematic showing the curves in the bottom of the bottle taken along line 12—12 of FIG. 10.

DETAILS OF THE INVENTION

FIG. 1 shows a front view of a thermoplastic bottle incorporating the noneverting bottom design of the present invention. The bottle 1 is a hollow container having an opening 2 at one end used to pour liquid into or out of the bottle. The bottle is made up of a lip portion 3 surrounding opening 2, a narrow, generally cylindrical neck section 4, a cone frustum section 5, a large, generally cylindrical section 6 and a noneverting bottom section 7 which will be described below in detail. The upper configuration of the bottle is not critical to this invention. For example, the neck portion can be short with a definite shoulder in the bottle or elongated with a smooth transition into the generally cylindrical portion of the bottle. The main portion of the bottle, namely, the generally cylindrical section, can be fluted or otherwise shaped to obtain a desirably aesthetic appearance.

The term "evert" is used in its common sense, i.e., to turn outward; and a bottle having a noneverting bottom is used to mean a bottle in which the bottom will not turn outward under normal use conditions to a point where it is unsightly or would not stand. Normal use conditions are generally no greater than a temperature of about 0°–50°C. and an autogenous, i.e., internal positive, pressure up to about 100 psig. It is to be understood that under an autogenous pressure some movement, usually nominal elongation, will occur that is not eversion.

Eversion can be caused by a number of factors. Perhaps the two most important factors are (a) overstressing of the plastic material used to make the bottle, particularly where the internal pressure of the bottle causes stresses in the bottle that exceed the yield stress of the material resulting in large material deflections and deformations; and (b) geometric instability. The noneverting bottle of the present invention balances the type and amount of thermoplastic material used with a particular geometric design to the bottom of the bottle.

The bottom geometry of the bottle will now be described in relation to FIGS. 1 to 4 of the drawings with particular reference to FIG. 4 drawn as an aid to show the curves involved in a three-lobed bottom along the line 3—3 of FIG. 2.

In describing the bottom geometry and as hereinafter used, D equals the outside diameter of the bottle taken perpendicular to the major axis of the bottle, i.e., imaginary line running from top center to bottom center, where the bottom section of the bottle meets the generally cylindrical section of the bottle. All dimensions are outside dimensions, i.e., mold dimensions.

The set points for the bottle are three lobes 8, 9, and 10. In between the lobes are strap sections 11, 12, and 13. The portions of the bottom between the lobes and the strap sections curve to form smooth transitions between the lobes and the straps. The inward extending portions of the lobes and strap sections, in uniform circumferential spacing, meet around the base 14 of a re-entrant cylinder 15 formed by two spaced-apart side wall sections 16 and 17 joined by a toroidal knuckle 18. Side wall 17 then connects with the center portion 19 of the bottom of the bottle which has a generally circular configuration that is axially aligned and usually recessed to a position where it is about tangent to the bottom portion of the curve defining straps 11, 12 and 13.

In more particular detail, strap sections begin at the right cylinder section indicated by 20, 21 and 22 and extend downward in a circular manner toward the central axis of the bottle with a radius (R_1) of about 0.45 to 0.70 D, including about 75° to 90° of arc and terminating at the base 14 of the bottom of the re-entrant cylinder. The width of each strap is determined by the following formula:

EQUATION 1

$$w=\frac{\pi FR}{N\left[\frac{(C_1)Syp}{P\frac{R}{t}}-(1-F)\right]}$$

where:

w = average width of an individual strap,

N = number of straps,

R = outside radius of the generally cylindrical section of the bottle taken where the bottom meets the generally cylindrical section and is equal to $D/2$,

P = autogenous design pressure,

Syp = yield stress of the thermoplastic,

C_1 = 0.75–0.95 (design stress factor),

F = fraction of the total load on the lobes of the bottle to be carried by the straps,

t = shell thickness of a strap, and

$\pi = 3.14$.

In the formula, F is the fraction of the total load on the lobes of the bottle carried by the straps and is greater than zero and less than one ($0<F<1$). The most conservative value for F would be 1 in which case the straps would be designed to carry all of the pressure load on the lobes.

F can be determined by first making an experimental lobed bottle having strap widths designed according to Equation 1 wherein the value of F is approximated, the value of yield stress is known from independent testing of the thermoplastic, a value is given to C_1 between 0.75 and 0.95 with the lower value being the more conservative design, a design pressure is used for P, the actual dimensions of the bottle are measured for radius R and thickness T and the number of lobes N is determined by counting the number on the bottle. Thereafter, the experimental bottle is pressurized and the amount of pressure that the bottle can withstand without undergoing permanent deformation is measured. Using this value of pressure for P, Equation 1 is resolved for F. This value of F can then be used to design the width of the straps.

Typically, in a three-lobed bottom bottle such as that illustrated in the drawings having a capacity of 10 ounces, an inside diameter of about 2.25 inches and three straps each 7/16 inch wide, F was about 1/3 to 1/2.

The strap sections generally have a uniform width, however, they can have a varying width in which case the average width is used in the formula. In a strap having a varying width satisfactory results have been achieved when the strap section connected to the right cylinder section is relatively wide and the width of the strap uniformly diminishes or tapers as the strap extends around toward the central axis of the bottle.

A typical calculation for the width of a strap (w) follows wherein a four-lobed bottle (N=4) is made having a radius (R_1) of 1.125 inches and a shell thickness (t) of 0.03 inch. The polymer has a tensile yield stress (Syp) of 6000 psi. The bottle is designed to withstand an autogenous pressure (P) of 100 psig, the fraction of the total load (F) on the lobes of the bottle to be carried by the straps is 0.33 and the design stress factor is 0.875.

$$w=\frac{\pi F R}{N\left[\dfrac{(C_1)\,Syp}{P\,\dfrac{R}{t}}-(1-F)\right]}$$

$$w=\frac{3.14(.33)\,1.125}{4\left[\dfrac{(.875)\,(6{,}000)}{100\left(\dfrac{1.125}{.03}\right)}-1-.33)\right]}$$

$$w=0.4\ \text{inch}$$

Equation 1 provides the minimum width requirements for straps sufficient to prevent eversion of the bottom of the bottle at the design pressure. There are many desirable reasons, however, for exceeding this minimum requirement and frequently this is the case. For example, straps wider than the minimum design are sometimes desirable for appearance or aesthetic reasons or perhaps to provide increased eversion to protect the bottle from everting from some unexpected or unusual conditions. Therefore, the minimum width requirement of Equation 1 is provided to determine the lower limit on design width but may be exceeded to obtain other desirable effects.

The lobes **8**, **9**, and **10** fit between the strap sections and each lobe starts at the right cylinder section **23**, **24** and **25** and extends downward with a radius (R_2) of about 0.8–1.5 D measured from the plane between the right cylinder section and the bottom section of the bottle and includes about 20° to 40° of arc which is in turn connected to a toroidal knuckle **26**, **27** and **28** having a radius (R_3) of about 0.03 to 0.10 D, including about 90° to 150° of arc directed inward and upward toward the central axis of the bottle. The toroidal knuckle forms the standing surface of the bottle and the central curvature of the toroidal knuckle is located a distance (L_3) of about 0.3 to 0.4 D away from the center line (℄) of the bottle. The toroidal knuckle is met with a smooth transition of material directed into the base **14** of the re-entrant cylinder in the bottom of the bottle.

The re-entrant cylinder **15** defined by spaced apart side walls **16** and **17** wherein each side wall has a length L_1 and L_2, respectively, of about 0.05 to 0.22 D. However, the side walls **16** and **17** need not be the same length. The side walls are joined by a toroidal knuckle **18** having a radius R_4 of about 0.02 to 0.04 D with an arc of about 180°.

The re-entrant cylinder is very significant to the structural integrity of the plastic bottles of this invention. It acts as a structural arch supporting the internal pressures of the bottle and also acts as a retaining band to retain the straps and lobes otherwise the lobes, in particular, tend to diametrically bulge, increasing the diameter of the bottom causing serious problems in packaging, shipping and storing.

The number of straps and lobes on a bottle can vary and FIGS. **5–8** show such a variation on a bottle having six lobes and six straps.

Referring to the drawings, the bottle itself **29** is generally cylindrical having a typical bottle shape from the top or lip portion down through the right cylinder section to the bottom. The bottom section is made up of six lobes **30**, **31**, **32**, **33**, **34** and **35** equally sized and uniformly spaced around the bottom of the bottle with six strap sections **36**, **37**, **38**, **39**, **40** and **41** equally sized and uniformly spaced in between the lobes. The width of each strap is first determined by Equation **1** above, and the lobes are sized to fit in between each strap. The lobes and straps each meet in the base **42** of the re-entrant cylinder **43** in the bottom of the bottle. One wall of the re-entrant cylinder then terminates in the central disc **50** of the base.

FIG. **8** illustrates the curves along line **8—8** of FIG. **6** involved to form the bottom of the bottle wherein R_1 is the radius of curvature for the strap sections, R_2 is the radius of curvature for the lobes, R_3 is the radius of curvature for each of the toroidal knuckles **44**, **45**, **46**, **47**, **48** and **49** on which the bottle sits and R_4 is the radius of the toroidal knuckle connecting the two side walls of the re-entrant cylinder **43**. L_1 and L_2 represent the length of the side walls forming the distance between the center line (℄) of the bottle and the center of the radius of curvature of the toroidal knuckles that establish the seat of the bottle. More specific geometric details are discussed above in reference to the three-lobed bottle along with definitions of R_1, R_2, R_3, R_4 and L_1, L_2, and L_3.

In still another embodiment, the re-entrant cylinder has a reinforcing ring adding an increased amount of eversion resistance to the bottom of the bottle. FIGS. **9**, **10**, **11** and **12** show the incorporation of re-entrant cylinder, coupled with a reinforcing ring, in the bottom section of a four-lobed bottle wherein the straps and lobes have the same geometric configuration as described above.

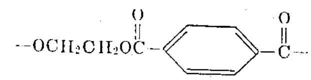
Referring to the drawings, FIG. **9** shows the front view of a four-lobed bottle **51** having a typical bottle shape from the top or lip portion of the bottle down through the right cylinder section of the bottle. The bottom section, more particularly illustrated in FIGS. **10**, **11** and **12**, is attached to the right cylinder section and has four lobes **52**, **53**, **54** and **55** and four hemispherical strap sections **56**, **57**, **58** and **59** spaced between the four lobes. The lobes and strap sections have the same general geometric configuration as the lobes and straps described above, except that there are four of each instead of three.

A re-entrant cylinder **60** is formed in the same manner as that described above by two spaced-apart side wall sections **61** and **62** each having a length of about 0.05 to 0.22 D joined by a 180° toroidal knuckle **63** having a radius of about 0.02 to 0.04 D as discussed above. A reinforcing ring **64** is formed on the toroidal knuckle **63**. The reinforcing ring is formed by two concentric contacting side wall sections **65** and **66** each having a length of about 0.05 to 0.20 D joined by a toroidal knuckle **67**.

The lobes and strap sections are connected to the outer wall **61** of the re-entrant cylinder and the inner wall **62** is connected to the recessed central disc **68**.

Thermoplastics useful in preparing bottles having a bottom designed according to the present invention are polyethylene terephthalate, acrylonitrile/styrene/methyl acrylate copolymer, acrylonitrile/ethylene/methyl acrylate copolymer, methacrylonitrile copolymers, polycarbonates, polysulfones, polybis(p-aminocyclohexyl)-dodecaneamide or polyformaldehyde resin. Polyethylene terephthalate is preferred because of its excellent strength properties, particularly a high tensile strength, excellent impact strength and relatively low creep. This high tensile strength is particularly important since the bottles of this invention are designed with strap sections that extend from the side walls to the reentrant cylinder and are placed in tension as internal bottle pressure is applied. The strength of the strap sections in tension plus the strength added from the axially aligned reentrant cylinder is great enough that the whole bottom area is not needed to support the internal pressure of the bottle, therefore, part of the bottom area can be used to form the lobes on which the bottle stands.

Polyethylene terephthalate useful in preparing the thermoplastic articles of this invention includes (a) polymers wherein at least about 97 percent of the polymer contains the repeating ethylene terephthalate units of the formula:



with the remainder being minor amounts of ester-forming components, and (b) copolymers of ethylene terephthalate wherein up to about 10 mole percent of the copolymer is derived from other ester-forming components which are substituted for corresponding amounts of the usual glycol and/or the carboxylic reactants. Other ester-forming components include the monomer units of diethylene glycol; propane-1,3-diol; butane-1,4-diol; polytetramethylene glycol; polyethylene glycol; polypropylene glycol; 1,4-hydroxymethylcyclohexane and the like; or isophthalic, bibenzoic, naphthalene 1,4- or 2,6-carboxylic, adipic, sebacic, decane-1,10-dicarboxylic acid, and the like.

The specific limits on the comonomer are governed by the glass transition temperature of the polymer. It has been found that when the glass transition temperature extends below about 50°C., a copolymer having reduced mechanical properties results. Accordingly, this corresponds to the addition of no more than about 10 mole percent of a comonomer. One exception to this, for example, is the addition of bibenzoic acid where the glass transition temperature of the copolymer remains above 50°C. and does not drop with the addition of more than 10 mole percent. Others would be obvious to those skilled in the art.

In addition, the polyethylene terephthalate polymer can include various additives that do not adversely affect the polymer in use such as stabilizers, e.g., antioxidants or ultraviolet light screening agents, extrusion aids, additives designed to make the polymer more degradable or combustible, such as oxidation catalysts, as well as dyes or pigments.

The polyethylene terephthalate should have an inherent viscosity (10 percent concentration of polymer in a 37.5/62.5 weight percent solution of tetrachloroethane/phenol, respectively, at 30°C.) of at least 0.55 to obtain the desired end properties in the articles formed and preferably the inherent viscosity is at least about 0.7 to obtain an article having excellent toughness properties, i.e., resistance to impact loading. The viscosity of the polymer solution is measured relative to that of the solvent alone and the

$$\text{Inherent viscosity} = \frac{\text{natural logarithm}\ \dfrac{\text{viscosity of solution}}{\text{viscosity of solvent}}}{C}$$

where C is the concentration expressed in grams of polymer per 100 milliliters of solution.

In the preferred embodiment wherein the thermoplastic is polyethylene terephthalate, the plastic bottle preferably has a shell thickness in the right cylinder section of at least about 20 mils and at least about 30 mils in the bottom section with at least the following characteristics, particularly in the bottom portion of the bottle:

a. a modulus of elasticity at yield of 180,000 psi;
b. a tensile strength at break of at least 5,000 psi;
c. a Poisson's Ratio of 0.35 to 0.4; and
d. a deformation constant equal to the slope of the log (reciprocal of the strain rate) versus strain having a value of at least about 0.65.

The modulus of elasticity at yield is the ratio of stress to strain of a specimen in tension wherein the tensile yield stress is that stress at which the specimen begins to stretch without an increase in load. The modulus of elasticity at yield is determined by ASTM D-882, Tensile Properties of Thin Plastic Sheeting.

The tensile strength at break is also determined by ASTM D-886 wherein a specimen is placed under increasing tension until it breaks.

The deformation constant is a measure of creep. Creep is usually measured on polymers by placing a sample under a fixed load, i.e., stress, at a constant temperature and measuring the strain deformation as a function of time. The curves for thermoplastics have a characteristic shape in which the rate of strain decreases as a function of time. A plot of the log (reciprocal of the strain rate) versus strain results in a linear plot over a substantial part of the creep curve. The slope of the straight line segment herein referred to as the deformation constant, is mathematically expressed as:

$$DC = [d \log (dt/d\epsilon)]/d\epsilon$$

where

DC = deformation constant,

dt = differential of time, and

$d\epsilon$ = differential of the strain.

This deformation constant is applicable to related thermoplastics and can be used to compare the creep behavior by comparing the slope values. A deformation constant equal to 0 indicates that the sample being tested is extending at its natural strain rate or for the load indicated, the strain rate is constant. A deformation constant of infinity indicates that there is no measurable strain indicated.

For bottles prepared from polyethylene terephthalate according to the preferred embodiment of the present invention, the deformation constant is at least about 0.65, indicating a deformation of less than 5 percent in 100 hours at 50°C. with an autogenous pressure of 75 psig.

A preferred process for preparing bottles having the bottom geometry designed according to the present invention is disclosed in U.S. Pat. application Ser. No. 93,571, filed Nov. 30, 1970, hereby incorporated by reference. The process produces a hollow, biaxially oriented, thermoplastic article by extruding a hollow, cylindrical, thermoplastic slug with a ramrod through an annular orifice into a slidable mold at a temperature within its molecular orientation range to a shape relatively larger than the original shape of the slug wherein the mold has an annular bead recess at one end to accept and hold one end of the extrudate while simultaneously drawing the extrudate in the direction of extrusion and expanding the extrudate by forcing a gas or liquid against the interior portions of the extrudate, expanding the extrudate to conform to the mold while sliding the mold past the extrusion orifice as continuous extrusion takes place. The lobes and strap sections of the bottle are formed by properly shaping the mold and expanding the polymer to conform to the mold. The reentrant cylinder and reinforcing ring are formed by first forming the bottle including lobes and strap sections, then reversing the direction of the mold, against the direction of extrusion forming the recessed re-entrant cylinder and/or reinforcing ring in the bottom of the bottle. Alternatively, the mold cavity is shaped to reproduce a bottle having the bottom geometry described in the present application.

It will be appreciated that other processes can be used to reproduce a bottle having a bottom geometry in accordance with the design of the present invention.

The bottom design of the present invention can be used on various types or sizes of plastic bottles and can be used in pressurized or unpressurized applications. However, it finds particular use in bottling liquids under pressure such as soda or beer.

The following examples illustrate this invention.

EXAMPLE 1

Plastic bottles are prepared according to the process of U.S. Pat. application Ser. No. 93,571, filed Nov. 30, 1970, wherein a hollow thermoplastic slug is extruded through an annular orifice into a slidable mold wherein the mold has a bead recess at one end to accept the extrudate. Then the mold is made to slide by the extrusion orifice as continuous extrusion takes place, drawing the extrudate as the mold slides while the extrudate is simultaneously forced against the interior walls of the mold by introducing a fluid under pressure into the interior of the extrudate.

The slug is amorphous and is prepared from polyethylene terephthalate having an inherent viscosity of about 0.85.

Three different molds are used each producing 10 bottles having (a) three-lobed bottoms such as that shown in FIGS. 1–4, (b) four-lobed bottoms such as that shown in FIGS. 9–12 except that the reinforcing ring is not included, and (c) six-lobed bottoms such as that shown in FIGS. 5–8. In the mold the straps are specifically formed of metal in relief to obtain the desired strap design. The lobes in the three-lobed bottle form when the polymeric slug is expanded and polymer is blown into the spaces between the metal in relief, defining the straps. In the four- and six-lobed bottles, the transition curves between the lobes and the straps are formed by metal in relief in the mold; however, it has been found that this is not necessary since the blown polymer will flow and form natural transition curves that are acceptable for use.

The straps in the three-lobed bottom have a uniform width of about 0.58 of an inch. The strap in the four-lobed bottle have a width of about 1.08 of an inch where the strap connects to the right cylinder section tapering to a width of about 0.625 of an inch where the strap connects to the circular recessed section of the bottom. The straps in the six-lobed bottle have a width of about 0.60 of an inch where the strap connects to the right cylinder section tapering to a width of about 0.30 of an inch where the strap connects to the circular recessed section of the bottom.

Each bottle holds a capacity of about 10 ounces and has an inside diameter at the right cylinder section of about 2.25 inches with a corresponding shell thickness of about 20 mils. In the bottom section of the bottle, the average thickness of the shell is about 50 mils.

The following dimensions also obtain:

Dimension	3-lobed Bottle (In.)	4-lobed Bottle (In.)	6-lobed Bottle (In.)
R_1 (radius of strap)	1.13	1.13	1.13
R_2 (radius of lobe)	0.44	2.27	2.27

R_3 (radius of seating toroidal knuckle)	0.09	0.13	0.13
R_4 (radius of toroidal knuckle in re-entrant cylinder)	0.05	0.05	0.05
L_1 (side wall of re-entrant cylinder)	0.375	0.375	0.375
L_2 (side wall of re-entrant cylinder)	0.375	0.250	0.250
L_3 (center line of bottle to center of toroidal knuckle on which the bottle sits)	0.625	0.75	0.75

The bottles are tested by filling each bottle with about 10 ounces of liquid (water) and pressurizing the bottle to 100 psig. at room temperature for about 2 minutes. In all cases, the bottle elongates in the axial direction a nominal amount but the bottom does not evert and will stand on a flat surface.

Thereafter, the internal pressure in the bottle is reduced to 80 psig. and the bottles are stored for 5 days at 50°C. In all cases the bottles do not evert.

EXAMPLE 2

A four-lobed bottle is prepared in the same manner as that disclosed in Example 1 except that the bottom is provided with a re-entrant cylinder and a reinforcing ring such as that described in the specification and particularly illustrated in FIGS. **11** and **12**. The contacting side walls of the reinforcing ring have a length of about 0.5 inch and an overall thickness of about 0.1 inch.

This bottle is tested by filling it with about 10 ounces of water and pressurizing the bottle. It is found that this bottle withstands about 300 psig. pressure at room temperature for about 2 minutes. While the bottle elongates in the axial direction a nominal amount, the bottom does not evert and it will stand on a flat surface.

I claim:

1. In a generally cylindrical thermoplastic bottle, biaxially oriented at least in the generally cylindrical section, the improvement wherein the bottom configuration consists essentially of at least three lobes around the bottom perimeter of the bottle on which the bottle stands; strap sections located between each lobe; an axially aligned re-entrant cylinder; and a generally circular and axially aligned recessed section with a smooth transition of material between the lobes, straps, re-entrant cylinder, and recessed sections of the base wherein

a. the strap sections begin at the generally cylindrical section of the bottle and extend downward toward the central axis of the bottle with a radius of about 0.45 to 0.7 D, including about 75° to 90° of arc and terminating in the base of the re-entrant cylinder and the width of each strap is determined by the following formula:

$$w = \frac{\pi F R}{N\left[\frac{(C_1)Syp}{P\frac{R}{t}} - (1-F)\right]}$$

where:

w = average width of an individual strap,

N = number of straps,

R = outside radius of the generally cylindrical section of the bottle taken where the bottom meets the generally cylindrical section and is equal to $D/2$,

P = autogenous design pressure,

Syp = yield stress of the thermoplastic,

C_1 = 0.75–0.95 (design stress factor),

F = fraction of the total load on the lobes of the bottle to be carried by the straps,

t = shell thickness of a strap, and

π = 3.14;

b. the lobes fit in between the strap sections and each lobe starts at the generally cylindrical section of the bottle extending downward with a radius of about 0.2–1.5 D measured from the plane between the right cylinder section and the bottom section of the bottle, including about 20° to 40° of arc and is connected to a toroidal knuckle having a radius of about 0.03 to 0.1 D including about 90° to 150° of arc directed down and inward toward the central axis of the bottle terminating in the base of the re-entrant cylinder wherein the toroidal knuckle forms the standing surface of the bottle and the center of curvature of the toroidal knuckle is located a distance of about 0.3 to 0.4 D away from the central axis of the bottle; and

c. the axially aligned re-entrant cylinder in the bottom of the bottle is defined by two concentric walls each having a length of about 0.05 to 0.22 D wherein one wall is connected to the inward extending portions of lobes and strap sections, in uniform circumferential spacing around the base of this wall, the other wall is connected to the recessed central disc and the two walls are interconnected with a toroidal knuckle having a radius of about 0.02 to 0.04 D including about 180° of arc where D equals the outside diameter of the bottle taken perpendicular to the major axis of the bottle where the bottom section of the bottle meets the generally cylindrical section of the bottle.

2. The bottle of claim **1** having three lobes and three strap sections.

3. The bottle of claim **1** having four lobes and four strap sections.

4. The bottle of claim **1** having five lobes and five strap sections.

5. The bottle of claim **1** having six lobes and six strap sections.

6. The bottle of claim **1** having a reinforcing ring of thermoplastic on the interior surface of the toroidal knuckle connecting the walls of the re-entrant cylinder wherein the reinforcing ring is formed of two concentric contacting side wall sections each having a length of about 0.05 to 0.20 D.

7. The bottle of claim **1** wherein the thermoplastic is polyethylene terephthalate having an inherent viscosity of at least about 0.55.

8. The bottle of claim **7** having a shell thickness of at least 20 mils in the generally cylindrical section and 30 mils in the bottom section, prepared from a polymer having a modulus of elasticity at yield of at least about 180,000 psi, a tensile strength of at least 5,000 psi, a Poisson's ratio of 0.35 to 0.4 and a deformation constant equal to the slope of the log (reciprocal of the strain rate) versus strain having a value of at least about 0.65.

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