A plastic bottle base is formed with a seating ring perpendicular to the axis for supporting the bottle on any underlying surface prior to hot filling. An inner portion within the seating ring extends upward and inward to a center bottom wall surrounding the axis. A flexible diaphragm portion extends outward from the seating ring to join a heel portion at a substantially horizontal inflection point. The diaphragm portion is sufficiently flexible to respond to changes in bottle volume and vacuum to allow the seating ring to move upward so that the seating ring is above the heel portion of the bottle. This flexible base is combined with a sidewall defined by a small number of barrel shaped surfaces separated by indented ring segments to form a panelless plastic bottle capable of hot-filling and capping. The sidewall geometry is configured such that the plastic bottle prior to hot filling can be a lighter weight and/or can have a reduced number of indented ring segments, while having a satisfactory vacuum resistance to localized paneling and/or ovalization.
The present invention is directed to plastic bottles used to contain foods and beverages that are filled and capped at an elevated temperature of at least $160^\circ$F, and more typically about $185^\circ$F. The present invention is particularly directed to such plastic bottles that are devoid of any vacuum panels in the body and shoulder areas.

Lightweight, thin-walled containers made of thermoplastic materials such as polyester resin are well known in the container industry. For example, polyethylene terephthalate (PET) has a wide range of applications in the field of containers for foodstuffs, flavoring materials, cosmetics, beverages, and so on. PET can be molded, by orientation-blowing, into transparent thin-walled containers having a high stiffness, impact strength and other improved qualities with a high molding accuracy. In the past, some cold-filled carbonated bottles have employed chimes having additional material at the standing ring surface. The formation of such bottles requires either heavy material distribution to blow out the ring or some other non-standard forming process. Examples of such bottles are to be found in US Patents 4,780,257; 4,889,752; and 4,927,679. At elevated temperatures, however, such a thickened chime will soften and roll out so such a base is unsuitable for hot-filling.

Strong, transparent and substantially heat resistant containers may be produced by the biaxial-orientation blow-molding process in which a parison is oriented both laterally and longitudinally in a temperature range suitable for such orientation. Heat-set PET containers are particularly heat resistant. Biaxially-oriented blow-molded containers have greater stiffness and strength as well as improved gas barrier properties and transparency. Areas of thick accumulations of material, such as the thickened chimes discussed above, may not be sufficiently oriented to achieve the desired stiffness and strength to resist
movement when subjected to hot-filling operations. The desirability of avoiding areas having accumulations of material for bottles intended for use in hot-filling operations is suggested generally by US Patents 5,585,065 and 5,735,420. However, both these patents resort to an extensive multi-blow heat-treating operation to achieve the desired product.

[0004] Garver et al., U.S. Patent 5,067,622, discloses a bottle made of PET that is expressly configured for hot filled applications. The bottle's body sidewall is rigidized against radial and longitudinal vacuum distortion so that paper labels can be applied to the bottle. The rigidized sidewall is achieved by providing a plurality of radially inward, concave ring segments which are spaced apart from one another and separated from one another by cylindrically shaped flats or land segments. In addition, the amorphous threaded mouth of the bottle is rigidized by gussets molded into the bottle at the junction of the neck and shoulder portion of the bottle to resist deformation when the bottle is capped. To accommodate the post capping vacuum, a bulbous vacuum deformation area is provided in the shoulder adjacent the bottle neck, a plurality of vacuum deformation panels are provided in a frusto-conical portion of the shoulder, and a further vacuum deformation panel is provided in the base. As a result, any post capping vacuum is confined to the specifically designated areas of the bottle and the sidewall remains undistorted. The lack of post capping sidewall distortion is disclosed to be the result of a critical sizing of the ring segments relative to the land segments in combination, to some extent, with the crystallinity level, which is disclosed to be greater than 30%. Other bottles made of PET that have sidewall including spaced ring segments designed to rigidize the sidewall are disclosed, for example, in U.S. Patents 6,929,139; 7,051,890 and 7,296,701. Other bottles made of PET that have vacuum responsive panels in the sidewall are disclosed, for example, in U.S. Patents 5,704,503; 6,932,230; and 7,243,808.

[0005] In the bottles referenced above, the land segments between the spaced indented ring segments are generally formed as right cylindrical or flat
surfaces having a constant radius from a vertical axis of the bottle. Such flat surfaces generally perform satisfactorily when the indented ring segments are sufficiently close together. However, the sidewall can experience reduced satisfactory performance when the ring segments become increasingly spaced from each other so that the intervening lands can individually experience an inward deformation resulting in a concavity or crease. As a result, the vertical extent of each of the lands is generally minimized to diminish the area that might be subject to such a concave inward deformation, also known as localized paneling. Additionally, special shapes and relationships have also been adopted for the indented ring segments to minimize the opportunity for such a concave inward deformation of a land portion, which can result in a rippled appearance for any covering label.

[0006] Another problem with bottles having a series of indented ring segments with land segments therebetween is the tendency to fail by ovalization under vacuum pressures. Depending on the configuration of the indented ring and transition to each land segment, portions of the indented ring may tend to move radially outward, while other portions of the same indented ring may tend to move radially inward, resulting in a cross-section that appears to be more oval than circular. Ovalization of bottles not only increases the risk of failure, but also can lead to unaesthetic looking bottles. Other attempts have been made to increase the number of indented ring segments along the sidewall. While each indented ring added rigidizes the sidewall to reduce the risks associated with ovalization and localized paneling, the bottle often experiences axial shortening or compression, like an accordion, for each additional indented ring. This is problematic because it can inhibit the vertical stacking of bottles on top of each other and possibly distort or even tear the label affixed to the sidewall due to such axial movement.

[0007] Accordingly, it is an object of the present invention to form a plastic bottle with a sidewall having a plurality of spaced indented ring segments
separating lands that will resist any tendency toward ovalization. It is a further object of the present invention to form a plastic bottle with a sidewall having a plurality of spaced indented ring segments that are sized in relation to the lands separated by the ring segments so that the lands will resist any tendency toward a concave inward deformation. It is a further object of the present invention to form a plastic bottle with a sidewall having lands with a preferred geometry and maximum size to further separate indented ring segments to maximize the vacuum resistance of the plastic bottle to ovalization and/or localized paneling.

SUMMARY
[0008] A molded plastic bottle in its pre-hot fill state can have a base surrounding a vertical axis that is responsive to changes in pressure and vacuum with the bottle. A sidewall can have a lower edge that is coupled to the base. The sidewall can extend upward from the base to a sidewall upper edge. The sidewall can be devoid of any vacuum responsive panels. A shoulder portion can be coupled to the sidewall upper edge. The shoulder portion can lead upward and radially inward to a neck portion. The shoulder portion can also be devoid of any vacuum responsive panels. A finish can be coupled to the neck portion adapted to receive a closure. The finish can surround an opening leading to the plastic bottle interior. The various portions of such a plastic bottle can be molded in a single integral unit by various processes, including two-step reheat stretch blow molding of a preform within a mold defining the outside surface of the various bottle portions.

[0009] In one aspect, the base of the plastic bottle can have a continuous seating ring surrounding the vertical axis at a fixed radius. The base can also have at least a first inner surface coupled interiorly to the continuous seating ring that extends upwardly and inwardly from the continuous seating ring. The base can also have a diaphragm surface coupled exteriorly to the continuous seating ring. The diaphragm surface can include an inner edge extending upwardly and
outwardly from the continuous seating ring. The diaphragm surface can also include an outer edge extending substantially horizontally outwardly. The base portion can also include a heel portion joining the diaphragm outer edge to the sidewall lower edge. The diaphragm surface can flex upward in response to any drop of pressure within the bottle. Given a sufficient drop in pressure, the diaphragm surface can flex upward at least until the continuous seating ring is situated above the heel portion.

[0010] In another aspect, the sidewall of the plastic bottle can be molded to have an outer surface having at least one land segment bounded by vertically spaced indented ring segments. Each land segment can be defined by a vertical arc rotated around the vertical axis to form an outwardly curved surface or outwardly bowed barrel-shaped surface having an outermost surface defining a maximum label diameter $D_L$ of the bottle. Each land segment can be formed to resist any tendency toward a concave inward deformation in response to any drop of pressure within the bottle. The distance between the vertical axis and the closest point on the indented ring segments to the axis can be between about 0.8 and 0.9 times the maximum distance between the vertical axis and the outermost surface of the land segments. The vertical dimension of the land segments can be such that there are only two of the land segments and three of the indented ring segments between the sidewall lower edge and the sidewall upper edge. The vertical dimension of each land segment can be at least $0.49 D_L$. The vertical arc that forms the outwardly curved surface of each land segment can have a vertical radius $R_A$ of up to $2.45 D_L$. The indented ring depth can be a depth of at least $0.08 D_L$. The vertical radius $R_B$ of the inwardly curved surface of the indented ring segments can be up to $0.02 D_L$. The plastic bottles preferably molded in its pre-hot fill state to have a sidewall geometry with one or more of the aforementioned ratios, such that the plastic bottle can be a lighter weight and/or can have a reduced number of indented ring segments, while having a satisfactory vacuum resistance to localized paneling and/or ovalization.
Other features of the present invention and the corresponding advantages of those features will become apparent from the following discussion of the preferred embodiments of the present invention, exemplifying the best mode of practicing the present invention, which is illustrated in the accompanying drawings. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like referenced numerals designate corresponding parts throughout the different views.

**Brief Description of the Drawings**

[0012] Fig. 1 is a perspective view of an exterior surface of a bottle molded in its pre-hot fill state.

[0013] Fig. 2 is a perspective view of an exterior surface of another bottle molded in its pre-hot fill state.

[0014] Fig. 3 is a perspective view of an exterior surface of yet another bottle molded in its pre-hot fill state.

[0015] Fig. 4 is a sectional view of a base of the bottles shown in Fig. 1 - Fig. 3 molded in its pre-hot fill state.

[0016] Fig. 5 is a sectional view of a base of the bottles shown in Fig. 1 - Fig. 3 when subjected to a vacuum induced by hot-filing and capping of the bottle.

[0017] Fig. 6 is a sectional view of a portion of the sidewall of the bottles shown in Fig. 1 or Fig. 3.

[0018] Fig. 7 is a sectional view similar to Fig. 6 of a portion of the sidewall of the bottle shown in Fig. 2.

[0019] Fig. 8 is a line graph comparing the vacuum failure pressure of a bottle with the vertical radius of a curved land segment of the bottle.

**Description of a Preferred Embodiment**
A bottle 10 is shown in Figs. 1 - 3 to include a base 12, which is shown in its initial molded form prior to hot filling. The bottle can appear different in response to the post capping development of a partial vacuum within the bottle after hot filling to accommodate the change in volume and pressure. A sidewall 14 having a lower edge 16 is coupled to the base 12. It will be understood that the word "coupled" is used in this disclosure to include structures that are simultaneously molded as a single unit, and is not used to suggest necessarily any assembly of parts subsequent to the formation of those parts. The sidewall 14 extends upward from the lower edge 16 to a sidewall upper edge 18. The sidewall lower edge 16 is shown to include a step 20 defining a lower edge of a label panel 21. The sidewall upper edge 18 is shown to include another step 22 defining an upper edge of the label panel 21. A shoulder portion 24 is coupled to the sidewall upper edge 18. The shoulder portion 24 can lead upward and radially inward as shown to a neck portion 26. A finish 28 is generally coupled to the neck portion 26. The finish 28 is adapted to receive a closure, not shown. The finish 28 can have a variety of surface features for engaging a suitable closure. The finish 28 generally surrounds an opening 30 leading to the interior of the bottle 10. It is to be noted from the figures that neither the sidewall 14 nor the shoulder portion 24 contains any vacuum responsive panels of the type often found in prior art containers, although vacuum responsive panels can be found in at least one those areas, in combination with the bottle embodiments described herein, as appreciated by those skilled in the art. As can be seen from the variations presented by Figs. 1 - 3, a bottle 10 having the desired operative features can take a variety of forms that will allow for a number of design variations.

A base 12, shown in detail in Fig. 4 in the configuration that the bottles 10 are initially molded, can include a heel portion 34 that extends from the lower edge 16 of the sidewall 14 downward and inward to an inflection point 32. The inflection point 32 can be an outer perimeter of a diaphragm portion 38.
extending from the inflection point 32 to a continuous seating ring 36. Consequently, the diameter $D_s$ of the seating ring 36 is generally smaller than the diameter $D$ of the lower edge 16 of the sidewall 14. The seating ring 36 is spaced uniformly outward from a vertical axis $Y$ that is perpendicular to any underlying planar surface on which the bottle 10 might be situated prior to the bottle 10 being hot-filled and capped. As a general rule, the vertical axis $Y$ extends upward through the approximate center of the opening 30. The continuous seating ring 36 when initially molded preferably contacts any underlying planar surface on which the bottle 10 might be situated around the entire circumference of the seating ring 36. The heel portion 34 is shown to have a uniform inside vertical radius so that the surface of the heel portion 34 is smooth as shown in Figs. 1 - 3, but the surface of the heel portion 34 could be undulating or grooved or include other surface features. As initially molded, the outer edge of the diaphragm portion 38 at the inflection point 32 is preferably horizontal and is spaced upward from the plane defined by the seating ring 36.

The base 12, as shown in detail in Fig. 4, can include an inner portion 40 that lies wholly within the seating ring 36. The inner portion 40 of the base 12 can extend upward and inward toward a center bottom wall 42 surrounding the axis $Y$. The inner portion 40 can include a first conical surface section 44 joined to and extending inward from the seating ring 36. The inner portion 40 can also include a second conical surface section 46 having an outer edge 48 joined to and extending upward and inward from an outer edge of the first conical surface section 44. An inner edge 48 of the second conical surface section 46 can be joined to an outer edge 50 of an axial portion 52 surrounding the vertical axis $Y$. The axial portion 52 can include a central downward extension 54. An axial ring portion 56 can separate the central downward extension 54 from the second conical surface section 46. The inner portion 40 is designed to withstand the initial fluid force and temperature of the hot-fill process. The whole of the base 12 is intended to react to the post capping development of
a partial vacuum within the bottle 10 by evolving from the initially molded form, its pre hot-fill state, shown in Fig. 4 to the post filled form shown in Fig. 5 to accommodate entirely the change in volume and pressure.

The post capping vacuum, which develops as the product-filled bottle cools from the filling temperature to an ambient or even refrigerated temperature, causes the inner portion 40 of the base 12 to move vertically upward along axis Y. The upward movement of the inner portion 40 causes the diaphragm portion 38 to flex from the position shown in Fig. 4 to the position shown in Fig. 5 to the point that the continuous seating ring 36 becomes positioned above the heel portion 34. As a consequence, the bottle 10, when hot-filled and capped, has an even wider and more stable base than when empty. In order for the bottle 10 to have a satisfactory stability before and after the hot filling operation, it is desirable that the continuous seating ring 36 is situated at a radius of between 0.75R and 0.85R, where R is the radius of the diaphragm outer edge 32. If the continuous seating ring 36 is smaller than this specified range, the bottle 10 becomes increasing unstable and difficult to handle during the filling operation. If the continuous seating ring 36 is larger than this specified range, the radial dimension of the diaphragm portion 38 is insufficient to provide the necessary change in volume as the product-filled bottle cools from the filling temperature to an ambient or even refrigerated temperature. While this base structure 12 can perform in a satisfactory manner in bottles having a variety of sidewall configurations, it is particularly useful with the panelless sidewall configuration 14 shown in Figs. 1 - 3 as well as Figs. 6 and 7.

With reference to Figs. 6 and 7, the sidewall 14 of the bottle, in its pre-hot fill state, between the sidewall lower edge 16 and the sidewall upper edge 18 can include an outer surface 60 having at least one land segment 62 bounded by vertically spaced indented ring segments 64. Each land segment 62 can be defined by a vertical arc 66, which can be of constant or varying radius $R_A$, rotated around the vertical axis Y to form an outwardly bowed barrel-shaped
or curved surface 68. The label diameter $D_L$ is defined between the outermost surface 68 of the land segments 62 situated diametrically opposite from one another through the vertical axis. The curved surface 68 of each land segment 62 can be dimensioned to resist any tendency toward any concave inward deformation of the surface 68 or localized paneling in response to any drop of pressure within the bottle 10. The vertical radius $R_A$ of the curved surface 68 of each land segment can be less than or equal to 2.45$D_L$.

[0025] The indented ring segments 64 can have arcuate shoulder portions 70 and 72 with a vertical radius $R_{BL}$ separated by a concave ring portion 74 defined by a vertical radius $R_B$. The vertical radii $R_B$ and $R_{BL}$ are generally much smaller in absolute value than the vertical radius $R_A$. In one embodiment, the absolute value of the vertical radius $R_B$ can be from 0.2% to 1.4% of the absolute value of the vertical radius $R_A$, and the absolute value of the vertical radius $R_{BL}$ can be from 1% to 6.5% of the absolute value of the vertical radius $R_A$ and can be greater than $R_B$. The vertical radius $R_B$ can be less than or equal to 0.02$DL$. The transition 76 from the upper most or lower most indented ring to the respective sidewall upper or lower edges 18, 16 can also be arcuate with a vertical radius $R_t$ typically greater than the vertical radius $R_{BL}$, having an absolute value from 1.5% to 7% of the absolute value of the vertical radius $R_A$. Angle $\alpha$ is the inflection angle of the indented ring segment measured from a horizontal axis that is perpendicular to the vertical axis $Y$. Angle $\alpha$ can be 0° to about 25° (preferably 20°), with a smaller angle providing more sideload resistance and ovalization resistance.

[0026] In another embodiment, the distance $D_R$ between the vertical axis $Y$ and the closest point 77 on the indented ring segments 64 to the axis $Y$ can be between about 0.8 and 0.9 times the maximum distance $D_s$ between the vertical axis $Y$ and the outermost surface 68 of the land segments 62. The difference between distances $D_R$ and $D_s$ is known as the ring depth 78 of the indented ring segment 64 relative to the outermost surface 68. A greater ring depth 78 can
provide more resistance to ovalization. The ring depth 78 can be equal to or
greater than 0.08D_L. The effective ring depth 79 is the distance from the closest
point 74 of the indented ring segments 64 to the axis Y to a point 80 that is
defined as the outward tangent point of the vertical radius R_{BL}.

[0027] The vertical dimension H_L is the label panel height measured from
the top of the upper most indented ring segment to the bottom of the lower most
ring segment, or alternatively, between the steps 20, 22 that define the edges of
the label panel 21. The vertical dimension H_s of the land segments 62 can be
equal to or greater than 0.49D_L. In the illustrated embodiments, the vertical
dimension H_s of the land segments 62 can be such that there are only two of the
land segments 62 and three of the indented ring segments 64 between the
sidewall lower edge 16 and the sidewall upper edge 18. It will be appreciated,
however that a few additional land segments 62 and indented ring segments 64
could be included having the same described character without departing from
the central concept of having only a small number, no more than five, of such
land segments 62 separated by the requisite number of indented ring segments
64 to define the sidewall 14. However, in some instances it is preferred to at
least minimize the number of indented ring segments and maximize the size of
the land segments. For every indented ring segment included in the sidewall, the
bottle can undesirably become axially shorter after cooling, and the bottle may
have an increase axial springiness, like an accordion. This is problematic
because it can inhibit the vertical stacking of bottles on top of each other and
possibly distort or even tear the label affixed to the sidewall due to such axial
movement. Maximizing the size of the land segments can increase the surface
area contact for the label to affix to and may even be more aesthetically pleasing.

[0028] Plastic bottles similar to the illustrated embodiments in Fig. 1
were analyzed using Finite Element Analysis (FEA). The bottles had an overall
vertical distance of 7.663 inches from the top of the finish to the bottom of the
base, and a maximum diameter at the outermost surface of the land segment of
2.862 inches, each being a constant dimension for all bottles. A ring depth of 0.223 inches, a vertical radius \( R_b \) of 0.056 inches, and an inflection angle of 20 degrees were also maintained constant for all bottles. The wall thickness of the bottles varied between 0.011 inches to 0.02 inches. All of the bottles analyzed had three indented ring segments surrounding the two land segments, or 3-2 design.

[B0029] Bottles with a 3-inch label height \( H_L \) were analyzed at various vertical radii \( R_A \): 2.069 inches; 2.713 inches; 4.3 inches; 7 inches; and 1000 inches. Bottles with a 3.22-inch label height \( H_L \) were analyzed at various vertical radii \( R_A \): 5.954 inches; 7 inches; 8.388 inches; and 10.812 inches. Bottles with a 3.44-inch label height \( H_L \) were analyzed at various vertical radii \( R_A \): 5.954 inches; 7 inches; 8.388 inches; and 1000 inches. Bottles with a 3.67-inch label height \( H_L \) were analyzed at various vertical radii \( R_A \): 4.3 inches; 5.954 inches; 7 inches; 8.388 inches; 10.812 inches; and 1000 inches. Bottles with a 4.5-inch label height \( H_L \) were analyzed at various vertical radii \( R_A \): 4.3 inches; 5.954 inches; 7 inches; 8.388 inches; 11.899 inches; and 1000 inches. Bottles with a 5-inch label height \( H_L \) were analyzed at various vertical radii \( R_A \): 4.3 inches; 5.954 inches; 7 inches; 8.388 inches; and 1000 inches. Bottles with a 1000-inch vertical radius \( R_A \) represent substantially flat land segments. The bottles were held in a fixed location along the neck, while the internal vacuum pressure was increased from 0 psig to negative 20 psig. During the analysis, the temperature of the material was maintained at about 72 degrees F. The vacuum was increased until one of two failures occurred: localized paneling along the land segments, or ovalization along the indented ring segments. The vacuum pressure at the instance of failure was then recorded for each bottle.

[B0030] Fig. 8 depicts a graph 100 with plotted data from the analysis. The X-axis 102 of the graph represents the various vertical radii \( R_A \) of bottles analyzed on a logarithmic scale, and the Y-axis 104 represents the vacuum pressure at the instance of failure. There are six trend lines representing the
respective bottles with the six different label heights \( H_L \): 3-inch (110), 3.22-inch (120), 3.44-inch (130), 3.67-inch (140), 4.5-inch (150), and 5-inch (160). According to the graph 100, the bottles demonstrated a higher failure pressure or greater vacuum resistance when the vertical radius of the land segment \( R_A \) is about 7 inches for the bottles having label heights \( H_L \) 3.44-inch, 3.67-inch, 4.5-inch, and 5-inch. If the vertical radius of the land segment is larger (making the land segments more flat), the bottles would have a tendency to fail at a lower pressure due to localized paneling. If the vertical radius of the land segment is smaller (making the land segments more bulbous), the bottles would have a tendency to fail at a lower pressure due to ovalization.

\[0031\] It was surprising that the bottles, across most of label heights \( H_L \), had superior vacuum resistance performance at approximately the same vertical radius \( R_A \) of about 7 inches. According to the graph 100, there may also be a more preferred aspect ratio (label height \( H_L \) to label diameter \( D_L \)), as the vacuum resistance noticeably changes between the 3.22-inch bottles (aspect ratio of 1.13) and the 3.44-inch bottles (aspect ratio of 1.20). The 3.22-inch bottles demonstrated a lower vacuum resistance, which was probably from failure caused by ovalization instead of localized paneling. On the other hand, a high aspect ratio (e.g., 2.3) can make the effective ring depth very shallow, making the bottles more susceptible to ovalization and/or localized paneling. Thus, if the aspect ratio is too high (making the land segments more flat), the container will have a tendency to fail at a lower pressure due to localized paneling. On the other hand, if the aspect ratio is too low (making the land segments more bulbous), the container will have a tendency to fail at a lower pressure due to ovalization. Because the bottles across most of label heights \( H_L \) had unexpected superior vacuum resistance performance at approximately the same vertical radius \( R_A \), the vertical radius \( R_A \) seems less dependent on the vertical dimensions \( H_s \) or \( H_L \), and more dependent on the label diameter \( D_L \).
The graph further reveals that the bottles having land segments with the curved surface had far superior vacuum resistance than the bottles having land segments with a flat surface (i.e., when the vertical radius $R_A$ is 1000 inches). Results show a vacuum resistance improvement in the range of about 20% to 55% (average of 38%) of the bottles having the curved land segments over the bottles having the flat land segments.

Accordingly, the bottles described herein have a sidewall that includes land segments with a preferred curved geometry to increase the resistance to localized paneling, as well as including indented ring segment configurations sufficient to maintain the resistance to ovalization. Within a more desirable aspect ratio range, the vertical radius $R_A$ of the curved surface of each land segment can be less than or equal to $2.45D_L$ because a larger ratio may cause the bottle to be more susceptible to localized paneling at a lower vacuum pressure. The vertical dimension $H_s$ of the land segments can be equal to or greater than $0.49D_L$ because a smaller ratio may result in land segments that are so short that the bottles are more prone to failure at a lower vacuum pressure caused by ovalization than by localized paneling. The ring depth can be equal to or greater than $0.08D_L$ because a smaller ratio may cause the bottle to be more susceptible to ovalization at a lower vacuum pressure.

In one example, a 20-ounce bottle plastic bottle (with a 3-2 design) having an overall vertical distance of 7.663 inches; a label diameter $D_L$ of 2.862 inches; a ring depth 78 of 0.223 inches; an indented ring segment vertical radius $R_B$ of 0.056 inches; an arcuate shoulder vertical radius $R_{B_L}$ of 0.259 inches; an effective ring depth of 0.207 inches; an inflection angle of 20 degrees; a vertical radius $R_T$ of 0.283 inches; a land segment height $H_s$ of 1.516 inches; a label height $H_L$ of 3.670 inches; a land segment vertical radius $R_A$ of 7.000 inches; and a wall thickness between 0.011 inches to 0.02 inches. The plastic bottle with these dimensions has a relatively light weight of about 31 grams, yet still has a sufficiently high vacuum failure pressure between 6 to 8 psi.
Comparable 20-ounce bottles having similar vacuum resistance performance are known to weigh at least 37 grams, primarily from the added material thickness along the sidewall to strengthen it for satisfactory vacuum failure resistance. Accordingly, the plastic bottles described herein having a sidewall geometry with one or more of the ratios above can permit the plastic bottle to have a lighter weight and/or a reduced number of indented ring segments, while having a satisfactory vacuum failure resistance. The lighter weight (about 16% lighter) of the plastic bottle further reduces the material cost per bottle.

While these features have been disclosed in connection with the illustrated preferred embodiment, other embodiments of the invention will be apparent to those skilled in the art that come within the spirit of the invention as defined in the following claims.
Claims:

1. A molded plastic bottle in its pre-hot fill state comprising:
   a base surrounding a vertical axis, having a portion extending upward to define an outer edge, a sidewall having a lower edge coupled to the outer edge of the base, the sidewall extending upward from the base to a sidewall upper edge, a shoulder portion coupled to the sidewall upper edge and leading upward and radially inward to a neck portion, a finish coupled to the neck portion adapted to receive a closure, the finish surrounding an opening leading to a plastic bottle interior, the sidewall being defined by an outer surface including
   at least one land segment bounded by vertically spaced indented ring segments, each land segment being defined by a vertical arc rotated around the vertical axis to form an outwardly curved surface having an outermost point to define a maximum label diameter $D_L$ of said bottle, the outwardly curved surface of the at least one land segment adapted to resist any tendency toward a concave inward deformation in response to any drop of pressure within the bottle.

2. The plastic bottle of claim 1, wherein the vertical arc forming the outwardly curved surface of the at least one land segment has a vertical radius $R_A$ of up to 2.45 $D_L$.

3. The plastic bottle of claim 1, wherein each indented ring segment has a depth of at least 0.08 $D_L$, the indented ring segment depth being a relative distance between the vertical axis and the closest point on the indented ring segments and the maximum distance between the vertical axis and the outermost point of the outwardly curved surface of the at least one land segment.
4. The plastic bottle of claim 1, wherein the at least one land segment has a vertical distance of at least 0.49 $D_L$.

5. The plastic bottle of claim 1, wherein the indented ring segments are defined by an inwardly curved surface having a vertical radius $R_B$.

6. The plastic bottle of claim 5, further comprising an arcuate shoulder portion joining the inwardly curved surface of the indented ring segments to the outwardly curved surface of the at least one land segment, where the arcuate shoulder portion has a vertical radius $R_{BL}$ that is greater than the vertical radius $R_B$.

7. The plastic bottle of claim 5, wherein the vertical radius $R_B$ of the inwardly curved surface of the indented ring segments is up to 0.02 $D_L$.

8. The plastic bottle of claim 1, wherein there are only two of the land segments and three of the indented ring segments between the sidewall lower edge and the sidewall upper edge.

9. The plastic bottle of claim 1, wherein the distance between the vertical axis and the closest point on the indented ring segments to the axis is between 0.8 and 0.9 times the maximum distance between the vertical axis and the outermost surface of the at least one land segment.

10. The plastic bottle of claim 1, wherein the vertical arc forming the outwardly curved surface of the at least one land segment has a vertical radius $R_A$ of up to 2.45 $D_L$, and at least one of:
    each indented ring segment has a depth of at least 0.08 $D_L$, the indented ring segment depth being a relative distance between the vertical axis and the
closest point on the indented ring segments and the maximum distance between the vertical axis and the outermost point of the outwardly curved surface of the at least one land segment; and

the at least one land segment has a vertical distance of at least 0.49 $D_L$.

11. A molded plastic bottle in its pre-hot fill state comprising:

a base surrounding a vertical axis, a sidewall having a lower edge coupled to the base, the sidewall extending upward from the base to a sidewall upper edge, the sidewall being free of any vacuum responsive panel and including at least one indented ring segment, a shoulder portion coupled to the sidewall upper edge and leading upward and radially inward to a neck portion, a finish coupled to the neck portion adapted to receive a closure, the finish surrounding an opening leading to a plastic bottle interior, the base being defined by an outer surface including

a seating ring surrounding the vertical axis at a fixed radius, at least a first inner surface coupled interiorly to the seating ring and extending upwardly and inwardly from the seating ring, a diaphragm surface coupled exteriorly to the seating ring, the diaphragm surface including an inner edge extending upwardly and outwardly from the seating ring and an outer edge extending substantially horizontally outwardly, and a heel portion joining the diaphragm outer edge to the sidewall lower edge, the diaphragm surface being sufficiently flexible to permit an upward flexing of the diaphragm surface in response to any drop of pressure within the bottle at least until the seating ring is situated above the heel portion.

12. The plastic bottle of claim 11, wherein the inner surface coupled interiorly to the seating ring comprises a set of circumferentially continuous conical surface sections joined to and extending inward from the seating ring.
13. The plastic bottle of claim 11, wherein the continuous seating ring is situated at a radius of between 0.75R and 0.85R, where R is the radius of the diaphragm outer edge.

14. The plastic bottle of claim 11, wherein the sidewall is defined by an outer surface including at least one land segment bounded by two or more indented ring segments, each land segment being defined by a vertical arc rotated around the vertical axis to form an outwardly curved surface having an outermost point to define a maximum label diameter $D_L$ of said bottle.

15. The plastic bottle of claim 14, wherein the vertical arc forming the outwardly curved surface of the at least one land segment has a vertical radius $R_A$ of up to 2.45 $D_L$.

16. The plastic bottle of claim 15, wherein each indented ring segment has a depth of at least 0.08 $D_L$, the indented ring segment depth being a relative distance between the vertical axis and the closest point on the indented ring segments and the maximum distance between the vertical axis and the outermost point of the outwardly curved surface of the at least one land segment.

17. The plastic bottle of claim 16, wherein the at least one land segment has a vertical distance of at least 0.49 $D_L$.

18. A molded plastic bottle in its pre-hot fill state comprising:
   a base surrounding a vertical axis, having a portion extending upward to define an outer edge, a sidewall having a lower edge coupled to the outer edge of the base, the sidewall extending upward from the base to a sidewall upper edge, a shoulder portion coupled to the sidewall upper edge and leading upward and radially inward to a neck portion, a finish coupled to the neck portion adapted
to receive a closure, the finish surrounding an opening leading to a plastic bottle interior, the sidewall being defined by an outer surface including

at least one land segment bounded by vertically spaced indented ring segments, each land segment being defined by a vertical arc rotated around the vertical axis to form an outwardly bowed barrel-shaped surface with an outermost surface defining a maximum label diameter $D_L$ of said bottle, said vertical arc having a vertical radius $R_A$ of up to $2.45 \ D_L$, the outwardly bowed barrel-shaped surface of the at least one land segment adapted to resist any tendency toward a concave inward deformation in response to any drop of pressure within the bottle.

19. The plastic bottle of claim 18, wherein each indented ring segment has a depth of at least $0.08 \ D_L$, the indented ring segment depth being a relative distance between the vertical axis and the closest point on the indented ring segments and the maximum distance between the vertical axis and the outermost point of the outwardly curved surface of the at least one land segment.

20. The plastic bottle of claim 18, wherein the at least one land segment has a vertical distance of at least $0.49 \ D_L$. 
FIG. 8

Failure Pressure vs Barrel Profile Radius

Failure Pressure (psi)

Vertical Radius \((R_A)\)

- 3
- 3.22
- 3.44
- 3.67
- 4.5
- 5

104

100

102

1000
**INTERNATIONAL SEARCH REPORT**

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