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(54) DRAWN AND IRONED CAN CONTAINING LIQUID

(71) We, DAIWA CAN COMPANY LIMITED, a joint stock company organised under the Laws of Japan of No. 1-10, 2-chome, Nihombashi, Chuo-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a drawn and ironed can filled with liquid. Such a can is produced by first forming a can body by ironing the side wall of a cup which has been produced by drawing a metal disc (which can body is hereinafter referred to as a D&I can body), filling the can body with a pressurized gas-containing liquid, e.g. a beverage, for example, beer or a carbonated beverage, and seaming the filled can body with a metallic top closure to form a drawn and ironed, filled can (hereinafter called a D&I can).

A top closure of a known D&I can now available on the market has, in sequence from the outermost edge of said closure as shown in Figure 1, a seamed portion 31, a counter-sunk portion 32 which extends almost parallel to the side wall of the can body, a bead portion 33 which continues from said countersunk portion 32 (portion 31, 32 and 33 constituting an outer peripheral portion 39 of the top closure), a central portion 34 of the top closure which extends from and is surrounded by said bead portion 33 beyond a small curved portion 37, said central portion 34 being slightly domed upwardly and staying inside of the cam end plane 40 (the remaining of "can end plane" is defined hereinafter) and a ready tearing and opening tab 36 fixed to the center of said central portion 34 with a rivet 35 (normally termed an easy opening top closure). The D&I can body of said D&I can has a bottom 2 which comprises an outer peripheral portion 5 having a semi-circular inwardly turning portion 3 which turns upwardly from the lower end of the straight side wall 1, an inclined wall 4 which extends upwardly from said turning portion 3, and a high domed central portion 6 which is an extension of and is surrounded by said inclined wall and which in whole stays inside of the can end plane 7.

Another type of bottom of a known D&I can bodies comprises, as illustrated in Figure 7, a turning portion 73 which turns sharply at the lower end of the straight side wall 71 of said D&I can body, inclined wall 74 which connects to said turning portion 73 and extends upwardly, a second turning portion 79 which turns sharply at the upper end 78 of said inclined wall 74, (73, 73 and 79 constituting a bottom peripheral portion 77), inclined inner wall 76 which is an extension of said second turning portion 79 and extends downwardly, and a flat portion 75 which is connected to said inclined inner wall 76 and stays inside of the can end plane 81 (75 and 76 constitute a dish-shaped central portion 80), and the outer peripheral portion is provided with buckling resistant strength which is the same as that of the bottom of the can illustrated in Figure 1 which prevents buckling when subjected to the internal pressure, said buckling resistant strength of the bottom with aforementioned profile being achieved by using adequate dimensions and wall thickness of said bottom.

Known beer-filled D&I cans having the bottom illustrated in Figure 7 and a diameter of approximately 65 mm comprise D&I can bodies made of 0.40mm thick aluminium alloy sheet and an easy opening top closure seamed thereto.

The thickness of the outer peripheral portion of the bottom and top closure of any one of the conventional D&I cans illustrated in Figures 1 and 7 is such that the buckling resistant strength will withstands the maximum allowable pressure for a rigid container such as a bottle, which is the average pressure calculated by measuring the positive internal pressure value in a plurality of bottles filled with pressurized beverage such as beer and heated to the specified maximum temperature, such as a pasteurization temperature, plus a safety margin, and thus do not buckle, and the centre of the bottom is so constructed as to undergo little if any deformation.

According to the present invention there is provided a drawn and ironed sealed can containing pressurized-gas-containing liquid which has been subjected to a pasteurization process, said can including a can body having a bottom closure wall made integral with a straight side wall and a top closure wall at the opening end of said side wall, said bottom wall comprising an outer peripheral portion including annular projecting means defining a standing base for said can body, and a central closure wall portion connected with said peripheral portion, said central portion being sufficiently flexible to distend under the influence of pressures generated in said can to increase the internal volume thereof, the outer peripheral portion of said bottom closure wall having a buckling resistant strength at least sufficient to withstand an internal pressure (B) plus an extra safety pressure, but not sufficient to withstand an internal pressure (A) plus said extra safety pressure, said pressure (B) being a pressure generated within said can containing said liquid subsequent to sealing of said can is heated up to pasteurization temperature with which said contained liquid has met, said pressure (A) being the pressure which would be generated within the can under the circumstances under which the pressure (B) is generated if the can were rigid, said extra safety pressure being a pressure less than 0.5 kg/cm^2.

The invention also provides a drawn and ironed sealed can containing pressurized-gas-containing liquid which has not been subjected to a pasteurization process, said can including a can body having a bottom closure wall made integral with a straight side wall and a top closure wall and the opening end of said side wall, said bottom closure wall comprising an outer peripheral portion including annular projecting means defining a standing base for said can body, and a central closure wall portion connected with said peripheral portion, said central portion being sufficiently flexible to distend under the influence of pressures generated in said can to increase the internal volume thereof, the outer peripheral portion of said bottom closure wall having a buckling resistant strength at least sufficient to withstand an internal pressure (B) plus an extra safety pressure, but not sufficient to withstand an internal pressure (A) plus an extra safety pressure, said pressure (B) being a pressure generated within said can containing said liquid when said liquid subsequent to sealing of said can is heated up to 50°C, said pressure (A) being the pressure which would be generated within the can under the circumstances under which the pressure (B) is generated, if the can were rigid, said pressure (B) being lower than said pressure (A), said extra safety pressure being a pressure in the range from 0.5 to 0.2 kg/cm^2.

In the accompanying drawings:

Figure 1, already referred to, is a partially cutaway elevational view of a known D&I can shown in section,

Figure 2 is a graphic display of the correlation between the temperature and the internal pressure in a bottle filled with beer having a 2.3 G.V. (as defined below),

Figure 3 is a graphic display of the correlation between the pressure and the increase of internal volume in a sealed container containing beer at 65°C.

Figures 4, 5 and *6* are cross sectional elevations showing the basic profile of the bottom of a can of this invention, showing in particular, the basic profile of the central portion.

Figure 7 is a cross sectional elevation showing the profile of a bottom of a known form of can, alternative to the can bottom seen in Figure 1.

Figure 8 is a cross sectional elevation showing the profile of a bottom for use in a specific example of the present invention.

Figure 9 is a cross sectional elevation showing a top closure having a flat central portion for use in a specific example of the present invention in which the top closure is seamed to the opening end of the can body.

Figure 10 is a cross sectional elevation showing the profile of a bottom for use in another example of the present invention.

Figure 11 is a graphic display of the correlation between the height of the peripheral portion of the bottom of the can body and the material sheet thickness, and the correlation between the material sheet thickness and the displacement of the center of the central portion of the bottom of the can body at an internal pressure of 2 kg/cm^2, the contents being beer at room temperature.

Figure 12 is an elevational view in cross section showing the profile of a bottom of a can for use in another specific example of the present invention.

Figures 13 to *16* are schematic representations showing examples of the profile of the bottom of a can of the invention.

Figures 17 and *18* are schematic representations showing examples of the profile of the inclined wall of the bottom peripheral portion of a can of the invention.

Figures 19 to *22* are schematic representations showing examples of the profile of the bottom central portion of a can of the invention.

Figure 23 is a schematic representation showing an example of the profile of the top closure central portion of a can of the invention.

The abbreviation "G.V." stands for "gas volume", and represents the volumetric ratio of a gas to a liquid, when the gas is dissolved in the liquid, the gas volume being measured at 0°C.

Definitions of the terms used herein are given below.

"Can end plane" means an imaginary plane touching the top or bottom ridge of the can and intersecting the longitudinal axis of the can at right angles.

"Inwardly" means a direction along the longitudinal axis from one end of the can toward the other end of the can and "outwardly" means the reverse direction.

"Displacement" means the shift of a point on an end wall surface when distended, such shift being parallel to the longitudinal axis of the can.

"Buckling" is an abrupt outward deformation of a part or whole of any inwardly directed portion of the bottom or top closure, for example a sudden deformation of the peripheral portion of the can bottom, the occurrence of which diminishes or prevents the can from being placed or stacked standing in a stable upright position.

"Buckling resistant strength" means the strength expressed in the minimum pressure value that causes buckling, and the buckling resistant strength of the bottom and top closure changes with the change of any of its profile, dimensions, wall thickness and the quality of the material used.

Some types of D&I can bodies and top closures are mass-produced, i.e., large quantities of D&I can bodies and top closure of same specifications are produced in many production lines using materials of the same specifications at a rate of several hundreds of cans and several hundreds of top closures per one production line per minute, but materials of the same specifications are not always completely uniform in thickness, having a tolerance of ± 0.01mm for aluminum alloy sheet and ± 0.5% for tinplate. The quality of the material also varies within a specified range, and likewise there are variations in the clearance between the parts incorporated in manufacturing machines and the quantity of lubricant to be applied thereto, and accordingly dimensions and the buckling resistant strength of the can bottoms and the top closures are not free from variation despite similarity in profile. For example, referring to Figure 10 which depicts the profile of a bottom of a D&I can body, the bottom comprises the first curved turning portion 83 which is an extension of the lower end of the straight side wall 81, the inclined wall 84 which extends upwardly in the direction of the can longitudinal axis, the second curved turning portion 85 which is an extension of the top of said inclined wall 84 (83, 84 and 85 mentioned above constituting the bottom peripheral portion 82), and the bottom central portion 86 which is an extension of the peripheral portion, said central portion 86 comprising the annular generally horizontal portion 87 and the central dome portion which is surrounded by said annular portion and formed into a small shallow dome. Consider a can body having such bottom construction and manufactured from an aluminum alloy sheet with thickness of 0.34mm, with a height H_o of the peripheral portion of the bottom from the can end plane *b* of this bottom to the outer surface of the second curved turning portion 85, and a height *So* of the central portion from the can end plane *b* to the outer surface of the annular portion 87 of the central portion. The mean values $\overline{X}$ of the buckling resistant strength of the bottom wall, the can body weight and the values *Ho* and *So* and deviations σ thereof are shown below.

$\sigma = 0.0060\text{mm}$

where $\overline{X}$ of the height of Ho of the peripheral portion equals 6.729mm.

$\sigma = 0.0149\text{mm}$

where $\overline{X}$ of the height So of the central portion equals 3.098mm.

$\sigma = 0.080\ \text{kg/cm}^2$

where $\overline{X}$ of the buckling resistant strength equals 5.48 kg/cm^2.

$\sigma = 0.0474$ gr.

where $\overline{X}$ of the can body weight equals 12.224 gr.

In the case of a can body made of 0.39mm thick aluminum alloy sheet with bottom having a profile the same as shown in Figure 10.

$\sigma = 0.0053$ mm

where $\overline{X}$ of the height Ho of the peripheral portion equals 6.723mm.

$\sigma = 0.0076$ mm

where $\overline{X}$ of the height So of the central portion equals 3.106mm.

$\sigma = 0.0735$ kg/cm^2

where $\overline{X}$ of the buckling resistant strength equals 6.53 kg/cm^2.

$\sigma = 0.0492$ gr.

where $\overline{X}$ of the can body weight equals 12.725 gr.

In fact, mass-produced cans, though of the same specifications, have variations of height *So* of the central portion between 0.05 to 0.09mm and of buckling resistant strength by approximately 0.5 kg/cm^2. For example, a can body having a nominal buckling resistant strength of 5.5 kg/cm^2 may have an actual buckling resistant strength ranging from 5.25 to 5.75 kg/cm^2. Therefore, "nearly equal buckling resistant strength" of the bottom wall and the top closure wall of a can means that the respective mean values of the buckling resistant strength of the bottom wall and the top closure wall are substantially equal, and the meaning of a can having the bottom wall and the top closure wall of substantially equal buckling resistant strength is that both the bottom and the top closure have buckling resistant strengths within the respective variation range.

The "specified maximum temperature" in the case of liquids subjected to pasteurization is the maximum temperature used for the pasteurization. In the case of beer, for example, it is the temperature during the pasteurizating process specified by canners; in the case of carbonated gas-dissolved beverage, the temperature specified by the canner is based on the temperature to which the can filled with the beverage is to be exposed after filling and before ultimate use, and in the case of carbonated fruit juice, it is the temperature during the pasteurizing process specified by the canner. In the case of liquids not subjected to pasteurization it is the maximum temperature to be encountered by the canned liquid during storage and transportation. For the purpose of this specification the said maximum temperature to be encountered is taken to be 50°C.

The present invention is based on the findings of two experiments. One of those two experiments was undertaken to determine the precise relationship between the change of volume of a container and the change of pressure as occurs in a can when the volume changes and has proven that as the internal volume of a container filled with pressurized beverage and sealed is increased at a certain temperature, the internal pressure in said container becomes significantly lower than that in said container before the internal volume is increased. The other of the two experiments is referred to below. The inventor of the present invention obtained the graph shown in Figure 3 through experiments carried out on the assumption that when the internal volume of a sealed container filled with pressurized gas-containing beverage (e.g. beer) and sealed is increased, with the temperature of the beverage being kept constant, though the gas dissolved in the beverage may be discharged into the increased space in the container, the internal pressure in the container is less than that which existed in the container before the internal volume thereof was increased. This graph shows the change of the internal pressure in a container with a capacity of 383ml. filled with 360ml. of beer with 2.3 G.V. and sealed in a normal method as the internal volume of the container is increased while the temperature of the beer is kept at 65°C. As shown in the graph, when the internal volume is increased by 10ml., the internal pressure decreases by approx. 1.0 kg/cm^2 compared with that before the internal volume is increased, and when the internal volume is increased by 15ml., the internal pressure decreases by approx. 1.5kg/cm^2.

Figure 2 is a graphic display of the correlation between the temperature of bottled beer and the internal pressure in a bottle. It shows that the internal pressure in a bottle filled with beer of 2.3 G.V. is approximately 6.0 kg/cm^2 at 65°C, which is the pasteurization processing temperature of beer.

The bottom of a non D&I can has the thickness which is provided with such a buckling resistant strength as to resist buckling of the outer peripheral portion of said bottom under the internal pressure of 6.0 kg/cm^2 at the pasteurization processing temperature plus an extra safety pressure of 0.3 kg/cm^2.

It can then be concluded that a can need only possess a reduced buckling resistant strength capable of withstanding the said reduced internal pressure, and such strength is obtainable by properly engineering the necessary profile, dimensions and wall thickness of the bottom and top closures.

The other of the two experiments mentioned above was carried out to investigate whether or not the central portion of the bottom of the conventional D&I can bodies shown in Figures 1 and 7 will distend at the internal pressure in the cans, to measure the amount of the distension of the bottom if it distends, and furthermore, to determine the profile of a bottom that distends to a greater degree, without causing buckling at the specified internal pressure, than that to which the bottom of a conventional can body may distend. In the experiment, can bodies of six categories were manufactured from an aluminum alloy sheet of 0.4mm in thickness; namely, a can body D with a flattened bottom, (see Figure 4 which shows a bottom comprising an outer peripheral portion 42, made up of an annular ridge portion 44 which turns at the lower end of a straight side wall 41 and an inclined wall 45 which is an extension of the annular ridge portion 44 and which rises upwardly at a slant, and a flattened disk-shaped central portion 43 which extends to the outer peripheral portion 42), a can body A with a domed bottom (see Figure 5 which shows a bottom comprising an outer peripheral portion 52 of the same profile as that of the outer peripheral portion 42 in Figure 4, and has a central portion provided with a convexly domed central portion 53, and whose height h1 from the periphery to the center *a* of the domed central portion 53 is 6.0mm), can bodies B and C of which the height h1 is 1.2mm and 0.8mm respectively and is below 3% of the diameter d of the domed central portion, a can body E with a concavely domed bottom see Figure 6 which shows a bottom comprising an outer peripheral portion 62 of the same profile as that of the outer peripheral portion 42 in Figure 4, and has a concavely domed central portion 63 whose depth h2 is at the center of concavely domed central portion is 0.5mm, and a can body F having a bottom of which depth h3 of the dish-shaped portion 80 (see Figure 7) is 2.6mm. Here, the respective heights H1, H2, H3 and H4 of the outer peripheral portion of each can body was so specified that the buckling resistant strength of the outer peripheral portion of each can body was 5.0 kg/cm^2. The diameter of each can body was approximately 66mm. The following table shows the bottom displacement at the center of the central portion where the displacement was the largest, when the can bodies were subjected to an internal pressure of 4 kg/cm^2.

Classification of can bodies	Displacement dimensions (mm)	Remarks
A : h1 of central portion = 6.0mm	0.6	Prior art can body
B : h1 of central portion = 1.2mm	3.2	
C : h1 of central portion = 0.8mm		
D : flattened central portion	1.8	
E : h2 of central portion = 0.5mm	1.2	
F : h3 of central portion = 2.6mm	0.8	Prior art can body

Each can body distended very little in the outer peripheral portion and stood in a stable upright position. As a result, it has been proven that among the bodies A to F having the bottoms whose central portions are surrounded by the outer peripheral portions and remain inside of the can end plane when distended, the can bodies B to E whose height or depth *h* is smaller than that of the can bodies A and F are subject to larger distension and greater increase of the internal volume than the can bodies A and F. Thus, it is known from the first experiment above described that the internal pressure in a can reduces as the internal volume of the can increases, and, from the second experiment above described that there are some profiles of the bottom of a can body which permit the central portion to distend more than the cans shown in Figure 1 and Figure 7 under internal pressure.

Described below is an example of a calculation that determines the height of the outer peripheral portion of the bottom (assuming that other dimensions of the bottom are given) and the thickness of the material of a can body of the minimum weight when the diameter and the height of the can body, the material of the can body and the profile of the bottom are given. According to experimentation regarding the present invention, when a can body, whose diameter is approximately 66mm and whose height is approximately 122mm, having a bottom formed into the profile shown in Figure 8 (which includes the first annular ridge portion 25 which is an extension of the lower end of the straight side wall 21 and forms a part of the outer peripheral portion 22 of the bottom, the inclined wall 26 which extends inwardly and tangentially from said first annular ridge portion 25 and forms another part of the outer peripheral portion 22 of the bottom, the second annular ridge portion 27 which is an extension of the inclined wall 26 and forms the remaining pat of the outer peripheral portion of the bottom, and the flat central portion 28 which is surrounded by the second annular ridge portion 27) is manufactured from an aluminum alloy sheet whose thickness is within the range from 0.34mm to 0.39mm, the buckling resistant strength of the outer peripheral portion increases or decreases by 0.28 kg/cm^2 on the average when the height H5 of the outer peripheral portion is increased or decreased by 1mm from a standard height of 5.5mm while the thickness of the material remains unchanged, and the buckling resistant strength increases or decreases by 0.23 kg/cm^2 on the average when the thickness of the material is increased or decreased by 0.01mm while the height of the outer peripheral portion remains unchanged. In the latter case, the displacement of the center of the central portion at an internal pressure of 5 kg/cm^2 decreases or increases by 0.25mm. If the diameter *d* of the central portion is approximately 50mm, and if one assumes an initial displacement of, say 4mm, such increase or decrease in displacement by 0.25mm causes an increase or decrease of approximately 0.5cc in the internal volume of the can body, and in turn, causes a decrease or increase of 0.05 kg/cm^2 in the internal pressure.

When the sheet thickness of the material is decreased by 0.01mm, the resultant decrease in the buckling resistant strength is 0.18 kg/cm^2 greater than that occurring in the internal pressure, whereby it becomes necessary to increase the height of the outer peripheral portion by $1\text{mm} \times \frac{0.18}{0.23} = 0.65\text{mm}$ in order to maintain an adequate buckling resistant strength. Since the increase of 0.65mm in the height of the outer peripheral portion causes an increase of 0.65mm in the height of the bottom central portion, the height of the can body must be increased in order to maintain the internal volume which is given to the can body before the increase in the height of the outer peripheral portion. An increase in the height of the outer peripheral portion of the bottom, without changing the area of the central portion of said bottom, will increase the total area of said bottom including said higher outer peripheral portion and cause the central portion to be located more inwardly of said can body than would have been the case had the outer peripheral portion not been made higher. As a result of that, the internal volume of said can will be decreased. In order to avoid such a decrease in the internal volume and keep the original internal volume, it is necessary to increase the height of the can body by the same amount as increase in height of said outer peripheral portion. Thus the weight of the can body of which the can body is increased by making the outer peripheral portion higher, the increase being made up of the increased weight of the outer peripheral portion plus increased weight of the higher can side wall. However, this increase is at least partly compensated by the fact that the weight of the can bottom is less because of the thinner material used.

Consider, by way of example, a can body having a bottom whose outer peripheral portion and center of central portion are 6.5mm and 3.6mm in height respectively, and in which the thickness of the material is decreased by 0.01mm. The aforementioned increase in weight of the can body, for the can to have the same internal volume, is approximately 0.139 gr, and the partly compensating decrease in weight of the can bottom was 0.1 gr, giving a net increase of 0.039 gr.

By contrast with what has been described above, an increase in the sheet thickness causes a decrease in the weight of the can body. However, a can of the present invention using a can body with the top closure seamed thereto should preferably sit in a stable upright position at the maximum specified temperature, or in other words, the can body preferably satisfies the condition that the bottom central portion of the can body does not protrude outside the can end plane, from which condition the following formula limitting the range of available wall thickness is derived;

Height of outer peripheral portion $\geqslant$ Height of the central portion + displacement dimensions of the center of the central portion.

In Figure 11, the line (X) represents the relationship between the height of the outer peripheral portion of the bottom formed into the profile shown in Figure 8 and provided with a given buckling resistant strength, and the corresponding thickness of the material, and the line (Y) represents the relationship between the displacement dimensions of the center of the central portion at the internal pressure of 2 kg/cm^2 at the aforementioned specified maximum temperature and the thickness of the sheet material. Since the height of the center of the central portion of the aforementioned bottom is 3.6mm, a sheet thickness of 0.35mm is obtained by locating the point on the line (X) where the distance to the line (Y) in the direction of the vertical axis is close to and greater than 3.6mm. This can body made of 0.35mm thick material showed reduction in weight of approximately 6% compared with the conventional can body which is formed into the profile as shown in Figure 1 from 0.43mm thick material and provided with the same height and diameter as this can body.

The aforementioned thickness of 0.35mm is the desired thickness to provide a bottom which satisfies the basic data used in the above calculations, which bottom should preferably have not only the necessary buckling resistant strength but also maximization of the internal volume, and a stable upright standing at the specified maximum temperature. However, the sheet thickness obtained from the above calculations is just one example of the can body and it should be calculated for different types of bottom profile on a case-by-case basis.

In the present invention, the flexibility of the central portion of the bottom (and top closure) and the buckling resistant strength of the outer peripheral portion are provided by using adequate profile, dimensions and wall thickness, and accordingly the bottom and the top closure of the can or the can body of this invention can be embodied using various combinations of said profile, dimensions and wall thickness.

Following is the detailed description on the second finding which led to the present invention. The aforementioned sheet thickness of 0.35mm was calculated without considering the relation with a top closure, and according to the second finding which led to the present invention, the increased internal volume of the can, as caused by the distension of the bottom wall of the can body, affects reduction of the wall thickness of the top closure, and therefore the wall thickness of the bottom must be determined with this factor in mind.

D&I can bodies having bottoms of the same profile and dimensions were made of aluminum alloy sheets thicknesses of 0.36mm, 0.38mm and 0.39mm, filled with beer and then seamed with top closures of the same profile and dimensions made of 0.29mm and 0.32mm thick aluminum alloy sheets to measure the temperature of beer at which the top closure would buckle. The results are shown in Table 1 below.

TABLE 1

Material Thickness (can body)	0.36mm	0.38mm	0.39mm
Material thickness (top closure)			
0.29mm	67.5°C	67.0°C	66.0°C
0.32mm	77.8°C	77.5°C	76.8°C

As seen from this table 1, the top closure seamed to a can body with 0.39mm thick bottom which distends due to the internal pressure, though such distension is smaller than that of 0.36mm thick bottom, i.e., the increase of internal volume of a can with 0.39mm thick bottom is smaller than that of a can with 0.36mm thick bottom, buckles at a lower temperature than the temperature where a top closure of same profile, dimensions and thickness seamed to a can body with 0.36mm (or 0.38mm) thick bottom which causes a larger increase of the internal volume than a 0.39mm thick bottom does. Also as is shown in the table, a 0.29mm thick top closure, for example, seamed to a can body with 0.39mm thick bottom buckled at 66°C. In order to obtain a suitable can whose top closure and bottom do not buckle at such temperature, the inventor adapted an alternative approach to increasing the thickness of top closure which buckles, that is to say, so far as the above example is concerned, to reduce the thickness of the bottom which did not buckle at 66°C so as to enable the bottom to distend more largely, which consequently decreases the internal pressure to an extent that the buckling resistant strength of the top closure withstands the pressure. If the top closure still buckles at the reduced internal pressure while the bottom does not buckle, the thickness of the bottom wall can be further reduced. In this manner, the wall thickness of both the bottom and the top closure can be reduced enough to meet the necessary buckling resistant strength, i.e., where both the bottom and top closure do not buckle at the specified maximum temperature. In this manner, there can be produced a can of reduced weight that meets the aforementioned requirements, serving the purpose of material conservation at the same time.

The D&I can body of this present invention is a can which features a bottom that distends by influence of the internal pressure in the can, still maintaining the capability of standing in a stable upright position at the specified maximum temperature. Several sample cans manufactured by the present inventor are given below by way of further explanation of the invention.

Example 1

In the case of beer cans, they are placed upright on a conveyor and transferred in many rows and lines during the pasteurizing process. If a single can topples over during the process, it may tip surrounding cans over and thus transfer of the cans from the conveyor to the subsequent process may be hampered. For this reason, the cans on the conveyor may slightly incline but should never topple over. The following can was manufactured as an example of the cans which satisfy the aforementioned condition. The body of this D&I can, having a bottom which is formed into the profile illustrated in Figure 10, was manufactured from T-1 tinplate of 0.28mm in thickness, the diameter of the body being approximately 66mm, the thickness of the straight side wall being approximately 0.09mm, and the wall thickness of the bottom being 0.28mm and equivalent to the original thickness of the material. The radius R1 of the arc of the first annular ridge portion 25 of the outer peripheral portion was approximately 1.5mm, the angle θ of inclination of the inclined wall 26 was approximately 25°, the radius R2 of the arc of the second annular ridge portion 27 was approximately 1mm, the height H5 from the can end plane b to the outer surface of the peak 29 of the second annular ridge portion 27 was 6.6mm, the diameter d of the central flat portion 28 was approximately 50mm and the height S from the can end plane b to the outer surface of the central portion 28 was 4.0mm. The top closure was made in the same profile as that in Figure 1 from a H-19 aluminum alloy sheet of 0.32mm in thickness.

The can was filled with beer of 2.4 G.V.

When this can was subjected to a pasteurizing process at 65°C, the central portion of the bottom distended by almost 4mm, but the can did not topple over on the conveyor, and the internal pressure at that time was approximately 5.5 kg/cm^2 (in the case of a bottle, the internal pressure during the above process is 6.6 kg/cm^2). The center of the central portion of the top closure distended approximately 2.1mm.

When the can was filled with water instead of beer, the water being pressurized in order to increase the internal pressure from 5.5 kg/cm^2 to 6 kg/cm^2, the center of the central portion of the bottom distended by approximately 4.3mm from the original position and protruded a little outside the can end plane, and the center of the top closure distended by approximately 2.4mm from the original position and protruded a little outside the other can end plane. However, neither the bottom nor the top closure buckled. In the course of further increase in the internal pressure to 6.5 kg/cm^2, either the top closure or the bottom buckled.

When the can was cooled down after the pasteurization, the whole bottom central portion stayed inside the can end plane.

The can body was made of a material (0.28mm) thinner than the material used for a conventional tinplate D&I can (0.34mm) shown in Figure 1 and the top closure was made of a material (0.32mm) thinner than the material for the conventional top closure (0.34mm). Therefore, the above mentioned can which is a combination of the can body and the top closure of this example has realized a significant reduction in weight over the conventional can. The profile, but not the dimensions of the bottom illustrated in Figure 8 as well as the profile of the top closure illustrated in Figure 1 are known.

However, the object of the present invention is not to determine a profile itself but to realize reduction in weight of the can or can body. Considering the fact that in a can whose internal volume increases under internal pressure, the internal pressure (B) within a can the central portion of the bottom of which is deformable is less than the internal pressure (A) produced in a rigid bottle, wherein no expansion is possible the D&I can of the present invention is provided with such buckling resistant strength that cannot withstand the pressure (A) plus an extra safety pressure, but can withstands the internal pressure (B), which is lower than the pressure (A), plus the said extra safety pressure. The extra safety pressure is less than 0.5 kg/cm^2 and is calculated in consideration of various factors such as increase in the internal volume of the can after sealing, volume of filled beverage, G.V. in filling, variation in temperature, and others). The aforementioned buckling resistant strength is obtainable by using adequate profile, dimensions and wall thickness of the bottom and the top closure as one skilled in the art would in light of the teaching herein, readily determine.

As a result, when the bottom of the both can bodies is otherwise identical in profile and dimensions, the can body of the present invention can be provided with the outer peripheral portion of the bottom which is thinner than that of the conventional can which is provided with such buckling resistant strength that withstands the aforementioned maximum allowable pressure (A) for a rigid container. Furthermore, when the profile of the bottom of the can body of the present invention is similar to that of the conventional can and the wall thickness of the bottom of the both can bodies is the same, for example, the height of the outer peripheral portion of the bottom of the can body of the present inventon, which bottom is provided with such buckling resistant strength that withstands the internal pressure (B), which is lower than the internal pressure in a bottle (A), plus extra safety pressure, can be made lower than that of the conventional can whose bottom is provided with such buckling strength that withstands the internal pressure in the bottle (A) plus extra safety pressure of less than 0.5 kg/cm^2 (maximum allowable pressure for a bottle), and accordingly, the can body of the present invention can be made lighter in weight than the conventional can.

Example 2

A D&I can, whose can body is provided with the bottom illustrated in Figure 10 and whose top closure is formed in the profile illustrated in Figure 9, has the specifications given below.

Diameter of can	Approx. 66mm
Height of can	Approx. 122mm
Thickness of material	T-4 tinplate, 0.32mm thick
Thickness of side wall	0.09mm
Dimensions of each portion of bottom	
First annular ridge portion	R3 1.8mm R4 0.9mm
Angle of inclined wall	θ 20°
Second annular ridge portion	R5 0.75mm R6 0.8mm
Height of outer peripheral portion	H_o 4.3mm
Height of central portion	S_o 3.3mm
Height of center of central portion	T_o 4.4mm
Diameter of central domed portion 88	d Approx. 40mm
Diameter of seamed portion of top closure	Approx. 66mm
Material of top closure	H-19 aluminum alloy sheet, 0.32mm thick
Dimensions of each portion of top closure	
Radius of bead portion	r1 0.7mm
Countersunk	l_1 6.3mm
Radius of the portion connecting the bead portion and central portion 93	r2 0.6mm
Depth of central portion	l_2 4.4mm
Depth of the tab	l_3 1.8mm

The weight of this D&I can is 34.9 gr., on the average, that is 2.8 gr. lighter than the conventional D&I can which is made up of a 0.34mm thick material. Plural numbers of the D&I can body of this example were filled with beer of 2.3 G.V. by a usual method, seamed with a top closure, and heated. Internal pressure in the cans and displacement dimensions of the center of the central portion of the bottom and the top closure of the cans at the different heating temperatures are shown in table 3.

TABLE 3

Temperature (°C)	Internal Pressure k(kg/cm^2)	Average of n=5 Displacement dimensions (mm) Top closure	Bottom
30	2.4	1.2	1.45
50	3.8	1.45	2.05
60	5.05	1.7	3.05

The table shows that the centre portion of both the top closure and the bottom of the D&I cans displace gradually with increasing temperature and the internal pressure also increases gradually.

Neither the bottom nor the top closure of the cans of this example buckled during pasteurizing processing, but either the bottom or the top closure of the majority of the cans buckled before the internal pressure in the cans reached 6.0 kg/cm^2. The cans of this example also stood in a stable upright position at the specified maximum temperature, and did not buckle at maximum allowable pressure for the can of this particular example. When the internal pressure was further increased, however, either the bottom or the top closure buckled before the internal pressure reached the maximum allowable pressure for a rigid bottle.

The bottom and the top closure of the can of this example are provided with nearly equal buckling resistant strength and the can does not topple over during pasteurizing. Thus, the D&I can of this example embodies the object of the present invention.

Example 3

A D&I can provided with a bottom as shown in Figure 10 and seamed with a top closure as shown in Figure 9, has dimensions as follows:

Diameter of Can	Approx. 66mm
Height of Can	Approx. 122mm
Material of Can Body	H-19 aluminum alloy sheet, 0.36mm thick
Thickness of Side Wall	0.13mm
Thickness of Bottom Wall	0:36mm
Dimensions of Bottom;	
First Curved Turning Portion	R3 2.3mm R4 0.9mm
Angle of Inclined Wall	8°
Second Curved Turning Portion	R5 1.3mm
Portion connecting the Second Curved Turning Portion and Central Portion	R6 0.8mm
Height of Outer Peripheral Portion	Ho 6.7mm
Height of Central Portion	So 3.1mm
Height of the Center	tO 4.2mm
Material of Top Closure	0.31mm thick aluminum sheet
Dimensions of Top Closure;	
Countersunk	l_1 6.3mm
Radius of Bead Portion	r1 0.7mm
Portion connecting the bead Portion and Central Portion	r2 0.6mm
Depth of Central Portion	12 4.4mm
Depth to Tab	13 1.8mm

A plural number of cans were filled with beer with 2.3 G.V. in a normal method and seamed with the top closures and then were subjected to a pasteurizing process at 65°C. The displacement of the centers of the bottom and the top closure immediately after the pasteurizing process were as follows:

Displacement of the Center of Bottom	$\overline{X}$ = 4.7mm
Displacement of the Center of Top Closure	$\overline{X}$ = 2.6mm

It was known from the above that the center of the bottom distended by approximately 0.5mm outside of the can end plane and the top closure by approximately 0.8mm. However, none of the cans toppled while travelling on the conveyor in the pasteurizing process. The internal pressure in the can was 5.2 kg/cm^2 on the average while the can was undergoing pasteurization, and the buckling resistant strength of the bottom was 5.7 kg/cm^2 on the average and that of the top closure was 5.8 kg/cm^2 on the average. The weight of this can was 17.41 gr. on the average which was approximately 7% lighter than the conventional can (made of 0.43mm thick sheet).

Example 4

Cans filled with pressurized gas-containing beverage which has not been subject to pasteurization are transported normally by vehicles for distribution and may be heated up to around 50°C during such transportion in mid-summer, which may cause the central portions of the bottom and/or the top closure to distend outside of the can end plane, and furthermore markings such as the date of filling, etc. stamped with ink on such distended central portions may be rubbed off by the opposing surface of the packing case containing such cans due to vibration during the transportation.

Therefore, it is necessary in these cans that the center of the central portion of the bottom does not distend outside of the can end plane at 50°C. Given below is an example of the can which was made based on the present invention in order to avoid such problems.

A D&I can having a can body seamed with the top closure shown in Figure 9 is provided with a bottom as shown in Figure 12. Said bottom has the outer peripheral portion 132, comprising the first curved turning portion 135 which is an extension of the lower end of the straight side wall 131 and turns upwardly, the inclined wall 136 which extends upwardly and nearly tangentially from the said first curved turning portion 135 toward the can longitudinal axis and the second curved turning portion 137 which is an extension of said inclined wall 136, and the bottom central portion, comprising the peripheral grooved portion 138 which is an extension of the second turning portion 137 and extends upwardly toward the can longitudinal axis, forming a shallow groove, and the flat portion 139 surrounded by said peripheral grooved portion 138.

The dimensions of this can are given below.

Diameter of Can	Approx. 53mm	
Height of Can	Approx. 133mm	
Material of Can Body	−1 tinplate, 0.32mm thick	
Thickness of Side Wall	0.09mm	
Dimensions of Bottom;		
First curved turning portion	R11	1.6mm
	R12	1.6mm
Angle of inclined wall		26°
Second curved turning portion	R13	1.1mm
Third turning portion	R14	4.8mm
	R15	2.1mm
Height of peripheral portion	H10	4.4mm
Height of central portion	S10	4.6mm
Height of third turning portion	S11	3.5mm
Diameter of central flat portion	d	21mm
Dimensions of Top Closure;		
Diameter of seamed portion	Approx. 53mm	
Radius of bead portion	r1	0.7mm
Depth of countersunk	l_1	6.1mm
Radius of the portion connecting bead portion and central portion	r2	0.8mm
Depth of central portion	l_2	4.7mm
Depth to tab	l_3	2.5mm

A plurality of the cans in this Example 4 filled with pressurized gas-containing beverage not subjected to pasteurization and with 3.0 G.V. were heated up to 55°C with no buckling on either the bottom or the top closure. Both the top closure and the bottom had the same buckling resistance strength and both buckled when they were heated up to 60°C. The average buckling resistant strength of the bottom was 7 kg/cm^2 and that of the top closure was 6.9 kg/cm^2 which could be considered nearly equal to that of the bottom. The displacement before buckling occurred, was approximately 4.1mm at the center of the bottom and approximately 2.4mm at the center of top closure. The internal pressure in the cans at 50°C was approximately 0.3 kg/cm^2 lower than that in a rigid bottle, and when the central portion of the bottom and the top closure stayed inside of the can end plane under the pressure. The average weight of the D&I cans in this Example was 22.5 gr. which was 0.25 gr. less than that of the conventional D&I can.

In view of the above, if the average internal pressure in the can in this Example at the specified maximum temperature of the beverage, i.e. 50°C is within the range from 6.4 kg/cm^2 to 6.6 kg/cm^2 and also if the can is used for the beverage whose extra safety pressure is in the range from 0.5 kg/cm^2 to 0.3 kg/cm^2, such a can satisfies all the requisites which the can of the present invention should be provided with and meets the condition that the central portion of the bottom and the top closure do not distend outside of the can end plane at 50°C.

Example 5

A D&I can, like the D&I can in Example 4, provided with a combination of the bottom in Figure 12 and the top closure in Figure 9 has the dimensions given below.

Diameter of can	Approx. 55mm	
Height of can	Approx. 122mm	
Material of can body	H-19 aluminum alloy sheet, 0.36 mm thick	
Thickness of side wall	0.135mm	
Dimensions of each portion of bottom		
First curved turning portion	R11	2.0mm
	R12	1.2mm
Angle of inclination of inclined wall	θ	3°
Second curved turning portion	R13	1.2mm
Third curved turning portion	R14	4.5mm
	R15	2.9mm
Height of outer peripheral portion	H10	6.8mm
Height of central portion	S10	6.7mm
Height of third turning portion	S11	5.5mm
Diameter of central flattened portion	d	25mm
Material of top closure	H-19 aluminum alloy Sheet, 0.32mm thick	
Diameter of seamed portion		Approx. 53mm
Radius of bead portion	r1	0.7mm
Depth of countersunk	l_1	6.3mm
Radius of the portion connecting bead portion and central portion	r2	0.8mm
Depth of central portion	l_2	5.1mm
Depth to tab	l_3	3.0mm

A plurality of the cans in this Example 5, filled with beverage of 3.0 G.V. and seamed with the top closures thereto, were heated up to 50°C. The internal pressure in the cans was lower than that in the bottle by 0.3 kg/cm^2. The displacements of the each center of the bottom and the top closure were 4.3mm and 2.1mm respectively, with no protrusion outside the can end plane. Accordingly, the cans stood in a stable upright position at the specified maximum temperature. The buckling resistant strength of both the bottom and the top closure was 7.4 kg/cm^2, and either the bottom or the top closure buckled on being heated up to 65°C. Therefore, if the average internal pressure in the can in this Example at the specified maximum temperature of the beverage is within the range from 6.9 kg/cm^2 to 7.2 kg/cm^2 and if the can is used for a beverage which has an extra safety pressure within the range from 0.5 to 0.2 kg/cm^2, such a can satisfies the requisites with which the can of the present invention should preferably be provided, with no protrusion of the central portions of both the bottom and the top closure outside of the can end plane at 50°C.

Besides the profiles in the specific examples mentioned above, there are various possible applications of the profile of the bottom of the can body of the present invention as shown in Figures 13 to 22. The top closure for such forms of cans can be, for example, of a shallow convexly domed shape (Figure 25), besides being flat in the central portion or of a shallow concavely domed shape, and also is not limited to the easy opening type closure. The can body and the top closure materials are not limited to use of aluminum alloy sheet and tin plate, and other metal sheets for cans, for example, back plate, chemically treated steel, plastic coated metal plate and others can also be used.

In addition to U. S. Patent 3,904,069 discussed before, other art pertinent to the present invention includes U.S. Patents Nos. 3,905,507; 3,105,765; 1,987,817; 3,693,828; and 2,894,844 and Japanese Utility Model Specification No. Sho 51-519. While such art teaches that container end walls may be made flexible to account and compensate in the structure for pressure conditions both inside and outside the container, and while such action as occurs, e.g., in the can disclosed in U. S. Patent 1,987,817 may serve to reduce pressure within the container, such art neither recognizes nor suggests that reduction in pressure allows for reduction in the buckling resistant strength of the end wall structure. Such prior art can ends are designed to have a buckling resistant strength which does not take into account the effect of reduced pressure.

As those skilled in the art will readily appreciate, the can of the present invention is a significant improvement in can construction and allows for substantial savings in the amount of metal stock required for producing such cans. The invention makes use of the fact that by increasing the volume in a can by employing pressure distensible walls, there is produced a corresponding reduction in pressure in the can. Thus the can wall end closure need only be designed, i.e., given a buckling resistance to withstand not the level of pressure as would exist if no volume increase occurred, but rather the actual pressure in the can which is of a lower value. Therefore, the can end closures can be designed with suitable profile, dimensions and wall thickness of the closure walls to take into account this advantage and thus use less material in making a can for the same service as conventional D&I cans. To further illustrate the invention, consideration is had of the packaging of beer in a conventional D&I can as compared to a can made in accordance with the present invention. When beer is pasteurized, it is heated to say, for example, 65°C. This results in creation within a bottle (wherein no expansion is possible) of a pressure of predetermined magnitude, i.e., on the order of 6 kg/cm^2. A safety margin of 0.3 kg/cm^2 is designed into the bottle, so the same will withstand a pressure of 6.3 kg/cm^2. A conventional D&I can used for the same purpose is also designed to withstand the same pressure value although there may in fact occur within such D&I can a distension of an end closure wall and pressure reduction. Thus the D&I can of conventional construction is designed with a buckling resistant strength of about 6.3 kg/cm^2 in mind. A can of the present invention takes into account, however, that during pasteurization, if the end wall closure distends there will be a limitation of the pressure generated by virtue that the can volume increase so that the actual pressure produced in the can is, e.g., of a lower value on the order of 5.3 kg/cm^2. Thus, the can need only be designed to give the closure wall peripheral portion a buckling resistant strength sufficient to withstand that pressure plus a safety factor of up to an additional 0.5 kg/cm^2. The result is that material savings can be achieved by reducing the wall thickness of the closure wall, the height of the wall outer peripheral portion or the like.

WHAT WE CLAIM IS:

1. A drawn and ironed sealed can containing pressurized-gas-containing liquid which has been subjected to a pasteurization process, said can including a can body having a bottom closure wall made integral with a straight side wall and a top closure wall at the opening end of said side wall, said bottom wall comprising an outer peripheral portion including annular projecting means defining a standing base for said can body, and a central closure wall portion connected with said peripheral portion, said central portion being sufficiently flexible to distend under the influence of pressures generated in said can to increase the internal volume thereof, the outer peripheral portion of said bottom closure wall having a buckling resistant strength at least sufficient to withstand an internal pressure (B) plus an extra safety pressure, but not sufficient to withstand an internal pressure (A) plus said extra safety pressure, said pressure (B) being a pressure generated within said can containing said liquid when said liquid subsequent to sealing of said can is heated up to pasteurization temperature with which said contained liquid has met, said pressure (A) being the pressure which would be generated within the can under the circumstances under which the pressure (B) is generated if the can were rigid, said extra safety pressure being a pressure less than 0.5 kg/cm^2.

2. A can in accordance with claim 1 in which the buckling resistant strength of both said bottom closure wall and top closure wall peripheral portions are of substantially equal values.

3. A can in accordance with any preceding claim in which said top closure wall is provided with a readily tearing and opening tab member.

4. A drawn and ironed sealed can containing pressurized-gas-contaning liquid which has not been subjected to a pasteurization process, said can including a can body having a bottom closure wall made integral with a straight side wall and a top closure wall and the opening end of said side wall, said bottom closure wall comprising an outer peripheral portion including annular projecting means defining a standing base for said can body, and a central closure wall portion connected with said peripheral portion, said central portion being sufficiently flexible to distend under the influence of pressures generated in said can to increase the internal volume thereof, the outer peripheral portion of said bottom closure wall having a buckling resistant strength at least sufficient to withstand an internal pressure (B) plus an extra safety pressure, but not sufficient to withstand an internal pressure (A) plus an extra safety pressure, said pressure (B) being a pressure generated within said can containing said liquid when said liquid subsequent to sealing of said can is heated up to 50°C, said pressure (A) being the pressure which would be generated within the can under the circumstances under which the pressure (B) is generated, if the can were rigid, said pressure (B) being lower than said pressure (A), said extra safety pressure being a pressure in the range from 0.5 to 0.2 kg/cm^2.

5. A can in accordance with claim 4 in which the buckling resistant strength of both said bottom closure wall and top closure wall peripheral portions are of substantially equal

values.

6. A can in accordance with any one of claims 4 and 5, in which said top closure wall is provided with a readily tearing and opening tab member.

7. A drawn and ironed can containing liquid according to claim 1 or 4, substantially as herein described with reference to the accompanying drawings.

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1586986 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG.1

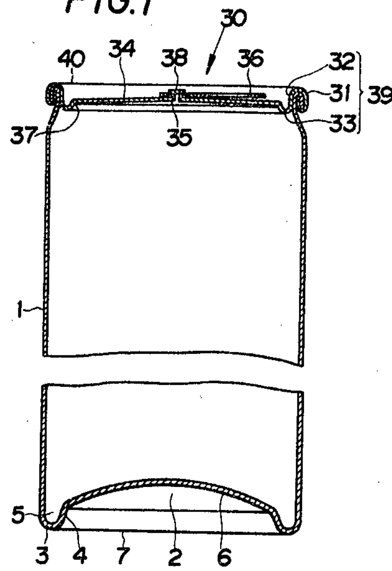


FIG. 2

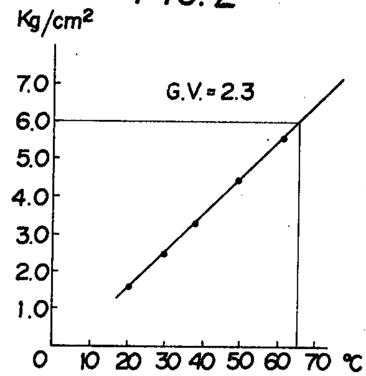
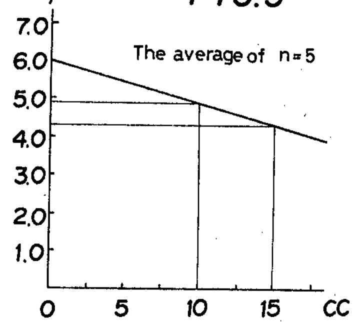


FIG.3



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Sheet 2

FIG.4

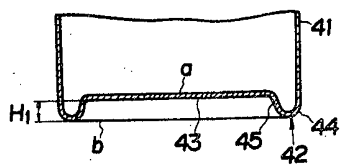


FIG.5

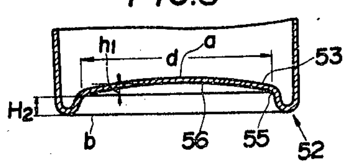


FIG.6

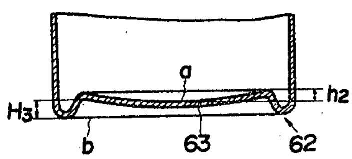


FIG.7

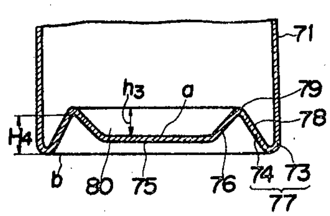


FIG.8

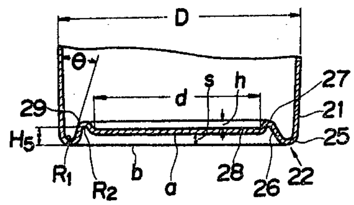


FIG.9

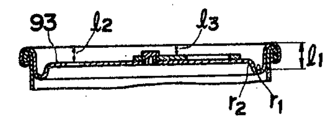


FIG.10

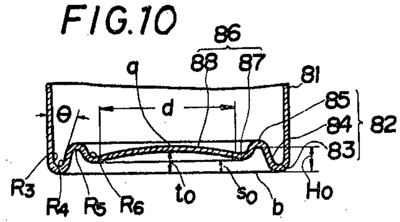
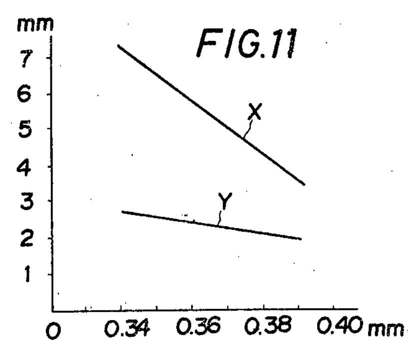


FIG.11



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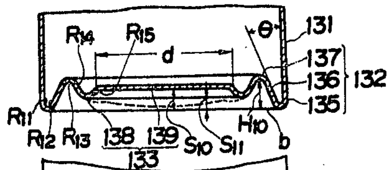
Sheet 3

FIG.12



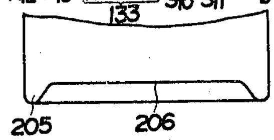


FIG.13

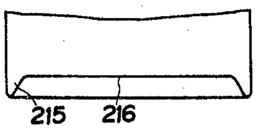


FIG.14

FIG.15

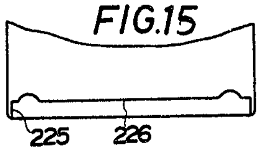


FIG.16

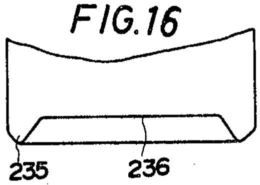


FIG.17

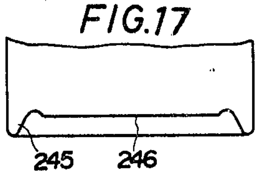


FIG.18

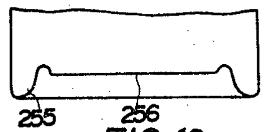


FIG.19

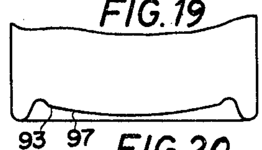


FIG.20

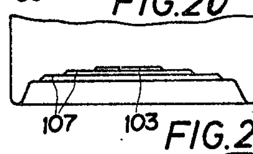


FIG.21

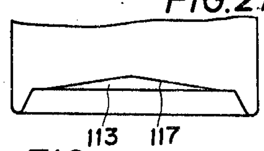


FIG.22

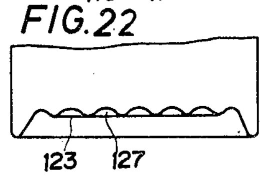


FIG.23