

[54] **METHOD AND APPARATUS FOR BEADING, NECKING-IN AND FLANGING METAL CAN BODIES**

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[51] Int. Cl. **B21d 41/04**

[58] Field of Search **72/91, 110, 370, 72/121; 113/7 R, 7 A, 120 AA, 120 R, 120 M, 116 QA, 120 W**

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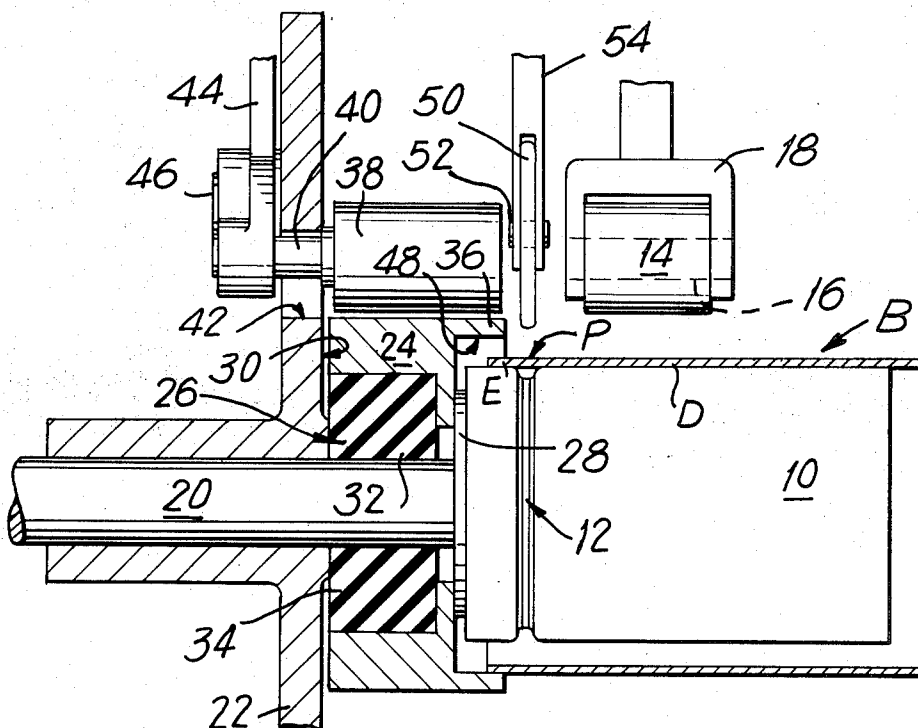
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[57] **ABSTRACT**

A method and apparatus for reducing the circumference of a portion of a metal can body to form a necked-in (and/or beaded) feature and for producing a flange feature on one side of the can body portion wherein the can body is rotated about its own axis which is offset from the mandrel axis, both sides of the can body portion are restrained from undergoing movement relative to the mandrel by bringing clamping pressure to bear against said both sides by means of rotatable clamping rolls, the can body portion, being circumferentially aligned with a circumferentially undercut section of the mandrel, is reduced in circumference by moving a rotatable beading roll inwardly toward the axis of the mandrel and against the can body portion, after a predetermined initial reduction in the circumference of the can body portion, the side of the can body on which the flange feature is to be produced is freed from its restraint by removing the clamping pressure imposed by its respective clamping roll, and, finally, as the can body portion is further reduced in circumference by continuing the movement of the rotatable beading roll inwardly against the can body portion, the free, unrestrained side of the can body portion is drawn between predetermined radiused surfaces on the mandrel and the beading roll which causes the marginal edge of that side of the can body portion to pivot and swing outwardly beyond the original circumference of the can body to produce a flange feature on the end of the can body.

16 Claims, 18 Drawing Figures



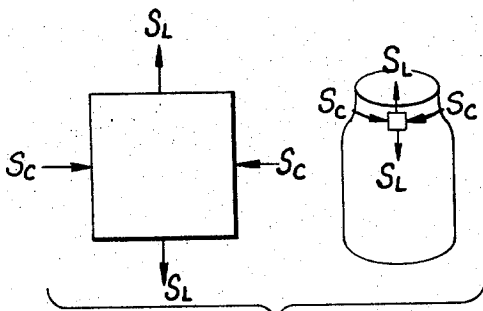
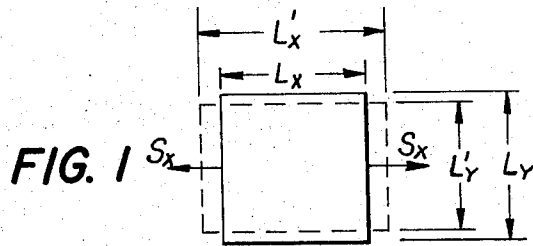


FIG. 2

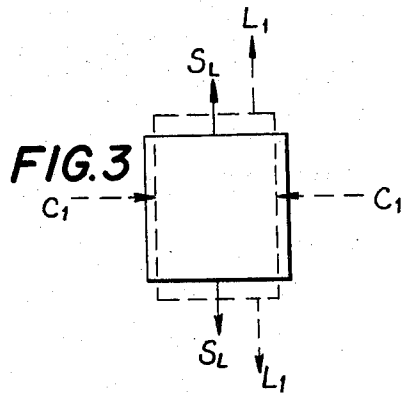


FIG. 3

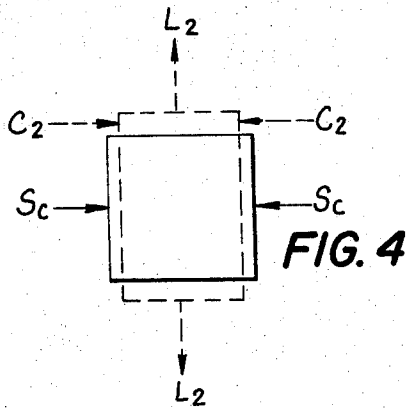


FIG. 4

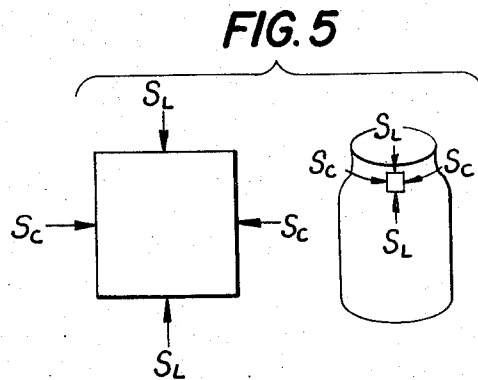


FIG. 5

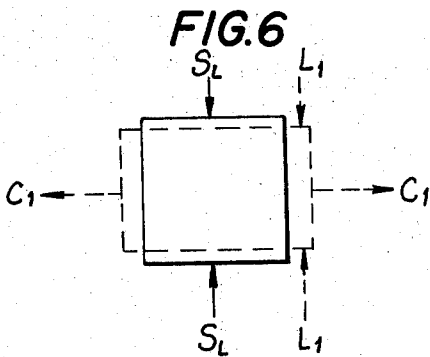


FIG. 6

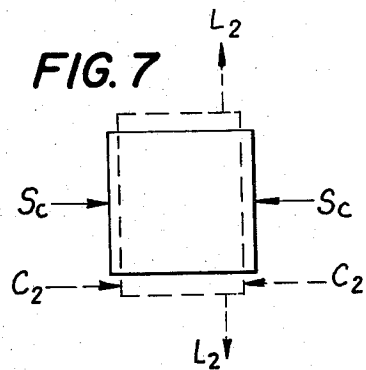


FIG. 7

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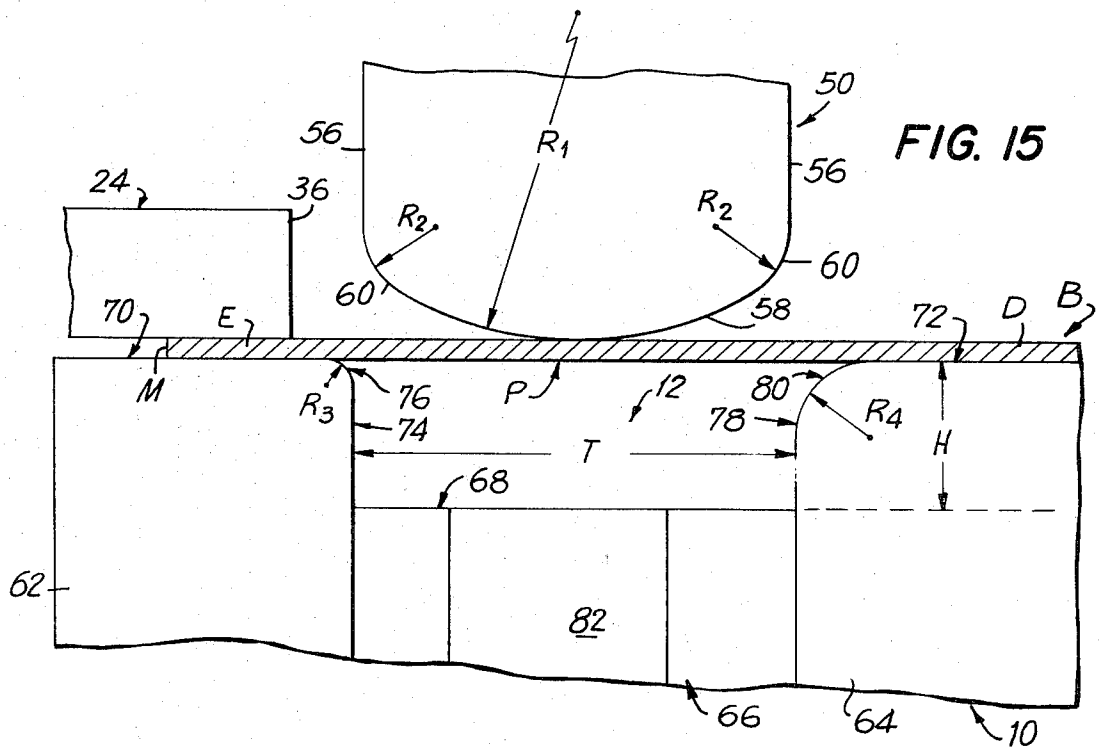


FIG. 15

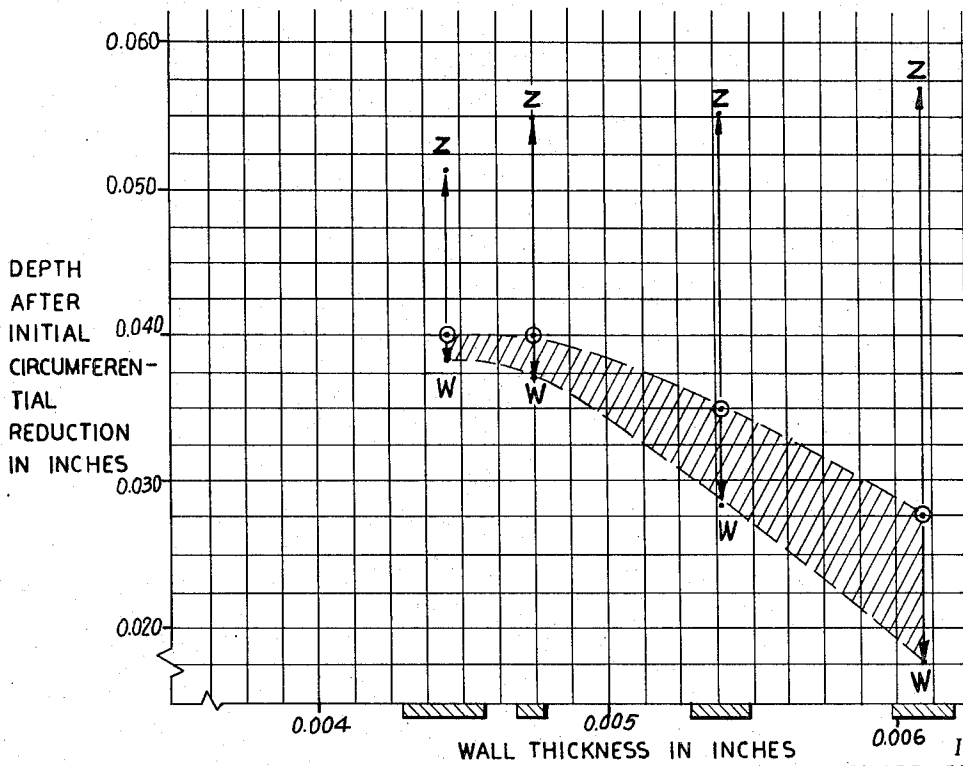


FIG. 16

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FIG. 17

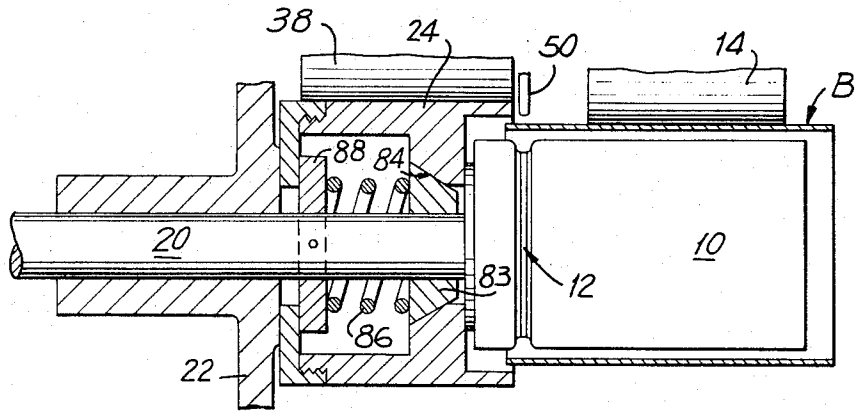
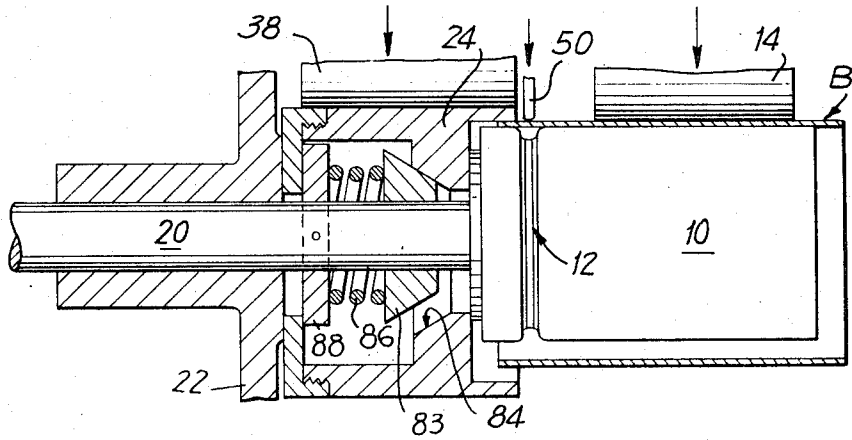


FIG. 18



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METHOD AND APPARATUS FOR BEADING, NECKING-IN AND FLANGING METAL CAN BODIES

BACKGROUND OF THE INVENTION

The present invention relates broadly to metal receptacles such as beer and beverage cans which are made from thin metal stock. The bodies of such cans may be formed in a variety of ways, as by impact extrusion or in a drawing and ironing process, which methods produce bodies which are seamless and have only one open end, or from flat blanks which are formed into cylinders and have their longitudinal edges secured together in any conventional manner, as by soldering, welding, or by means of an organic adhesive, to form them into strong leakproof side seams. This latter type of can body has two open ends. In all types, the open ends are sealed by having separate can closures secured onto them in conventional multilayered double seams wherein the flanges of the can bodies and the end closures are interfolded together.

Until fairly recently, commercially produced can bodies were straight-sided, with the result that the double seams projected outwardly beyond the adjacent peripheral contour of the body sidewall. Recently, however, the demand for a more economical can, among other reasons, has created a trend toward the necking-in of the open end, or ends, of the can bodies to such extent that the double seam, or seams, do not project outwardly of the body sidewall, but rather form an extension of it. In other words, the external diameter of the double seam is desirably about equal to the external diameter of the can body. This construction provides a number of advantages, not the least of which is that it permits the use of a smaller sized, and consequently more economical, end closure.

The demand for a more economical can has further created another trend in the can manufacturing industry toward the continuous reduction of the amount of metal in the can body, particularly by the reduction of the metal thickness of the can body sidewall. However, as the metal thickness of the can body sidewall is continuously decreased, necking-in and flanging of the open end, or ends, of the can body by conventional techniques, such as the die necking and free roll beading techniques, will become exceedingly more difficult.

The present invention utilizes the effect of the Poisson Strain Ratio to permit greater can body circumference reductions than are possible with any of the known techniques for necking-in (and/or beading) and flanging metal can bodies, such as the die necking and the free roll beading techniques.

As stated hereinbefore, one feature provided by the present invention is a necked-in and/or beaded feature. Whether this structural feature is to be characterized as a beaded or a necked-in feature depends upon the proximity of the feature to either end of the can body. When the feature is provided adjacent either the top or bottom end of the can body, it is termed a necked-in feature; otherwise, when located remote from either end of the can body, it is termed a beaded feature. For purposes of clarity, hereinafter, this feature will be referred to as a necked-in feature with the understanding that what is meant is the necked-in and/or beaded feature.

Poisson's Ratio is defined as the ratio of the transverse contraction per unit dimension of a bar of uni-

form cross-section to its elongation per unit length, when subjected to a (stretching) tensile stress. A description of the Poisson Effect is as follows: If a rod of material is stretched with sufficient force (tensile stress), it can be elongated. The unit elongation (elongation per unit of length) is the strain. At the same time, the elongation of the rod induces or causes the lateral dimensions of the rod to contract. The ratio of unit lateral contraction to unit longitudinal elongation, which is constant for a given material within its elastic limit, is known as Poisson's Ratio.

By the method and apparatus of the present invention, the can body is secured or restrained at either side of the portion of the can body desired to be reduced in circumference so that, as the material between the two restraints is reduced in circumference, it is simultaneously stretched in the longitudinal direction. By this manner, a preferential biaxial stress condition is established within the material of said can body portion which allows the necking-in and flanging of a can body having a substantially lower sidewall thickness than that of a can body which is necked-in and flanged by conventional techniques such as die necking and free roll beading where no attempt is made to establish such a preferential biaxial stress condition.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for necking-in and flanging a metal can body portion by, first, restraining the can body from undergoing movement on both sides of the body portion and, concurrently, rotating the can body about its own longitudinal axis. Thereafter, a rolling element reduces the circumference of the can body portion between the two restraints. After an initial reduction in the body circumference, the restraint on the side of the body portion on which it is desired to produce a flange is relaxed to allow that side freedom to move during the subsequent further reduction of the circumference of the body portion. Then, the body portion circumference is further reduced and, simultaneously, the free, unrestrained side of the body portion is drawn between predetermined radiused surfaces causing the marginal edge of this side of the body portion to swing outwardly beyond the original circumference of the can body to form a flange feature on the end of the can body.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the Poisson Effect on a single element of material;

FIGS. 2 through 4 illustrate the theoretical mechanics operating on a single element of material taken from the portion of the can body to be reduced in circumference by the present invention;

FIGS. 5 through 7 illustrate the theoretical mechanics operating on a single element of material taken from the portion of the can body to be reduced in circumference by the known die necking process;

FIG. 8 is a side elevational view partially in section of the necking-in and flanging apparatus showing the initial position of the component parts of the apparatus relative to the metal can body;

FIG. 9 is an end elevational view of the apparatus shown in FIG. 8;

FIG. 10 is a side elevational view partially in section of the necking-in and flanging apparatus showing clamping rolls restraining both sides of the can body

portion to be necked-in immediately prior to the initial necking-in operation;

FIG. 11 is an end elevational view of the apparatus shown in FIG. 10;

FIG. 12 is an enlarged fragmentary side elevational view partially in section showing the position of the component parts of the apparatus relative to the metal can body after the necking-in and flanging roll has partially reduced the circumference of the can body portion;

FIG. 13 is an enlarged fragmentary side elevational view partially in section showing the position of the component parts of the apparatus relative to the metal can body after the necking-in and flanging roll has further reduced the circumference of the can body portion;

FIG. 14 is a side elevational view partially in section of the necking-in and flanging apparatus showing the position of the component parts of the apparatus relative to the finished necked-in and flanged metal can body;

FIG. 15 is an enlarged schematic view of a circumferential undercut section of a mandrel and a beading roll in relation to the portion of the can body to be necked-in and flanged by the present invention;

FIG. 16 is a graph illustrating actual test results obtained by using the preferred and exemplary embodiment of the present invention which will be described hereinafter;

FIG. 17 is a fragmentary side elevational view partially in section of the necking-in and flanging apparatus as similarly shown in FIG. 8 with modified components for clamping the open end of the metal can body; and

FIG. 18 is a fragmentary side elevational view partially in section of the necking-in and flanging apparatus as similarly shown in FIG. 10 with modified components for clamping the open end of the metal can body.

DETAILED DESCRIPTION OF THE INVENTION

The principle underlying the present invention, the Poisson Effect, is best illustrated by FIG. 1 which shows a single element of material subjected to an uniaxial, elongative strain, $Lx'-Lx/Lx$. When a given elongative stress, Sx , applied along a given axis of the element, imposes the elongative strain $Lx'-Lx/Lx$ on the element along the given axis, such as the X-axis, the element will exhibit a proportional, compressive strain along other axes. In particular, the material along an axis, such as the Y-axis, orthogonal to the primary or given axis will exhibit a compressive strain, $Ly'-Ly/Ly$, in a definite ratio, u , to the elongative strain $Lx'-Lx/Lx$, the ratio u being Poisson's Ratio. The ratio for steel is approximately 0.25 to 0.30. Therefore, $Ly'-Ly/Ly = u \cdot Lx'-Lx/Lx$.

In the present invention, the can body is restrained at both sides of a body portion to be reduced in circumference and as the material of this body portion between the two restraints is reduced in circumference by the application of a roll tool, against said body portion, which is directed radially inwardly toward, and perpendicular to, the longitudinal axis of the can body, the material is simultaneously stretched or elongated in its longitudinal direction, that is, in a direction parallel to the longitudinal axis of the can body. The condition thereby imposed on the material of this body portion, as the body portion undergoes this simultaneously oc-

curing circumferential compression and longitudinal elongation, is called a preferential biaxial stress condition.

FIG. 2 illustrates this preferential biaxial stress condition as imposed on a single element of material taken from the portion of the can body being reduced in circumference by the method and apparatus of the present invention. If this preferential biaxial stress condition is analyzed as a superposition of two uniaxial stress conditions, in other words, as a longitudinal, elongative stress S_L and a circumferential, compressive stress S_C , what is illustrated by FIGS. 3 and 4 occurs.

As shown in FIG. 3, the longitudinal, elongative stress S_L imposes a longitudinal, elongative strain L_1 and causes a circumferential, compressive strain C_1 in proportion thereto which reduces the circumference of the element (and also the can body portion) and results in no attendant stress condition change because of this circumferential, compressive strain C_1 . In other words, the result of this first uniaxial stress condition S_L is a reduced circumference of the can body portion with essentially the original stress conditions existing in the circumferential (transverse) direction. Now, superimposed upon this first uniaxial stress condition S_L is a second uniaxial stress condition S_C , as shown in FIG. 4, which is imposed on the element by the positive step of further reducing the can body circumference beyond the circumference established by the first uniaxial stress condition S_L . The circumferential, compressive stress S_C imposes a circumferential, compressive strain C_2 which further reduces the circumference of the element (and also the can body portion) and causes a longitudinal, elongative strain L_2 . The amount of circumferential, compressive strain C_2 that can be sustained without inducing instability, or buckling, in the can body portion is further enhanced by the reduced circumference of the body portion at which this further reduction occurs.

The concave, circumferential feature on the can body which results from the method and apparatus of the present invention exhibits relatively large longitudinal, elongative strain $L_1 + L_2$ parallel to the can body longitudinal axis and concurrently large circumferential, compressive strain $C_1 + C_2$. This combination, which allows and encourages metal deformation in a manner consistent with the physical requirements of the material, permits greater circumference reduction of thin-walled metal can bodies than any other known technique.

As stated before, in the conventional free roll beading technique, no attempt is made to establish a preferential biaxial stress condition since the material of the can body portion to be reduced circumferentially is not restrained longitudinally. Since this preferential biaxial stress condition is not established, circumferential reductions are limited by the maximum circumferential, compressive stress S_C that the can body portion can sustain without producing instability, such as buckling of the can body circumference. This theoretically would limit the free roll beading approach to approximately seventy percent of the reduction accomplished by the present invention; however, in actual practice, on thin-walled can bodies, due to the reduced stability of the greater diameter at which the circumferential, compressive stress S_C is impressed, the free roll beading technique is limited to zero percent reduction, while the present invention permits circumferential reduc-

tions of about 7.5 to 8.0 percent on can bodies with diameter to sidewall thickness ratios of approximately 575 to 1.

In the conventional die necking-in process, the resulting stress condition in the necked-in portion of the can body is exactly the opposite of the desired preferential biaxial stress condition achieved by the method and apparatus of the present invention. Considering an element of material taken from the necked-in portion of a can body, as shown in FIG. 5, it can be seen that the element is biaxially stressed with longitudinal, compressive stress S_L and circumferential, compressive stress S_C . If this biaxial stress condition is analyzed as the superposition of two uniaxial stress conditions, in other words, as a longitudinal, compressive stress S_L and a circumferential, compressive stress S_C , what is illustrated by FIGS. 6 and 7 occurs.

As shown in FIG. 6, the longitudinal, compressive stress S_L imposes a longitudinal, compressive strain L_1 and causes a circumferential, elongative strain C_1 in proportion thereto which enlarges the circumference of the element (and also the can body portion). Now, superimposed upon this first uniaxial stress condition S_L is a second uniaxial stress condition S_C , as shown in FIG. 7, wherein the circumferential, compressive stress S_C imposes a circumferential, compressive strain C_2 and causes a longitudinal, elongative strain L_2 in proportion thereto which reduces the circumference of the element (and also the can body portion). The result of superimposing one of these two uniaxial stress conditions upon the other is that while the circumferential, compressive stress S_C acts to reduce the circumference by the imposed circumferential, compressive strain C_2 , the longitudinal, compressive stress S_L acts to enlarge the circumference by causing the circumferential, elongative strain C_1 . This biaxial stress condition produces compressive instability of the circumference of the can body portion at much lower diameter to sidewall thickness ratios than either the free roll beading technique or the Poisson Effect technique of the present invention, and is, therefore, not a satisfactory technique either.

As a preferred and exemplary embodiment of the instant invention, FIGS. 8 through 14 disclose the method and apparatus for reforming the initially straight marginal end portion of a cylindrical can body, generally designated B, shown in FIG. 8, to the structure shown in FIG. 14, wherein the marginal end portion is provided now with an outwardly extending flange feature F and inwardly circumferentially grooved or necked-in feature N. After the body B has been thus necked-in and flanged, its open end, or ends, may be closed by means of an end closure, or closures, (not shown) which are sealed onto the flanged body by means of a conventional interfolded double seam (not shown). The application of an end closure to the body B is not a part of the instant invention.

The can body B as illustrated is preferably of the seamless type, having only one open end, formed, for example, by an impact extrusion or in a drawing and ironing process, wherein the material of the can body B is a thin metal, such as aluminum, tin plate, or tin-free steel. However, the can body B may be of the type which is formed from a flat, rectangular blank of thin metal, such as aluminum, tin plate, or tin-free steel, which is rolled into cylindrical form and has its longitudinal edges overlapped and secured together in a side

seam, which may be of any conventional type, such as soldered, welded or adhesively bonded. Such bodies are conventionally formed with two open ends.

In accordance with the method of the instant invention, initially, as the can body B is rotated about its own axis, both side portions D, E of a can body portion, generally designated P which is to be reduced in circumference, are restrained from undergoing longitudinal movement. With both side portions D, E of the body portion P so restrained, the body portion P undergoes an initial predetermined reduction in its circumference by subjecting said body portion P to a preferential biaxial stress condition which is comprised by a simultaneously occurring circumferential compression and longitudinal elongation of the material of said body portion P. After this predetermined reduction of the circumference of the body portion P, the side E of the can body B on which the flange feature F is to be produced is freed from its restraint. As the body portion P is further reduced in circumference to complete formation of the necked-in feature N by subjecting said body portion P to a uniaxial stress condition, which is comprised by a further circumferential compression of the material of said body portion P, the free, unrestrained side E of the body portion P is drawn radially inwardly toward, and perpendicular to, the longitudinal axis of the can body B, which causes the marginal edge M of that side E of the body portion P to pivot and swing outwardly beyond the original circumference of the can body B to produce a flange feature F on the end of the can body B.

In accordance with the apparatus of the instant invention, initially, as illustrated in FIG. 8, the metal can body B is mounted on a mandrel 10 having a circumferential undercut section, generally designated 12, such that the can body portion P which is to be reduced in circumference is aligned contiguous with the undercut section 12. The diameter of the mandrel 10 may be undersized relative to the diameter of the can body B in order that the finished necked-in and flanged can body B may be readily removed from the mandrel 10. Thereby, the longitudinal axis of the can body B is offset from the axis of the mandrel 10.

A clamping roll 14 is rotatably mounted on a shaft 16, the longitudinal axis of which is aligned parallel to the axis of the mandrel 10. The shaft 16 is journaled to a support arm 18 which arm 18 aligns the clamping roll 14 with the one side D of the can body portion P and is movable along a path perpendicular to the axis of the mandrel 10, between the positions shown in FIGS. 8 and 10, to bring the clamping roll 14 into pressurized contact with the one side D of the body portion P. When the clamping roll 14 is in contact with the one side D of the body portion P, as shown in FIGS. 10, 12, 13, and 18, the clamping roll 14 is rotated or driven by the mandrel 10 through the one side D. Although the clamping roll 14 is so driven by the mandrel 10, and, further, even though it must be capable of yielding slightly during its rotation, if the can body B is of the type having a longitudinal side seam of several sidewall metal thicknesses, the clamping roll 14 still applies sufficient pressure against the can body B to restrain the one side D from undergoing any movement relative to the mandrel 10.

The use of the clamping roll 14 is necessary for providing restraint of the one side D of the body portion P during the necking-in and flanging of the can body B

when the can body B is the type used in the formation of a three-piece can, such type body having both top and bottom open ends. However, when the can body B is the type used in the formation of a two-piece can, such type having a closed bottom end, the clamping roll 14 may be omitted since sufficient restraint of the one side D may be provided by positioning the closed bottom end (not shown) of the can body B against the end of the mandrel 10.

The mandrel 10 is fixed on a shaft 20 which is rotatably mounted in a frame 22 and rotatably driven by any suitable source of power (not shown).

A sleeve member 24 is coupled to the rotatable shaft 20 via an elastomer element 26 which is secured to both the sleeve member 24 and the shaft 20. Thereby, the sleeve member 24 rotates with the mandrel 10. The sleeve member 24 by being coupled to the shaft 20 through the elastomer element 26 is further capable of movement along a path perpendicular to the axis of shaft 20 between a guide ring 28 secured to the end of the mandrel 10 and a surface 30 of the frame 22, during which movement sections 32, 34 of the elastomer element 26 between the sleeve member 24 and the shaft 20 along said path of sleeve member movement will be respectively compressed and elongated.

The opposite side E of the can body portion P fits between an annular rim 36 of the sleeve member 24 and the mandrel 10. The inside diameter of the annular rim 36 is slightly greater than the outside diameter of the annular flange feature F formed on the finished necked-in and flanged can body B, as shown in FIG. 14, in order to accommodate and center the finished can body B for removal from the mandrel 10.

Another clamping roll 38 is rotatably mounted on a shaft 40, the longitudinal axis of which is aligned parallel to the axis of the mandrel 10. The shaft 40 extends through a slot 42 defined in the frame 22 and is journaled to a lever arm 44, which arm is pivotal about a shaft 46 fixed to the frame 22 to move the clamping roll 38 between the positions shown in FIGS. 8 and 10. When the lever arm 44 moves the clamping roll 38 into the position shown in FIG. 10, the clamping roll 38 makes pressurized contact with the sleeve member 24 and forces the sleeve member 24 to move downwardly relative to the shaft 20 such that the axis of the sleeve member 24 becomes offset below the axis of the mandrel 10 and shaft 20. The sleeve member 24 will move relative to the shaft 20 until the top interior surface 48 of the annular rim 36 makes pressurized contact with the opposite side E of the can body portion P. When the sleeve member 24 assumes this position, as shown in FIG. 10, section 32 of the elastomer element 26 becomes compressed and section 34 becomes elongated.

As the lever 44 is pivoted by any suitable means (not shown) to place the clamping roll 38 into the position shown in FIG. 10, the clamping roll 38 is rotated or driven by the shaft 20, and, further, even though it must be capable of yielding slightly during its rotation, if the can body B is of the type having a longitudinal side seam of several sidewall metal thicknesses, the clamping roll 38 still supplies sufficient pressure against the can body B through the sleeve member 24 to restrain the opposite side E from undergoing any movement relative to the mandrel 10 and shaft 20. The fact that the clamping roll 38 rotates against the sleeve member 24 eliminates cold working of the can body wall embodied by the opposite side E (which will be later formed into

a flange) which would occur if the clamping roll 38 rotated directly in contact against the opposite side E. Furthermore, the rotation of the clamping roll 38 against the sleeve member 24 increases the area of contact between the clamping roll 38 and the opposite side E of the can body portion P, in contrast to the situation where the clamping roll 38 itself contacts the can wall, thereby permitting control of the metal therein away from the line of tangency of the clamping roll 38 with the sleeve member 24.

A beading roll 50, aligned with the circumferential undercut section 12 of the mandrel 10 perpendicular to the axis of the mandrel 10 and positioned between the clamping rolls 14, 38, is rotatably mounted on a shaft 52 for rotational contact with the can body portion P and movable inwardly toward the longitudinal axis of the mandrel 10. Shaft 52 is journaled to a support arm 54 in which arm 54 is reciprocally moved by any suitable means (not shown). The mandrel 10 rotatably drives the roll 50 through the body portion P when the roll 50 is in contact with the can body B.

As shown in FIGS. 12 and 13, and in greater detail in FIG. 15, the periphery of the beading roll 50 is comprised by side surfaces 56 which are in planes perpendicular to the axis of the can body B and the mandrel 10, an arcuate end surface 58 having a predetermined radius R_1 , and arcuate corner surfaces 60 integrally merging the side surfaces 56 with the end surface 58 and each having a predetermined radius R_2 .

As shown in FIGS. 8, 10 and 12 through 14, and in greater detail in FIG. 15, the mandrel 10 is comprised by a head portion 62 and a body portion 64 with a segmented neck portion 66 therebetween. The cylindrical surface 68 of the segmented neck portion 66 defining the bottom of the undercut section 12 of the mandrel 10 has a diameter substantially less than the diameter of the cylindrical surfaces 70, 72 of the head and body portions 62, 64. The head portion 62 is further comprised, in part, by an annular surface 74, which integrally merges at one end with one end of the cylindrical surface 68 of the neck portion 66, and integrally merges at the other end with an arcuate corner surface 76 which integrally merges with the cylindrical surface 70. The annular surface 74 is in a plane perpendicular to the axes of the can body B and the mandrel 10. The arcuate corner surface 76 has a predetermined radius R_3 . The integrally merged annular surface 74 and arcuate corner surface 76 together define one side of the undercut section 12 of the mandrel 10. The body portion 64 is further comprised, in part, by an annular surface 78, which integrally merges at one end with the other end of the cylindrical surface 68 of the neck portion 66, and integrally merges at the other end with an arcuate corner 80 which integrally merges with the cylindrical surface 72. The annular surface 78 is in a plane parallel to the plane of annular surface 74 and perpendicular to the axes of the can body B and the mandrel 10. The arcuate corner surface 80 has a predetermined radius R_4 . The integrally merged annular surface 78 and arcuate corner surface 80 together define the other side of the undercut section 12 of the mandrel 10.

A removable cylindrical segment element 82, as shown in FIGS. 8, 10 and 12 through 15, forms part of the neck portion 66 of the mandrel 10. The head and body portions 62, 64 of the mandrel 10 may be adjustable in a direction toward and away from each other by

any suitable means (not shown) so that the segment element 82 may be replaced with another having a different thickness, if desired. In such manner, a predetermined distance T may be established between annular surfaces 74, 79 to thereby define a predetermined width of the undercut section 12 of the mandrel 10.

During the initial necking-in operation, when the beading roll 50 moves from the position shown in FIG. 10 to that shown in FIG. 12, the annular surfaces 74, 78 with integrally merged arcuate corner surfaces 76, 80 respectively of the head and body portions 62, 64 of the mandrel 10 and the side surfaces 56 and arcuate end surface 58 which are integrally merged with arcuate corner surfaces 60 of the beading roll 50 provide early control of the metal of can body portion P between the beading roll 50 and the undercut section 12 to prevent propagation of buckles in the necked-in feature N formed in the can body B. Furthermore, the predetermined radius R_2 of arcuate corner surfaces 60 of the beading roll 50 aids in the elongation of the metal of can body portion P throughout the operation of reducing the circumference of the body portion P.

Table I illustrates the comparative dimensions of the respective surfaces of the undercut section 12 of the mandrel 10 and the beading roll 50 for different sidewall thicknesses of seamless metal can bodies necked-in by the method and apparatus of the present invention.

TABLE I

Metal thickness	Width of side E	R_3	T	R_4	H	R_1	R_2
.006-.0062----	$\frac{3}{64}$ - $\frac{5}{64}$	.020	.315	.050	.100	.350	.050
.006-.0062----	$\frac{3}{64}$ - $\frac{5}{64}$	.030	.310	.050	.100	.350	.050
.0053-.0055----	$\frac{3}{64}$ - $\frac{5}{64}$	.020	.310	.050	.100	.350	.050
.0053-.0055----	$\frac{3}{64}$ - $\frac{5}{64}$	.020	.308	.050	.100	.350	.050
.0047-.0048----	$\frac{3}{64}$ - $\frac{5}{64}$	.020	.308	.050	.100	.350	.050

Additionally, the beading roll 50 may be 0.300 inches in width. As a general rule, the radii R_3 and R_4 of the arcuate corner surfaces 76, 80 vary as the metal thickness of the can body B varies, that is, the thinner the metal thickness, the smaller the radii of the corner surfaces 76, 80. Also, the clearance between the annular surfaces 74, 78 respectively of the head and body portions 62, 64 of the mandrel 10 and the side surfaces 56 of the beading roll 50 needs to be only slightly greater than the respective metal thickness of the can body B where the can body is the seamless type. Where the can body is the type having a longitudinal side seam, this clearance must be equal to about one and a half metal thicknesses to three metal thicknesses of the sidewall of the can body depending on the metal thickness of the side seam. Tests show that this clearance, when operating on both the seamless and side seam type of can bodies, may be significantly larger than the sidewall metal thickness, for example, two to three times larger, until the sidewall metal approaches, and drops below, 0.005 inch. While generally can bodies of the three-piece type, with longitudinal side seams as described hereinbefore, have sidewall thicknesses greater than 0.0055 to 0.006 inch, if such type bodies are constructed with sidewall thickness less than that, it may be necessary to modify the mandrel 10 to allow a yieldable expansion of the T distance of the undercut section 12 to accom-

modate the passage of the multiple metal thickness of the side seam through the clearance between the respective sides of the head and body portions 62, 64 and the beading roll 50.

In FIG. 12, the necking-in roll 50 has been moved toward the axis of the mandrel 10 into contact with the body portion P and has reached a predetermined depth just prior to the start of producing a flange feature F on the side E of the body wall portion P. After the necked-in feature N has been partially produced, as shown in FIG. 12, by the initial reduction of the circumference of the body portion P by the rotating roll 50, the restraint on side E imposed thereon by the clamping roll 38 through the sleeve member 24 is removed by pivoting the lever arm 44 to the left from the position shown in FIG. 11 to a position intermediate to the arm positions shown in FIGS. 11 and 9. Upon removing the force applied by the clamping roll 38 against the sleeve member 24, the sleeve member 24 assumes a position intermediate between the positions shown in FIGS. 8 and 10. Upon the continued movement of the rotatable beading roll 50 inwardly toward the axis of the mandrel 10 reducing the circumference of the body portion P still further, to the position as shown in FIG. 13, the now free, unrestrained side E of the body portion P draws over the arcuate corner surface 76 of the head portion 62 of the mandrel 10 and, simultaneously, the marginal edge M of side E pivots upwardly or swings outwardly beyond the original circumference of the can body B to produce the flange feature F.

After the flange feature F has been produced, the lever arm 44 is moved to its original position shown in FIG. 9 whereby the sleeve member 24 returns to its original position as shown in FIGS. 8 and 14. As shown in FIG. 14, the rim 36 now accommodates and retains the flange feature F of the can body B therein in contact with the interior surface 48 of the rim 36 to center the can body B relative to the mandrel 10 to facilitate easy removal of the can body B therefrom.

Test results illustrated graphically in FIG. 16 shown that for a given sidewall metal thickness of the can body B, there apparently exists an optimum depth to which the circumference of the can body portion P should be reduced during the initial necking-in operation, as shown in FIG. 12. The Z limit on the graph for each respective sidewall metal thickness tested represents the deepest plunge of the beading roll 50 before the clamping roll 38 was released and is essentially meaningless as a lower limit since the deeper the initial necking-in operation is performed, the more conical the flange feature F will be when it is produced during the final necking-in operation. The W limit on the graph for each respective sidewall metal thickness tested represents the shallowest plunge of the beading roll 50 before the clamping roll 38 was released and is very significant since the purpose of the present invention is to produce as flat a flange feature as possible subsequent to the initial necking-in operation, but, at the same time, as the flange is made more flat, control of the metal must be lost earlier in the forming of the final necked-in feature N and therefore wrinkling can result. Thus, the W limit is the maximum initial necking-in depth which will subsequently consistently produces wrinkles in the flange. Finally, the circled data point is the apparent optimum found by the tests and represents the best compromise between flatness of the subsequently formed flange and freedom of the subse-

quently formed flange from wrinkles. As can be readily seen from the graph there is a converging zone of operation apparently available for the initial necking-in operation as the sidewall metal thickness decreases. In another sense, the margin for error between the apparent optimum and a wrinkled flange decreases rapidly as the sidewall metal thickness decreases.

It should be noted that certain cooperative relationships and structural parts of the apparatus hereinbefore described could be modified without changing the underlying principles of the present invention. One such modification is shown in FIGS. 17 and 18 wherein a conical member 83 is slideably mounted on the shaft 20 and resiliently biased against a lower internal surface 84 of the sleeve member 24 by means of a spring 86 which is anchored by a cylindrical support plate 88 fixed to the shaft 20. The conical member 83 together with the spring 86 and support plate 88 may be substituted in place of the elastomer element 26 to perform the functions of said element 26. FIGS. 17 and 18 are identical to FIGS. 8 and 10 except for the above described modification. As another modification, the shaft 20 and the mandrel 10 associated therewith could be maintained stationary and the frame 22 rotated by any suitable source of power about the shaft 20. In such modified form, the operation of the clamping rolls 14, 38 and the beading roll 50 would remain unchanged except that in addition to the rotation of these respective parts about their own axes, they would also revolve about the axis of the shaft 22.

It is thought that the invention and many of its attendant advantages will be understood from the foregoing description and it will be apparent that various changes may be made in the form, construction and arrangement of the parts and that changes may be made in the steps of the method described and their order of accomplishment without departing from the spirit and scope of the invention or sacrificing all of its material advantages, the form hereinbefore described being merely a preferred or exemplary embodiment thereof.

We claim:

1. A method of forming a necked-in feature on a metal can body, comprising the steps of:
 - restraining the can body on both sides on a circumferential portion of said can body; and
 - reducing the circumference of said portion of said can body,
 - said restraining of said can body on both sides of said circumferential portion of said can body permitting longitudinal stretching of the material of said can body only in said circumferential portion.
2. A method of reducing the circumference of a circumferential portion of a metal can body, comprising the steps of:
 - restraining the can body on both sides of the circumferential portion of said can body; and
 - establishing a preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion,
 - said restraining of said can body on both sides of said circumferential portion of said can body permitting longitudinal stretching of the material of said can body only in said circumferential portion.
3. A method of reducing the circumference of a circumferential portion of a metal can body, comprising the steps of:

rotating the can body about its longitudinal axis; restraining the can body on both sides of the circumferential portion of said can body; and establishing a preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion,

said restraining of said can body on both sides of said circumferential portion of said can body permitting longitudinal stretching of the material of said can body only in said circumferential portion.

4. A method of reducing the circumference of a circumferential portion of a metal can body, comprising the steps of:

- restraining the can body on both sides of the circumferential portion of said can body;
- establishing a preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion;
- removing the restraint on one side of the circumferential portion of said can body; and
- establishing a uniaxial stress condition in the circumferential portion which effectuates further circumferential compression of said portion.

5. A method of reducing the circumference of a circumferential portion of a metal can body, comprising the steps of:

- rotating the can body about its longitudinal axis;
- restraining the can body on both sides of the circumferential portion of said can body;
- establishing a preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion;
- removing the restraint on one side of the circumferential portion of said can body; and
- establishing a uniaxial stress condition in the circumferential portion which effectuated further circumferential compression of said portion.

6. A method of reducing the circumference of a circumferential portion of a metal can body and producing a flange on one side of said portion, comprising the steps of:

- restraining the can body on both sides of the circumferential portion of said can body;
- establishing a preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion;
- removing the restraint on the side of the circumferential portion of said can body on which the flange is to be produced;
- establishing a uniaxial stress condition in the circumferential portion which effectuates further circumferential compression of said portion; and
- simultaneously drawing the free, unrestrained side of the circumferential portion of said can body so as to cause said side to pivot and swing outwardly to form a circumferential flange on said can body.

7. A method of reducing the circumference of a circumferential portion of a metal can body and producing a flange on one side of said portion, comprising the steps of:

- rotating the can body about its longitudinal axis;
- restraining the can body on both sides of the circumferential portion of said can body;

establishing a preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion;

removing the restraint on the side of the circumferential portion of said can body on which the flange is to be produced;

establishing a uniaxial stress condition in the circumferential portion which effectuates further circumferential compression of said portion; and

simultaneously drawing the free, unrestrained side of the circumferential portion of said can body so as to cause said side to pivot and swing outwardly to form a circumferential flange on said can body.

8. A method of reducing the circumference of a circumferential portion of a metal can body and producing a flange on one side of said portion, comprising the steps of:

rotating a mandrel having a circumferential undercut section to cause rotation of the can body about its longitudinal axis which is offset from the mandrel axis;

restraining the can body, from undergoing movement relative to the mandrel, on both sides of the circumferential portion of said can body by moving rotatable clamping rolls to respectively secure said both sides of said circumferential portion;

establishing a preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion by moving a rotatable beading roll, aligned with the circumferential undercut section of said mandrel, inwardly toward the axis of said mandrel against said portion;

relaxing the restraint on the side of the circumferential portion of said can body on which the flange is to be produced by removing the clamping roll which was securing that respective side of said portion;

establishing a uniaxial stress condition in the circumferential portion which effectuates further circumferential compression of said body portion by moving the rotatable beading further inwardly toward the axis of said mandrel against said portion; and

simultaneously drawing the free, unrestrained side of the circumferential portion of said can body between a side surface of said rotatable beading roll and a surface of said mandrel which defines one side of the circumferential undercut section of said mandrel so as to cause said side of the circumferential portion to pivot and swing outwardly to form a circumferential flange on said can body.

9. Apparatus for forming a necked-in feature on a metal can body, comprising:

means for restraining the can body on both sides of a circumferential portion of said can body; and

means for reducing the circumference of said portion of said can body,

so that said restraining means permits longitudinal stretching of the material of said can body only in said circumferential portion.

10. Apparatus for reducing the circumference of a circumferential portion of a metal can body, comprising:

means for restraining the can body on both sides of the circumferential portion of said can body; and

means for establishing a preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion,

so that said restraining means permits longitudinal stretching of the material of said can body only in said circumferential portion.

11. Apparatus for reducing the circumference of a circumferential portion of a metal can body, comprising:

means for rotating the can body about its longitudinal axis;

means for restraining the can body on both sides of the circumferential portion of said can body; and

means for establishing preferential biaxial stress condition in the circumferential portion which effectuates circumferential compression and longitudinal elongation of said portion,

so that said restraining means permits longitudinal stretching of the material of said can body only in said circumferential portion.

12. Apparatus for reducing the circumference of a circumferential portion of a metal can body, comprising:

means for restraining the can body on both sides of the circumferential portion of said can body;

means for removing the restraint on one side of the circumferential portion of said can body; and

means for establishing a preferential biaxial stress condition in the circumferential portion when both sides of said portion are restrained which effectuates circumferential compression and longitudinal elongation of said portion and for establishing a uniaxial stress condition in the circumferential portion when the restraint on the one side of said portion has been removed which effectuates further circumferential compression of said portion.

13. Apparatus for reducing the circumference of a circumferential portion of a metal can body, comprising:

means for rotating the can body about its longitudinal axis;

means for restraining the can body on both sides of the circumferential portion of said can body;

means for removing the restraint on one side of the circumferential portion of said can body; and

means for establishing a preferential biaxial stress condition in the circumferential portion when both sides of said portion are restrained which effectuates circumferential compression and longitudinal elongation of said portion and for establishing a uniaxial stress condition in the circumferential portion when the restraint on the one side of said portion has been removed which effectuates further circumferential compression of said portion.

14. Apparatus for reducing the circumference of a circumferential portion of a metal can body and producing a flange on one side of said portion, comprising:

means for restraining the can body on both sides of the circumferential portion of said can body;

means for removing the restraint on the side of the circumferential portion of said can body on which the flange is to be produced;

means for establishing a preferential biaxial stress condition in the circumferential portion when both sides of said portion are restrained which effectuates circumferential compression and longitudinal

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elongation of said portion and for establishing a uniaxial stress condition in the circumferential portion when the restraint on said side of said portion has been removed which effectuates further circumferential compression of said portion; and means for drawing the free, unrestrained side of the circumferential portion of said can body, simultaneously as said establishing means effectuates further circumferential compression of said portion, so as to cause said side to pivot and swing outwardly to form a circumferential flange on said can body.

15. Apparatus for reducing the circumference of a circumferential portion of a metal can body and producing a flange on one side of said portion, comprising: means for rotating the can body about its longitudinal axis; means for restraining the can body on both sides of the circumferential portion of said can body; means for removing the restraint on the side of the circumferential portion of said can body on which the flange is to be produced; means for establishing a preferential biaxial stress condition in the circumferential portion when both sides of said portion are restrained which effectuates circumferential compression and longitudinal elongation of said portion and for establishing a uniaxial stress condition in the circumferential portion when the restraint on said side of said portion has been removed which effectuates further circumferential compression of said portion; and means for drawing the free, unrestrained side of the circumferential portion of said can body, simultaneously as said establishing means effectuates further circumferential compression of said portion, so as to cause said side to pivot and swing outwardly to form a circumferential flange on said can body.

16. Apparatus for reducing the circumference of a

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circumferential portion of a metal can body and producing a flange on one side of said portion, comprising: a rotating mandrel, having a circumferential undercut section, for supporting the can body and causing rotation of said can body about its longitudinal axis which is offset from the mandrel axis; rotatable clamping means for restraining the can body on both sides of the circumferential portion of said can body to prevent said can body from undergoing movement relative to said mandrel; actuating means for removing the restraint on the side of the circumferential portion of said can body on which the flange is to be produced which was applied thereto by said rotatable clamping means; a rotatable beading roll, aligned with the circumferential undercut section of said mandrel, movable along a path perpendicular to the axis of said mandrel and against said portion for establishing preferential preferential biaxial stress condition in the circumferential portion when both sides of said portion are restrained which effectuates circumferential compression and longitudinal elongation of said portion and for establishing a uniaxial stress condition in the circumferential portion when the restraint on said side of said portion has been removed which effectuates further circumferential compression of said portion; and said rotatable beading roll having a side surface facing a surface on said mandrel which defines one side of the circumferential undercut section of said mandrel, said respective surfaces providing a channel through which to draw the free, unrestrained side of the circumferential portion of said can body, simultaneously as said beading roll effectuates further circumferential compression of said portion, so as to cause said side to pivot and swing outwardly to form a circumferential flange on said can body.

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