

Sept. 8, 1964

R. J. O'BRIEN ET AL
WRINKLE-FREE METAL SHELLS AND THE PRODUCTION
THEREOF FROM FLAT METAL SHEETS

3,147,724

Filed Dec. 15, 1959

4 Sheets-Sheet 1

Fig. 1.

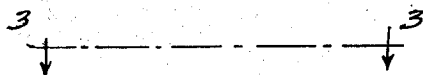
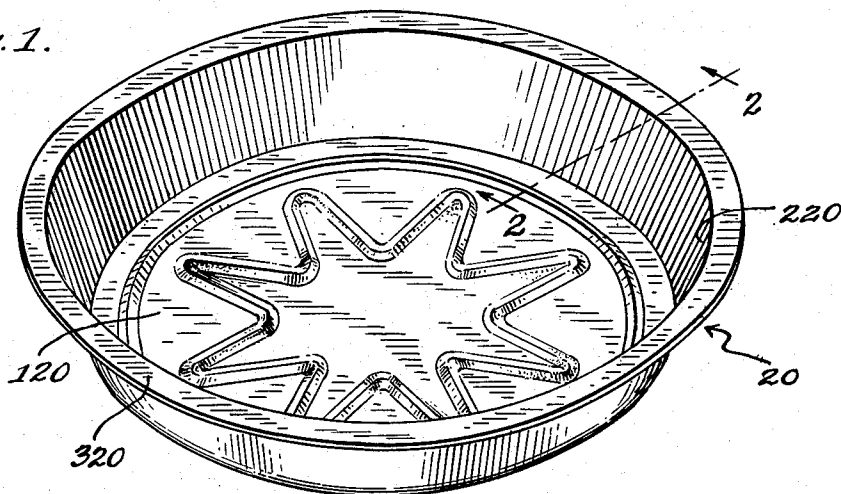
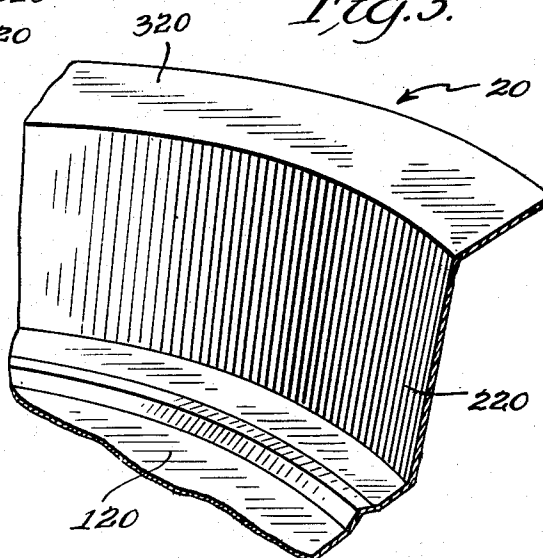


Fig. 2.

Fig. 3.



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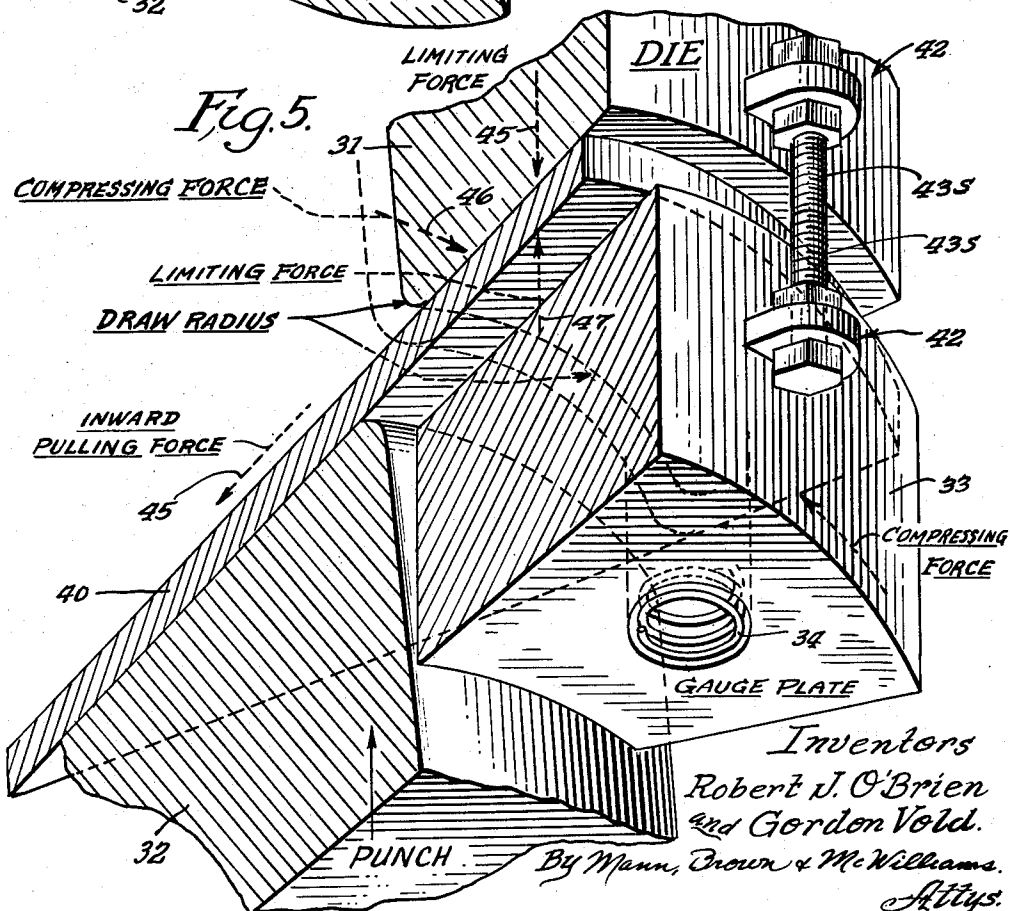
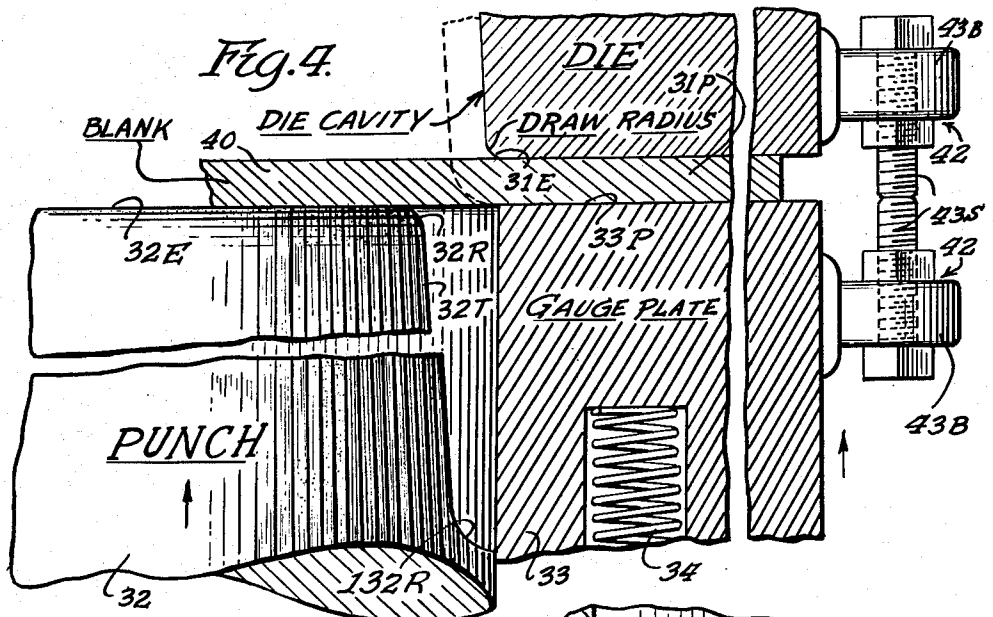
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Fig. 6A.

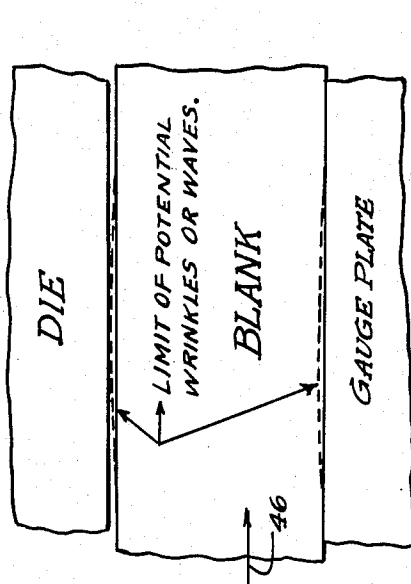


Fig. 7A.

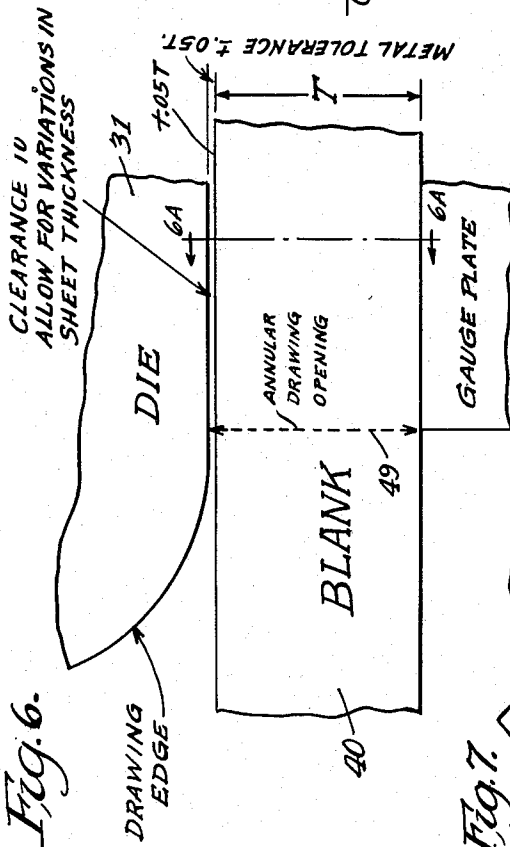
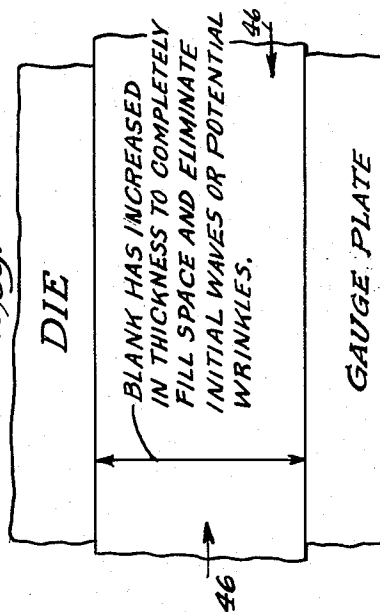
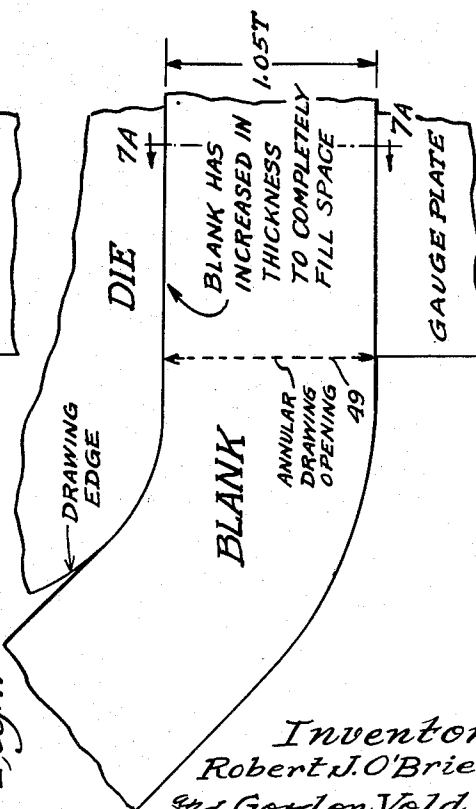


Fig. 7.



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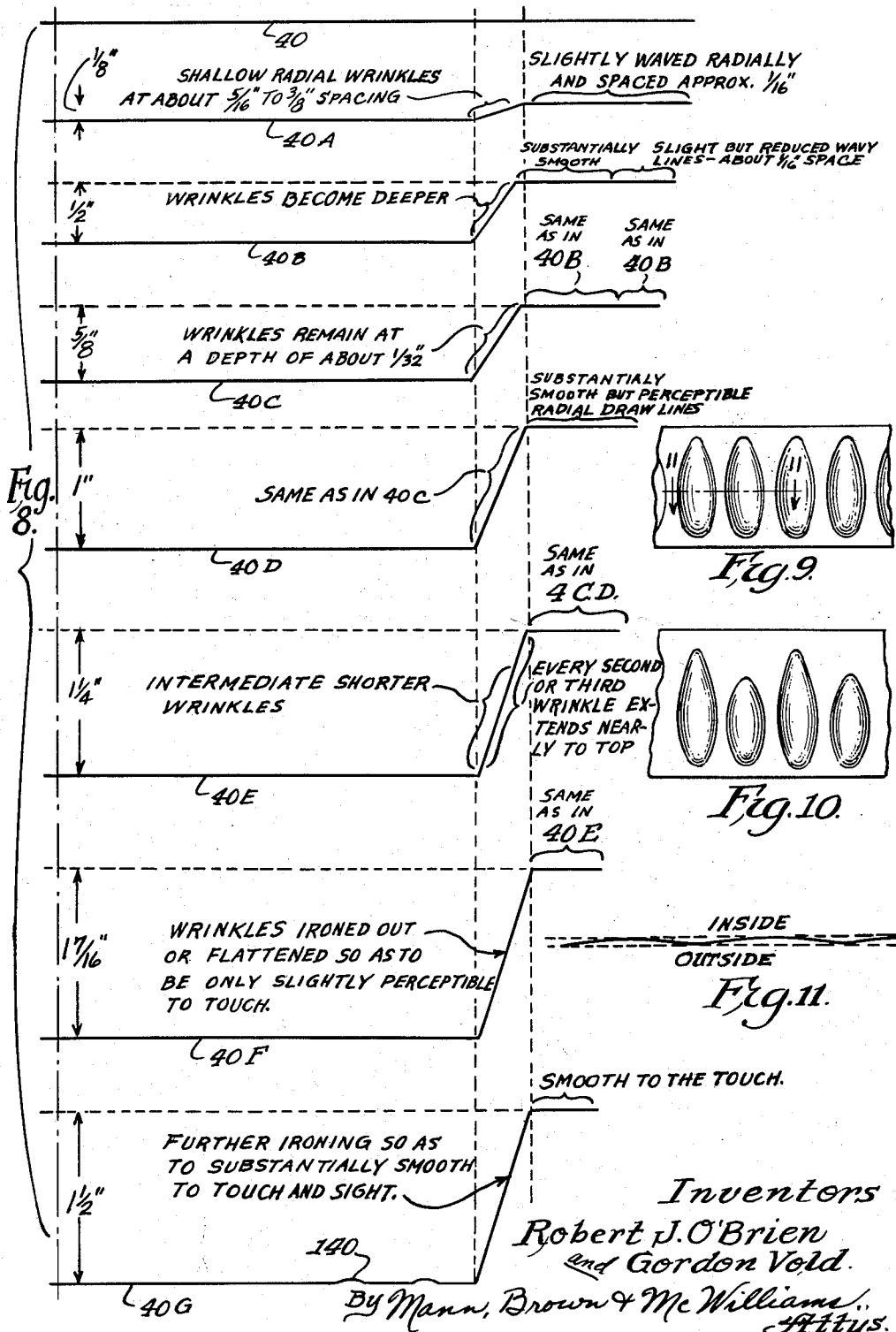
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WRINKLE-FREE METAL SHELLS AND THE PRODUCTION THEREOF FROM FLAT METAL SHEETS

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3 Claims. (Cl. 113-51)

This invention relates to thin walled metal shells and particularly to wrinkle-free shells of this character and to the production thereof from thin metal sheets.

Thin walled metal shells are customarily formed by drawing processes from flat sheet metal blanks, and in the drawing process the edges of the blank are clamped between a die face and a yielding pressed blank holder so that as the central portions of the blank are forced into the die cavity by a punch, the metal of the blank is drawn or stretched so there is a marked thinning of the metal as the drawing operation proceeds. The border portion of the blank that has been clamped during such a conventional drawing operation becomes a border flange about the upper edge of the side walls of the completed shell, and as a final operation the flange is trimmed.

It has long been recognized that drawing processes have an inherent tendency not only to objectionably stretch and thin the sheet but also to produce wrinkles in the sides and flanges of the drawn shells, and while the art of producing drawn metal shells has been widely used and highly developed, the problem of eliminating wrinkles in the sides and flanges of the finished shell has never been satisfactorily solved in respect to many forms of shells and in respect to many kinds and thicknesses of metal.

It is, therefore, the primary object of this invention to provide a new and improved method of producing thin walled metal shells from flat sheet metal blanks, and another and related object is to provide such a novel process which avoids stretching and thinning of the metal of the blank, and through the use of which wrinkle-free shells or containers may be produced from thin metal sheets such as aluminum foil.

According to conventional drawing practice the sheet metal blank is put in position across a die cavity and is held in place against the die face by a yielding blank holder or pressure pad through which a punch is moved to engage the sheet and force the same into the die cavity, and as the punch enters the die, the border portion of the blank, that is held by yielding clamping pressure between the die face and the pressure pad, is drawn inwardly toward the drawing edge, as for example in the formation of a circular shell, or at the rounded corners of a rectangular shell, there must be a progressive reduction in the circumferential dimension of the diverging portions of the flange as they approach the drawing edge. In other words, each segmental portion of the border must become narrower as it approaches or is drawn inwardly toward the drawing edge, and this produces what may be termed circumferentially acting compressive forces in such border which tend to produce radially extending waves or wrinkles in the border portion of the blank.

The tendency that thus exists in conventional drawing operations to produce radially extending waves in the border portion of the blank varies of course with the properties of the metal and with the thickness of the blank, but in any case, such radial waves tend to increase in depth or amplitude as the operation progresses. Thus, where the depth of the waves progresses to a point such that the metal is stressed beyond its elastic limit, wrinkles

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are produced in the flange which must thereafter be ironed out by the cooperation of the punch with the wall of the die cavity. The problem of flange wrinkles is encountered in the drawing of all different types of shells, but with respect to shells having tapered sides, further difficulties are met because of the intermediate uncontrolled area presented in the blank between the drawing edge of the die and the working edge of the usual forms of punch. The present invention is concerned with the elimination of both flange wrinkles and side wall wrinkles or puckers in shells of the kind usually produced by drawing, so as to enable smooth surfaces to be attained on both the side walls and the flanges of thin walled shells formed from flat sheet metal blanks.

There are, of course, instances in conventional sheet metal drawing where the tendency to produce waves or wrinkles in the flange is not particularly objectionable because of the nature of the metal or the relatively great thickness of the blank, but with the softer or more ductile metals, and with relatively thin blanks, this tendency toward the formation of waves or wrinkles in the flange has provided one of the most difficult problems involved in the production of such sheet metal shells. The usual and generally accepted solution for correction of this problem is to add to or increase the pressure applied by the pressure pad to the border or flange portion of the blank. This use of additional pressure on the border of the blank does not, however, provide a universal answer to the problem that is presented because, as the thickness of the blank is decreased, the amount of pressure that may be applied to the border tends to reach a point where the border is held or retarded to such an extent that excessive stresses are produced in the metal and the blank is excessively thinned in the side wall or flange and tends to tear in the side wall portion or at the end edge of the punch where the maximum force is applied to the metal. This problem is even more serious where the shell is to be drawn from aluminum because the coefficient of friction of aluminum is much higher than that of the other metals that are conventionally used in drawing operations, and the ductility or plasticity of the metal is substantially greater. Thus, with respect to the drawing of shells from aluminum the usual expedient of increasing the pressure applied to the flange cannot be followed, and the pressure must in fact be reduced to such a point that in the production of tapered wall pans and the like from aluminum foil, the resulting shell does not constitute a drawn shell, but is formed with wrinkles and folds in both the flange and the side.

The shells that are thus formed from extremely thin aluminum sheets within the thickness range of .001 to .005 inch, which is normally classified as foil, are in fact shaped by a process that involves intentional wrinkling and folding of the excess metal that is pulled inwardly from the border portion of the blank, and while such shells or containers are satisfactory for many purposes, they involve the use of metal in a wasteful manner and result in containers that cannot be properly cleaned in the removal of the contents thereof. Moreover, the wrinkles in the flanges render it extremely difficult to seal a cover onto the container.

In view of the foregoing it is a further object of the present invention to enable containers to be made from metal foil with smooth surfaced side walls, and with border flanges that have smooth surfaces to facilitate sealing of the container. A more specific object of the present invention is to enable foil containers to be made with smooth surfaced tapered side walls and smooth surfaced flanges, and a related object is to enable this to be accomplished without tearing or otherwise rupturing the metal foil from which the containers are made.

While the problem of tearing or rupturing the metal

blank in conventional drawing operations has been discussed primarily as applied to extremely thin metal foil blanks, this same problem exists in thicker blanks of other metals including steel, and to guard against such tearing of the blanks, broad general rules are usually prescribed based upon or measured by the maximum percentage in diameter reduction that can be obtained in a blank in a single draw without danger of tearing the blank. Thus where relatively deep drawn shells are made it is usually necessary to resort to a series of drawing operation. The present invention, however, is applicable also to thicker metal blanks and by the controlled metal working operation of the present invention, it has been found possible to radically increase the percentage of blank reduction over and above the normal rules or standards that have been established for conventional drawing operations.

The foregoing objectives of the present invention are accomplished through a controlled working of the sheet metal blank in which all of the forces that are to be effective in producing metal flow are applied to the blank by the forming punch and all resistive forces that are effective on the border of the blank and which oppose change of form of the blank are produced as resultants of the forces initially applied to the blank by the punch. Hence, the resulting stresses that tend to produce metal flow in the blank are equalized and are limited to magnitudes just sufficient to flow the metal into its new form.

Other and further objects of the present invention will be apparent from the following description and claims, and are illustrated in the accompanying drawings, which, by way of illustration, show a preferred embodiment of the present invention and the principles thereof, and what is now considered to be the best mode in which to apply these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the invention.

In the drawings:

FIG. 1 is a perspective view of a smooth wall, smooth flanged metal foil container that may be produced under the present invention;

FIG. 2 is a sectional view taken along the line 2—2 of FIG. 1;

FIG. 3 is a fragmentary plan view taken from the line 3—3 of FIG. 2;

FIG. 4 is a fragmentary and somewhat schematic vertical sectional view taken through a die set and showing the blank at a greatly increased scale;

FIG. 5 is a bottom perspective that fragmentally shows the relationship of the parts of the die set to the blank and to each other;

FIG. 6 is a further enlarged portion of FIG. 4 showing the relationship of the die and the cooperating gauge plate to each other and to the blank;

FIG. 6A is a vertical sectional view taken substantially along the lines 6A—6A of FIG. 6;

FIG. 7 is a view similar to FIG. 6 showing the relationship of the blank to the die and gauge plate after the operation has caused thickening in the flange of the blank;

FIG. 7A is a sectional view taken substantially along the line 7A—7A of FIG. 7;

FIG. 8 is a diagrammatic view illustrating successive changes in the form of the blank as the operation progresses;

FIG. 9 is an outside elevational view of the side of the blank at the depth and in the form that has been assumed in the opposite portion of FIG. 8;

FIG. 10 is an outside elevational view of the side of the blank in the form that it has assumed in the portion of FIG. 8 that is opposite FIG. 10; and

FIG. 11 is a greatly enlarged cross sectional view taken along the line 11—11 of FIG. 9.

For purposes of disclosure the invention is herein illustrated in FIGS. 1 to 11, as applied to the production of a circular tapered wall container 20 that is made from aluminum foil as will be described in detail hereinafter. The container 20 is pan-like in form and has a bottom wall 120, a tapered side wall 220 and a horizontal flange 320 at the upper edge of the side wall 220. Under the present invention, the container 20 is made with smooth surfaces on the side wall 220 and on the flange 320 so that the appearance of the container is improved as compared to prior foil containers of this form and so that smooth surfaces on the flange 320 lend themselves to the application of a sealed covered member as is desirable in the production of hermetically sealed food packages or containers.

The smooth walled, smooth flanged tapered container 20 is produced from metal foil through the use of a die set 30 of the inverted type having a die 31 disposed opposite a cooperating punch 32, and about the punch 32 a gauge plate 33 is provided which has a gauge race or surface 33P disposed in opposed relation to the die face 31P of the die 31. The die 31 has a tapered die cavity 31C which is connected with the die face by a rounded edge 31E, and the punch 32 has tapered side surfaces 32T that merge with the end surface 32E of the punch through a rounded corner 32R. The tapered surface 32T, at its larger end, has a rounded surface 132R that is adapted for cooperation with the radius 31E as the punch reaches the end of its stroke.

The gauge plate 33 is urged endwise on and with respect to the punch 32 by resilient means of any conventional kind such as expansive springs 34 so that as the punch approaches the die cavity, the punch and the gauge plate 33 will travel together.

The Novel Mode of Operation

The die set 30 as thus described necessarily resembles a conventional drawing die set, but in such a conventional drawing die set, the plate 33 would constitute a pressure pad and would engage the border portion of a flat metal blank 40 so as to press and clamp the same against the die face 31P. Under the present invention, however, it should be noted that the function and operation of the gauge plate 33 with relation to the die 31 distinguishes in a major and important sense from prior practice so that a novel controlled metal flow is attained that prevents wrinkle formation in the shell as it is produced.

Thus, under the present invention, the approaching movement of the gauge plate 33 with respect to the die face 31 is limited by stop means so that the relative approaching movement of the gauge plate 33 is stopped in a final working position such that no appreciable clamping force or pressure is exerted initially upon the interposed border portion of the blank 40. Thus, as shown herein, the stop means that are thus effective to limit the approaching movement of the gauge plate 33 take the form of adjustable shims 42. These shims comprise brackets 43B located on the die and the gauge plate 33 with aligned vertical stop screws 43S extended there-through, and the stop screws 43S of each pair of shims are arranged so that the ends of the stop screws 43S will engage and thus terminate the relative approaching movement of the gauge plate 33. Several sets of shims 42 are of course provided at spaced points about the outer edge of the die set.

Under the present invention the resilient means which apply the pressure to the gauge plate 33 serve only to hold the gauge plate 33 in a stationary relation in its final working position as determined by stop means 42, and the resilient pressure applied to the gauge plate 33 is selected so as to apply an excess amount of pressure to hold the

gauge plate 33 in such position. The excess of pressure is such that forces created by metal flow or deformation of the blank between the die 31 and the gauge plate 33 in the course of the operation cannot cause separating movement of the gauge plate and the die. Thus the gauge plate 33 and the die face 31P do not function as a clamping or retarding means as in conventional metal drawing operations, but in contrast serve as a confining means or chamber of fixed dimensions within which the border portion of the blank must undergo such metal flow or changes of form as may be necessary in response to the inward tension resulting from the action of the punch.

Through the use of means which thus limit the approaching movement of the gauge plate and which hold the gauge plate stationary in the working position determined by the stop means, the present invention causes an entirely new cooperation of the parts of the die set with each other and with metal blank, and the net result of this new cooperative action in the illustrated example is the production of thin walled shells or containers 20 that have smooth tapered side walls and smooth surfaced flanges. The theory and manner of cooperation of the parts of the die set 30 is illustrated schematically in FIGS. 4 to 11 of the drawings.

Thus, in FIGS. 4 and 5, the thin metal foil blank 40 is shown at a highly exaggerated scale in position with its border portions located between the die face 31P and the gauge plate 33 and with the leading end of the punch 32 in engagement with the adjacent face of the flat blank 40. The precise relationship of the die face 31P and the gauge face 33P to the blank 40 cannot be clearly shown in FIGS. 4 and 5, but in FIGS. 6 and 7, this relationship has been shown at a further enlarged scale to illustrate the manner in which the control of the metal stress and flow is attained under the present invention.

It has been pointed out hereinbefore that the approaching movement of the gauge plate 33 is so limited by the stop means that in its final working position, the gauge plate 33 exerts no appreciable force upon the border portion of the flat blank, and it should be observed that the space between the gauge plate 33 and the die face 31P in its final relationship should approach as closely as possible to the actual thickness of the metal blank 40 without applying initial pressure to the flat blank. Thus, in a theoretical sense, the final spacing of the gauge plate 33 from the die face 31P might correspond precisely with the thickness of the metal blank, but as a practical matter, the thickness of the metal sheet material that is used in the production of such shells varies within certain relatively small tolerances and provision must be made to take care of such variations. Thus, as to metal foil, it is recognized that a tolerance of about five percent must be expected for any particular rolled sheet, and in order to take care of plus tolerances, the stops or shims 42 are set so that the final spacing of the gauge plate 33 from the die face 31P is about five percent greater than the specified or nominal thickness of the sheet metal that is to be used.

The action of the apparatus under such a setting of the shims 42 will be discussed hereinafter, and to facilitate such discussion, attention is directed to the schematic illustration of FIG. 5. Thus, in FIG. 5, a fragmentary bottom perspective view has been shown wherein a pie-shaped or segmental portion of the flat blank 40 is disposed between the die 31 and the gauge plate 33, and in FIG. 5 the punch 32 is shown at its initial point of engagement with the blank 40 opposite the die cavity. It will be apparent that when the punch 32 advances toward and into the die cavity from the position shown in FIG. 5, the material of the blank 40 that is located radially inwardly from the radius 31E will be moved into the die cavity, and the portion of the blank 40 that is located between the radius 31E is drawn at an angle into

the die cavity so as to have a radially inward force 45 applied thereto as indicated in FIG. 5. This radially inward force 45 will of course tend to pull the flange or border portion of the blank in a radially inward direction, and in order for the flange portion to move radially inward it is necessary that the flange portion be compressed in a circumferential direction. This circumferential compression may be said to develop circumferentially acting forces 46 in the flange areas as indicated in FIG. 5. As a result of such circumferential forces, there is an initial tendency for the flange portion to form into radial waves to the extent that is permitted by the excess space between the die face 31P and the gauge plate 33, and the space between the gauge plate 33 and the die face thus acts to limit the depth or amplitude of any such radial waves that do form, and serves to limit the thickness to which the flange portion of the blank may expand or thicken by metal flow as a result of the circumferential forces 46. The restrictive forces that thus limit the maximum thickness of the border portion are indicated at 47 in FIG. 5, and to maintain the desired maximum spacing of the die face and the gauge plate such forces must exceed the separating forces created by the thickening of the border portions of the blank.

In FIGS. 6 and 6A, the blank 40 has been schematically illustrated at a greatly enlarged scale to show the final or fixed gauging position of the gauge plate 33 with relation to the die 31, and the illustration has been based on the assumption that the metal thickness that may be expected is to be within a tolerance of plus or minus five percent. Thus, when the gauge plate 33 and the die 31 have approached to the final working position or relation determined by the stop means, there is a clearance of about .05T with respect to one of the surfaces of the blank, the thickness of the blank 40 being taken as 1.00T. In the event that the sheet metal used for the blank 40 has been maintained at a smaller tolerance, the actual final spacing of the pressure pad from the die face may be correspondingly smaller.

Thus, when the circumferential forces 46 are developed in the flange portion of the blank as indicated in FIG. 6A, any radial waves 40W that may tend to form between the opposed faces of the die 31 and the gauge plate 33 have their amplitude or depth limited by the space between the blank and the opposed face of the die, and such maximum amplitude or form of such wave 40W for a blank having a thickness of 1.00T is indicated by a dotted line in FIG. 6A. It is important to note that any tendency toward waviness in the flange portion of the blank is thus limited to such an extent that the metal of the blank cannot be stressed beyond its elastic limit, even though such waves reach their maximum depth or amplitude as indicated in FIG. 6A, and hence, in the subsequent working of the metal of the blank, these waves may be eliminated by ironing or compression to such an extent that they are not appreciably perceptible to the touch or sight.

The slightly waved condition that is represented in FIG. 6A by the dotted line showing of a potential radial wave in the border portion of the blank, is, however, corrected as the operation progresses, and this will become apparent by a comparison of FIGS. 6A and 7A. Thus, as the inward pulling forces 45 cause continued inward radial displacement of the border portion of the blank, the circumferential forces 46 have the effect of causing the border portion of the blank to thicken by reason of metal flow so that before the operation has progressed to any marked extent the space between the gauge plate 33 and the die face 31P becomes completely filled by reason of such thickening of the blank. This thickening apparently takes place initially at a radial point relatively close to the drawing radius 31E of the die, and progresses outwardly as the operation is continued so that throughout a substantial portion of the operation, the vertical

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space between the die 31 and the gauge plate 33 is completely filled by the metal of the blank.

The metal that is confined in the fixed and accurately defined space between the die 31 and the gauge plate 33 is thus pulled inwardly through what amounts to an annular drawing opening 49, FIGS. 6 and 7, and the slight waves that may have been initially formed in the border portions of the blank are removed or eliminated by thickening of the metal which presses opposite faces of the blank against the surfaces 31P and 33P with such force that smooth surfaces are formed on the metal of this border portion. The pressing of the faces of the blank against the die face 31 and the gauge plate 33 serves of course to produce a frictional retarding action, but since such forces are created by metal flow in the blank itself, such retarding forces do not cause appreciable stretching or thinning of the metal in the walls of the shell that is being formed. Near the radius 31E, the metal is smoothed to such a degree that the originally formed waves 40W are substantially imperceptible to the sight and are not perceptible to touch. Further out on the flange portion, these original waves 40W are also eliminated but appear to result in what might be termed draw lines that are in some instances visually perceptible but are practically imperceptible to the touch.

Thus, when the metal of the blank moves inward over the radius 31E, it is substantially smooth surfaced and free of all wrinkles, but where a tapered wall container is being made, the uncontrolled annular area of the blank that is located between the radius 31E and the working edge 32R of the punch tends to assume a scalloped or puckered appearance as the drawing operation proceeds, but in this scalloped form, the scallops or puckers are relatively shallow and are of such a character that in the final portion of the punch stroke, the scallops or puckers may be entirely eliminated so that the inner and outer surfaces of the side wall 220 are substantially smooth to the touch and sight. In FIGS. 8 to 11 the progressive changes in the form of the blank have been illustrated and notations have been made upon various steps of FIG. 8 to illustrate the size, position and relationship of the waves in the formation of a shallow pan having a final bottom diameter of $7\frac{1}{2}$ inch, a depth of $1\frac{1}{2}$ inch and a side wall tape of substantially ten degrees, and the pan being formed from aluminum foil having a thickness of .004 inch.

Thus in FIG. 8, and at the top thereof, the blank 40 is illustrated in its flat or original form. Immediately beneath the blank 40, the form thereof is indicated at 40A where the punch has progressed into the die cavity to a depth of $\frac{1}{8}$ inch. As this takes place, substantially uniform radial waves or scallops are formed in the uncontrolled annular portion of the blank, and these scallops are relatively shallow and at a spacing of from $\frac{5}{16}$ inch to $\frac{3}{8}$ inch. In the border portion of the blank, the inward radial forces applied as at 46 in FIG. 5, have caused a slightly waved appearance to be assumed, these waves being in a radial relationship and being spaced at approximately $\frac{1}{16}$ inch. In FIG. 8, the next step shows the blank at 40B where the punch has progressed to a $\frac{1}{2}$ inch depth, and in this instance, the waves or scallops in the uncontrolled portion of the blank become somewhat deeper as indicated, and in the flange or border portion, the thickening of the metal has progressed to such an extent that the inner portion of the flange is substantially smooth while the waves in the outer portion thereof have been eliminated or flattened to some extent by thickening of that portion of the blank.

The blank is next shown in FIG. 8 at 40C in the form that it assumes when the punch has progressed to a depth of $\frac{5}{8}$ inch, and as indicated by the legends associated with the blank 40C the side wall waves and the surfaces of the flange remain substantially the same as hereinbefore described with respect to the blank 40B.

The blank is next shown in FIG. 8 as indicated at 40D where the punch has progressed to a 1 inch depth,

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and in this instance, the entire surface of the bordering flanges has become smooth although perceptible radial draw lines may be seen. In the side wall, the radial scallops or waves have assumed the form shown in FIGS. 9 and 11, FIG. 11 being a horizontal sectional view at a greatly enlarged scale. It might be noted that these waves or scallops have a depth of about $\frac{1}{32}$ inch, and their spacing is in most instances about $\frac{5}{16}$ inch so that the depth is not more than one-tenth of the width of the wave or scallop. This relationship is such that the metal is not stressed beyond the elastic limit, and hence in the subsequent operation of the apparatus, the scallops or waves in the side wall may for all practical purposes be eliminated by the ironing and compressive action between punch and the die cavity.

The blank is next shown in FIG. 8 at 40E in the form that it assumes when the punch has progressed to a depth of $1\frac{1}{4}$ inch. At this stage in the operation, the flange remains substantially smooth, while the waves or scallops in the side wall take a somewhat different form or relationship. Thus, by comparison of FIG. 10 with FIG. 9 it will be noted that certain of the scallops or waves in the side wall have remained at substantially the same form and size in which they appear in FIG. 9, but about every second or third one of the original scallops or waves has enlarged to a greater extent in an upward direction. At this point in the formation of the container, the side wall of the punch 32 is extremely close to the side wall scallops or waves, and as the entry of the punch progresses, the blank assumes the form shown at 40F in FIG. 8. This view shows the form where the punch has progressed to a depth of $1\frac{1}{16}$ inch, or in other words to a point where the punch is $\frac{1}{16}$ inch away from its final or home position. The flange portion of the blank, as shown at 49F, still remains in its smooth condition and the co-operation of the side of the punch with the side wall of the die cavity has substantially flattened or ironed out the scallops or waves that have been in FIG. 10. Then, as the punch moves to its final or home position, the side wall is further ironed so that it becomes substantially smooth to the touch and the sight and in this final movement, the bottom wall 120 of the shell may be embossed as at 140 to produce the final form of the container that has been indicated at 40G in FIG. 8.

The present invention has been described particularly as applied to the production of shells in the form of shallow pans with tapered sides from thin metal foil such as aluminum foil, but it has been found that the broad principles of the present invention have highly advantageous application to the production of cylindrical shells and to the production of shells from other metals and from thicker blanks. Thus as applied to the making of shells in cylindrical form from steel blanks the invention has resulted in the attainment of highly improved performance, particularly as to the percentage of diameter reduction that could be obtained. Thus where a $7\frac{1}{4}$ inch diameter blank was formed to a shell having $4\frac{1}{2}$ inch diameter in cylindrical form it was possible to obtain a diameter reduction of 36.2 percent without rupture of the blank. Using a $7\frac{3}{4}$ inch diameter blank and in making a shell with a diameter of $4\frac{1}{2}$ inch, it was possible to obtain a diameter reduction of 39.4 percent. In further work, with a blank having an 8 inch diameter was used in making a shell with a diameter of $4\frac{1}{2}$ inches, and the blank diameter reduction was carried to 42.3 percent. This represents a radical increase over and above conventional drawing operation where the usual recommended diameter reduction would be 32 percent.

In other work on straight side wall containers of a somewhat smaller drawn diameter, even a greater percentage of blank diameter reduction was obtained. Thus using a steel blank $4\frac{1}{2}$ inch outer diameter and a shell diameter of $2\frac{3}{4}$ inches, the usual recommendation as to the maximum diameter reduction possible in conventional drawing operations for a .015 material is 32 percent, but

by application of the principles of the present invention, this diameter reduction was carried up to 47.3 percent without causing rupture of the blank.

The present conclusion is that the principles of the present invention are of greatest value in working with thin gauges of metal, but even where thicker metal sheets are employed, a marked improvement is attained by enabling deeper shells to be made without rupture of the metal. In the employment of the principles of the present invention, the stresses in the blank tending to produce metal flow are equalized and are applied in such a way as to limit these stresses to values just sufficient to produce the metal flow required to produce the desired change of form of the blank. Moreover, the formation of waves in the flange is so controlled as to prevent stressing of the metal beyond its elastic limit, and there is no thinning or folding of the metal of the blank. Hence, any tendency toward weakening or rupturing of the metal is minimized.

From the foregoing description it will be apparent that the present invention enables wrinkling of the metal in the formation of shells to be eliminated in such a way that more perfect shells are produced and the workability of the metal throughout the operation is preserved. It will also be evident that the present invention enables metal foil sheets to be formed into shells without production of objectionable wrinkles in the sides or flanges thereof, and it will also be evident that the present invention enables lighter gauges of metal to be employed in shell making operations.

It will also be apparent from the foregoing description that the present invention, through the elimination of folding or wrinkling in the making of metal foil dishes and pans, materially reduces the amount of material required, and because the flanges are smooth and wrinkle-free, it is possible to seal such pans or containers to provide vacuum sealed or hermetically sealed packaging.

Thus while we have illustrated and described a preferred embodiment of the invention, it is to be understood that changes and variations may be made by those skilled in the art without departing from the spirit and scope of the appending claims.

We claim:

1. In the production of shells from flat sheet metal blanks through the use of a punch, a die and an associated gauge plate, the method of equalizing and minimizing the stresses in the blank which comprises placing a blank with its border portions between the gauge plate and the die face, setting the gauge plate and die face in substantial but non-clamping contact with opposite faces of the blank, and holding said gauge plate and die face immovable in such set relation while the punch is operated through its forming stroke whereby all frictional restraining forces exerted on the border portions of the

blank are created solely by metal flow in the border portions of the blank in response to forces applied to the blank by the punch in its forming stroke and the metal of the blank is re-oriented to produce a shell with a smooth flange and smooth walls of a thickness not less than the original blank thickness.

2. The method of forming a shell from a sheet metal blank through the use of a punch and die and an associated gauge plate which comprises locating the blank between the gauge face of the gauge plate and the die face in centered relation with respect to the die cavity, causing relative approaching movement of the gauge plate and the die to a working relation wherein said faces are spaced apart in a dimension approximately equal to but not less than the thickness of the metal blank to define a confining chamber in which the metal of the blank may flow, the dimension being such that said faces are in substantial contact with but exert no clamping forces on the blank prior to a forming operation, and maintaining said die face and said gauge plate face in said fixed dimension while said punch and die move relative to each other through a forming stroke in which the portions of the blank outwardly of the die cavity are drawn from said confining chamber as the blank is forced into the die cavity and wherein the confining chamber dimension limits the amplitude of waves tending to form in the border portions of the blank to a value such that the metal in such waves is not stressed beyond its elastic limit.

3. The method of claim 2 wherein the spaced apart dimension of the confining chamber is of a range between that of the nominal thickness of the sheet metal of the blank and such thickness plus the approximate plus tolerance of the sheet metal used.

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