

[54] **METHOD OF FORMING A RIVET**

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 [73] Assignee: **Ermal C. Frazee**, Dayton, Ohio
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 [21] Appl. No.: **866,064**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 617,128, Feb. 20, 1967, and a continuation-in-part of 704,766, Feb. 12, 1968.

Primary Examiner—Charles W. Lanham
Assistant Examiner—Michael J. Keenan
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[52] U.S. Cl.113/116 FF, 29/509, 113/1 F, 113/15 A, 113/121 C, 113/116 CC
 [51] Int. Cl.B21d 51/00, B21d 51/26
 [58] Field of Search.....113/1 F, 15 A, 116 CC, 116 FF, 113/120 Q, 121 R, 121 A, 121 C; 29/509, 522, 522 R

[57] **ABSTRACT**

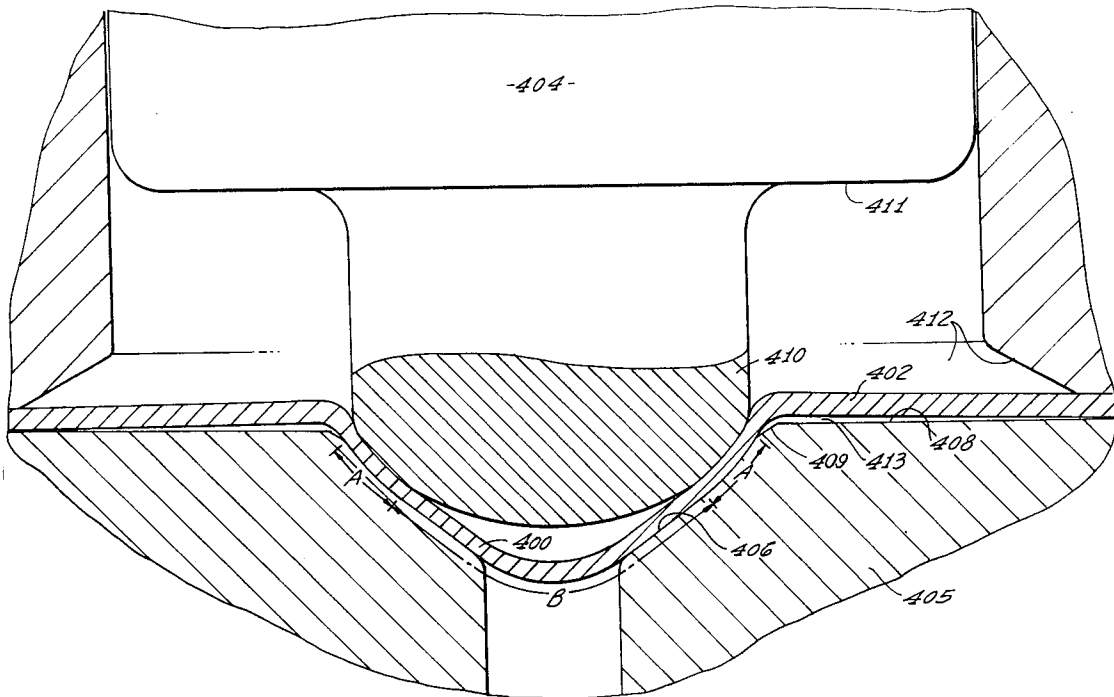
A hollow rivet is formed in sheet metal by first forming a dimple or hollow boss and then converting the dimple into the hollow rivet. Attenuation of sheet metal to form the dimple is carried out by initially stretching metal and subsequently squeezing the sloping wall of the dimple to extrude the sheet metal in opposite directions. The squeezing step to complete the attenuation makes it possible to keep the stretching of the metal within acceptable limits by a wide margin.

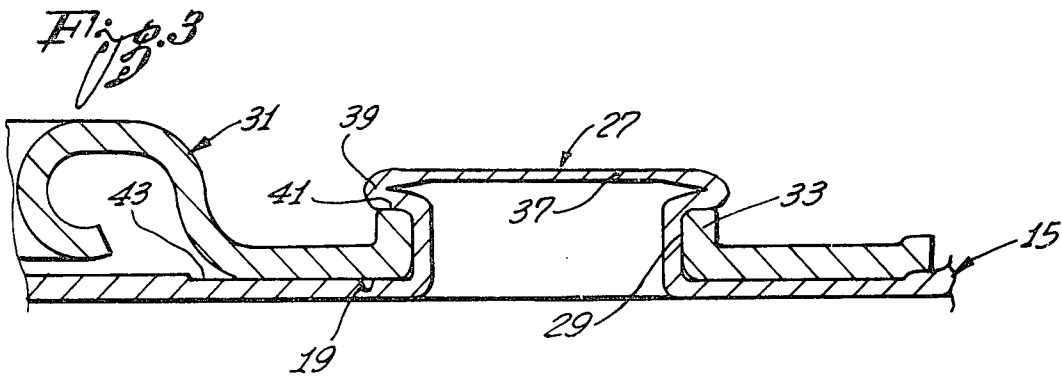
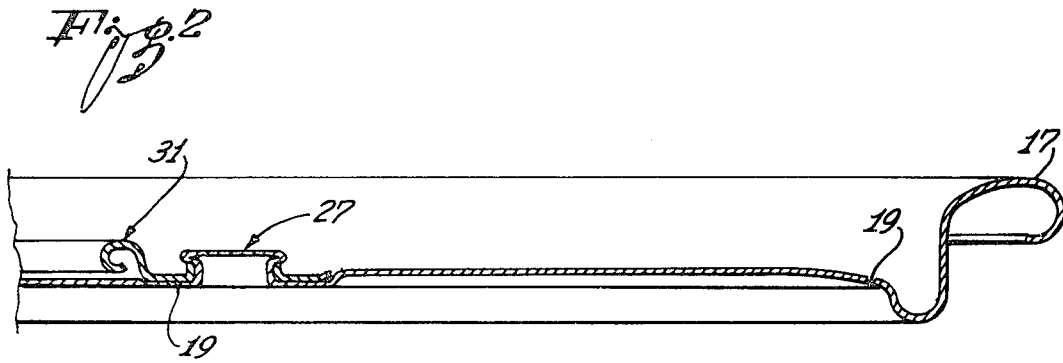
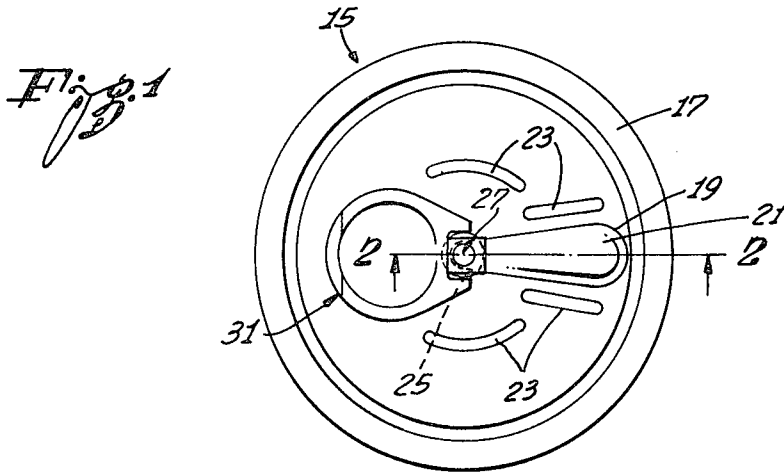
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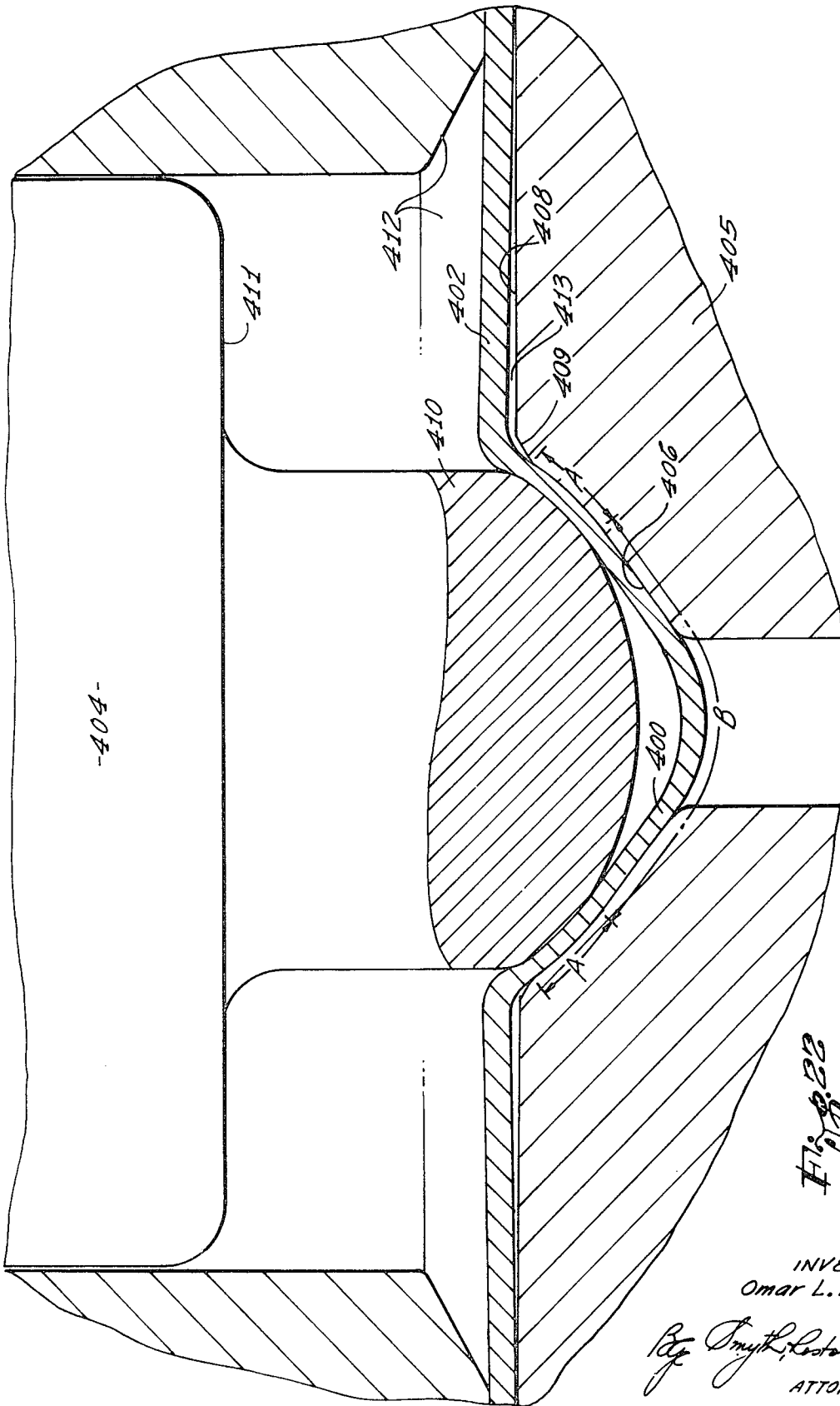
72 Claims, 30 Drawing Figures





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Fig. 404

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Fig. 4

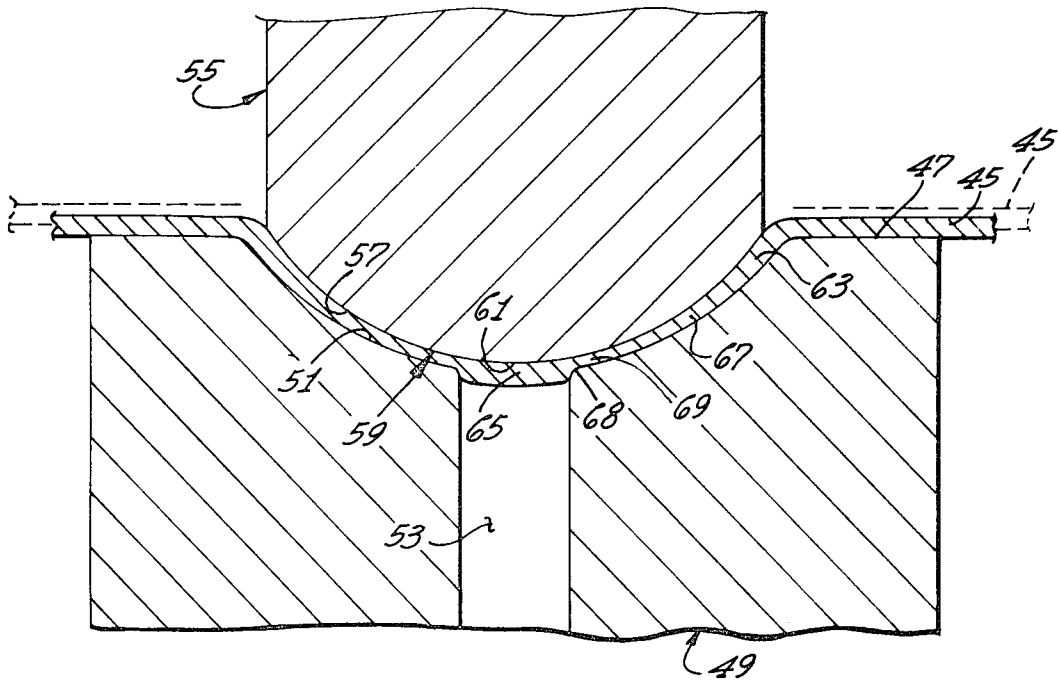
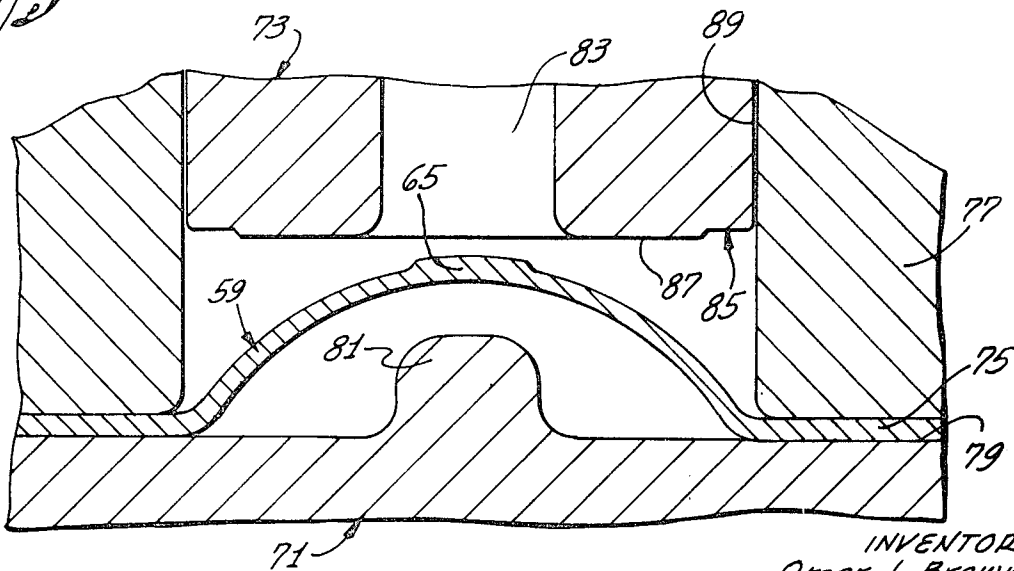
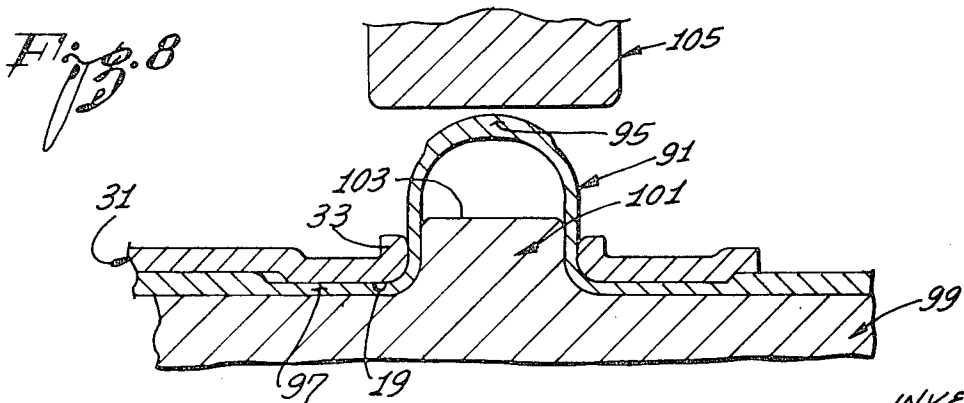
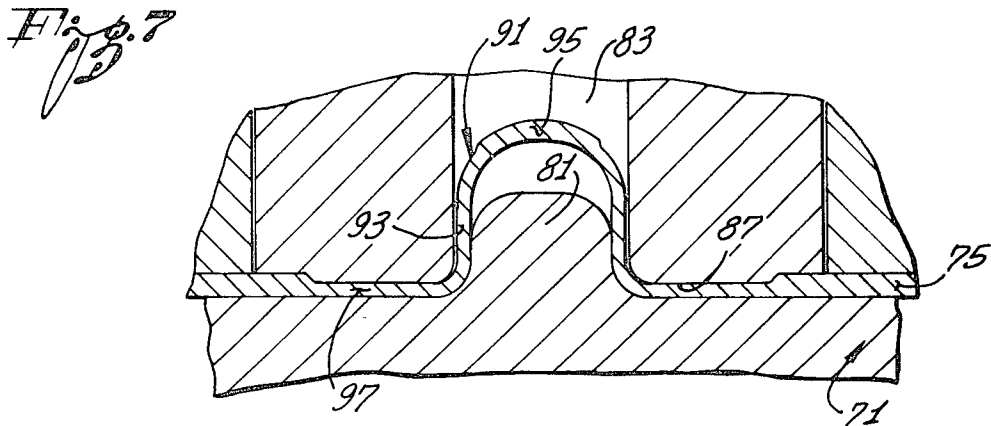
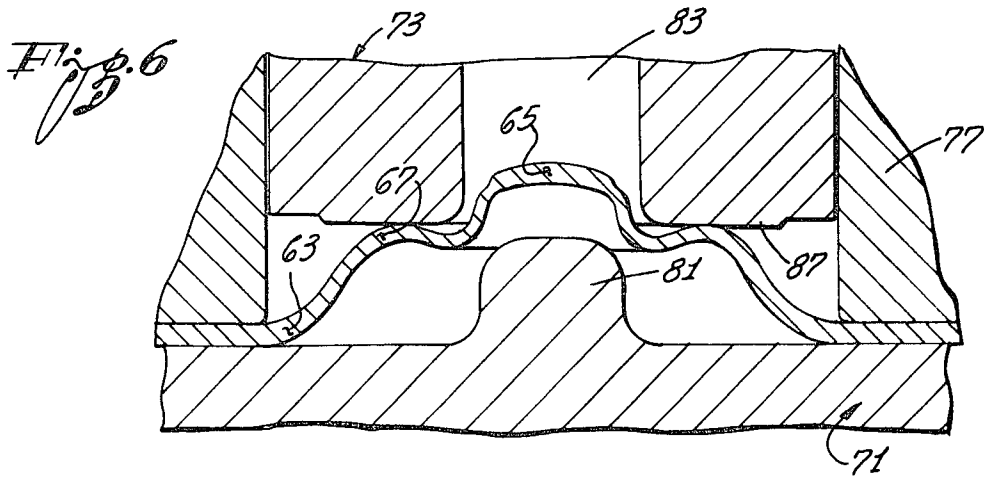


Fig. 5



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Fig. 9

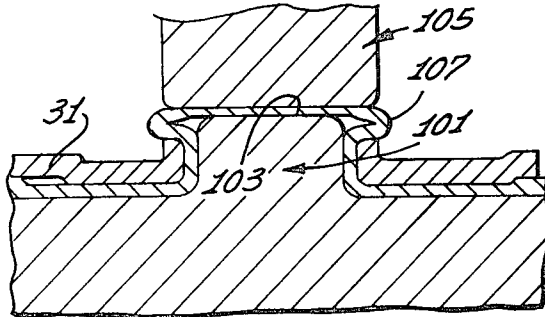


Fig. 10

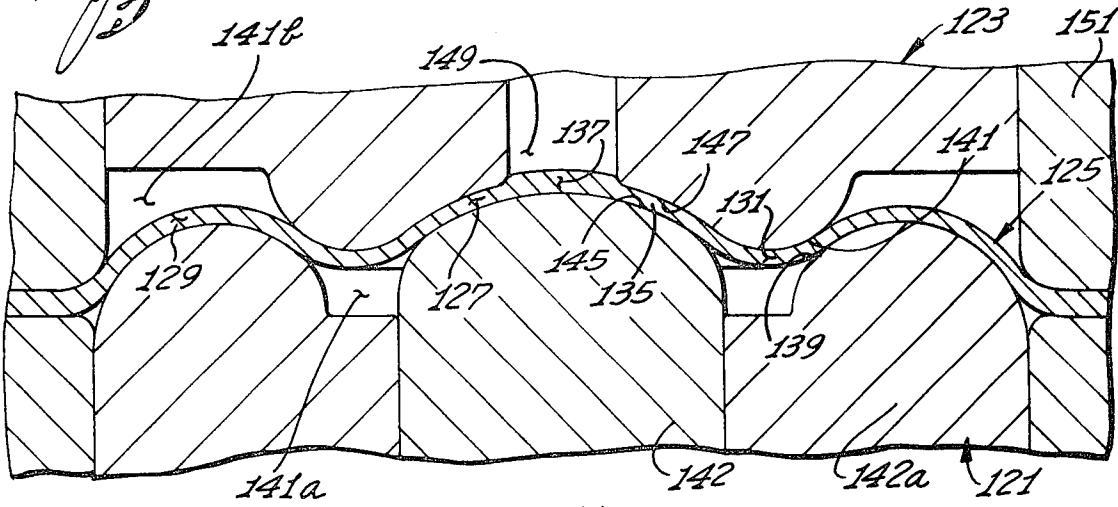
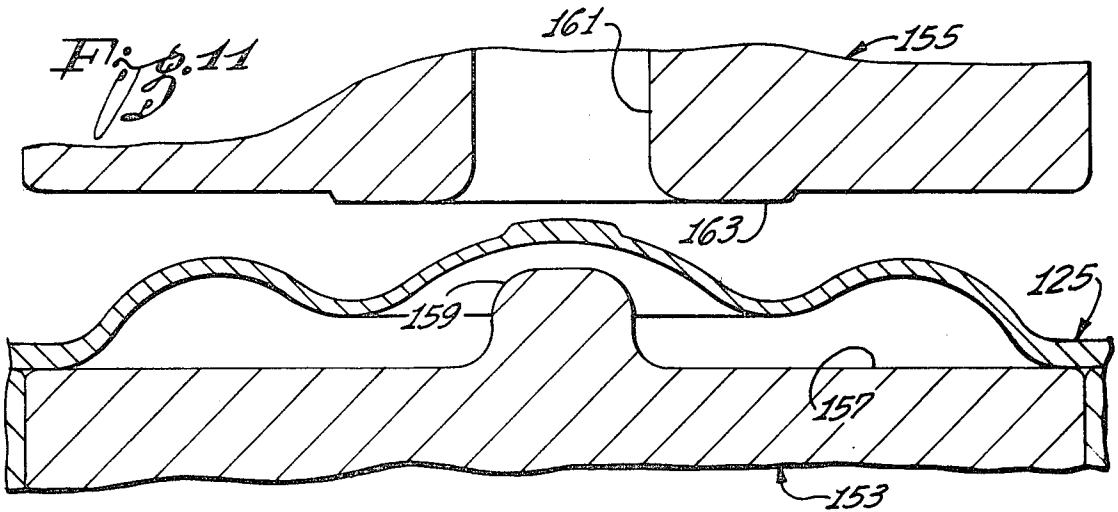


Fig. 11



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Fig. 12

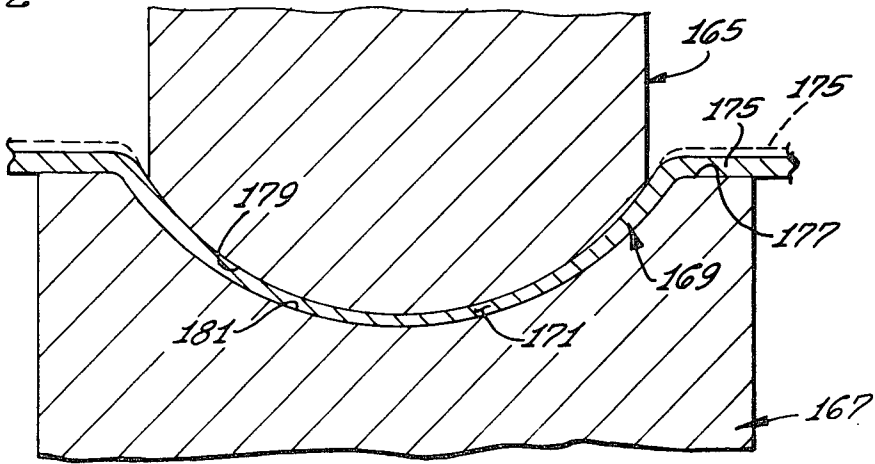


Fig. 13

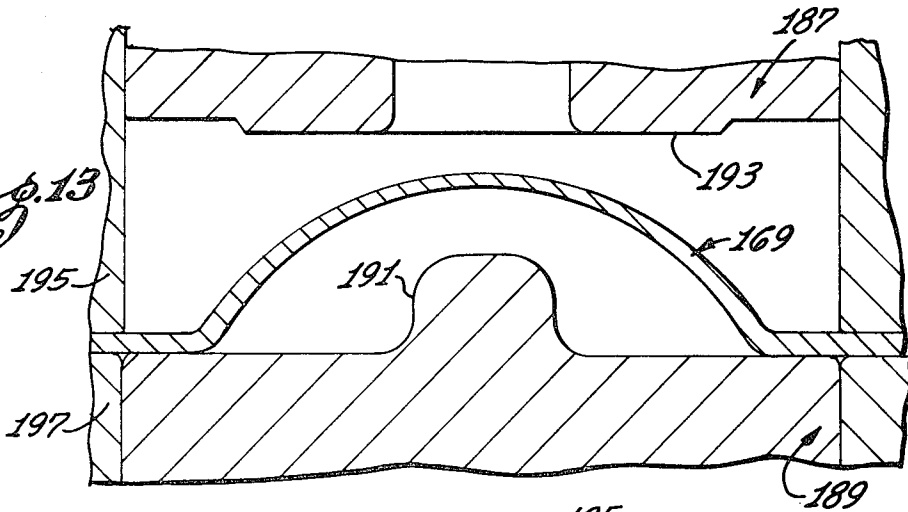
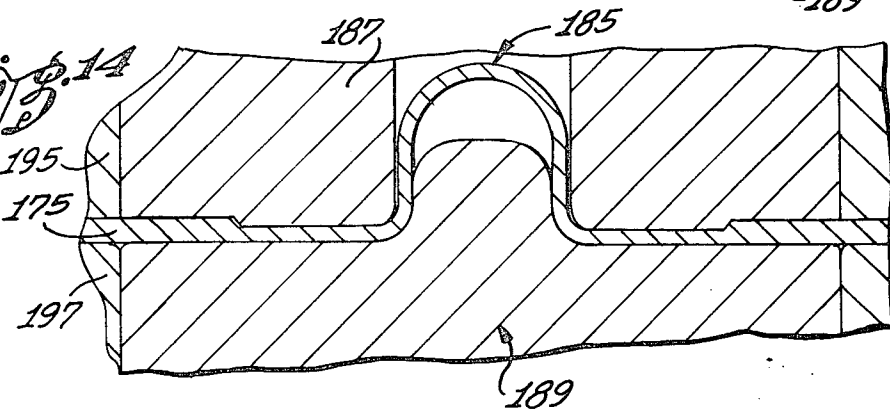
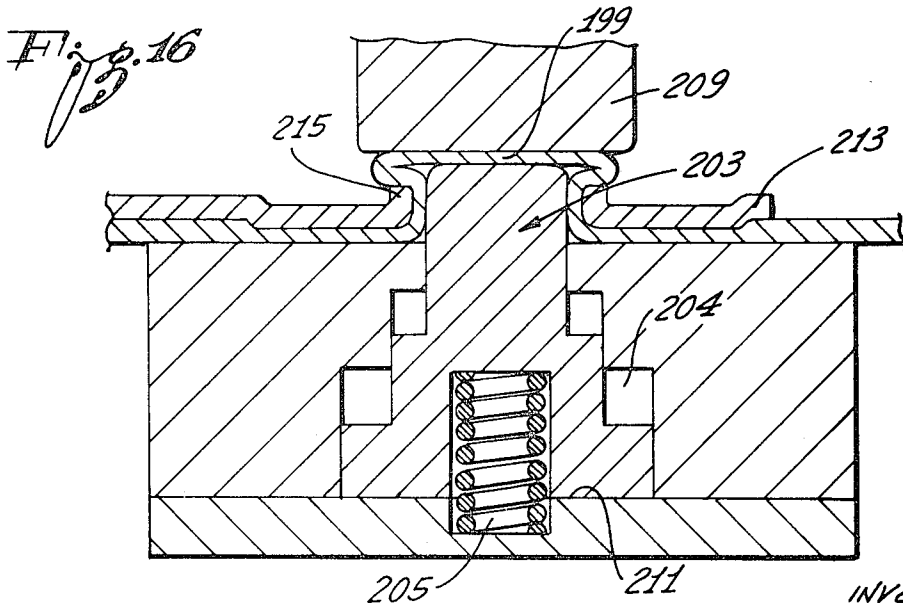
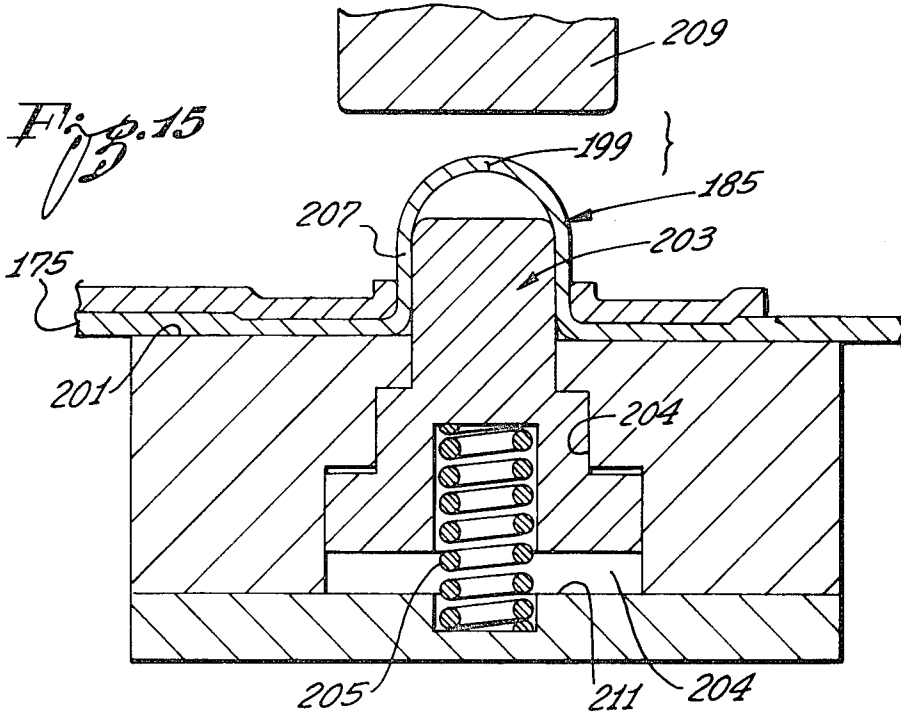


Fig. 14



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Fig. 17

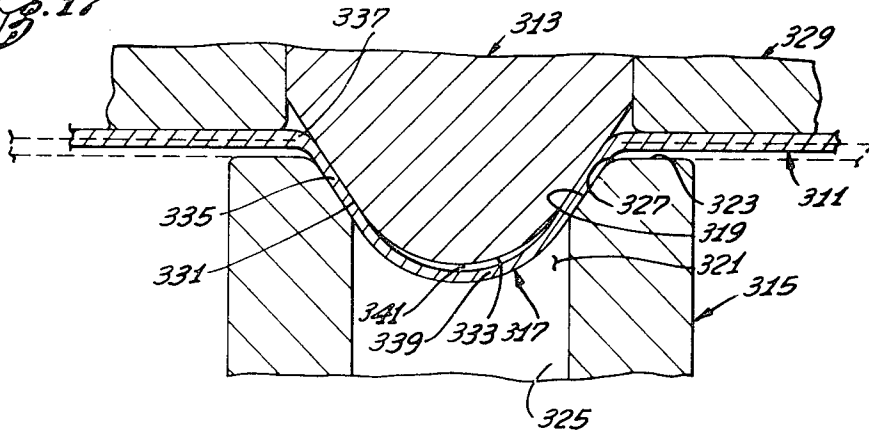


Fig. 18

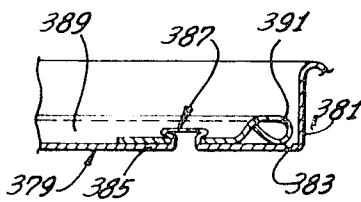
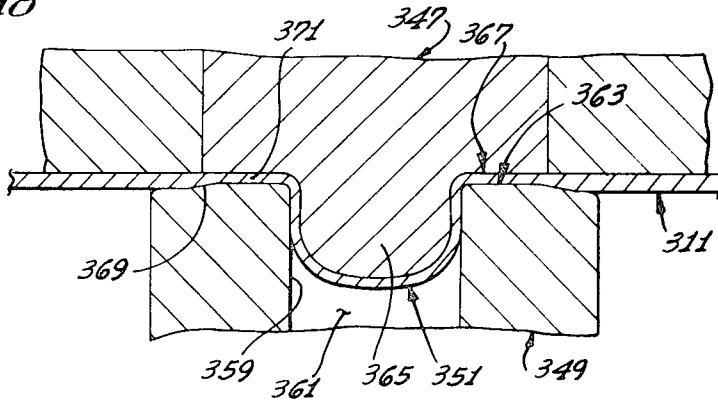


Fig. 21

Fig. 20

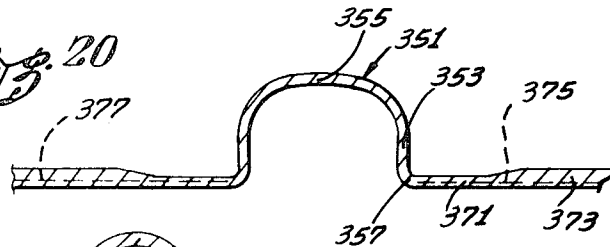
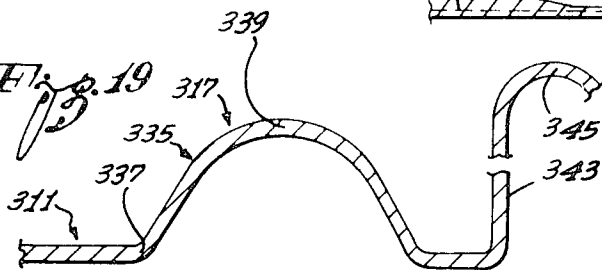


Fig. 19



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Fig. 23

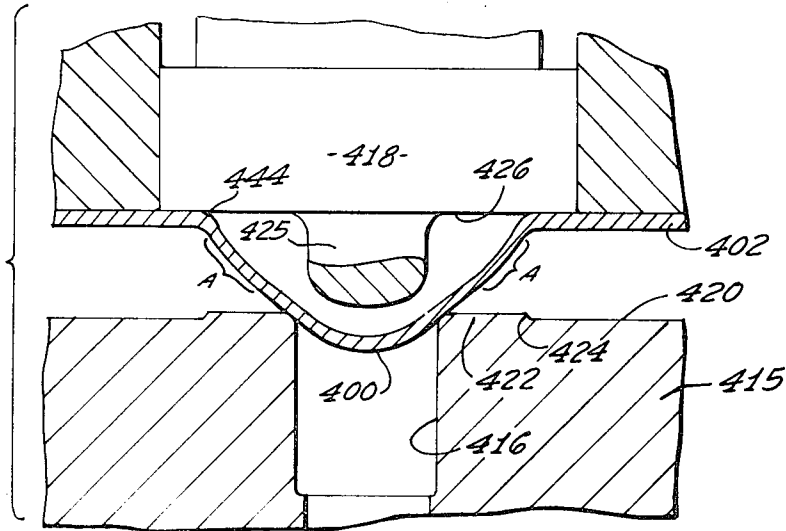


Fig. 24

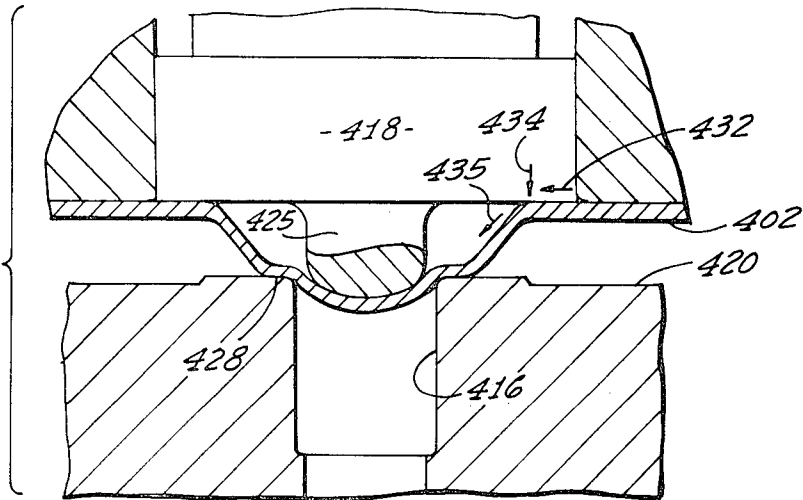
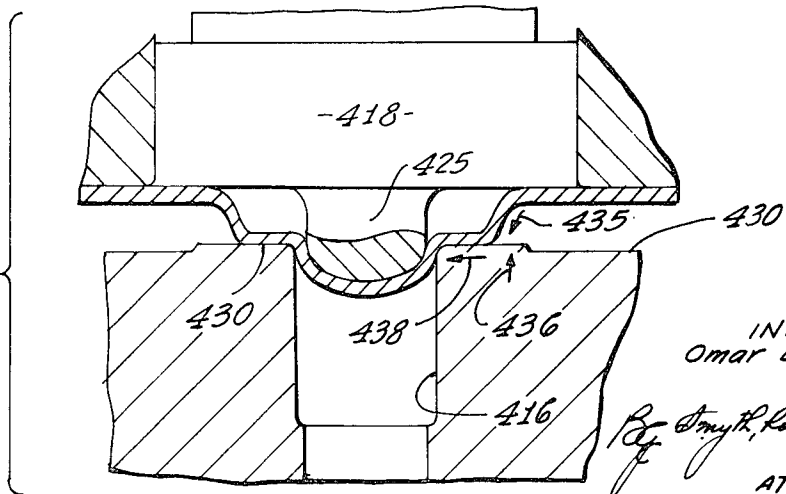


Fig. 25



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Fig. 26

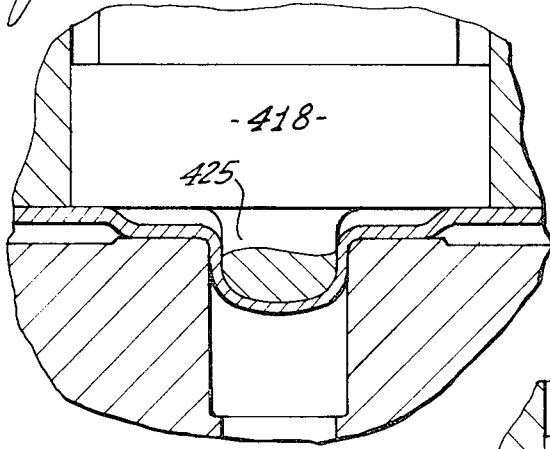


Fig. 27

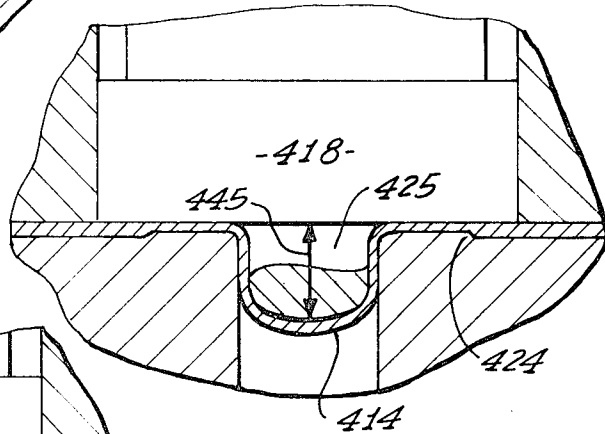


Fig. 30

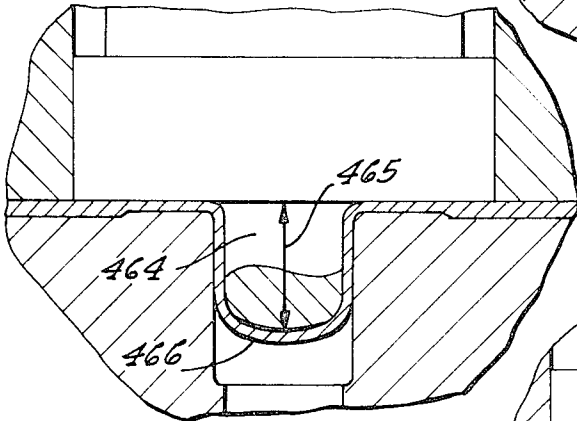


Fig. 28

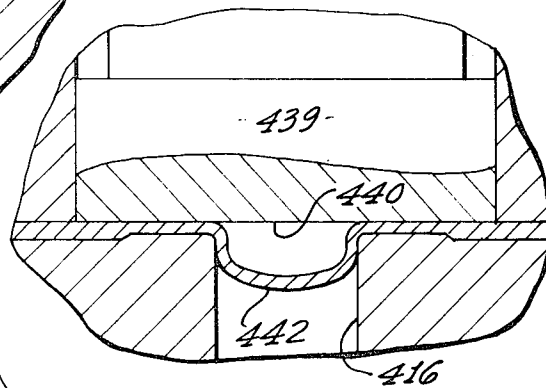
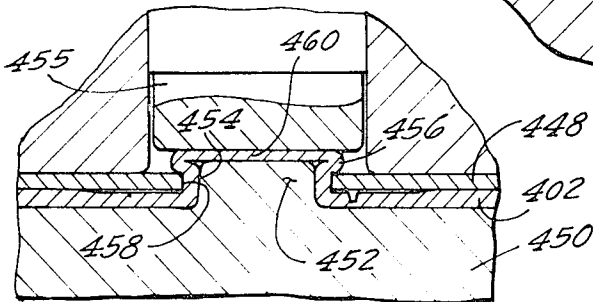


Fig. 29



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METHOD OF FORMING A RIVET

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a Continuation-in-part of my copending application entitled Method and Apparatus for Producing an Integral Rivet, Ser. No. 617,128, filed Feb. 20, 1967, and my copending application entitled Method of Forming a Rivet, Ser. No. 704,766, filed Feb. 12, 1968.

BACKGROUND OF THE INVENTION

In an easy-opening container, the container wall is scored to form a tear strip or panel and a tab for manual severance of the strip or panel is connected thereto by a hollow rivet that is formed in the metal of the tear strip or panel itself. The present invention relates in general to a method of forming such a hollow rivet as disclosed, for example, in the Frazee Pat. No. 3,191,564. That method is characterized by the concept of first forming a minor portion of the strip or panel into a gradually sloping boss or dimple in substantially greater area in plan than the desired rivet and subsequently reforming the dimple into the desired rivet configuration.

The broad object of the present invention is to meet certain needs for improvement in this multiple-step method and especially to avoid certain limitations that are encountered in prior art practices.

One limitation that is inherent in prior art methods of forming hollow rivets in sheet metal walls is that different dies must be employed for processing different thicknesses of sheet metal, for example to handle sheet metal varying from a given thickness by 0.003 of an inch plus or minus. The ideal would be the use of a single set of dies to process many thicknesses of sheet metal in a given range. Such a set of dies would drastically reduce the cost of the tooling as well as reduce the time necessary for changing over from processing sheet metal of one thickness to sheet metal of another thickness.

Another limitation of the prior art procedures is that tooling designed for successfully processing a given sheet metal having particular characteristics may not prove acceptable when a sheet metal having different characteristics is substituted. It is to be borne in mind that sheet metals employed for beverage can tops may be selected from a wide range of aluminum alloys, the alloys varying in hardness and ductility. The major portion of the cost involved in producing a beverage can of the easy-opening type is in the cost of the material and for this reason there is a trend towards using thinner sheet metal of relatively high tensile strength. The ideal process then, is a process having a wide margin of tolerance with respect to the properties of the sheet material.

Another pressing need is to provide a rivet-forming technique that will make it possible to locate the rivet close to the chuck wall of a can end thereby to provide a mechanical advantage in initiating the severance of a tear strip or panel. Conventional dies for forming hollow rivets are of too large diameter to position a rivet close to a chuck wall and, moreover, if conventional dies are employed too close to a chuck wall, the chuck wall will be deformed by the inherent tendency of the dies to pull the sheet metal radially inwardly into the region of the rivet. In this regard, the pressing need is for a rivet-forming process that may be carried out by tooling of small diameter with no significant tendency for the tooling to draw in the surrounding metal or to buckle or otherwise deform the surrounding metal.

Another need for improvement is to increase the service life of the dies and especially the dies that are employed to stake the rivets for permanently fastening the tabs to the tear panels. Heretofore it has been necessary to replace staking dies after relatively short periods of use.

Another pressing need is to reduce the pressure in tons that is required to fabricate an easy-opening can, the tonnage being high because a number of different operations are carried out on each stroke of a press including the operation of forming the hollow rivet and the operation of staking the hollow rivet into engagement with the tab. Usually the tonnage

pressure required is so high that a relatively massive press must be used to carry out the progressive die operations simultaneously.

The problem of arriving at a method of fabrication that will meet all of these needs may be understood by first considering what kind of a hollow rivet is to be sought and by then considering how a preliminary dimple may be formed that will make such a rivet possible.

The basic requirements for a hollow rivet are, first, that it be of sufficient strength to withstand the loads in tension and shear that are imposed on the rivet by the operation of manually severing the tear strip and, second, that the tubular wall of the rivet have sufficient resistance to axial compression to withstand the force of staking the rivet without buckling or collapsing. These basic requirements have been met by prior rivets but the additional requirement to be met is that the rivet be of a structure to reduce the pressure or impact force that is needed to stake the rivet.

The energy required to stake a hollow rivet into permanent engagement with the associated tab depends primarily on the height of the rivet relative to the thickness of the tab. In a heretofore prevalent fabrication procedure the height of the rivet relative to the tab is too low to permit the rivet to be staked by axial compression and therefore the staking operation is necessarily carried out by applying high-impact force across the thickness of the end wall of the hollow rivet to form the necessary bead or head by radial extrusion of the end wall metal. For example, in the staking of a hollow rivet with an initial end wall thickness on the order of 0.0135 of an inch, the thickness of the end wall may be drastically reduced to a residual of approximately 0.004 of an inch. The difficulty is that when the end wall thickness is reduced to a residual less than 0.0045 of an inch, the impact force required on the part of the staking punch rises drastically. The pressing need, therefore, is for a technique to increase the relative height of the hollow rivet so that the rivet head may be formed to a significant extent by bulging of the peripheral wall of the rivet under axial compression and thus lessen the extent to which the staking operation depends upon forcible thinning of the end wall. Reducing the impact force has the further advantage of minimizing damage to the metal of the end wall as well as damage to the seal coat inside the end wall. Since the height of the rivet and the amount of metal in the rivet is determined by the preliminary dimple, this problem boils down to how to form a dimple of sufficient surface area to make a high rivet possible. An associated problem, of course, is how to reduce the die pressure that is required to form the dimple since this die pressure is a major factor in the total tonnage pressure required for operating the multiple-station press for fabricating easy-opening can tops.

A dimple is formed by offsetting the sheet metal into a suitable die cavity and stretching the sheet metal to form the dimple must be kept within moderate bounds not only because excessive stretching unduly work-hardens the metal, but also because alloys used for can ends vary with respect to their tolerance for stretching and any rivet-forming method that requires immoderate stretching of the metal will be applicable to only a limited range of sheet metal alloys. As heretofore noted the trend is in the direction of thinner and harder metals for fabricating can tops and the thinner the metal and the harder the metal the less its tolerance for stretching.

The necessity for stretching the sheet metal could be reduced by pulling surrounding metal into the dimple area but, unfortunately drawing surrounding metal into the dimple area must be minimized because it buckles or otherwise deforms the surrounding metal and will distort the chuck wall or peripheral flange of a can end that is at all close to the dimple. Increasing the area of the flat metal that is offset to form the dimple would reduce the extent to which the sheet metal must be stretched to form the dimple, but this solution is ruled out for a number of reasons. One reason is that the greater the dimple-forming area the greater the tendency for surrounding metal to be drawn into the area. Still another reason is that in-

creasing the size of the dimple area correspondingly increases the diameter of the dimpling dies with corresponding intolerable increase in the minimum distance by which the ultimate rivet must be spaced from the chuck wall of the can end. For good reasons, then, the flat metal that is to be used to form the dimple must be of restricted area and with the limited area, the stretching of the metal within safe limits will not attenuate the metal enough to produce a dimple of sufficient size to make a high rivet possible.

There is also a need for improvement that arises if the flat sheet metal around the base of a dimple is coined to extrude metal into the dimple area or if the flat area around a rivet is coined to cause radially inward metal flow to the rivet. Such a coining operation in thinning the sheet metal forms a step where the metal increases abruptly in thickness at the outer edge of the coined area. In processing a can end to form a tear strip, it is desirable to score the metal close to the rivet with the line of scoring crossing the step in the thickness of the sheet metal but to do so tends to fracture the metal in the region of the step. This problem is made more acute by the use of harder and thinner sheet metals.

SUMMARY OF THE INVENTION

A basic concept of the invention is that to produce a dimple of suitably restricted diameter having the high ratio of surface area to plan area that is required for conversion of the dimple into a high rivet, the initially flat sheet metal may be attenuated in part by stretching and in further part by squeezing or coining the metal of the sloping wall of the dimple to increase the surface area of the dimple by extrusion. It has been found that the sheet metal may be attenuated so effectively by adding the squeezing operation, that attenuation by stretching may be kept within a permissible range for the whole spectrum of alloys that are suitable for metal containers.

A feature of the preferred practice of the invention is that the squeezing operation is performed by the same punch that stretches the sheet metal. Thus in a single stroke of the press, the punch first stretches the sheet metal by offsetting the sheet metal into a die cavity and then the punch completes the attenuation of the sheet metal by squeezing the sheet metal against the wall of the die cavity as the end of the stroke is approached.

When the sheet metal is squeezed or coined in an annular zone by a punch the displaced metal tends to flow in opposite directions away from the coining zone and if the coining zone is outside of the die cavity, only one of the two directions of flow can increase the height of the resulting dimple. An important advantage of locating the coining zone inside the die cavity on the slope of the shoulder of the dimple, is that both the forward flow and the reverse flow may increase the height and surface area of the dimple and for this purpose the dimple-forming dies may be designed to utilize the useful reverse flow.

An important advantage of the new dimple-forming method is that the force required to thin metal in a plane that is at an acute angle to the direction of die travel is less than the force required to thin metal in a plane that is perpendicular to the direction of die travel. The same amount of work is performed, of course, but a lesser force acts through a greater distance. This fact may be understood when it is considered that the ratio between the rate of the thinning of the sheet metal and the rate of travel of the punch is the sine of the angle of the cooperating die surfaces relative to the axis of the punch. For example, if the angle is 50° the sine is 0.766 and to reduce the thicknesses of the sheet metal by a given amount the punch must travel $1/0.766$ times the given amount or approximately 1.3 times the given amount. If the angle is 42° the ratio is 1.5 and if the angle is reduced to 30° the ratio becomes 2.0. Thus at 42° the punch travel is 50 percent more than the extent to which the metal is thinned and at an angle of 30° the punch travel is twice the amount that the sheet metal is thinned.

It is apparent that in comparison to the pressure that must be exerted by the press to thin metal in a plane that is perpendicular to the direction of die travel, the pressure required in a plane at a 50° angle to the direction of die travel is reduced 24 percent and the pressure required in a plane at 30° to the direction of die travel is reduced by 50 percent. In addition, the increased attenuation of the dimple wall by the squeezing operation makes it easier to reform the dimple into the rivet even though the rivet is higher than heretofore possible, the required die pressure being reduced by more than 50 percent.

By virtue of the increased rivet height, the head of the rivet may be formed in part by simple axial compression of the rivet to reduce the extent that the end wall of the rivet must be thinned to form the rivet head. Thus the increased height of the rivet makes it possible to form a rivet head of increased diameter and the staking operation may involve reducing the end wall of the rivet only to a residual thickness of approximately 0.007-0.008 instead of a residual thickness of 0.004, the reduction in the staking die pressure being more than 50 percent. The rivet height may be increased to such extent as to make it unnecessary to thin the transverse wall of the rivet head in the staking operations.

Since the operations of forming the dimple, forming the rivet and staking the rivet account for the major portion of the pressure that must be exerted by the press, it may be understood how the new technique makes it possible to lower the total die pressures by more than 50 percent. This reduction may permit a relatively light multiple station "C" press to be substituted for the usual heavy-duty multiple press having a sliding ram head, the result being drastic reduction in capital investment. The frame structure of a C-shaped press is inherently so responsive to die pressures that if the total die pressure is immoderate such a press cannot be used for multiple station operation with a degree of precision that is required for fabricating easy-opening can ends.

The concept of squeezing the sloping shoulder of the dimple to reduce the degree to which the sheet metal must be attenuated by stretching to produce the desired increase in the surface area of the dimple, not only makes the method applicable to a wide range of alloys but also has the important advantage of making a single set of dimple-forming dies capable of processing different thicknesses of sheet metal stock. All that is necessary is to vary the shut height of the dimple dies in accord with the thickness of the stock and for this purpose a set of shims may be used to enable the dies to process sheet metal varying from a given thickness by as much as 0.003 of an inch plus or minus. Here again the acute angle of the plane of the squeezing action relative to the direction of die travel is advantageous because adjusting the shut height by a given distance causes the spacing between the cooperating squeezing surfaces of the die to vary by less than the given distance. Thus the inclination of the extrusion zone makes the die adjustment less critical and simplifies the changeover from one stock thickness to another.

Given an attenuated dimple with a higher ratio of surface area to plan area than heretofore possible, the next step is to convert such a dimple into a high rivet. The conversion method set forth in the above-mentioned Frazee patent is not suitable in this instance because the object of that method is to thicken the wall of the rivet and especially the end wall whereas now the emphasis is to attain rivet heights. As will be explained, a new conversion method involves correlating two concurrent actions, one action being cooperation of opposed planar die surfaces to flatten the dimple progressively in a manner to urge the dimple metal into the rivet die cavity, the other action being the action of a rivet punch to draw the sheet metal into the die cavity. Thus the sheet metal of the dimple is pushed into the die cavity by coating planar die surfaces and at the same time is pulled into the die cavity by the punch to make possible a higher rivet than heretofore attainable. The pushing action by the planar die surfaces makes it possible to increase the stroke of the punch for increasing the height of the rivet without consequent rupturing of the sheet metal by the punch.

Fortuitously the new fabrication procedure may be used to produce rivets smaller in diameter than three thirty-seconds of an inch or if desired, rivets larger in diameter than one-quarter of an inch and the new fabrication procedure may be carried out in such manner as to avoid rupture of the sheet metal by a score line crossing a step at a periphery of a coined zone.

The various features and advantages of the invention may be understood from the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are to be regarded as merely illustrative:

FIG. 1 is a top plan view of an easy-open can end utilizing a rivet constructed in accordance with the teachings of this invention;

FIG. 2 is an enlarged fragmentary sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is an enlarged fragmentary sectional view showing how the rivet secures the tab to the tear strip of the container;

FIG. 4 is a fragmentary vertical sectional view through the dies used to form the dimple;

FIG. 5 is a vertical sectional view through a pair of reforming dies and the dimple just prior to beginning of the reforming operation;

FIG. 6 is a view similar to FIG. 5 with the dies being illustrated at the beginning of the reforming operation;

FIG. 7 is a view similar to FIG. 5 showing the dies after the reforming operation has been completed;

FIG. 8 is a vertical sectional view through the staking dies before the staking operation has begun;

FIG. 9 is a view similar to FIG. 8 with the staking dies being shown at the completion of the staking operation;

FIG. 10 is a fragmentary sectional view through a second form of dies which are utilized to form a dimple having a central cap and an annular protrusion;

FIG. 11 is a fragmentary sectional view through the dimple and the reforming dies which are utilized to reform the dimple into a hollow rivet;

FIG. 12 is a fragmentary sectional view through a third form of dimple-forming dies;

FIG. 13 is a fragmentary sectional view through the dimple and a set of dies which are utilized to reform the dimple into a hollow rivet;

FIG. 14 is a fragmentary sectional view similar to FIG. 13 after the dies have been moved together to convert the dimple into a hollow rivet;

FIG. 15 is a fragmentary sectional view through the hollow rivet, a staking punch, and a staking hammer prior to the time that the rivet is headed;

FIG. 16 shows the dies illustrated in FIG. 15 after they have been utilized to head the hollow rivet;

FIG. 17 is a fragmentary sectional view of a dimple and a fourth set of dimple-forming dies to form the same;

FIG. 18 is a sectional view illustrating the tooling used to reform the dimple of FIG. 17 into a hollow rivet;

FIG. 19 is a sectional view through a dimple formed with the tooling shown in FIG. 17 with the dimple closely adjacent the chuck wall of the can end;

FIG. 20 is a sectional view of a hollow rivet formed by the tooling shown in FIG. 18;

FIG. 21 is a fragmentary sectional view through an easy-opening container of the full panel pullout type, the tooling employed to form the rivet including the tooling shown in FIGS. 17 and 18;

FIG. 22 is a greatly enlarged sectional view of a dimple and a set of dies to form the dimple;

FIG. 23, is a sectional view illustrating an initial stage in the conversion of the dimple of FIG. 22 into a rivet by a set of dies;

FIGS. 24—26 are sectional views like FIG. 23 showing further successive stages in the conversion of the dimple into a rivet;

FIG. 27 is a similar sectional view showing the completion of the rivet-forming operation;

FIG. 28 is a sectional view illustrating the result of omitting the nose of the punch shown in FIGS. 23—27, the result being a rivet of inadequate height;

FIG. 29 is a sectional view showing the step of staking a hollow rivet into engagement with a pull tab; and

FIG. 30 is a view similar to FIG. 27 showing the completion of the formation of a rivet by a set of dies in which the punch is of substantially greater axial dimension than the punch shown in FIGS. 23—27.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

FIGS. 1-9

Referring to FIGS. 1-3, reference numeral 15 designates an easy-opening can end. The can end 15 has a peripheral flange 17 for attachment to a cylindrical sidewall of a container (not shown). A score line 19 defines a generally teardrop-shaped tear strip 21 in the can end 15. A plurality of beads 23 are formed integrally in the can end 15 to take up excess material produced in the scoring operation and to make the can end 15 more rigid. The tear strip 21 has a narrow leading end 25 positioned centrally of the can end 15. A high rivet 27 is formed integrally with the leading end 25 and extends through an aperture 29 in a tab 31 to secure the tab to the tear strip.

The tab, which may be of the ring type illustrated or any other suitable type, preferably has a hub 33 extending upwardly and surrounding the aperture 29. The rivet 27 as shown in FIGS. 2 and 3 has a generally cylindrical peripheral wall 35, a transverse end wall 37, and a bead 39. As best seen in FIG. 3, the hub 33 embraces the peripheral wall 35 and has an upper end or shoulder 41 on which the circumferentially extending bead 39 rests. A coined area 43 extends around the rivet 27 as shown in FIG. 3.

By lifting the end of the tab 31, stress is applied to the leading end 25 of the tear strip 21 and to the score line 19 adjacent the leading end of the tear strip. The rivet 27 and the leading end 25 of the tear strip 21 is of very small area, and accordingly, the force applied by the tab is highly concentrated along a relatively short length of the score line 19 at the leading end to thereby substantially facilitate initial severance thereof. The upwardly extending hub 33 provides a support for the bead 39 and strengthens the tab to tear strip jointure.

A preferred method of making the hollow rivet 27 is illustrated in FIGS. 4-9. The rivet-forming method consists of forming a minor portion of the can end into a dimple or bubble (FIG. 4) and reforming the dimple (FIGS. 5-7) into a hollow rivet. The resulting hollow rivet may then be staked as shown in FIGS. 8 and 9.

In the dimple-forming operation shown in FIG. 4 a section of deformable sheet material 45 is first positioned on an upwardly directed exterior face 47 of a female die 49. The female die has an arcuate surface 51 that defines a die cavity which opens at the exterior face 47. A recess 53 is formed axially in the arcuate surface 51. In the particular embodiment shown, the recess 53 is a passageway extending completely through the female die 49. However, if desired, the recess need only extend a portion of the way through the female die.

A male die or punch 55 having an arcuate working surface 57 cooperates with the female die 49 to form a dimple 59 in the metal 45. The working surface 57 is adapted to be received within the die cavity formed by the arcuate surface 51 as shown in FIG. 5. With the working surface 57 so received in the die cavity, the arcuate surface 51 and the working surface 57 taper away from each other as they extend toward the exterior face 47. Such tapering may be produced by making the arcuate surface 51 and the working surface 57 portions of spheres with the radius of the former being greater than the radius of the latter. It is preferred to flatten slightly a central end portion 61 of the working surface 57.

With the sheet metal 45 positioned on the exterior face 47 the punch 55 is advanced toward the die cavity to offset a portion of the sheet metal 45 into the die cavity. No holddown means are provided for holding the portion of the sheet metal 45 immediately adjacent the die cavity in contact with the exterior face 47 during the dimple-forming operation. Because of the extruding of the metal as more fully described hereinbelow, the sheet metal 45 moves upwardly during the dimple forming operation to the position shown in phantom lines in FIG. 4.

The dimple 59 has a base portion 63, a thickened central region 65, and a sloping wall or wall section 67 extending therebetween. The wall 67 progressively decreases in thickness as it extends toward the central region 65. The central region 65 is preferably circular in plan and has an arcuate lateral wall 68. By way of example, when the sheet metal 45 is initially 0.015 of an inch thick the base portion 63 may have a thickness of 0.014 of an inch and an annular region 69 immediately surrounding the central region 65 may have a thickness of 0.009 of an inch. This progressive thinning of the wall 67 is caused by extrusion of the material of the wall 67 and results in a flow of metal along the surfaces 51 and 57 to form the thickened central region 65 and to elongate the wall 67 thereby causing the sheet metal 45 to move upwardly to the position shown in phantom line in FIG. 4 and increasing the height of the dimple 59. The expression "dimple height" is used herein whether the dimple is formed downwardly as shown in FIG. 4 or upwardly as shown in FIG. 10.

Because the transverse end wall of the hollow rivet formed in the operation shown in FIGS. 5-7 should be quite thick, the recess 53 (FIG. 4) is provided to receive some of the extruded material of the wall 67 so that the central region 65 will be substantially thicker than the annular region 69. For example, the central region 65 may have a thickness of about 0.0135 of an inch when the sheet metal is originally of 0.015 of an inch thickness.

The method described herein may be used with sheet material of various thicknesses to produce dimples of various dimensions and the dimensional data stated herein is given solely by way of illustration. Thus, the diameter of the dimple 59 across the base 63 may be, for example, about 0.406 of an inch and the diameter of the thickened central region 65 may be, for example, about 0.085 of an inch. The die cavity in the female die 49 may have a depth of about 0.095 of an inch and the overall height of the dimple as measured from the upper surface of the sheet metal 45 (as viewed in FIG. 4) to the outer surface of the central region 65 may be about 0.121 of an inch.

The dimple 59 is reformed by a male die 71 and a female die 73 shown in FIG. 5. An annular zone 75 surrounding the base portion 63 of the dimple 59 is clamped between an annular clamping member 77 and an upper surface 79 of the male die 71. This clamping arrangement prevents the metal in the dimple 59 from flowing radially outwardly thereof or buckling during the reforming operation.

The male die 71 has a cylindrical member or punch 81 which extends axially into the dimple 59. As shown in FIG. 5, the height of the punch 81 is less than the height of the dimple 59 and may be about 0.071 of an inch high. The diameter of the punch 81 is somewhat greater than the diameter of the central region 65 and may be about 0.103 of an inch.

The female die 73 has a cylindrical opening 83 of sufficient diameter, e.g., 0.125 of an inch, to receive the punch 81 and an annular layer of the sheet metal of the dimple 59. The female die 73 has a lower face 85 with an annular coining face 87 thereon immediately surrounding the opening 83. The female die 73 is adapted to move downwardly toward the dimple 59 in a cylindrical passageway 89 formed in the clamping member 77.

FIG. 6 illustrates the initial stages of the reforming operation. The female die 73 moves downwardly to engage the wall 67 of the dimple 59 and begins to deform the dimple in the manner illustrated. The relatively thick portions of the wall 67

support thinner portions of the wall 67 adjacent the thickened central region 65 so that the thickened central region 65 remains at substantially the same height throughout the reforming operation. The thinner portions of the wall 67 are initially engaged by the die 73 and the metal thereof is deformed inwardly to begin the formation of the peripheral wall of a rivet 91 (FIG. 7). At the completion of the reforming operation, the progressively thinned wall 67 has been converted into a peripheral wall 93 if the rivet 91 and the thickened central region 65 has been converted into a transverse end wall 95 of the rivet.

FIG. 7 shows the hollow rivet 91 at the completion of the reforming operation. The peripheral wall 93 is annular and the transverse end wall 95 is relatively thick and dome-shaped. The coining face 87 forms an annular coined zone 97 immediately surrounding the rivet 91. Because the annular zone 75 surrounding the coined zone 97 is clamped between the clamping member 77 and the male die 71 during the reforming operation, metal from the coined zone 97 is substantially prevented from flowing outwardly and flows radially inwardly into the peripheral wall 93 of the rivet 91. This causes the peripheral wall 93 to have substantial thickness even though the height of the rivet 91 is equal to or substantially equal to the height of the dimple 59. By way of illustration, when the sheet metal is initially of 0.015 of an inch thickness, the peripheral wall 93 may have thickness of the coined zone 97 and which may be approximately 0.009 of an inch.

The rivet formed by the operation described can have numerous uses of which the can end shown in FIGS. 1-3 is illustrative. Similarly, the rivet 91 may be staked according to any suitable procedure. However, it is preferred to stake the rivet 91 as illustrated in FIGS. 8 and 9.

In the staking operation, a die member 99 having a cylindrical anvil 101 is provided. The anvil 101 has an upper generally planar working face 103. When the rivet 91 is placed over the anvil 101, the working face 103 is preferably spaced substantially from the inner surface of the transverse end wall 95 and is at a suitable height to prevent interference with the tab 31 or hub 33. The peripheral wall of the anvil 101 is in engagement with or in substantial engagement with the peripheral wall 93 of the rivet. Next, the tab 31 is placed over the rivet with the hub 33 embracing the lower portion of the peripheral wall 93.

A hammer or punch 105 is positioned above the transverse end wall 95 of the rivet 91. The punch is forced downwardly into engagement with the transverse end wall 95 to cause an initial folding of the peripheral wall 93 and partial axial collapse of the rivet 91. The folding of the peripheral wall initiates formation of a bead 107 (FIG. 9). The punch 105 drives the transverse end wall 95 downwardly into engagement with the working face 103 of the anvil 101 to cause the transverse end wall to be thinned or extruded between the punch and the working face 103. This causes the metal of the transverse end wall 95 to flow radially outwardly to further assist in the formation of the bead.

FIGS. 10 and 11

illustrate a second embodiment of the invention. Briefly, FIG. 10 shows a male die 121 and a female die 123 being utilized to form a dimple or bubble 125. The dimple 125 includes a central cap 127 surrounded by an annular protrusion 129. The central cap 127 intersects the annular protrusion 129 to form an annular valley 131. It is apparent that the dimple 125 is very similar to the appearance of the dimple 59 as it appears during an intermediate stage of the reforming operation as shown in FIG. 6.

The wall of the annular protrusion 129 is thinner than the sheet metal blank from which the dimple is formed. The thinning through the wall of the annular protrusion 129 is the result of stretching of the metal by the dies 121 and 123. By way of illustration, when the sheet metal stock is originally of 0.015 of an inch thickness the wall of the annular protrusion 129 may be thinned to approximately 0.011 of an inch or 0.012 of an inch.

The central cap 127 has a sloping progressively thinned wall section 135 which extends from the valley 131 to a central protrusion 137 which is formed at a central region of the dimple 125. By way of illustration, the wall section 135 may be progressively thinned from about 0.011–0.012 of an inch adjacent the valley 131 to approximately 0.009 of an inch immediately adjacent the protrusion 137. This thinning of the wall section 135 is preferably brought about by extrusion of the material thereof between the coacting dies 121 and 123. The extruded metal of the wall section 135 will flow toward the central region of the dimple 125 and is utilized to produce the protrusion 137. The protrusion may have a thickness of about 0.0135 of an inch and a diameter of about 0.085 of an inch.

Although all of the dimensions given herein are merely exemplary, it is preferred to make the dimple 125 of relatively large diameter. For example, the diameter of the dimple may be approximately 0.7 of an inch, the distance between diametrically opposite points on the crest of the annular protrusion 129 may be about 0.48 of an inch and the distance between diametrically opposed points on the lowest region of the valley 131 may be about 0.28 of an inch. Although the height of the dimple 125 may also vary depending upon the desired final configuration of the rivet, the overall height of the central cap 127 may be about 0.1 of an inch and the height of the annular protrusion 129 may be 0.080 of an inch.

As shown in FIG. 10, the dies 121 and 123 have working surfaces 139 and 141, respectively, the contours of which generally conform to the final shape of the dimple 125 except for annular recesses 141a and 141b. The die 121 includes an axial pin or punch 142 which is fixed relative to an annular portion 142a of the die 121. The working surfaces 139 and 141 have tapered portions 145 and 147, respectively, which taper away from each other as they extend radially outwardly of the protrusion 137. It is the tapering portions 145 and 147 which squeeze the wall section 135 and cause extrusion of the material thereof to form the thickened protrusion 137 and the progressively thinned wall section. Unlike the dimple-forming operation of FIG. 4, this extrusion does not cause the sheet metal around the dimple 125 to move away from the supporting surface. The die 123 has a recess or cavity 149 into which the extruded material from the wall section 135 may flow to form the protrusion 137. The extruded material from the wall section 135 also flows outwardly to assist in the formation of the annular valley 131 and the annular protrusion 129. The recess 149 may take the form of a passageway which extends all or a portion of the way through the die 123. The dies 121 and 123 can be moved toward each other in any suitable controlled manner. The die 123 may have a supporting body 151.

FIG. 11 shows the dimple 125 resting on a male die 153 with a female die 155 disposed thereabove. The male die 153 is substantially identical to the male die 71 (FIG. 6) and has a broad flat supporting surface 157 and a working surface or punch 159 which extends upwardly into the dimple 125.

The die 155 is similar to the die 73 shown in FIG. 5. Thus, the die 155 has a passageway or cavity 161 therein of sufficient diameter and depth to receive the punch 159 and the resultant hollow rivet. The die 155 also has a coining face 163 which causes flow of metal inwardly into the walls of the rivet to further thicken them. The dies 153 and 155 are movable toward each other in the same manner shown in FIGS. 6 and 7 to produce a hollow rivet as shown in FIG. 7. The height of the resulting rivet is about equal to the height of the dimple 125 and the resulting rivet may be staked as illustrated in FIGS. 8 and 9.

FIGS. 12–16

These figures illustrate a third embodiment of a preferred practice of this invention. FIG. 12 shows how a male die or punch 165 and a female die 167 can be utilized to form a dimple 169 which has a progressively thinned sloping wall or wall section 171 and a central region 173 which is no thicker than the surrounding portions of the wall 171. Generally, the dimple 169 is identical to the dimple 59 (FIGS. 4 and 5) except

that the former has no thickened central region and is somewhat higher than the dimple 59. In the formation of the dimple 169, the thickened central region is eliminated and the material that would have been utilized to form such thickened central region is utilized to provide additional elongation of the wall 171 and hence additional dimple height. The sheet metal 175 surrounding the dimple 169 is unrestrained so that it can move away from the exterior face 177 to the position shown in phantom in FIG. 12 to allow for elongation of the wall 171. Illustrative dimensions of the rivet 169 are the same as those given in connection with a dimple 59 except that the central region 173 would have a thickness of only about 0.009 of an inch and the height of the dimple 169 is greater.

The punch 165 has a working face 179 and is generally identical to the male die 55. The female die 167 is identical to the female die 49 except that the former has no recess for thickening of the central region 173. The female die 167 has a cavity forming an arcuate surface 181. The working surface 179 and the arcuate surface 181 taper away from each other as described in connection with the first embodiment and act to squeeze the wall 171 to extrude the material thereof to elongate or provide increased height to the dimple 169. Accordingly, the dimple 169 may be somewhat higher than a corresponding dimple formed in accordance with the teachings of the first embodiment of the invention.

As shown in FIGS. 13 and 14, the dimple 169 is reformed into a hollow rivet 185 by a female die 187 and a punch 189. The punch 189 has a working surface 191 extending axially into the dimple 169 and the female die 187 has a coining face 193 for causing flow of metal radially inwardly into the wall of the rivet 181. During the reforming operation and the coining operation, the sheet metal 175 is clamped between two members 195 and 197 which retard or substantially prevent outward flow of metal during the coining operation. The female die 187 and the punch 189 function in the same manner described above in connection with the die 73 and the punch 71 to reform the dimple 169 into a hollow rivet 185 of a height approximately equal to the height of the dimple 169. The hollow rivet 185 is identical to the hollow rivet 91 shown in FIG. 8 except that the former has a constant wall thickness which may be approximately 0.009 of an inch throughout and also is somewhat higher than the rivet 91.

It is preferred to stake the rivet 185 without substantially thinning a dome-shaped transverse end wall 199 thereof. Generally, optimum results are achieved when the transverse end wall 199 is thinned approximately 0.001 of an inch to 0.003 of an inch to a final thickness of approximately 0.006–0.008 of an inch, the preferred final thickness being 0.007–0.008 of an inch. FIGS. 15 and 16 illustrate one way in which this can be accomplished. The sheet metal 175 is supported by a surface 201 and a stepped staking punch 203 which is mounted in a stepped recess 204 is biased upwardly by a coil spring 205. The staking punch 203 enters the hollow rivet 185 and is spaced from the interior surface of the transverse end wall 199 and may form a sliding fit with the interior surface of a peripheral wall 207 of the rivet. A punch or hammer 209 is utilized to strike the outer surface of the transverse end wall 199 to partially axially collapse the rivet 185. The interior surface of the transverse end wall 199 is thus moved into engagement with the staking punch 203 to drive the latter downwardly as the rivet 185 is further collapsed. Preferably, the punch 203 is driven downwardly until it contacts a lower wall 211 of the recess 204. At this instant the punch 209 is at, or substantially at, the bottom of its stroke and at this instant the transverse end wall 199 is thinned about 0.001 of an inch to 0.003 of an inch, preferably 0.001–0.002 of an inch. The punch 203 also serves to prevent radial inward collapse of the peripheral wall during the staking operation. The rivet 185 firmly secures a tab 213 having a hub 215 to the tear strip.

It is apparent that the operation illustrated by FIGS. 15 and 16 has three stages. In the first stage the initial lowering movement of the upper punch 209 tends to flatten the domed end

wall of cavity, rivet against the stationary lower punch 203 with consequent initiation of the bead-forming operation by radially outward bulging of the end of the rivet.

In the second stage the transverse end wall of the rivet is clamped between the two punches under spring pressure and the two punches move downward in unison to carry the end wall downward with consequent collapse of the rivet axially. With the lower or inner punch 185 preventing inward collapse, the collapse of the rivet is outward. Thus the formation of the bead that is continued in the second stage is carried out by outward folding the peripheral wall of the rivet on itself, the folding action occurring because the leading lower face of the upper punch 209 is large enough in area to overhang the radially expanding end wall of the rivet throughout the second stage.

In the third stage the lower punch 203 stops and the upper punch 209 continues downward a short distance to squeeze the transverse end wall of the rivet against the lower punch for slight thinning of the end wall. For example a transverse end wall of the rivet of an initial thickness of 0.009 of an inch may be reduced by only 0.001-0.002 of an inch since only slight additional radial expansion of the end wall of the rivet is required to complete the circumferential bead of the rivet in view of the fact that the first two stages of the operation expand the end wall so effectively.

FIGS. 17-21

In this fourth embodiment of the invention, FIG. 17 shows a piece of deformable sheet material 311 such as aluminum sheet metal being offset by a bubble punch 313 and a bubble die 315 to form a bubble or dimple 317. The die 315 has a conical die surface 319 at least partially defining a die cavity 321 and extending between an exterior face 323 of the die and a central recess or bore 325 which also partially defines the die cavity 321. The die 315 has a chamfer 327 intermediate the die surface 319 and the exterior face 323 to substantially prevent drawing of any of the sheet material 311 into the die cavity 321 from an area of the sheet material lying radially outwardly of the dimple 317. By way of example, the chamfer 327 may form an included angle with the exterior face 323 of about 145° and be blended into the inner die surface 319 and the face 323 with relatively small radii to form relatively sharp corners to thereby prevent this radial inward flow of material during the dimple-forming operation.

The punch 313 is retained within a suitable holder 329 and has a frustoconical lateral working surface 331 and a rounded nose 333 which blends into the conical working surface 331. The punch 313 and the die 315 are suitably arranged to be axially advanced toward each other in any suitable conventional manner. In the embodiment illustrated in FIG. 17, the dimple 317 is formed downwardly to better illustrate the coining of the dimple wall; however, it should be understood that the dimple 317 may be formed upwardly, if desired.

To form a dimple 317, the sheet material 311, which may be assumed to be in a substantially flat condition, is positioned between the punch 313 and the die 315. The punch 313 and the die 315 are then relatively axially advanced toward each other to cause the nose 333 of the punch 313 to engage the sheet material and deform a portion thereof downwardly into the die cavity 321 to initiate formation of the dimple 317. Thus, in the initial phase of the dimple-forming operation, the sheet material forced into the die cavity 321 is stretched and therefore made thinner in accordance with conventional dimple forming methods. However, due to the chamfer 327 and the adjacent relatively sharp corners, substantially no material is drawn radially inwardly into the dimple 317 from an area surrounding the dimple.

The step of relatively advancing the punch 313 and the die 315 toward each other is continued to allow the wall 335 of the dimple 317 to be squeezed between the die surface 319 and the working surface 331 to displace material of the dimple wall along such surface to thereby increase the axial dimension of the dimple. Such squeezing or extrusion of the material of the dimple wall 335 causes flow of the material in both

directions along the surfaces 319 and 331. The flow of material toward a base 337 of the rivet 313 may operate to elevate the surrounding portions of the sheet material 311 above its original position, the original position of the sheet material being illustrated in phantom lines in FIG. 17. Such elevation is made possible by not clamping the sheet material around the dimple 317. The flow of material toward a central region 339 may move such central region axially away from the nose 333 of the punch 313 to form a gap or space 341. The squeezing or coining of the dimple wall 335 is very important in producing a dimple having substantial height, i.e., a substantial axial dimension, without fracturing or excessively thinning the dimple wall. Without such coining step, excessive thinning or fracture of the dimple wall would occur and the central region 339 of the dimple would be punched out by the nose portion of the punch before the desired dimple height was reached.

The dimple formed with the punch 313 and the die 315 is shown more clearly in FIG. 19. FIG. 19 illustrates the dimple in an inverted position from that shown in FIG. 17 and as having been formed from the sheet material 311 of a can end. As the dimple forming method shown in FIG. 17 substantially prevents drawing of sheet material from an area surrounding the base 337 of the rivet 313 into the dimple wall 335, the dimple 317 may be formed closely adjacent a chuck wall 343 of the can end without distorting the latter. In the form shown in FIG. 19, it is important that such drawing action be substantially prevented in the area of the sheet material lying intermediate the dimple 317 and the closely adjacent portion of the chuck wall 343 illustrated. The chuck wall 343 terminates upwardly in the usual peripheral curl or flange 345 for attaching the can end to a body of a container (not shown). The relatively small diameter of the punch 313 and the die 315 also contribute to the formation of the dimple 317 closely adjacent the chuck wall 343.

The importance of coining of the dimple wall 335 and in particular the importance of the conical surfaces 319 and 331 can best be illustrated by reference to a specific example. Assuming the sheet material 311 to have an original thickness of about 0.010 of an inch, the dimple 317 may have an axial dimension measured from the underside of the sheet material 311 to the upper surface of the central region 339 of approximately 0.090 of an inch, and a diameter across the base 337 of only approximately 0.250 of an inch with the diameter of the recess 315 being about five thirty-seconds of an inch. The dimple wall 335 may have a thickness of about 0.007 to 0.008 of an inch. A dimple having such substantial height and wall thickness for such a relatively small diameter could not be produced without coining of the dimple wall 335. The use of a conical die surface 319 and a conical lateral working surface 331 is also preferred because of the relatively steep angle which the dimple wall 335 may assume relative to the sheet material 311. Although the specific angle in the embodiment illustrated is not critical, such angle may be about 57°. A steep angle has the advantage of tending to produce a relatively high dimple for a given diameter across the base 337.

Of course, the particular dimensions given above are stated solely by way of example and can be varied over a wide range depending upon the results desired. If the coining of the dimple wall 335 is allowed to progress sufficiently, the central region 339 may be somewhat thicker than the surrounding regions of the dimple wall 335. The portion of the dimple wall 335 that is squeezed between the die surface 319 and the working surface 331 is of accurately controlled thickness and shape, and in the embodiment shown such portion is the region of the dimple wall 335 adjacent the base 337. Preferably, the dimple-forming operation is carried out so that the dimple is slightly thicker adjacent the base 337 than adjacent the central region 339. This may be accomplished, for example, by utilizing slightly different angles on the die surface 319 and the working surface 331 so that these surfaces are slightly inclined toward each other as they extend toward the central region 339. A dimple with a base which is thicker than the region of the dimple wall immediately surrounding the central region can be more easily reformed into a hollow rivet.

Thus, with the present invention the dimple is initially formed by an offsetting procedure during which the material of the dimple is stretched. Ultimately, the dimple wall 335 is forced into the die cavity to the extent that it can be squeezed between the die surface 319 and the working surface 331 to extrude some of the material of the dimple wall as described above. Both of these stretching and coining functions can be carried out with a single punch and die as shown in FIG. 17; however, these functions could be carried out with different punches and dies, if desired.

The dimple 317 is reformed by a button punch 347 and a button die 349 into a hollow rivet 351. As best seen in FIG. 20 where the rivet 351 has been inverted, the rivet has a peripheral wall 353, a transverse end wall 355, and a base 357. The button die 349 has an interior die surface 359, defining a die cavity or recess 361 and opening at an annular working surface 363 which surrounds the recess. The button punch 347 has a head portion 365 which is receivable within the recess 361 and an annular working surface 367 surrounding the head portion. The outer annular regions of the annular working surfaces 363 and 367 should preferably taper away from each other and this is accomplished in the embodiment illustrated by the die 349 which has an annular inclined or tapered surface 369 which extends away from the annular working surface 367 as it extends radially outwardly of the rivet 351.

To reform the dimple 317, the dimple is positioned between the punch 347 and the die 349 and then these tools are axially advanced toward each other. The dimple 317 and the rivet 351 can be formed upwardly or downwardly or in any other orientation although it is preferred not to invert the dimple in preparation for the reforming step. The annular working surface 363 of the die 349 contacts a peripheral region of the dimple wall 335 and collapses or flattens the latter toward the annular working surface 367 of the punch 347. The peripheral region of the dimple wall so collapsed, is converted into a circumscribing zone 371 which surrounds the base 357 of the rivet 351 as may be seen in FIG. 2. An inner region of the dimple is converted into the rivet 351. The head portion 365 of the punch 347 is within the dimple 317 to thereby control the ultimate shape of the rivet 351. The circumscribing zone 371 is inherently of lesser thickness than the material of an area 373 lying radially outwardly of the circumscribing zone. This is so because the circumscribing zone 371 was originally formed from a peripheral region of the dimple wall 335 which has been thinned by stretching and coining as described above in connection with FIG. 17. To eliminate any abrupt change of thickness of the sheet material intermediate the circumscribing zone 371 and the area 373, the punch 347 and the die 349 are relatively advanced to allow the annular working surfaces 363 and 367 to squeeze or coin very slightly the sheet material of the circumscribing zone 371 and of an inner annular region of the area 373. Specifically, the parallel portions of the working surfaces 363 and 367 engage the sheet material of the circumscribing zone 371 to iron out the material thereof to assure that this region will at least be substantially flat. The material of the circumscribing zone 371 may be extruded or coined only very slightly to iron out these irregularities without significantly or materially increasing the axial dimension of the rivet 351 or without increasing the thickness of the wall 351 and 353 of the rivet. The annular tapered surface 369 of the die 349 cooperates with the outer annular regions of the working surface 367 to form a tapered transition section 375 of gradually increasing thickness as it extends radially outwardly to thereby prevent any substantial change in thickness between the circumscribing zone 371 and the area 373. Thus, when a line of weakness such as a score line 377 (FIG. 30) is formed through the area 373 and the circumscribing zone 371, as is often the case in easy-opening containers, such score line will not extend through any abrupt change of thickness of the sheet material. This ironing or slight coining around the base of the rivet is useful with any rivet-forming method which leaves abrupt changes of thickness in the sheet material adjacent the rivet.

Although the rivet 351 may be used in many different environments, it is particularly adapted for use with an easy-opening container as shown by way of example in FIG. 21. FIG. 21 illustrates a can end 379 of the full-panel pullout type having a chuck wall 381 and a line of score 383 in the can end defining a panel 385 at least partially removable therefrom and covering substantially all of the can end. A rivet 387 constructed in accordance with the teachings of this invention is formed integrally with the can end 379 and lies very close to the score line 383 and the chuck wall 381. The rivet 387 secures a tab 389 of suitable construction to the can end. The tab 389 has a nose end 391 which overlies the score line 383 and which bears downwardly against the score line upon lifting of the opposite end of the tab to thereby initiate rupture of the material of the can end along the score line 383 in a conventional manner. The tab 389, when lifted upwardly pivots about a hinge line which preferably extends intermediate the rivet and the adjacent portion of the chuck wall 389 in a conventional manner. As the rivet is located very close to the score line 383 and to the chuck wall 381 as permitted by the features of the present invention, the length of the tab from the hinge line to the nose end 391 can be materially reduced to significantly increase the mechanical advantage of the tab 389.

FIGS. 22-30

FIG. 22 illustrates a method of forming a dimple 400 in a sheet 402 of deformable materials by means of a punch, generally designated 404, and a cooperating die, generally designated 405. The die 405 has a cavity 406 with a transverse surface 408 of the die extending in all directions from the rim of the cavity. The rim of the cavity is formed with a chamfer 409, the surface of which is at an angle of 30° relative to the transverse surface 408. The punch 404 has a nose portion 410 and has a transverse surface 411 that extends in all directions from the root or base of the nose portion 410. The two transverse surfaces 408 and 411 are spaced substantially apart to keep from confining the sheet 402 in the regions surrounding the cavity.

When the nose portion 410 initially advances into the die cavity 406 it stretches the sheet material to the configuration of the nose portion and thus forms what may be termed a preliminary dimple. After the preliminary dimple is formed by stretching the metal in this manner, an annular surface of the leading end of the punch cooperates with a corresponding annular surface of the die cavity 406 to squeeze the preliminary dimple across the thickness of its wall in an annular zone that is designated "A" in FIG. 22. The die surfaces that cooperate in the squeezing operation are preferably at least in part of spherically curved configuration and both surfaces are inclined in general at an acute angle to the axis of the punch.

Just what portion of the dimple is converted into a rivet itself and what portion is converted into the adjacent portion of the container wall that surrounds the rivet depends upon the shape and dimensions of the rivet forming dies. In general, however, the annular zone "A" in FIG. 22 becomes a part of the container wall surrounding the rivet and at least a major part of the remaining central portion of the dimple that is designated "B" in FIG. 22 is converted into the rivet itself.

The squeezing of the sheet material across its thickness in the annular zone "A" causes the sheet material to flow or extrude towards the central zone "B" with consequent bulging of the central zone or peak portion of the dimple away from the nose of the punch 410. Thus an important advantage of squeezing the sloping wall of the dimple is that it occurs when the punch approaches maximum penetration into the die cavity and in the absence of the squeezing action would abruptly increase the tension of the sheet material with possible rupture of the sheet material. With the sheet material squeezed to such extent as to cause the sheet material to bulge in advance of the punch, however, the squeezing operation actually completely eliminates tensioning of the material of the dimple as the maximum offsetting of the sheet material is approached.

It is to be noted that the two dies shown in FIG. 22 provide an annular space 412 surrounding the nose portion 410, this annular space providing ample freedom for the squeezing action on the dimple to cause reverse flow or extrusion of the material in addition to the forward flow towards the peak of the dimple. The reverse flow of the material increases the height of the dimple and causes the surrounding sheet 402 to rise somewhat above the transverse die surface 408 as indicated by the gap 413. It is also to be noted that the edge of the rim formed by the chamfer 409 substantially prevents the punch from drawing the sheet material into the die cavity during the stretching stage of the die operation and thus prevents distortion of the surrounding portion of the sheet 402 to make it possible to locate the dimple close to the chuck wall of a can top. The chamfer is equivalent to a radius but has less tendency to tear the sheet material.

The described method of forming a dimple is highly advantageous in the manner in which it distributes the material of the dimple in preparation for the rivet-forming operation. The displacement of sheet material from the annular zone "A" into the central zone "B" where the rivet is to be formed increases the mass of the rivet with consequent increase in the strength of the rivet. The described method of forming the dimple is also advantageous in that the peak or crown of the dimple 400 is relatively thick, being thicker than the rest of the dimple and this relatively thick peak portion of the dimple is largely utilized for the end wall of the rivet. Using some of the increased mass of the rivet to thicken the end wall of the rivet reduces the die pressure that is necessary to stake the rivet into engagement with a pull tab and using some of the increased mass to increase the height of the rivet also reduces the required staking pressure.

A dimple produced in the heretofore conventional manner substantially solely by stretching the sheet material has a given area in plan and a given ratio of surface area to area in plan and is capable of producing a rivet of a given size and strength. Referring again to FIG. 22, the new method of fabricating the dimple has three results, namely, increase in the ratio of surface area to the plan area of the dimple; increase in the mass of the part of the dimple that ultimately forms the rivet; and the improved distribution of that mass to increase the strength of the rivet. With these three results in mind, it may be readily understood that the gains achieved by the new dimple-forming technique may be used in various ways.

The new technique may be applied to a dimple of the above-mentioned given area in plan to produce a rivet of greater size than the previously mentioned given rivet size, i.e., a rivet that is of greater height and/or greater diameter from a dimple of the above-mentioned given area. Or the new dimple-forming method may be utilized to produce a rivet of the previously mentioned given rivet size from a dimple of less than the previously mentioned given area in plan and thus make it possible to locate the rivet closer to the chuck wall of a can top.

Or the new technique with the resulting more efficient distribution of the mass of the rivet may be utilized to produce a strong rivet of less diameter than the diameter of the previously mentioned rivet of a given size from a dimple of substantially less area in plan than the previously mentioned given area in plan. Thus the new technique makes it possible to reduce the diameter of a hollow rivet in a beverage can top to a relatively small diameter in the range of less than three thirty-seconds of an inch and further makes it possible to locate such a rivet relatively close to the chuck wall of the can top.

As heretofore noted, the fact that the coacting squeezing surfaces of the dies in FIG. 22 are inclined at an acute angle to the axis of the punch results in reduction of the die pressure that is required to thin the wall of the dimple to a given degree, the rate of advance of the punch being low relative to the rate of displacement of the sheet material by the squeezing action.

It is contemplated that the set of dies shown in FIG. 22 will be capable of forming dimples in a selected list of sheet materials that vary widely in ductility, i.e., vary widely in the percentage of stretch of the sheet material that may be

tolerated without damaging the sheet material. For this purpose the set of dies shown in FIG. 22 is designed to stretch the sheet material within the minimum tolerance to stretch found in the selected list of sheet materials. The stretch tolerance of the sheet material no longer limits the height of the rivet. This feature of the invention makes it possible to employ a single set of dimple-forming dies successfully for a number of widely different sheet metal alloys in the selected list.

Heretofore it has been customary to design a set of dimple-forming dies to handle sheet material of a particular thickness, it being necessary to provide a number of different sets of dies to handle sheet material of a number of different thicknesses. In this regard, a feature of the set of dies shown in FIG. 22 is it may be used to process sheets of a wide range of different thicknesses, for example the range of thickness that might vary 0.003 plus or minus. The degree to which the set of dies enlarges a preliminary dimple configuration by the squeezing action depends upon the extent to which the punch penetrates the wall of the preliminary dimple. Thus to form a dimple in relatively thin sheet material the degree to which the punch approaches the cavity surface is increased and to make a dimple in thicker sheet material the extent to which the punch approaches the cavity surface is reduced.

In practice it is a simple matter to employ interchangeable shims to back up one of the two dies of the set so that to change from processing sheet material of one thickness to processing sheet material of a different thickness it is merely necessary to substitute one shim for another. In this regard it is to be noted that by virtue of the inclination of the coacting die surfaces, a given amount of axial adjustment of the coacting dies changes the extent to which the metal is squeezed by less than the given amount. In other words, the inclination of the coacting die surfaces reduces the criticalness of the die adjustment in addition to reducing the required die force or pressure.

FIGS. 23-27 show successive stages in the conversion of the dimple 400 of FIG. 22 into the hollow rivet 414 in FIG. 27 by a set of dies comprising a lower die 415 with a cylindrical cavity 416 and an upper punch 418. The lower die 415 has a transverse surface 420 that extends generally radially from the rim of the cavity 416 and this transverse surface includes an annular plateau 422 that surrounds the cavity and is formed with an annular sloping shoulder 424. The upper punch 418 has a nose portion 425 that is dimensioned to fit into the die cavity 416 with clearance for the wall of the rivet and the upper die has a transverse surface 426 that extends radially from the root or base of the nose portion.

At the start of the rivet-forming operation the dimple 400 seats on the rim of the die cavity 416 as shown in FIG. 23 with the sheet 402 parallel with the transverse surface 426 of the punch 418. In FIG. 24 illustrating an early stage in the closing movement of the two dies, the nose portion 425 of the punch is pushing the peak portion of the dimple into the die cavity 416 and the rim of the die cavity forms an annular shoulder 428 in the sloping wall of the dimple. In FIG. 25 where the nose portion is further advanced into the die cavity 416, a somewhat wider annular shoulder 430 is formed in the sloping wall of the dimple.

Throughout the rivet-forming operation from the start shown in FIG. 23 to the completed stage shown in FIG. 27, a pushing force created by the cooperation by the horizontal die surfaces 420 and 426 cooperates with a pulling force by the nose portion 425 that places the sheet material under tension as the sheet material progressively enters the die cavity 416. In effect the pushing force funnels the material of the dimple into the die cavity and the nose 426 acting against the peak portion of the dimple pulls the sloping circumferential wall of the dimple into the die cavity. The pushing and pulling forces must be correlated to avoid, on the one hand, tearing of the material by the punch and on the other hand to avoid wrinkling of the sheet material.

The manner in which the pushing force funnels the material of the dimple of the die cavity 416 may be understood by con-

sidering the forces involved. In FIG. 24 the arrow 432 represents a force which is the tremendous resistance to radial outward flow of the metal in the plane of the flat sheet 402 that surrounds the base of the dimple. The arrow 434 represents the closing force of the dies, i.e., the downward movement of the upper horizontal die surface 426 towards the lower horizontal die surface 420. The arrow 435 is the resultant of the two forces and it is to be noted that the inclination of the arrow at least approximates the inclination of the sloping wall of the dimple to minimize any tendency of the sloping wall to be buckled or folded by the resultant force.

FIG. 25 shows the same inclined force 435. A vertical arrow 436 represents the resistance to downward movement of the material that is offered by the lower die surface 420. The resultant of forces 435 and 436 is the horizontal radially inward force represented by the arrow 438 which drives the sheet material towards the brink of the die cavity 416. Since initially the dimple is bowed into the die cavity as shown in FIG. 23 and since the dimple is increasingly bowed into the die cavity, the consequence of the radially inward force 438 is a pronounced tendency for the material of the dimple to curl inwardly into the die cavity.

The fact that the pushing force tends to funnel the material of the dimple into the die cavity 416 may be demonstrated in the manner shown in FIG. 28 where a plain metal block 439 with a lower planar working surface 440 is substituted for the punch 418. When a dimple 400 is initially positioned on the lower die 415 in the manner shown in FIG. 23 and the dies shown in FIG. 28 are progressively closed, the result of the funneling of the material of the dimple into the die cavity 416 is the formation of an inadequate hollow rivet 442 which is too low in height to serve the purpose of attaching a pull tab to a tear strip. It is apparent that to the extent that the cooperating transverse surfaces 426 and 420 of the dies shown in FIGS. 23-27 tend to form the hollow rivet 442 shown in FIG. 28, the burden placed on the nose portion 425 of the punch 418 to stretch the sheet material is correspondingly reduced.

With this explanation of the mode of operation of the rivet-forming dies shown in FIGS. 23-27, a person skilled in the art can readily design an effective die set empirically by simply starting with a die set that would seem to be capable of obtaining the desired result and then changing the shapes and dimensions of the die parts to arrive at a final design by cut and try. A good procedure is first to arrive at a dimple configuration and a lower die configuration which will produce the result shown in FIG. 28 in the absence of the upper punch. Once the result shown in FIG. 28 is obtained a punch with a nose portion dimensioned in accord with the die cavity size will produce the desired rivet.

As heretofore explained, the squeezing of the material of a dimple in an annular zone "A" creates an abrupt shoulder or change in the thickness of the sheet material at the base of the dimple and since, as indicated in FIG. 27, the area "A" becomes the portion of the container wall that surrounds the base of the dimple, the abrupt change in thickness of the sheet material of the dimple at the outer circumference of the annular area "A" produces an abrupt annular shoulder in the sheet material, the location of the annular shoulder being indicated at 444 in FIG. 23. The function of the sloping annular shoulder 424 of the lower die 415 is to reduce the abruptness of the annular shoulder in the manner heretofore explained. Thus at the completion of the rivet-forming operation the annular wall of the container surrounding the base of the rivet has a gradual change in thickness that is determined by the inclination of the annular die shoulder 424.

The finished rivet shown at 414 in FIG. 27 has an axial dimension or height of 0.080 of an inch which is determined by the axial dimension 445 of the nose portion 425 of the punch and which is greater than the axial dimension of a conventional rivet formed in the conventional manner. FIG. 29 shows how the rivet 414 shown in FIG. 27 may be staked into engagement with a surrounding pull tab 448 of an easy-opening can top. The lower die 450 in FIG. 29 has an anvil portion

452 that nests into the underside of the rivet to give support to the circumferential wall 454 of the rivet within the planes that are defined by the tab 448 and the can top 402. The upper die has a punch 455 of substantially greater diameter than the rivet which cooperates with the lower die to stake the rivet, i.e., to form an annular bead 456 in overhanging engagement with the rim of the circular opening 458 in the pull tab.

The increased height of the rivet 416 that results from the process illustrated by FIGS. 22-27 greatly reduces the downward force required by the punch 454 to stake the rivet. As heretofore stated the increased height of the rivet makes it possible to form the bead 456 in part by outward bulging and collapse of the circumferential wall of the rivet and obviously less force is required to form a bead in part by such folding of the metal than is required to form the bead solely by squeezing the end wall 460 of the rivet to extrude the end wall material radially outwardly. The staking operation does squeeze the end wall of the rivet for radially outward extrusion of the end wall material but only a relatively small amount of metal need be extruded and it takes less force to create the required amount of radial extrusion in a relatively thick end wall than in a relatively thin end wall. If sheet metal of a starting thickness of 0.0135 of an inch is reduced by the staking operation to the usual residual thickness of 0.004 the die pressure rises tremendously at the end of the die stroke. The end wall 460 of the rivet in FIG. 29 has a liberal residual thickness of at least 0.007 and a further advantage is that the outside diameter of the bead 456 is 0.156 of an inch instead of the usual 0.150 of an inch.

A special advantage of the described rivet-forming operation is that the dies shown in FIGS. 23-27 may be used for sheet metal varying from a given thickness by 0.003 of an inch plus or minus with no change other than change in the shut height to which the dies close.

Because of the helpful funneling action on the dimple of the transverse surfaces of the rivet-forming dies as exemplified by FIG. 28, the axial dimension of the nose portion of the upper punch of the rivet-forming dies may be even greater than shown in FIG. 27 to produce a rivet of even greater height than the rivet 414. FIG. 30, for example shows a nose portion 464 of an axial dimension 465 that is greater than the axial dimension 445 to result in a rivet 466 of a height of approximately 0.110 of an inch. Increasing the height of the rivet in this manner while still producing a rivet of adequate strength even further reduces the amount of the die pressure that is required in the staking operation.

The importance of the invention has been emphasized with reference to the dies and punch presses that may be employed for mass production of the end walls of easy-opening containers. It is also to be emphasized that the invention minimizes the causes of damage to the seal coat on the inner surface of the sheet metal. Exposure of a minute area of the metal can spoil the flavor of a beverage and for this reason it is conventional practice to "postseal" the can ends, i.e., apply additional seal coating on the inner coated side of the can ends along the score lines and inside the staked hollow rivets. It is a simple matter to postcoat the scored areas but postcoating the inner surfaces of the staked heads of the rivets is difficult and is a problem in high-speed production.

The most important feature of the invention for minimizing damage to the seal coat is the reduction in the pressure of the dies across the thickness of the sheet material in the step of staking the hollow rivet. As heretofore pointed out the usual exponential rise in pressure across the end wall of the rivet as the reduction in thickness of the end wall approaches 0.004 of an inch is avoided and the necessary pressure is reduced 50 percent by increasing the height of the rivet so that the staking or radial expansion of the bead of the rivet may be accomplished largely by collapsing the circumferential wall of the rivet instead of largely by radial extrusion of the metal of the end wall.

The staking procedure illustrated by FIGS. 15 and 16 is especially advantageous in converting the sealing efficiency of

the inner coat. In the first stage of the operation, the dome-shaped end wall of the rivet is flattened against the lower punch by spring pressure instead of by the relentless pressure of the press. Throughout the second stage the clamping of the end wall between the two punches effectively protects the end wall seal coat and at the same time the retracting lower punch effectively reinforces the hollow rivet against inward collapse. In the final stage of the operation the end wall of the rivet is only slightly thinned by squeezing action and it is especially advantageous that the actual metal-to-metal collision is remote from the seal coat since it occurs between the bottom of the lower punch 203 and the fixed lower wall 211 of the recess 204. Thus the final slight thinning of the end wall of the rivet is accomplished merely by a terminal rise of the sustained pressure across the thickness of the end wall.

In the described procedure for forming the rivet shown in FIG. 16, all of the bends in the inner seal coat of the rivet are moderate rounded bends well within the elastic limits of the seal coat. The only sharp bend in the seal coat is the 180° bend in the inner circumferential region of the bead of the rivet and it can be seen that this region is effectively isolated by an annular sealing zone where the inner coat makes face-to-face sealing contact with itself.

With proper care in the design and operation of the dies involved, the various expedients to conserve the integrity of the seal coat can eliminate the necessity for postsealing the interior of the finished rivet.

My description in specific detail of the selected practices of the invention will suggest various changes, substitutions and other departures from my disclosure within the spirit and scope of the invention.

I claim:

1. In a method of making a hollow rivet, the steps of: providing a section of deformable sheet material; deforming a portion of said section of sheet material to form a bubble having a sloping wall section of progressively substantially decreasing thickness as said wall section extends toward a central region of the bubble; and reforming said bubble into a hollow rivet having a peripheral wall and a transverse end wall by converting said central region into at least a portion of said transverse end wall of the rivet and by converting at least a portion of said sloping wall section into at least a portion of said peripheral wall of the rivet whereby the relatively thick portion of said sloping wall section of said bubble supports the thinner portion of said sloping wall section during the reforming of the bubble to thereby give the rivet substantial height.
2. A method as defined in claim 1 wherein said step of reforming includes displacing the material from an annular zone immediately surrounding said rivet inwardly into the peripheral wall of said hollow rivet.
3. In a method of making a hollow rivet, the steps of: providing a member of deformable sheet material; offsetting a portion of said member to form a dimple having a base, a central region, and a wall surrounding said central region extending toward said base; progressively thinning at least a portion of said wall between cooperating die members to cause the material of said portion of said wall to flow so that said wall is relatively thin adjacent the central region of the dimple and is progressively thickened as it extends outwardly thereof; and reforming said dimple into a hollow rivet having a peripheral wall and an end wall.
4. A method as defined in claim 3 wherein said step of reforming includes converting said central region into at least a portion of said end wall of the hollow rivet, converting at least a portion of said wall of said dimple into at least a portion of said peripheral wall of the rivet, and displacing a portion of the deformable material around the base of the rivet into said peripheral wall of the rivet.

5. A method as defined in claim 3 wherein said central region is not thicker than the thickness of the portion of the wall of the dimple immediately thereadjacent.

6. In a method of making a hollow rivet, the steps of: providing a member of deformable material; offsetting a portion of said member to form a dimple having a base, a central region, and a wall section surrounding said central region and extending outwardly thereof; squeezing said wall section between cooperating die members to cause at least a portion of the material of said wall section to flow toward the central region to increase the thickness thereof so that the central region is thicker than the portion of the wall section immediately thereadjacent; and reforming said dimple into a hollow rivet having a peripheral wall and a relatively thick transverse end wall by converting the central region of the dimple into at least a portion of the transverse end wall and by converting at least a portion of the wall section of the dimple into at least a portion of said peripheral wall.

7. A method as defined in claim 6 wherein the material that flows toward the central region forms a generally axially extending protruding projection at the central region.

8. In a method of forming a hollow rivet in a member of deformable sheet material, the steps of:

deforming a section of said member to form a dimple having a base, a central region, and a wall section surrounding said central region and extending away from said central region toward said base, said wall section being of minimum thickness adjacent the central region and progressively increasing in thickness as it extends away from said central region, said central region having an inner surface spaced a predetermined distance from the plane of said member; and reforming said dimple into a hollow rivet having a peripheral wall and a transverse end wall with the inner surface of the transverse end wall being at least at said predetermined distance from the plane of said member while preventing said peripheral wall and said transverse end wall from having thicknesses materially less than said minimum thickness.

9. In a die set for forming a hollow rivet in a member of deformable material, the combination of:

a female die having an exterior face and a sloping surface, said sloping surface defining a die cavity extending a predetermined distance into said female die and opening at said exterior face; and

a cooperating male die having a sloping working surface adapted to be at least partially received within said die cavity, the member of deformable material being positionable between said die cavity and said working surface, said working surface being movable toward said member to offset a portion of the member into said female die to form a dimple having a sloping wall between said sloping surface and said working surface, the working surface of said male die and the sloping surface of said female die tapering away from each other as they extend toward said exterior face of said female die when said working face is at least partially received within said recess whereby continued movement of said working surface causes progressive thinning of the sloping wall.

10. In a method of making a hollow rivet, the steps of: providing a section of deformable sheet metal of predetermined thickness;

deforming a portion of said section of sheet metal to form a bubble having a base and a sloping wall surrounding a central region of the bubble;

causing the sheet metal at said central region of the bubble to be of greater thickness than the portion of said sloping wall section immediately surrounding the central region by extruding at least some of the metal of the sloping wall so that the sloping wall is thinner adjacent the central region than adjacent the base and to cause a portion of the

metal of the sloping wall to flow toward the central region; and

reforming said bubble into a hollow rivet having a peripheral wall and a transverse end wall by converting said central region into at least a portion of said transverse end wall of the rivet whereby the transverse end wall is of substantial thickness and by converting at least a portion of said sloping wall section into at least a portion of the peripheral wall of the rivet.

11. In a method of making a hollow rivet from deformable sheet material, the steps of:

offsetting a portion of the sheet material to form a dimple having a dimple wall, a base and a central region with the dimple wall protruding outwardly from a surrounding zone of sheet material;

squeezing at least a section of the dimple wall while the dimple wall protrudes outwardly from the surrounding zone to displace at least some of the material of said section to thereby influence the configuration of the dimple; and reforming the dimple into a hollow rivet.

12. A method as defined in claim 11 wherein said step of squeezing is carried out by die members and each of said die members has a generally spherical portion for squeezing said section of the dimple wall whereby said dimple is generally bowl-shaped and has a general spherical portion.

13. A method as defined in claim 11 wherein said dimple has a central cap surrounded by an annular protrusion, said central cap containing a central region of the dimple and said section of the dimple wall with the latter extending outwardly from said central region toward the annular protrusion to an area adjacent said annular protrusion.

14. A method as defined in claim 11 wherein said step of squeezing includes displacing the material of the dimple wall so that the dimple wall is thinner adjacent the central region of the dimple that adjacent the base of the dimple.

15. A method as defined in claim 11 wherein said step of reforming is carried out subsequent to said step of squeezing.

16. A method as defined in claim 11 wherein said section of the dimple wall lies intermediate the base and the central region of the dimple.

17. In a method of making a hollow rivet from deformable sheet material, the steps of:

providing a die having a surface defining a die cavity and a punch having a working surface;

relatively advancing said punch and said die toward each other to forcibly engage the sheet material and force a portion of the sheet material into the die cavity to form a dimple having a dimple wall and a central region;

continuing said step of relatively advancing to squeeze at least a section of the dimple wall between said surfaces to extrude some of the material thereof toward the central region of the dimple; and

reforming the dimple into a hollow rivet.

18. A method as defined in claim 17 wherein the squeezing of the section elongates the dimple wall and increases the axial dimension of the dimple and including the step of allowing a zone of the sheet material surrounding said die cavity to move away from said die during the squeezing of the dimple wall, whereby the increase in the axial dimension of the dimple forces the material of said zone away from the die.

19. A method as defined in claim 7 wherein said surface of said die has a recess therein disposed generally axially within said die cavity and the squeezing of said dimple wall causes a portion of the material of the dimple wall to flow into the recess to form an outwardly extending projection on said dimple, said projection being thicker than the portions of said wall section immediately thereadjacent.

20. A method as defined in claim 17 wherein said surface of the die and said working surface taper away from each other when said punch is advanced into said die cavity whereby the squeezing of said dimple wall between said surface of the die and said working surface progressively thins said dimple wall so that the dimple wall is relatively thin adjacent the central

region and progressively increases in thickness as it extends away from said central region.

21. In a method of securing a tab having an aperture therethrough to a container wall of sheet material, the steps of:

deforming a portion of the container wall to form a bubble having sloping wall section and a central region;

forcibly engaging at least a portion of the sloping wall section between cooperating die surfaces to extrude at least some of the material thereof along said die surfaces toward the central region, without deforming said portion into the plane of the container wall;

reforming said bubble into a hollow rivet;

forming a line of weakness in the container wall adjacent the hollow rivet to define a segment of the container wall at least partially removable therefrom;

placing the tab over the hollow rivet with the rivet extending through the aperture; and

heading the rivet to securely clamp the tab to the container wall.

22. A method as defined in claim 21 wherein said step of forcibly engaging displaces the material of the wall section so that said wall section is of maximum thickness adjacent the base thereof and of lesser thickness adjacent a central region of the dimple.

23. In a method of making a hollow rivet from deformable sheet material the steps of:

offsetting a portion of the sheet material to form a dimple having a central region and a sloping dimple wall which slopes with respect to a region of the sheet material surrounding the dimple;

applying a compressive force to at least a section of said sloping dimple wall with such force being sufficient to cause flow of at least some of the material of said section generally toward the central region of the dimple;

said step of applying being carried out with said section of the sloping dimple wall sloping relative to said region which surrounds the dimple and without deforming said section of the sloping dimple wall into the plane of said surrounding region whereby said section of the dimple wall continues to form a portion of the dimple during said step of applying; and

reforming the dimple into a hollow rivet.

24. A method as defined in claim 23 wherein said compressive force is applied by coacting die surfaces each of which slopes relative to said region of sheet material surrounding the dimple.

25. In a method of making a high dimple from sheet material without fracturing the sheet material, the steps of:

providing a die having a die surface defining a die cavity and a punch having a sloping working surface at least partially receivable in the die cavity;

relatively advancing said punch and die to offset a portion of the sheet material into said die cavity to form a dimple having a base, a central region and a sloping wall with the dimple being surrounded by a surrounding zone of the sheet material which lies outside of said die cavity and with the sloping dimple wall protruding outwardly from said surrounding zone;

forcibly engaging at least a section of said sloping dimple wall between coacting compression surfaces to apply a compressive force to said section with said compressive force being sufficient to cause flow of at least some of the material of said section along said compression surfaces to cause said sloping dimple wall to assume a predetermined configuration;

said step of forcibly engaging being carried out with said section of the sloping dimple wall sloping relative to said surrounding zone and without deforming said section of the sloping dimple wall into the plane of said surrounding region whereby said section of the sloping dimple wall is surrounded by said surrounding zone of sheet material.

26. A method as defined in claim 25 wherein said step of relatively advancing includes relatively advancing said punch and die a predetermined amount, said compression surfaces including said working surface and said die surfaces, and said step of forcibly engaging includes continuing said step of relatively advancing to squeeze the dimple wall between said working surface and said die surface to apply said compressive force to said section of said sloping wall.

27. A method as defined in claim 25 wherein said step of forcibly engaging displaces the material of the sloping dimple wall so that said sloping dimple wall is of maximum thickness adjacent the base thereof and of lesser thickness adjacent the central region of the dimple.

28. A method as defined in claim 25 wherein said surrounding region is not rigidly restrained immediately adjacent said die cavity and said step of forcibly engaging causes at least some of the material of said section of said sloping wall to flow toward the base of the dimple to thereby move the base of the dimple away from said die cavity whereby the axial dimension of the dimple is increased.

29. In a method of making a hollow rivet of deformable sheet material wherein the sheet material in a circumscribing zone at least partially surrounding the rivet is thinned as a result of the formation of the rivet and the sheet material in an area outside of the circumscribing zone and adjacent thereto is thicker than the sheet material of the circumscribing zone thereby resulting in a relatively abrupt change of thickness of the sheet material between the area and the circumscribing zone, the improvement to prevent fracture of the sheet material as a result of scoring through the area and the circumscribing zone comprising the step of:

squeezing the sheet material of an inner region of said area adjacent the circumscribing zone between coacting die members to displace at least some of the sheet material of said inner region to gradually reduce the thickness of said inner region as it extends toward the rivet without materially increasing the axial dimension of the rivet and to convert said inner region into a tapered transition section joining the circumscribing zone to the outer region of the area without any abrupt changes of thickness of the sheet material.

30. A method as defined in claim 29 wherein each of said die members has an outer annular region with the outer annular regions of said die members being generally confronting and tapering away from each other as they extend radially outwardly, said outer annular regions of the die members engaging the inner region of said area during said step of squeezing, each of said die members also including cooperating surface portions for engaging the circumscribing zone therebetween during said step of squeezing to smooth out the sheet material of the circumscribing zone to prevent any abrupt change of thickness therein.

31. In a method of making a hollow rivet from deformable sheet material, the steps of:

forming a dimple in the sheet material having a dimple wall of lesser thickness than the original thickness of the sheet material and with the sheet material of an area surrounding the dimple wall being of substantially said original thickness;

reforming the dimple to convert the dimple into a hollow rivet having lesser area in plan than said dimple and to convert a peripheral region of the dimple wall into a circumscribing zone at least partially surrounding the hollow rivet with such circumscribing zone of the dimple wall having a lesser thickness than the original thickness of the sheet material; and

displacing some of the sheet material from said area adjacent the circumscribing zone to gradually reduce the thickness of the sheet material in a region of said area adjacent the circumscribing zone to thereby taper said region of said area to avoid any abrupt change in thickness of the sheet material between said areas of the circumscribing zone as a result of formation of the rivet.

32. A method as defined in claim 31 wherein said step of displacing includes squeezing the sheet material of the circumscribing zone between coacting die members to iron out the sheet material so squeezed to thereby further guard against abrupt changes in thickness of the sheet material as a result of formation of the rivet.

33. In a method of fabricating an easy-opening container in which a container wall of deformable material is scored along a line defining a tear strip and a tab is attached to the tear strip by a hollow rivet formed in the tear strip and wherein the hollow rivet is formed by first forming in the container wall a dimple and then a central portion of the dimple is converted into the rivet with the remaining outer annular portion of the dimple forming a wall portion adjacent the rivet that is crossed by the line of scoring,

the improvement comprising:

forming the dimple by attenuating the container wall in part by stretching the wall material and in part by squeezing the wall material across its thickness with consequent formation of a shoulder in the region of said outer annular portion of the dimple where the thickness of the wall material is changed abruptly by the squeezing operation;

forming said central portion of the dimple into the rivet and forming the outer annular portion of the dimple into said wall portion adjacent the rivet in one operation and in the same operation subjecting said wall portion to pressure across its thickness to reduce the abruptness of said shoulder thereby to permit the wall portion to be scored across the shoulder without rupture of the wall material at the shoulder.

34. An improvement as set forth in claim 33 in which a punch is employed to offset a portion of the container wall into a die cavity to form the dimple and the punch cooperates with a surface of the die cavity to squeeze the wall material and the squeezing action is carried out with sufficient attenuation of the wall material to cause the wall material to bulge away from the nose of the punch.

35. A method of forming a dimple of a desired configuration in a sheet of deformable material characterized by the steps of:

placing the sheet material across a die cavity;

advancing a punch against the sheet material to offset the sheet material into the die cavity with consequent attenuation of the sheet material by stretching; and

continuing the advance of the punch relative to the cavity to cause an annular portion of the punch to squeeze the dimple wall across its thickness against the surface of the cavity for further attenuation of the sheet material, the squeezing action extruding the sheet material to the extent of causing the dimple to bulge beyond the nose of the punch to increase the area of the dimple.

36. In means to form a dimple in a sheet of deformable material wherein the dimple is formed by a punch making a stroke to offset the sheet material laterally of its plane into a die cavity.

the improvement to reduce the tendency of the punch to damage the sheet material by excessively stretching the sheet material, comprising:

the punch and the die cavity having respective surfaces at acute angles to the axis of the punch formed to cooperate to squeeze the sheet material progressively in response to approach of the punch to the end of the stroke to cause extrusion of the sheet material in the direction of the punch travel and thus curtail stretching of the sheet material by the punch.

37. In a method of forming a hollow rivet in a sheet of deformable material by first forming a minor portion of the sheet into a dimple in the sheet and then reforming the dimple to the desired rivet configuration, wherein the amount of material for the rivet provided by a dimple of a given area in plan depends on the ratio of the surface area to the plan area of the dimple and if the dimple is formed by stretching the sheet material within the tolerance of the material a dimple of

a given area in plan with a given area ratio is required to form a rivet of adequate strength of a given size,

the improvement to increase the area ratio of the dimple to make possible the formation of a rivet of adequate strength of said given size by means of a dimple of less than the given area in plan or to make possible the formation of a rivet of adequate strength of larger than said given size by means of a dimple of said given area in plan, comprising:

attenuating said minor portion of the sheet by stretching the minor portion within the tolerance of the sheet material; and

additionally attenuating the minor portion of the sheet by squeezing the sheet across its thickness in a zone of the minor portion to extrude the sheet material out of the zone.

38. An improvement as set forth in claim 37 in which the stretching step is carried out by first forming an initial dimple of a particular area ratio and then the squeezing step is carried out to convert the initial dimple into a dimple of a higher area ratio.

39. An improvement as set forth in claim 38 in which the wall of the initial dimple slopes at an acute angle to the axis of the dimple and the squeezing step is carried out at least in part in an annular zone of the sloping wall.

40. An improvement as set forth in claim 38 in which the initial dimple is formed by offsetting a portion of the sheet into a die cavity;

and in which the squeezing step is carried out by a punch positioned inside the preliminary dimple to squeeze the material of the preliminary dimple against the inner surface of a die cavity.

41. An improvement as set forth in claim 38 in which the initial dimple is formed by advancing a punch into a die cavity to stretch the sheet by pushing a portion of the sheet laterally into the die cavity; and

in which the squeezing step is carried out by continuing to advance the punch into the die cavity to squeeze the wall of the dimple between the surface of the punch and the surface of the cavity.

42. An improvement as set forth in claim 41 in which the squeezing step is carried out by squeezing an annular portion of the preliminary dimple against an annular portion of the surface of the cavity.

43. An improvement as set forth in claim 42 in which the squeezing step is carried out both to extrude the sheet material towards the peak of the dimple and to extrude the sheet material in the opposite direction out of the die cavity to increase the height of the dimple by two opposite directions of extrusion.

44. An improvement as set forth in claim 37 in which the squeezing step is applied to a portion of the dimple to provide a pattern of thickness variation across the cross section of the dimple that results in a pattern of thickness across the cross section of the rivet to make the rivet stronger than a rivet of the same size that is produced without the squeezing operation.

45. A set of dies to form dimples or the like in sheets of various deformable materials, the tolerance of the various materials to stretch lying within a given range, comprising:

a die with a cavity therein; and

a punch shaped and dimensioned to force a portion of the sheet material into the cavity to stretch said portion to form an initial dimple and then to cooperate with the die by squeezing the wall of the dimple against the surface of the cavity to cause flow of the wall material to increase the size of the initial dimple,

said die and punch being shaped and dimensioned to form an initial dimple of a size that requires stretching of the sheet material within the minimum tolerance of said range so that the die and punch may be used to form dimples in all of said various deformable sheet materials.

46. In the fabrication of easy-opening containers having pull tabs attached to tear panels by hollow rivets formed in the tear panels, a method of forming dimples in sheets of deformable material for subsequent conversion into the hollow rivets, the thicknesses of said sheets lying within a given range of thicknesses,

characterized by the steps of:

providing a die with a cavity therein having an annular portion with a surface at an acute angle relative to the axis of the cavity;

providing a cooperative punch dimensioned to enter the cavity and force the sheet material into the cavity to form a preliminary dimple,

said punch having an annular portion to cooperate with said annular portion of the die cavity to squeeze the wall of the preliminary dimple across its thickness for extrusion of the wall material to increase the size of the dimple; and

varying the extent to which the die and punch approach each other by increasing the extent when a changeover is made from sheet material of a given thickness to sheet material of a lesser thickness and decreasing the extent when a changeover is made from sheet material of a given thickness to sheet material of greater thickness,

whereby the single set of die and punch may be used for all sheets of said given range of thicknesses.

47. In the operation of a multiple-station press for progressively fabricating easy-opening can ends having pull tabs attached to tear panels by hollow rivets formed in the tear panels,

wherein dimples of a given ratio of surface area to plan areas are conventionally formed in the can ends substantially solely by stretching the material of the can ends within the tolerance of the sheet material at one of the press stations, the dimples are conventionally reformed into hollow rivets of a given size by a set of dies at another station of the press, and the hollow rivets are staked into engagement with the tabs at still another station of the press,

the improvement to lower the total of the die pressures at the stations of the press thereby to permit a relatively light press to be used at a relatively low investment cost, comprising:

providing a punch at said one station to force the sheet material into the cavity to stretch the sheet material to form a preliminary dimple therein and then to squeeze the wall of the preliminary dimple against the surface of the cavity to cause extrusion flow of the sheet material to convert the preliminary dimple into a larger final dimple, said punch and die cavity having cooperative squeezing surfaces inclined at acute angles to the axis of the punch to cause the rate of the squeezing of the sheet material to be low relative to the rate of die travel and thus require relatively low die pressures.

48. An improvement as set forth in claim 47 in which the squeezing step is carried out to give the final dimple a ratio of surface area to plan area greater than said given ratio thereby to increase the material available for forming the hollow rivet; and

which includes providing a set of dies at said another station of the press to take advantage of the increase in available material by forming rivets higher than rivets of said given size with consequent reduction in the pressure required to stake the rivets at said still another station.

49. An improvement as set forth in claim 47 in which the final dimple has a peak portion surrounded by an annular sloping wall;

in which said another station of the press is equipped with a die having a cavity of the cross section of the desired rivet with a surface extending laterally in all directions from the rim of the cavity;

and in which said another station of the press is further equipped with a punch having a nose portion with a surface extending laterally in all directions from the base of the nose portion,

said cavity and said lateral surfaces being shaped and dimensioned relative to the dimple to force material of the dimple into the cavity with a funneling action in the absence of the nose portion to such extent as to form a shortened hollow rivet in the cavity in such absence, whereby the rivet is formed in part by pushing of the material into the cavity by cooperation of said lateral surfaces and the rivet is formed in further part by the nose portion of the punch acting on said peak portion of the dimple to pull said annular sloping wall into the cavity.

50. In an apparatus for fabricating a hollow rivet in a sheet of deformable material wherein a first set of dies forms a dimple of a given configuration in the sheet and a second set of dies including a die with a cavity therein together with a punch cooperative with the cavity reforms the dimple into the hollow rivet, the improvement comprising:

said die of the second set of dies being shaped and dimensioned to cause the dimple to be converted into a hollow rivet of inadequate axial dimension in the die cavity when a block of larger area than the cavity is substituted for the punch,

whereby the punch is relieved of a portion of the burden of forcing the material of the dimple into the die cavity thereby to reduce the stretching of the material by the punch and to make possible the formation of a rivet of increased axial dimension.

51. In a method of forming a hollow rivet in a sheet of deformable material wherein a dimple is formed in the sheet and then the dimple is reformed to utilize a central portion of the dimple to form the rivet and to utilize the surrounding annular portion adjacent the base of the dimple to form the wall that extends radially from the base of the rivet,

the improvement to increase the strength of the rivet, comprising:

squeezing said annular portion of the dimple across the thickness of the dimple wall prior to the reforming step to displace material from the annular portion into the central portion to increase the mass of material in the subsequently formed rivet.

52. In a method of forming a hollow staked rivet in a sheet of deformable material to attach an apertured sheet metal member to the sheet wherein an initial step is to form a dimple in the sheet, a subsequent step is to reform the dimple into a hollow rivet and a still later step is a staking step to form a circumferential bead around the head of the rivet in engagement with said sheet metal member, the staking step including a final operation of thinning the end wall of the rivet by squeezing the end wall across its thickness,

the improvement over conventional rivet-forming methods for the purpose of reducing the degree to which the end wall of the hollow rivet is reduced in thickness by the staking operation and for the further purpose of reducing the damage to any seal coat that may be present on the inner surface of the rivet, comprising:

increasing the surface area of the dimple relative to its area in plan in comparison to the surface areas of conventional dimples relative to their areas in plan by attenuating the sheet material to form the dimple not only by deforming the sheet material in a conventional manner but also by squeezing the sheet material across its thickness to increase the height of the dimple;

utilizing the consequent increased size of the dimple to form a hollow rivet of greater height relative to the area in cross section of its midsection than the height of conventional rivets relative to the areas in cross section of their midsections;

placing the apertured sheet metal member on the hollow rivet;

and then staking the rivet of increased height to provide it with an overhanging circumferential bead by first collapsing the rivet to the height of a conventional rivet, thereby taking advantage of its exceptional height to form the major part of the desired bead and then only slightly thinning the transverse end wall of the rivet by squeezing the end wall across its thickness to complete the bead.

53. An improvement as set forth in claim 52 which includes the step of blocking bulging of the material of the rivet beyond the plane of the end wall during the collapsing of the rivet.

54. An improvement as set forth in claim 52 which includes the step of internally reinforcing the rivet throughout substantially the full length of the circumferential wall of the rivet and throughout substantially the whole collapsing step to prevent radially inward collapse of the circumferential wall of the rivet.

55. An improvement as set forth in claim 52 in which the step of axially collapsing the rivet is carried out by first clamping the end wall of the rivet across its thickness under pressure and, while still clamping the end wall, forcibly moving it axially of the rivet towards the base of the rivet.

56. An improvement as set forth in claim 55 in which the thinning of the end wall is accomplished by increasing the clamping pressure on the end wall after the rivet is collapsed.

57. An improvement as set forth in claim 52 in which the step of forming the dimple is carried out by closing a male die and a cooperating female die that has a cavity to receive the formed dimple:

and in which the two dies respectively have surfaces cooperative to squeeze the sheet material for extrusion of the sheet material to increase the surface area of the dimple relative to its plan area.

58. An improvement as set forth in claim 52 in which the step of staking the rivet includes:

placing a first die inside the rivet against the inner surface of the end wall thereof;

placing a second die against the outer surface of the end wall of the rivet;

urging the two dies toward each other to clamp the end wall of the rivet under pressure across its thickness;

moving the two dies simultaneously toward the base of the rivet to collapse the rivet to a desired height by moving the clamped end wall towards the base of the rivet;

and then moving one of the two dies towards the other of the two dies to thin the end wall of the rivet.

59. A method of staking a hollow rivet of deformable sheet material to provide the rivet with an overhanging circumferential bead, including the steps of:

placing a first die inside the rivet against the inner surface of the end wall thereof;

placing a second die against the outer surface of the end wall of the rivet;

urging the two dies toward each other to clamp the end wall of the rivet under pressure across its thickness;

moving the two dies simultaneously toward the base of the rivet to shorten the rivet by collapsing the rivet to a desired height by moving the clamped end wall towards the base of the rivet;

and then moving one of the two dies towards the other of the two dies to thin the end wall of the rivet.

60. A method of staking a hollow rivet of deformable sheet material to provide the rivet with an overhanging circumferential bead, including the steps of:

placing a first die outside of the rivet in position confronting the outer surface of the end wall of the rivet;

placing a second retractable die inside the rivet in extended position confronting the inner surface of the end wall of the rivet, with the second die urged by spring pressure to its extended position;

advancing the first die towards the second die to cooperate with the second die to clamp the end wall under pressure and to retract the clamped end wall in opposition to spring pressure to collapse the rivet to a selected height and thereby to form the major part of the desired bead;

and then stopping the retraction of the second die and continuing the advance of the first die to squeeze and thin the end wall to complete the said bead.

61. A method as set forth in claim 58 in which the second die is dimensioned to prevent inward collapse of the rivet.

62. A method as set forth in claim 58 in which the leading face of the first die overhangs the end wall of the rivet to

prevent the material of the rivet from bulging past the plane of said leading face.

63. In the processing of a hollow rivet having circumferential wall and a transverse end wall, means to stake the hollow rivet by forming a continuous bead around the circumference of the rivet, comprising:

a first die having a leading face to contact the outer surface of the end wall of the hollow rivet;

a second retractable die to advance into the hollow rivet into contact with the inner surface of the end wall of the rivet;

a second retractable die to advance into the hollow rivet into contact with the inner surface of the end wall of the rivet;

spring means to urge the second die to advance;

means to advance the first die a predetermined distance to cause the first die to cooperate with the second die to clamp the end wall of the rivet under the pressure of the spring means and to retract the clamped end wall to collapse the rivet, thereby to form the major portion of said bead; and

means to stop the retraction of the second die before the advance of the first die is completed, thereby to cause the first die to cooperate with the second die to thin the end wall of the rivet thereby to complete said bead.

64. Means to stake a hollow rivet as set forth in claim 63 in which the second die is dimensioned to prevent radially inward collapse of the rivet.

65. Means to stake a hollow rivet as set forth in claim 64 in which the leading face of the first die overhangs the end wall of the rivet to prevent the material of the rivet from bulging past the plane of said leading face.

66. In the processing of a hollow rivet having circumferential wall and a transverse end wall, means to stake the hollow rivet by forming a continuous bead around the circumference of the rivet, comprising:

two dies to clamp the end wall of the rivet under pressure;

means to move the two dies simultaneously to retract the end wall towards the base of the rivet to collapse the rivet to a predetermined height and thereby form the major portion of said bead; and

means to increase the pressure of the two dies on the end wall of the rivet when the rivet is collapsed thereby to thin the end wall to complete said bead.

67. In an apparatus to form a dimple in sheet material in preparation for forming a hollow rivet in the sheet material, the combination of:

first die means including a die with a cavity;

second die means including a punch to force the sheet metal into the cavity for the purpose of forming the dimple,

the punch and the die cavity having respective surfaces

formed to cooperate to squeeze the sheet material in response to approach of the punch to the end of its stroke to cause extrusion of the sheet material and thus curtail stretching of the sheet material by the punch; and

means provided by at least one of the two die means to substantially prevent the punch from drawing the sheet material into the die cavity thereby to substantially prevent distortion of the sheet material adjacent to the die cavity.

68. A combination as set forth in claim 67 in which the means to substantially prevent the punch from drawing the sheet material into the cavity comprises a chamfer around the rim of the cavity.

69. A combination as set forth in claim 67 in which the die with the cavity therein has a surface surrounding the cavity that is at an angle of 90° relative to the axis of the punch;

and in which the means to substantially prevent the punch from drawing the sheet material to the die cavity comprises a chamfer around the rim of the cavity, the chamfer being at an angle of substantially 30° relative to the said surrounding surface.

70. In an apparatus to form a hollow rivet in a sheet of deformable material, the combination of:

first die means including a pair of coactuating dies to form a dimple in the sheet, one of said dies having a cavity, the other of the dies being a punch to enter the cavity with consequent initial stretching of the sheet, the punch and die cavity being shaped and dimensioned to squeeze and thin a portion of the sheet in an annular zone in the base region of the dimple; and

second die means including dies cooperative to form the dimple into a hollow rivet, the second pair of dies being shaped and dimensioned to position substantially all of said annular thinned zone outside of the rivet.

71. A combination as set forth in claim 70 in which the die with said cavity therein is formed with a bore at the bottom of the cavity to permit the crest portion of the dimple to bulge into the bore during the operation of forming the dimple.

72. In an apparatus of the character described for forming a dimple in a sheet of deformable material, the combination of:

a die with a cavity therein and a punch to force a portion of the sheet into the die cavity,

the punch and the wall of the die cavity being shaped and dimensioned to squeeze the metal in an annular zone of the dimple spaced radially away from the crest of the dimple with consequent extrusion of the sheet material towards the crest of the dimple,

said punch and die cavity being shaped and dimensioned to provide clearance for the crest of the dimple to bow away from the punch in response to the squeeze operation.

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