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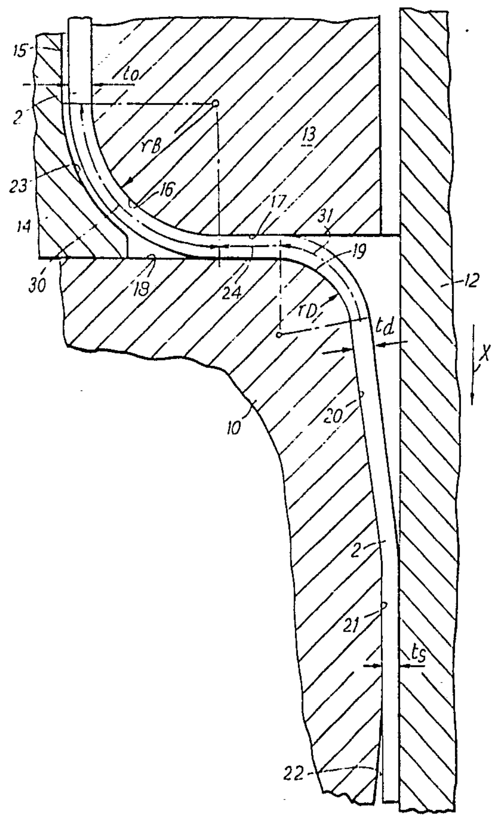
(54) Title: A METHOD AND TOOL FOR REDRAWING

(57) Abstract

In manufacture of a can body by drawing a cup from a blank and subsequently redrawing the cup, one or more redrawing steps are performed by pulling the sidewall of the cup (2) by means of a punch (12) through an S-shaped path (30, 24, 31), whereby the wall is bent first in one direction and then in the other, to reduce its diameter, which is then reduced further in a convergent portion (20) of the die (10). The bending induces back tensions which stretch the metal and reduce its wall thickness



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A METHOD AND TOOL FOR REDRAWING

TECHNICAL FIELD

The invention relates to a method for redrawing a predrawn cup, particularly a cup of thin metal in a process for making a can body, in a tool including a punch and a die; the invention relates equally to a said tool for performing such a redrawing operation.

BACKGROUND ART

Redrawing is performed in the so-called drawing-redrawing method (DRD method) which is hereinafter described in more detail. The redrawing step used in this method has some inherent disadvantages which will also be explained.

DISCUSSION OF THE INVENTION

The invention provides a method and tooling for imparting substantial wall thickness reduction during the redrawing operation of the cup drawn from slightly wax lubricated material, without applying the extreme compression usually necessary in a typical wall-ironing operation, by achieving wall thickness reduction subjecting the material to simultaneous bending and tension. This is followed, if desired, by slight sizing (i.e. corrective ironing) to ensure for the consistency of final wall thickness, whilst some additional lubricant may be used, the method of the invention does not call for essential provision of such lubricant, and therefore can avoid the requirement to wash the finished article to remove the residual lubricant.

The invention in a first aspect provides a method for redrawing a predrawn cup in a tool comprising an annular die and an annular blank holder having a common axis and a punch movable forwardly along the axis through first the blank holder and then the die, wherein the wall of the predrawn cup, being of predetermined initial thickness, is drawn by the punch through a path which is delimited by parts of the tool and is substantially S-shaped in radial section, and the path includes (a) a first curved portion defined by a radiused leading outer edge of the blank holder, the first curved portion being in contact with the interior of the cup and the wall being bent convexly in the first curved portion so that the diameter of the cup wall is reduced; (b) an optional transitional portion between the blank holder and the die, in which the convexly bent wall is straightened; and (c) a second curved portion defined by a radiused rear inner edge of the die, the second curved portion being in contact with the exterior of the cup and the straightened wall of the cup being bent concavely thereon, the wall, after leaving the second curved portion, passing through a convergent part of the die which leads forwardly from the second curved portion and in which the wall is in contact with the die but out of contact with the punch, the radii of the two curved portions being three to four times the initial thickness of the wall. The wall thickness is reduced mainly in the second curved portion and the converging portion of the path.

In a preferred embodiment the method includes a sizing step. The method of the invention, irrespective whether or not it includes sizing, represents a single step. However several such steps may be repeated discretely in succession. A method according to the invention will be referred to herein as a "bend stretching" method, since the wall thickness is reduced by stretching due to back tension induced mainly by bending the material of the wall through the S-shaped path.

The invention in a second aspect also provides a tool for the redrawing of a predrawn cup having a predetermined wall thickness, the tool comprising an annular die and an annular blank holder having a common axis, and a punch movable along the axis through first the blank holder and then the die, the leading outer edge of the blank holder and the rear inner edge of the die being radiused and the bore of the die, leading forward from its said inner edge, being convergent, the die and blank holder optionally having opposed radial rear and leading faces respectively which are substantially planar, so that when the blank holder and the die are in position for redrawing, the cup wall can be drawn between them by the punch in a substantially

S-shaped path delimited successively by the blank holder leading outer edge, the said rear and leading faces (if provided), the rear inner edge of the die, and the convergent bore of the latter. The radii of the two radiused edges are from three to four times the initial wall thickness of the cup.

In one preferred embodiment the transitional portion of the path defined between the two planar faces comprises a rectilinear flat region joining the first curved portion and the second curved portion of the path by mutually-parallel portions of the opposed radial faces of the blank holder and of the die.

The convergent bore of the die preferably merges into a throat of a substantially constant cross-sectional area. The throat preferably merges into a divergent bore.

The tool may include a nest ring situated behind the die and radially outwardly of the blank holder. The nest ring may have a concave portion situated defining the outward boundary of the first curved portion of the path.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 illustrates the steps in a known DRD method of can manufacture;

Figure 2 is a graph showing wall thickness of a can made by the known DRD method and of a can made by the "bend stretching" method according to the invention;

Figure 3 shows details of a tool for carrying out a bend stretching method according to the invention;

Figure 4 shows one embodiment of a tool of the kind shown on a larger scale in Figure 3;

Figure 5 shows another embodiment of tool according to the invention; and

Figure 6 illustrates three discrete and successive bend-stretch-size operations.

MODE OF CARRYING OUT THE INVENTION

Figure 1 (i) shows a circular metal disc or blank 1 of a diameter $\underline{d}_o$, typically obtained by stamping from a pre-lubricated or pre-waxed sheet or strip in a preliminary blanking operation. In the first step of a known draw-redraw (DRD) method, namely the drawing or cupping step, the disc is drawn into a cup of a diameter $\underline{d}_c$ 2, Figure 1(ii). The cupping reduction $\underline{R}_c$, usually expressed as a percentage, is given by the expression $\underline{R}_c = \frac{\underline{d}_o - \underline{d}_c}{\underline{d}_o}$. The cupping reduction can be as high as 50%, although in practice about 35% is an optimum value. The drawn cup 2 is redrawn to reduce its diameter from $\underline{d}_c$ to a value $\underline{d}_1$, Figure 1(iii). The diameter reduction $\underline{R}_1$, so obtained, given by the expression $\underline{R}_1 = \frac{\underline{d}_1 - \underline{d}_c}{\underline{d}_c}$, would normally be not more than about 25%.

Typically, a second redrawing operation follows as a third step, Figure 1(iv), in which the diameter is reduced in a reduction $\underline{R}_2$ from the diameter $\underline{d}_1$ to a diameter $\underline{d}_2$, where $\underline{R}_2 = \frac{\underline{d}_2 - \underline{d}_1}{\underline{d}_1}$, reduction $\underline{R}_2$ being usually again no more than about 25%. In a final operation the redrawn cup 2 is trimmed to leave an end flange 3 of uniform radial width. At the same time the base of the cup may be re-formed, typically to a shape such as shown at 4 in Figure 1(v), to satisfy the processing requirements. Figure 1(v) shows the cup in the form of a now-finished can 4. Usually, no washing operation will be necessary to remove residual lubricant or wax from the finished can 4.

Although in Figure 1 the wall thickness in all the sections is shown the same for the sake of simplicity, in practice this is not so. Figure 2 shows in graphical form how wall thickness varies along the height of a cup at various stages both in the known DRD method and in the bend stretching method according to the invention, to be described below. The cup 2 of Figure 1(ii), after cupping, represented by the curve $\underline{C}$, and after the first redrawing operation (Figure 1(iii)), represented by the curve $\underline{R1}$, are the same both for the known DRD method and the bend stretching method; only the second redrawing operations differ. The cup after its second redrawing operation by the the DRD method is represented by the curve R2, in Figure 2, whilst the cup after a second redrawing operation according to the invention (without wall thickness sizing) is represented by the curve R2a. The cup after a second redrawing operation according to the invention, with wall thickness sizing, is represented by the curve R2b.

The curves in Figure 2 were plotted using results from experimental work to determine the influence of tool parameters on wall thickness variation during can manufacture. For this purpose the pre-waxed metal sheet, from which the blank 1 (Figure 1) was formed, was 0.0087 in (0.22 mm) thick. As can be seen from curve C in Figure 2, during the cupping operation a gradual increase in wall thickness takes place from the original value to about 0.011 in (0.28 mm), so that the wall of the finished cup 2 (Figure 1 (ii)) is considerably thicker at its open end than at its bottom. When the cup is reformed in the first redrawing step, Figure 1(iii), its wall thickness is reduced to about 0.0080 in (0.20 mm), except for about the uppermost 25% of its height in which the wall thickness gradually increases to about 0.0105 in (0.267 mm), as will be apparent from the curve R1.

After the second redrawing step the wall thickness remains at about 0.0080 in (0.20 mm) except for approximately the last 20% of the height at the top of the can which increases gradually in thickness up to

0.010 in (0.254 mm), as will be apparent from the curve R2.

When the tools for the second redrawing operation were modified according to the invention, then without any wall sizing the wall thickness of the can was reduced to 0.0062 in (0.157 mm) over most of the can the thickness of the rest of the can wall being below 0.007 in (0.178 mm). Only the area in the immediate vicinity of the upper edge of the can is slightly thicker, as shown by the curve R2a.

The introduction of sizing to the second redrawing operation, in a method according to the invention, keeps the wall thickness very close to 0.0060 in (0.152 mm) throughout the whole height of the can, as will be seen from the curve R2b.

It will be evident from the foregoing that the can height is proportionally increased in the bend-stretching method as compared with the known DRD method, so that the diameter d_o of the blank may be smaller than that needed for the same can made by the DRD method. This represents considerable savings in material. Furthermore, calculation of the required blank diameter is easier. Also the adverse influence caused by "ears and valleys" due to anisotropy of material is diminished, so that a smaller amount of material can be allowed for flange trimming purposes whilst still ensuring a clean uninterrupted flange 3.

Figure 3 shows in detail the second redrawing operation of the cup 2, with sizing according to the invention. The tool comprises using a tool according to the invention. The tool comprises an annular die 10, a punch 12, a blank holder 13 and a nest ring 14, all being arranged on a common axis, not shown.

The direction of movement of the punch 12, through first the blank holder 13 and then the die 10, is indicated by the arrow X. The terms "leading", "rear" and the like, as used herein, relate to this direction of motion.

In the illustrated example the blank holder 13 has a substantially cylindrical outer face 15 which merges via a radiused leading outer edge 16, having a radius r_B, into a substantially flat, radial forward face 17. The die 10 has a substantially flat, radial rear face opposed to the face 17. The face 18 merges, via a radiused rear inner edge 19 having a radius r_D, into a convergent bore 20 which is generally frusto-conical. The bore 20 merges into a substantially cylindrical throat 21, which in turn leads into a divergent bore 22. The generatrix of the convergent bore 20 may be a tractrix instead of a straight line as is the case in the frusto-conical bore shown.

The surface of the nest ring 14 may if desired have a concave portion 23 opposite the radiused edge 16 of the blank holder.

The adjacent and mutually parallel portio of the end faces 17,18 of the blank holder 13 and die 10 respectively define a radially-straight annul. gap 24 between them.

As is apparent from Figure 3, the cup 2 is guided on, and controlled, by the blank holder 13 and (if necessary) the nest ring 14. This is to prevent an tendency for wrinkles forming when the wall of the cup is drawn round the radiused edge 16.

The cup 2 is initially positioned so that its flat bottom rests on the rear face 18 of the die, with the leading face 17 of the blank holder 13 resting on the flat bottom, the punch 12 being retracted behind the latter. As the punch moves forward in the direction X, it engages the flat bottom of the cup 2 and pushes it forward, thereby pulling the cup wall forward through a path defined by the various elements 10,12,13 of the tool. This path is substantially S-shaped in radial section, and includes: (a) a first curved portion 30 defined by the radiused edge 16; (b) a transitional portion consisting of the gap 24; (c) a second curved portion 31 defined by the radiused edge 19; and finally a convergent portion defined by the convergent die bore 20.

Because of the reduction of wall diameter of the cup 5 as its wall is pulled by the punch 12 through and bent in this S-shaped path, back tension is induced in the metal of the wall. This tension decreases gradually from the die throat 21 to the rear end of the curved portion 30 of the path.

Up to the curved portion 30, the wall thickness $\underline{t_o}$ remains unchanged. In the path portion 30, the wall is bent around the radiused edge 16, and simultaneously the diameter of the cup is reduced. The resultant back tension in the cup wall increased steadily, due partly to the hoop stress resulting from diameter reduction and friction between the cup wall and the blank holder 13, and partly to bending stresses which, in the region 30, are tensile at the outer surface of the cup wall and compressive at its inner surface (this situation then being reversed as the wall passes through the region 31, as will be seen).

In the transitional region 24, the resultant back tension in the cup wall is further increased steadily, as a result of the hoop stress induced by diameter reduction and friction forces between the cup wall and the faces 17,18.

In the region 31 there is a still further increase in resultant back tension, due to hoop stress, resulting partly from diameter reduction and friction between the cup wall and the surface of the die 1, radiused edge 19, but mainly from bending stresses which in this region are compressive at the outer surface of the cup wall and tensile at its inner surface.

From the region 31, the cup wall material passes along the convergent die face 20 into the die throat 21, where it is sized between the die 10 and the punch 12 to its final thickness t_s. In and after the die throat 21, the material is pulled forward by the punch 12, whilst still subjected to the resultant back tension explained above.

Generally it has been observed that if the original thickness t_o of the can wall was about 0.0080 in (0.20 mm), then the thickness t_d is below 0.0070 in (0.018 mm), but on average is about 0.0064 in (0.016 mm), the lowest figure being 0.0062 in (0.0157 mm). The final thickness t_s, after sizing in the die throat 21, is 0.0060 in (0.015 mm).

Because the final sizing step is only marginal and the main wall thickness reduction takes place when the material is bent under tension in the region 30, no additional lubrication combined with cooling is required. After sizing, therefore, the can is free of residual lubricant necessitating washing of the can before it can be printed, lacquered etc. Moreover, in the case of a tinplate can, the tin coating on the steel is subjected to gentle ironing. In bend stretching the main wall thickness reduction is obtained by bending of the material in the curved portions 30,31 of the S-shaped path. Although frictional forces contribute to the required back tension, this is mainly due to the fact that the material is bent over the first curved radiused edge 16, straightened in the region 24 where provided, and bent again in the opposite direction over the second radiused edge 19. It is of particular significance that the radius $\underline{r_B}$, and particularly the radius $\underline{r_D}$, are small and kept within the range to be mentioned later.

It is necessary to avoid excessive friction due to clamping, because this may induce seizure between the die 10 or blank holder 13 surfaces of the cup wall. The presence of the converging face 20 in the die 10 is desirable in order to separate the part portions of the cup wall stressed due to bending from those stressed due to sizing in the die throat. Because there is also quite considerable back tension in the material moving along the converging face 20, less effort is necessary for sizing in the die throat 21.

Material thickness decreases by a substantial amount, the degree of thickness reduction being dependent on the ratio between the radius $\underline{r_D}$ and the thickness $\underline{t_o}$, as will be mentioned later.

The tool shown in Figure 4 includes a die 10 and a punch 12, a blank holder 13 and a nest ring 14, generally as already described.

The tool shown in Figure 5 has a nest ring 54 without a concave portion, and there is no horizontal flat region such as 24 between the blank holder, 53, and

and the die, 51, so that the curved portion of the path defined by the radiused edge 16 merges directly into that defined by the radiused edge 19. By contrast with the blank holder 13 of Figure 4, the blank holder 53 is of the minimum practicable width, which is approximately equal to $r_B + r_D$ (see Figure 3).

The second redrawing step combined with sizing (represented in Figure 2 by the curve R2d) resulted in a reduction in cup diameter of about 20%. As indicated earlier the smallest diameter reduction will be limited by the minimum possible width of the blank holder in which the S-shaped path has no intermediate region 24.

Experimental work on tinplate cups has shown that the minimum value of the radius r_D of the edge 19 (Figure 3) is equal to 3 times the thickness t_o, whilst its maximum value should be below 4 times the wall thickness t_o for bend stretching to be fully effective, leaving only slight sizing to be done in the throat 21. If more work is required in the sizing operation, then excessive heat is generated which in turn would cause melting and reflowing of tin, thus spoiling the surface quality. The value of the radius r_B should be within the same range.

The bend stretching operation uses a very small blank-holding force, which can be kept almost to zero if the blank holder is radially narrow enough and the radii r_B and r_D are near their minimum values. The blank holder therefore acts essentially as a guide for the cup material in its radially inward movement between the curved path portions 30 and 31. The process is equally effective for smaller and larger diameter reduction. The upper limit of diameter reduction can only be determined in practice and depends on a number of parameters, but mainly on the mechanical properties of the basic material of the can.

The basic material of the can may be a sheet metal such as aluminium or steel, which may be coated with tin or other electroplating materials, such as chromium or chromium and chromium oxide. The sheet metal may be coated with a suitable lacquer or other organic coating before drawing. Laminates of sheet metal and organic films may also be used.

Figure 6 shows, reading downwardly, three discrete and successive bend-stretch-size steps which may be performed in three successive tools 10,12-14; 10',12',13',14'; and 10",12",13",14" respectively, as three stages of the second redrawing operation. If these three steps are to be used the first redrawing step may be left out in suitable circumstances. In the second step, a suitable mist lubricant may be introduced between the punch 12' and blank holder 13' and between the die 10' and nest ring 14', as indicated at 60 and 61 respectively. In the third step, a similar lubricant may be introduced where indicated at 62 and 63.

CLAIMS

1. A method of redrawing a predrawn cup in a tool comprising an annular die and an annular blank holder having a common axis, and a punch movable forwardly along the axis through first the blank holder and then the die, characterised in that the wall of the cup, being of predetermined initial thickness, is drawn by the punch through a path delimited by portions of the tool and substantially S-shaped in radial section, the path including

(a) a first curved portion defined by the blank holder to bend the wall radially inwardly,

(b) a second curved portion defined by the die and curved in the reverse direction from the first curved portion, to bend the wall back towards a more nearly cylindrical configuration, and

(c) a convergent portion of the path defined by a bore of the die and leading forward from said second curved portion,

the cup wall being out of contact with the punch but in contact with the die in the convergent portion and the radii of said curved portions being three to four times the said initial thickness, whereby the wall thickness is reduced mainly in the second curved portion and convergent portion of the path.

2. A method according to Claim 1, characterised in that the convergent portion of the path leads into a

substantially cylindrical throat portion, the cup wall being lightly sized between the punch and die in said throat portion.

3. A method according to Claim 1 or Claim 2, characterised in that the cup wall is drawn from said first curved portion of the path to said second curved portion through a generally-radial straight intermediate portion of the path defined between the blank holder and the die.

4. A method according to Claim 1, characterised in that the cup is redrawn in a succession of discrete stages using a separate one of said tools in each stage.

5. A tool for redrawing a predrawn cup of predetermined initial wall thickness, the tool comprising an annular die and an annular blank holder having a common axis, and a punch movable forwardly along the axis through first the blank holder and then the die, the tool being characterised in that a leading outer edge of the blank holder and a rear inner edge of the die are radiused in opposite directions, the value of such radius being three to four times the said predetermined initial wall thickness, whereby to define a substantially S-shaped path around the said leading outer edge and then the said rear inner edge, the die having a convergent bore portion leading forwardly from its radiused rear inner edge.

6. A tool according to Claim 5, characterised in

that the convergent portion of the die leads into a substantially cylindrical throat portion.

7. A tool according to Claim 5, characterised in that the blank holder has a substantially planar leading face and the die a substantially planar rear face, said leading and rear faces being disposed opposite each other to define between them a substantially straight radial portion of the S-shaped path joining the two curved portions thereof.

8. A tool according to Claim 5, characterised by a nest ring surrounding the blank holder with an annular gap therebetween.

9. A tool according to Claim 8, characterised in that the nest ring has a concave bore portion radially separated from, but conforming in profile substantially to the profile of the radiused leading outer edge of the blank holder.

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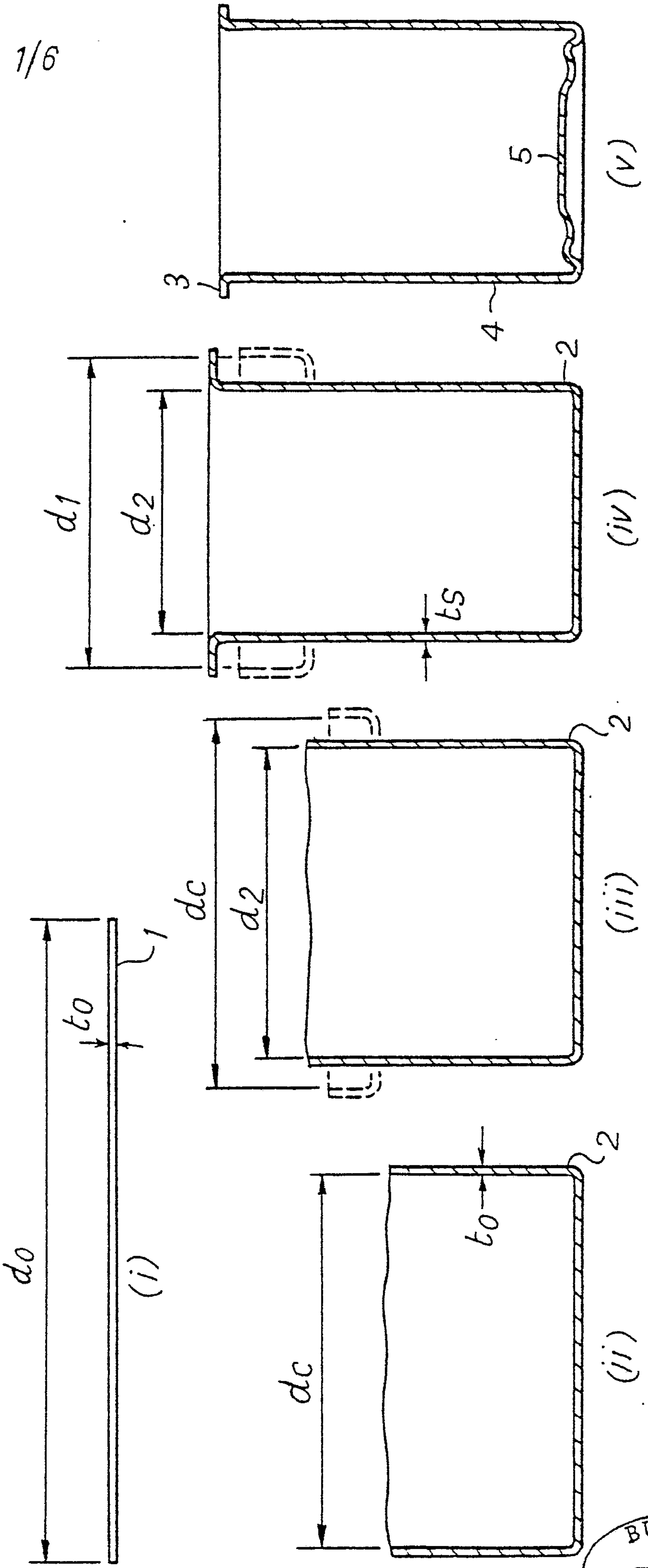

FIG. 1

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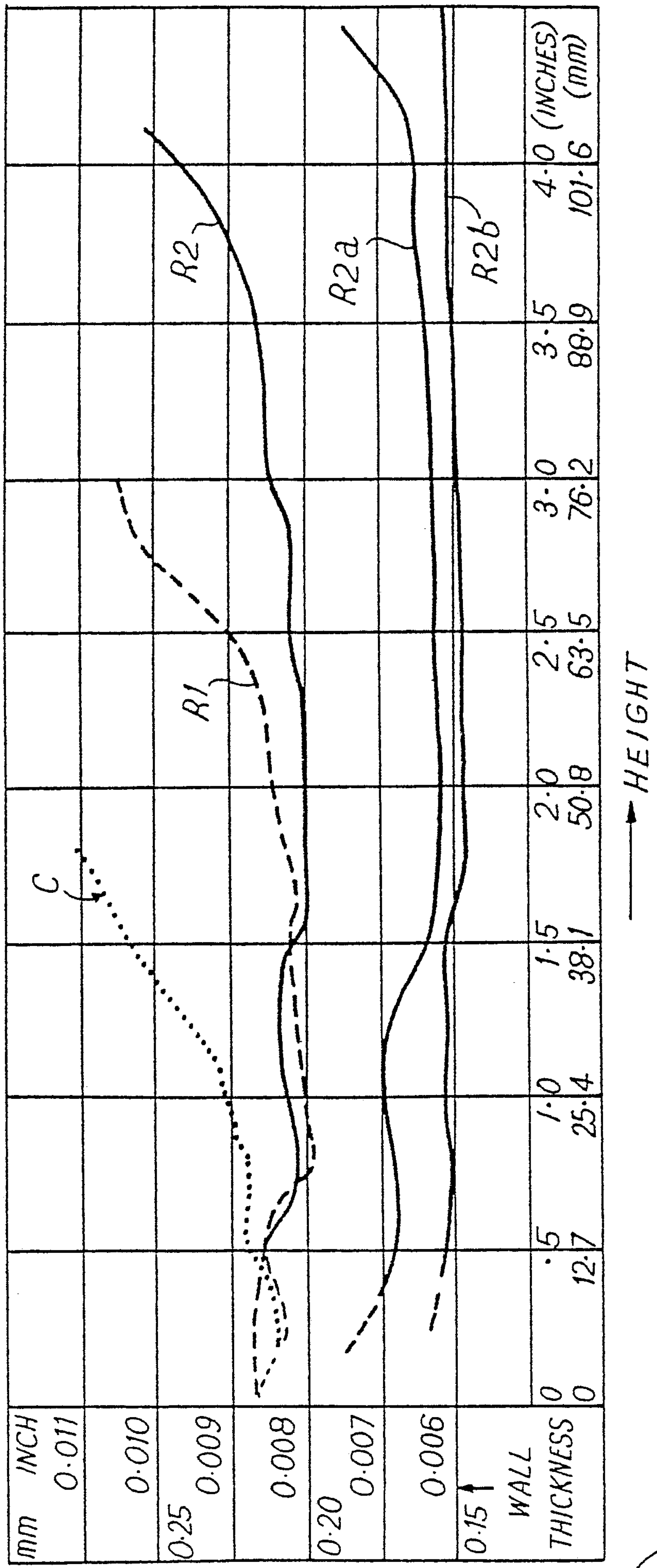
FIG. 2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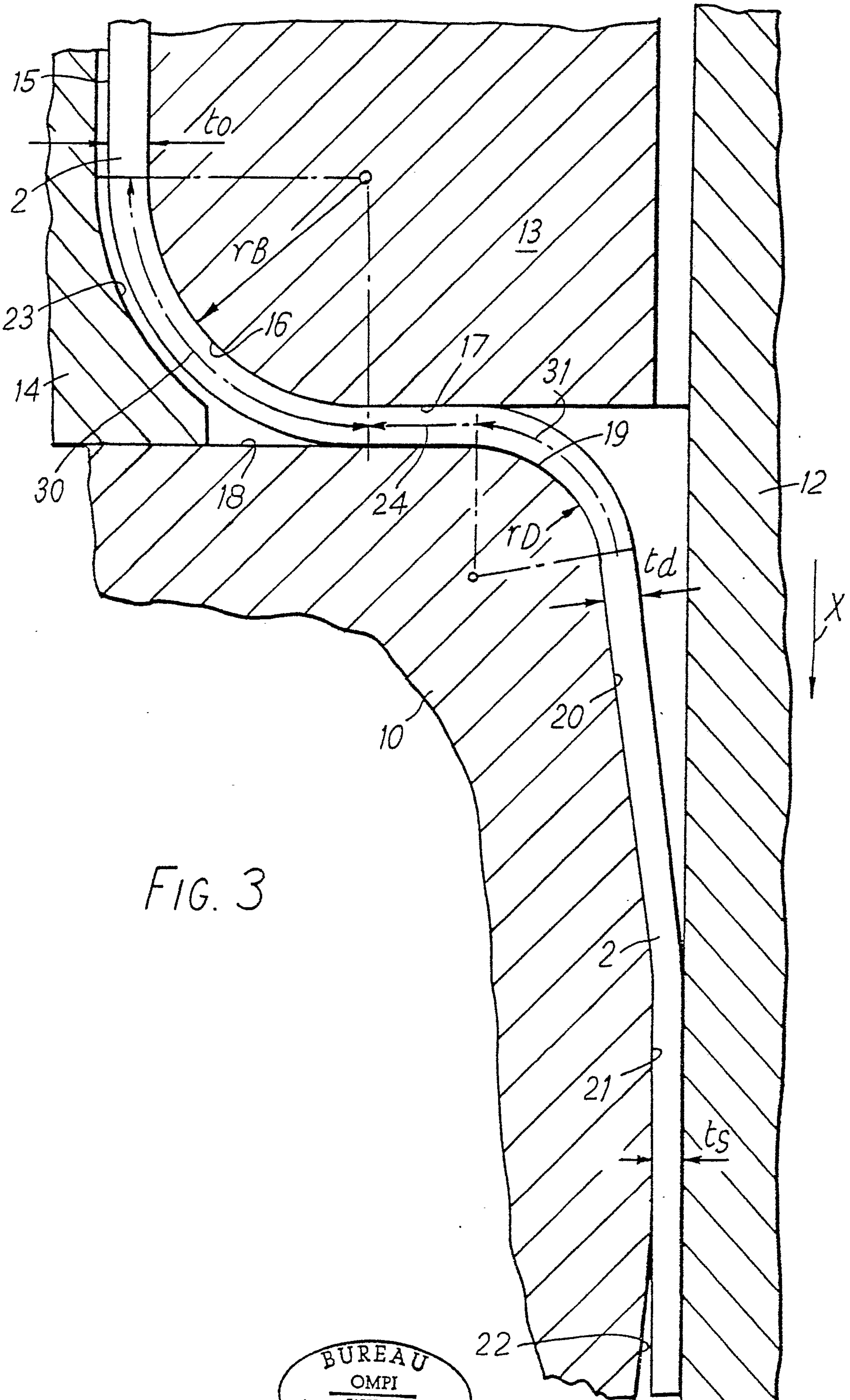
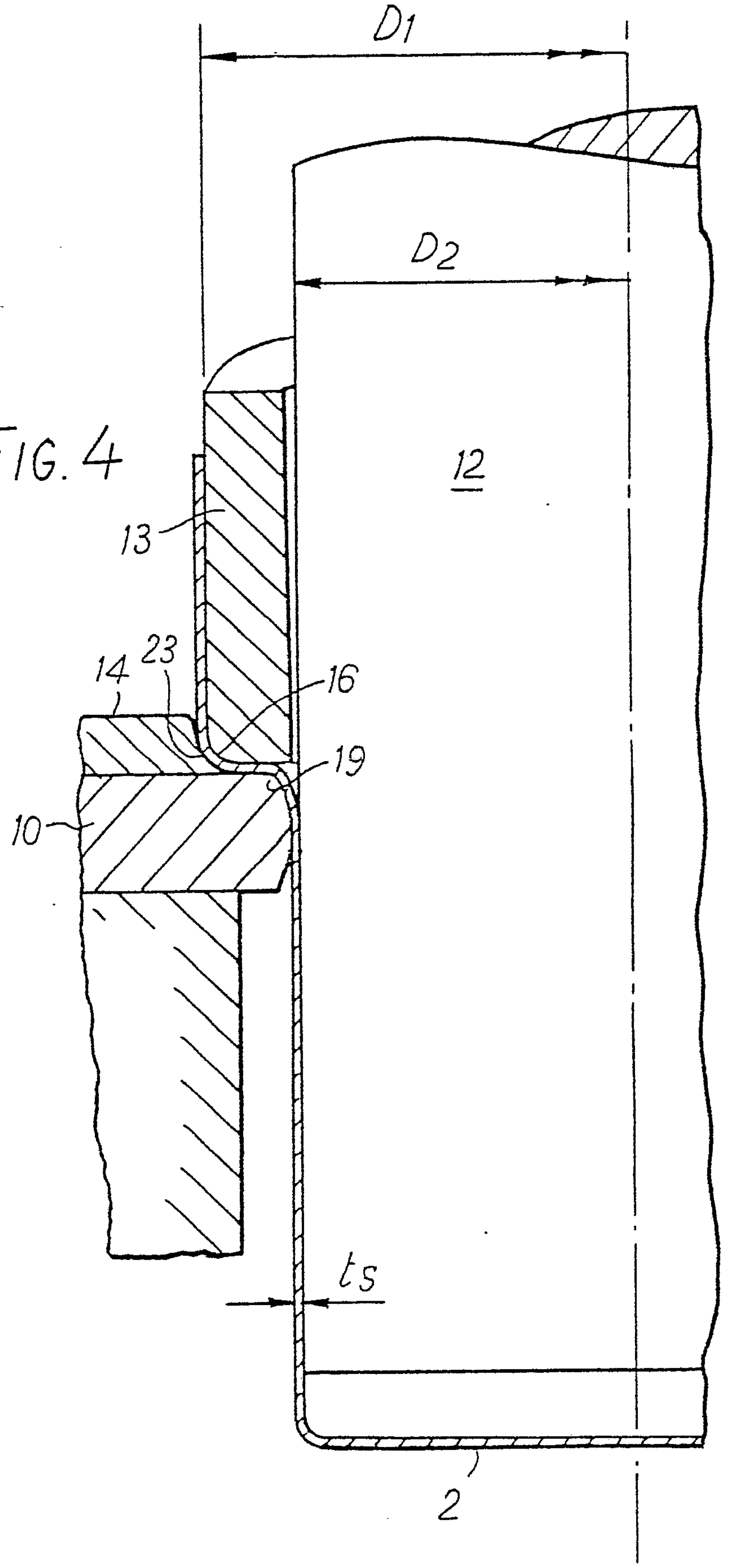


FIG. 3

FIG. 4



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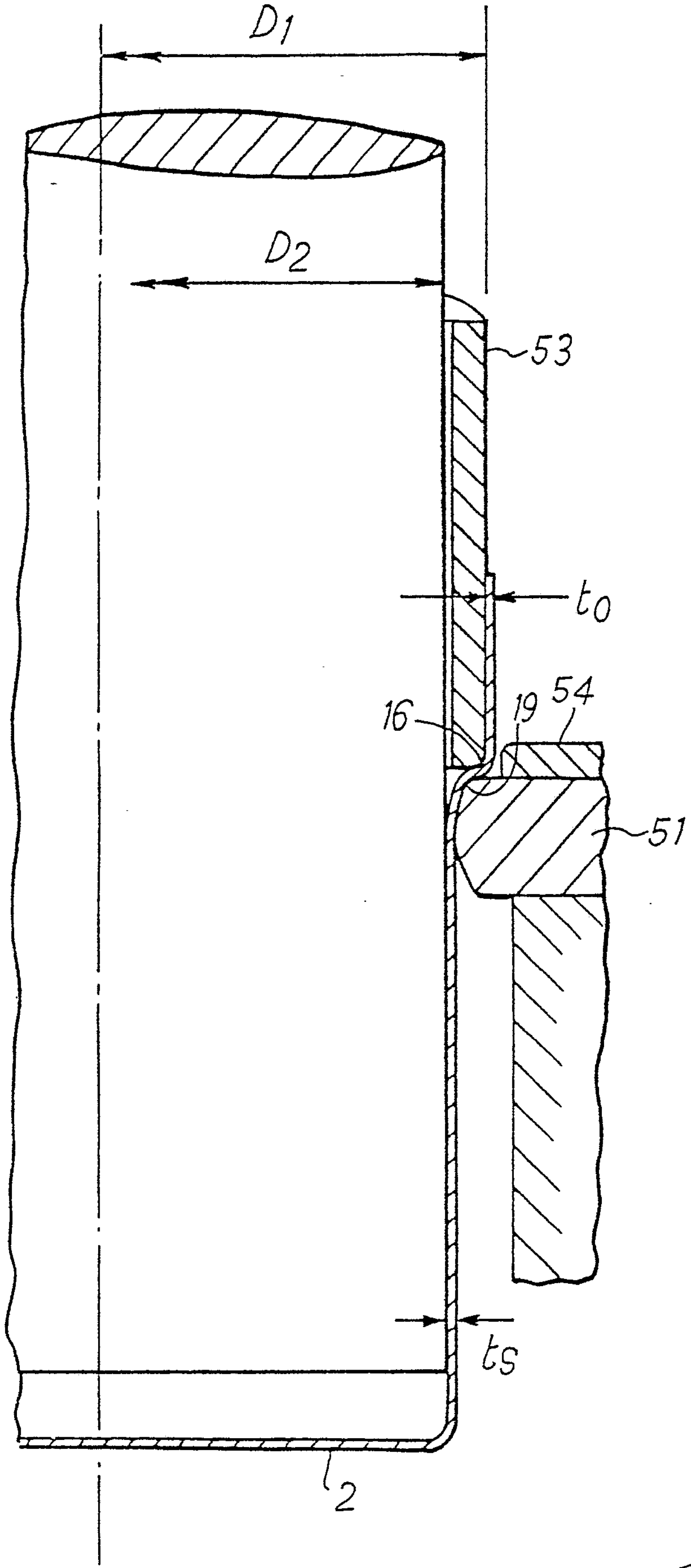
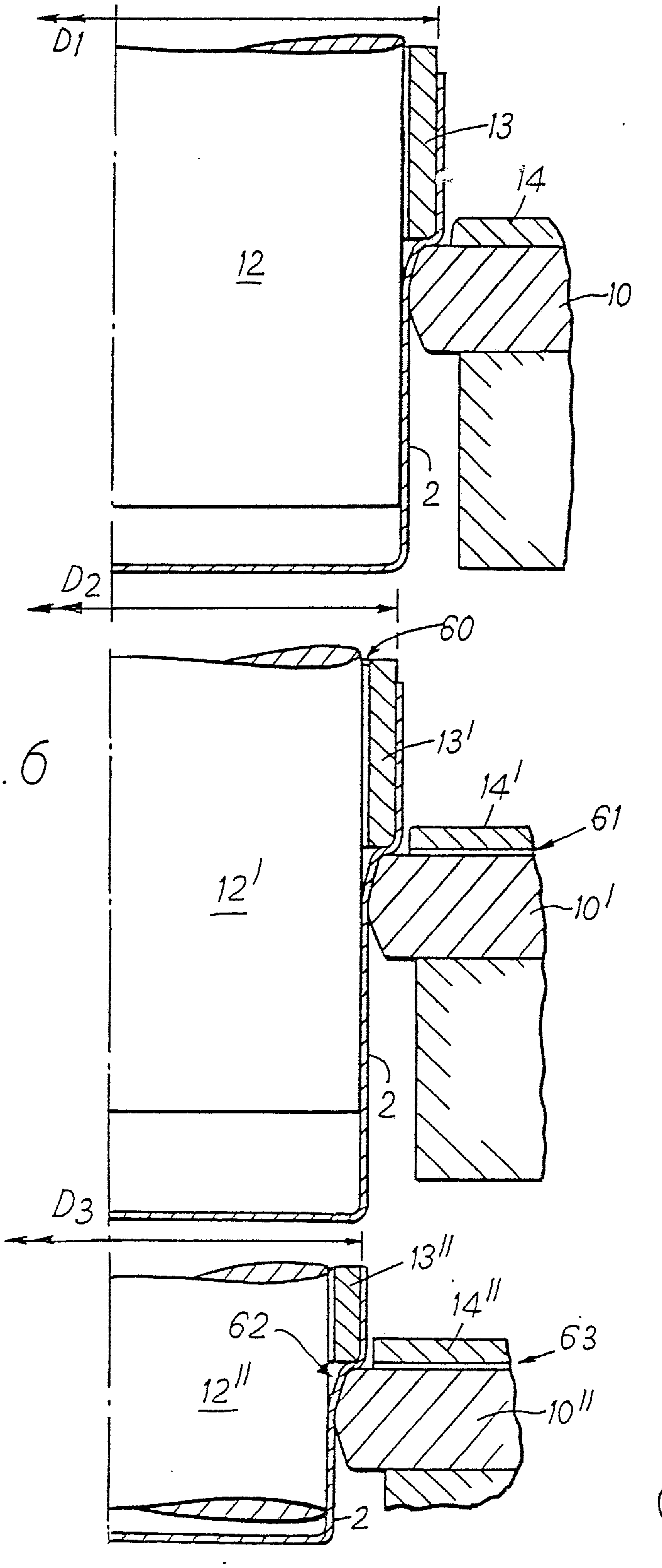


FIG.5

FIG. 6



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 80/00184

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{3} B 21 D 22/30

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
Int.Cl.^{3}	B 21 D

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
	FR, A, 2226227, published November 15, 1974 see pages 11-15; figure 8, Continental Can Company corresponding to US, A, 3855862	1-7
	DE, A, 2625170, published December 15, 1977 see pages 1-2; figures 5-7, Supik	1,3,5,7
A	DE, C, 87629, published July 8, 1896 Stampacchia	1
A	FR, A, 2096812, published March 3, 1972 Alurec	1
A	US, A, 1486746, published March 11, 1924 Heisel	1
A	US, A, 1486964, published March 18, 1924 Heisel	1
A	US, A, 1942930, published January 9, 1934 Ludington	1

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"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
22nd January 1981	2nd February 1981
International Searching Authority [1]	**Signature of Authorized Officer [20]**
EUROPEAN PATENT OFFICE Branch at The Hague P.O.Box 5818 Patentlaan ,2 2280 HV RIJSWIJK (ZH) The Netherlands	G.L.M. Kruydenberg

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