July 5, 1960 J. H. S. SAMUELSSON 2,943,587

METHOD OF FORMING SHEET METAL ARTICLES HAVING COMPOUND CURVES

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Fig. 1.

PRIOR ART

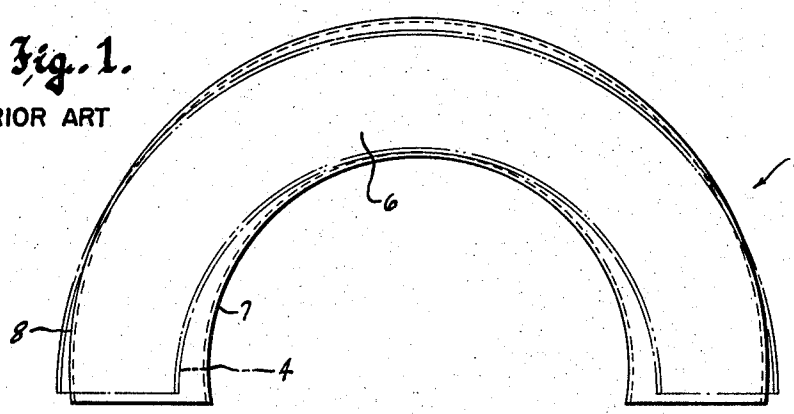


Fig. 2.

PRIOR ART

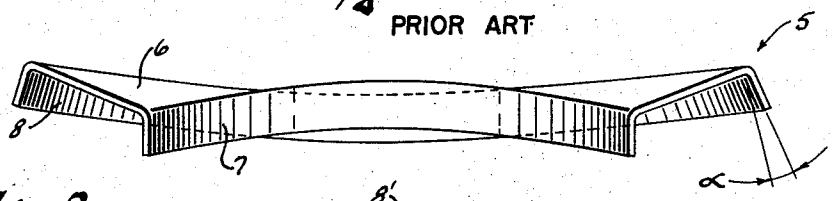


Fig. 3.

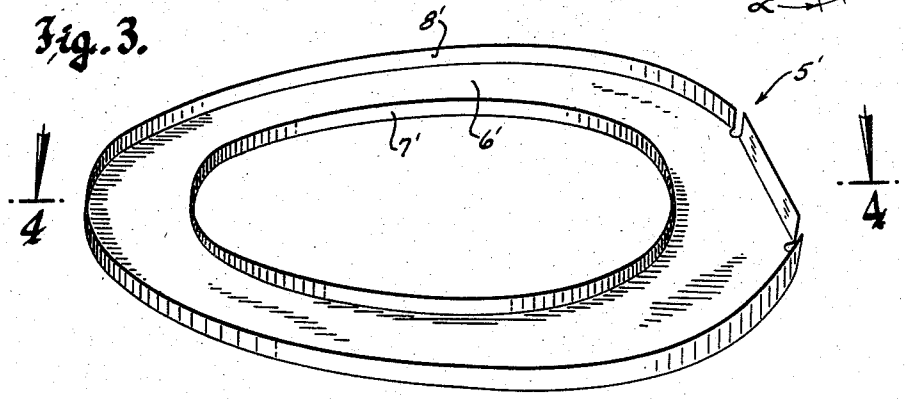
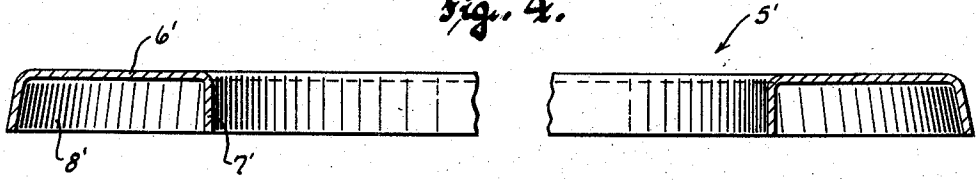


Fig. 4.



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Fig. 5.

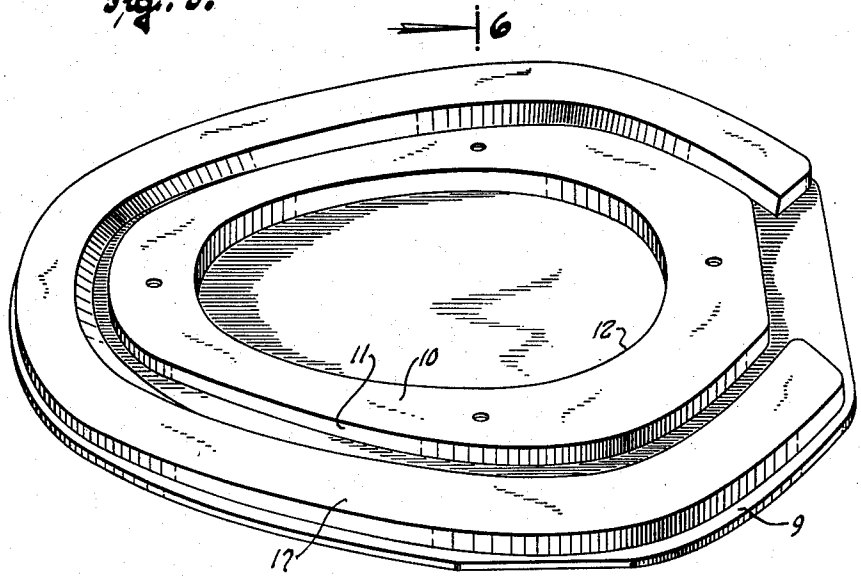
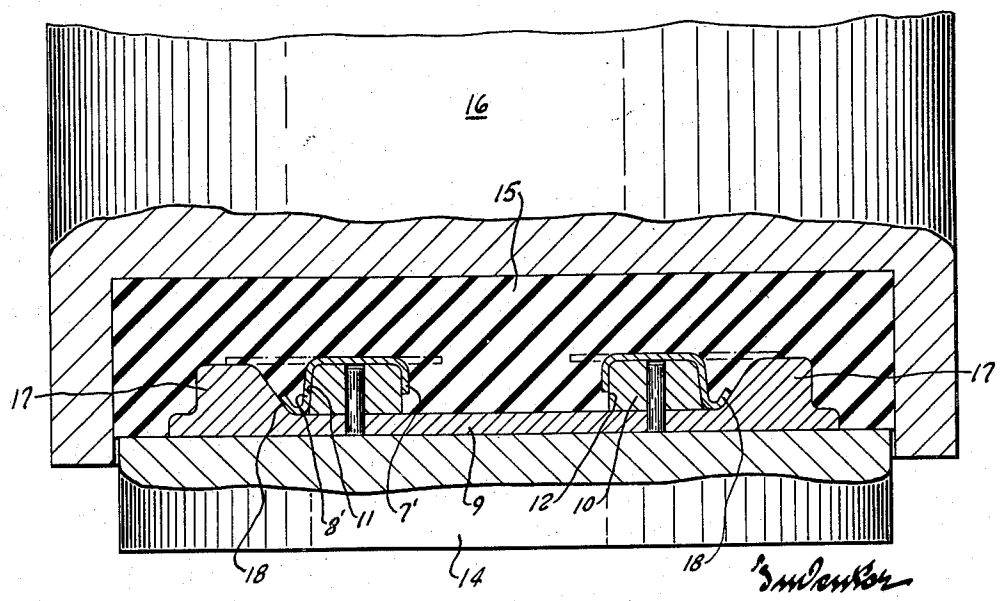


Fig. 6.



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METHOD OF FORMING SHEET METAL ARTICLES HAVING COMPOUND CURVES

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Fig. 7.

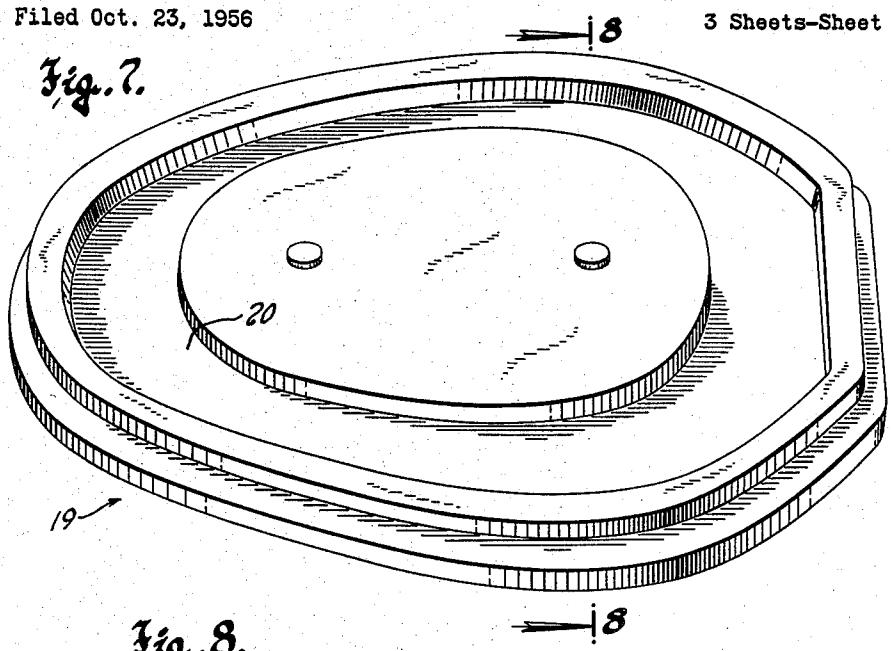


Fig. 8.

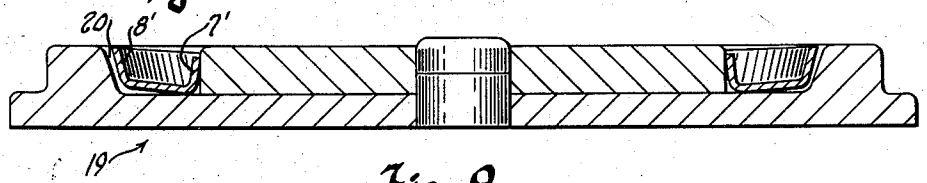
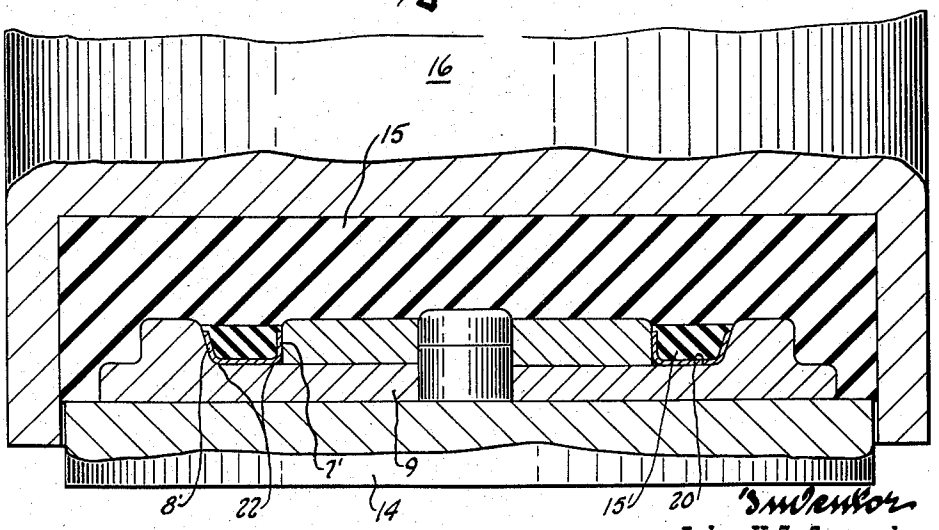


Fig. 9.



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United States Patent Office

2,943,587

Patented July 5, 1960

2,943,587

METHOD OF FORMING SHEET METAL ARTICLES HAVING COMPOUND CURVES

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Filed Oct. 23, 1956, Ser. No. 617,784

Claims priority, application Sweden Oct. 25, 1955

3 Claims. (Cl. 113—51)

This invention relates to the bending of sheet metal articles having compound curvatures, and refers more particularly to a method of forming, from a unitary, substantially flat sheet metal blank, an article having a portion curved along radii disposed in mutually perpendicular planes.

In forming blanks of sheet metal having a high elastic limit into articles having compound curves, it has heretofore been necessary to provide some compensation in the forming die for the spring-back which is inevitable in working with such metal. Since it has not heretofore been feasible to produce forming dies which provided complete compensation for spring-back in parts with relatively complex shapes, the customary practice has been to employ a die which produced as nearly as possible a part having the desired form, and then to rework the part to bring it into conformity with the desired shape.

The reworking was usually done after the part had been heat treated, using a template or templates to insure that the required form was obtained. The necessity for such reworking was in itself burdensome, but a more serious disadvantage of the previous practice arose from the fact that the reworking imposed internal stresses upon the metal. In the case, for example, of an aircraft part, such as a portion of a fuselage shell, the formed metal was frequently drilled at several points after it had been finally worked to the desired shape, and the boring or punching of holes therein released the internal stresses which had been introduced by the reworking operation, with the result that the part would spring slightly out of its desired form and therefore would not mate up or align properly with other parts of the assembly.

With the foregoing disadvantages of the prior practice in mind, it is an object of the present invention to provide a method of forming sheet metal articles having compound curves, i.e., curves on radii lying in planes that are perpendicular to one another, whereby the final forming operation upon the article may be accomplished with the use of a die having a shape which accurately conforms to that of the desired part, thus obviating the necessity for special reworking of the part to bring it to the required shape.

Another object of this invention resides in the provision of a method of shaping sheet metal articles having compound curves, which method essentially entails two forming operations, the second of which creates internal stresses in the metal of the article which substantially offset those created therein by the first, so that the finished product has a stable form that is not affected by the drilling or punching of holes therein or by other operations which may locally relieve internal stresses.

A further object of this invention resides in the provision of a method for forming, from unitary, substantially flat sheet metal blanks, articles having compound curves, which method may be practiced by the use of a forming die and a cooperating body of rubber or similar resilient material, used in a press, and which method permits accurate predetermination of the configuration of the required finish forming die to produce a desired shape without the necessity for extensive experiment.

Still another object of this invention resides in the provision of a method of forming sheet metal articles having compound curves, such as an article having an integral flange extending along a curved edge thereof, wherein smaller radii of bend can be obtained in the finished article than has heretofore been possible.

With the above and other objects in view which will appear as the description proceeds, this invention resides in the novel method and process substantially as hereinafter described and more particularly defined by the appended claims, it being understood that such changes in the precise embodiment of the hereindisclosed invention may be made as come within the scope of the claims.

The accompanying drawings illustrate one complete example of the physical embodiment of the practice of the method of this invention according to the best mode so far devised for the practical application of the principles thereof, and in which:

Figure 1 is a top plan view of an article of a type which may be produced by the method of this invention, but which was produced in accordance with the prior practice, the article being shown before reworking thereof;

Figure 2 is a front view of the article shown in Figure 1;

Figure 3 is a perspective view of an article produced by the method of this invention the article being shown in finished form;

Figure 4 is a sectional view taken on the plane of the line 4—4 in Figure 3;

Figure 5 is a perspective view of a die or forming block employed in the first step of producing the article shown in Figures 3 and 4 according to the method of this invention;

Figure 6 is a sectional view taken on the plane of the line 6—6 in Figure 5 but showing the die in use in a forming press;

Figure 7 is a perspective view of a die or forming block by which the second step in the forming of the article shown in Figure 3 may be performed;

Figure 8 is a sectional view taken on the plane of the line 8—8 in Figure 7, but with the partially formed article in place in the die; and

Figure 9 is a sectional view similar to Figure 6 but showing the die block of Figure 7 in use in a forming press.

Referring now to the accompanying drawings in which like numerals designate like parts throughout the several views, the numeral 5 designates generally an article formed from a unitary sheet of metal, such as aluminum, and having an arcuate body portion 6 with an inner flange 7 and an outer flange 8 extending along its arcuate edges. (See Figure 1.) If the part 5 has been bent according to prior practice by means of a die block (not shown) which gives it the contour indicated by the broken line 4 so long as forming pressure is applied to the part while in the die block, the article will at once assume the configuration indicated by solid lines when it is removed from the die, due to the spring-back inherent in metal having a high elastic limit. In the initial bending operation the material forming the inner flange 7 is expanded, while that which forms the outer flange 8 is compressed, and consequently the spring-back also causes the body portion 6 of the article to be sprung or warped out of flatness, as shown in Figure 2. Moreover, the flange angle departs from that provided by the forming block, as indicated by the angle α.

The extent of the departure from the desired form depends upon the geometry of the particular part or article, the thickness of the sheet metal material, the

condition of the material (as, for example, whether it is annealed, heat-treated but unaged, or heat-treated and aged), and the forming practice employed. Because of these several variables, the spring-back in any given portion of the formed article can only be determined empirically, and full compensation for spring-back in the forming block or die has not heretofore been practicable. It has been the practice, heretofore, to rework the part after heat treatment, because heat treatment introduces further discrepancies into its shape or form, so that if the article were heat treated after being reworked, further reworking would usually be required.

The present invention contemplates that the article will be initially formed from a flat blank, and that a predetermined departure from the desired form will be incorporated into the shape of the article; and then, preferably after heat treatment, the article will be reformed to impart the final desired shape thereto, such reforming being done along a bending zone displaced from that of the initial bend and substantially parallel thereto, and being accomplished by means of a die or forming block which exactly corresponds in shape to the desired final shape of the article, without any compensation for spring-back.

The method is hereinafter more particularly illustrated and described with reference to the forming of an airplane fuselage member **5'** (see Figures 3 and 4) having a flat, substantially annular body portion **6'**, an inner flange **7'** bent on a small radius and extending around the inner periphery of the body portion and disposed substantially normal thereto, and a similar outer flange **8'** extending around the outer periphery of the body portion. The blank (not shown) from which the article is formed is of course annular and has an outline roughly similar to the shape of the finished article, as will be well understood by those skilled in the art.

The first forming operation is preferably accomplished with the blank in annealed condition, employing a die having a base **9** (see Figure 5) and an annular forming body **10** projecting up from the base and the shape of which corresponds approximately to that of the desired article, but which varies therefrom in predetermined respects, and specifically, in that the forming body **10** of the die is narrower than the body portion **6'** of the desired article. Thus the outer periphery **11** of the annular forming body of the die will have a slightly smaller radius than the radius along which the outer flange **8'** extends on the finished article, while the inner periphery **12** of the annular forming body will have a larger radius than that along which the inner flange **7'** of the article will be finally bent. Stated another way, the forming die is so constructed that in the first forming operation the flanges will extend along curved zones which are displaced radially, in directions away from the curved edges of the blank, from the zones along which the flanges of the article will be disposed in its finished form. The amount of this radial displacement of the bent zones in the initial forming operation is preferably substantially equal to the thickness of the metal of the blank.

The die block is used in a conventional forming press, being placed on the lower jaw **14** thereof (see Figure 6), and, by means of a rubber or other resilient forming member **15** held by the upper jaw **16** of the press, the sheet metal blank is formed around the forming body portion **10** of the die block. A supporting wall **17** on the die block, surrounding the forming body portion and having an obliquely disposed surface, prevents wrinkling of the outer flange **8'** as compressive forming force is applied to the outer marginal edge portion of the blank to form the same.

As those skilled in the art will recognize, the outermost marginal edge portion of the blank which overlies the supporting wall **17** cooperates with the latter to compel the resilient forming member **15** to exert evenly distributed pressure over the surface of the portion of the blank which is being formed into the flange **8'**, and it

is as a result of this even, all-over application of pressure on the flange defining portion of the blank that this portion of the metal of the blank is caused to undergo a contractive cold flow whereby wrinkles are prevented from developing therein, but whereby evenly distributed internal compressive forces are set up in the outer flange. Similarly, the metal of the inner flange defining portion of the blank is placed under evenly distributed tensions which cause an elongating cold flow therein, generating internal tension forces in it.

After the part is thus preliminarily shaped, the burr **18** comprising the outermost marginal edge portion of the blank is removed and the part is preferably solution heat treated. Next the partially finished article is placed in a finish forming die **19** (see Figures 7 and 8) having a cavity **20** therein which corresponds in shape to the desired form of the finished article. When inserted into the cavity in this die, the partially finished article will of course fit it somewhat loosely because of the fact that its body portion **6'** was deliberately made too narrow, and in addition it will of course be substantially warped and twisted due to spring-back from the previous forming operation and the relief of internal stresses during heat treatment.

The finish die **19** is also used with a forming press and a cooperating resilient forming member **15'**, and during the second forming operation the zones of bend **22** are of course displaced radially toward the free edges of the blank. In consequence of such displacement of the zones along which the flanges are bent, internal tension stresses are set up in the outer flange and internal compression stresses are created in the inner flange, and these new stresses, being opposite to the internal stresses set up in the metal by the first forming operation, substantially offset them. As a result, the article comes out of the second forming operation with a true form, having its body portion flat and its shape accurately corresponding to that of the finish forming die.

Those skilled in the art will readily appreciate that the employment of a resilient forming member **15'** in the second forming operation insures that substantially evenly distributed reforming pressures will be applied over all parts of the surface of each flange. As a result of this even application of pressure to the surfaces of the outer flange a sort of outward recoining of the bend line of the outer flange takes place which assures that there will be created in the outer flange evenly distributed internal tension forces which cancel out the compressive forces created by the first forming operation. Similarly, the employment of a resilient forming member results in the application to the inner flange of evenly distributed pressures which displace it in a direction normal to its surface to effect a recoining of its bend line and which, by reason of their even distribution, prevent wrinkling and compel a uniform contractive cold flow of metal of the inner flange by which evenly distributed compressive forces are set up in it that substantially cancel out the tension forces set up in it by the first forming operation.

In general, therefore, the method of this invention may be said to comprise two forming steps, in the first of which a flange is formed along a curved zone or zones displaced from the zone of curvature desired in the finished article and substantially parallel thereto, and in the second of which (performed after heat treatment) the blank is reformed along a zone corresponding exactly to the bend desired in the finished article and to the exact finished form desired. The important feature of these two operations is the displacement of the curved zone of bend radially in a direction to impose upon the article internal stresses, created by the second bending operation, which substantially offset or counteract those created by the first bending operation so that the finished article will have no spring-back.

The performance of the second forming operation after heat treatment assures that the part will have a compara-

tively small remainder of equally distributed stresses, which will not be released by the formation of holes, or other local operations; and this follows from the fact that the strains involved in the second forming step after heat treatment, and the related spring-back, are of about the same magnitude as the strains and related spring-back involved in the first forming step performed upon the blank in annealed condition.

Because the zone along which each flange is bent is displaced parallel to itself, a flange formed by the method of this invention will have no spring-back in relation to the finish forming die block, and no compensation for spring-back need be made in the provision of the flange angle forming elements of the finish forming die.

From the foregoing description taken together with the accompanying drawings it will be apparent that this invention provides a method of forming, from sheet metal blanks, articles having compound curves, whereby the final form of the article may be imparted thereto by means of a finish forming die having a shape exactly corresponding to that of the desired finished article (no compensation for spring-back being necessary) and whereby a finished article is produced which is stable in that it will accurately hold its shape even when holes are made therein or other local operations are performed thereon by which internal stresses might be released.

What is claimed as my invention is:

1. The method of forming a substantially flat blank of metal into an article having a substantially planar body portion and an integral flange connected with the body portion by a bend which follows a line curved in the plane of the body portion, which method is characterized by the steps of: applying substantially evenly distributed forming forces to the blank in directions which are at all times and in all places on the blank substantially normal to the surfaces thereof, to compel a marginal edge portion of the blank to undergo a displacement which forms the same into a flange connected to the body portion by a bend that follows a line which is curved in the plane of the body portion correspondingly to the curve of the bend between the body portion and flange in the finished article, but is radially spaced inwardly with respect to the body portion from the desired location of the bend in the finished article, the even distribution of forming forces insuring that the flange will be unwrinkled and will have substantially evenly distributed internal stresses in one direction therein; and thereafter holding the body portion of the blank against deformation and displacement while applying to the flange substantially evenly distributed reforming forces which are substantially normal to the surfaces of the flange along the entire length thereof and act in a direction outwardly with respect to and along lines parallel with the plane of the body portion, to cause every portion of the flange to be bodily displaced substantially along said lines away from the body portion and to move the bend between the flange and the body portion to its desired location, and to also generate in the flange evenly distributed internal stresses which are opposite and substantially equal in magnitude to the stresses previously generated in the flange so that the effects of the stresses in the flange cancel one another.

2. The method of forming a substantially flat blank of metal into an article having a substantially planar body portion connected with an integral flange along a zone of compound curve, which method is characterized by the steps of: flatwise supporting one surface of the blank by means of a rigid forming member which engages the body portion of the blank and leaves unsupported a curved marginal portion of the blank, the inner edge of which marginal portion being radially spaced inwardly with respect to the body portion from the desired zone of compound curve in the finished article; simultaneously compressing a yielding forming member against the other surface of the blank, over the entire unsupported marginal portion thereof and over a substanital part of the supported area adjacent thereto, to apply to the blank an evenly distributed forming force which is at all times substantially normal to the surfaces thereof, thereby producing in the blank a bend along a zone of compound curve radially spaced inwardly with respect to the body portion from the desired zone of compound curve connecting the flange with the body portion in the finished article and forming the unsupported marginal portion of the blank into an unwrinkled flange having substantially evenly distributed internal stresses in one direction therein; and thereafter compressing a resilient forming member against substantially all of that surface of the flange which faces the body portion of the blank, while confining the body portion of the blank against displacement, to apply to the flange substantially evenly distributed reforming pressure by which the flange is translatingly displaced in a direction away from the body portion, to cause the bend between the flange and the body portion of the article to be moved to said desired zone of compound curve connecting the flange with the body portion, and to generate in the flange uniformly distributed internal stresses in the opposite direction whereby the effects of said first named stresses are substantially cancelled.

3. The method of cancelling the effect of distorting stresses from a sheet metal article of the type having a substantially planar body portion and an unwrinkled lengthwise curved integral flange connected to the body portion by a bend curved in the plane of the body portion, which article is warpedly distorted from its desired form by reason of stresses in its flange acting in directions lengthwise thereof and generated during the formation of the flange, which method comprises: holding the body portion of the article against deformation and displacement while applying to the flange forces distributed substantially evenly over its entire surface and acting in a direction away from the body portion along lines that are parallel with the plane of the body portion to bodily move the entire flange and the bend substantially along said lines outwardly with respect to the body portion and generate new internal stresses in the flange which are opposite in direction and substantially equal in magnitude to the stresses originally present in the flange so that the effects of the stresses in the article cancel one another.

References Cited in the file of this patent

UNITED STATES PATENTS

2,309,998	Misfeldt	Jan. 19, 1943
2,346,990	Oftedal	Apr. 18, 1944
2,377,664	Berger	June 5, 1945
2,449,428	Timmons	Sept. 14, 1948
2,693,637	Peabody et al.	Nov. 9, 1954

OTHER REFERENCES

"How to Rubber-Form Light Metals," American Machinist, March 10, 1949, pages 106–108 relied on.