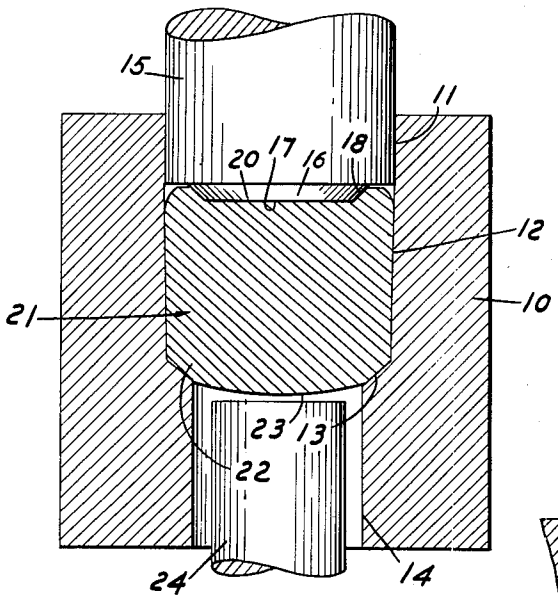
June 5, 1956 B. KAUL 2,748,932

PROCESS AND APPARATUS FOR COLD SHAPING STEEL

Filed May 13, 1950 3 Sheets-Sheet 1

FIG. 2



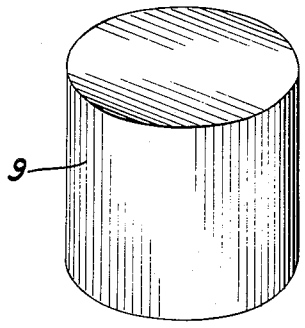
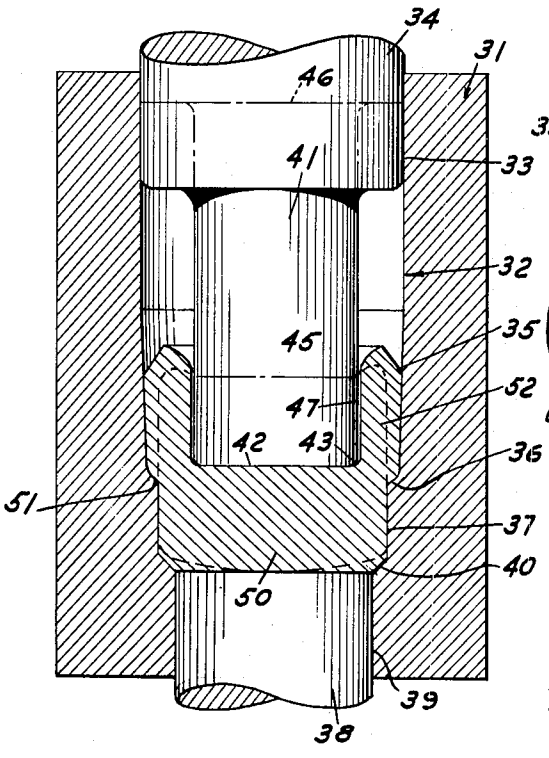


FIG. 1

FIG. 3



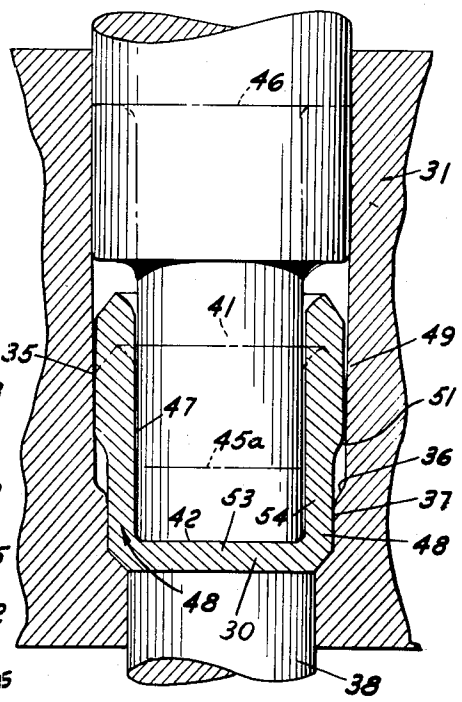


FIG. 4

INVENTOR.
BEN KAUL
BY
Barnes, Kisselle, Laughlin & Raisch
ATTORNEYS

June 5, 1956 B. KAUL 2,748,932

PROCESS AND APPARATUS FOR COLD SHAPING STEEL

Filed May 13, 1950 3 Sheets-Sheet 2

FIG. 6

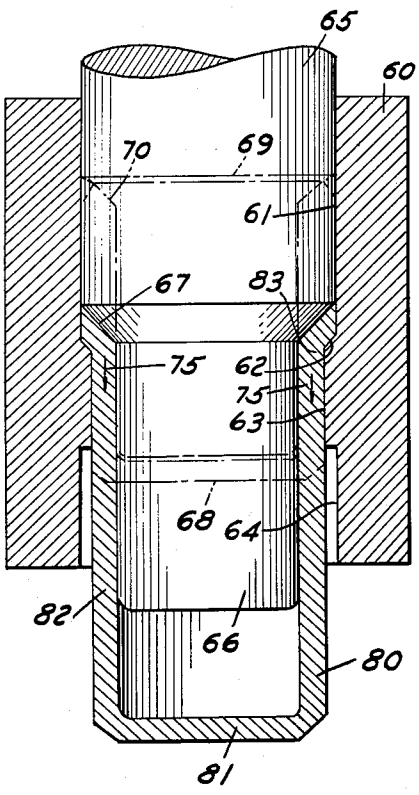


FIG. 7

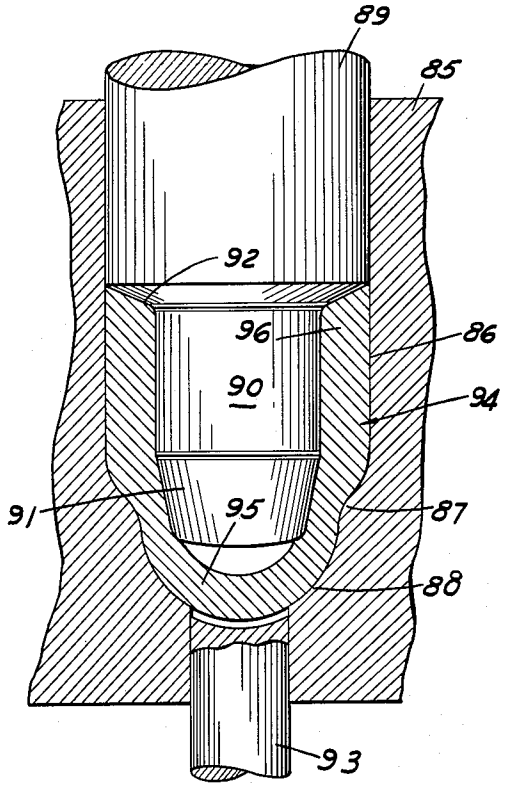
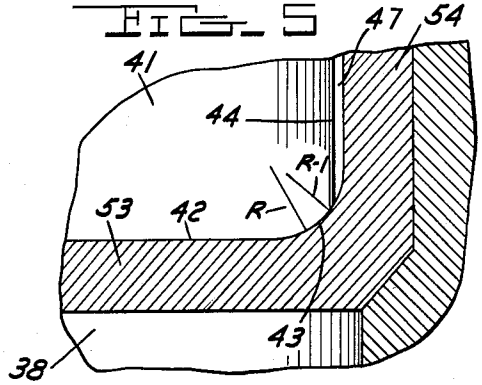


FIG. 5



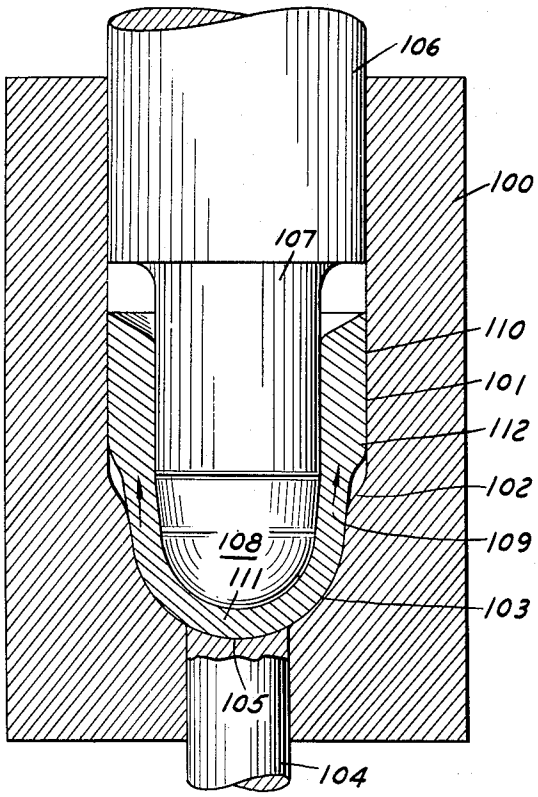
INVENTOR.
BEN KAUL
BY
Barnes, Kisselle, Laughlin & Raisch
ATTORNEYS

June 5, 1956 B. KAUL 2,748,932

PROCESS AND APPARATUS FOR COLD SHAPING STEEL

Filed May 13, 1950 3 Sheets-Sheet 3

FIG. 8



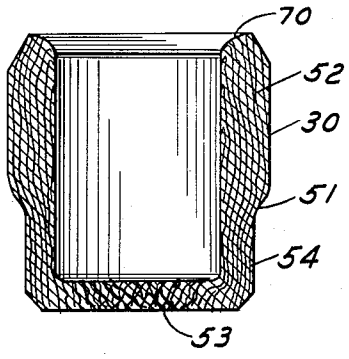


FIG. 11

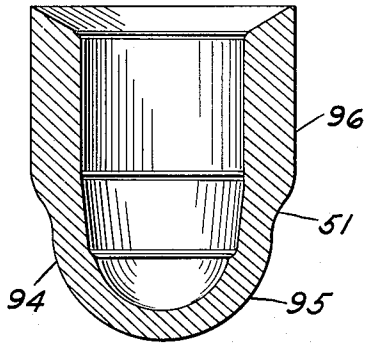


FIG. 12

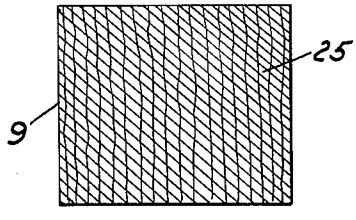


FIG. 9

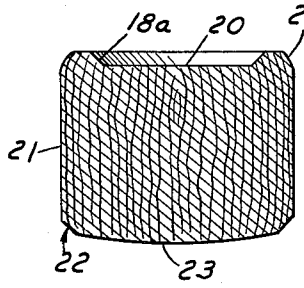


FIG. 10

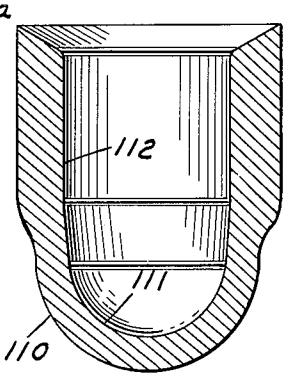


FIG. 13

INVENTOR.
BEN KAUL
BY
Barnes, Kisselle, Laughlin & Raisel
ATTORNEYS

United States Patent Office 2,748,932 Patented June 5, 1956

2,748,932

PROCESS AND APPARATUS FOR COLD SHAPING STEEL

Ben Kaul, Warren, Ohio, assignor, by mesne assignments, to American Radiator & Standard Sanitary Corporation, New York, N. Y., a corporation of Delaware

Application May 13, 1950, Serial No. 161,760

13 Claims. (Cl. 207—6)

This invention relates to cold shaping of steel and more particularly to the cold working of steel from a blank, preferably a solid bar blank, into an article having tubular side walls and a bottom or partition wall extending between the tubular side walls.

Various procedures have heretofore been developed for cold shaping steel to form an article having tubular side walls, the most common of these being cold drawing and cold extrusion. In the process of cold extrusion of steel as practiced in the past, much emphasis has been placed upon the need for proper lubrication between the work piece and the dies. It has been thought that cold extrusion can be performed successfully only if a high grade coating is employed which provides a thin lubricant film so durable that when the work piece is subjected to the high compressive force required to produce flow of the metal through the extrusion die, the lubricant film is maintained between the die and the work piece. Heretofore it has been believed that the limiting factor in successful cold extrusion resided in the provision of a lubricant which would stand up and provide a continuous film under the relatively high pressures employed in cold extrusion processes.

In cold extrusion of steel as taught in the prior art, it has always been the practice to form the tubular article by a series of successive extrusion and drawing operations and to subject the work piece to a suitable annealing treatment between successive cold working operations. When such a procedure is employed, a final uniform hardness can be obtained only by a suitable heat treatment of the finished work piece. If the steel employed is of a type which cannot be hardened to any degree by a heat treatment, then the final piece will not be hardened to any great extent in excess of the hardness of the original blank.

I have discovered that cold extrusion can be performed successfully without the use of special lubricants which have heretofore been considered as essential. Lubricants, such as graphite and the like, which have been used for cold shaping of metal for many years may be employed successfully for cold extruding steel in accordance with my invention. I have found that the selection of a proper lubricant is of minor importance in the production of cold extruded parts as compared with controlling the flow of the extruded metal so as to maintain the friction between the work piece and the dies at a minimum. By directing the flow of the metal properly so as to reduce the friction, I have been able to cold extrude steel with much less pressure than heretofore believed to be necessary and have been able to cold extrude steels of a higher carbon content than formerly considered possible. The reduction in die friction reduces the wear on the dies and has extended the life of the dies far in excess of what has heretofore been considered the normal life.

I have also discovered that tubular articles, with or without a closed bottom end, can be extruded in a manner such that the desired uniform hardness of the finished article can be obtained solely by cold working the metal,

that is, without any final heat treatment for obtaining the desired hardness.

My invention furthermore enables the production of a tubular article by the process of cold extrusion without the necessity, in most instances, for annealing the work piece between successive cold working operations.

Accordingly, it is the primary object of this invention to provide a method and apparatus for cold extrusion working steel at a much lower pressure than has been heretofore deemed necessary.

It is another object of the invention to provide a process for cold extruding steel which enables the desired uniform hardness of the finished article to be obtained solely through cold working.

A further object of the invention resides in the provision of a die arrangement for shaping a blank by cold extrusion which provides a minimum of friction between the work piece and the surfaces of the die and punch.

It is a further object of the invention to provide a cold extrusion process for steel which enables the use of cheaper grades of steel for the extruded part and results in a higher and more uniform strength of the finished part.

More specifically, the invention contemplates a procedure for cold extrusion wherein the steel is permitted to flow to a great extent in an unconfined manner within a range of elongation permitted by the yield strength of the steel. When steel is permitted to flow freely, not only are the pressures required for cold shaping substantially reduced, but of equal importance is the fact that the extent to which the metal is hardened by cold working is substantially reduced. This latter fact is extremely important in any process of cold extrusion or cold shaping of steel because when the steel has been cold worked to substantially its yield point, further cold working will produce failure or rupture unless the steel is annealed prior to the further cold working operation.

My invention provides a method of cold extruding steel wherein successive portions of the article being formed are brought down to the final size and up to the final hardness desired simply by cold working these sections of the article. In my method of cold extrusion, after a particular section of the article has been brought down to final size, it has been cold worked to the extent necessary to bring the hardness and strength up to the desired value and it is not thereafter cold worked to any great extent. Likewise, the sections of the article which are to be subsequently cold worked are maintained in a soft flowable condition so that, in most instances, an annealing treatment is not necessary before subjecting these sections to further cold working operations for the purpose of bringing them down to their final size and shape.

My improved method and apparatus for cold shaping steel to form tubular articles are illustrated in a diagrammatic way by the following drawings in which:

Fig. 1 is a perspective view of a metal blank cut from steel bar stock as received from the mill which is used as the starting blank in my cold extrusion process.

Fig. 2 is a diagrammatic sectional view showing the die arrangement employed in carrying out the first step of my process.

Fig. 3 is a diagrammatic sectional view of a die arrangement employed in the second step of my process, that is, the forming of the extrusion blank, the punch being shown in solid lines in the position it occupies at a point above the lower end of its stroke.

Fig. 4 is a view similar to Fig. 3 showing the punch at the lower end of its stroke.

Fig. 5 is a fragmentary enlarged view of a portion of the apparatus shown in Fig. 4.

Fig. 6 is a diagrammatic sectional view of the die ar-

rangement employed for the next step of my improved process.

Figs. 7 and 8 are diagrammatic sectional views illustrating the die arrangements which may be employed when it is desired to form a container with other than a flat bottom wall.

Fig. 9 is a diagrammatic sectional view of the blank illustrated in Fig. 1 showing the grain flow lines in the blank.

Fig. 10 is a view similar to Fig. 9 showing the distortion in grain flow resulting from the operation illustrated in Fig. 2.

Fig. 11 is a view similar to Figs. 9 and 10 showing the distortion of grain flow lines resulting from the operation shown in Figs. 3 and 4.

Figs. 12 and 13 are diagrammatic views showing the shape of the blanks produced by the operations illustrated in Figs. 7 and 8.

The drawings illustrate the method and apparatus for cold shaping a steel blank so as to form a closed bottom tubular container. It will become apparent as the description proceeds that the invention is not limited to the extrusion of closed bottom containers but is equally adapted for producing tubular articles which are open from one end to the other. The method and apparatus is described with reference to a closed bottom container only for the purposes of illustration and it will be readily appreciated that many different forms of tubular articles can be produced by the method and apparatus described herein.

The starting blank in my process of cold extrusion comprises a cylindrical piece of steel designated **9** in the drawings, which is cut from a length of steel bar stock as received from the mill. The starting blank **9** is shown as having a round cross section but it will be appreciated that the blank may have any cross section desired such as square, rectangular, hexagonal, etc.

Steel bar stock as received from the mill is not always of accurate dimension. It may be slightly out-of-round and the diameter thereof may vary slightly. These variations must be eliminated in the first step so as to control the accuracy of later steps of my new procedure because, for instance, out-of-roundness if not eliminated will carry through all later stages of the procedure and may result in an imperfect finished article or in the possibility of die injury. Thus the first step in the process consists of a coining operation which sizes the blank and provides true concentricity in the coined blank so as to eliminate irregularities in later operations employed for cold shaping the blank into the final article.

The steel employed in my process of cold shaping need not be of a high quality. An ordinary carbon steel with the carbon ranging up to .40% is satisfactory. The carbon or other alloy content of the steel selected will depend upon the size and shape of the finished article, the use to which the article is put and the amount of cold shaping required to transform the steel blank into the finished article. The hardness obtainable by cold working varies in accordance with the carbon or other alloy content of the steel but, on the other hand, the amount of cold work which is permissible before the yield strength of the steel is reached varies inversely with the amount of alloys contained in the steel. Therefore, although a particular high quality analysis of steel is not required in my process, a steel should be selected which will meet the cold working and strength requirements of the finally shaped article.

In order to size blank **9**, the blank is first subjected to the coining operation illustrated in Fig. 2. The blank is placed within a die **10** having a cavity **11** which has a tapered portion **12**, an angular shoulder **13** and a reduced cylindrical portion **14**. The punch **15** is cylindrical in shape and is provided with a shallow nose **16**. Nose **16** has a flat lower face **17**, rounded corners, and conical side walls **18**. The diameter of nose **16** is less than the diameter of punch **15**. The upper end of cavity **11** is cylindrical and has a close fit with punch **15**. When punch **15** is forced down on blank **9**, nose **16** forms a depression **20** at the central portion of the top face of blank **9**. At its lower end, blank **9** is supported on the angular shoulder **13** so that when punch **15** reaches the limit of its downward stroke, the sized blank, indicated generally as **21**, has an angular reduced portion **22** at the bottom corner thereof, the bottom face of the blank being slightly convex in contour as is illustrated at **23**. It will be observed that the knock out member **24** in the reduced portion **14** of cavity **11** is spaced below the convex bottom face **23** of the sized blank **21**. Since the walls **12** of cavity **11** taper inwardly from the top to bottom, blank **21** is readily ejected from die **10** by upward movement of knock out member **24**.

In carrying out the sizing operation illustrated in Fig. 2, the side walls of the blank **9** are expanded by the pressure of the punch **15** to fill the accurately-sized, tapered die cavity **12**, thereby removing all out-of-roundness that may have been present in the bar stock from which the blank **9** was cut and providing perfect roundness for the blank **21** at all sections, thereby eliminating any irregularities which may have been present in the mill product. By establishing perfect concentricity in the blank **21**, the accuracy of later operations is controlled and irregularities are avoided. Furthermore, the coining-sizing operation compresses the grain in the blank **21** to provide a sound structure.

Since the punch nose **16** is perfectly centered with respect to the die cavity **11**, the depression **20** formed in the top face of the blank is perfectly centered with respect to the side walls of the blank **21**, thereby forming a centering means for the punch used in the next operations so that the cup-shaped blank to be formed thereby will have walls of uniform thickness. One of the difficulties heretofore encountered in the cold extrusion of steel has been to provide for perfect concentricity and uniform wall thickness in the finished article. If a punch used in an extrusion operation does not or is not permitted to center exactly, the punch may be crowded to one side or the other and may break; or in the absence of breakage, non-uniform wall thicknesses may result, which in turn may produce non-uniform hardness in the walls of the finished article at any section.

The formation of the depression **20** in the top face of blank **21** also commences the preparation of the extrusion angle **18***a*, Fig. 10, at the top of the blank for a subsequent extrusion step. This extrusion angle is formed by the conical side walls **18** of the punch nose **16**. Incident to the formation of the extrusion angle **18***a*, the top outer corner of the blank **21** necks in slightly at **21***a*. Thus there is no working of the top outer corner **21***a* of the blank **21** at this stage of the procedure and the metal in this zone remains soft and may be cold worked at a later stage in the procedure. Accordingly, sharp corners are avoided which might cause difficulty or require further treatment for subsequent processing.

Since the sizing-coining operation of Fig. 2 is performed by permitting the metal to expand or enlarge slightly under compression, no appreciable friction is encountered by the die and punch surfaces, and only a slight amount of cold working is performed on the blank **9**; namely, at corners **22** at the lower end of the blank and at the center depression **20** at the upper end of the blank. The remaining portions of the blank therefore retain substantially the softness present in the starting blank **9**.

The effect of the coining operation on blank **9** upon the grain flow lines indicated at **25** in Fig. 9 is illustrated diagrammatically in Fig. 10. At the lower circumferential corner **22** of blank **21**, the flow lines are deformed angularly inwardly and the grain flow lines in the rest of the blank are deformed into a wavy contour. As is brought out in my co-pending application, Serial No. 113,536, filed September 1, 1949, the particular con-

tour into which the grain flow lines are deformed becomes of relatively great importance only when it is desired to produce an article having a sound bottom wall. If a sound bottom wall is not required of the article being produced, then the grain lines are not of particularly great importance, with the exception, however, that ruptures and failures are less likely to result when the grain flow lines are merely distorted rather than sheared by the cold shaping operation.

After blank 9 has been shaped into the accurately sized blank 21, it is in a condition ready for cold shaping into the extrusion blank which is indicated generally as 30. To deform blank 21 into the shape of blank 30, the die arrangement illustrated in Figs. 3 and 4 is employed. This arrangement includes a die 31 having a cavity 32, the upper end of which is cylindrical, as at 33, so as to receive with a nice fit, the cylindrical punch 34. Below the cylindrical portion 33, cavity 32 tapers inwardly in a downward direction as is indicated at 35. At the lower end of the tapered portion 35, cavity 32 is provided with an angular shoulder 36 which terminates in a reduced cylindrical portion 37. Cylindrical portion 37 has a diameter substantially equal to the diameter of the bottom portion of blank 21 so that the blank, when placed in cavity 32, will drop into the reduced cylindrical portion 37 of the cavity with its bottom convex face 23 seating on a knock out member 38 slidably arranged in a further reduced cavity 39. A circumferential shoulder 40 connects the reduced cylindrical cavity 37 with the further reduced cavity 39. Punch 34 has a cylindrical nose 41 at its lower end which in turn has a flat bottom face 42. As is illustrated in Fig. 5, flat bottom face 42 has a curved circumferential corner 43 which is formed by a first large radius R tangent to bottom face 42 but not tangent to the side walls 44 of the nose 41, and by a second sharper but not true radius or curved portion R–1 which connects the larger radius R to the side walls 44 of nose 41.

Figs. 3 and 4 show the arrangement of the members for progressive downward movement of punch 41. In Fig. 3, the initial position of blank 21 is shown by broken lines 45, and the position of punch 34 at the start of the operation is illustrated by broken lines 46. In Fig. 4, the shape and location of the blank at the stage of punch movement shown in Fig. 3 is shown in broken lines 45*a*.

As the punch 34 moves downward into cavity 32 during a portion of its stroke from the broken line position to the full line position illustrated in Fig. 3, the flat bottom face 42 of punch nose 41 engages within and is centered by the centered depression 20 at the upper end of blank 21 and forces the metal in the blank below the depression 20 downwardly. However, the knock out member 38 closes the bottom end of the die so that the metal at the lower end of the blank 21 cannot move downward but is compressed into and fills the shape defined by cavity 37, angular shoulder 40, flat top face of knockout 38, and the flat bottom face 42 of punch nose 41. The metal in the lower portion of the blank below the punch nose 41 thus subjected to pressure flows outwardly beneath the flat bottom face 42 of the punch nose 41 and upwardly around and with respect to the punch nose 41 to fill the tapered cavity 35 which is larger in diameter than blank 21, thereby increasing the diameter of the blank.

The outward displacement of the metal, however, must be limited. If the metal is permitted to flow freely and to enlarge or to increase in diameter wholly unconfined or without restraint, a point will be reached where the elongation will exceed the yield strength of the outermost fibers on the surface, and the metal will crack or split open or fracture around the periphery when the yield point is reached. Hence, in working the blank 21 to form the blank 30, there must be a limit beyond which diameter enlargement should not be permitted, although until such limit is reached it is desirable to permit the metal to flow freely in an unconfined manner so as to reduce punch and die pressures. Thus the increase or enlargement or expansion of the outer diameter of the blank and the metal flow incident thereto, is held to an elongation less than that permitted by the yield strength of the particular steel being worked. In other words, the diameter increase is controlled so that the resulting elongation is substantially short of the maximum elongation permitted by the ultimate strength of the steel.

For example, if the yield strength of the steel is 85,000 pounds per square inch, the elongation should be held to, say 15%, under which circumstances no substantial work hardening occurs. Furthermore, if the metal flow to increase the diameter is within the limits of such yield strength without increasing the height of the metal and without substantial change in area, little work hardening occurs. If the yield strength of the metal is 45,000 pounds per square inch, the elongation could be of the order of 30%.

The size of the tapered portion 35 of the die 31 thus is designed so that the metal, in flowing to expand and fill the die cavity portion 35 around the punch nose 41, contacts the tapered walls of portion 35 and is confined thereby from further diameter increase before maximum elongation of the steel being used has occurred. Until thus confined, the metal flows freely outwardly, and when confined, to a slight extent upwardly, and the height of the metal filling the die cavity 35 as it flows upwardly has only slightly increased from the broken line to the full line position of Fig. 3. There is no appreciable work hardening of the metal in the enlarged, expanded, or thickened wall portion 52 of the blank resulting from the deformation or outward displacement because of the relatively free or unconfined manner described in which the metal has been permitted to flow to fill the die cavity portion 35. When the punch reaches the position shown in full lines in Fig. 3, the metal of the blank has just completely filled the lower end of the die cavity below and around the punch nose 41 and against die shoulder 36 and further downward movement of the punch causes the shoulder 51 on blank to separate and move upwardly away from the die shoulder 36.

Blank 9 and the enlarged cavity 35 are designed such that at this time (Fig. 3), the flat bottom face 42 of the punch nose 41 is substantially opposite the die shoulder 36 and a backward extrusion orifice of toroidal shape is formed between the bottom corner 43 of punch 41 and the side walls 37 and lower inner corner of shoulder 36 of the die, through which orifice metal in the bottom portion of the blank 21 below the punch nose, flows, as the punch continues to move downwardly from the full line position of Fig. 3 (the broken line position of Fig. 4) to the full line position of Fig. 4.

As the punch 34 completes the downward portion of its movement illustrated in Fig. 4, the metal in the bottom portion of the blank subjected to pressure extrudes upwardly or backwardly through the extrusion orifice between the side walls 44 of nose 41 and the side wall of die cavity 37, as indicated by arrows 48. Thus as the punch 34 reaches its limit of downward movement indicated by solid lines in Fig. 4, a substantial portion of metal at the lower end of the blank, indicated at 50 in Fig. 3, has been extruded upwardly and meanwhile the shoulder 51 formed on the blank by the die shoulder 36 (Fig. 3) at an intermediate time during the downward travel of the punch, moves upwardly away from die shoulder 36 as shown in Fig. 4.

To summarize, there are two phases to the cold extrusion operation illustrated in Figs. 3 and 4 in forming the blank 30 from the blank 21. During the first phase of the operation, as illustrated in Fig. 3, the enlarged cavity 35 is filled by metal flow between the moving punch edge 43 and the lower edge of shoulder 36 to form the blank portion 52. After cavity 35 has been filled the expanded portion 52 is not further extruded or worked. The second phase of the operation comprises the back-

ward extrusion of metal between the punch walls **44** and the reduced cavity wall **37** after the punch nose has passed below shoulder **36**, as illustrated in Fig. 4, which substantially increases the height of the blank and forms blank wall portion **54**.

The two phases of the cup-forming operation have been illustrated and described in connection with Figs. 3 and 4 as taking place in a single set of dies in one operation. However, in the case of blanks having different sizes, shapes, diameters, or heights, the operation may be performed in two or more successive dies in which the final cup shape is progressively formed. Likewise, in the case of a relatively deep cup, it may be necessary to anneal the blank between successive cup-forming operations in order to obtain the desired depth of cup.

Because the backward extrusion flow of metal during that portion of the downward movement of the punch illustrated in Fig. 4 occurs between the walls of cavity 37 and the outer cylindrical surface of nose **41**, during this stage of punch movement there is no flow of metal in the enlarged portion **52** of the resulting blank **30**, and this portion **52** moves freely upwardly in cavity **35** away from shoulder **36**. During this upward movement of the thickened portion **52** of the blank **30**, a clearance space indicated at **49** in Fig. 4 of increasing magnitude develops between the outer tapered surface of the thickened portion **52** (formed at the stage of punch travel illustrated in full lines at Fig. 3) and the tapered portion **35** of the die cavity **32**.

As an incident to the formation of the cup-shaped extrusion blank **30** by backwardly extruding certain portions of the side walls of the cup and permitting other portions of the cup side walls to expand, the shoulder **51** is formed intermediate the ends of the blank **30**, which forms the extrusion shoulder on the blank for the subsequent forward extrusion operation to be performed thereon. This enables the shape of the bottom and side walls of the cup-shaped blank to be completed before further extrusion of the side walls, and likewise enables the desired amount of cold working to be performed upon and the resulting desired hardness to be developed in the bottom and side walls of the blank below the extrusion shoulder **51** before extruding the thicker portion **52** of the side walls of the blank **30**.

This fact is of particular importance in carrying out the procedure of the present invention because it enables the desired final hardness to be developed in certain zones of the blank progressively or in stages, which hardened zones are not thereafter cold worked when subsequent operations are used to cold work other softer zones of the blank. By these means, the present invention in accomplishing progressive hardening of the article avoids the necessity of annealing one portion of a blank in order to permit working another portion of the blank, and likewise avoids the necessity of a final heat treatment for hardening and the use of heat treatable steel as a raw material in order to develop the desired degree of hardness at various places in the walls of the finished article.

As a further incident to the formation of the cup-shaped extrusion blank **30**, the formation of the upper extrusion shoulder **70** is completed, which was started in the blank **21** at **18***a*.

Referring to Fig. 5, the particular shape of the punch nose bottom wall **42** and corner **43** is of vital importance in accomplishing the objectives of the present invention. Throughout the downward movement of the punch nose **41**, as the metal in the lower portion of the blank below the punch nose is displaced outwardly and upwardly around the punch nose by the downward pressure, the metal flows outwardly along the flat bottom face **42** of the punch nose. As the direction of metal flow changes from outwardly to upwardly with respect to the bottom wall of the punch and as the metal flows around the rounded corner **43** of the punch nose, the direction of metal flow tends to continue in the path of travel established by the large radius R tangent to the bottom face **42**, but not tangent to the side walls **44** of the nose **41**. In this manner, the metal flow, before turning completely to an upward direction, clears and does not hug the side walls **44** of the punch, thereby reducing pressure on the punch and leaving a slight clearance **47** between the side walls **44** of the punch and the inner surface of the cavity formed in the resulting blank **30**. In actual practice, the hole as formed in blank **30** is always slightly larger than the diameter of the punch **41**. Because of the described construction and mode of operation of the punch and die resulting in such clearance **47**, no appreciable friction develops between the side walls **44** of the punch **41** and the walls of the cavity formed in the resulting blank during the upward or backward movement of the metal in the blank with respect to the punch, so that the blank does not bind on or freeze to the punch and does not have to be stripped from the punch.

The described pressure relief on the punch cooperating with the die relief at **35** permitting expansion of the blank diameter prevents pressure from building up; and because of the formation of clearance space **49** little or no friction is developed between the outer surface of the enlarged portion **52** of the blank and the die cavity as the enlarged portion **52** of the blank moves upward in the die cavity. The only area in which a substantial amount of friction develops is between the lower end of the blank and the walls of the reduced portion **37** of the die cavity, and between the metal in the lower end of the blank and the flat bottom face **42** of the punch, as the metal in the blank is extruded upwardly through the toroidal extrusion orifice described. The cold working or deformation of the metal in the blank incident to backward extrusion thus produces a considerable amount of cold working in the bottom wall **53** of the blank, as well as in the thin side wall portions **54** thereof. On the other hand, the thickened portions **52** of the blank are formed by a more or less free outward flow of the metal and have therefore been subjected to relatively little cold working. In actual practice, it will be found that in deforming a blank having the shape of blank **20** into a blank having the shape of blank **30**, the metal at the portions **53** and **54** will be cold worked to a point approaching the yield point of the metal whereas the metal in the thickened portions **52** is capable of being further cold worked substantially before the yield point of the steel is reached.

If the article being formed has a flat bottom wall and straight side walls, such as indicated at **53** and **54**, respectively, on blank **30** in Fig. 11, then the dimensions of blank **9** may be easily calculated such that by cold working the blank into the shape of blank **30**, the metal in the bottom wall **53** and in the side wall **54** will be cold worked to the extent necessary to develop the necessary strength and hardness in these portions of the blank that is desired in the final article. Likewise, the thickness of the thickened side walls **52** may be determined such that when they are subsequently cold extruded to form the side walls of the finished article, they will have been cold worked an amount necessary to bring up the hardness and strength of these portions to that of walls **53** and **54**.

If the side walls and bottom wall of the finished article are to be of the size and shape shown at **53** and **54**, these portions of blank **30** need not be further cold worked and therefore it does not become necessary to anneal these portions of the blank. Blank **30** may then be subjected to a forward extrusion operation to reduce the thickened portions **52** down to the thickness of the portions **54**. This forward extrusion operation is performed by the die arrangement illustrated diagrammatically in Fig. 6 which includes a die **60** having a cylindrical cavity **61**. The die cavity **61** is provided with an extrusion shoulder **62** which terminates in a cylindrical cavity **63**,

die cavity 63 being relieved as at 64. A punch 65 having a nose 66 and an extrusion shoulder 67 is associated with die 60.

When blank 30 is inserted in die 60 it locates itself in the position shown by dotted lines 68 with shoulder 51 seated on extrusion shoulder 62 of the die. Die cavity 61 has a diameter equal to the outer diameter of the thickened wall portions 62 of blank 30 and cavity 63 has a diameter equal to the outer diameter of the thinner walls 54 of the blank. The position of punch 65 at the start of the forward extrusion operation is shown by broken lines 69, the extrusion shoulder 67 on the punch resting on the shoulder 70 at the upper end of blank 30. The diameter of nose 66 is substantially equal to the inside diameter of the wall portions 54 of blank 30. It will be observed that at the start of the forward extrusion operation, the lower end of nose 66 is disposed at a point below extrusion shoulder 62 on die 60. It will also be noted that at the start of the forward extrusion operation, the lower end of the punch is spaced slightly above the bottom wall 53 of blank 30.

When punch 65 is forced downwardly, the extrusion shoulder 67 of the punch exerts a compressive force on the upper end of the thickened wall portions 52 of blank 30 and the metal in portions 52 flows downwardly and is extruded around extrusion shoulder 62 and through the clearance between the nose 66 of punch 65 and the walls of cylindrical cavity 63. The metal flow is indicated by arrows 75. This operation thins out the thickened portions 52 down to the thickness of the walls desired in the finished article and in so doing, the metal is cold worked to the degree desired to obtain the strength and hardness required of the finished article. As has been previously explained, the size of portions 52 will be calculated at the start so that after the forward extrusion operation, the side walls of the finished article will be work hardened to an extent such that they have substantially the same strength and hardness obtained in portions 53 and 54 by the previous backward extrusion operation.

When punch 65 reaches the limit of its downward movement the blank 80 is extruded, the bottom wall 81 of which is substantially the same in thickness as the wall portions 53 of blank 30. At this stage of the process wall 81 and sidewalls 82 have been cold worked to the size and shape desired of the finished article. The forward extrusion operation leaves an angular extension 83 at the upper end of blank 80. The unextruded metal in extension 83 is relatively soft as compared with the metal in the walls 81 and 82 and extension 83 can therefore be further cold worked to shape the upper end of the blank into the form desired of the top portion of the final article. Extension 83 may be further cold worked by subsequent operations to form a radially outwardly extending flange at the upper end of blank 80, a radially inwardly extending flange at the upper end of the blank, or any other shape desired. It will be appreciated, of course, that the stroke of punch 68 is controlled such that only sufficient metal remains in extension 83 to provide the necessary top portion required of the final work piece.

It it is desired to form a container with other than a flat bottom wall, such as is shown at 81, it becomes necessary to subject blank 30 to one or more cold shaping operations prior to the forward extrusion operation illustrated in Fig. 6. Assuming, for the purposes of illustration, that it is desired to produce a container with a rounded bottom wall then I prefer to subject blank 30 to the operations illustrated in Figs. 7 and 8. However, if the metal at portions 53 and 54 in blank 30 have been worked to substantially their yield point or if the extent of further cold shaping required would stress the metal beyond its yield point, blank 30 is preferably annealed prior to subsequent cold shaping of the bottom portion thereof. The annealing treatment to which blank 30 is subjected is just sufficient to soften the metal in portions 53 and 54 to the extent that the subsequent further cold working of these portions of the blank will bring up their hardness and strength to the value desired of the finished article.

To produce a container having a round bottom wall which is very sound, blank 30 is first placed into a die 85 having a cylindrical cavity 86 terminating in a reduced shoulder 87 and a rounded bottom cavity 88. A punch 89 having a nose 90 tapered at its lower end, as at 91, and having an angular shoulder 92 at its upper end is associated with die 85. A knockout member 93 is also associated with die 85.

Downward movement of punch 89 causes a compressive force to be applied to the upper end of blank 30 by shoulder 92 and the metal in portion 53 and 54 is compressed into cavity 88 so as to form the round bottom wall 95 and sidewalls 96 of substantially the same thickness as walls 52 of blank 30. The compression and squeezing of the metal inwardly at the lower end of the blank compacts the grains in the rounded bottom wall 95 so that the grain in this bottom wall tends to assume a dense matted structure as is described and ilustrated in said co-pending application Serial No. 113,536.

Blank 94 is shaped to its final form in the die arrangement illustrated in Fig. 8 which includes a die 100 having a cylindrical cavtiy 101 terminating in an angular shoulder 102 and a rounded bottom cavity 103. A knockout member 104 has a rounded upper end 105 which closes the lower end of cavity 103 so that the lower end of the die cavity presents a continuous semi-spherical surface. A punch 106 having a nose 107 terminating in a rounded end 108 is also associated with die 100. When blank 94 is placed within die cavity 101 and punch 106 is forced downwardly into the blank, a compressive force is applied by the rounded end 108 of punch 106 to the bottom wall 95 of blank 94. The metal in bottom wall 95 is therefore further compressed and thinned down to its final size so that a portion thereof is extruded upwardly, as is indicated by the arrows 109, to form a blank 110 having a rounded bottom end 111 shaped to the contour desired of the finished article and thickened side walls 112 at the upper end thereof. The operation illustrated in Fig. 8 completes the working of the metal in bottom wall 111 so that the grain asumes a compact interwoven fibrous mass as is illustrated and described in said co-pending application Serial No. 113,536.

As was previously expained, the metal in bottom wall 111 has been cold worked by the operations illustrated in Figs. 7 and 8 to the extent that the hardness and strength desired of the finished article have been obtained. The metal in the thickened portion 112 of blank 10 has not been cold worked to any great extent and is therefore capable of being further cold worked by a forward extrusion operation, such as is illustrated in Fig. 6, to produce a blank having a bottom wall and side walls shaped to the contour desired of the finished article.

It will thus be seen that I have provided a cold extrusion process in which the metal is to a great extent permitted to flow in an unconfined manner within a range of elongation permitted by the yield strength of the metal so that a minimum of friction is encountered. By reducing the friction, it will be appreciated that the amount of force required to shape the article is reduced considerably. I have found that I can cold shape articles with a pressure of 625 tons which, by cold shaping methods taught by the prior art, require 2,000 tons. At the same time, I have accomplished these remarkable results by the use of lubricants, such as graphite or the like, which have been conventional for many years in cold shaping of metals. It is obvious that by reducing the die friction to a minimum, I have eliminated the high pressure lubricating requirements strongly advocated by the prior art as a cure to the problems of cold shaping of steel.

It will be furthermore appreciated that by permitting

the metal to flow in a more or less unconfined manner, that is, by reducing the friction to a minimum, the life of the dies employed can be prolonged considerably. In an arrangement substantially identical with that shown in the drawings, I have produced 4,000 finished articles with no evidence of wear on the dies. This fact is in sharp contrast to present practice wherein die failures and die wear has been a large cost factor to the cold shaping of steel parts.

The process and die arrangement herein disclosed permits the steel to flow, within the limits of yield strength and elongation, in an unconfined manner. In Fig. 4, for instance, the thickened wall portions **52** move upwardly as the punch moves downwardly without any substantial contact between the metal of portions **52** and the sides of the punch and the die. When metal is permitted to flow or move freely in this manner, it is not cold worked to any substantial degree and the necessity for numerous annealing treatments between successive cold shaping operations is therefore eliminated. The elimination of the annealing operations enables the blank to be cold worked progressively so that the final strength and hardness of the finished piece can be obtained solely by cold working and not by a final hardening heat treatment.

It will also be appreciated that by reducing the friction to a minimum and by permitting the metal to flow in the unconfined manner described, substantially all of the force required in a cold shaping operation may be utilized for causing the metal to flow where desired rather than in overcoming friction between the die walls and the work piece. Under such circumstances, the stresses set up in the die parts are considerably lower than those encountered in conventional methods of cold shaping. I have found that under such circumstances, a steel having a higher carbon content may be cold shaped without stressing the die parts excessively. This feature of my invention has a two-fold advantage. Steels containing .40% carbon are usually cheaper than steels containing .10% carbon and the hardness and strength obtainable solely by cold working varies in accordance with the carbon content of the steel. I am therefore enabled to use a cheaper grade of steel and nevertheless obtain a finished article of superior strength than is obtainable by cold shaping processes as practiced by the prior art.

One of the important and fundamental aspects of the present invention is the ability, by reason of the character of the described operations and of the dies used to carry out such operations, to progressively cold work and harden the work piece in making the finished article. In other words, in making the extrusion blank **30** of Fig. 11, that portion of the blank which does not benefit in succeeding stages from the work hardening of subsequent operations is cold worked so as to develop the desired degree of hardness in such portion. This portion of the blank, namely the bottom wall **53** and side wall portions **54**, is not again subjected to working in excess of the yield strength of the metal. When the extrusion blank **30** is later extruded, the cold extrusion of the side wall portions **52** work hardens these portions to the desired degree of hardness. In the completed article the physical properties are high and have the desired degree of hardness in every zone thereof, such hardness having been developed progressively in selected or predetermined zones of the article by cold working. Thus metals may be used which cannot be hardened in heat treatment, and no heat treatment is used or needed to develop the desired hardness although a stress relief treatment may in certain instances be desirable and when used the hardness values may actually be increased.

Stated in another way, at various stages of manufacture the metal in the article, being worked by applied compressive forces causing flow of deformation, is maintained in soft, flowable condition below its yield point in certain zones, while the metal in other zones is being work hardened; and the work hardened zones are not thereafter worked under such conditions that the yield strength will be exceeded.

For the purpose of the present invention, an extrusion cup or blank is always formed first and the formation thereof is carried out by compressive forces or by the application of compressive forces accompanied by relieved backward (flow against the direction of punch movement) extrusion resulting from the compressive forces. Ordinarily, when a predetermined zone of the blank is being work hardened, the metal in such zone is work hardened to its limit of workability, the strength of the die steel permitting.

In the cup-forming operation, the metal below the punch is compressed, but in being extruded backward and in being permitted to expand outward, the pressure on the extruded metal is relieved and little friction is developed. This enables the use of low pressure and small presses; and also enables progressive hardening in successive operations to be practiced, and controlled hardness in predetermined zones to be obtained.

Although the die stresses which are encountered in my process are much less than in dies used in conventional cold extrusion processes, I have found it desirable to preload the die such as by a conventional die ring.

A further advantage of my cold extrusion process resides in the fact that the steel selected for cold extrusion with my process may have a manganese content lower than steels used in other cold extrusion processes and, at the same time, the strength of the finished article can be developed without heat treatment to a desired relatively high value.

It will also be noted that in the coining operation illustrated in Fig. 2, the cylindrical surfaces of the blank are not cold worked to any great extent and that, subsequent to the coining operation, the blank is expanded in diameter. Any slight seam or imperfection in the surface of the bar stock will be opened up and smoothed out when the blank is expanded, instead of being confined as in other methods of cold extrusion. If the seam or imperfection is at all serious it will become evident from a visual inspection of the partially formed blank before subsequent cold extrusion operations. Conventional methods of cold extrusion, where the cylindrical surface of the blank is compressed by displacing metal in forming the hole in the cupped blank, tend to conceal rather than accentuate such seams and imperfections.

In some cold extrusion processes with which I am familiar, the extrusion shoulder is formed at the lower corner of the cupped blank. In my cupped extrusion blank **30** it will be noted that the extrusion shoulder **51** is spaced upwardly from the lower end of the blank and that the wall portion **54** below shoulder **51** is already worked to the desired hardness and size. Therefore, when blank **30** is inserted in the die **60** illustrated in Fig. 6, and punch **65** is driven downwardly, the pilot end **66** of the punch is disposed below shoulder **51** before the shoulder **67** of the punch seats on the upper end of the blank. Thus, when pressure is exerted on the upper enlarged portion of the blank, the lower end of the punch serves as a guide for the wall portion **54** and there is no distortion of either the side wall **80** or the bottom wall **81** of the extruded blank. Where the extrusion shoulder is formed around the lower corner of the blank, there is no internal guide for the bottom and side walls of the cupped blank at the start of the forward extrusion operation and the pressure of extrusion will tend to distort these walls at the lower end of the extruded blank.

The procedure for crossing the grain at the bottom of the cold-worked tubular steel article disclosed but not claimed herein is claimed in my copending application Serial No. 113,536, filed September 1, 1949, of which this application is a continuation-in-part; and the cold-worked tubular steel article described but not claimed herein is claimed in my copending application Serial No. 193,349, filed November 1, 1950.

What I claim is:

1. In the method of cold working a solid steel blank of bar stock, the steps comprising confining the bottom and lower side walls of a blank against outward flow, applying a punching force to the top of the blank over a central area of smaller extent than the top surface thereof to indent the blank and cause upward and side flow of the metal in the upper portion of the blank, confining said side flow of the metal to a diameter larger than the diameter of the original blank, continuing said punching force into the zone of lower side wall confinement, whereby as said punching force pierces or moves into said zone of confinement, the confined metal therein is placed under pressure and allowed to extrude upwardly as a hollow extruded section, and stopping said punching force at a point spaced from the bottom of said blank a distance sufficient to form a cup having an intermediate extruded side wall section and a top section of larger thickness joined to the intermediate section and forming an outer shoulder therewith.

2. The method called for in claim 1 including the preliminary step of concentrically sizing the blank.

3. The method called for in claim 1 wherein by said step of continuing said punching force into the zone of lower side wall confinement, said shoulder and said top section of the blank are bodily moved upwardly without substantial friction against the inner and outer surface of said top section, whereby the intermediate extruded side wall section of said cup is comprised of metal substantially harder than the original blank and said thicker top section is comprised of relatively soft, cold workable metal.

4. The method called for in claim 1 wherein said punching force is applied flatwise to the upper central portion of the blank.

5. The method called for in claim 1 including the step of forwardly extruding the thicker side wall section of the blank to elongate and thin the same by axially supporting the blank by means of said shoulder, internally and externally laterally confining said thicker wall section of the blank and an adjacent portion of the extruded wall section of the blank and applying an axial pressure to the free end of said thicker wall section, and wherein said steps of expanding and extruding the blank are controlled such as to harden the blank by said successive cold working steps to substantially the final hardness of the article progressively in a direction from the lower to the upper end of the blank.

6. The method called for in claim 1 wherein the side flow of the upper end portion of the blank is controlled such that when the locus of application of said punching force closely approaches said zone of lower side wall confinement, the upper end portion of the blank comes into at least partial contact with the surface for confining the side flow of the upper portion of the blank.

7. The method called for in claim 2 wherein said step of concentrically sizing the blank comprises laterally confining only the lower end portion of the blank and axially supporting only the outer annular portion of the lower end of the blank on a downwardly and radially inwardly sloping supporting surface, applying flatwise axially downwardly directed pressure to the central portion of the upper end of the blank and by said sloping supporting surface, applying upwardly and inwardly directed reactive pressure to said outer annular portion of the lower end of the blank to form a flat, shallow depression at the upper central portion of the blank, and to radially expand the upper portion of the blank and squeeze the lower portion of the blank laterally inwardly to provide said blank with true tapered side walls and with an angular peripheral corner around the bottom end of the blank.

8. In a die arrangement, a punch having a substantially flat leading end and side walls extending from said leading end parallel with the axis of the punch, said leading end being connected with said side walls by a rounded corner portion, said corner portion being defined by an arc which is tangent to said leading end of the punch but slightly non-tangent to the side walls of the punch, said arc comprising at least two portions of different radii, the portion of larger radii being tangent to said leading end and the portion of smaller radii being of less arcuate extent and connecting another arc portion with the side walls of the punch.

9. In a die arrangement, a punch having a leading end and side walls extending from said leading end and parallel with the axis of the punch, said leading end being connected with said side walls of the punch by a rounded corner portion, said corner portion being defined mainly by an arc which is tangent to said leading end but slightly non-tangent to the side walls of the punch, said corner portion being fashioned such that a tangent to said arc at the point of merging with the side walls is inclined in a direction generally axially of the punch and away from the leading end and the side walls of the punch, the cross section of the punch at said point of merging being no greater than at a point spaced more remotely from said leading end.

10. In a die arrangement for backwardly cold extruding a solid steel blank, a die having a punch receiving cavity, said cavity comprising two concentric portions, one above the other, the lower portion of said cavity being of smaller cross section than the upper portion of said cavity and being connected therewith by an outwardly and upwardly extending shoulder, means at the lower end of said lower cavity portion forming a support for the lower end of a blank positioned within said cavity, the side walls of said lower cavity portion being parallel to the vertical axis of said cavity and the side walls of said upper cavity portion being tapered from said peripheral shoulder in an outwardly and upwardly direction.

11. In a die arrangement for backwardly cold extruding a solid steel blank, the combination of a punch having a shank provided with a leading end and a die cooperatable with said punch, said die having a cavity comprising two concentric portions, one above the other, the lower portion of said cavity being of smaller cross section than the upper portion of said cavity and being connected therewith by an outwardly and upwardly extending peripheral shoulder, the cross section of the shank of said punch adjacent the leading end thereof being smaller than the cross section of said lower die cavity and being axially aligned therewith whereby the leading end of the punch may be moved axially downwardly into the lower portion of said cavity, means at the lower end of said lower cavity portion forming a support for the lower end of a blank positioned within said cavity, the side walls of said lower cavity portion being parallel to the vertical axis of said cavity and the side walls of said upper cavity portion being tapered from said peripheral shoulder in an outwardly and upwardly direction.

12. In a die arrangement for backwardly cold extruding a solid steel blank, the combination of a punch having a shank provided with side walls extending parallel to the axis of the punch, a leading end face and a corner portion connecting said side walls and leading end face, said corner portion being defined by an arc, and a die having a punch receiving cavity comprising a lower cavity portion and an upper cavity portion of greater diameter than the lower cavity portion, said cavity portions being connected by an outwardly and upwardly extending shoulder, the side wall of said lower cavity portion being substantially parallel to the axis of the punch and the side wall of said upper cavity portion being tapered upwardly in an outwardly direction and said corner portion being shaped such that when the punch is forced downwardly into a blank disposed within said upper and lower cavity portions and having a volume greater than the lower cavity portion, said corner

portion directs the metal of the blank outwardly from the side walls of the punch and when said punch is forced downwardly past the level of said shoulder, the metal within the upper cavity portion is moved bodily upwardly free of contact with the adjacent side wall of said upper cavity portion.

13. The combination called for in claim 12 wherein said leading end face is flat and substantially perpendicular to the axis of said punch shank.

References Cited in the file of this patent

UNITED STATES PATENTS

268,011	Goehler	Nov. 28, 1882
682,359	Keithley	Sept. 10, 1901
918,154	Hooker	Apr. 13, 1909
1,212,120	Steedman	Jan. 9, 1917
1,918,858	Metzger	July 18, 1933
2,140,775	Talbot-Crosbie et al.	Dec. 20, 1938
2,183,502	Lefere	Dec. 12, 1939
2,183,637	Biginelli	Dec. 19, 1939
2,251,094	Witter	July 29, 1941
2,261,304	Sparks	Nov. 4, 1941
2,457,626	Atlee	Dec. 28, 1948
2,533,942	Jongedyk	Dec. 12, 1950

FOREIGN PATENTS

542,043	France	Aug. 4, 1922
469,550	Great Britain	July 27, 1937

OTHER REFERENCES

Cold Shaping of Steel, July 1, 1947.
The Iron Age, Aug. 4, 1949.