

June 23, 1959

B. KAUL
METHOD OF COLD SHAPING PARTITIONED
TUBULAR STEEL ARTICLES

2,891,298

Filed April 7, 1954

6 Sheets-Sheet 1

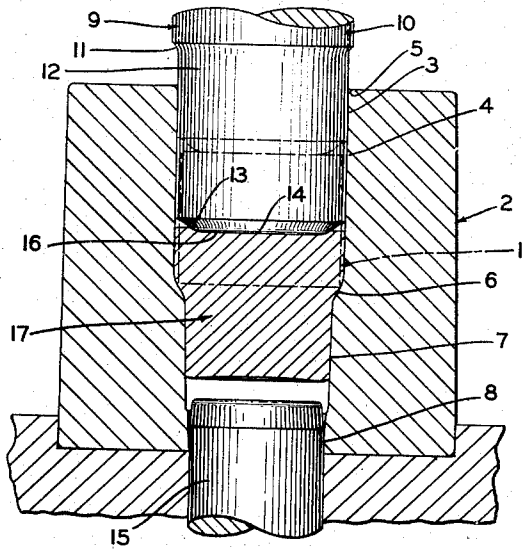


Fig. 2

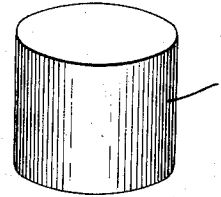


Fig. 1

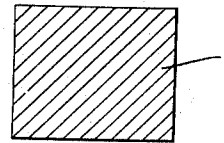


Fig. 11

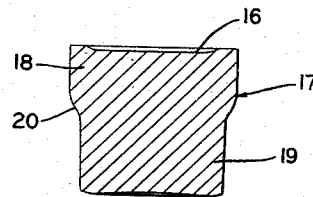


Fig. 12

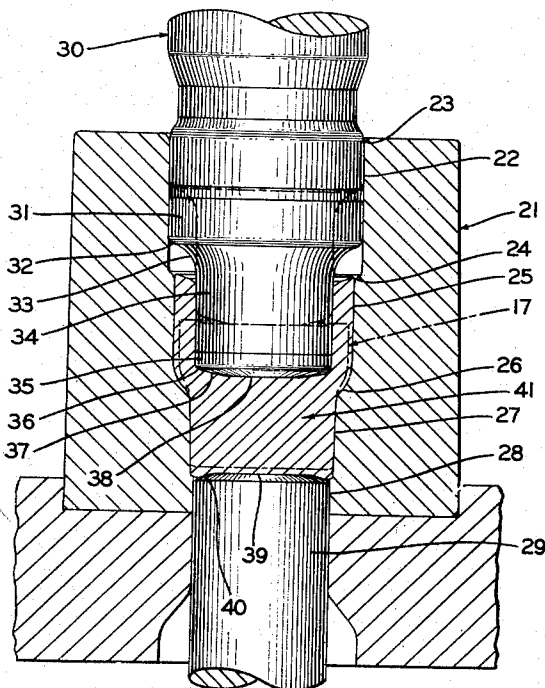


Fig. 3

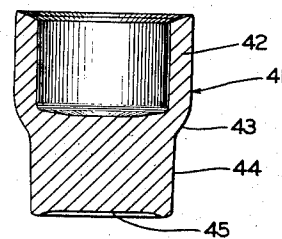


Fig. 13

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6 Sheets-Sheet 2

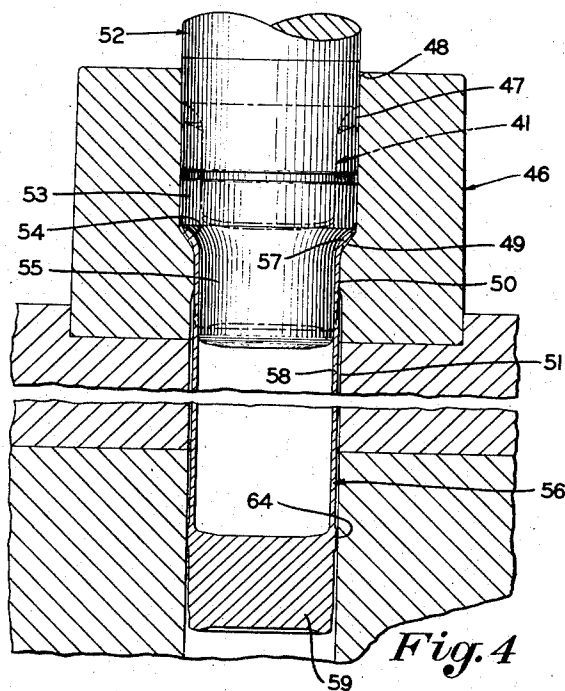


Fig. 4

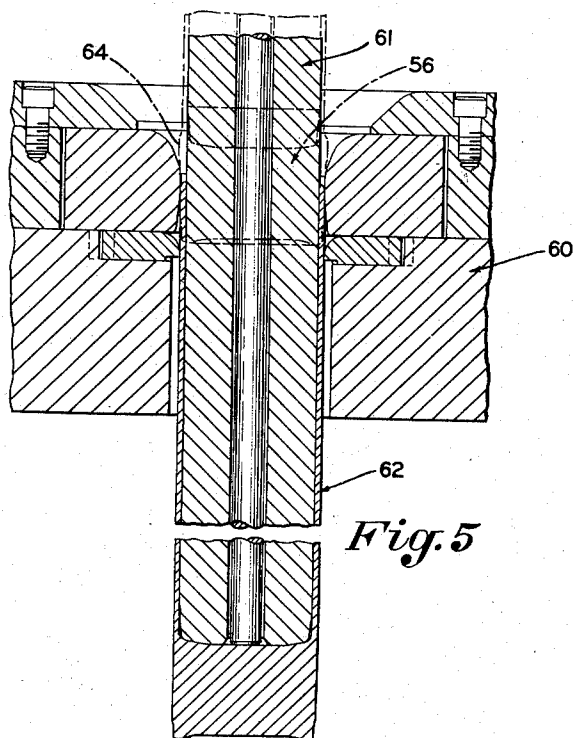


Fig. 5

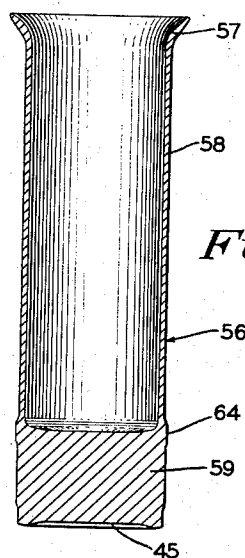


Fig. 14

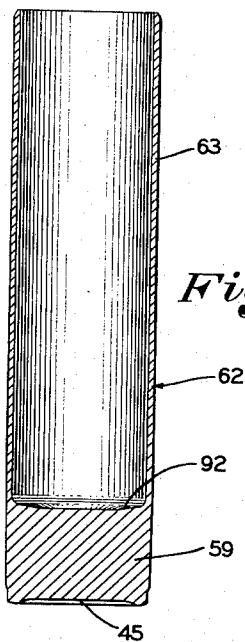


Fig. 15

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6 Sheets-Sheet 3

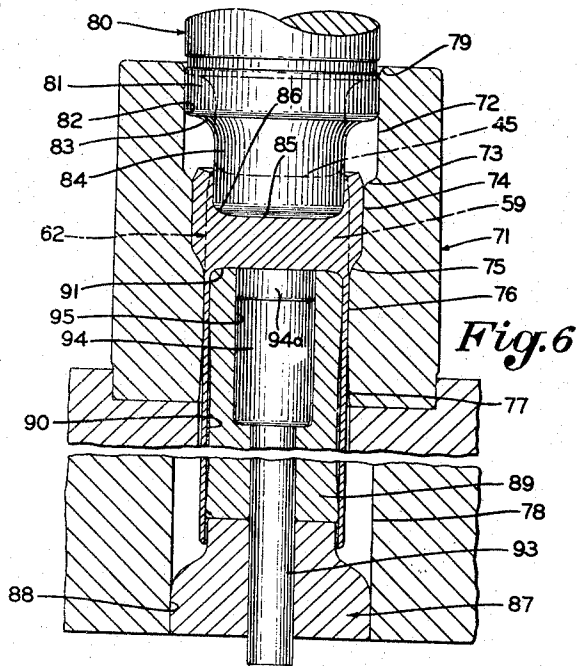


Fig. 6

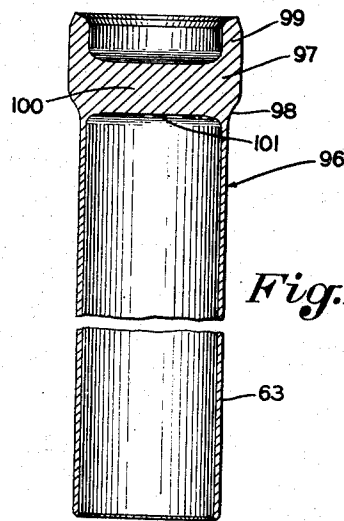


Fig. 16

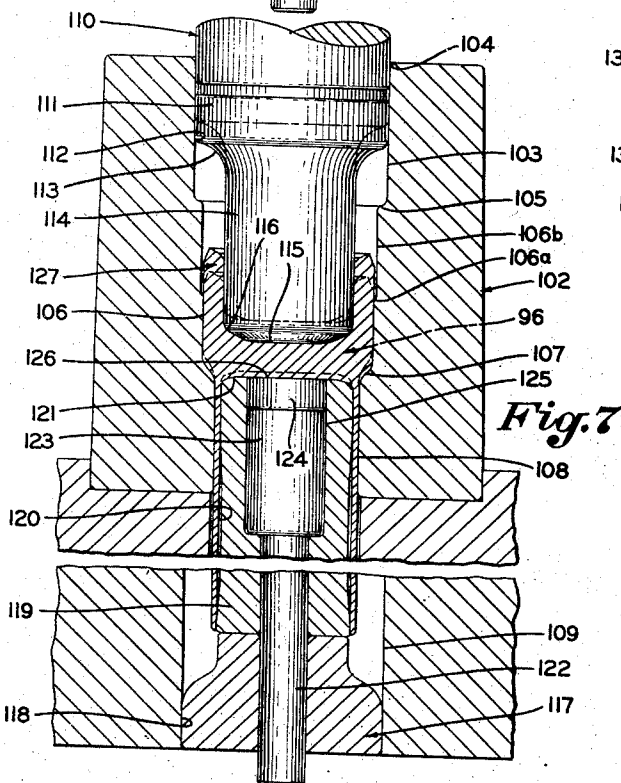


Fig. 7

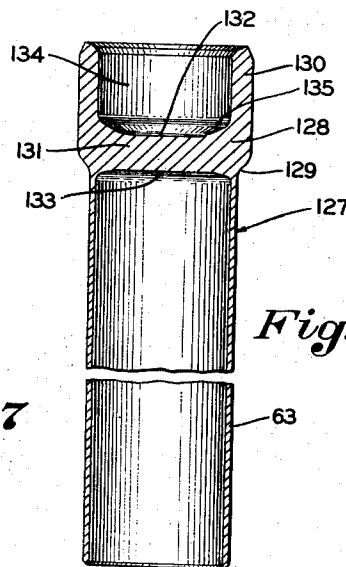


Fig. 17

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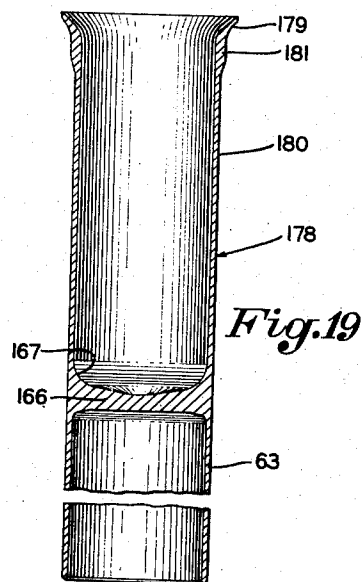
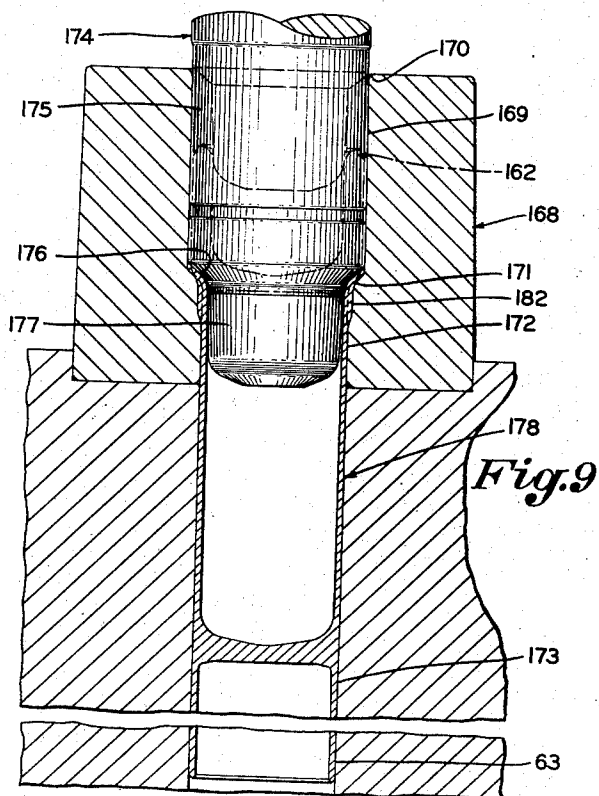
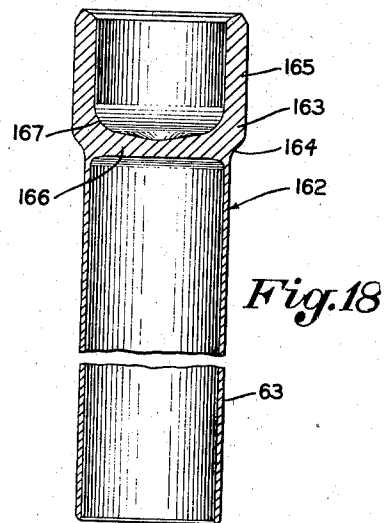
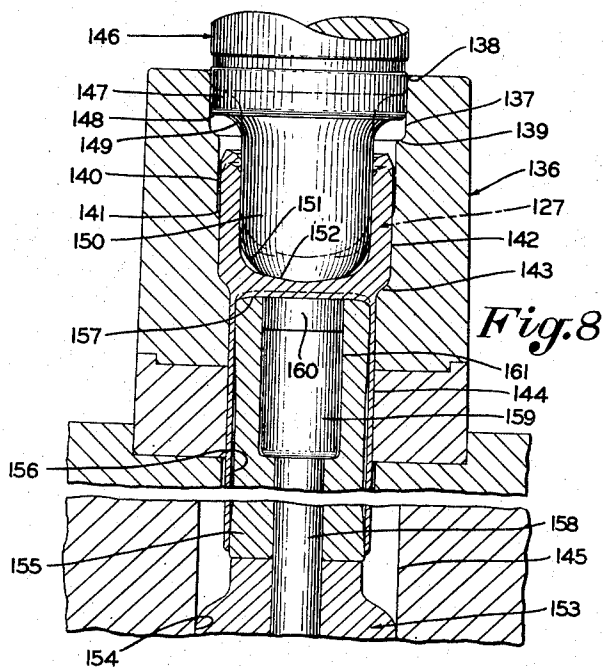
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6 Sheets-Sheet 4



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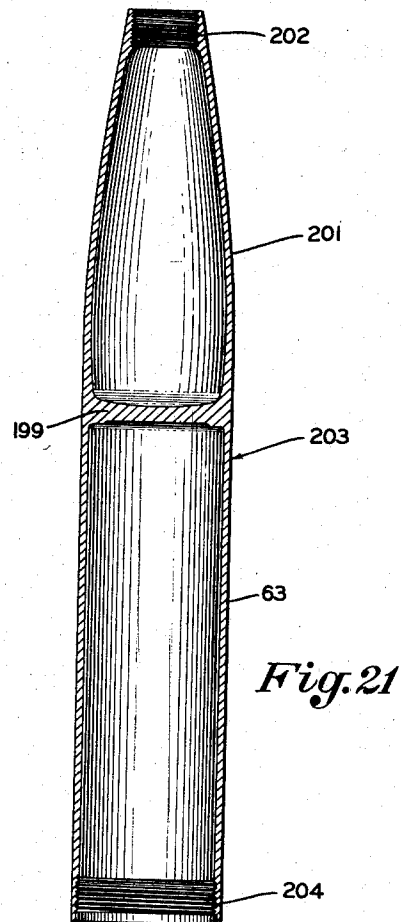
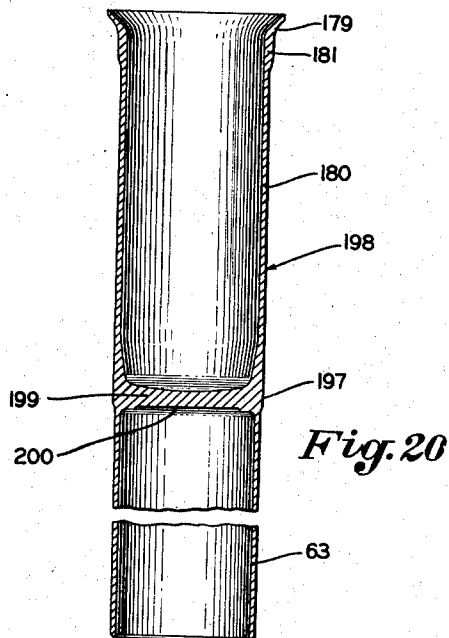
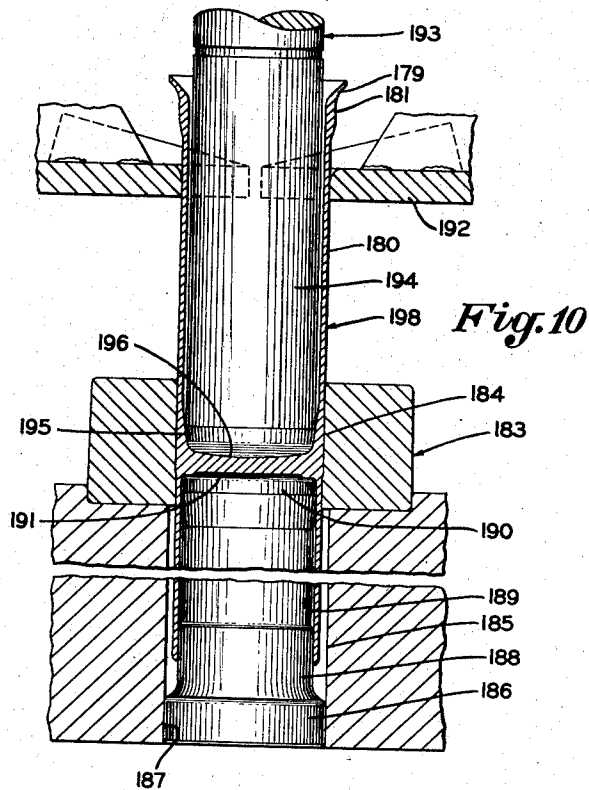
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6 Sheets-Sheet 5



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6 Sheets-Sheet 6

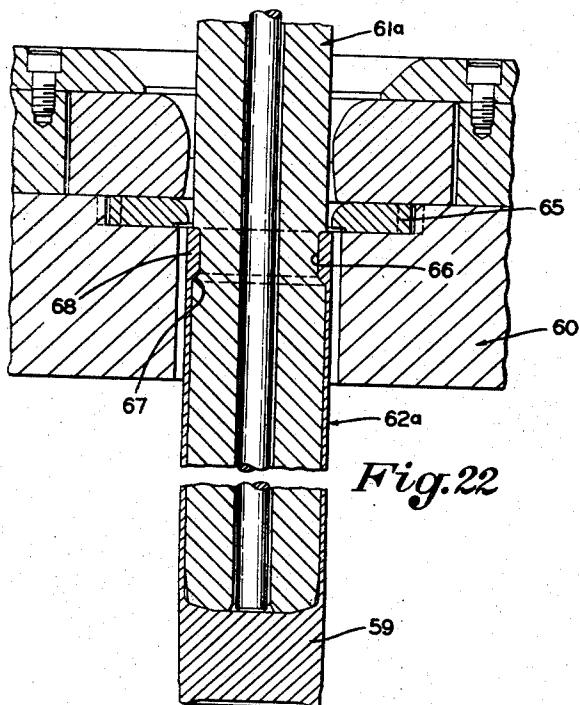


Fig. 22

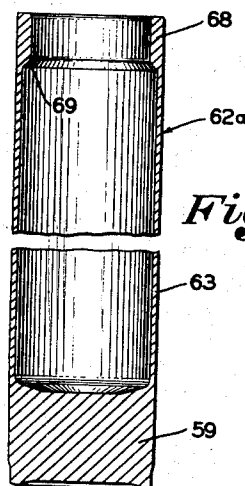


Fig. 23

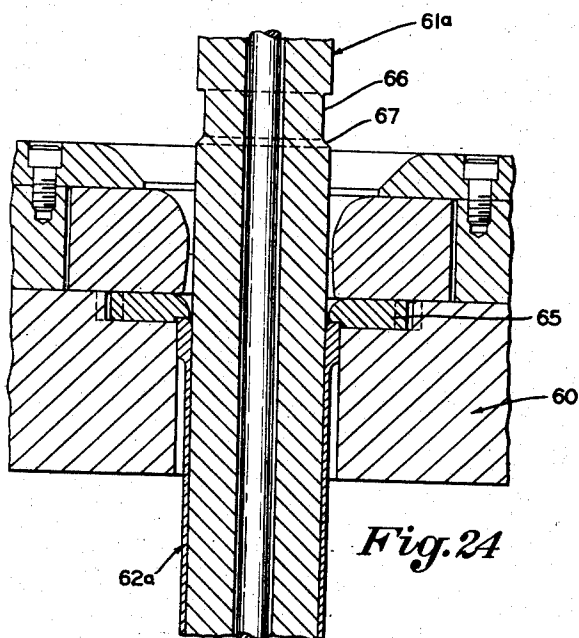


Fig. 24

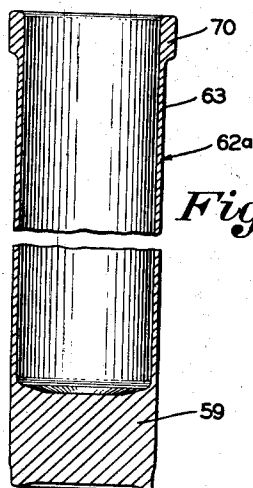


Fig. 25

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1

2,891,298

METHOD OF COLD SHAPING PARTITIONED TUBULAR STEEL ARTICLES

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Application April 7, 1954, Serial No. 421,561

13 Claims. (Cl. 29—1.21)

The invention relates generally to cold shaping tubular steel articles having an integral partition intermediate the ends thereof and having tubular walls of desired shape and thickness extending axially in either direction from the partition wall, and more particularly to cold forming, shaping, flowing and working a solid steel blank into an integral, one piece, article having a partition wall and tubular walls extending in each direction from the partition wall.

Partitioned tubular steel articles have been made for and used for a variety of purposes, among others, as the body of a rocket shell including a motor tube extending in one direction from a partition wall and a warhead tube extending in the other direction from a partition wall located intermediate the ends of the rocket body or shell. Heretofore, such rocket bodies have been made of steel in a plurality of pieces or components welded or otherwise secured together, including, for instance, a motor tube component, a warhead tube component, a partition component, etc., each fabricated separately and thereafter joined together to form the finished rocket.

Difficulties, however, have been encountered in the manufacture of such a completed article from a plurality of components from the standpoint of accuracy in concentricity, alignment, wall thickness and uniformity of strength in the assembled components, as well as the soundness or efficiency of the joints, however formed, between the components, in preventing leakage under pressure between the compartments formed on either side of the intermediate partition wall.

I have discovered that the leakage difficulties or defects may be avoided by making the completed article integrally from a one piece starting blank. In this manner, the partition wall metal can be cold worked in such manner as to develop the necessary strength, hardness and lack of porosity to resist pressure or leakage to which it may be subjected from either side thereof.

Likewise, concentricity in an axial direction of the two tubular portions extending in either direction from the intermediate partition wall, uniformity in wall thickness of either of the tubular portions at any cross section, the desired strength and hardness characteristics of the metal in the walls of the tubular and partition portions, and other desirable characteristics can be developed in the finished product by forming the same in one piece by cold working from a single starting blank of low carbon and preferably low manganese steel, without heat treatment to develop the desired physical properties.

These results, however, can only be achieved by following a certain cold working procedure in which concentricity is initiated throughout the blank and maintained during each forming operation, provided that the necessary forming pressures are developed and sustained during each cold working step without destroying a characteristic, shape, condition or form established or completed in one or more portions of the article by a previous operation.

The manufacture of a partitioned tubular steel article

2

from low carbon steel by cold working and by satisfying the foregoing conditions or requirements presents a most difficult problem where the processing is to be carried out without metal loss incident to the cold working, shaping, flowing, or forming operations required to provide the desired finished shape with strong, sound, leakproof and pressure-resistant walls having the necessary concentricity. The problem is even more complex where it is necessary to create and duplicate the same properties, conditions and shapes within extremely close tolerances and limits in all completed articles intended to be the same.

Thus with respect to the last mentioned consideration, where there is absolute uniformity, piece by piece, in the manufacture of rocket shells, the motor and warhead portions thereof may be charged with uniform amounts of propellants and explosives and the performance thereof more accurately predicated without selecting and grading, because it will be known that each piece is identical with every other piece as to weight, wall thickness, concentricity, etc.

I have discovered a solution to this complex problem involving a procedure or series of steps in the cold working of a steel blank and in which the series of steps are interrelated and coordinated such that partitioned tubular articles of the type described may be successfully produced by cold shaping operations including cold extrusion steps to obtain a desired finished shape, concentricity, uniformity, strength and hardness provided by the cold working, with a substantial reduction in the cost of making such articles as compared with the manufacture of comparable but less accurate articles from a plurality of separately formed pieces or components later joined together.

Fundamentally, the new procedure involves so controlling the character, location and direction of metal flow in the blank as the same is subjected to cold working under compression in successive stages, that the desired wall thickness, strength and shape may be provided in the tubular portions extending in either direction from the intermediate partition wall; that the directed flow of metal, and the zones of metal cold worked, in any stage of the procedure, does not interfere with the directed flow and cold working of metal in the same or different zones of the blank in subsequent stages of the procedure; and that the directed metal flow and zone of metal cold worked in a zone of the metal extending in one direction from the intended location of the partition wall are related during any working operation to the metal in the other zone of the blank extending in the other direction from the intended location of the partition wall such that concentricity is always maintained.

Accordingly, it is a general object of the present invention to provide a new method of cold shaping a tubular steel article to provide a finished article having concentric tubular walls extending in each direction from an intermediate partition wall.

Furthermore, it is an object of the present invention to provide a new procedure of cold working a tubular steel article having concentric tubular walls extending in either direction from an intermediate partition wall in which the partition wall metal is strong, dense and pressure-resistant.

Also, it is an object of the present invention to provide a new method of making a partitioned tubular steel article by cold working, from a starting blank or slug of low carbon steel without metal loss incident to the forming or cold working of the article.

Finally, it is an object of the present invention to solve the complex problems stated, to eliminate difficulties in the manufacture of partitioned tubular steel articles, to generally improve cold working procedures, and to ob-

tain the foregoing advantages and desiderata in an effective and simple manner.

These and other objects and advantages, apparent to those skilled in the art from the following description and claims, may be obtained, the stated results achieved, and the described difficulties overcome by the methods, steps, operations, procedures and discoveries, which comprise the present invention, the nature of which are set forth in the following general statements, a preferred embodiment of which—illustrative of the best mode in which applicant has contemplated applying the principles—is set forth in the following description and shown in the drawings, and which are particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

The nature of certain discoveries and improvements in my method of cold shaping partitioned tubular steel articles may be stated in general terms as preferably including the steps of drawing a tubular wall through a die opening and against a punch in one direction during forward movement of the punch and in then expanding the metal in the tubular wall upon retracting the punch therefrom.

The nature of other discoveries and improvements in my method of cold shaping partitioned tubular steel articles may be stated in general terms as including the steps of forming a blank by compression with a reduced diameter at one end and an expanded diameter at the other end, then completing the tubular wall formation in the expanded diameter end of the blank, then expanding the reduced diameter end of the blank, and then forming a tubular wall in the initially reduced and subsequently expanded diameter end of the blank.

By way of example, the improved method of the present invention is shown somewhat diagrammatically in the accompanying drawings forming part hereof, wherein:

Figure 1 is a perspective view of a metal blank cut from a piece of bar steel as received from the mill which is used as a starting blank in the cold shaping method of the present invention;

Fig. 2 is a somewhat diagrammatic sectional view illustrating the first or slug sizing operation of the new cold shaping method;

Fig. 3 is a view similar to Fig. 2 showing a first backward extrusion operation at the motor end of the blank in the new cold shaping method;

Fig. 4 is a view similar to Fig. 3 showing the next, forward extrusion operation of the motor end of the blank;

Fig. 5 is a view similar to Fig. 4 showing the next drawing operation performed on the motor end of the blank;

Fig. 6 is a view similar to Fig. 5 illustrating the next compressing and expanding operation performed on the head end of the blank;

Fig. 7 is a view similar to Fig. 6 showing the next backward extrusion operation performed on the head end of the blank;

Fig. 8 is a view similar to Fig. 7 showing the second backward extruding and partition working operation performed on the head end of the blank;

Fig. 9 is a view similar to Fig. 8 showing the next forward extrusion operation performed on the head end of the blank;

Fig. 10 is a view similar to Fig. 9 showing the next operation performed to expand the bourrelet at the head end of the blank and optionally to further work the metal in the partition wall;

Fig. 11 is a sectional view of the blank illustrated in Fig. 1 used as a starting blank for the operation shown in Fig. 2;

Fig. 12 is a sectional view of the blank produced by the operation shown in Fig. 2 and which constitutes the starting blank for the operation shown in Fig. 3;

Fig. 13 is a view similar to Fig. 12 illustrating the blank produced by the operation shown in Fig. 3 which

constitutes the starting blank for the operation shown in Fig. 4;

Fig. 14 is a view similar to Fig. 13 illustrating the blank produced by the operation shown in Fig. 4 which constitutes the starting blank for the operation shown in Fig. 5;

Fig. 15 is a view similar to Fig. 14 illustrating the blank produced by the operation shown in Fig. 5 which constitutes the starting blank for the operation shown in Fig. 6;

Fig. 16 is a view similar to Fig. 15 illustrating the blank produced by the operation shown in Fig. 6 which constitutes the starting blank for the operation shown in Fig. 7;

Fig. 17 is a view similar to Fig. 16 illustrating the blank produced by the operation shown in Fig. 7 which constitutes the starting blank for the operation shown in Fig. 8;

Fig. 18 is a view similar to Fig. 17 illustrating the blank produced by the operation shown in Fig. 8 which constitutes the starting blank for the operation shown in Fig. 9;

Fig. 19 is a view similar to Fig. 18 illustrating the blank produced by the operation shown in Fig. 9 which constitutes the starting blank for the operation shown in Fig. 10;

Fig. 20 is a view similar to Fig. 19 illustrating the blank produced by the operation shown in Fig. 10;

Fig. 21 is a sectional view of a completed product made by the method illustrated; and

Figs. 22, 23, 24 and 25 are views similar to Figs. 5 and 15 illustrating a modification of the draw-through procedure.

Similar numerals refer to similar parts throughout the various figures of the drawings.

In the drawings, the improved method illustrates the manufacture of a one piece, partitioned, tubular steel article which may be a rocket shell; but the invention is not limited to the manufacture of a rocket shell, or the particular partitioned article illustrated, inasmuch as the discoveries of the invention may be used for the manufacture of partitioned tubular steel articles intended for other purposes and of different sizes, wall thicknesses, etc.

The starting blank for the new method is indicated at 1 in the drawings and is illustrated as a cylindrical slug which may be cut from bar stock as rolled and as received from the steel mill. Preferably, if the physical properties required in the finished article involve say 100,000 lb. per sq. in. strength and a relatively high Rockwell B scale hardness, the steel should be low carbon and low manganese steel, such as C-1012 steel. Although the use of a cylindrical slug is preferred where a cylindrical tubular article is to be produced, nevertheless, the solid starting blank or slug 1 may have a different cross sectional shape such as oval, square, rectangular, hexagonal, etc., depending on the character of the finished article to be produced.

The amount of steel present in the blank 1 is determined by the amount of steel to be present in the finished article since there is no scrap loss in carrying out the new cold shaping steps of the improved method. Thus, the blank 1 will have the proper weight and size for forming the desired finished article; and the steel used need not be a special or premium analysis steel but as indicated may be an ordinary low carbon steel.

Bar steel as received from the steel mill may be slightly out of round or have slight diameter variations and these variations must be eliminated from the starting blank in order to preclude die injury or the formation of imperfect articles in subsequent operations. That is to say, if true circular cross sections are to be obtained and true concentricity between the inner and outer wall surfaces of the tubular portions of the finished article is

to be maintained, and uniformity from piece to piece

5

is also to be maintained; the actual slug or blank used must be processed to provide a truly concentric blank.

Accordingly, the first step in the procedure is in part a slug sizing operation for providing a truly concentric blank and eliminating other dimensional variations which may be present in the bar stock from which the starting blank is cut.

The slug should not be smaller in diameter than the diameter of the finished article for otherwise extra operations may be involved in connection with providing sufficient metal in the proper places in the blank to carry out the necessary forming operations, to at the same time complete the article to proper size or diameter, and to enable the blank to be made truly round.

The diameter of the starting blank 1 is such that one end portion thereof may be expanded laterally to provide a truly circular shape in cross section for subsequent forming operations, and that the other portion may be compressed laterally to form it with a truly circular cross section while still of a diameter substantially that of the finished product.

Preferably, the starting blank 1 is pickled, provided with a bonderizing coating, and then coated with soap or other usual drawing compound coating. The blank 1 is then placed in the slug sizing die, generally indicated at 2 (Fig. 2), the blank 1 being shown in dot-dash lines in Fig. 2 at the start of the operation. Die 2 is formed with a cavity 3 which has an upper cylindrical portion 4 provided with a rounded upper corner 5 and connected by an angular shoulder 6 with a reduced cylindrical portion 7 which may be slightly tapered for draft. The die portion 7 terminates in a cylindrical knockout opening 8.

A punch generally indicated at 9 is associated with the die 2 having a main cylindrical shank 10 and a rounded corner 11 merging with a further cylindrical shank portion 12 having a close sliding fit within cylindrical die cavity portion 4 so that the punch is centered and guided in its movement within the die cavity 3. The punch portion 12 terminates in a nose formed by a rounded corner 13 merging into a flat bottom or end wall 14; and a knockout member 15 is associated with the knockout opening 8 of the die.

After blank 1 is inserted in die 2, punch 9 is moved downward and engages the top of the blank, the location on the punch at this time being shown by dot-dash lines in Fig. 2. Continued downward movement of the punch applies a compressive force driving the blank downward in die cavity 3. The punch nose formed by rounded corner 13 and flat nose end wall 14 enters the metal in the top of the blank and forms a central flat bottomed recess 16 in the top of the resulting sized slug generally indicated at 17 in Figs. 2 and 12.

As the punch moves downward the compressive force exerted flatwise on the top of the metal in the blank by the flat punch nose acting on top of the blank causes the blank metal to flow and fill out and expand in the upper portion of the blank into the die cavity portion 4 above the die cavity shoulder 6. The compressive force exerted by punch 9 in forming recess 16 in expanding the outer periphery of the upper portion of the blank to increase the diameter thereof may be accompanied by a very small amount of backward extrusion around the punch nose. At the same time, the compressive force exerted by punch 9 pushes the lower end of blank 1 into the smaller diameter cavity portion 7 to reduce the diameter of this portion of the blank and form it under compression with a truly circular cross section.

The cold working of the blank 1 to form the prepared blank 17 thus accurately sizes the periphery of the blank under compression at all sections to be truly round and removes all out of roundness that may have been present in the bar stock from which the blank 1 was cut.

The blank 17 (Fig. 12) thus formed by the slug

6

sizing operation illustrated in Fig. 2 has an upper expanded portion 18 of larger diameter than the diameter of the slug 1 and a lower reduced diameter portion 19 of smaller diameter than the diameter of slug 1 with an angular shoulder 20 connecting the expanded and reduced diameter portions 18 and 19. The portion 19 also has a diameter substantially that of the finished article or that portion thereof formed from the lower end of the blank 17.

In forming the sized or prepared blank 17, the metal in the upper portion of the blank below the recess 16 is cold worked somewhat, and the metal in the outer annular portions of the expanded portion 18 and reduced portion 19 is cold worked somewhat, accompanied by some work hardening. However, the metal in the remainder of the blank is only cold worked to a slight extent and is not appreciably work hardened so that it may be subjected to substantial cold working in the next operation without any annealing.

The angular shoulder 20 on the prepared blank 17 is so located and formed with respect to the blank portions 18 and 19 at either end of the shoulder that a subsequent backward extrusion may be performed on the expanded portion 18 of the blank in one operation and without annealing, and which backward extrusion may form a deep hole in the expanded portion 18 of the blank with an exterior shoulder intervening the ends of the backwardly extruded blank that may be used for subsequently forwardly extruding the backwardly extruded metal to provide an elongated thin tubular wall at one end of the blank having the desired finished diameter and which finished diameter approximates the diameter of the reduced diameter portion 19 of the starting blank 17.

After the slug sizing operation has been completed in the die illustrated in Fig. 2, punch 9 may be withdrawn and the sized slug 17 ejected from the die by knockout member 15, sufficient clearance being provided as illustrated in Fig. 2 between the top of the knockout member 15 and the final location of the sized slug 17 in die 2 to prevent any bottoming of the sized slug on the knockout member during the operation illustrated.

The sized slug 17 may then be washed, pickled, and bonderized in the usual manner and provided with a usual draw compound coating in preparation for the next operation illustrated in Fig. 3, wherein the blank 17 is shown in dot-dash lines at the start of the operation. The operation illustrated in Fig. 3 is essentially a backward extrusion operation and is performed in a die generally indicated at 21 having a cavity provided with an upper cylindrical portion 22 and a rounded upper corner 23. The cylindrical portion 22 is connected by an angular shoulder 24 with a reduced cylindrical portion 25 which in turn is connected by an angular shoulder 26 with a further reduced portion 27 having the shape of the reduced portion 19 of prepared blank 17. The lower end of the die cavity terminates in a knockout opening 28 in which a knockout support member 29 is located.

A punch generally indicated at 30 is associated with die 21 having a main cylindrical shank portion 31 provided with a rounded corner 32 and the shank 31 has a close sliding fit within cylindrical die portion 22 so that the punch is centered and guided in its movement therein. The rounded corners 23 and 32 insure proper entry and alignment of punch 30 in die 21 when performing the backward extrusion operation on prepared blank 17 inserted in die 21. The punch shank 31 is joined by a fillet 33 with a cylindrical nose 34 terminating in a tapered end portion 35 joined by a rounded corner 36 with a tapered nose portion 37 terminating in a flat central nose portion 38.

After the blank 17 is inserted in die 21, as shown in dot-dash lines in Fig. 3, punch 30 is moved downward and engages the top of blank 17, the location of

the punch at this time also being shown by dot-dash lines. Continued downward movement of punch 30 within the die cavity applies a compressive force first from the flat nose end portion 38 and then from the entire nose portion of the punch within recess 16 of blank 17, which recess 16 centers the blank with respect to the punch nose.

During continued downward movement of the punch 30 in die 21, the metal in the upper portion 18 of blank 17 is displaced first outwardly and then outwardly upward, backward of the direction of punch travel, to radially fill the cylindrical portion 25 of the die cavity. During this downward movement of the punch the axial length of the upper portion of the blank is increased because of the backward extrusion, and at the same time, the metal in the lower portion of the blank is pushed downward somewhat in the die cavity portion 27 to fill out the die cavity portion above member 29 and to bottom on the top of the support member 29 which may be shaped with the flat portion 39 terminating in an annular angular portion 40 somewhat similar in shape to the portions 14 and 13 respectively of punch 9.

An extruded blank 41 is thus formed which may be ejected from the die cavity by support member 29 upon withdrawal of punch 30. The extruded blank 41 (Fig. 13) has a cup formation 42 at the upper or motor end thereof extending above an angular shoulder 43 which terminates below in the reduced diameter portion 44 having a flat shallow recess 45 in its bottom end, similar to the recess 16 formed in the upper end of starting blank 17.

There are a number of important aspects to the particular manner in which the backward extrusion operation of the motor end of the blank is carried out as illustrated in Fig. 3 to produce the backwardly extruded blank 41 shown in Fig. 13. First of all, the diameter of punch nose portion 34 should be equal to or larger than the finished inside diameter of the motor tube to be formed at the motor end of the blank. Second, in order to eliminate excessive pressures, the metal in the blank is allowed to move outward and upward freely as illustrated in Fig. 3 within die cavity portion 25 which is larger in diameter than the outer diameter of the upper end portion 18 of the prepared blank as shown in dot-dash lines in Fig. 3.

Third, because of the free outward expanding of the metal in a wall portion 42 of the resulting blank 41, any hidden seams that may have been present in the bar stock from which the starting slug 1 has been formed will be opened up, enlarged and made clearly visible for removal. The enlarging of the seams or other imperfections on the outer surfaces of the upper portion 42 of blank 41 due to the expansion thereof enables grinding operations to be performed readily on the blank 41 whereby the seams may be removed and will not result in defects in the finished part.

Fourth, the downward pressure of punch 30 is resisted by the bottoming of the blank metal on support member 29 so that the metal in the upper region of the blank must flow upwardly and outwardly freely around the punch nose as the punch descends; and at the same time, a centering depression for a punch in a subsequent operation is formed at 45 on the lower end of the blank.

Because of the substantial cold working to which the blank 41 has been subjected, it is substantially work hardened and must be annealed to prepare it for subsequent operations. The annealing operation may be carried out, following the removal of seams, by washing, and by heating the blank 41 to from 1250° F. to 1450° F., followed by pickling, bonderizing and the application of another drawing compound coating. The blank 41 is now ready for the next or forward extrusion operation shown in Fig. 4 which may be performed in a die generally indicated at 46 formed with a cavity

having an upper cylindrical portion 47 with a rounded upper corner 48, an extrusion shoulder 49, a reduced cylindrical extrusion orifice portion 50 and a relieved guide opening 51.

A punch generally indicated at 52 is associated with the die 46 having a main cylindrical shank 53 formed with an extrusion shoulder 54 which merges into a reduced nose portion 55. The punch portion 53 has a close sliding fit within cylindrical portion 47 of the die cavity so that the punch is centered and guided in its movement within the die cavity, the rounded corner 48 cooperating with the extrusion shoulder 54 to insure proper entry and alignment of the punch 52 in the die 46.

When the blank 41 is inserted in die 46, as shown in dot-dash lines in Fig. 4, the shoulder 43 thereof rests on the die extrusion shoulder 49 with the blank portion 44 extending downward through extrusion orifice 50. After blank 41 is inserted in die 46, punch 52 is moved downward and its nose enters the blank until the punch extrusion shoulder 54 engages the top annular surface of upper side wall portion 42 of blank 41. The location of the punch at this time also is shown by dot-dash lines in Fig. 4.

Continued downward movement of punch 52 applies an extrusion pressure or force through extrusion shoulder 54 to the upper end of the side walls 42 of blank 41 and the metal in the thick side walls is forced under compression downward and is extruded through the escape area between extrusion shoulder and orifice 50 and punch nose 55. This forward extrusion operation not only thins and elongates the metal in the side walls of the piece at the motor end of the blank but work hardens the same to the desired degree of hardness depending upon the character of the restricted escape or flow area between the punch and extrusion shoulder through which the metal is extruded.

The final limit of downward movement of punch 52 and of the extruded tubular blank 56 resulting from the forward extruding operation are shown in full lines in Fig. 4, the blank 56 also being illustrated in Fig. 14. A flange 57 remains at the upper end of the tubular side walls 58 at the motor end of blank 56, and side walls 58 extend upward from the head end of the blank 59 which has the same shape as the portion 44 formed in the blank 41 by the operation shown in Fig. 3. The blank 56 is then washed, pickled, bonderized and provided with a drawing compound coating in preparation for the next draw through operation illustrated in Fig. 5.

The draw through operation is performed in a usual manner with a usual die and punch illustrated respectively at 60 and 61 in Fig. 5, the blank 56 being placed in die 60 initially as shown in dot-dash lines in Fig. 5, and the punch 61 then being moved downward to draw the blank through the die 60 to form the drawn blank 62 illustrated in Fig. 15 and in full lines in Fig. 5.

The draw through operation of Fig. 5 reduces the thickness of the side walls of the motor end of the tube, indicated at 63 to the desired completed cylindrical size, the metal in the side walls 63 being worked to final hardness and to develop the desired physical characteristics therein. The metal in the head end 59 of the blank not having been cold worked following the annealing operation performed on the blank 41, remains soft so that it may be subjected to further cold working operations. The draw through blank 62 is now ready, without further preparation, to be subjected to further operations to provide the desired formations on the head end of the blank.

Before describing the further operations carried out on the blank 62, several aspects of the procedure carried out in the forward extrusion operation of Fig. 4 and the draw-through operation of Fig. 5 warrant comment. The blank 56 (Fig. 14) produced by the forward extrusion operation of Fig. 4 shows a slight enlargement or bulge,

indicated at 64, at the region where the side walls 58 join the head end 59 of the blank 56, the bulge 64 also being indicated in Fig. 4 in full lines and in Fig. 5 in dot-dash lines.

This bulge 64 occurs during the forward extrusion operation of Fig. 4 and is apparent by measuring actual blanks 56 produced by the operation. When blank 41 is placed in die 46 and punch 52 descends, the punch forces some of the metal in shoulder 43 of blank 41 under compression against the die orifice 50 in such manner as to produce an outward resultant when the pressure or compression is relieved, as when a portion of the metal in what was once the shoulder portion 43 of blank 41 passes to the relieved die portion 51. Because of the relatively large volume of metal in the particular region of shoulder 43, the metal in passing through orifice 50 is not stressed to anywhere near its elastic limit; and after passing into the clearance zone 51 (Fig. 4) the metal tends to expand slightly as indicated at 64. While this localized expansion 64 is reduced in diameter momentarily when the knock-out member associated with die 46 (not shown) ejects the blank 56 from die 46 since the metal in the expanded portion 64 was not stressed beyond its elastic limit, the expanded portion 64 springs back, or recovers, after ejection of blank 56, so that the localized expanded portion 64 is present in the completed blank 56, as shown in Fig. 14.

While this metal flow or shaping is taking place, the metal in the head end 59 of blank 56 is neither subjected to pressure nor worked, and the shape of portion 59 remains unchanged. However, since the metal in the blank 56 forming the extruded tubular side walls 58 is stressed beyond its elastic limit during the extrusion operation, it retains in completed blank 56, the inner and outer diameters resulting from the diameters of the die orifice opening 50 and of the punch nose 55.

When the blank 56 is then subjected to the draw-through operation of Fig. 5, the bulged or expanded portion 64 is eliminated or ironed out in drawing blank 56 through the die 60 to form the blank 62.

Referring to Figs. 22, 23, 24 and 25, a slightly modified form of punch 61a is illustrated for carrying out the draw-through operation of Fig. 5. Fig. 22 represents the punch 61a and draw-through die 60 and drawn blank 62a in substantially the same relative positions as corresponding elements in Fig. 5 excepting that the blank 62a has completed its limit of downward movement in the draw-through operation past the stripping ring 65.

The punch 61a is provided with an annular recessed groove 66 having a lower outwardly downwardly angled annular corner 67 into which the metal in the upper end 57 of blank 56 flows during the draw-through operation to produce a thickened upper end portion 68 at the upper end of the side walls 63 of the drawn through blank 62a. This thickened blank upper end side wall portion 68 is illustrated in Fig. 23, which represents a cross-section of the blank at the stage of the draw-through operation illustrated in Fig. 22, assuming that the blank 62a could be removed from punch 61a at this time without shape change, which, of course, is impossible. The thickened blank portion 68 has a lower angular annular shoulder 69 formed by the punch recess shoulder 67. Referring to Fig. 24, when the draw-through punch 61a is retracted to strip the punch from the blank 62a, the punch recess shoulder 67 expands the thickened blank portion 68, held by the stripping ring 65, so that the thickened portion 68 is enlarged as indicated at 70 in Fig. 25 providing an outturned flange portion at the upper end of drawn through blank 62a.

In other words, the punch 61a is undercut at 66 and 67 so as to form the thickened portion 68 on the downstroke of the draw-through operation; and in retracting the punch 61a, the undercut shoulder 67 expands the

upper end of the blank to enlarge the thickened portion 68 and form an outturned thickened flange 70. In this manner, the drawn through blank 62 of Fig. 15 may be provided with a thickened outturned flange portion at the upper end of its side walls 63 as illustrated in the blank 62a of Fig. 25.

The blank 62 or 62a now may be subjected to further operations for forming the head end of the final product from the metal in the head end 59 of blank 62 or 62a, the motor end side walls 63 of the article having been completed or finished.

The next operation, that is the compressing and expanding of the head end 59 of the blank 62 or 62a, may be performed in a die generally indicated at 71 in Fig. 6. The die 71 is formed with a cavity having an upper cylindrical portion 72, a shoulder 73, a reduced cylindrical portion 74, another shoulder 75, a further reduced cylindrical portion 76 and a flared end 77 communicating with an enlarged portion 78 at its lower end. The upper cylindrical portion 72 is provided at its upper end with a rounded corner 79, as shown.

A punch generally indicated at 80 is associated with the die 71 having a main cylindrical shank 81 provided with a rounded corner 82, and the shank 81 has a close sliding fit within cylindrical die portion 72 so that the punch is centered and guided in its movement therein. The rounded corners 79 and 82 insure proper entry and alignment of punch 80 in die 71 when performing the backward extrusion operation on blank 62 or 62a inserted in die 71. The punch shank 81 is joined by a fillet 83 with a cylindrical nose 84 terminating in a flat end 85 joined by rounded corner 86 with cylindrical nose portion 84.

Also associated with die 71 is a support member generally indicated at 87 having a cylindrical portion 88 centered and closely fitting within cylindrical die portion 78. Support member 87 mounts a tubular support shank 89 having side walls slightly concave in cross-section as indicated at 90, terminating in an annular upper end portion 91 having a shape complementary to the shape of the surface 92 at the bottom of the recess formed by the tubular walls 63 of blank 62. A knockout pin 93 extends through support members 87 and 89 and is provided with an enlarged knockout member 94 with a head 94a slidably mounted within the enlarged recess 95 at the upper end of support shank 89.

The blank 62 of Fig. 15 is turned upside down or end-for-end from the position illustrated in Fig. 15, and inserted in die 71, as shown in dot-dash lines in Fig. 6. The punch 80 is then moved downward and engages the top of blank 62, the location of punch 80 at this time also being shown by dot-dash lines. The blank 62 as thus inserted and positioned within the die 71 is centered within the die by being supported on support shank 89, as shown, which support shank 89 and support member 87 are centered in the die cavity as previously described. Meanwhile, punch 80 is centered within die 71 and the nose 84 thereof is centered with respect to blank 62 in the initial engagement with the blank by the recessed formation 45 in the end of the head 59 of the blank. This recess 45 was formed in the operation illustrated in Fig. 3 and the formation 45 is not disturbed or changed in either of the operations illustrated in Figs. 4 and 5, as indicated at 45 in the blanks illustrated in Figs. 14 and 15.

Continued downward movement of punch 80 within the die cavity 71 applies a compressive force from the flat end 85 of the punch within recess 45 of blank 62. During such movement the metal in the head end 59 of the blank is displaced first outwardly to radially fill the cylindrical portion 74 of the die cavity. During this downward movement of the punch, the axial length of the head end portion 59 of the blank 62 remains substantially the same, as indicated by a comparison of the full and dot-dash lines in Fig. 6, defining the upper end portion of the blank 62 before and after forming. There

11

may be a very slight increase in the axial length of the head end portion 59, too small to indicate in the drawings, incident to a slight amount of backward extrusion which may occur during the head expanding operation.

A blank 96 is thus formed which may be ejected from the die cavity by knock-out pin 93 upon withdrawal of punch 80. The blank 96 (Fig. 16) has an enlarged head end 97 formed from the metal in head end 59 of blank 62 (Fig. 15), the head end 97 joining the tubular motor end wall 63 by an annular shoulder 98, and terminating upwardly in a thick annular wall portion 99 extending upward from a thick partition wall portion 100.

There are a number of important aspects of the compressing and expanding operation performed on the head end of the blank carried out as illustrated in Fig. 6 to produce the blank 96 shown in Fig. 16, and of the particular shaping of the expanded head end 97 of the blank 96. When the ultimate hole or cavity to be formed in the head end of the blank must have the same internal diameter as, or a larger diameter than, the internal diameter of the finished tubular walls 63 of the motor end of the blank, it becomes necessary to provide for a resistance area in some manner on the motor end of the blank to supplement the resistance area 101 at the motor end surface of partition wall 100, so that the total motor end resistance area is greater than the pressure which must be applied to the head end of the blank to displace and flow the metal therein for later forming the head end of the blank to cylindrical shape with a hole or cavity.

In the operation illustrated in Fig. 6 a punch is used with a nose 84 slightly smaller in diameter than the internal diameter of the cylindrical walls 63 to expand and compress the metal in the head end 59 of blank 62 to the expanded shape 97 in blank 96. In so doing, the support area of support member portion 91 and knock-out member head 94a is slightly greater than the area of punch nose 84 so that as punch nose 84 moves downward into head end portion 59 of blank 62, the head end portion 59 is supported at 101 and the metal therein expands outwardly around and is compressed under flat end 85 of punch nose 84.

As a result of expanding the head end 59 of the blank 62 to form the expanded head end portion 97 of blank 96, the shoulder 98 is formed which now provides a resistance area which, added to the area of the bottom 101 of recess in the motor end of the blank, is as great or greater than the area at the bottom end of the ultimate hole to be formed in the head end of the blank. In this manner the shape of the blank has now been prepared to enable a tubular hole to be formed in the head end of the blank as large as or larger than the internal diameter of the finished tubular wall 63.

The metal in the head end 59 of blank 62 is soft prior to the operation illustrated in Fig. 6 but the metal in the walls 63 thereof is hard, the desired hardness having been developed therein by cold working. In carrying out the operation illustrated in Fig. 6, to compress and expand the head end to the shape indicated at 97 in Fig. 16, the metal in the head end 97 does not become as hard as the metal in the walls 63 of the motor end of blank 96. However, because the mass of metal in head end 97, partially hardened, exceeds the strength of the thin finished work-hardened tubular walls 63, it is necessary in order to further cold work the metal in the expanded end 97 of blank 96, to locally anneal the same. Such local annealing of the metal in the head end 97 of blank 96 is also necessary to prevent fracture during the next operation of the zone of metal between the hard and partially hardened expanded metal.

This local annealing operation of the enlarged portion 97 of blank 96 may be carried out in a usual manner, preferably by induction heating the portion 97 of blank 96 while maintaining the motor end walls 63 cold by water sprays so as to prevent the annealing heat from affecting the hardness previously developed in the tubular

12

walls 63. The annealing operation may be carried out by the localized heating of head end portion 97 to about 1450° F. followed by washing, pickling, bonderizing, and the application of another drawing compound coating.

The blank 96 is now ready for the next backward extrusion operation shown in Fig. 7 which may be performed in a die generally indicated at 102 formed with a cavity having an upper cylindrical portion 103 with a rounded upper corner 104, a shoulder 105, a reduced cylindrical portion 106, another shoulder 107, and a reduced cylindrical portion 108 communicating with an enlarged portion 109 at its lower end.

A punch generally indicated at 110 is associated with the die 102 having a main cylindrical shank 111 provided with a rounded corner 112, and the shank 111 has a close sliding fit within cylindrical die portion 103 so that the punch is centered and guided in its movement therein. The rounded corners 104 and 112 insure proper entry and alignment of punch 110 in die 102 when performing the backward extrusion operation on blank 96 inserted in die 102. The punch shank 111 is joined by a fillet 113 with a cylindrical nose 114 terminating in a flat end 115 joined by a rounded corner 116 with cylindrical nose portion 114.

Also associated with die 102 is a support member generally indicated at 117 having a cylindrical portion 118 centered and closely fitting within cylindrical die portion 109. Support member 117 mounts a tubular support shank 119 having side walls slightly concave in cross-section as indicated at 120, terminating in an upper end portion 121 having a shape complementary to the shape of the surface 101 of blank 96. A knock-out pin 122 extends through support members 117 and 119 and is provided with an enlarged knock-out member 123 with a head 124 slidably mounted within the enlarged recess 125 at the upper end of support shank 119.

Blank 96 is inserted in die 102, as shown in dot-dash lines in Fig. 7, and the shoulder 98 rests on die shoulder 107 with initially a slight clearance 126 between blank surface 101 and the top end of support member 121 and knock-out head 124, as shown in Fig. 7. After blank 96 is inserted in die 102, punch 110 is moved downward within blank walls 99 until it engages the top of thick partition wall 100, also as shown in dot-dash lines in Fig. 7. The blank 96 as thus inserted in die 102 and supported on support member 117 is centered with respect to the die and the punch 110; the punch and support members being centered with respect to the die cavity as previously described, and the cavities in the blank 96 being concentric as previously described.

Continued downward movement of punch 110 applies an extrusion pressure flatwise from the flat end 115 of the punch against the metal in the thick partition wall 100 of the blank 96 to drive the blank downward and seat blank surface 101 on the upper end of support member 121 and knock-out member head 124 and to rearwardly extrude metal in the blank outwardly and then outwardly upward, backward of the direction of punch travel, within die cavity portion 106, the upper portion of which may be slightly relieved for clearance at 106a to provide a slightly larger diameter as shown at 106b. During this downward movement of the punch 110 the axial length of the head end portion 97 of blank 96 is increased because of the backward extrusion, and at the same time, the metal in partition wall 100 is substantially reduced in thickness.

A blank generally indicated at 127 is thus formed which may be ejected from the die cavity by knock-out pin 122 upon withdrawal of punch 110. The blank 127 (Fig. 17) has a head end portion 128 joining the tubular motor end wall 63 by an annular shoulder 129, and terminating upwardly in elongated thick annular wall portion 130 extending upward from partition wall portion 131, the partition wall portion being provided with an upper head end recess surface 132 and a lower motor end recess surface 133.

13

In carrying out the operation illustrated in Fig. 7, the outer diameter of the head end portion 128 may be slightly enlarged over the outer diameter of the head end portion 97 of blank 96, and the internal diameter of thick walls 130 may be formed slightly larger than the internal diameter of thick wall portion 99 of blank 96 as the hole 134 is deepened therein.

Furthermore, the hole 134 in blank 127 is slightly larger in diameter than the ultimate hole to be formed in the head end; and preferably the bottom surface 132 of the hole, that is the top surface of partition wall 131, is shaped with a tapered angular portion 135 for purposes to be later described. The blank 127 has now been prepared so as to enable the final formation of the center section or partition wall of the ultimate product; which preparation includes the described enlarged diameter of hole 134, the enlarged outer diameter of wall portion 130, and the radial formation of the hole bottom surface 132—135.

The metal in the head end portion 128 of blank 127 has again become hardened by cold working in performing the operation shown in Fig. 17 and must again be locally annealed in the manner previously described with respect to the blank 96, followed by washing, pickling, bonderizing, and the application of another drawing compound coating. During the annealing operation, the finished wall 63 is maintained cold by water sprays to prevent affecting the physical properties previously developed therein by cold working.

In forming the blank 127, the area of shoulder 98 of blank 96 and the support area 101 provides sufficient resistance area or strength to resist the pressure of punch nose 114 entering the head end of the blank for carrying out the backward extrusion operation.

The blank 127 is now ready for the next backward extruding and partition wall coining operation shown in Fig. 8 which may be performed in a die generally indicated at 136 formed with a cavity having an upper cylindrical portion 137 with a rounded upper corner 138, a shoulder 139, a clearance portion 140 slightly reduced at shoulder 141 and connected with cylindrical portion 142 terminating in a shoulder 143 and a reduced cylindrical portion 144 communicating with an enlarged portion 145 at its lower end.

A punch generally indicated at 146 is associated with die 136 having a main cylindrical shank 147 provided with a rounded corner 148, and the shank 147 has a close sliding fit within cylindrical die portion 137 so that the punch is centered and guided in its movement therein. The rounded corners 138 and 148 insure proper entry and alignment of punch 146 in die 136 when performing the operation on blank 127 inserted in die 136. The punch shank 147 is joined by a fillet 149 with a cylindrical nose 150 terminating in a rounded nose end 151 having a slightly conical central nose end surface 152.

Also associated with die 136 is a support member generally indicated at 153 having a cylindrical portion 154 centered and closely fitting within cylindrical die portion 145. Support member 153 mounts a tubular support shank 155 having side walls slightly concave in cross-section as indicated at 156, terminating in an upper end portion 157 having a shape desired for shaping the bottom end of the recess in the motor end of the blank. A knock-out pin 158 extends through support members 153 and 155 and is provided with an enlarged knock-out member 159 with a head 160 slidably mounted within the enlarged recess 161 at the upper end of support shank 155.

The blank 127 is inserted in die 136, as shown in dot-dash lines in Fig. 8 with the shoulder 129 resting on die shoulder 143. Punch 146 is then moved downward and the nose thereof engages blank partition wall 101 and by axial compression reduces the thickness thereof and coins the metal therein to the shape shown in Fig. 8. In this operation, the outer diameter of the thickened head end

14

portion 128 of blank 127 is at the same time slightly reduced within die cavity portion 142 so that the metal in and adjacent the partition wall is compressed both axially and radially to form a sound partition wall metal structure.

In thus cold working and flowing metal in the partition wall, a certain amount of backward extrusion takes place which elongates the side walls of the enlarged head end portion of the blank as shown by comparing the dot-dash and full line showing of the upper ends of the blanks in Fig. 8. These operations, including the reducing of the outside diameter of the head end of the blank adjacent the partition wall, the coining of the metal in the partition wall, and the axial and radial compression of the metal in the partition wall constitute the final stage in what may be termed a "grain crossing" step in the cold working of the metal in the partition wall.

A blank 162 is thus formed which may be ejected from the die cavity by knock-out pin 158 upon withdrawal of punch 146. The blank 162 (Fig. 18) has a further elongated expanded head end 163 joining the tubular motor end wall 63 by an annular shoulder 164, and terminating upwardly in a thick annular wall portion 165 extending upward from the substantially finished partition wall portion 166.

In performing the operation illustrated in Fig. 8, no substantial cold working of the metal in wall portion 165 is performed so that this wall portion is not work-hardened but remains soft. The only work-hardened portion is the metal in the zone of the partition wall 166 in which the desired physical properties have now been developed as well as in the previously work-hardened motor end tubular wall 63.

In shaping the blank 162, sufficient metal remains at rounded areas 167 which are formed from the zones 135 in the blank 127, at the upper surface of partition wall 166 from which the bourrelet may subsequently be expanded. The metal in annular zone 167 was not work-hardened under compression because it was not contacted by the rounded portion 151 of punch 146, as shown in full lines in Fig. 8.

If the work-hardening of the metal in partition wall 166 has resulted in any substantial work-hardening of the metal at an immediately adjacent shoulder 164 in blank 162, then this portion of the blank only should be locally annealed in the manner previously described while maintaining the partition wall 166 and motor end wall 63 cool by water sprays to prevent the physical properties developed therein from being affected.

The local annealing is then followed by pickling, bonderizing, and the application of another drawing compound coating; and the blank 162 is now ready for the next or forward extrusion operation shown in Fig. 9 which may be performed in a die generally indicated at 168 formed with a cavity having an upper cylindrical portion 169 with a rounded upper corner 170, an extrusion shoulder 171, and a reduced cylindrical extrusion orifice 172 terminating in a guide opening 173.

A punch generally indicated at 174 is associated with die 168 having a main cylindrical shank 175 formed with an extrusion shoulder 176 which merges into a reduced nose portion 177. The punch portion 175 has a close sliding fit within cylindrical portion 169 of the die cavity so that the punch is centered and guided in its movement within the die cavity, the rounded corner 170 cooperating with the extrusion shoulder 176 to insure proper entry and alignment of the punch 174 in the die 168.

When the blank 162 is inserted in die 168, as shown in dot-dash lines in Fig. 9, the shoulder 164 thereof rests on the die extrusion shoulder 171 with the blank portion 63 extending downward through the extrusion orifice 172. After blank 162 is inserted in die 168, punch 174 is moved downward and its nose enters the blank until the punch extrusion shoulder 176 engages the top annular surface of side wall portion 165 of blank 162.

15

Continued downward movement of punch 174 applies an extrusion pressure or force through extrusion shoulder 176 to the upper end of the side walls 165 of blank 162 and the metal in the thick side walls 165 is forced under compression downward and is extruded through the escape area between extrusion shoulder 171 and orifice 172, and punch nose 177. This forward extrusion operation not only thins and elongates the metal in the side walls of the head end 163 of the blank 162 but work-hardens the same to the desired degrees of hardness, depending upon the character of the restricted escape or flow area between the punch and the die extrusion shoulder through which the metal is extruded.

The final limit of downward movement of punch 174 and of the extruded tubular blank 178 resulting from the forward extruding operation are shown in full lines in Fig. 9, the blank 178 also being illustrated in Fig. 19. A flange 179 remains at the upper end of the tubular side walls 180 at the head end of the blank 178, said side walls 180 extending upward from the motor end of the blank 178 and from the intermediate partition wall 166, the motor end side walls again being indicated at 63.

The blank 178 now has thin work-hardened tubular side walls 63 and 180 having the same external diameter, this diameter being smaller than the diameter of the thickened wall portion 163 of blank 162 and being smaller than the initial diameter of the starting slug 1. Below the flange 179, the side walls 180 may be slightly thicker as indicated at 181 for a purpose to be subsequently described, this thickened portion 181 being formed in die 168 by the enlarged die recess 182 below extrusion shoulder 171 and above escape orifice 172.

The blank 178 is then washed, pickled, bonderized and provided with a drawing compound coating in preparation for the next operation of expanding the bourrelet, illustrated in Fig. 10.

The operation of expanding the bourrelet is performed in a die arrangement generally indicated at 183 including a cylindrical die cavity 184 in a die block supported on a support block having an enlarged opening 185 receiving a lower support member generally indicated at 186 having a cylindrical portion 187 centered and guided in die portion 185. The lower support member 186 is formed with a reduced cylindrical portion 188 above portion 187, a hollowed portion 189, and an enlarged head 190 provided with a flat central projection 191.

Above the upper end of die 183 is a blank centering fixture 192, and associated with die 183 is a punch generally indicated at 193 having a cylindrical portion 194 and a tapered nose portion 195 terminating in a slightly convex nose end 196.

As shown in Fig. 10, the lower support member portions 188 and 190 contact within the motor end side walls 63 of blank 178 supported thereon, and center the same with respect to die 183, the support member 186 being centered with respect to the die cavity as explained. Relief portion 189 of lower support member 186 does not internally contact the side walls 63 of blank 178. Fixture 192 engages the outside of the head end side walls 180 of blank 178 and centers the same with respect to the die cavity. Punch cylindrical portion 194, as shown, is of smaller diameter than the internal diameter of blank walls 180.

After the blank 178 is inserted in die 183, punch 193 is moved downward and the nose portions 195 and 196 thereof engage the head end surface of partition wall 166, the motor end partition wall surface being supported on top of lower support member 186. Continued downward movement of punch 193 applies expanding and compressive forces to the partition wall metal. Tapered nose portion 195 engages the rounded area 167 previously formed in blank 162, which formation 167 remained in blank 178, and punch portion 195 drives metal from the upper portion of rounded areas 167 slightly outward to expand

16

a bourrelet or band annularly around the blank just above the partition wall at the motor end thereof. Further expansion of the metal in the blank wall is resisted and stopped by the cylindrical opening 184 of the die 183.

This expanded bourrelet is small, but of a usual nature and tapers into the motor and head end side walls 63 and 180, being generally indicated in the drawings by the numeral 197 in the resulting blank generally indicated at 198 in Fig. 20. As the metal in the rounded areas 167 can no longer move outward on continued downward movement of punch 193 in die 183, the rounded punch nose portion 196 drives the metal toward the center of the partition wall or axis of blank 198, resulting in a slight central thickening of the partition wall as indicated at 199 in Fig. 20, the underside of the partition wall 199 being formed with a slight central recess 200 by the support member formation 191.

This thickening and inward movement of the metal in the partition wall 199 of blank 198 also completes the "grain crossing" step in the cold working of the metal in the partition wall.

The blank is then removed from die 183, and as illustrated in Fig. 20, the blank 198 with the expanded bourrelet 197 and finished partition wall 199 has finished head end side wall portions 180 and motor end side wall portions 63 in which all physical properties required have been developed by the various cold working operations except in flange 179 and thickened portion 181 at the upper end of the head end, the shape of which has not been completed.

The upper end of blank 198 may then be subjected to a usual stress-relieving operation in the zone of the flange 179 and thickened portion 181, and then washed, pickled and bonderized and subjected to a usual series of drawing and nosing operations with intervening stress relief etc. until the desired head end shape 201 is developed as shown in Fig. 21. The metal originating in flange 179 and thickened wall portion 181 in blank 198 provides metal for substantial metal thickness at the nosed-in end of the blank after the nosing operations have been completed and thus provides sufficient metal for internally threading the head end as indicated at 202 in the final article illustrated generally at 203 in Fig. 21.

The article 203 may then be threaded internally as at 204 at the end of motor end walls 63. The motor end walls 63 and head end walls 201 thus extend from the strong partition wall 199 integrally in one piece, the article 203 having been formed from a single metal blank by cold working operations.

Articles cold formed in the manner described have been tested under hydrostatic pressures without failure or leakage in either direction through the partition wall, indicating the sound, dense, sealed and leakproof metal structure in the partition wall as well as in the head and motor end walls extending integrally therefrom.

One of the fundamental aspects of the present invention is the maintenance of true concentricity throughout in every operation which results in the final product 203 having true concentricity throughout with uniform wall thicknesses at any cross-section. Thus a product results which has a partition wall intermediate its ends and substantially uniform diameter throughout its length from the open end of the motor end to the zone in the head end where the nose tapers inward, except for the slight intended enlarged diameter where the bourrelet was expanded.

Furthermore, due to the strength and metal structure of the partition wall, it may be subjected to extreme pressures from either side thereof without failure, thus providing a rocket body which need not be made in a plurality of pieces or components, and which does not have lack of uniformity as to concentricity, alignment, wall thickness and uniformity of strength which lack of uniformity is inherent in a rocket body formed as an assembly of a plurality of components.

17

Another fundamental aspect of the present invention is the relationship between the series of operations performed in obtaining the double-ended generally cylindrical product with tubular side walls of substantially the same diameter extending in either direction from the partition wall. This result is obtained by starting with a blank 1 of preselected diameter, somewhat greater than the diameter of the finished article; compressing one end portion of the blank to have a reduced cross-sectional area, which may, for example, be the head end of the blank; carrying out the necessary operations on the other or enlarged end of the blank to form the tubular side walls of the motor end of the blank; then expanding the reduced cross-sectional area head end of the blank to a larger diameter than the initial diameter of the starting blank; and carrying out the series of operations thereon to form the tubular walls of the head end of the blank.

In this manner, sufficient support areas are formed in the blank for holding the blank in the several succeeding operations so that fully cold worked or completed wall portions of the blank are not ruptured or fractured or broken away from other portions of the blank being worked in any operation; and so that the support areas thus developed, direct and control the nature, location and direction of metal flow in the particular operation being carried out.

Finally, another aspect of the invention is the ability to provide whatever formation is desired in the tubular walls of the partitioned tubular steel article. For instance, the outturned thickened flanged portion 70 at the motor end of the blank may be formed, as illustrated in Fig. 25.

Accordingly, the present invention provides a new procedure for the manufacture of partitioned tubular steel articles by cold shaping in which manufacturing costs are reduced, scrap losses are eliminated, and difficulties avoided which heretofore have been encountered in the manufacture of such partitioned articles from a plurality of components; in which uniformity of the partitioned product manufactured is maintained as to concentricity, alignment, wall thickness and strength; and which accomplishes the many new functions hereinafter described, and overcomes prior art difficulties and solves long standing problems in the art.

In the foregoing description, certain terms have been used for brevity, clearness and understanding; but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such terms are utilized for descriptive purposes herein and not for the purpose of limitation and are intended to be broadly construed.

Moreover, the description of the improvements is by way of example, and the scope of the present invention is not limited to the exact details illustrated, or to the specific articles shown, or to the uses of the articles described.

Having now described the features, discoveries and principles of the invention, the operations and procedures of preferred method steps thereof, the characteristics of the products obtained thereby, and the advantageous, new and useful results achieved; the new and useful methods, steps, operations, procedures, discoveries, principles, elements, combinations, and sub-combinations, and mechanical equivalents obvious to those skilled in the art are set forth in the appended claims.

I claim:

1. The method of cold working a one-piece steel blank to form a partitioned tubular article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a blank and forming a reduced diameter at one end and an expanded diameter at the other end thereof; then cold working the metal in the expanded diameter end of the blank to form a first tubular wall; then axially compressing and radially expanding the reduced di-

18

ameter end of the blank; and then forming a second tubular wall in the initially reduced and subsequently expanded diameter end of the blank.

2. The method of cold working a one-piece steel blank to form a partitioned tubular article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter at the other end of said blank to concentrically size the same; then cold extruding a first concentric tubular wall in the expanded diameter end of the blank and developing desired physical characteristic in said first wall by said cold working; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall; then cold extruding a second concentric tubular wall in the greater expanded diameter end of the blank and developing desired physical characteristic in said second wall by said cold working; leaving a partition wall intermediate said first and second tubular walls; and cold working the metal in said partition wall to develop a sound grain structure and desired physical characteristics therein.

3. The method of cold working a one-piece steel blank to form a partitioned tubular article having a partition wall and concentric tubular walls extending in each direction from the partition wall with the tubular walls of substantially the same diameter at least adjacent the partition wall; the steps of axially compressing a bar-like steel blank of nominal diameter larger than the external diameter of the article to be made, and by said axial compression, expanding the nominal diameter at one end of said blank, reducing the nominal diameter at the other end of said blank to a diameter substantially that of the article to be made, and concentrically sizing the expanded and reduced diameter blank; then cold backward and forward extruding a first concentric tubular wall with a diameter substantially the same as the reduced diameter end of the blank in the expanded diameter end of the blank; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall; then cold backward and forward extruding a second concentric tubular wall in the greater expanded diameter end of the blank to a diameter substantially the same as the diameter of the first tubular wall; leaving a partition wall intermediate said first and second tubular walls; and cold working the metal in said partition wall to develop a sound grain structure therein.

4. The method of cold working a one-piece steel blank to form a partitioned tubular steel article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter at the other end of said blank to concentrically size the same; then cold backward extruding and further enlarging the diameter of the expanded diameter end of the blank to form a thick tubular wall in the expanded diameter end of the blank and to form a hole therein of a diameter at least as large as the finished inside diameter of a first tubular wall to be subsequently formed from said backwardly extruded thick tubular wall; then cold forward extruding a first concentric tubular wall having an external diameter approximating the diameter of the reduced diameter end of the blank from the metal in said backwardly extruded thick tubular wall; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall; then cold extruding a second concentric tubular wall in

the greater expanded diameter end of the blank; leaving a partition wall intermediate said first and second tubular walls; and cold working the metal in said partition wall to develop a sound grain structure therein.

5. The method of cold working a one-piece steel blank to form a partitioned tubular steel article having a partition wall and concentric tubular walls extending in each direction from the partition wall; the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter at the other end of said blank to concentrically size the same, and at the same time by said axial compression forming a first concentric recess in the expanded diameter end of the blank; then cold backward extruding by axial compression an enlarged tubular wall in the expanded diameter end of the blank, centering the application of said axial compression by said first concentric recess, and by said backward extruding pressure forming a second concentric recess in the reduced diameter end of the blank; then cold forward extruding a first concentric tubular wall from the metal in the backward extruded wall; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall, and centering the application of said axial compression to said reduced diameter end by said second recess previously formed therein; then cold extruding a second concentric tubular wall in the greater expanded diameter end of the blank; leaving a partition wall intermediate said first and second tubular walls; and cold working the metal in said partition wall to develop a sound grain structure therein.

6. In a method of cold working a tubular steel blank, the steps of forming a cup-shaped blank, forwardly extruding an elongated tubular wall with an outturned extrusion flange at its free end from the metal in the side walls of the cup-shaped blank, drawing the tubular wall through a die opening and against a punch in one direction during forward movement of the punch and forming a thickened intumed flange-like wall portion from the metal in the extrusion flange at the free end of the tubular wall during said forward punch movement, and then expanding the metal in the intumed flange-like wall portion upon retracting the punch from within the tubular wall to form an outwardly projecting thickened wall portion at the free end of the tubular wall.

7. The method of cold working a one-piece steel blank to form a partitioned tubular steel article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter at the other end of said blank to concentrically size the same; then cold extruding a first concentric tubular wall in the expanded diameter end of the blank; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall, and by said axial compression forming a hole in the greater expanded diameter end of the blank having a diameter smaller than the internal diameter of said first tubular wall; then cold extruding a second concentric tubular wall in the greater expanded diameter end of the blank; leaving a partition wall intermediate said first and second tubular walls; and cold working the metal in said partition wall to develop a sound grain structure therein.

8. The method of cold working a one-piece steel blank to form a partitioned tubular steel article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter

at the other end of said blank to concentrically size the same; then cold extruding a first concentric tubular wall in the expanded diameter end of the blank; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall, and by said axial compression forming a hole separated from said first tubular wall by a thick partition wall portion in the greater expanded diameter end of the blank having a diameter smaller than the internal diameter of said first tubular wall, and by said axial compression also forming an external shoulder joining the greater expanded diameter end of the blank with the first tubular wall; then supporting the thus-formed blank on said shoulder and on said thick partition wall portion within the first tubular wall; then cold extruding metal from said thick partition wall portion thereby increasing the diameter and depth of said hole and the external diameter of said greater expanded diameter end of the thus-supported blank, and reducing the thickness of said thick partition wall portion; then cold working the metal in said partition wall to develop a sound grain structure therein; and then cold extruding a second concentric tubular wall in the greater expanded diameter end of the blank.

9. The method of cold working a one-piece steel blank to form a partitioned tubular steel article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter at the other end of said blank to concentrically size the same; then cold extruding a first concentric tubular wall in the expanded diameter end of the blank; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall, and by said axial compression forming a hole separated from said first tubular wall by a thick partition wall portion in the greater expanded diameter end of the blank having a diameter smaller than the internal diameter of said first tubular wall; then further axially compressing the greater expanded diameter end of the blank to further enlarge the diameter thereof and to increase the diameter of said hole to be larger than the ultimate hole to be formed therein and to form an annular tapered angular portion on a surface of said thick partition wall portion at the bottom of said hole; then reducing the external and internal diameters of the metal in the greater expanded diameter end of the blank surrounding the hole and compression cold working the metal in said partition wall to develop a sound grain structure therein; and then cold extruding a second concentric tubular wall in the greater expanded diameter end of the blank.

10. The method of cold working a one-piece steel blank to form a partitioned tubular steel article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter at the other end of said blank to concentrically size the same; then cold extruding a first concentric tubular wall in the expanded diameter end of the blank; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall, and by said axial compression forming a hole separated from said first tubular wall by a thick partition wall portion in the greater expanded diameter end of the blank; then axially and radially compressing the metal in said partition wall portion and reducing the external and internal diameters of the metal in said greater expanded diameter end of the blank surrounding said hole; and then cold

extruding a second concentric tubular wall in the greater expanded diameter end of the blank.

11. The method of cold working a one-piece steel blank to form a partitioned tubular steel article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter at the other end of said blank to concentrically size the same; then cold extruding a first concentric tubular steel wall in the expanded diameter end of the blank; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall, and by said axial compression forming a hole separated from said tubular wall by a thick partition wall portion in the greater expanded diameter end of the blank; then axially and radially compressing the metal in said thick partition wall portion and forming a rounded fillet-like area in the partition wall surface at the bottom of said hole; then cold extruding a second concentric tubular wall in the greater expanded diameter end of the blank; and then radially expanding metal from said rounded area to form an expanded annular band surrounding the article adjacent said partition wall and intervening the first and second concentric tubular walls.

12. The method of cold working a one-piece steel blank to form a partitioned tubular steel article having a partition wall and concentric tubular walls extending in each direction from the partition wall, the steps of axially compressing a bar-like steel blank of nominal diameter and by said axial compression expanding the nominal diameter at one end and reducing the nominal diameter at the other end of said blank to concentrically size the same; then cold extruding a first concentric tubular wall in the expanded diameter end of the blank; then axially compressing the reduced diameter end of the thus-formed blank and expanding the diameter thereof to be greater than the external diameter of said first tubular wall, and by said axial compression forming a hole separated from the first tubular wall by a thick partition wall portion in the greater expanded diameter end of the blank; then axially and radially compressing the metal in said thick partition

wall portion and forming a rounded fillet-like area in the partition wall surface at the bottom of said hole; then cold extruding a second concentric tubular wall in the greater expanded diameter end of the blank; then expanding portions of the metal from said rounded area to form an annular expanded band around the article adjacent said partition wall, and at the same time axially compressing other metal in said rounded area and displacing the same inward to thicken said partition wall portion.

13. In a method of shaping a metallic blank to form an article having an interior partition wall intermediate a first tubular end portion and a second tubular end portion, the steps of cold working said first end portion to size an inside diameter therein smaller than the inside diameter of said second end portion and the outside diameter thereof greater than the outside diameter of said second end portion and by said cold working causing metal contained in said partition wall to be expanded radially outwardly; and then subsequently cold working said first end portion to reduce the outside diameter thereof and by said cold working causing metal contained in said partition wall to be simultaneously compressed partially radially inwardly and partially radially outwardly, said cold working being initiated by axially opposed compressive forces; and said cold working further causing permanent deformation of said metal contained in said partition wall.

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