June 3, 1947. O. A. LANGOS 2,421,629

METHOD FOR CLOSING THE END OF A METAL TUBE

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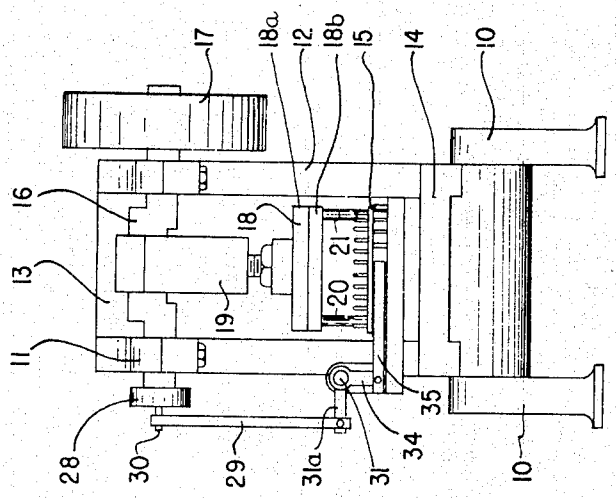


FIG. 1

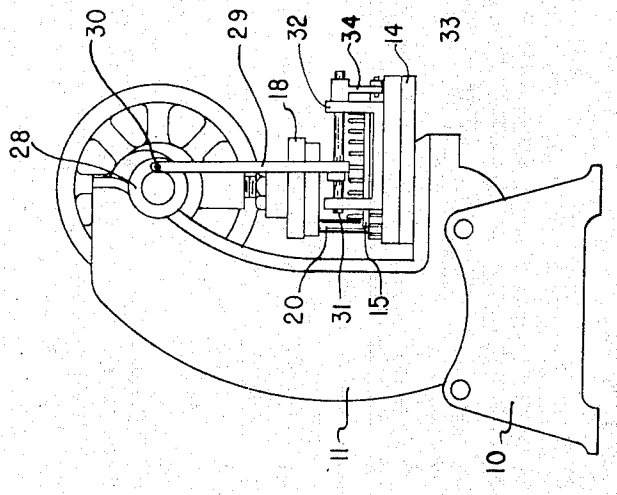


FIG. 2

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METHOD FOR CLOSING THE END OF A METAL TUBE

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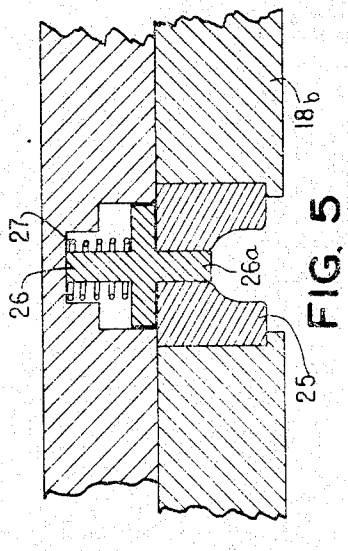


FIG. 5

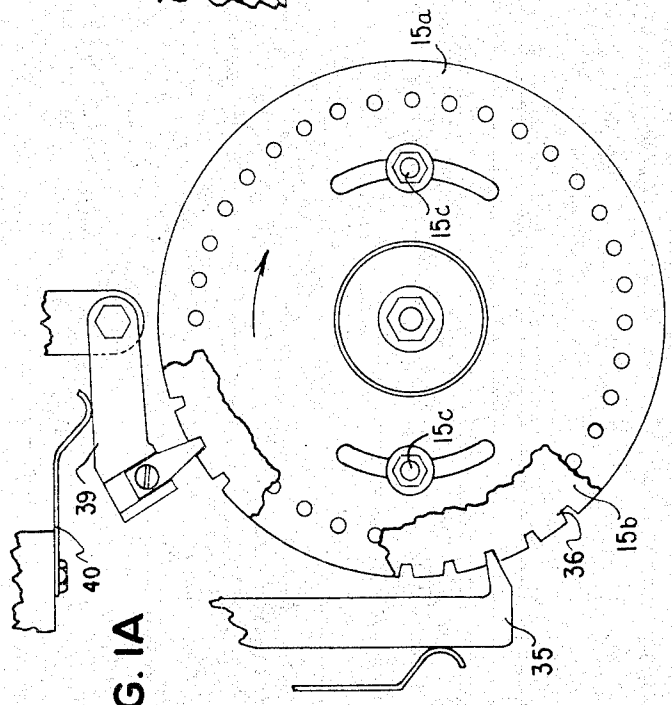


FIG. 1A

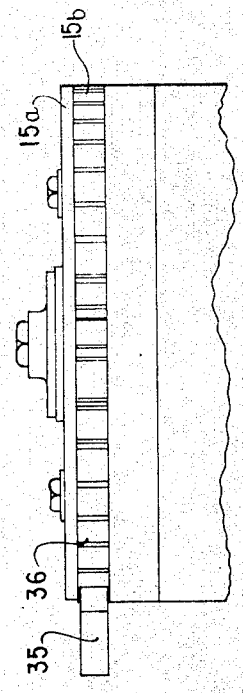


FIG. 1B

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METHOD FOR CLOSING THE END OF A METAL TUBE

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FIG. 3

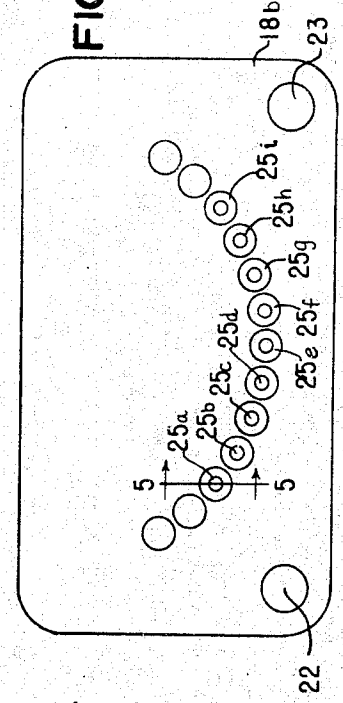


FIG. 6

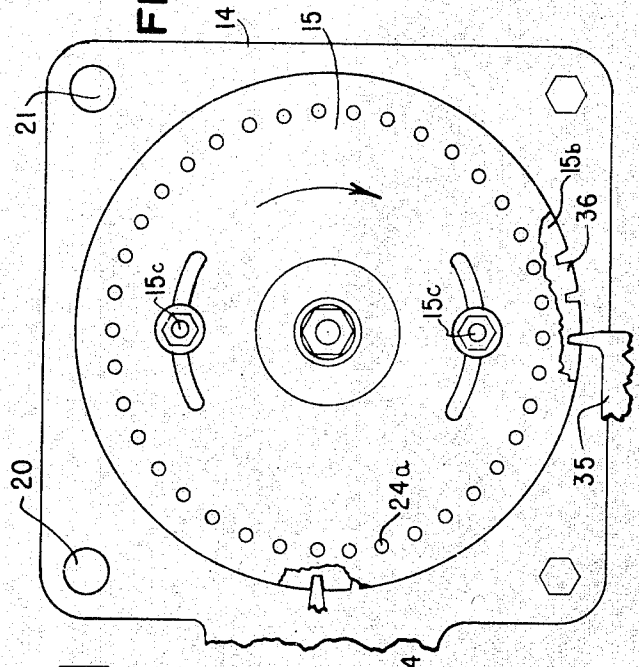
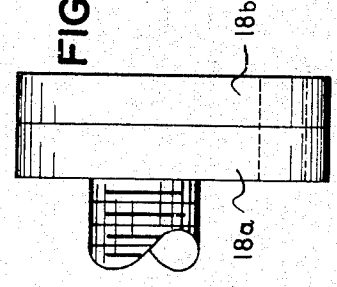


FIG. 4



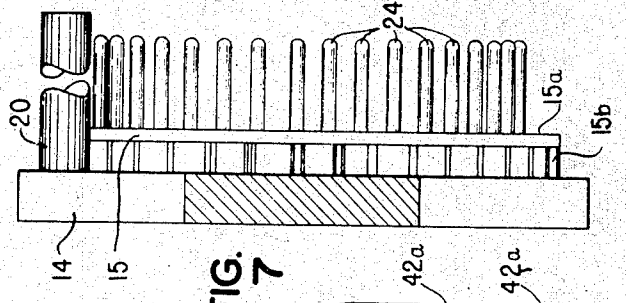
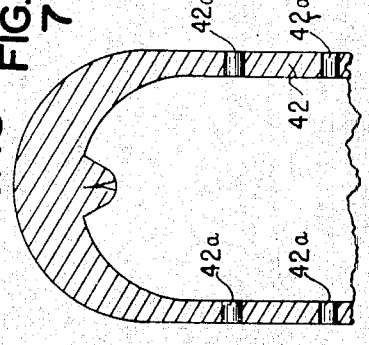


FIG. 7

FIG. 18



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METHOD FOR CLOSING THE END OF A METAL TUBE

Filed Feb. 10, 1943 4 Sheets-Sheet 4

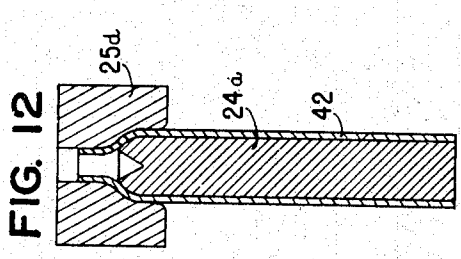


FIG. 12

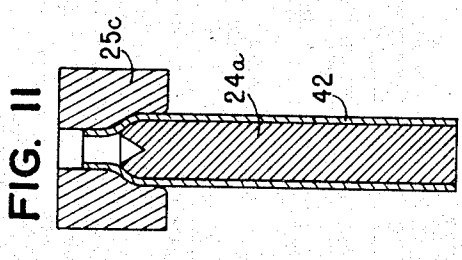


FIG. 11

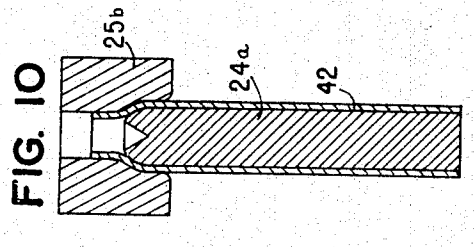


FIG. 10

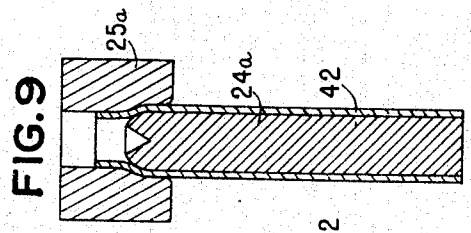


FIG. 9

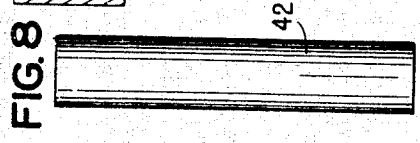


FIG. 8

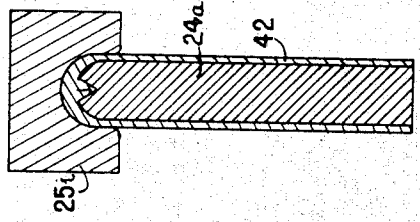


FIG. 17

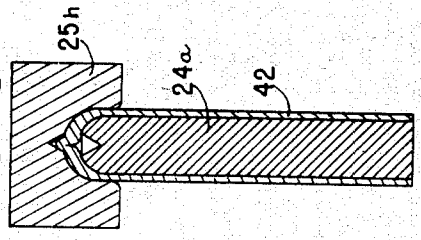


FIG. 16

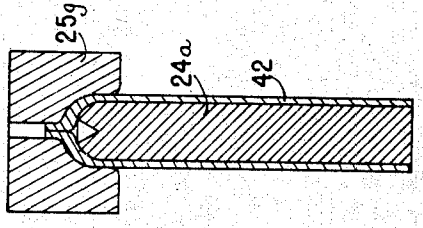


FIG. 15

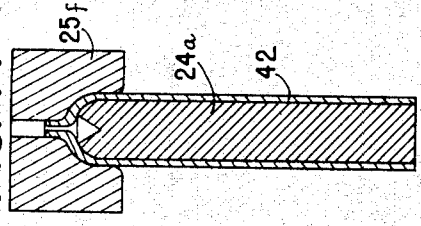


FIG. 14

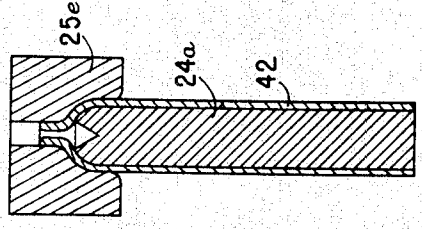


FIG. 13

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UNITED STATES PATENT OFFICE

2,421,629

METHOD FOR CLOSING THE ENDS OF METAL TUBES

Otto A. Langos, Chicago, Ill.

Application February 10, 1943, Serial No. 475,368

3 Claims. (Cl. 29—148.2)

1

The present invention relates to an improved method of deforming the end portion of a tube, and more particularly to an improved method of closing the end of a metal tube. The invention also relates to the improved pressure tight tube end closure structure which is obtained by utilizing the present improved method. Although generally applicable to the formation of end closures on both soft and hard metal tubes, of all sizes, dimensions and cross-sectional configurations, the improved method disclosed herein is particularly applicable to the formation of pressure tight end closures on annealed steel or other workable ferrous metal tube blanks having a round or oval cross-sectional configuration.

In general, the prior art practice of closing the ends of metal tubes is limited to the use of spinning and swedging methods. The spinning method, wherein the work is turned at high speed while a hard metal tool, usually formed of tool steel, is brought to bear with increasing pressure against the metal of the tube end being worked upon, is limited to the working of soft metal tubes, such, for example, as those made of copper, brass, aluminum and other soft non-ferrous metals. It has been found, in attempts to utilize this method to form end closures on hard metal tubes, that an affinity between the tube metal and the tool is developed early in the process and long before an end closure can be formed on the tube. This affinity is probably caused by the heat resulting from the frictional engagement between the tube metal and the tool, and has the effect of causing the tube metal or the tool metal, or both, to bind and tear when the tool is brought to bear under pressure against the spinning tube end. So far as is known, no tool material, steel or otherwise, is available which lacks affinity for workable ferrous metals and yet is hard enough to carry out the shaping of the tube metal required during the spinning operation. Thus it is commercially impractical to employ conventional spinning methods in the formation of end closures on hard metal tubes. Moreover, this method as commercially employed in the formation of end closures on soft metal tubes is somewhat slow and must be practiced with care, since if the pressure of the shaping tool against the end side wall metal of the tube is increased too rapidly, the tube may buckle or be otherwise deformed at some weak point along its length.

The method of swedging the end side wall metal of a tube to form an end closure thereon is so slow and costly as to have little utility in the

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production of tube end closures in large volumes, regardless of whether the tubes are formed of hard metal or soft metal. Moreover, in utilizing this method to work hard ferrous metals, such, for example, as annealed carbon steel, it is necessary to preheat the metal to a workable state before the swedging operation can be started and to maintain the metal in a workable state by reheating as the swedging operation progresses. Such heating causes a scale to form on the outer surface of the metal which usually must be removed by dipping the metal in a pickling bath after the swedging is completed. A further disadvantage of the swedging method resides in the fact that regardless of the hardness of the metal worked upon, a smooth finished surface cannot be obtained. Accordingly, a finishing operation, such, for example, as grinding and polishing, is, in the manufacture of many articles, required after the metal shaping has been effected by swedging. This is also true of the spinning method, although perhaps to a lesser degree.

In general, it is an object of the present invention to provide an improved method of closing the end of a metal tube, which is entirely free of the above-outlined limitations and disadvantages characterizing the known methods of spinning and swedging.

More positively stated, it is an object of the invention to provide an improved method of forming end closures on tubes, which method may be easily and cheaply practiced to produce the end closures in production quantities with a minimum of labor and with a minimum of readily obtainable and relatively cheap equipment.

It is another object of the invention to provide an improved method of the character described, which is not limited to the formation of end closures on tubes formed of soft workable materials but may be employed with equal facility and at little or no additional cost in the formation of end closures on hard metal tubes formed of workable ferrous metals and the like.

According to another object of the invention, the present improved method may be utilized to form an end closure which is entirely finished, whereby the machining operations usually required in the production of an article of this character are not required.

In accordance with still another object of the invention, the present improved method may be employed to form a tube end closure which is pressure tight, contains no fissures extending entirely between the inside and the outside surfaces

of the tube, and possesses great structural strength.

It is a further object of the invention to provide for sealing an end of a pressure chamber, an improved pressure tight end closure which is capable of withstanding high pressures, is of simple and economical construction, and may easily be manufactured in production quantities.

According to another and more specific object of the invention, the end closure is, during the formation thereof, provided with a portion having a small fissure therein which is exposed to any pressure developed within the chamber, and provisions are made in the structure for utilizing the pressure developed within the chamber to assist in preventing the fissure from expanding.

In brief, the objects as set forth above are realized in accordance with the present invention by utilizing a die molding method to shape the end side wall metal of a tube progressively and in non-continuous steps. More specifically, the method comprises the steps of intermittently applying pressure to the end side wall metal of the tube both along the length thereof and radially inward, thereby to crowd the end side wall metal of the tube inward to form a mass disposed substantially in the center of the tube end, and then exerting pressure on the mass along a line substantially parallel to the longitudinal axis of the tube in order to close any fissure remaining in the mass. As each metal crowding operation proceeds, the thickness of the crowded mass of metal increases and the hardness of the metal increases. Accordingly, the pressure exerted during each intermediate crowding operation to produce a given amount of crowding must be substantially greater than that exerted on the metal during the preceding crowding operation. In order to prevent the increasing pressure applications from deforming the tube along its length, the end side wall metal of the tube is, during the first application of pressure thereto, extruded to provide a surface on the inner side thereof which bears against the end of an anvil disposed within the tube, and this bearing surface is progressively increased during succeeding pressure applications, thereby to transfer an increasing proportion of the pressure load from the barrel of the tube to the anvil.

The invention, both as to the method and the article produced thereby, together with further objects and advantages thereof, will best be understood by reference to the specification taken in connection with the accompanying drawings in which:

Figs. 1 and 2 are front and side views, respectively, of a die press which may be utilized in practicing the present invention;

Figs. 1A and 1B schematically illustrate a portion of the carriage rotating mechanism forming a part of the press shown in Figs. 1 and 2.

Fig. 3 is an underside view of the die carrying press head forming a part of the press shown in Fig. 1, which illustrates the manner in which the metal shaping dies are disposed on the under side of the head;

Fig. 4 is an end view of the die carrying press head shown in Fig. 3;

Fig. 5 is a detail view partially in section, illustrating the knockout device used for ejecting the tubes from the molding dies at the end of each pressure application;

Figs. 6 and 7 are top and side views, respectively, of the stationary platform and rotatable work carriage forming a part of the press shown in Fig. 1;

Fig. 8 is a side perspective view of a tube blank;

Figs. 9 to 17, inclusive, illustrate the plurality of progressive metal crowding steps utilized in closing the upper end of the tube shown in Fig. 8; and

Fig. 18 is an enlarged view partially in section showing the end closure in completed form.

Referring now more particularly to Figs. 1 to 7, inclusive, of the drawings, the press there illustrated is well adapted for use in practicing the present improved method in the manner explained below. In brief, this press comprises the usual pedestal 10 which carries side frame members 11 and 12 joined at the top by a cross-over piece 13. The L-shaped frame members 11 and 12 support the usual work platform 14 on the bases thereof, this platform in turn having a tube carriage 15 mounted for rotation on the upper side thereof in a suitable manner. An eccentric shaft 16, journaled in the frame members 11 and 12 at the upper ends thereof, and carrying a driving pulley 17 at one end thereof, is provided for actuating a press head 18 which is arranged to coact with the tube carriage 15. More specifically, the head 18 is mounted upon the lower end of a ram 19 which is journaled on the off-center portion of the shaft in such a manner that the head 18 may be reciprocated along a vertical path without tilting during the up and down movement thereof. Guide rods 20 and 21, laterally spaced apart and rigidly mounted upon the stationary platform 14 are provided, which extend through snugly fitting holes 22 and 23 provided in the head 18 and function to guide this head in its up and down movement.

The tube carriage 15 comprises a round anvil plate 15*a* which is rigidly secured by means of bolts 15*c* to a ratchet plate 15*b* having a portion of reduced diameter journaled in a matching recess machined in the top side of the platform 14. The plate 15*a* rigidly supports a plurality of tube anvils in the form of vertically extending steel posts 24 which are equally spaced apart and form a circle having a center coincident with the center of the plate. As best shown in Figs. 9 to 18, inclusive, of the drawings, each of the anvils 24 is provided with an upper end which forms a half globe having the diameter of the anvil. At the upper central portion of each rounded anvil end, a conical recess is provided which, in the illustrated arrangement, has surfaces diverging thirty degrees from the longitudinal axis of the anvil.

A plurality of shaping dies 25 are carried by the head 18 in a manner such that they may be brought to bear against the ends of tubes supported by the anvils 24 during operation of the press. More specifically, the head 18 comprises two plates 18*a* and 18*b* which are provided with suitable die receiving recesses and are suitably clamped together to retain the dies therebetween. As best shown in Fig. 3 of the drawings, the die receiving recesses are cut in the lower plate 18*b*. These recesses are arranged in an arc which is coincident with the arc formed by the anvils 24. More specifically, the recesses are so arranged that with dies held therein, the axis of the molding cavity in each die is coincident with the long axis of one of the anvils. In the illustrated arrangement and as shown in Fig. 3, recesses are provided for receiving thirteen different shaping dies thus permitting a maximum of thirteen different shaping operations. It is understood, of

course, that the invention is not limited to this specific number but it is illustrative. When, however, the present improved method is practiced in the specific manner described below, only nine different shaping dies are required. Of these nine dies, those which perform the first seven metal crowding operations are each provided with a hole extending through the die and into which the metal is crowded. For the purpose of preventing the tubes from sticking in these seven dies at the end of each shaping operation, the knockout arrangement illustrated in Fig. 5 of the drawings may be provided in conjunction with each die receiving recess of the head 18. This arrangement comprises a knockout piece 26, disposed in a recess provided in the plate 18a opposite the die receiving recess in the plate 18b and biased by a heavy spring 27 to engage a die 25 disposed in the die receiving recess. Each knockout element 26 is provided with a projection 26a of the appropriate size to enter the metal receiving hole provided in a die of given size. These projections of course vary in dimensions in accordance with the sizes of the particular die holes with which they are required to mate.

For the purpose of rotating the tube carriage 15 step by step, thereby to advance each tube supported by an anvil 24 so that it will be operated upon successively by different ones of the several dies carried by the head 18, a driving connection is provided between this carriage and the shaft 16. This connection comprises a collar 28 rigidly secured to the end of the shaft 16 opposite that upon which the pulley 17 is mounted; and a link 29 which is connected at its upper end to an eccentric pin 30, and is pin connected at its lower end to the arm 31a of a rocker shaft 31. This shaft is journaled in the legs of a U-shaped frame 32 mounted upon the platform 14, and carries a rocker arm 34 which is arranged to reciprocate an edge biased slide 35 engaging the teeth 36 of the ratchet plate 15b. The teeth of the ratchet plate 15b are angularly spaced apart by the same number of radians as the anvils 24 carried by the plate 15a. In order to prevent the carriage 15 from being retracted during the back stroke of the slide 35, a stop pawl 39 pivotally mounted upon the platform 14 and biased by the leaf spring 40 is provided to engage the teeth 36 of the ratchet plate 15b.

In adapting the illustrated press for use in forming end closures on metal tubes of a given length and diameter, an anvil plate 15a carrying anvils 24 having a diameter only slightly less than the internal diameter of the tubes, is employed. The anvils are of exactly the same shape and length. More specifically, the anvil length is enough less than the length of each tube blank that a sufficient amount of side wall metal remains above the end of the anvil to permit the end closure to be formed. This difference in the lengths of the anvils and the tube blanks will, of course, vary somewhat depending upon the wall thickness of the particular tube blank which is to have an end closure formed thereon. A plurality of shaping dies having the proper molding cavity dimensions to progressively crowd the end side wall metal of the tube toward the center of the tube end in the manner explained below, are also assembled in the die receiving recesses of the head 18 in the precise order required to obtain the progressive crowding of the end side wall metal of the tube. Thus if the tube carriage 15 is to be rotated in the direction of the arrow, as shown in Fig. 6 of the drawings, and the nine dies 25a to 25i, inclusive, shown in Figs. 9 to 17, inclusive, of the drawings, are to be used, these dies may be mounted in the head 18 in the manner and order indicated in Fig. 3 of the drawings.

After the press has been thus adapted for use, operation of the press may be started, it being understood in this regard that the press is belt driven either directly or through a suitable speed reducing mechanism from a line shaft or an electric motor. During each revolution of the shaft 16, the head 18 is moved downward so that the dies 25 are positioned adjacent the rounded ends of the anvils 24, and is then retracted to its raised position wherein sufficient space is provided between the head 18 and the ends of the anvils to permit tube blanks to be placed upon and removed from the anvils. Also during each revolution of the shaft 16, the slide 35 is moved from its retracted position to its extended position and then back to its retracted position to advance the tube carriage 15 one step. More specifically, the rotary movement of the shaft 16 is so related to the movement of the rocker arm 34 that the slide 35 is retracted during retraction of the head 18 to its raised position, and only reaches its extended position to engage one of the teeth 36 of the ratchet plate 15b slightly after the head 18 reaches the limit of its downward movement. Thus the tube carriage 15 is only rotated from a given position to the next succeeding position during upward movement of the head 18 when the dies 25 are moving away from the anvils 24. By suitably adjusting the position of the anvil plate 15a relative to the ratchet plate 15b to position nine of the anvils 24 directly beneath the nine dies 25a to 25i, inclusive, the desired alignment between the anvils and the dies may be retained at the end of each increment of movement of the carriage 15.

From the foregoing explanation it will be understood that after operation of the press is initiated, the tube blanks may be fed to the press one or more at a time during each interval when the head 18 occupies its raised position. The press may be fed by manually telescoping the tube blanks over the vertically extending anvils 24. After each tube blank has been operated upon by each of the nine dies 25a to 25i, inclusive, it may be manually removed from its supporting anvil by the press operator. Thus it will be understood that after operation of the press is under way, the operator can, during each interval when the die carrying head 18 occupies its raised position, remove a finished tube from its supporting anvil and telescope a new tube blank over the adjacent anvil from which a finished tube blank has just been removed. Thus the manual operations required continuously to practice the present improved method are reduced to an absolute minimum.

Referring now more particularly to the manner in which the end of a tube blank may be closed by employing the present improved method, it may be assumed that the blank 42, as shown in Figs. 8 to 18, inclusive, of the drawings, is telescoped over the anvil 24a shown in Fig. 6 of the drawings. Thereafter and when the tube 42, as carried by the anvil 24a, is rotated with the carriage 15 into a position beneath the first die 25a, it is subjected to the first metal shaping operation. More specifically, with the tube 42 in this position, the upper end side wall metal of the tube is crowded radially inward as the shaping surfaces of the die 25a are brought into engage-

ment with the upper end of the tube during the downward movement of the head **18**. Thus immediately the lower shaping surface of the die **25***a* engages the end of the tube **42**, pressure is exerted on the wall metal of the tube both along the length of the tube and radially inward. This pressure causes the end side wall metal of the tube to be crowded radially inward and at the same time extruded slightly to increase the length of the tube. As the die **25***a* is brought to its lowermost position, the inwardly tapering shaping surfaces thereof squeeze a segment of the end side wall metal of the tube into engagement with a segment of the rounded end of the anvil **24***a*, so that bearing surfaces are provided between the end of the anvil and the metal of the tube. In this regard it is noted that the taper between the outer circumference of the entrant opening into the molding cavity of the die **25***a* and the metal receiving opening at the top of the die, is so proportioned that the pressure applied to the tube **42** along its longitudinal axis is insufficient to cause the tube to buckle or be otherwise deformed at any weak point along its length. After the metal has been deformed through the action of the die **25***a* and during the initial retraction of the head **18**, the tube knockout arrangement, as illustrated in Fig. 5 of the drawings, functions to eject the tube **42** from the die **25***a*, thereby to maintain the tube positioned on the anvil **24***a*. Also during the retraction of the head **18**, the carriage is rotated to bring the anvil **24***a* and the tube **42** into a position beneath the die **25***b*. Thereafter, and during the second downward movement of the head **18**, the shaping surfaces of the die **25***b*, upon engagement with the extruded end metal of the tube, further crowd this metal towards the center of the tube end and further increase the surface of this metal which bears upon the rounded end of the anvil **24***a*. From this point on, the progressive crowding of the end side wall metal toward the center of the tube end progressively increases when the anvil **24***a* and the tube **42** are successively positioned beneath the dies **25***c* to **25***g*, inclusive, all in a manner which will be clearly apparent from a consideration of Figs. 11 to 15, inclusive, of the drawings. From an inspection of these figures, it will be observed that at each stage of the metal crowding procedure the bearing surfaces between the end side wall metal of the tube and the rounded end of the anvil **24***a* are increased, and also that the thickness of the mass of metal disposed at the end of the tube is progressively increased. This is accomplished by progressively decreasing the diameter of the openings at the tops of the dies into which the metal is forced at the different shaping stages.

From a consideration of Fig. 16 of the drawings, it will be observed that the die **25***h*, which is utilized to perform the eighth metal crowding operation, is not provided with a metal receiving opening through the thickness thereof, but on the contrary is provided with an inverted conical recess exactly in the center of its molding cavity. Accordingly, at the end of the eighth shaping operation a small mass of metal, forming substantially an inverted cone shaped tit, remains at the top center portion of the tube **42**. At the end of the seventh shaping operation a small hair line fissure remains in the metal which is forced into the metal receiving opening of the die **25***g*. This fissure is, during the eighth shaping operation, completely closed to provide a pressure tight seal, by crowding the excess of metal which remains at the end of the tube following the seventh shaping operation, into the inverted conical shaped recess provided in the molding cavity of the die **25***h*.

From a consideration of Fig. 17 of the drawings, it will be observed that the shaping surfaces of the ninth die **25***i* follow the contour of a half globe. Accordingly, when the tube **42**, as deformed in the manner shown in Fig. 16 of the drawings, is operated upon by the die **25***i*, the mass of excess metal forming the inverted cone at the center of the tube end is crowded into the conical recess provided in the central portion of the rounded end of the anvil **24***a*. During this particular operation, the end side wall metal of the tube which is utilized in forming the closure, is finished to present a smooth, rounded outer surface, and the fissure extending therethrough is confined in its extent substantially entirely to the metal which is forced into the conical recess provided at the central end portion of the anvil **24***a*. Thus a pressure tight end closure is formed on the tube **42**.

To examine the above-described method somewhat more closely, it will be noted that at the end of each shaping operation an increasing proportion of the end side wall metal of the tube **42** is brought to bear upon the rounded end surface of the anvil **24***a*. This, of course, means that during the next shaping operation when pressure is applied to the tube along the longitudinal axis thereof, a greater proportion of the pressure load is removed from the barrel of the tube and transferred to the anvil **24***a*. In this regard it is pointed out that during each succeeding shaping operation an increasing amount of pressure on the end side wall metal of the tube is required in order to effect a given amount of metal crowding. This is true not only for the reason that, as the shaping of the metal proceeds, the thickness of the metal being worked upon is increased and the diameter of the excess metal being forced into the metal receiving openings of the dies is decreased, but for the additional reason that the metal is progressively hardened during each shaping operation. In other words, the "work hardness" of the end side wall metal of the tube increases with each deformation thereof. By utilizing the anvil **24***a* to carry an increasing proportion of the pressure load, however, the increasing pressure required to distort the metal during the later shaping stages, is prevented from buckling or otherwise deforming the tube at a point along its length. It will also be noted in this connection, that the initial step of extruding the end side wall metal of the tube **42** to provide a bearing surface between this metal and the rounded end of the anvil **24***a*, is of importance since it permits an increased pressure application at the second shaping stage without danger of deforming the tube at a point along its length.

From the foregoing explanation it will be understood that the rate at which the end side wall metal of a tube may be deformed to form the desired end closure, depends upon a number of factors. Thus, the character of the metal from which the tube is made, the diameter of the tube, the thickness of the side walls of the tube, and the extent to which the work hardens during a given shaping operation, must all be considered in determining the rate at which the tube metal may be deformed. More explicitly, if the tube upon which the end closure is to be

formed is of soft metal, such, for example, as brass or copper, has a large diameter, and has thin walls, the deformation of the metal to form the end closure may proceed at a rapid rate. On the other hand, if the tube is formed of a hard workable ferrous metal, such, for example, as annealed steel, is of small diameter, and has heavy walls, the shaping of the end side wall metal to form the end closure must necessarily proceed at a much slower rate. All of the above factors must be considered in the design of the molding cavities of the dies, and also in the determination of the number of shaping stages which must be used in obtaining the desired end closures. When, however, the method is to be utilized in the formation of end closures on tube blanks of uniform size, wall thickness and material, the number of shaping steps required and the configuration of the molding cavities provided in the dies may be readily determined on an experimental basis. In this regard it is noted that the limiting factor in determining the shapes of the molding cavities, and hence the number of shaping steps required, is the amount of pressure which may be applied along the long axis of a particular tube without causing the undesired deformation of the tube along its length.

It has been found that the above-described method of forming end closures on the ends of metal tubes on a production basis is of particular utility in closing the ends of the primer tubes conventionally used in the manufacture of shells, bombs, and the like. Prior to the advent of the present invention, the spinning method was employed in the formation of end closures on brass primer tubes. However such method was limited to materials such as brass which are soft enough to permit spinning. This excluded the use of steel tubing, and thus represented a serious handicap to large volume, production from all suitable and available metals. The formation of the tube blanks from steel tubing presented no problem to the primer tube manufacturers, but the method of swedging was all that was available in the formation of end closures on steel primer tubes and this method is expensive, and generally unsatisfactory from a large volume, high quality output standpoint. The present improved method represents a complete solution of this problem. In fact, the production of end closures on workable steel tubes of the character now available to the primer tube manufacturing industry may, by utilizing the present improved method, proceed at a rate equaling if not surpassing the rate at which end closures may be formed on brass primer tubes by utilizing the spinning method referred to above.

It has been found that in forming end closures on annealed steel tube blanks having the following dimensions, the nine shaping steps illustrated in Figs. 9 to 17, inclusive, of the drawings and employing die molding cavities of substantially the configurations there shown, are sufficient to provide a smooth rounded end closure which is wholly free of fissures except possibly at the very inside surface and is absolutely pressure tight:

	Inches
Tube length	3.25
Outside diameter of tube	.5625
Tube wall thickness	.01405

In utilizing the method to close the ends of tubes having these particular described dimensions, the diameter of the end side wall metal of the tube is decreased by approximately .125" during the first shaping operation and the length of the tube is, by extrusion, increased by approximately the same amount. During each of the second to sixth shaping operations the diameter of the extruded metal is decreased at the rate of .0625" for each step, while the overall length of the tube is not substantially altered. During the seventh shaping operation the diameter of the extruded metal is decreased by approximately .03125" and the overall length of the tube is also decreased slightly. During the eighth and ninth shaping operations the pressure is exerted primarily upon the mass of metal which has been crowded to the center of the tube end. More specifically, this pressure is applied along a line which is substantially parallel to the longitudinal axis of the tube, and is primarily applied through this mass of metal to the anvil **24***a*.

The finished end closure as formed upon a steel primer tube in the manner just explained, is illustrated in the sectionalized view shown in Fig. 18 of the drawings. From a consideration of this closure, it will be noted that after the closure is completed the excess metal which projects within the pressure chamber of the tube forms a conical mass, the side surfaces of which converge to a narrow end at the lowermost portion of the mass and have a base line along the body portion of the end closure. This small mass of excess metal contains a small fissure which is substantially coincident with the long axis of the tube and is exposed to any pressure developed within the tube. Thus in the absence of the radially displaced outer side walls of the excess metal portion, the pressure exerted upon the sides of the fissure would tend to expand this fissure and might, if sufficiently great, cause a rupture of the end closure. With the illustrated structure, however, the pressure developed within the tube chamber is also exerted radially inward on the tapering side surfaces of the excess metal portion of the closure. Since the area of these surfaces is greatly in excess of the exposed surface area of the fissure, the pressure directed radially inward is far in excess of that exerted against the side walls of the fissure and thus positively prevents the fissure from expanding.

This feature of the illustrated structure, is of particular utility in the formation of primer tubes, since any rupture of the tube metal may cause segments of the metal to be expelled from the firing chamber of a shell into the bore of the rifle wherein the shell is fired, to become lodged in the rifling and thus cause scoring of the rifling during a subsequent firing operation. After a primer tube blank has been provided with an end closure in the manner just explained, firing or explosion ports **42***a* may be formed in the side walls thereof in the manner illustrated in Fig. 18 of the drawings. These ports are usually formed by a punching operation and define four equally spaced apart lines extending along the barrel of the tube.

From the foregoing explanation it will be understood that the present invention is of great utility in the metal tube art since it permits of the use of hard workable ferrous metals in the formation of tube blanks, while permitting closed ends to be formed on such tubes in production quantities and on a low unit cost basis. Moreover, the method is applicable to the formation of end closures on tubes made of softer metals at a per unit cost which is comparable, if not less than, that presently possible using the methods known to the prior art. In this regard it is

pointed out that the method is not limited to the formation of end closures on round tubes, but may be employed in closing the ends of tubes having oval, octagonal, square, or other cross-sectional configurations. The shape of the closure which may be formed, utilizing the present improved method, is also not limited to that of a half globe, but may be different, depending upon the requirements of the particular tube application. It is noted further that the structure of the end closure formed by the present improved method is especially well adapted to the closing of tubes which are to be used as pressure chambers, since the pressure sealing action of the fissure remaining in the excess metal portion of the closure, positively precludes any rupture of the end closure due to the pressure developed within the tube chamber.

While one embodiment of the invention has been disclosed, it will be understood that various modifications may be made therein which are within the true spirit and scope of the invention.

I claim:

1. The method of closing the end of a cold hard metal tube about the end of an anvil disposed within the tube which comprises extruding the end side wall metal of the tube to provide a bearing surface between the extruded metal and the end of said anvil, and progressively crowding the extruded metal of the tube inward and against the end of said anvil by a series of pressure applications and in a manner such that the bearing surface of the metal against the end of said anvil is increased upon each pressure application to offset the increase in pressure required to crowd the metal upon the next pressure application, whereby deformation of the tube along its length during the pressure applications is prevented.

2. The method of closing the end of a cold hard metal tube about the end of an anvil disposed within the tube and provided with an excess metal cavity at its end, which comprises extruding the end side wall metal of the tube to provide bearing surfaces between the extruded metal and the end of said anvil, progressively crowding the extruded metal inward by applying pressure to the tube at least partially along the length thereof, thereby to form a mass of metal disposed substantially in the center of the tube end, concurrently crowding the extruded metal against the end of said anvil to progressively increase the bearing surface of the metal against the end of said anvil and thus increasingly relieve the barrel of the tube of the pressure exerted along the length of the tube, and crowding said mass into said cavity in order to close any fissure remaining in said mass.

3. The method of closing the end of a cold hard metal tube about the end of an anvil which is disposed within the tube and is provided with an excess metal cavity at its end, which comprises collapsing the end side wall metal of the tube radially inward to form a mass disposed substantially in the center of the tube end, and crowding said mass into said cavity in order to close any fissure remaining in said mass.

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