

Jan. 22, 1946.

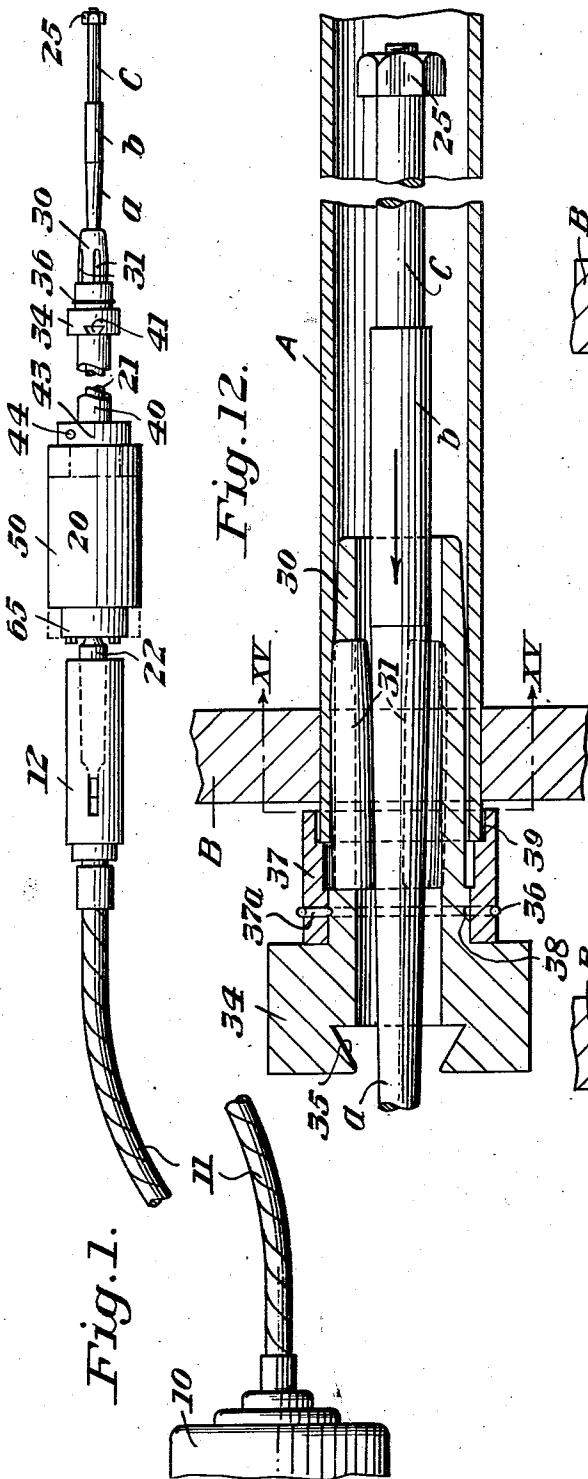
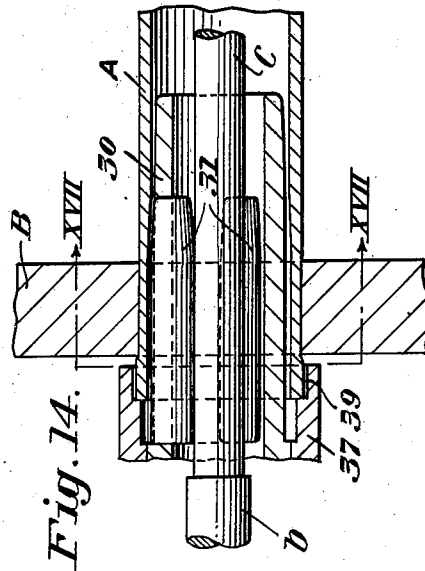
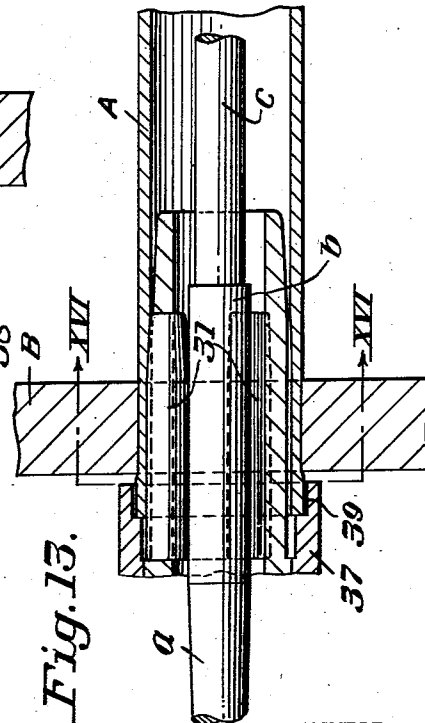
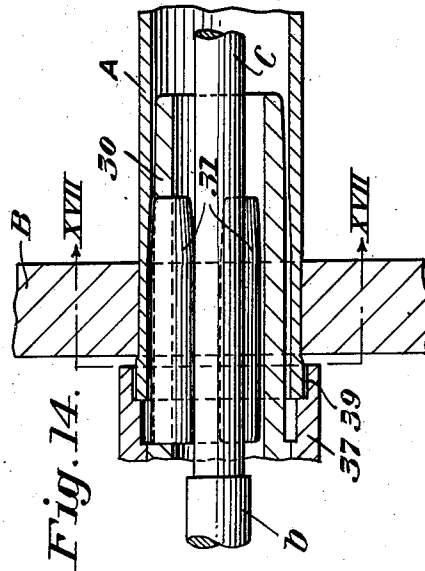
H. BOYLES ET AL.

2,393,283

METHOD OF EXPANDING TUBES

Filed July 29, 1942

3 Sheets-Sheet 1

**INVENTOR**

INVENTOR
Harry Boyles and
Raymond W. Grubb,
by Thomas G. Miller
their attorney.

Jan. 22, 1946.

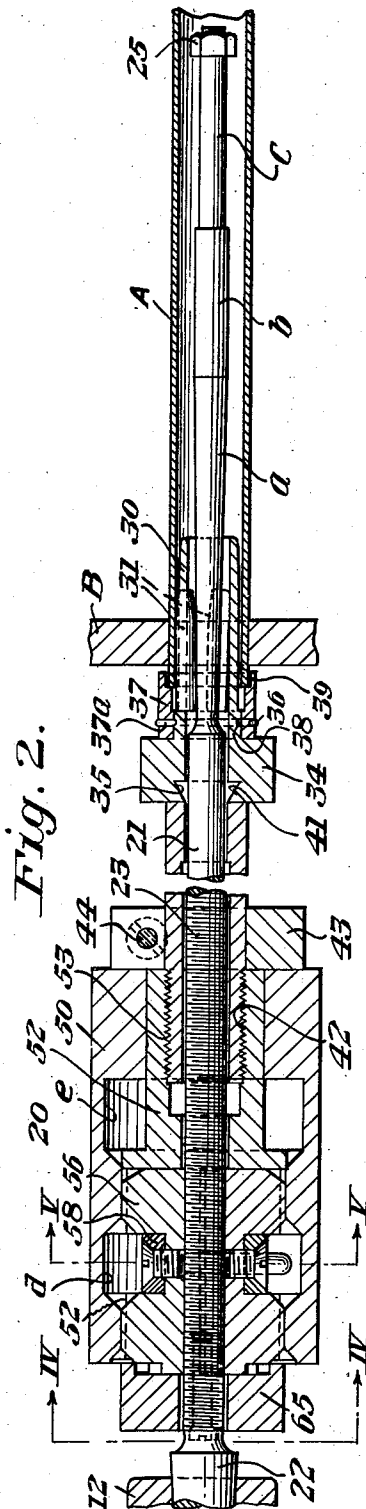
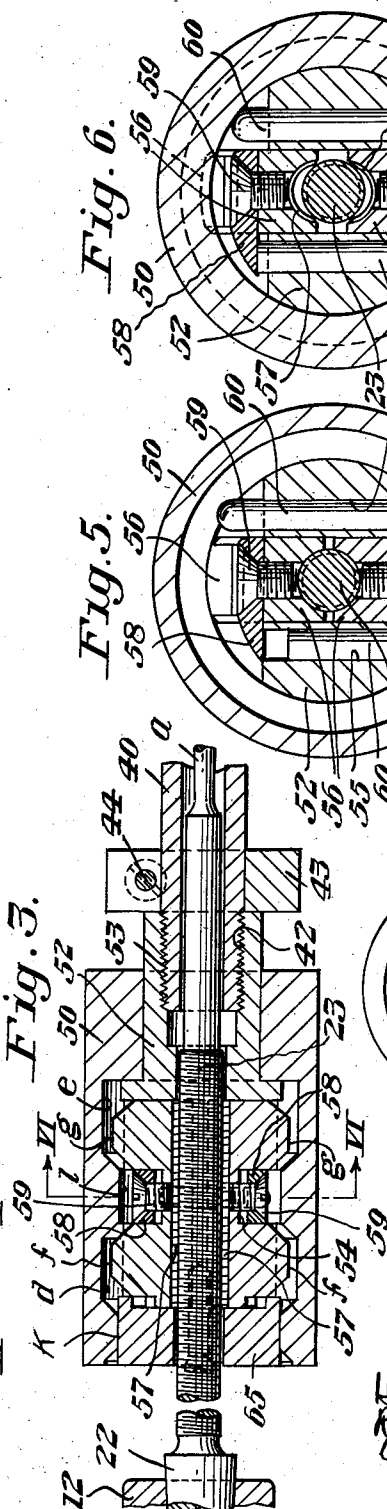
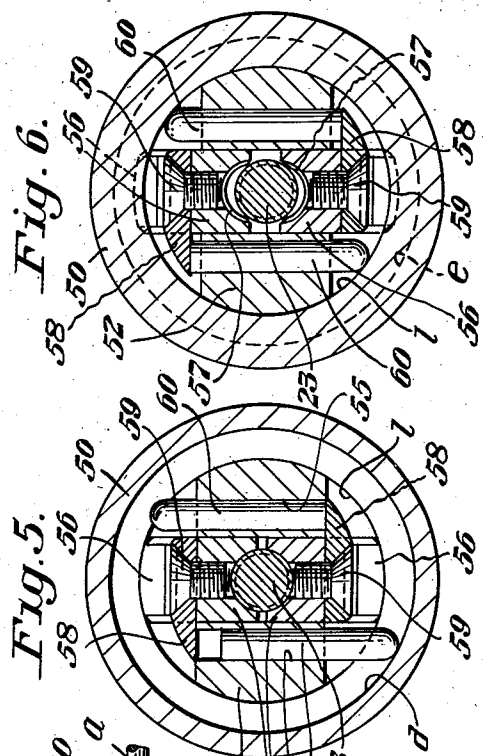
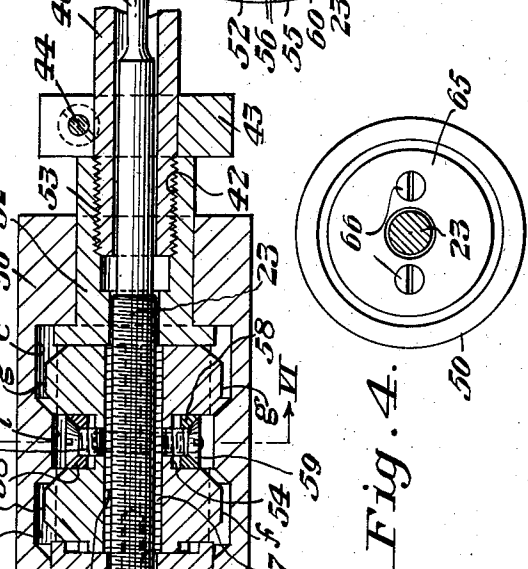
H. BOYLES ET AL

2,393,283

METHOD OF EXPANDING TUBES

Filed July 29, 1942

3 Sheets-Sheet 2



INVENTOR
Harry Boyles and
Raymond W. Gabb
Thomas S. Miller,
their attorney

Jan. 22, 1946.

H. BOYLES ET AL

2,393,283

METHOD OF EXPANDING TUBES

Filed July 29, 1942

3 Sheets-Sheet 3

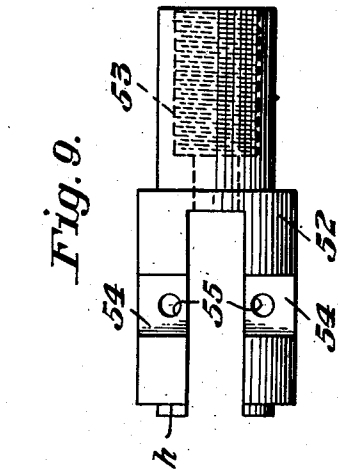


Fig. 9.

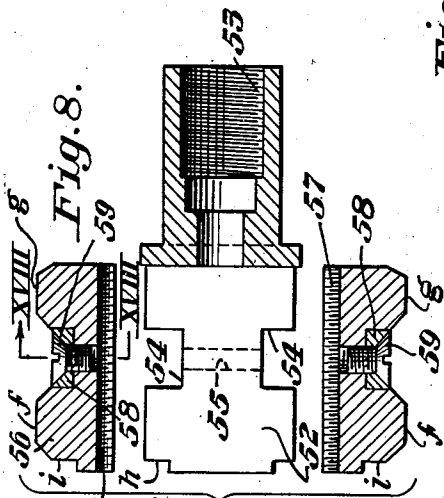


Fig. 8.

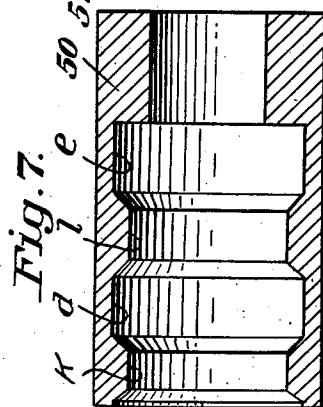


Fig. 7.

Fig. 11.

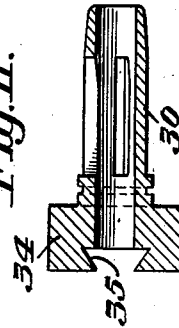


Fig. 10A.

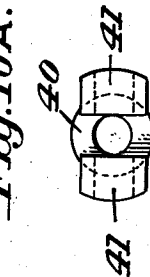


Fig. 10.

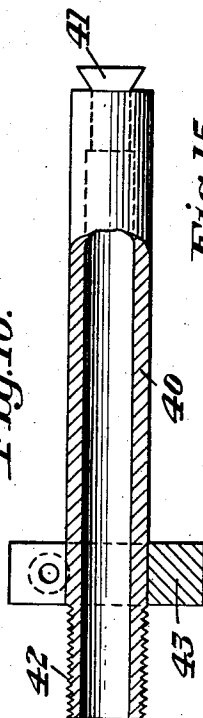


Fig. 17.

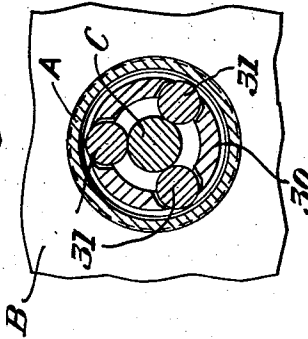


Fig. 16.

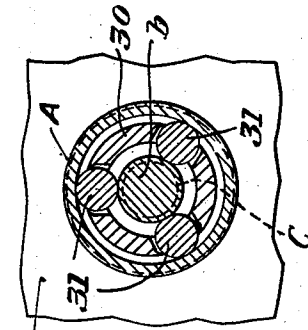


Fig. 15.

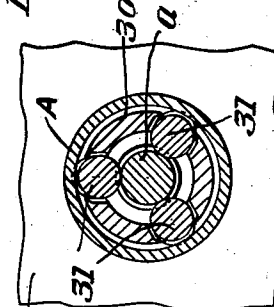
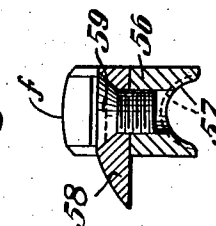


Fig. 18.



INVENTOR
Harry Boyles and
Raymond W. Brabb
by
Thomas E. Miller,
their attorney

UNITED STATES PATENT OFFICE

2,393,283

METHOD OF EXPANDING TUBES

Harry Boyles and Raymond Walter Grabb,
Jeannette, Pa., assignors to Elliott Company,
Pittsburgh, Pa., a corporation of Pennsylvania

Application July 29, 1942, Serial No. 452,810

3 Claims. (Cl. 29—157.5)

This invention pertains to methods and apparatus for expanding tubes, and particularly, for expanding heat exchange tubes such as employed in a condenser, boiler, or feed water heater.

In the manufacture of boilers, condensers, and similar apparatus, tubular heat exchange members are mounted in suitable tube sheets or baffles that support or hold them in position. The tube sheet or baffle is holed-out to provide openings to receive the tubular members. The tubular members are inserted in or through such holes and their wall portions expanded to press them tightly against the bounding edges of the holes provided. After the tubes have been mounted within the holes in the tube sheets, their edge portions are rolled in.

Particularly due to the temperature changes and conditions to which apparatus of this type is subjected, considerable difficulty has arisen in providing a suitable type of connection or mounting construction between the tube sheets and the heat exchange tubes. In the first place, it is customary, and in many cases advisable, to provide sheets of one type of metal and tubes of another type. For example, the heat exchanger shells may be of iron, while the tubular surfaces of some suitable material such as an alloy of copper. Consequently, due to the different coefficients of expansion, the tubes will expand more than the shell when the condenser is heated up. In some heat exchange apparatus, the exterior of the condenser may be less severely heated than the interior portions and the shell and the tubes may have different thicknesses, all of which contribute to the different coefficients of expansion and to differences in temperature between the shells or sheets and the tubes, themselves.

As a result of the different temperature conditions and different coefficients of expansion as above outlined, the tubes may break away from their mounted relationship with respect to the shells and vice versa, as many tons of pressure may be exerted between such portions of the apparatus. Some have attempted to alleviate these conditions by providing a form of flexible packing for the tubes or by making the entire tube sheet in which one end of all the tubes is mounted subject to movement in a floating head. It will be apparent that such methods have their difficulties and limiting features, particularly due to the high temperature conditions involved. For example, a flexible packing has a tendency to leak and its life is limited.

In view of conditions such as above outlined, we have endeavored to develop a new method of

attack which will meet the problems presented. In our development, heavy tube sheets are employed and an initial bow is made in the tubes so that there is a slight arc along the tube length.

As expansion occurs, the tube length may vary with the curvature of the arc. The present invention deals particularly with procedure and apparatus for enabling a new and improved utilization of such a construction.

It will be noted that a small amount of expansion may produce a great change in curvature, and that a very moderate change in temperature may produce a very great change in tube deflection. In longer tubes, it is difficult to initially secure straightness of the tube, and to hold the initial deflection due to weight in the same direction. Consequently, with varying temperatures the deflection of the tubes is not only variable in amount, but differs in direction. We have also found it advisable to provide a tube construction that will not fail due to the stresses and strains involved even if the apparatus is overloaded beyond its normal capacity for a period of time; this will give the vent or other safety devices full opportunity to operate.

If the apparatus such as a condenser or heater is rolled with the tubes heated, the differential expansion upon cooling puts the tubes under a partial tension, at least in theory. If the tension becomes heavy enough, the tubes may elongate within their elastic limits due to the stresses imposed. We have found the structure is more flexible with the tubes in tension as water boxes normally are of heavy section of cast iron or welded steel to provide corrosion-resistance. Such boxes tend to prevent the tube sheets from expanding outwardly and hold them in place more positively than if the tube sheets are pulled inwardly by contracting tubes. It is also apparent that due to differences in temperature between the top and bottom of the apparatus and other parts thereof, some of the tubes may be under tension and others under compression. In accordance with this method, both tube ends were rolled in the tube sheet and the tube sheets were fixed slightly further apart in position than they would normally be if the tube sheets were to be positively held in position.

In rolling the tubes, holes in the tube sheets were drilled out and then reamed to a controlled size. The tube, itself, is manufactured with a predetermined diameter and within a closely held tolerance. As the tube materials are somewhat ductile, the wall portions were expanded by a tool inserted in the interior of the tube and re-

volved. This tool rolled the tube metal to a larger diameter until tight contact was made between the tube exterior wall and the inner edges of the hole in the tube sheet. In order to insure suitable contact and provide holding power, it was found necessary to continue the expansion, the equivalent of several thousandths of an inch on a one inch diameter of the tube, for example, beyond the point where actual contact was made, in order to provide a mechanical and continuous contact between such surfaces. This last operation after contact was made tends to extrude metal of the tube and heavy pressures and plastic flow of the tube material results.

In carrying out the operation, it is obviously necessary to have the workmen on the outer side of the tube sheet away from the tubes. Heretofore, it has been the customary practice in the art to extrude the tubular wall towards the spacing between tube sheets or towards the interior of the condenser or away from the open end through which the tool was inserted. This extrusion, even when a few thousandths of an inch, was significant enough to produce a considerable change in the deflection of the tube.

We have been able to meet the problems involved in this type of operation as well as in the general operation of securing or mounting a tubular member in tube sheets, by certain new and improved operative methods. In this connection, we prefer to extrude the metal, if the tube is to be rolled from the inside, towards the operator and to avoid superimposing the extruded portion upon the tube to, in effect, stretch rather than compress the metal. As above intimated, the tool should have a tapered head so that it may be inserted and withdrawn from the tube; previous constructions had a tendency to anchor about the point at which they first came into contact with the inner wall of the tube and to extrude away from this point.

In accordance with the present invention, we determined the advisability of beginning the tube rolling or expanding operation at a portion of the tube farthest from the end which is to be mounted, or in other words, farthest removed from the operator, and to cause the extrusion to take place in direction towards the end of the tube that is to be mounted and thus towards the operator. We have also been able to develop a tool that will effect such a result in an improved manner.

Although as above intimated, our invention has particular value in expanding heat exchange tubes for suitably mounting them in tube sheets or header constructions, it will be apparent that the present invention may also be applied with efficacy in other cases where walled members are to be expanded outwardly.

Thus, it has been an object of our invention to provide a solution to the problems encountered in suitably mounting tube members in their header sheets.

Another object of our invention has been to provide new and improved procedure and apparatus for suitably securing or mounting tubular members in tube sheet members, particularly adjacent end portions thereof.

A further object has been to expand or extrude walled members in a new and improved manner.

A still further object has been to provide a new and improved type of mounting construction for tubular members such as employed in heat exchangers, condensers, and the like.

These and many other objects of our invention will appear to those skilled in the art from the drawings, the description thereof, and the appended claims.

In carrying out our invention, we preferably insert a suitable mandrel-like roller device into the end of a tube and then actuate the device in such a manner as to begin the rolling operation at the far end of the device and to move it, while increasing the expanding pressure, in a direction towards the operator, or in other words, towards the end of the tube through which the tool has been inserted. After this preliminary operation, we preferably automatically change the angle (decrease the angle of application) of the device to roll the inside of the tube substantially parallel, and finally, to provide a gradually or smoothly tapered transition between the balance of the tube and the portion which has been expanded, all with a minimum of stress and strain upon the tube and without leaving sharp areas or rings and without overstressing any portion of the inside of the tube.

Previously, apparatus of this type produced a sharp thin edge at the point where the rolling was discontinued. This edge, of course, tended to initiate corrosion. We have found that a projection on the inner wall tends to increase turbulence and to aid the forming of cavities and the ultimate collapse of the tube at such a point. The tool is also employed in such a manner that the extent of each step of the rolling or extruding operation is automatically controlled and such that it automatically releases itself upon completion of the work, permitting its removal by the operator, all without damaging the quality of the tube and additionally producing an improved outer surface from the standpoint of holding the tube in position with respect to its tube sheet.

The drawings show a preferred apparatus embodiment of the present invention:

Figure 1 is a side elevation of apparatus for expanding tubular members in accordance with our invention;

Figure 2 is a longitudinal sectional view through a tool constructed in accordance with our invention and shown in Figure 1; in this view, the device is shown in an initial or starting position with respect to a tubular member A that is to be expanded in a tube sheet B;

Figure 3 is an enlarged longitudinal section of the apparatus of Figure 2, but showing it in a final position after it has completed the expanding operation and is ready for removal from the tube member;

Figure 4 is a section taken along the line IV—IV of Fig. 2;

Figures 5 and 6 are transverse sectional views taken along the lines V—V and VI—VI of Figures 2 and 3, respectively;

Figure 7 is a longitudinal sectional view of a clutch sleeve of the apparatus shown, for example, in Figure 2; Figure 8 is an exploded longitudinal sectional view of chuck-like clutch jaws and their associated parts;

Figure 9 is a plan view of the clutch body;

Figure 10 is a view part in elevation and part in section of the mandrel tube of the apparatus; Figure 10a is an end elevation of the tube of Figure 10;

Figure 11 is a longitudinal sectional view of the roller cage.

Figures 12, 13, and 14 are all longitudinal sec-

tional fragments of the expander portion of the apparatus shown in Figures 2 and 3, in different positions; in Fig. 12, the apparatus is near the end of its so-called inner extruding operation; in Fig. 13, it has finished the inner extruding operation and is rolling a substantially parallel surface; and in Fig. 14, the rolling operation has been completed, and the apparatus automatically released from rolling contact with the inner wall portions of the tubular member A;

Figures 15, 16, and 17 are cross-sectional views taken along the lines XV—XV, XVI—XVI, and XVII—XVII of Figures 12, 13, and 14, respectively; and

Figure 18 is a section taken on the line XVIII—XVIII of Figure 8.

As shown, for example, in Figure 1, the device of the present invention includes an operating shaft 21 that at one end has mandrel-like portions *a*, *b*, and *c*, that are operatively engaged by a tube-expanding unit 30. The shaft 21 also has a threaded portion 23 operably mounted within a clutch unit 20 and terminating at one end in a connecting shank portion 22. The device may thus be rotated by a motor 10 through a shaft 11 and connector 12.

In using the device, the operator grips sleeve 50 of clutch unit 20, retains the clutch in a released position (see Fig. 3), and inserts the tool in the tube A in a position for rolling. The operator then pushes or slides the threaded portions 23 to their extreme forward relationship with respect to the clutch 20; sleeve 50 is moved forwardly with respect to part 65 (from the position shown in Fig. 3 to that shown in Fig. 2, for example) to engage the clutch (see Fig. 2). The motor 10 then rotates the entire device including the unit 20 within the hands of the operator. During such rotation the mandrel portions *a*, *b*, and *c* move backwardly and effect the desired expanding or swaging operation through rollers 31 of the roller or cage expanding unit 30. Friction between the rollers 31 and the inside of the tube during the rolling operation produces a progressive backward turning of the screw portions 23 of the shaft 21 within the clutch member 20, moving the mandrel portions backwardly and automatically advancing the various steps of the expanding operation until the operation has been completed and the apparatus has been moved to the position shown in Figures 3 and 14.

Referring particularly to Figures 1, 2 and 3, the object of the tapered ends of rolls 31 is to blend the large rolled diameter of the tube A to the small unrolled diameter of the tube to avoid sharp shoulders that, in turn, produce eddy currents in the liquid stream. The roller cage 30 is provided with openings adapted to receive rollers 31 whose front ends are somewhat beveled to correspond to the forward bevel of the cage 30. As will be noted, the cage 30 is inwardly drilled out to receive the mandrel portions of the shaft 21 and to permit the rollers 31 to suitably operably engage between the mandrel portions *a*, *b*, and *c*, and the inner wall portions of the tube A being rolled. A tube sheet is represented by B.

As shown, see Figure 11, the cage portion 30 terminates in a base portion 34 having a grooved female slide portion 35 adapted to removably receive a complementary male slide or stud portion 41, see Figures 1 and 10, of a mandrel shaft enclosing tube 40. That is, the portions 35 and 41 are, in effect, slideably and removably dovetailed. The base 34 has a forward ledge portion for receiving a sleeve-like stop element 37 thereover.

As will be noted, this sleeve-like element is held in position by a circular lock spring 36 having an inwardly depending finger 37a that engages an annular groove 38 of the base member 34. The sleeve stop 37 is provided with an offset inner front edge portion 39 for receiving an end of the tube A to be expanded and for thus governing the distance the tool is inserted within the tube. This sleeve-like stop 37 being removable, may be interchanged with other stops having different depth of ledge portions 39 as desired, depending upon the desired depth of insertion of the tool within the tube A.

The clutch member 20 comprises an outer sleeve member 50 having a pair of inwardly-offset annulus-like portions *d* and *e*. A pair of chuck-like jaws or follower elements 56 are slidably positioned within bifurcated end portions of a mount element 52, see Figure 8. The clutch mount element 52 has a portion 53 threaded to receive and be secured to a like threaded portion 42 of the mandrel shaft enclosing sleeve 40.

The elements 52 and 56, shown particularly in Figures 2, 3, 5, 6, 7, and 8, are operably mounted within the clutch sleeve 50 and are held in position by a removable cap 65, see Figure 4, that has a flange portion engaging offset portions *h* and *i* of the elements 52 and 56, respectively. The cap 65, itself, is removably held in position by set screws 66.

As shown, for example, in Figures 8 and 9, each of the threaded followers or chucks 56 is provided with a shoe 58 removably mounted as shown by a set screw 59. Each shoe 58 is beveled as shown and extends over upon one offset ledge portion 54 of the bifurcated core or mount element 52.

A pair of follower-positioning pins 60 slidably extend through holes 55, see Figures 5, 6, and 8, and in the core element 52 and have a flat surface that contacts the lower surface portion of the shoes 58. The other end of each pin 60 is rounded off to engage, as shown in Figures 5 and 6, the inner wall portions of the sleeve 50. When the clutch sleeve 50 is moved forwardly against a slip-sleeve stop 43 (see Figure 2), projecting ledge portions *f* and *g* of the screw followers 56 abut against inwardly-extending ledge portions *k* and *l* of the sleeve 50, see Figures 2 and 3, holding or locking them against the threads 23 of the mandrel shaft 21. At the same time, the pins 60 enter the offset portion *d* of the sleeve 50 and are released, permitting the above-explained follower or clutch engagement.

When the sleeve 50 is moved backwardly to the position shown in Figure 3, it will be noted that the ledge portions *f* and *g* of the followers 56 enter the offset portions *d* and *e* of the sleeve 50, and that the pin elements 60 abut against the annular ledge *l* to effect an outward separation (spreading apart) of the followers 56 by pressing against and moving the shoes 58 outwardly, see Figures 3 and 6.

As will appear, the stop 43 is adjustably mounted on the mandrel-enclosing sleeve 40 by means of a set screw 44.

As will be noted particularly in Figures 1 and 2, the mandrel portion proper of the shaft 21 includes an outwardly beveled portion *a*, a parallel portion *b*, and a dropoff, or a portion of less diameter *c*.

As shown in Figure 12, the rolling and expanding operation upon the inner wall of tube A begins with the rollers 31 at the inner or lesser diameter beveled portion of mandrel *a*, to effect

an initial outward expansion, beginning at the forward end portions of the rollers 31. As the roller cage 30 and associated rollers 31 move forwardly over the portion a, whose diameter progressively increases, the expanding operation is progressively effected with a maximum extrusion away from the operator and a minimum towards the operator. When the cage 31 and its associated rollers reach the mandrel portion b, see Figure 13, the rollers 31 operate parallelly to even out the previous extrusion and make the inner walls of the tube A substantially parallel, with a gradual bevel that marks a transition point between the original surface of the tube and the portion that has been extruded. Later, when the cage 30 and its associated rollers 31 move upon the mandrel portion c, such rollers move inwardly and are thus released. The result is that the tool speeds up and the operator is warned that the operation has been completed and to withdraw the tool.

The backward feed of the mandrel shaft 21 and thus, the forward feed of the roller cage 31, or in other words, the relative movement between the same, is effected by the planetary action of the rollers 31 in contact with the tube wall A. The screw thread 23 on the mandrel is made lefthand for conventional rotation of a motor and, of course, would be made righthand if the direction is reversed. The principle may be termed that of a sun and planet gear, that is, the small diameter rollers 31 are compressed against the tube wall which is stationary while the mandrel shaft 21 rotates. Thus, equal pressure is exerted upon the rollers on opposite sides of their diameter, one surface, the tube surface, being stationary, the other, namely, the mandrel surface, being rotated. The frictional contact is such that the rollers 31 rotate with substantially the surface speed of the mandrel 21 and rotate upon the tubular wall A in such a manner that the cage 30 revolves, as its diameter is less than the diameter of the tube wall.

Driving force is transmitted from the mandrel 21 which is driven by the motor 10 through the tube rollers 31 and tube wall back to the roller cage 30, and from the roll cage 30, backward to the clutch unit 20 and its controlling mechanism. As a result, a relative rotation is effected between the clutch 20 which carries the female follower elements 56 and the portion 23 of the mandrel which constitutes the male element. The rolls 31, themselves, determine the relative difference in speed between the mandrel 21 and the cage 30, and thus, between male and female portions 23 and 56 of the clutch 20. This relative difference in speeds results in a progressive backward movement of the mandrel screw 23 with reference to the clutch unit 20; and, this in turn, moves the mandrel portions a, b, and c progressively backwardly with respect to the roller cage 30, forcing the rollers 31 against the inner walls of the tube A in the manner previously outlined.

The entire apparatus can be readily dismantled and taken apart for replacement and repair purposes or for adapting it to various sizes of tubes, etc. The clutch sleeve 50 is pulled backwardly over the cap 65, as shown in Figure 3, to effect a release of the clutch followers 56 prior to initiating the tube expanding operation, in order that the threaded mandrel shaft 21 may be pushed forwardly to its extreme forward position as shown in Figure 2 before inserting the roller cage 30 within the tube A. At the time of insertion

of the roller cage, the sleeve 50 is moved forwardly as shown in Figure 2, or to the position shown in full lines in Figure 1 (the previous position being shown in dotted lines in the same figure), to in effect, lock the female clutch follower portions 56 in threaded engagement with the male screw portion 23 of the mandrel shaft 21, and to initiate when actuated by the motor 10, the progressive expanding action previously explained.

Expanding the tube A outwardly towards its ends in mounting it within tube sheets B also prevents buckling as the force is applied away from the center of the tubing.

Although we have used the term "expanding action" in the claims, it will be apparent to those skilled in the art that this also includes extruding action whereby there is a plastic deformation of the metal under pressure.

In the claims the expression "inner side of the plate" is intended to refer to the side of the plate from which the inserted tube projects, quite independently of the use to which the final assembly is to be put.

As will appear to those skilled in the art, the procedure of the present invention may be accomplished by other suitable apparatus, and the present preferred apparatus construction may be modified and suitable subtractions, additions, etc., thereof may be made without departing from the spirit and scope of the invention as indicated by the appended claims.

We claim:

1. The method of uniting a tube with a plate, wherein an end portion of the tube is placed within a hole in the plate with the remainder of the tube extending from one side of the plate remotest from the end of the tube, which method comprises inserting said end of the tube in the said hole, introducing a rolling tool into the tube through said end to a zone beyond said one side of the plate, then rolling so as to extrude the tube interiorly by said tool at an angle at the said zone beyond said one side of the said plate, then expanding that portion of the tube between the internally angularly rolled zone and said tube end by rolling and extruding the tube interiorly radially from the said zone to the inserted end, thereby radially externally expanding the tube in the plate, and uniting the tube to the plate, and finally rolling and expanding the tube into a cylindrical configuration internally while restraining it from expansion by close fit with the hole in the plate, thereby firmly joining the tube and plate, while continuously extruding from the inserted end of the tube the metal removed from the interior of the tube by the aforesaid rolling operations.

2. The method of uniting a tube with a plate, wherein an end portion of the tube is placed within a hole in the plate with the remainder of the tube extending from one side of the plate remotest from the end of the tube, which method comprises inserting said end of the tube in the said hole in the plate, introducing a rolling tool into the tube through the said end to a zone beyond said one side of the plate, starting withdrawal of the tool from the tube through the said inserted end while first rolling and extruding the tube interiorly at an angle, then continuing the withdrawal of the rolling tool through the said inserted end while expanding the tube radially in the hole in the plate and uniting the tube and plate, and finally completing the withdrawal of the rolling tool through the inserted end while finally rolling and expanding the tube into a cy-

lindrical configuration internally, thereby completing the uniting of the tube and plate, while continuously extracting from the inserted end of the tube the metal removed from the interior of the tube by the aforesaid rolling operations.

3. The method of uniting a tube with a plate, wherein an end portion of the tube is placed within a hole in the plate with the remainder of the tube extending from one side of the plate remotest from the end of the tube, which comprises inserting the said end of the tube in the said hole, angularly deforming the tube internally thereof at a zone beyond said side of the plate, while avoiding external expansion of the tube by close fit in the hole, then enlarging the inside diameter 15

of the tube between the said internally angularly deformed zone and the said end, thereby radially externally expanding the tube in the plate and uniting the tube in the plate, and finally expanding and shaping the said radially expanded portion of the tube into a substantially cylindrical configuration internally, thereby finally and firmly joining the tube and plate, while continuously extruding through said end of the tube the metal removed from the interior of the tube by the aforesaid deforming, expanding and shaping operations.

HARRY BOYLES.
RAYMOND WALTER GRABB.