Sept. 15, 1931. W. B. CLIFFORD 1,823,532

METHOD OF FORMING BELLOWS FOLDS

Original Filed Oct. 4, 1924 3 Sheets-Sheet 1

Fig. 1

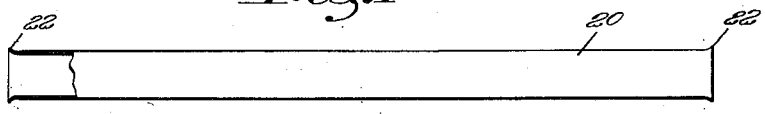


Fig. 2

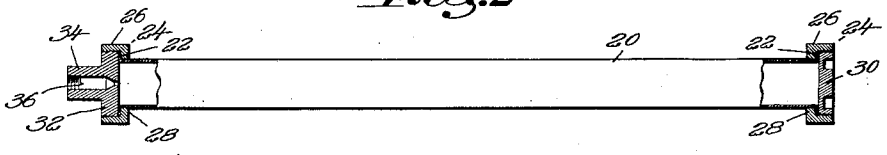


Fig. 3

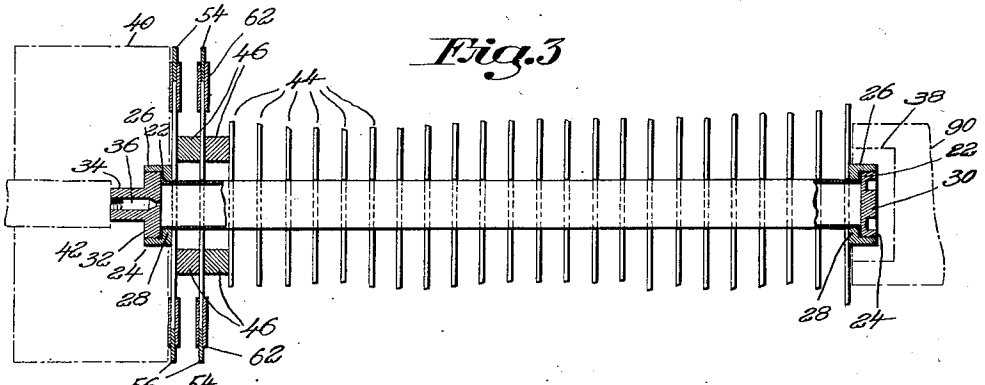
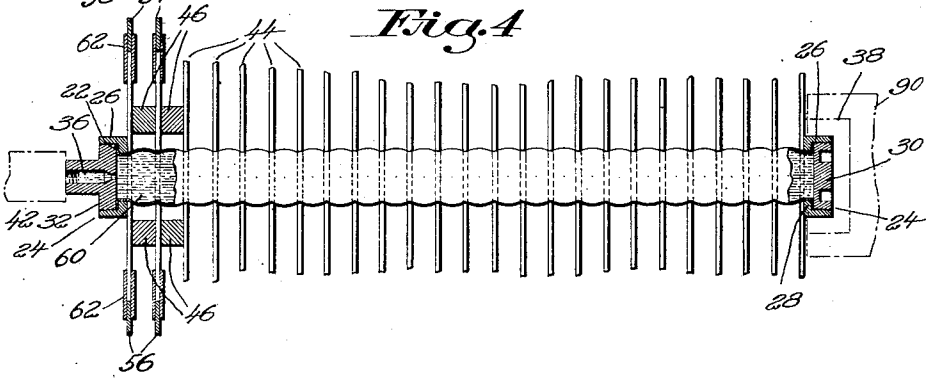


Fig. 4



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Fig. 5

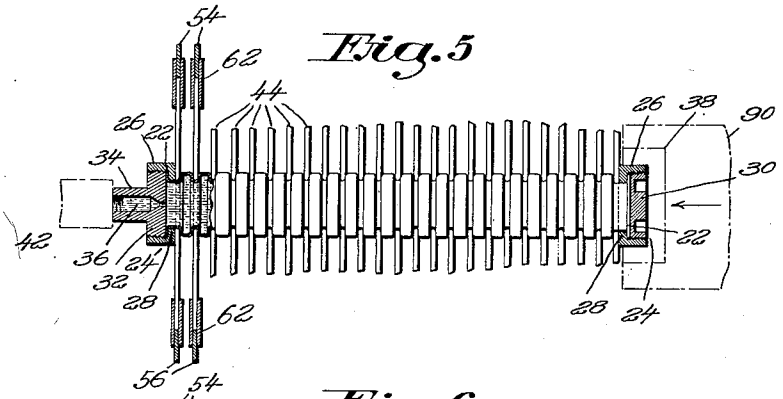


Fig. 6

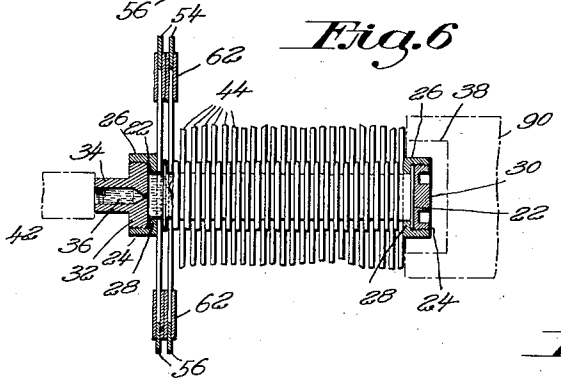


Fig. 7

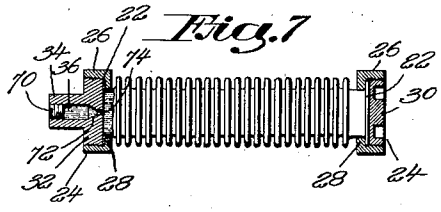


Fig. 9

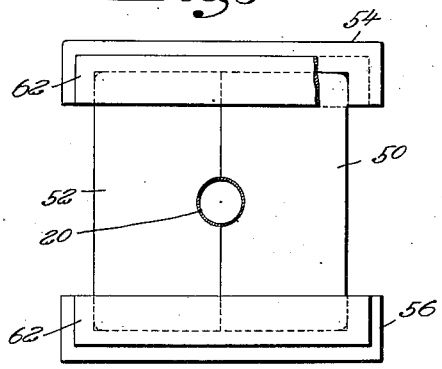
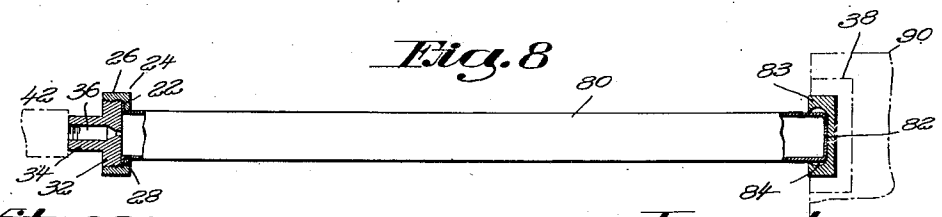


Fig. 8



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METHOD OF FORMING BELLOWS FOLDS

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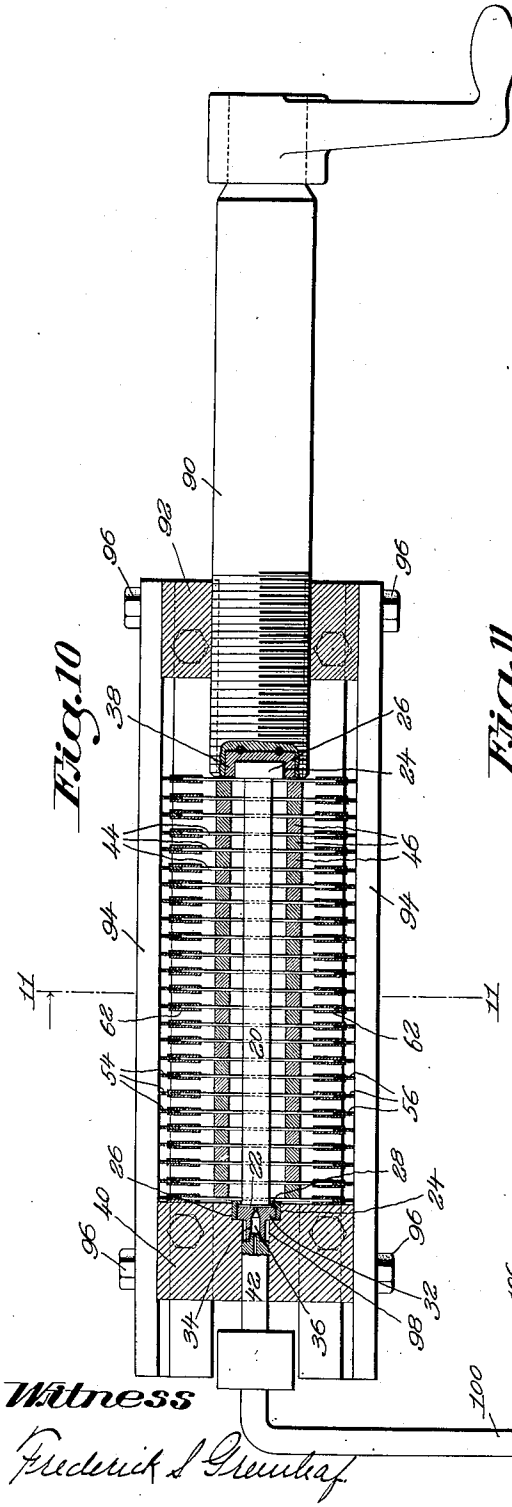


Fig. 10

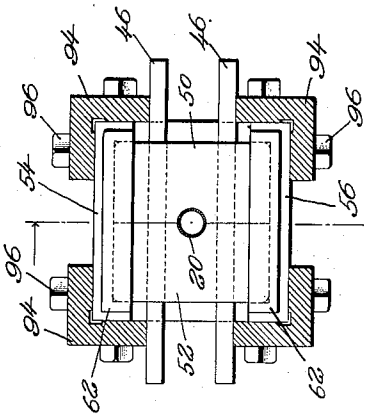


Fig. 11

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1,823,532

UNITED STATES PATENT OFFICE

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METHOD OF FORMING BELLOWS FOLDS

Application filed October 4, 1924, Serial No. 741,688. Renewed April 13, 1927.

The present invention relates to a method of forming bellows folds.

A well known type of thermostat consists of a corrugated thin wall tube having a series of bellows folds. The tube is hermetically sealed and filled with a liquid or gas which expands and contracts with variations in temperature, causing a similar expansion and contraction throughout the length of the thermostat. This type of thermostat may be employed for any one of the variety of purposes where it is desired to control the operation of a valve or other instrumentality in accordance with variations in temperature. The thermostatic tube is ordinarily composed of a tempered metal, such as a copper alloy, which tends to resume its normal dimensions after a forced expansion through heating of the liquid or gas contained therein.

This type of thermostat in actual practice is formed by rolling a plain tube between cooperating rolls positioned respectively within and without the tube. These drawing rolls, through a series of successive operations, form a plurality of concentric folds or corrugations in a plain tube. An alternative method of forming the corrugations is to thread a plain tube upon a mandrel in such a manner that a series of relatively coarse spiral corrugations are formed. Thereafter the tube is removed from the mandrel and contracted in length to bring the corrugations into close relation. In either case, the tube, after the formation of the corrugations, must be filled with the desired liquid or gas and hermetically sealed in order to prevent subsequent leakage of the contained liquid or gas therefrom. In actual practice, this type of tube is generally sealed at the ends through the employment of soldered connections. There are several disadvantages inherent in this method of manufacture. The drawing operation is relatively slow, due to the method employed in forming the corrugations or bellows folds. The tube must ordinarily be annealed at least once prior to completion of the corrugations and the smallest diameter of the tube which may be fabricated by this process is strictly limited by the necessity of inserting either a mandrel or a forming roll within the tube. The formation of the corrugations prior to the attachment of the end closures practically compels the use of solder for sealing the tube, with its attendant disadvantages. Ordinarily this type of tube is not employed where the temperatures exceed 300° F., due to the relatively low melting point of the solder.

The principal object of the present invention is to devise a new and much improved method for fabricating thermostats of the above described type, by virtue of which the process of manufacture will be simplified and the quality of the resulting product materially improved.

With this and other objects in view, one feature of the invention consists in preforming a plain tube with a series of slightly rounded or bulged portions extending lengthwise of the tube, and thereafter subjecting the tube to a longitudinal pressure sufficient to contract the tube and sustaining the rounded or bulged portions by an internal pressure to cause the tube to freely fold or roll up throughout these portions as it contracts in length. In the simplest and most efficient form of the invention yet devised, this preforming of the tube is accomplished by supporting the outer wall of the tube at predetermined spaced intervals and applying a preforming pressure from the inside in sufficient amount to stretch and cause the walls of the tube to bulge between the supports or forming members. This preforming is not carried to a point at which the walls are ruptured or substantially weakened. In actual practice, fluid is inserted within the tube and subjected to pressure to first preform the tube and to thereafter sustain the walls of the tube during the contraction in length. It will be obvious, however, that preforming of the tube might be accomplished in any desired manner, and the preformed tube later sustained by an internal fluid pressure during the contraction in length. During the final formation of the corrugations, sufficient internal pressure is exerted to maintain the walls of the tube

throughout the preformed areas under tension, this pressure when properly coordinated with the thickness of the tube, strength of the material and the length of the unsupported portion of the wall causing the wall to fold up into a bellows fold or rounded corrugation rather than to flatten or crimp, as would otherwise be the case. With this method the tube is initially divided into expanded or bulged portions of accurate and predetermined length measured off by the external spaced supports or forming members which are locked to the tube due to the expansion of the tube therebetween. After the initial locking of the forming members to the expanded tube, the expanded portions are caused to fold into bellows folds by the combined forces of internal pressure and axial contracting pressure while permitting the forming members or plates to move with the tube due to their interlocked relation therewith, in a simple embodiment of the invention this freedom of movement of the forming members being accomplished by releasing the forming members from spacers which determine the initial spacing.

Another feature of the present invention consists in forming an annular flange upon one or both ends of a length of plain tubing, assembling a fitting therewith and sealing the fitting to the flange in a manner to form a liquid or a gas tight joint, connecting the tube assembly with a source of fluid pressure through an opening formed in the fitting, and thereafter forming the corrugations or bellows folds as hereinbefore described. In one form of the method, the liquid employed for creating the internal pressure may be the liquid used for filling the thermostat assembly. Upon completion of the operation therefore, the completed assembly is merely disconnected from the source of liquid pressure, the ends sealed in a suitable manner, and the thermostat completed without subsequent operations. The utilization of the liquid employed for filling the thermostat in the operation of fabricating promotes economy and efficiency, as the filling of a preformed corrugated tube with liquid in a manner to completely expel all air or gas from within the tube may well be a tedious and difficult operation.

The present method is not to be confused with certain prior suggestions which purport to disclose methods of forming hollow metallic articles through the employment of an internal liquid pressure for forcing the article into conformity with an external mold. Although such methods have been known and disclosed for many years, they have never achieved any measure of practical success for the fabrication of corrugated tubing, in spite of the fact that the field for tubing formed in this manner which is capable of withstanding repeated expansion and contraction without failure is exceedingly great.

In the accompanying drawings illustrating the preferred form of the invention, Fig. 1 represents a side view of a plain tube cut to the proper length and flanged at opposite ends; Fig. 2 is a view illustrating the tube of Fig. 1 with the cap members applied to the opposite flanged ends to hermetically seal the interior of the tube; Fig. 3 is a view illustrating the complete tube assembly with the ends supported, the interior connected to a source of liquid pressure, and the tube intermediate its ends rigidly supported at spaced intervals; Fig. 4 is a view similar to Fig. 3 illustrating the partial formation of the bulges or rounds in the tube, these bulges occurring in the areas between the points of rigid support; Fig. 5 is a view illustrating the next step in the operation of fabricating the tube in which the latter has been contracted through pressure exerted at one end, causing the rounded areas to roll up between the points of support, as indicated; Fig. 6 is a view illustrating the thermostatic tube after the formation of the bellows folds has been completed, due to contraction in length of the tube; Fig. 7 illustrates a side view of a completed thermostat assembly filled with liquid and having the opening in one end sealed by a threaded plug; Fig. 8 is a side view partly in section illustrating a modified form of assembly prior to the formation of the corrugations. In this form the tube is opened at one end and sealed at the opposite end. Fig. 9 is a detail illustrating an elevation of a two part rigid supporting member with the tube shown in section therein; Fig. 10 is a side elevation partly in section of a relatively simple form of jig for aiding in the formation of the bellows folds in the tube; and Fig. 11 is a cross section in elevation of the jig taken upon the line 11—11 of Fig. 10.

According to the present invention, the corrugations or bellows folds in the thermostatic tube are produced by rigidly supporting the tube at spaced intervals throughout its length, subjecting the interior of the tube to an internal pressure properly coordinated with the length of the tube between supports, and finally completing the formation of the corrugations through endwise pressure, tending to contract the tube longitudinally while maintaining an internal pressure sufficient to keep the preformed areas under tension and prevent crimping. The internal pressure initially applied to the interior of the tube may be sufficient to slightly round or expand portions of the tube between the rigid supports but is insufficient to rupture the walls of the tube. With the tube preformed in this manner, the tube is subjected to an endwise pressure to compel a contraction in length. During the application of this pressure, internal pressure on the tube

is maintained in sufficient amount to compel the walls of the tube to roll outwardly between the rigid supports. This pressure should be substantially constant during the contraction of the tube and may be equal to or less than the initial pressure employed for bulging or rounding the tube. During the contraction of the tube, the rigid and initially spaced supports are free to move together, the position of the supports with relation to the tube being maintained by locking of the supports to the tube through the bulged or rounded areas therebetween. The preforming or bulging of the tube between rigid supports locks the supports in initial uniform spaced relation and avoids any additional spacing mechanism during the movement together. Any attempt to deviate substantially from the use of combined pressures as outlined results in failure. The employment of an internal pressure in sufficient volume to expand the bellows folds results in rupture of the walls after a partial formation of the corrugations. An attempt to form the corrugations by the use of an endwise pressure with an internal pressure intended to act merely as a liquid mandrel, without preforming, results in crimping or flattening of the corrugations, the walls of the tube tending to form in a series of folds unless preformed and compelled to roll on a curve.

Referring to the illustrated embodiment of the invention, a tube 20 of copper alloyed with other material, such as zinc, tin, or similar or equivalent material, is cut to the desired length. The opposite ends of the tube are then flanged outwardly at 22 through a spinning or drawing operation. The thermostatic tube blank so formed is next closed at opposite ends by heads or fittings 24. Each head comprises a sleeve 26 having an inwardly projecting shoulder 28 engaging with the flange 22 and clamped thereto by a head 30 threadedly connected with the inner face of the sleeve. The two parts of the head, preferably of steel or similar material, with the flange rigidly clamped therebetween, provide a joint which is liquid or gas tight, even under relatively high pressures. Referring to Fig. 2, it will be evident that the head at one end of the tube is slightly varied. In this case, the sleeve 26 cooperates with a head 32 having an extension 34 provided with a liquid opening 36 communicating with the interior of the tube. It will be evident to those skilled in the art that in the actual production of the thermostatic tube blank the flange is formed upon one end, the sleeves 26 next mounted, and the flange thereafter formed upon the opposite end. After the completion of the thermostatic blank, the tube with end caps mounted thereon is assembled in a suitable jig with opposite ends of the tube held rigidly in alignment by heads 38 and 40. The head provided with the opening 36 is connected to a source of liquid supply under pressure, indicated generally at 42. Surrounding the walls of the tube and spaced at uniform intervals are a series of rigid formers or supports 44, which may be retained in spaced relation by virtue of spacer members 46. As indicated in Fig. 9, each of the rigid supports may preferably comprise cooperating plates 50 and 52 of tool steel or similar material which, in assembled relation, fit closely about the tube blank 20. The cooperating plates are locked in assembled relation by oppositely disposed clips 54 and 56, which also serve to maintain the plates in spaced relation when the contraction of the tube blank has been completed. Having assembled the thermostatic tube blank as indicated in Fig. 3, with opposite ends held in alignment and the periphery of the tube throughout its length rigidly supported at spaced intervals, the interior of the tube is filled with a suitable liquid indicated at 60 through the opening 36. The pressure of this liquid is increased to a point at which the walls of the tube between the rigid supports are rounded or bulged, this preforming of the tube being exaggerated in Fig. 4. It will be evident that this preforming of the tube between points of supports locks the rigid forming and supporting members in spaced relation throughout the length of the tube and thereafter permits removal of the spacer members 46. Having thus preformed the thermostatic tube blank with a series of successive rounded or slightly bulged areas between supports and removed the spacer members, the assembly as a whole is subjected to a sufficient endwise pressure to compel contraction in length of the tube. During this endwise movement, the internal pressure is maintained in sufficient amount to maintain the walls of the tube in tension and compel the metal between supports to roll along curved lines. The approximate shape of the tube blank when partially contracted is indicated in Fig. 5. In this figure, the areas of the tube between supports have been rolled outwardly and the supports, due to the contraction of the tube, moved into closer relation. During the contraction of the tube, the internal pressure is maintained substantially constant through the employment of a relief valve or an accumulator. In actual practice, contraction of the tube is accomplished by moving the head 38 in the direction of the arrow in Fig. 5, while rigidly maintaining the opposite end in a fixed position. The endwise contracting movement is continued until the rigid supports have been moved into the relative positions shown in Fig. 6, with the side portions 62 of the clamps in contact with one another

limiting further movement of the supports together. The completed thermostatic assembly is well illustrated in Fig. 7, the tube being provided with a series of regularly spaced corrugations or bellows folds, the space between each two folds corresponding to the thickness of the rigid supports and approximating the outer thickness of the folds. It will be evident, furthermore, that the individual folds are of substantial depth and that the extreme diameter of the folds is materially greater than the original diameter of the tube and that the side walls of the folds are normal to the axis of the tube. As will be evident from an inspection of Fig. 7, the thermostatic assembly, after being disconnected from the source of liquid pressure, is closed with a plug 70 which threads within the opening 36 and engages with the tapered end 72 to tightly close the small opening 74.

Although obviously any desired liquid may be employed for maintaining the internal pressure upon the tube, it is preferable to employ the liquid which is to be later used in the operation of the thermostat. This avoids the necessity of emptying the tube and refilling it with a different liquid. The refilling of a corrugated tube of this character, especially where the corrugations are relatively small and closely spaced, may be a slow and tedious operation, due to the formation of air pockets in the folds. If these pockets of air are not completely expelled during the filling of the tube with liquid, the subsequent operation of the thermostat is irregular and faulty.

It will be evident to those skilled in the art that the formation of the corrugations in the manner above described is accomplished without imposing undue strains upon the metal or without imparting such a temper to the metal that it becomes brittle and liable to failure under repeated expansion and contraction of the thermostat. Furthermore the formation of the corrugations may be completed in a continuous operation and without the necessity of annealing the tube prior to its completion. An alternative form of thermostatic assembly is indicated in Fig. 8. In this construction, the blank instead of being cut from a previously formed tube is drawn from a sheet of the desired thickness to form a deep drawn tube 80 with a closed bottom portion 82. Having formed the tube in this manner, the opposite end is provided with a flange 22 and a two-part head 24 mounted thereon, the portion 32 of the head having the usual opening 36 for connection with a source of liquid supply 42. When the assembly is inserted in the usual jig, the closed end of the tube is assembled with a cap 83 having a recess 84 with reentrant or outwardly curved side portions. When internal pressure is applied to the tube blank, the end portion of the tube adjacent the cap is bulged out to fill the recess 84, locking the cap rigidly to the tube. Thereafter the formation of the corrugations is conducted in the manner previously described. With this method, the completed thermostatic assembly is similar to that illustrated in Fig. 7 but requires a hermetically sealed joint at one end only of the tube. Furthermore the formation of the lip at one end is eliminated and the cap mounted on the closed end of the tube is made in a single piece. In forming thermostatic assemblies of certain dimensions, the method illustrated in Fig. 8 is probably somewhat more efficient than the method previously described.

A form of apparatus adapted to carry out the new and improved process of making thermostatic assemblies is illustrated in Figs. 10 and 11. As indicated in these figures, the tube assembly is mounted between two heads 38 and 40. Each of these heads is recessed to receive and closely fit the opposite end caps upon the tube assembly. The head 38 is swiveled in the end of a lead screw 90 threadedly mounted in an end bearing 92. The end bearings 40 and 92 are rigidly maintained in predetermined relationship by angle bars 94 which extend lengthwise of the jig at each corner and are secured at opposite ends to heads through bolts 96. Each of the heads 40 and 92 is of rectangular outline and of such a size that the inner faces of the angle bars 94 when secured to the heads function as guides for the longitudinal movement of the rigid supports. As indicated more particularly in Fig. 11, the clamps 54 and 56 contact with the inner faces of the angle bars and slide thereon, these bars maintaining the supports in accurate alignment with the tube but permitting a free longitudinal movement thereof. The head 40 is provided with a centrally disposed passage 98 communicating with a recess, in which the end cap is seated. The passage 98 receives the end of a pipe 100 which is threaded within the opening 36 to form a liquid tight joint. The supporting members are maintained in spaced relation by a series of spacer rods 46 which are inserted between the supporting plates upon opposite sides of the tube assembly. After the initial internal pressure has been applied to expand the tube and the spacer rods removed, the latter is contracted by rotating the lead screw 90 to exert an endwise pressure upon the tube and cause a bodily movement of the head 38 toward the stationary head 40. During this movement, the supporting plates locked to the tube move therewith toward the head 40 and toward one another. In the actual operation two or more

of the angle bars 94 are first removed from the heads. The tube blank is inserted with the end caps received in the recesses in the heads 38 and 40. Thereafter the supporting plates are positioned about the tube, clamped together, and the spacers inserted. The angle bars are then secured to the heads and the source of liquid pressure connected to the open end of the tube assembly. After the initial bulging of the tube has been accomplished, the spacer members are removed and the tube is then contracted, while maintaining a substantially constant internal pressure. Although any desired form of mechanism may be employed for creating the internal pressure within the tube and maintaining this pressure constant during the contracting movement, this may be conveniently accomplished by a hand operated pressure pump 102 having a screw operated plunger 104 with a pressure gauge indicated at 106, which is intended to accurately visualize the internal pressure within the tube.

By a suitable manipulation of the hand operated pump, the desired pressure may be applied initially and maintained during the contraction of the tube. Obviously, as the tube is contracted in length and the corrugations formed, the capacity is decreased and the pump must be backed off to maintain a substantially constant pressure.

In actual practice, a phosphor-bronze tube having an outside diameter of 3/8″ and with walls 10/1000″ thick has been provided with rigid supports spaced 3/16″ apart between the opposite walls of successive supports, each disk being 32/1000″ thick. The application of an initial pressure approximating 2500 pounds per square inch preforms or bulges the tube between supports. Thereafter an endwise pressure in sufficient amount to contract the tube is applied while maintaining an internal pressure of 2000 pounds per square inch approximately. The initial preforming pressure actually exerts a slight stretching action upon the walls of the tube, whereas the sustaining pressure subsequently employed merely compels the walls of the tube to fold outwardly in the preformed areas and prevents crimping or folding of the corrugations between supports. It is the coordination of the internal pressure initially employed for preforming the tube between supports and thereafter the combination of an internal sustaining pressure with endwise pressure for rolling up the tube in the preformed areas which accomplish the desired result. Neither of these forces operating independently will suffice for the purpose.

It must be evident to those skilled in the art that although the formation of certain hollow metallic shapes may be successfully carried out by expanding a tubular blank into an external mold through internal pressure exerted upon the blank, this general mode of operation cannot be employed for the production of thermostatic tubes having relatively deep and closely spaced bellows folds. The desirability of a thermostatic element of this character having a large number of closely spaced bellows folds in a given length is self-evident, as the distortion of the individual folds for any given expansion of the thermostatic element is in inverse ratio to the number of folds.

It will be evident from the foregoing description that the formation and completion of bellows folds in a thin wall tube is accomplished in one operation by insuring an accurate initial spacing of the forming members, locking the forming members to the tube in such initial spaced relation through expansion of the tube by internal fluid pressure, and thereafter, by the combined forces of internal fluid pressure and endwise contracting pressure, causing the expanded portions to fold up into corrugations between the forming members or encircling supports, the metal being enabled to flow freely during the forming operation by permitting the forming members to move toward each other free from restraint by external spacing devices, and having their movement governed by the interlocked relation with the tube. The combination of the initial accurate spacing and subsequent freedom of movement serves to accurately predetermine the length of tube defined or marked off for each fold, and to thereafter permit folding up of these predetermined areas into folds with a minimum of constraint. The result is a bellows which may be quickly and economically made, and which has a resultant long life due to the substantially equal capacity to withstand a relatively great number of expansions and contractions.

The invention having been described, what is claimed is:

1. The method of forming a corrugated tubular thermostat which consists in forming a flange on the open end of a tubular blank, assembling a two part head about the flange with an opening therethrough for the introduction of liquid, corrugating the tube blank while supported internally by pressure exerted through the fluid introduced through the opening in the head, and finally sealing the opening in the head.

2. The method of making a corrugated tubular thermostat which consists in mounting heads upon opposite ends of a tubular blank, connecting the blank to a source of fluid pressure through an opening in one of the heads, forming corrugations while supporting the walls of the tube through internal fluid pressure introduced through the

opening in the head, and finally sealing the opening in the head.

3. The method of making a bellows which consists in providing a plain tube with opposite ends hermetically sealed except for an opening through one end, connecting the opening with a source of liquid pressure, assembling a series of divisible plates lengthwise of the tube, each of the plates having an opening corresponding to the exterior diameter of the tube, maintaining the plates rigidly in alignment with the axis of the tube, subjecting the tube to an internal liquid pressure to sustain the walls of the tube against collapse, thereafter subjecting the tube to an endwise contracting pressure while permitting the plates to move lengthwise of the tube, and thereafter sealing the opening in the tube.

4. The method of making a bellows which consists in forming a plain tube with a closed bottom portion, forming a flange on the open end of the tube opposite the bottom portion, assembling a head upon the flanged end of the tube with an opening extending therethrough, mounting a head at the opposite end of the tube with the closed end of the tube received in a recess in the head, and subjecting the tube to internal fluid pressure to distort the closed end of the tube and lock it firmly within the head.

5. The method of forming a series of bellows folds in a tubular blank which includes flanging the open end of the blank, assembling a head on the flange to seal the open end of the blank, the head having an opening therethrough communicating with the interior of the blank, connecting the interior of the blank through the opening in the head with a source of fluid supply, supplying fluid under substantial pressure to the interior of the blank through the opening, forming a series of bellows folds while maintaining the internal fluid pressure, and thereafter disconnecting the formed blank and attached head from the source of fluid supply.

6. The method of forming bellows folds from thin wall tubing which consists in positively locating spaced forming members lengthwise of a tube, expanding the tube to lock the members thereto in the initial spaced relationship, and thereafter causing the tube to expand outwardly into corrugations between the members by the combined forces of internal fluid pressure and axial contracting pressure, while enabling the metal to flow freely during the forming operation by permitting the forming members to move toward each other unrestrained by the spacing means but in their interlocked relation with the forming folds.

7. The method of forming bellows folds in tubing which consists in assembling a series of separable forming members about a tube and in spaced relation lengthwise thereof, positively retaining the members in the initial spaced relation, locking the members to the tube while so maintained, releasing the members to permit movement lengthwise of the tube, and thereafter expanding the tube unrestrained by the spacing means into bellows folds between the members by the action of an internal fluid pressure while permitting the forming members to move toward each other in a manner governed by the contraction of the tube to which the members are locked.

8. The method of making bellows folds in thin wall tubing which consists in assembling the tube within a series of separable forming members fixedly spaced lengthwise of the tube, locking the members to the tube in the spaced lengthwise relationship, and thereafter expanding the tube into circumferential folds between the members by the combined forces of internal fluid pressure and endwise contracting pressure while permitting the members to float unrestrained except for their interlocked relation with the tube during the contraction thereof.

9. The method of forming bellows folds in tubing which consists in applying and sealing a head having a passage therethrough upon the open end of the tube, assembling the tube with the thus connected head within a series of spaced forming members collapsible in an axial direction, connecting the passage in the head with a source of fluid pressure, and forming bellows folds through the combined forces of internal fluid pressure introduced through the passage and endwise contracting force.

10. The method of forming bellows folds in tubing which consists in applying and sealing a head having a passage therethrough upon the open end of the tube, assembling the tube with the thus connected head within a series of spaced forming members collapsible in an axial direction, connecting the passage in the head with a source of fluid pressure, forming bellows folds through the combined forces of internal fluid pressure introduced through the passage and endwise contracting force, and removing the completed bellows with attached head from within the forming members.

11. The method of forming bellows folds in tubing which consists in mounting a permanent head with a passage therethrough on the open end of a tube, assembling the tube with the mounted head within a series of spaced forming members collapsible axially of the tube and with the passage in the head connected to a source of fluid pressure, thereafter expanding the tube into bellows folds between the forming members by the combined forces of internal fluid pressure introduced through the passage and an endwise contracting force, and removing the

bellows with mounted head from within the forming members.

12. The method of forming bellows folds in thin wall tubing comprising the assembly of a series of separable forming plates about the tube in spaced axial relation, introducing members between the plates to insure fixedly holding the plates in spaced parallel relation, expanding the tube between the plates by internal pressure introduced therein, after locking of the plates to the tube through expanding removing the members for insuring the spacing and parallelism to permit freedom of movement of the plates with the tube, due to their interlocked relation therewith and thereafter deepening and narrowing the bulges between the plates through the combined forces of internal fluid pressure and endwise contracting pressure while guiding the plates to move in axial alignment and prevent axial buckling of the tube in process.

13. The method of forming bellows folds which consists in mounting a head on the open end of a tube to provide a projecting annular shoulder, the head having a passage therethrough communicating with the interior of the tube, maintaining the passage in the head sealed through engagement with the shoulder, surrounding the tube with a series of spaced forming members, and thereafter expanding the tube bellows folds between the members by the combined forces of internal fluid pressure and endwise contracting pressure.

14. The method of forming bellows folds in thin wall tubing, which comprises assembling the tube within a series of positively spaced forming members, maintaining the tube at one end in communication with a source of fluid pressure, expanding the tube between the forming members without contraction of the tube, and thereafter deepening and narrowing the expanded portions through maintenance of the internal pressure and application of an endwise contracting pressure to the tube while enabling the metal to flow freely during the forming operation by permitting the forming members to move toward each other unrestrained by the spacing means but in their interlocked relation with the tube.

15. The method of forming bellows folds in thin wall tubing which comprises assembling a tube within a series of axially spaced forming members held against axial movement lengthwise of the tube, expanding the tube between the forming members while so held against axial displacement, completely releasing the members to permit freedom of movement of the members with the tube, and when so released deepening and narrowing the expanded portions in the tube through the combined forces of internal fluid pressure and endwise contracting pressure while enabling the metal to flow freely during the forming operation by permitting the forming members to move toward each other unrestrained by the spacing means but in their interlocked relation with the tube.

16. In the method of forming a flexible bellows from thin walled tubing, the steps of locking a series of forming members to the tube in exact spaced relation by differences in diameter of the tube at and between the several forming members and then forming bellows folds having a substantially equal capacity to withstand a relatively great number of expansions and contractions by folding the metal between said members under the combined action of internal fluid pressure and an axial contracting pressure while enabling the metal to flow freely during the forming operation by permitting the forming members to move toward each other unrestrained except for their interlocked relation with the forming folds.

17. In the method of forming a flexible bellows from thin walled tubing, the steps of locking a series of forming members to the tube in spaced parallel relation by producing differences in diameter of the tube at and between the several forming members through expansion of the tube therebetween and then forming bellows folds having a substantially equal capacity to withstand a relatively great number of expansions and contractions by folding the metal between said members under the combined action of internal fluid pressure and an axial contracting pressure while enabling the metal to flow freely during the forming operation by permitting the forming members to move toward each other unrestrained except for their interlocked relation with the forming folds.

18. In the method of forming a flexible bellows from thin walled tubing, the steps of locking a series of forming members to the tube in spaced relation by differences in diameter of the tube at and between the several forming members and then forming bellows folds having a substantially equal capacity to withstand a relatively great number of expansions and contractions by folding the metal between said members under the combined action of internal fluid pressure and an axial contracting pressure while enabling the metal to flow freely during the forming operation by permitting the forming members to move toward each other, guided with the openings in the members maintained in alignment but otherwise unrestrained except for the interlocked relation of the members with the forming folds.

19. The method of forming bellows folds from thin walled tubing which comprises the employment of spacing means for initially locating forming members in predetermined and spaced relation lengthwise of

the tube, assembling the forming members about a tube in such predetermined and spaced relationship, locking the tube to the initially located forming members by expansion of the tube through internal fluid pressure and thereafter folding the metal between the members by the combined action of internal fluid pressure and an axial contracting force after having freed the members from control of the spacing means to permit movement of the members toward one another in a manner governed entirely by their interlocked relation with the forming folds of the tube.

20. In the method of forming a flexible bellows from thin walled tubing, the steps of locating a series of forming members in predetermined spaced relation about a tube to be formed, locking the tube to the spaced members by expansion of the tube therebetween and forming bellows folds by the combined forces of internal fluid pressure and an axial contracting pressure while allowing said members to float with the tube during contracting unrestrained by the locating means.

21. The method of making bellows which consists in assembling a permanent fitting with a tubular blank, locating the blank within a series of spaced forming members, subjecting the blank to internal fluid pressure to lock the fitting thereto through distortion of the tubular blank in the region of the fitting, expanding the tube into circumferential folds between the forming members by the internal fluid pressure and an endwise contracting pressure, and thereafter removing the formed bellows and attached fitting from the forming members.

22. The method of making a bellows which consists in hermetically sealing a tube with a permanent head having a restricted liquid opening through one end, connecting a source of fluid supply under pressure to the opening, providing the exterior of the tube with a series of encircling supports spaced lengthwise of the tube, exerting an internal fluid pressure to sustain the walls of the tube, and subjecting the tube to an endwise contracting pressure while permitting freedom of movement of the supports lengthwise of the tube and maintaining the internal fluid pressure.

23. The method of making a bellows which consists in forming a plain tube, sealing the tube except for a restricted opening therethrough by the application of a permanent fittting, connecting the opening with a source of fluid pressure, assembling about the tube a series of forming members each having an opening corresponding to the outer diameter of the tube, maintaining the members in alignment, subjecting the tube to an internal fluid pressure to sustain the walls of the tube between the supports, subjecting the tube to an endwise contracting pressure while permitting the members to move lengthwise of the tube in alignment therewith and maintaining the internal fluid pressure during the contracting movement.

24. The method of forming bellows folds which consists in assembling a series of two-part plates in spaced relationship about a tube, locking the two parts of each plate rigidly in assembled position, locating between successive plates and upon opposite sides of the tube spacer members for insuring both accurate spacing and parallelism of the plates, while thus fixedly maintained by the spacer members expanding the tube between the plates through the employment of internal fluid pressure to lock the plates to the tube in initial position, manipulating the spacer members to free the plates and permit unrestrained movement of the plates axially with the tube due to their interlocked relation therewith, and thereafter deepening and narrowing the expanded portions into bellows folds through the combined forces of internal fluid pressure and endwise contracting pressure.

In testimony whereof I have signed my name to this specification.

WALTER B. CLIFFORD.