Nov. 8, 1949 D. E. MORGAN 2,487,257

METHOD OF EXPANDING CONTAINERS BY FREEZING LIQUIDS THEREIN

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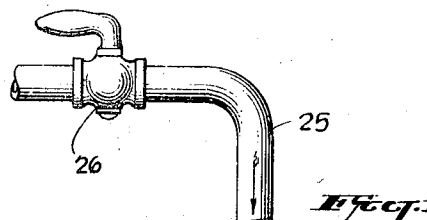


Fig. 1.

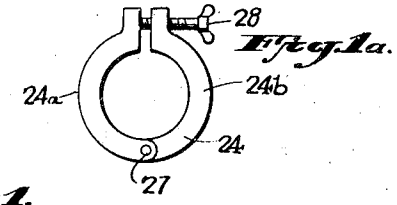
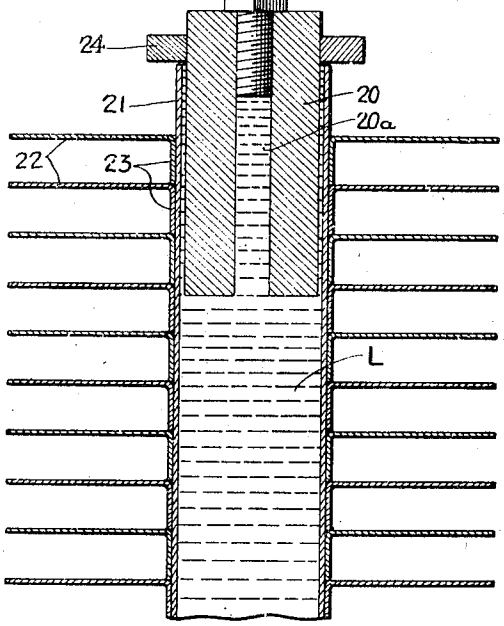


Fig. 1a.

Fig. 2.



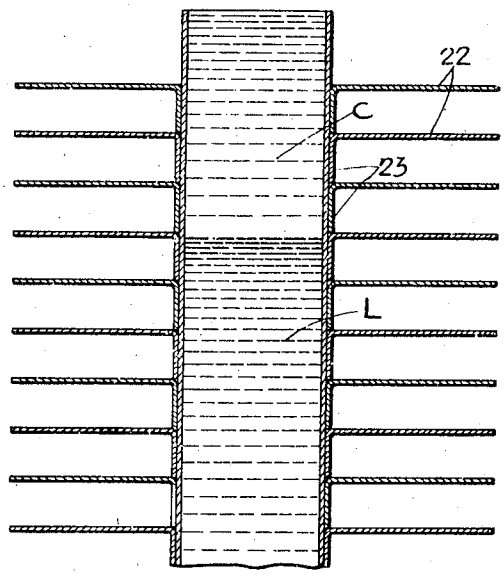


Fig. 3.

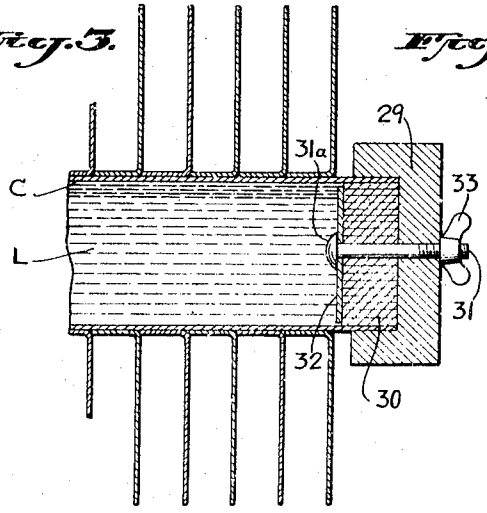
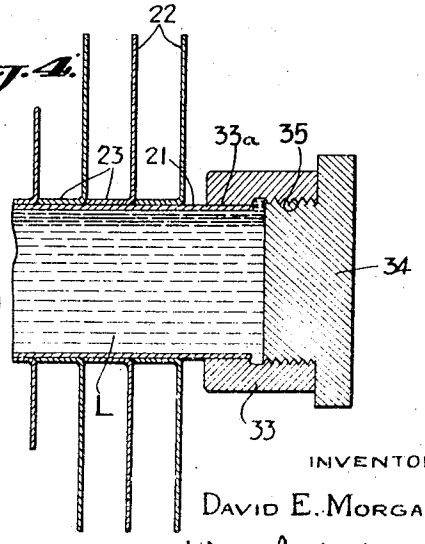


Fig. 4.



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Fig. 5.

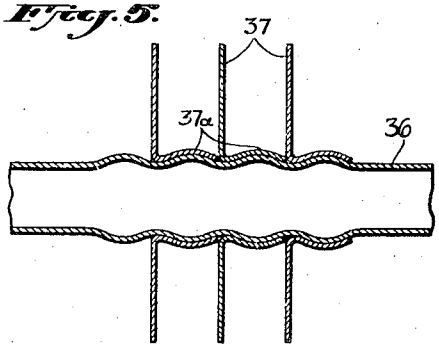


Fig. 6.

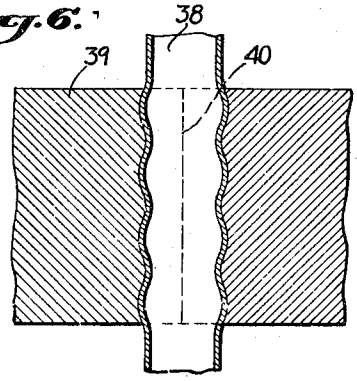


Fig. 7.

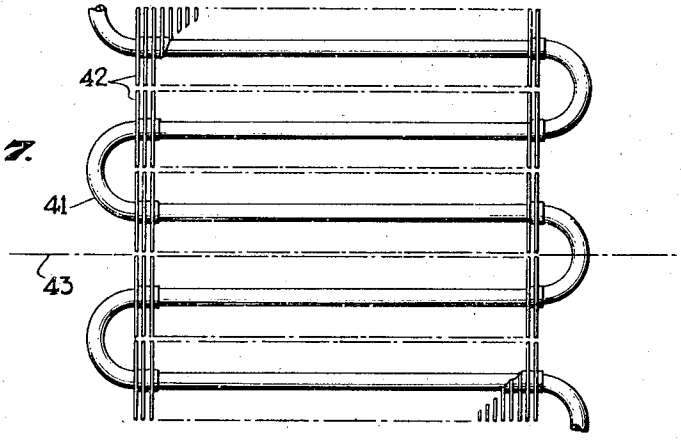


Fig. 8.

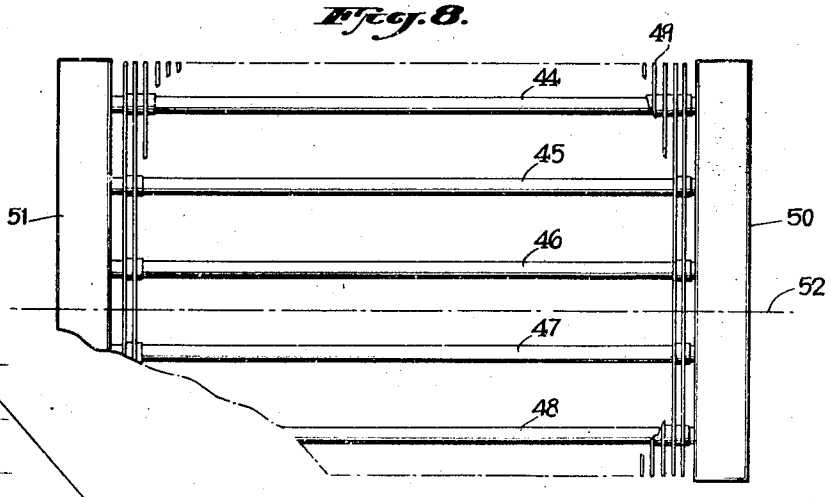
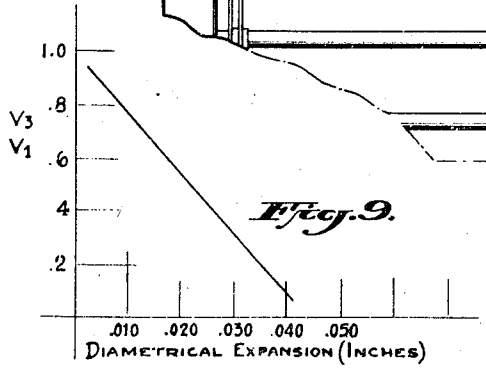


Fig. 9.



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METHOD OF EXPANDING CONTAINERS BY FREEZING LIQUID THEREIN

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Application November 23, 1946, Serial No. 711,994

3 Claims. (Cl. 113—118)

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This invention relates to methods for utilizing the expansion forces which occur when liquids or molten materials solidify in response to a lowering of the temperature thereof, and more particularly to methods for employing said forces to expand or alter the shape of tubular containers or the like.

The above mentioned expansion forces may be employed for a wide variety of industrial purposes in connection with the expanding of containers. For example, in manufacturing finned tubing such as that employed for radiation purposes or otherwise, a problem has arisen in providing adequate methods and apparatus for firmly and permanently securing the fins in place on the tubing in a manner which will insure such uniformly good contact between the fins and the tubing as will make possible the efficient transfer of heat.

This invention constitutes an improvement upon the method and apparatus for expanding containers as set forth in my copending application Serial No. 605,698, filed July 18, 1945, now Patent No. 2,458,189, issued January 4, 1949.

The methods and apparatus heretofore available prior to the invention set forth in said application and that disclosed herein have involved serious difficulties. For example, one method has been to apply the fins one after the other with a forced fit onto the tubing. This has the difficulty of requiring a multitude of successive operations individual to each fin. Also if a succession of the fins are forced along one end of the tube, it becomes increasingly smaller, resulting in lack of a uniform diameter of the tube.

Other methods have involved placing the fins on the tubing and then mechanically expanding same by drawing or projecting a mechanical expanding device through the tubing so that the walls thereof are expanded into contact with the fins. Such operations are expensive, difficult, and generally impossible with respect to tubing which has been bent or substantially curved or assembled in a radiator structure.

The invention set forth in the above identified application, in general, involves confining a liquid within a container and freezing same, the liquid expanding upon solidification, thus expanding the tubing or the container. Means for controlling the quantity of expansible fluid within a container or tubing have been proposed in said application which included the introduction of a rod or some solid object within the container, thereby to govern with accuracy the amount of expansible fluid which may occupy the space remaining therein. By accurately controlling said volume of expansible liquid, the total amount of expansion thereof upon solidification may be controlled with an accuracy heretofore unattained. Such a method and means may be employed with tubes which are bent or substantially curved or which may be of serpentine shape, by the use, for example, of a flexible rod therein. However, the use of the flexible rod may be inconvenient and may be impractical with respect to certain types of curved tubing. This is especially true where the tube diameters are very small and where very small containers of irregular configuration are to be expanded.

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It has also been determined that for certain types of tubing, it is difficult to control expansion because of an uneven distribution of mass from which heat must be removed and a consequent tendency for uneven freezing with the possibility of non-uniform expansion.

According to the present invention, methods and apparatus are provided which will eliminate the above noted difficulties.

Various further and more specific features and advantages of the invention will clearly appear from the detailed description given below taken in connection with the accompanying drawings which form a part of this specification and illustrate, by way of example, preferred arrangements of apparatus for carrying out the invention. The invention consists in such novel combinations of features, method steps and apparatus as may be shown and described in connection with the equipment herein disclosed.

In the drawings:

Figure 1 is a view partly in section and with parts broken away illustrating one form of apparatus employed for carrying out the present invention;

Fig. 1*a* is a detail view of one of the parts which may be used in the assembly of Fig. 1;

Fig. 2 is a view of a portion of the tubing illustrated in Fig. 1 with the filling device removed.

said tubing containing an expansible liquid together with a freeze control liquid;

Fig. 3 is a sectional view with parts broken away of a tube having one type of end closure attached thereto;

Fig. 4 is a sectional view of a tube having a second type of end closure therefor;

Fig. 5 is an enlarged detailed view showing portions of one form of tube structure with surrounding fins secured thereon in accordance with the invention;

Fig. 6 diagrammatically indicates the manner in which tubing may be expanded to form annular corrugations thereon in accordance with the invention;

Fig. 7 illustrates a section of bent or serpentine tubing with fins secured thereon in accordance with the invention;

Fig. 8 illustrates one form of radiator structure which may be made according to the invention; and

Fig. 9 is a graph illustrating certain factors involved in practising the invention.

By means of the present invention, a container may be expanded by a predetermined accurate amount by confining therewithin a primary liquid medium which is expansible upon solidification and also confining therein, in the presence of the primary liquid, a secondary liquid which has the function of assisting in controlling the expansion of the primary liquid. For a desired expansion, a predetermined ratio of the primary and the secondary liquids exists. For example, in securing fins to tubing, a plurality of the fins may be placed along the tubing in a desired spaced relation and then the tubing may be filled with the expansible and the freeze control liquids, and then under controlled conditions the assembly is subjected to a temperature which is low enough to cause freezing or solidifying of at least the primary or expansible liquid. The tubing thus may be expanded into firm and secure contact with the inner edges of all of the fins.

In prior methods and apparatus for expanding containers, such as tubing, the above mentioned uneven distribution of mass which exists in many types of containers may interfere severely with the uniformity of the freezing action and the uniformity of the pressures which result from solidification. This produces uneven exertion of this pressure which may produce bulges and undesirable distortion. In subjecting certain types of large tubes to this freezing action, an appreciable percentage of the uneven expansion effect may be absorbed because of the size thereof. However, with respect to small tubes or small containers it is difficult to overcome these effects of uneven expansion without the novel control method and means herein disclosed.

With respect to the time of completing the novel process herein set forth, it has been found that when employing a solid control member which is inserted into the container in accordance with said application, Serial No. 605,698, a desirable freezing temperature range for many types of containers and tubing, is approximately between 0° F. and −20° F. In the present invention, it has been determined that a considerably lower temperature conveniently may be used in freezing and that desirable results may be obtained thereby. For example, freezing may occur at −40° F. which effects a substantial saving in time of freezing, thus substantially reducing the cost of employing the process and apparatus which accomplishes the invention.

As above mentioned, the novel method comprises, in general, the introduction of an expansible or primary liquid into a container together with the predetermined volume of a secondary or control liquid which is of a different type from the primary one, thereafter subjecting the container to a temperature sufficient to cause solidification of at least the primary liquid, to effect the desired expansion of the container, and thereafter thawing the liquid.

The control liquid may be designated as a secondary liquid medium or as a foreign liquid relative to the primary liquid. In order to achieve the most beneficial results, it has been found desirable and preferable for the control liquid to meet the following specifications: (1) it should have a low freezing point, for example, −40° F. or below; (2) the specific gravity thereof should be different from that of the primary liquid in order to maintain the two liquids separate from one another, as for example water and oil; (3) it should be insoluble in the primary liquid. It may also be desirable that the control liquid: be of low volatility; not react adversely upon the substance which comprises the container or the tubing; and have a different coefficient of expansion relative to the primary liquid.

An example of the control liquid which meets the above requirements is kerosene employed jointly with water, the latter comprising the primary liquid.

In the use of a control fluid or secondary liquid it is important to determine the proper amount of the secondary liquid, that is, the exact volume of control liquid which is to be employed to accomplish a given expansion. Novel means for this purpose are set forth below.

This combination of liquids such as water and kerosene, may be employed for expanding a wide variety of containers for example the expanding of a tube in order to secure fins thereupon, and in order to produce desired configurations such as corrugations.

In order to determine the exact amount of kerosene which should be employed with water for the expansion of tubing, a standard or basic tube size may be employed which, in the example herein set forth, constitutes a 1-foot length of tubing having an outer diameter of 1.125'' with a wall thickness of .035''. The amount of kerosene or the kerosene percentages for control of expansion have been determined to vary substantially directly as the length of the tube. A graphic representation of the proper kerosene percentages is illustrated in Fig. 9. This graphic representation has been derived from the formula:

$$(V_1-V_3)C+V_1=V_2$$

Where

V_1=initial volume of tube
V_2=the final volume of tube
V_3=the volume of kerosene
C=.0855 (expansion factor).

The expansion factor "C" above mentioned represents the percentage which water will expand when solidified. For example, if the primary liquid medium is water, its volume will expand by approximately 8.55% upon passing from the fluid to the solid state, and the coefficient of expansion of ice is 0.0000507 per degree C., which latter factor may also in some cases, have to be

taken into consideration especially if low range freezing temperatures are used.

The above kerosene percentages

$$\left(\frac{V_3}{V_1}\right)$$

have been determined in accordance with the following:

V_1=10.49 cubic inches (based on said standard tube size, i. e., 12" length of tube having outer diameter of 1.125", wall thickness .035")

V_2=11.31 cubic inches for a diametric expansion of .040"

V_3=11.13 cubic inches for a diametric expansion of .030"

V_2=11.00 cubic inches for a diametric expansion of .025"

V_2=10.90 cubic inches for a diametric expansion of .020"

V_2=10.80 cubic inches for a diametric expansion of .015"

V_3=10.70 cubic inches for a diametric expansion of .010"

V_2=10.49 cubic inches for a diametric expansion of .000"

C=.0855

Applying the above values to the formula $(V_1-V_3)C+V_1=V_2$ the following values of

$$V_3 \text{ and } \frac{V_3}{V_1}$$

are obtained:

(1)

For expansion of .040, V_3=.902 cu. in., $\frac{V_3}{V_1}$=.086

(2)

For expansion of .030, V_3=3.01 cu. in., $\frac{V_3}{V_1}$=.287

(3)

For expansion of .025, V_3=4.53 cu. in., $\frac{V_3}{V_1}$=.434

(4)

For expansion of .020, V_3=5.7 cu. in., $\frac{V_3}{V_1}$=.544

(5)

For expansion of .015, V_3=6.87 cu. in., $\frac{V_3}{V_1}$=.656

(6)

For expansion of .010, V_3=8.05 cu. in., $\frac{V_3}{V_1}$=.767

(7)

For expansion of .000, V_3=10.49 cu. in., $\frac{V_3}{V_1}$=1.000

For purposes of simplicity as to the above computations, it has been assumed that the kerosene is at the freezing temperature of the primary liquid at the time it is introduced into the tube.

Referring to the drawings in detail, a novel charging device is indicated in Fig. 1 which is designed automatically to displace a sufficient amount of primary liquid from a given length tube in order to permit a correct amount of secondary liquid to be added to the space remaining when the device is withdrawn. This device constitutes in the form shown a nozzle member **20** having a central bore **20***a* and having an outer diameter which is slightly less than the inner diameter of a tube **21** into which it may be introduced. The tube **21** which is to be expanded has mounted thereupon a plurality of fins **22** which preferably are provided with suitable flanges **23**. The latter act as a means for spacing the fins by a predetermined desired amount.

It is desirable for the outer diameter of the nozzle **20** to be slightly less than said inner diameter in order to permit said primary liquid to flow around said nozzle and tube to the upper lip of the tube **21**, thereby to indicate that the primary liquid has reached a desired level within the tube.

A suitable collar **24** may be mounted upon the nozzle **20** and may be adjustably positioned along the axis thereof in order to govern the extent to which the nozzle may be introduced into the tube.

A suitable conduit **25** may be connected to the nozzle **20** through which said liquid may be fed. The conduit **25** may threadedly engage the bore **20***a* of the nozzle. A valve **26** may be interposed in the conduit **25** to control the flow of liquid therethrough.

As shown in Fig. 1*a*, the collar **24** may consist of two portions **24***a* and **24***b* which are hinged at **27** and which may be urged together, for example, by a threaded butterfly nut **28** which is mounted on a screw engaging both of said portions **24***a* and **24***b*. The outer surface of nozzle **20** may be calibrated, for example, in accordance with the percentages shown graphically above in order to indicate the position of the collar **24** upon the nozzle, thereby controlling the extent to which said nozzle may be introduced into the tube.

The primary liquid may be introduced through the charging device described above until the tube is filled excepting that portion occupied by said nozzle. Thereafter, the nozzle is withdrawn and the remaining unoccupied volume within the tubing may be filled with the secondary liquid such as kerosene.

When the requisite amount of primary liquid has been introduced into the tubing, the valve **26** may be closed and the charging device may be thereafter withdrawn. As this withdrawal occurs, a relatively small amount of liquid which occupies the bore **20***a* and a portion of the conduit **25** flows into the tubing. The size and shape of the charging device may be of such dimensions as to compensate for this slight addition to the amount of primary liquid to avoid inaccuracies in the amount of control liquid to be introduced.

As indicated in Fig. 2, the volume above primary liquid "L" is filled with a secondary liquid "C" preferably up to the upper level of the tubing whereby it is completely filled.

Thereafter the liquid may be confined within the tubing by suitable end closure means such as that indicated in Figs. 3 and 4.

The novel end closure illustrated in Fig. 3 is referred to as an elastic freeze header which comprises a cap **29** which acts in cooperation with a centrally disposed elastic plug **30**. The latter may be held in position upon the cap by means of a central shaft **31** which preferably extends through the plug **30** and through a central bore within the cap **29**.

In order to communicate a thrust to the elastic plug **30** whereby it may be compressed against the inner surface of the cap member **29**, a rigid washer **32**, for example of metal, may be held against the plug **30** by means of a head **31***a* upon the inner extremity of the shaft **31**. The outer extremity of said shaft may be threaded and may be provided with a suitable nut **33** the rotation of which will communicate a thrust to the washer

32 and thus squeeze the plug and expand the sides thereof outwardly. Thus when the elastic freeze header is in position as shown in Fig. 3, the plug 30 may be pressed by means of the nut 33 acting through shaft 31 and washer 32 whereby the sides of plug 30 are distended to urge the sides of the tube 21 against the flange of the cap 29.

The sides of the elastic plug 30 may be distended not only as a result of compression by means of the nut 33, the rod 31 and washer 32, but also by the force of expansion exerted by the primary liquid L and/or of the control liquid "C." There thus is provided an extremely tight fitting end closure which becomes tighter as the forces of expansion increase.

Fig. 4 illustrates a second form of end closure which may be employed comprising a sleeve member 33 having an internal surface 33*a* thereof adapted to be secured to the tubing by, for example, soldering or brazing. A plug 34 may be secured to the sleeve 33, for example, by a suitable threaded engagement as indicated at 35.

With reference to Fig. 5 if the walls of a tube such as shown at 36 are relatively thin and if fins 37 are provided with flanges 37*a* which also are relatively thin, as is usually the case, then the expansion of the tube according to this invention, will result in the formation of slight annular corrugations as shown in said Fig. 5. That is, along circumferential lines of the tubing which are engaged by the surrounding fins per se, the tubing will be restrained somewhat against expansion as compared with the tube portions which are surrounded only by the flanges. Accordingly, a slight outward bulge or corrugation will form beneath each of said flanges, and this bulge will be of a shape such as to tend firmly to lock the fin and its flange in position on the tube. This offers a substantial advantage, particularly where the finned tubing is to be used for radiation purposes and where the temperature of the tube may vary within considerable limits from time to time, thereby causing contraction and expansion difficulties which tend to loosen the fins in the absence of such locking effect. The corrugations also aid in preventing difficulties due to elongation of the finned tubing by reason of thermal expansion when the tubing is used in radiator structures. That is, the corrugations tend to impart a certain degree of longitudinal flexibility, and at the same time reduce thermal expansion longitudinally. Furthermore, the corrugation effect facilitates the firm securing of fins formed of exceptionally thin flexible material. For example, fins of thin aluminum may be applied to copper tubes with a considerable saving as compared with what has been obtainable with prior art structures of equivalent radiation capacity.

Certain of the features of the invention may be employed for the purpose of forming annular corrugations or other desired configurations on tubing which is not to be provided with fins. For example, as shown in Fig. 6, a tube 38, filled with the liquids above set forth and equipped with suitable end closure means such as shown in Figs. 3 and 4, may be inserted within an aperture of a die member 39 which has therein an internal aperture formed with corrugations or other desired configurations so that when the tube is expanded therein, its wall surfaces will be correspondingly formed or shaped. The die, of course, may be formed of parts separable as along a center line 40, to enable removal of the expanded tube.

Certain metal bellows-like shapes or similar devices, may be made in accordance with this embodiment of the invention by first expanding an annealed tube within a suitable die as shown in Fig. 6, then annealing the tube, and again expanding the same within a die having deeper corrugations, and repeating this process until a desired form is achieved.

In prior art mechanical methods, for applying and securing fins as hereinbefore referred to excepting the method set forth in said application, it has been necessary for the tubing to remain substantially straight, at least until after the fins are secured in place. Thereafter, it is substantially impossible to bend the assembly to form loops or turns in the tubing without loosening or displacing the fins.

With the present invention, as shown in Fig. 7, tubing 41 may be bent initially to conform to various desired curved shapes, such as a grid or serpentine shape. The fins 42 then may be slipped onto the desired positions and thereafter firmly secured in place by the freezing and expansion method of this invention. If desired, long grids of radiation structure may be made in the form shown in Fig. 7 and kept in stock. Then these may be cut into sections of any desired heating capacity as needed, as by cutting the tube along a line such as indicated by the broken line 43.

This embodiment of the invention makes it possible to provide finned U-shaped tubes with any desired number of "turns" without resorting to soldered or brazed connections as has heretofore been the necessary practice for such tubes.

As indicated in Fig. 8, a plurality of tubes as at 44—48 inclusive may all be treated as a group, according to this invention, thereby securing the fins 49 thereupon. Said fins may extend continuously from tube to tube. After the tubes have been expanded to secure firmly these fins thereupon, the assembly of tubes may be provided with headers or end enclosures, for example, as shown at 50 and 51, into which the tubes may be brazed or otherwise sealed. Such an assembly may be made with any number of tubes to produce a radiator of desired capacity. If a small radiator is required, the assembly may be cut as for example along a broken line indicated at 52, thereby cutting through the end closures as well as the fins.

While the invention as above described requires a refrigerant to be applied to the exterior of the container or tube, it is also possible to apply the refrigerant internally by methods such as disclosed in the above mentioned application.

Also while the invention has been described with particular reference to tubing, it will be understood that the principles of the invention also are applicable to the expansion of containers of other shapes.

It will be further understood that instead of using water and kerosene as the primary and the control liquids respectively, various other liquids may be used which have desired degrees of expansion of solidification. In the place of kerosene, various other hydrocarbon liquids, mineral or vegetable oils, etc., may be used. Furthermore, the expansion may be accomplished by using chemicals which will react with increased volume to cause expansion of the container. Furthermore, metal alloys may be used which will

expand when cooled, such as in the case of certain alloys of antimony or "type metal." The latter, for example, may be poured into a tube when hot and will expand the tube when it solidifies. Thereafter, the alloy may be remelted in order to remove it from the expanded tube.

Uneven expansion together with the accompanying undesirable distortions and bulges can be entirely eliminated by this invention. Moreover, the speed with which this method may be carried out is considerably in excess of that of prior methods.

While the invention has been described with respect to certain preferred embodiments, it will be understood by those skilled in the art after understanding the invention that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is intended therefore in the appended claims to cover all such changes and modifications.

What is claimed as new and is desired to be secured by Letters Patent is:

1. Method for securing fins in position surrounding a metal tube, which comprises confining within the tube a predetermined volume of a first liquid partially filling the tube, said liquid being capable of expanding upon solidifying, limiting the amount of said liquid by substantially filling the remainder of the space within the tube with a second liquid which is immiscible with the first and which is not subject to a change in state at the temperature of solidification of said first liquid, then while supporting the tube in generally horizontal position whereby each cross-sectional portion thereof is filled partly by the first liquid and partly by the second, subjecting the tube and contents to a temperature causing solidification of said first liquid, the volume of said first liquid being made sufficient to cause upon such solidification permanent expansive deformation of the tube into firm contact with the surrounding fins, and the volume of said second liquid being sufficient to so limit the volume of said first liquid upon solidifying that no rupture of the tube occurs,

2. Method for forming corrugations in the walls of metal tubing which comprises surrounding the tube with means which will tend to retain the tube relatively rigidly against substantial expansion along portions corresponding to the valleys of the desired corrugations, as compared with portions on the tube corresponding to the ridges of the desired corrugations. confining within the tube a predetermined volume of a first liquid partially filling the tube, said liquid being capable of expanding on solidifying, limiting the amount of said liquid by substantially filling the remainder of the space within the tube with a second liquid which is immiscible with the first and is not subject to a change of state at the temperature of solidification of said first liquid, then while supporting the tube in generally horizontal position whereby each cross-sectional portion thereof is partially filled by the first liquid and partially by the second, subjecting the tube and contents to a temperature causing solidification of said first liquid, the volume of said first liquid being made sufficient as compared with that of the second liquid to cause, upon such solidification, the formation of said corrugations, but being so limited by the presence of the second liquid that no rupture of the tube occurs.

3. Method for causing tubing to be permanently expanded to a predetermined degree, which comprises confining within the tube a predetermined volume of a first liquid partially filling the tube, said liquid being capable of expanding upon solidifying, limiting the amount of said liquid by substantially filling the remainder of the space within the tube with a second liquid which is immiscible with the first and which is not subject to a change in state at the temperature of solidification of said first liquid, then while supporting the tube in generally horizontal position whereby each cross-sectional portion thereof is filled partly by the first liquid and partly by the second, subjecting the tube and contents to a temperature causing solidification of said first liquid, the relative volumes of said liquids being such as to cause upon such solidification the said permanent predetermined degree of expansion of the tube, but without rupture of same.

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