April 29, 1941. B. L. QUARNSTROM ET AL 2,240,019

METHOD OF MAKING AND COOLING TUBES

Filed Oct. 21, 1938 2 Sheets-Sheet 1

Fig. 1A.

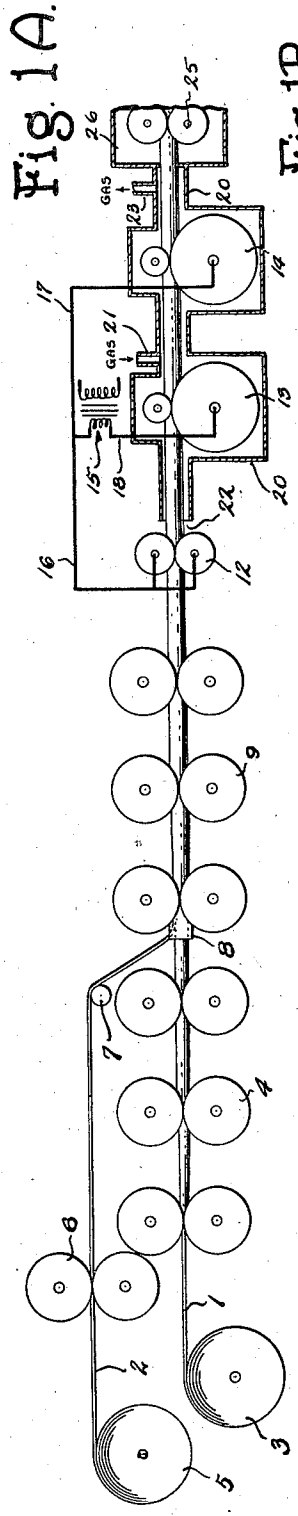


Fig. 1B.

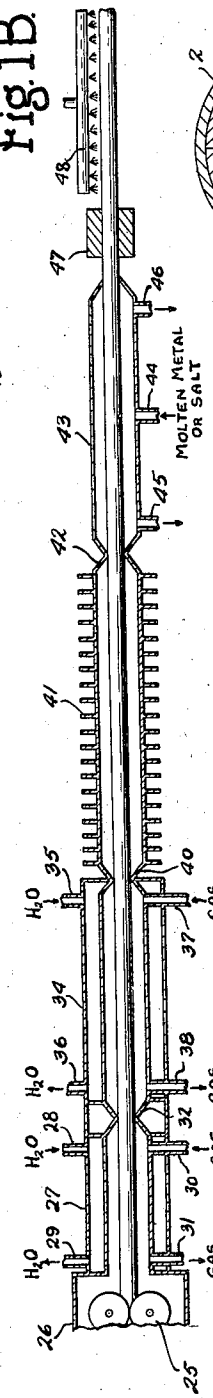


Fig. 6.

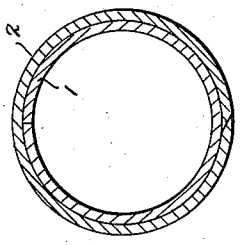


Fig. 2.

INVENTORS
Bert L. Quarnstrom
Raymond H. Hobrock
BY Barnes, Kisselle, Laughlin & Risch
ATTORNEYS

April 29, 1941. B. L. QUARNSTROM ET AL 2,240,019

METHOD OF MAKING AND COOLING TUBES

Filed Oct. 21, 1938 2 Sheets-Sheet 2

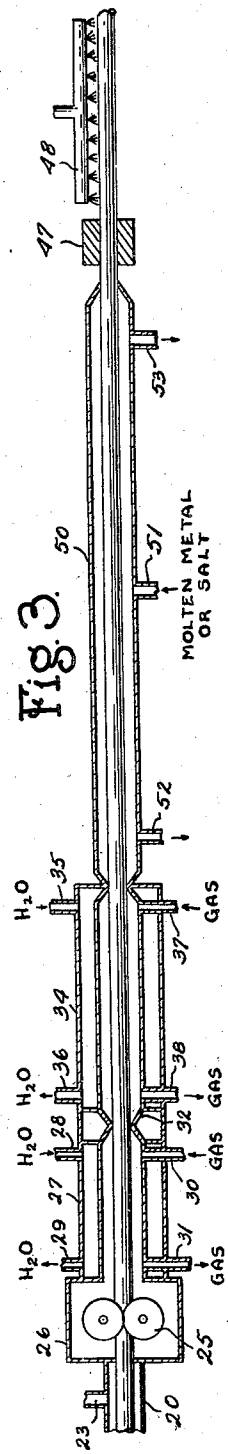


Fig. 3.

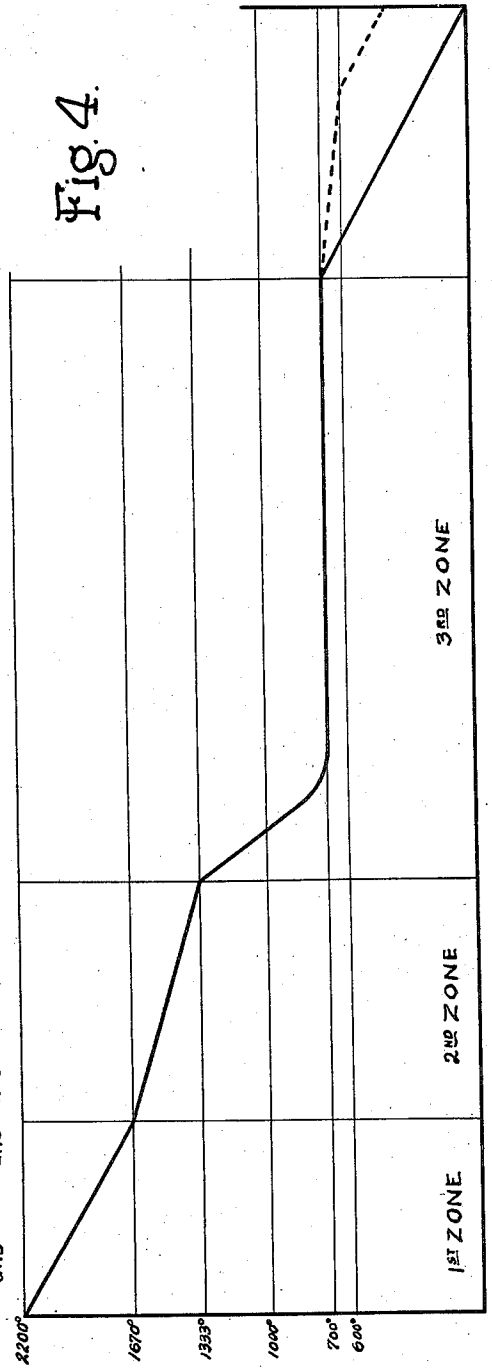


Fig. 4.

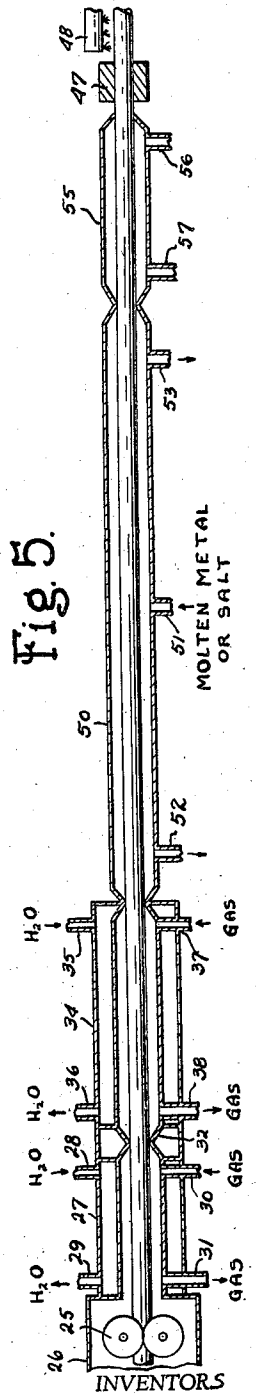


Fig. 5.

INVENTORS
Bert L. Quarnstrom
Raymond H. Hobrock
BY
Barnes, Kisselle, Laughlin & Raisch
ATTORNEYS

Patented Apr. 29, 1941

2,240,019

UNITED STATES PATENT OFFICE

2,240,019

METHOD OF MAKING AND COOLING TUBES

Bert L. Quarnstrom and Raymond H. Hobrock, Detroit, Mich., assignors to Bundy Tubing Company, Detroit, Mich., a corporation of Michigan

Application October 21, 1938, Serial No. 236,364

4 Claims. (Cl. 148—21.5)

This invention relates to the making of tube, and it has to do particularly with the making of tube fashioned from strip steel stock and sealed with a high melting point sealing metal such as copper, cuprous alloys or other so-called hard solder.

The invention is directed particularly to the making of such tube where the tube is fashioned from strip steel stock and is moved longitudinally, during which time the tube is subjected to a heat treatment to cause the sealing metal to melt, which, upon solidification incident to cooling, unites the seams or other overlapping or juxtapositioned parts of the steel stock, and plies where the tube is formed with two or more plies. The invention is particularly advantageous where the tube moves at a relatively great speed, although the invention is applicable to the making of tube where the tube moves at lower speeds. To state with clearness what is meant by relatively great speed of movement, it is pointed out, by way of example, that such a speed is in the vicinity of 100 feet per minute and may be as great as, or greater, than about 150 feet per minute. This is an example only, but serves to point out the invention with definiteness.

It will be appreciated that it is usually preferred to have small size tubing, which is used in automobiles for gasoline lines, oil lines, hydraulic brake lines or the like, and tubing used in condensers or evaporators for refrigeration, or other heat exchange devices, in a relatively ductile condition. This is desirous for a number of reasons and also such tube can be easily shaped or handled. Where such a tube is made with a relatively high rate of longitudinal movement, and is elevated to a high temperature, a cooler for cooling the tube at such a slow rate as to obtain requisite ductility would have to be so long as to be impracticable. On the other hand, if the cooler is shortened to a practicable length, and the steel is cooled too rapidly, the steel of the finished tube will be undesirably hard and brittle.

It is the aim of this invention to provide an improved arrangement for cooling tube made from strip steel stock and which, in its making, is subjected to a high temperature and which moves at a relatively high rate of speed, wherein the cooling action is so organized and zoned that the length of the cooler may be reduced to a practicable length, while at the same time the metal is given the desired ductile characteristic. As a matter of fact, the characteristic of the metal may be variably controlled; but in order to exemplify the invention, it will be described primarily with reference to production of relatively ductile tube. To this end, the cooler is so arranged that successive sections of the tube are cooled in different zones or steps and at different rates. Throughout some temperature ranges, rapid cooling may take place with no deleterious effect, and in such temperature ranges the tube is relatively rapidly cooled. Throughout other temperature ranges where rapid cooling results in hardness or brittleness, the tube is cooled less rapidly. The cooler is so organized that the successive cooling zones or steps act upon the continuously moving tube, with successive sections of the tube moving respectively through the different zones.

The invention is admirably adapted for use with a tube making apparatus which employs electrical resistance for the heat treatment of the tube; that is to say, electric current is passed through successive sections of the tube for heating it, and with this arrangement, the high speed of 100 or 150 feet per minute may be obtained.

The invention is exemplified in the accompanying drawings wherein

Fig. 1A is a diagrammatic illustration of a tube mill and heating means for the tube.

Fig. 1B is an illustration, of a diagrammatic nature, showing the cooling apparatus.

Fig. 2 depicts a temperature curve, showing the cooling of the tube in the several zones of the cooling structure shown in Fig. 1B.

Fig. 3 is a view showing a modified form of cooling apparatus.

Fig. 4 shows a temperature curve of the cooling structure shown in Fig. 3.

Fig. 5 is a view of a still further modified form of cooling apparatus.

Fig. 6 is a cross sectional view of one form of tube which may be made.

A strip of steel stock 1, forms the inner ply of the finished tube as shown in Fig. 6, and a strip of stock 2 forms the outer ply. The strip 1 may be drawn from a supply reel 3 and moved through a plurality of forming rolls of a tube mill generally illustrated at 4 and fashioned into tubular form as shown in Fig. 6. In the form of tube shown the edges of the strip 1 are arranged in a butt seam. The strip 2 may be drawn from a supply reel 5 and may be passed between rolls 6 for beveling the edges of the strip. The strip may then be passed over a guide roll 7 and through a guide die 8, and then the tubular inner ply and strip 2 are passed through a plurality of rolls of a tube mill generally illustrated at 9,

which fashion the strip 2 into tubular form around the inner ply, the edges coming together in a scarfed seam as shown in Fig. 6. This exemplifies one way of making a tube which may be treated in accordance with the present invention, and tube mills of this nature are known to those versed in the art and need not be further described in detail. Tube mills are also known for fashioning tube from a single strip having either a single ply or double ply.

The tube thus formed is subjected to heat treatment to melt a sealing metal which, upon solidification, unites the plies and the seams. This sealing metal may be supplied in the form of a coating on one or both of the strips. The strip 1 or the strip 2, or both, may be coated or plated on one or both sides with the sealing metal. Upon the heating of the tube above the sealing metal melting temperature, the sealing metal is rendered molten, and upon solidification seals the tube by uniting the overlapping and juxtapositioned parts. Some of the rollers of the tube mill may be driven for the purpose of propelling the strip and tube with longitudinal movement.

The tube may be heated by electrical resistance in a manner illustrated in Fig. 1A wherein a pair of electrodes 12 and electrodes 13 and 14 engage the tube. A transformer for alternating current is generally illustrated at 15 and the outside electrodes 12 and 14 are connected to one side of the secondary by leads 16 and 17, while the intermediate electrode 13 is connected to the other side of the secondary by a lead 18. With this arrangement there is no potential across electrodes 12 and 14. Accordingly, current flows through successive sections of the tube between electrodes 12 and 13 and between electrodes 13 and 14.

With this arrangement it is feasible to bring the tube up to the desired temperature between electrodes 12 and 13, and to maintain the temperature between electrodes 13 and 14. This, however, is claimed in application Serial Number 229,015, filed September 8, 1938.

Where desires or conditions dictate, the tube may be maintained in a non-oxidizing or reducing environment while in its heated condition. To this end, the electrodes and tube may be enclosed by a housing structure indicated at 20 and a non-oxidizing or reducing gas may be passed into the housing through an inlet 21. The gases may burn off at the entering end 22 and at a burn-off pipe 23.

The structure shown in Fig. 1B is to be placed in alignment with the structure shown in Fig. 1A so that the tube moves directly from the tube mill and heating apparatus of Fig. 1A into the cooling structure shown in Fig. 1B. The housing 20 may connect the two structures as indicated, and a pair of rolls, which may be for guiding or propelling the tube, is illustrated at 25 and may be disposed in a housing 26 connected to the housing 20.

It is thought best to first describe in a general manner, the several cooling zones, and then to follow the general description with a more detailed explanation. The first zone is diagrammatically depicted as a water-jacketed structure having an outer water-jacket structure 27 with the water entering the pipe 28 and leaving through pipe 29. A cooling gas may be circulated in direct contact with the tube, the gas entering through a pipe 30 and passing out through pipe 31. The first cooling zone extends substantially from the rollers 27 or the housing containing the rollers to the dividing partitions 32. The second cooling zone is also shown as a water jacketed arrangement having an outer water jacket 34 with the water being circulated therethrough and entering at 35 and leaving at 36. A cooling gas may also be circulated in direct contact with the tube by entering the cooling zone at 37 and passing out at 38.

The second cooling zone is shown terminating at the partition arrangement 40. The first section of the third cooling zone is illustrated as an air cooled arrangement having heat radiating fins 41 and terminating at the partitioning arrangement 42. This illustration is not intended to limit these zones to the precise type of cooling arrangement shown, since the first section of the third cooling zone may be water jacketed or may have gas introduced therein, and the first and second zones may likewise embody different cooling arrangements.

The second section of the third cooling zone is shown in the form of a liquid cooling or quenching arrangement, and comprises a tubular housing 43 surrounding the tube. Molten metal such as a molten lead or a molten lead and tin alloy or other similar metal, or molten salt, is preferably moved in a circuitous path by suitable pumping means, and is pumped into the housing 43 through the pipe 44 and is discharged at opposite ends thereof through pipes 45 and 46. Any suitable pumping means may be used. Where it is desired to have the finished tube coated with lead or tin, or an alloy of lead and tin, or other metal, such molten metal may be used in the second section of the third zone. Where no coating is desired molten salt may be employed. As the tube passes out of the second section of the third zone, it may be passed through a wiping device 47, wiping off the excess coating metal received in the chamber 43 or for wiping off the salt, and then the tube may be finally cooled by introducing it to the atmosphere or by means of a water spray 48. A hot water spray (not shown) may also be used for removing the last vestiges of salt.

Where steel strip is used for forming the tube and the strip is sealed by copper, it is preferred that the temperature to which the tube is subjected is considerably in excess of copper melting temperature. This tempertaure may be in the vicinity of 2200° F., as illustrated in Fig. 2. Ordinarily, with low carbon steel, the carbon exists as a constituent known as cementite usually surrounded by grains of iron called ferrite. If the steel, however, is elevated to a temperature in excess of the upper critical temperature, say 1670° F., the carbon dissolves in the crystal form of gamma iron to form a constituent known as austenite. The austenite constituent maintains at temperatures above the upper critical, but upon cooling through the transformation range, namely, from the upper critical, as for example 1670° F. to 1330° F., the austenite transforms to a type of dispersion of cementite in the alpha iron.

Since there is no tendency for the austenite to transform at temperatures above the critical temperature, the tube is cooled rapidly from its highest temperature down to the upper critical, and there is no deleterious effect. This is the function of the first cooling zone and the zone is to be designed to so cool the tube in the least possible time.

The second cooling zone is designed to cool

the tube through the transformation temperature range at a relatively reduced rate of speed in order to allow sufficient time for the transformation of the austenite to the desired phases or structures in the alpha iron, such as the so-called cementite. Unless the austenite is given an opportunity to transform, the resultant metal may be hard and brittle. Therefore, in order to produce a ductile tube, the second zone is arranged to cool the metal through the transformation range with such slowness as to facilitate the desired ductility. However, the second zone may be arranged to cool the tube to obtain any desired characteristics in the metal.

Moreover, it is desired that the cooling rate through the second zone be relatively constant. The tube enters the second zone at a higher temperature than it leaves the second zone and, accordingly, there would normally be a greater temperature gradient and a resultant more rapid cooling in the early stages of the second zone than in the later stages of the second zone. To meet this situation the cooling gases may be caused to enter the second cooling zone near the outlet end. These gases are heated in the action of cooling the tube near the outlet end and then move toward the inlet end of the second zone with the result that the temperature gradient throughout the second zone may be made relatively uniform.

After the tube is passed through the second zone, the ferrous metal is in the form known as alpha iron, and the austenite has been transformed so as to approach a condition of equilibrium in the alpha iron. However, the solubility of carbon in alpha iron is greater at higher temperatures than at lower temperatures. Accordingly, if the alpha iron is cooled too rapidly in the third zone, and particularly in the first section of the third zone, a condition of super-saturation will result at room temperature. Under these conditions a phenomenon known as aging may be detected in an increase in the hardness of the metal, a decrease of ductility, an increase in ultimate strength and an increase in brittleness. Thus aging of this kind results in a steady decline in a number of the desirable features of the metal in the course of time.

The cooling in the third zone is arranged to overcome this objection. One way is to avoid the supersaturation. In Fig. 2, the first section of the third zone cools the metal relatively slowly down to about 1000° F., and thus great supersaturation can be avoided, and such small supersaturation and the resulting aging which might occur will be entirely dependent upon the small change in solubility between 1000° F. and room temperature; but from 1000° F. downwardly there is not so much of a change. Another way is to set up an aging action, as will be later discussed with reference to Figs. 3 and 4.

The second section of the third zone may be arranged to cool the tube more rapidly but still preferably less rapid than the final cooling. Where the tube is to be coated with metal, a molten metal such as one of the metals above mentioned may be circulated through the second section of the third zone, and this is preferably arranged to lower the temperature of the tube to about 600° F. In any event, the tube is cooled to a temperature low enough to prevent rapid oxidation or discoloration of the metal when exposed to the atmosphere. If the tube is not to be coated, then a molten salt may be circulated through the second section of the third zone. Subsequently, the tube may be passed to the atmosphere and excess molten metal or salt may be removed by wiping means, and then the tube finally cooled either by the atmosphere or by a water spray.

In Fig. 3 a modified arrangement is shown. The first zone performs the same function as the first zone shown in Fig. 1B namely, a rapid cooling of the metal down to the upper critical temperature. The second zone is also designed to perform the same function as the second zone shown in Fig. 1B, namely, that of slowly cooling the metal through the transformation temperature range. The third zone, as distinguished from a zone for preventing supersaturation, is designed to first rapidly cool the alpha iron to set up an unstable condition, and then to allow a period of time for aging at high temperatures, during which time there is a precipitation or coagulation of excess carbon with little or no age hardening at room temperature. This third zone is shown in the form of a jacket 50 into which molten metal or salt may be introduced at 51 and removed at 52 and 53, the molten metal or salt being circulated through the third zone chamber. This cools the tube rapidly as shown by the corresponding temperature curve in Fig. 4, and then maintains this relatively high temperature for a period of time, as indicated, to allow for the aging action at high temperatures.

The aging action at relatively high temperature is, of course, much more rapid than at room temperature. As illustrated, this third zone quickly lowers the temperature to about 700° F. and then this is maintained for a period of time whereupon the tube is passed out of the cooling apparatus into the wiper and water spray as above described. In Fig. 3, the reference characters applied to the first and second zones and to the final wiper and water spray are the same as those used in the form shown in Fig. 1B. This third zone may cool the tube down to any desired temperature for the aging period; for example, the aging temperature may be from about 700° F. to 900° F.

In Fig. 5 a still further modified arrangement is shown wherein the first, second and third cooling zones correspond to the cooling zones shown in Fig. 3, and the same reference characters are applied. However, as illustrated by the curve in Fig. 4, the Fig. 3 form may pass the tube into the atmosphere at too high a temperature, resulting in rapid discoloration or oxidation and also resulting in some supersaturation at room temperature. In Fig. 5 an additional cooling section 55 may be employed, the same being shown in the form of a quenching unit, into which a suitable cooling liquid may be introduced and circulated through pipes 56 and 57. This liquid may also be a molten liquid or salt but maintained at a temperature lower than the metal or salt in the third zone. The temperature curve for this form throughout the first, second and third zones is shown in Fig. 4, and is the same as the temperature curve for the form shown in Fig. 3. However, the temperature curve for the final or fourth zone of cooling is shown by the dotted lines in Fig. 4 wherein it will be noted that the temperature of the tube is dropped to about 600° F. or lower more slowly, and then is finally passed to the atmosphere.

Accordingly, it will be observed that the cooling of the tube from a point above the upper critical temperature to a temperature at which the tube may be passed into the atmosphere is divided into

zones. Throughout such temperature ranges where rapid cooling produces no deleterious results the tube is cooled rapidly; throughout other temperature ranges where rapid cooling would produce deleterious effects, the tube is cooled relatively slowly. In one form, however, namely, the forms shown in Figs. 3 and 5, the tube is cooled rapidly from a point below the lower critical, which results in the setting up of a supersaturated condition, and then the tube is maintained at a relatively high temperature for a period of time resulting in a high temperature aging. The net result is an over-all reduction of the length of the cooling apparatus. Also, the characteristics of the metal of the finished product can be determined and controlled. For example, if a very hard brittle structure is desired, the second zone may be arranged so as to maintain some transitional structure such as martensite in the metal when it is cooled. On the other hand, the third zone may be arranged to act as a tempering or drawing zone in which the structure produced by the relatively rapid cooling in the second zone is tempered or modified so that the desired characteristics may be obtained in the finished product.

We claim:

1. In the method of making a ductile tube from strip carbon steel stock wherein the strip is fashioned into tube while the strip and the tube formed therefrom move longitudinally at a rate of speed in the vicinity of 100 feet per minute and upwards and wherein the entire tube is heated to a temperature above the transformation temperature of the steel and above 2000° F. for the uniting of juxtapositioned parts of the strip stock, the steps of cooling the moving tube which comprises, cooling the tube relatively rapidly throughout the temperature range above substantially the upper transformation temperature, cooling the tube throughout the range between substantially the upper and lower transformation temperatures relatively slowly and at such a rate and through a time period that the austenite transforms substantially into a type of dispersion of cementite in alpha iron, then cooling the tube substantially from the lower transformation temperature to a temperature where the tube may be passed to the atmosphere and through a time period such that when the tube is passed to the atmosphere there is substantially no objectionable supersaturation of cementite in alpha iron all with continuous movement of the tube.

2. In the method of making a ductile tube from strip carbon steel stock wherein the strip is fashioned into tube while the strip and the tube formed therefrom move longitudinally at a rate of speed in the vicinity of 100 feet per second and upwards and wherein the entire tube is heated to a temperature of about 2000° F. for the uniting of juxtapositioned parts of the strip stock, the steps of cooling the moving tube which comprises, cooling the tube relatively rapidly throughout the temperature range above substantially the upper transformation temperature, cooling the tube throughout the range between substantially the upper and lower transformation temperatures relatively slowly and at such a rate and through a time period that the austenite transforms substantially into a type of dispersion of cementite in alpha iron, and then cooling the tube substantially from the lower transformation temperature to a temperature where the tube may be passed to the atmosphere at a rate so that the decreasing solubility of carbon in the cooling iron does not exceed substantially the rate of precipitation and coagulation of the carbon in the alpha iron to prevent a super-saturation condition all with continuous movement of the tube.

3. In the method of making a ductile tube from strip carbon steel stock wherein the strip is fashioned into tube while the strip and the tube formed therefrom move longitudinally at a rate of speed in the vicinity of 100 feet per second and upwards and wherein the entire tube is heated to a temperature of about 2200° F. for the uniting of juxtapositioned parts of the strip stock, the steps of cooling the moving tube which comprises cooling the tube relatively rapidly down to substantially the upper transformation temperature, cooling the tube throughout the range between substantially the upper and lower transformation temperatures relatively slowly and at such a rate and through a time period that the austenite substantially transforms into a type of dispersion of cementite in alpha iron, cooling the tube from substantially the lower transformation temperature down to about 1000° F. through a time period and rate as to substantially prevent setting up a condition of supersaturation of the dispersion of cementite in alpha iron, and then relatively rapidly further cooling the tube for passage to the atmosphere.

4. In the method of making a ductile tube from strip carbon steel stock wherein the strip is fashioned into tube while the strip and the tube formed therefrom move longitudinally at a rate of speed in the vicinity of 100 feet per minute and upwards and wherein the entire tube is heated to a temperature substantially above the transformation temperature of the steel for the uniting of juxtapositioned parts of the steel for the uniting of juxtapositioned parts of the strip stock, the steps of cooling the moving tube which comprises cooling the tube relatively rapidly down to substantially the upper transformation temperature, cooling the tube throughout the range between substantially the upper and lower transformation temperatures relatively slowly and at such a rate and through a time period that the austenite substantially transforms into a type of dispersion of cementite in alpha iron, relatively rapidly cooling the tube substantially from the lower transformation temperature to a temperature of about 700° F. or above, maintaining said last named temperature for a period of time for effecting a high temperature aging to substantially eliminate supersaturation of cementite in alpha iron and then further relatively rapidly cooling the tube from the said maintained temperature all with continuous movement of the tube.

BERT L. QUARNSTROM.
RAYMOND H. HOBROCK.