

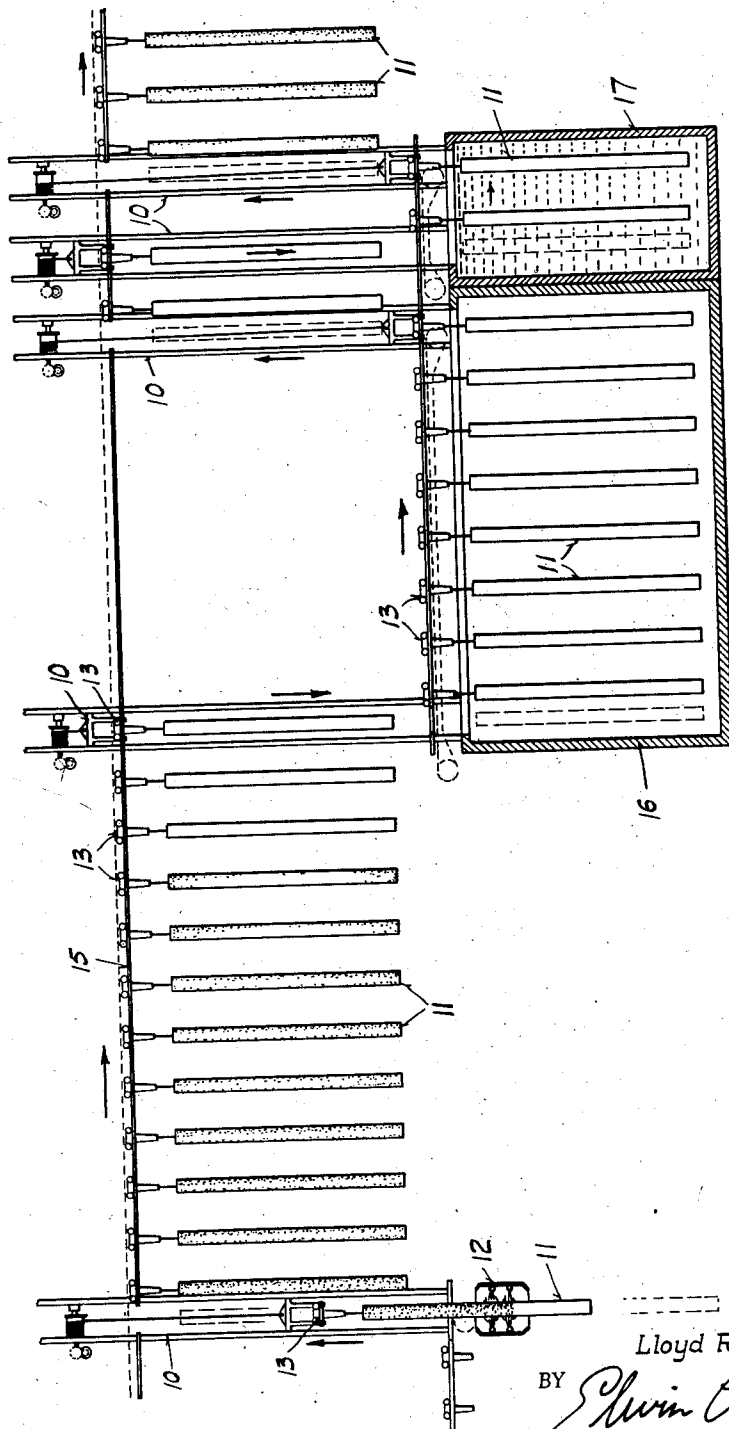
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ENAMELED METAL ARTICLES AND METHOD OF PRODUCING THEM

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ENAMELED METAL ARTICLES AND METHOD OF PRODUCING THEM

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The invention relates generally to metal articles of manufacture coated with vitreous enamel and methods of producing them.

The object of the invention is to provide for heat treating the metal of an enameled article contemporaneously with the process of enameling or afterwards to improve the mechanical and physical properties of the metal.

A further object of the invention is to provide an enameled article of manufacture having desired mechanical and physical properties which have been produced by controlled heat treatment.

For a fuller understanding of the nature and objects of the invention, reference may be had to the following detailed description taken in conjunction with the accompanying drawing, which is:

A diagrammatic view of apparatus suitable for enameling and heat treating articles in accordance with the teachings of my invention.

Any suitable apparatus may be utilized in carrying out the enameling and heat treating processes.

The apparatus for handling pipe shown in the drawing comprises elevators 10 for moving the pipe 11 along vertical lines to carry it through an enamel spraying device 12 or some other treating chamber. As illustrated, the pipe is suspended from a car 13 carried by an elevator 10 in such manner that it may be readily transferred from the elevator to a track 15, or vice versa, and conveyed to the furnace 16 and a quenching bath 17.

The article of manufacture shown in the drawing is a steel pipe 11. Many other articles, such as fence posts, I-beams, columns, angle irons, panels, etc., may be enameled and heat treated in the manner to be described hereinafter. A pipe 11 was selected for the illustration because, while demonstrating the utility of the invention, pipes were among the articles heat treated during the process of enameling.

Enamel may be applied to numerous articles of manufacture for many different purposes. In the case of pipe, it may be enameled on the inside for the purpose of

increasing its capacity to resist corrosion and erosion, and on the outside to protect it from corrosion when exposed to the elements or from corrosion and erosion when buried in the soil as when used in pipe lines.

A coating of corrosion and erosion resistant material, such as vitreous enamel, is desirable since enameled pipe may be made with thinner walls than pipe used heretofore, provided, of course, that the thin walls can be made adequate in strength. A thin walled structure is desirable since smaller amounts of metal are required in the manufacture of the articles, the handling and transportation of the articles would be easier and less costly, and for other reasons.

In the manufacture of pipe and many other articles which are subjected to stresses while in use, the greatest efficiency in the use of the steel may be obtained by heat treating it to improve the desired mechanical and physical properties. In the case of steel pipe, the metal may be heat treated to increase its tensile strength.

It has been found that steel articles composed of steel having certain characteristics can be coated with enamel and heat treated to give them the desired properties of lightness, strength, and resistance to corrosion and erosion. The steel used in accordance with the invention is characterized in that high strength and toughness are developed in the steel by quenching from temperatures which are high enough to produce a fusion of the constituents of the enamel.

The invention may be applied in enameling steels having widely varying percentages of carbon, and alloys such as vanadium steel, cobalt steel, chrome vanadium steel, manganese steel, etc. The details of the quenching process will be changed to meet the characteristics of the alloy.

The composition of the steels and alloys will depend on the purposes for which the enameled article is to be utilized. Steels having a widely varying percentage of carbon when treated in accordance with my invention have been found satisfactory for pressure pipe lines.

In enameling in accordance with my inven-

tion, while no changes will be made in the essential steps of the process, the details of the heat treatment such as temperatures and rates of cooling may be varied to suit the different characteristics of the metals and the enamels.

In order to obtain the desired constitutional and structural change in the metal enameled or being enameled, it is heated to a temperature approximating or slightly above the upper critical temperature and cooled at a predetermined controlled rate to the desired transformation temperature or below.

In order to illustrate the changes that are made in the heat treatment of steels of different compositions, reference will be made to .40%-.50% carbon steels and the changing of their structure to sorbite to give the desired physical and mechanical properties.

Since .40% carbon steel has a higher upper critical temperature than steel having a carbon content of .50%, the former is heated to a higher temperature during heat treatment than is the latter. In heating the .40% carbon steel to the higher temperature, care should be taken not to heat it to a temperature at which the enamel may be over-burned. Both steels are cooled at the same rate and to the same band of temperatures to produce sorbite.

In quenching these steels to produce sorbite, they are cooled to their respective transformation temperatures at a rate that is fast enough to maintain the carbon in solution and prevent the formation of ferrite and perlite down to the temperatures at which the production of the sorbitic structure takes place. In this particular instance, when the metal is quenched to 1100° F. or to a temperature within a band below 1100° F., the solid solution changes to sorbite. Ordinarily, the quenching bath temperatures which I employ with .40%-.50% carbon steel produce sorbite. The temperature range is sufficiently high that if any troostite is produced it will change to sorbite. In order to produce troostite, the metal should be quenched to a lower band of temperatures or the steel composition changed.

I have described only the changes made in my process in order to produce sorbite from steels having different percentages of carbon. In practicing my process, if it is desired to transform the steel to a structure other than sorbite, then the quenching operation may be varied. Assuming it is desired to produce martensite, then the article will be quenched to the band of temperatures at which martensite is formed, which is lower than the band of temperatures required for producing sorbite and is well known to metallurgists.

The enamel employed will depend on the conditions to which the article enameled is to be subjected. In order to resist soil corrosion, a harder enamel will be selected

than if the article is to be utilized above the ground.

There are many enamel mixtures known to the enameling art. These enamel mixtures do not have the same smelting or fusing temperatures, nor do they reach the same degree of hardness at the same temperatures. Therefore, enamels are selected which will give the characteristics desired in the final product.

I shall describe in detail the application of my process to the enameling of pipe fabricated from steel having a carbon content of from about .40%-.50%. Anyone skilled in the art having this information may, by changing the enamel mixture and the temperature to which the metal is heated and cooled and the rate of cooling, readily work out the details for enameling steels having widely varying carbon contents and alloys to produce the desired metal structure in the enameled article.

In the manufacture of enameled pipe for underground use, I have employed steels containing from .40%-.50% carbon. While this is a much higher carbon content than contained in the steels ordinarily used in the enameling art, I have obtained excellent results. The steels ordinarily used for receiving a coat of enamel do not contain more than about .03% carbon. I have also successfully employed my process in enameling steels having less than .40% and more than .50% carbon.

The enameling composition or mixture preferably employed is one which will fuse at or near the upper critical temperature of the steel or alloy from which the article is fabricated.

Many different enamel mixtures may be employed successfully. The selection of the enamel will depend upon the results desired. I have obtained good results by using the following formula:

	Parts by weight
Silicon dioxide-----	10
Felspar-----	30
Borax-----	41
Soda ash-----	6
Fluorspar-----	6
Sodium nitrate-----	5
Manganese dioxide-----	1.5
Cobalt oxide-----	.5

The enamel is applied to the pipe throughout its full length in a thin even layer as a mixture of powder suspended in a vehicle such as water. This may be accomplished in any suitable manner by using a single spray and moving the pipe spirally or by means of a circumferential spray or booth 12.

After the enamel has been properly applied and dried, the pipe is transferred to the furnace 16 where it is heated to a temperature of about 1575° F. to fuse the enamel. This

temperature is well above the upper critical temperature of .40%-.50% carbon steel which varies from 1490° F.-1440° F. on heating.

The pipe may be heated as desired. I have found an electric furnace 16 large enough to receive the pipe to be satisfactory because it gives an evenly distributed heat and enables me to heat the whole pipe to the same temperature at once.

After the enamel has been fused, the pipe is transferred to the quenching bath 17. The pipe is lowered endwise into the quenching bath at a rate which will maintain a substantially uniform temperature gradient between the quenched and unquenched portions to cool the pipe at a substantially constant rate. Since the pipe has been heated to a temperature of about 1575° F., which is well above the upper critical temperature on cooling, it may be easily transferred by some suitable method from the furnace to the quenching bath before any internal structural change has occurred.

Many different kinds of baths may be employed in enameling, for example a salt bath, an oil bath, a lead bath, a forced draught of air, etc. I have found a bath of sodium nitrate suitable for my purposes in enameling .40%-.50% carbon steel. It can be maintained in a fused condition or a liquid state at the temperature to which steel containing .40%-.50% carbon should be quenched in order to produce the results desired.

In quenching or heat treating steel containing .40%-.50% carbon, the bath is maintained at a temperature of about 850° F. and the pipe is lowered into the bath at a rate of about sixty feet per minute. In this manner, the temperature of the pipe is reduced at the proper rate to suppress the structural changes which occur on slow cooling and cause a transformation to sorbite and troostite at a temperature around 1100° F. or below. The elements controlling the heat treatment in this instance are the composition of the steel and the structure which gives the desired mechanical properties, in this instance sorbite.

The composition of the steel controls the temperature on heating and the quenching bath temperature, while the structure of the metal controls the rate of cooling and the quenching bath temperature. As will be noted, the quenching bath temperature is controlled by the composition of the metal and the structure of the metal. In selecting the quenching bath temperature, more attention is given to varying it to meet the requirements of the metal structure than to conform to the requirements of the composition of the metal.

Where the article to be quenched is pipe, it has been found preferable to lower it into the quenching medium endwise to prevent

warping of the pipe. The pipe is completely submerged in the quenching operation.

Where the pipe is enameled on one side only, a more severe quench may be employed without injury to the enamel as by directing water or steam against the unenameled surface of the pipe to rapidly lower its temperature. The air or water or other quenching medium may be directed uniformly against the surface of the article in carrying out the quenching step.

The enamel is cooled quickly, but it remains sufficiently elastic at the sorbite transformation temperature to conform without crazing to any change in volume that may occur in the metal. When the quenching is at the proper rate a hard, smooth, and well finished enamel will result.

After the quenching operation in a fused salt, the pipe or article of manufacture is cooled at a slower rate to reduce the temperature to atmospheric temperatures and thus complete the final step in the process.

When .40%-.50% carbon steel is heat treated in the manner described, a metal structure which is commonly identified as sorbite is produced. This is a desirable structural condition and gives a high tensile strength and the most suitable combination of tensile strength and ductility for pipe that can be obtained from such a carbon steel by heat treatment.

Other steel compositions may require lower quenching bath temperatures to produce the most desirable structural condition. The bath temperature employed will depend on the product desired.

In quenching pipe fabricated from .40% to .50% carbon steel, the sodium nitrate bath is maintained at a temperature of about 850° F. This bath temperature is for the purpose of cooling a particular steel to or through the sorbite transformation temperature at a rate which is fast enough to prevent the formation of perlite or ferrite.

To meet other conditions, the sodium nitrate bath temperature has been varied from about 600° to 1000° F. If the freezing point of the sodium nitrate bath is so high that the bath cannot be kept liquid, additions of other salts may be made to lower its freezing point, or some other suitable bath such as one of those referred to hereinbefore may be selected.

The process disclosed may be employed where several coats of enamel are applied to the article in which case the article is preferably quenched only after the fusing down of the last coat of enamel.

In applying the process to articles that have been previously enameled, the enameled metal article is first heated to a temperature above the critical temperature of the metal and then quenched by submerging in a bath of sodium nitrate or other suitable quenching

medium. In practicing the invention in this manner, an enamel should be selected which will not over-burn at the critical temperature of the steel. In this case, the process of heat treatment does not form part of the enameling process but is a special treatment given to the article for the purpose of improving the mechanical and physical properties of the metal.

The term "quenching" as employed in relation to this invention is intended to mean a forced cooling from a temperature above the upper critical temperature on heating to a temperature to or below the temperature at which the desired structural condition is produced and at a rate which will insure the desired structural transformation of the metal.

These temperatures and structural transformations are well known in the art of metallurgy. Thus a steel of an "air hardening" composition would be "quenched" at a lower rate than the .40%-.50% carbon steel described herein in detail.

The term "heat treatment" in its modified forms, as employed in relation to this invention, is intended to include the complete treatment in which the article is first heated to a temperature above the upper critical temperature of the metal on heating and then cooled at a controlled rate through a definite range of temperature as by quenching.

The benefits derived from enameling and heat treating, in accordance with my process, may be best illustrated by giving an example of the increased strength obtained. Innumerable tests have been made and pages of test results might be given, but it is thought that it will suffice to give a short table which is a generalization of the results obtained from longitudinal test specimens taken from pipe forty feet long, fabricated from plate of .45% carbon steel, one-eighth inch thick.

Longitudinal test specimens 2' long

	Yield point	Tensile strength	Percent elongation
Enameled and not quenched	50000-55000	80000-90000	20%-30%
Enameled and quenched	75000-85000	110000-125000	18%-24%

When the elastic limit of the steel has been raised by heat treating, the metal is capable of absorbing more energy before deformation than it was before it was heat treated. Therefore when employing a predetermined gauge of metal, a stronger support for the enamel is provided by heat treating the metal to raise the elastic limit.

The enamel produced in practicing this process is very hard and when supported by a metal which has a high elastic limit it will not crack as a result of the blows and stresses to which it is subjected in ordinary use. The supporting of the enamel so that it is not

cracked in use greatly prolongs the life of the enameled article.

This application is a continuation in part of application Serial No. 411,996, filed December 5, 1929, covering Improvements in enameled metal articles and the method of producing the same.

While the invention has been specifically applied to the treatment and manufacture of enamel pipe, it is applicable to the treatment and manufacture of other enameled articles which are made from metal responsive to such heat treatment and may also be employed in various enameling processes.

I claim:

1. In the manufacture of vitreous enameled metal articles, the step which consists in submerging the enamel coated article in a quenching medium of fused sodium nitrate maintained at a temperature of 600-900° F. when the article is at substantially the fusing down temperature of the enamel.

2. The method of treating a steel article which comprises applying vitreous enameling material to one side of the article, heating the article as an entirety to the temperature required to fuse down the enamel thereon, and then applying fluid quenching medium to contact with the uncoated side of the article and over its entire extent to uniformly and rapidly cool the article and vitreous enamel coating thereon, the rate of cooling and the lower temperature being such as to impart to the steel increased tensile strength.

3. In the manufacture of thin walled high tensile strength steel pipe having a vitreous enamel protective coating thereon, the steps of applying enameling material to the exterior surface of the pipe, heating the pipe and enamel material to a temperature above the upper critical temperature of the steel and at which the enameling material will be caused to fuse down, submerging the pipe and fused down coating thereon while in a vertical position into a quenching bath of fused sodium nitrate maintained at a temperature ranging from 600 to 900° F., and thereafter more slowly cooling the pipe and coating.

4. In the manufacture of thin walled high tensile strength steel pipe having a vitreous enamel protective coating thereon, the steps of applying enameling material to the exterior surface of the pipe, heating the pipe and material to a temperature above the upper critical temperature of the steel and at which the enameling material will be caused to fuse down, submerging the pipe and fused down coating thereon while in a vertical position into a quenching bath maintained at a temperature ranging from 600 to 900° F., and thereafter more slowly cooling the pipe and coating.

5. The method of making a thin walled high tensile strength steel pipe having a coat-

ing of vitreous enamel thereon, the steps comprising applying enamel material thereto, heating the coated pipe to a temperature above the upper critical temperature of the metal and at which the enamel material will be caused to fuse down, and then subjecting both the inside and outside surfaces of the pipe simultaneously to an application of a fluid quenching medium to thereby quench the heated pipe and its fused coating to a temperature below the lower critical temperature of the metal.

6. A method of treating a steel article having a vitreous enamel coating thereon which comprises heating the article to above the upper critical temperature of the metal, thereafter quenching the same by applying a cooling medium uniformly to the surface of said article in amount sufficient to rapidly cool the same and to cause a substantial increase in tensile strength of the metal and to cause the coating to resume its vitreous characteristic with such property at least unimpaired as a result of the treatment.

7. The method of treating a carbon steel article having an enameled coating thereon which comprises heating the article to above the upper critical temperature of the metal, and thereafter quenching said article by applying a cooling medium uniformly to the surface thereof in amount sufficient to rapidly cool the article to a predetermined temperature within such limits as to cause a substantial increase in tensile strength of the metal without adversely affecting the coating thereon.

8. The method of manufacturing vitreous enameled steel articles which comprises applying enamel coating to the surface of said article, heating the same to the fusing down temperature of the enamel and to above the upper critical temperature of the metal, and thereafter quenching said article by applying cooling medium uniformly to the surface thereof in amount sufficient to rapidly cool the article and to cause a substantial increase in tensile strength of the metal without adversely affecting the coating thereon.

9. The method of treating ferrous metal articles having a vitreous enamel coating and in which the metal responds desirably to heat treatment, the steps comprising heating the coated article to above the upper critical temperature of the metal, and then quenching the entire article by direct contact with a fluid cooling medium to rapidly lower the temperature thereof to a point below its lower critical temperature, to thereby produce a vitreous enameled metal article, the rate of cooling and the lower temperature being such as to impart to the metal increased tensile strength.

10. The method of treating articles composed of ferrous metal which desirably responds to heat treatment, the steps compris-

ing applying vitreous enamel material to the surface of the article, heating the article and the applied material to a temperature which is above the upper critical temperature of the metal and sufficiently high to fuse down the applied enamel material, then quenching the coated article by direct contact with a fluid cooling medium to rapidly lower its temperature to approximately 800° F., and thereafter cooling the article less rapidly out of contact with the said cooling medium to produce a vitreous enameled metal article, the rate of cooling from the upper critical temperature down to approximately 800° F. being such as to impart to the metal increased tensile strength.

11. In the manufacture of ferrous metal articles having a vitreous enamel coating thereon and in which the metal desirably responds to heat treatment, the steps of applying enamel coating material to the article, heating the article with the unfused enamel coating material thereon to a temperature above the upper critical temperature of the metal and at which the enamel coating material will be caused to fuse down, and thereafter quenching the entire article and its coating by direct contact on all sides with a fluid quenching medium to rapidly reduce the temperature of the article and fused-down coating simultaneously to below the lower critical temperature of the metal, the rate of cooling and the lower temperature being such as to impart to the metal increased tensile strength.

12. The vitreous enameled steel article produced by the method of claim 8, the steel of which has high tensile strength.

13. A method of treating steel articles having a coating of vitreous enamel thereon which comprises heating said enameled article to above the upper critical temperature of the steel, and thereafter quenching the same in a fluid medium maintained at a temperature ranging from 600° to 900° F., the said medium and the rate of cooling thereby being such as to impart increased tensile strength to the steel without injury to the enamel.

14. A vitreous enamel steel pipe section produced by the method of claim 8, the steel of the section having high tensile strength.

15. The method of treating a metal article having a vitreous enamel coating which comprises heating the article to a temperature above the upper critical temperature of the metal on heating, and then applying a sufficient amount of a cooling medium to rapidly cool the metal to a predetermined transformation temperature to change the metal structure and increase the tensile strength of the metal while maintaining the vitreous characteristics of the enamel coating.

16. A pipe comprising, in combination, a tubular steel member, the steel being heat

treated to produce a sorbitic structure which has high tensile strength, and a coating of vitreous enamel bonded to the tubular member.

- 5 17. The method of producing a heat treated pipe coated with a vitreous enamel which comprises fabricating a tubular steel member, fusing a coating of vitreous enamel on the tubular member, said tubular member
10 being heated to a temperature above the critical temperature of the steel on heating during the fusing operation, and quenching the tubular member coated with the fused enamel to a predetermined band of temperatures in which
15 steel is transformed to a structure having known characteristics at a rate which is fast enough to maintain the carbon in solution until said band of temperatures is reached, thereby utilizing the heat absorbed by the
20 pipe during the fusing of the enamel to effect a heat treating of the metal to produce a steel having the desired structure and a vitreous enamel which is hard and glossy.

18. The method of producing a heat treated pipe coated with a vitreous enamel which comprises fabricating a tubular member, applying a coating of enamel on the tubular member, fusing the enamel, said tubular member being heated during the fusing operation to a temperature above the critical temperature of the metal on heating, and quenching the tubular member coated with the fused enamel to a predetermined band of temperatures at which metal is transformed to a metallic structure known as sorbite, the quenching being at a rate which is fast enough to maintain the carbon in the steel in solution until said band of temperatures is reached, thereby utilizing the heat absorbed by the
40 pipe during the fusing of the enamel in the heat treating of the pipe to produce a steel having the desired sorbitic structure which has high tensile strength and a vitreous enamel which is hard and well finished.

- 45 19. The method of producing a heat treated pipe coated with a vitreous enamel which comprises fabricating a tubular member, fus-

ing a coating of enamel on the tubular member, the tubular member being heated to a temperature above the critical temperature on heating, and quenching the tubular member coated with the fused enamel in a bath of sodium nitrate to a predetermined band of temperatures at which metal is transformed into a structure known as sorbite, said quenching being at a rate which is fast enough to maintain the carbon in the steel in solution until said band of temperatures is reached, thereby utilizing the heat absorbed by the pipe during the fusing of the enamel in the heat treating of the pipe to produce a steel of sorbitic structure which has a higher elastic limit than the unquenched metal and a vitreous enamel which is hard and durable and which will not crack when the article is subjected to stresses that do not carry it beyond the elastic limit of the metal.

20. The method of producing a heat treated pipe coated with a vitreous enamel which comprises fabricating a tubular steel member, applying and fusing a coating of enamel on the tubular member by heating it to a temperature approximating 1575° F., the temperature being predetermined to assure that the metal is heated to a temperature above the upper critical temperature of the steel on heating, and quenching the tubular member coated with the fused enamel in a bath of sodium nitrate maintained at a temperature of about 850° F. to reduce the temperature of the tubular member and fused enamel to a band of temperatures around 1100° F. at which metal is transformed to a structure known as sorbite, the quenching being at a rate which is fast enough to maintain the carbon in solution and prevent the formation of other metal structures until the predetermined band of temperatures is reached, thereby utilizing the heat absorbed by the pipe during the fusing of the enamel in the heat treating of the pipe to produce a steel of sorbitic structure and a vitreous enamel which is hard and durable.

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