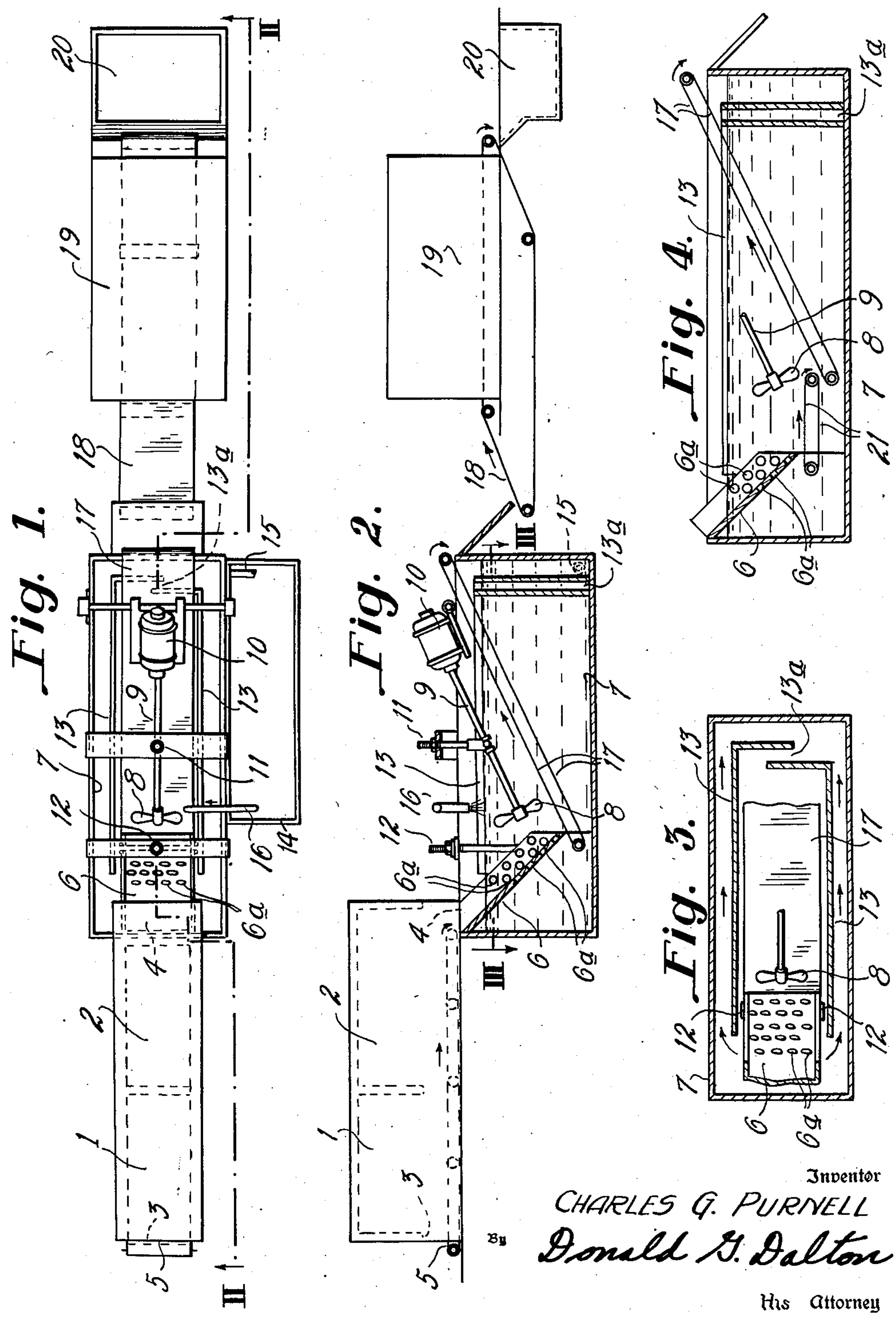
Nov. 18, 1952 C. G. PURNELL 2,618,284

HEAT-TREATMENT OF HARDENABLE STEEL

Original Filed July 18, 1940 2 SHEETS--SHEET 1



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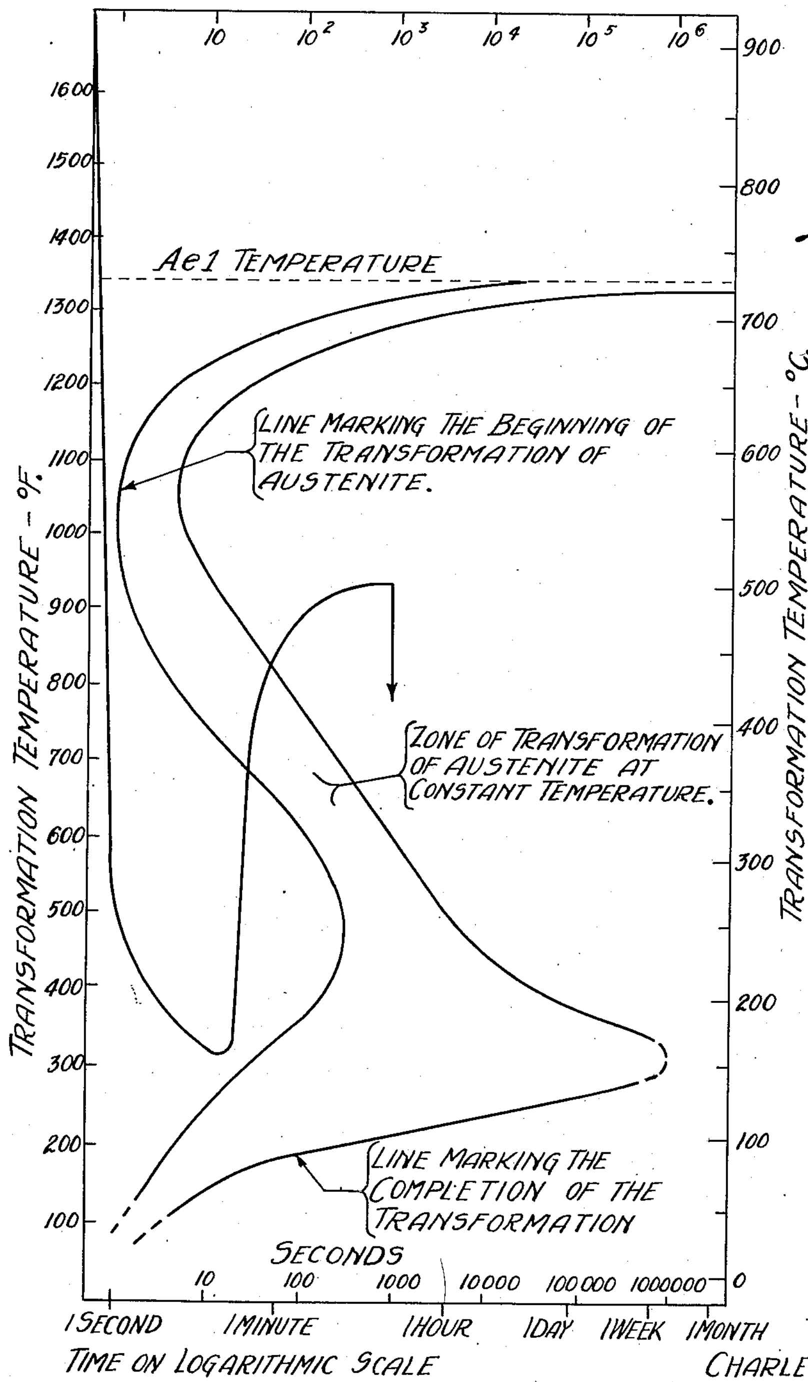
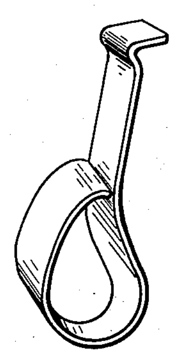


Fig. 5.

Fig. 6.



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HEAT-TREATMENT OF HARDENABLE STEEL

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Continuation of application Serial No. 478,535, March 9, 1943, which is a division of application Serial No. 346,224, July 18, 1940, now Patent No. 2,322,777, dated June 29, 1943. This application November 22, 1946, Serial No. 711,514

2 Claims. (Cl. 134—154)

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This invention relates to the hardening heat treatment of hardenable steel, and is a division of my Patent No. 2,322,777, dated June 29, 1943; and is a continuation of my copending application Serial No. 478,535, filed March 9, 1943.

Of the prior art methods, the one most widely used is to heat the steel above its critical temperature so that its microscopic structure transforms to austenite, it then being quenched at a rate at least equaling its critical cooling rate to a temperature causing its austenite to transform to martensite and then tempered as required to develop the physical properties desired. This method is objectionable in that it is difficult or impossible to quench certain steel shapes at a rate as fast as the critical cooling rate of the steel to sufficiently low temperature by prior art methods of quenching, the danger of quenching cracks is always present and the hardened steel is lacking in toughness and ductility.

A relatively recent method is to heat the steel to transform its structure to austenite and to then quench the steel at a rate at least equaling its critical cooling rate to a temperature causing its austenite to directly transform to the structure providing the physical properties desired, the temperature of the steel being held substantially constant during the austenitic transformation. This method eliminates many of the objectionable features of the method discussed in the preceding paragraph but is subject to certain limitations. Thus, the method is limited in its application to steel in relatively small sections, while cost prevents its use in some instances since the necessary quenching bath is expensive to maintain and the time required for the isothermal transformation may be extensive.

With the foregoing in mind, the primary object of the present invention was to improve on these prior art hardening heat treatments of hardenable steel to the end of developing a means for adjusting the physical properties of such steel without involving the objections of the more common prior art method or the limitations of the more recently developed method. The invention that will now be described successfully attains this object.

According to the invention, hardenable steel is first heated to a temperature above its critical temperature or, in other words, it is heated so that its structure transforms wholly to austenite. As in all heat treatments, this heating should be done as uniformly as possible while the maximum temperature and time factors depend largely on

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the grain structure it is desired to impart the steel.

The steel is then quenched at a rate at least equaling, and preferably exceeding, its critical cooling rate to a temperature materially below that causing its austenite to transform to the structure providing the physical properties desired. However, the steel should not be cooled to a temperature causing its austenite to transform to martensite at the rate the steel is cooling.

It is to be understood that if the quenched steel is allowed to remain at its quenched temperature sufficiently long, its austenite will ultimately transform completely to martensite or some other structure than the ultimate structure providing the exact physical properties desired. However, before any austenitic transformation, the steel is reheated to a temperature causing its austenite to transform to the structure providing the physical properties desired, the steel being held, preferably constant, at this temperature until transformation of its austenite is complete.

Since the treatment is a hardening one, the temperature where the austenitic transformation is effected is other than causes austenite transformation to coarse pearlite, and since martensite is neither tough nor ductile, the temperature is other than causes austenite transformation to martensite. This involves all the advantages of the prior art method of effecting isothermal austenite transformation but is not subject to its limitations, the quenching of the steel to a temperature materially lower than that where austenite transforms to the structure providing the desired properties conditioning the austenite in some manner so that it transforms directly to this structure much more rapidly than is possible when the steel is placed in a quenching bath maintained at the isothermal transformation temperature. Also it is possible to use water brine or light oil as a quenching medium in conjunction with an ordinary reheating furnace, the practice being economical in this respect.

In the case of steel having thick and thin sections, the quenching to a lower temperature than the austenite transformation temperature producing the ultimate structure desired, removed heat most rapidly from the thin section, and since during the reheating heat is put back into this thin section most rapidly, an equalizing effect is obtained, the thicker section cooling more slowly but reheating more slowly. By keeping the quenching temperature above that causing the production of martensite, quenching cracks cannot develop, it being understood that it is preferable to quench the steel to a temperature closely approaching but not reaching that causing quenching cracks. In any event, the quenching temperature should always be materially below the temperature at which the steel is quickly reheated so that its austenite may transform to the ultimate structure desired.

It is to be understood that when the steel has a physical shape providing both relatively large and small masses, that the invention cannot be simultaneously applied to both masses. That is to say, if the principles of the invention are applied to the large mass, martensite may not be avoidable in the small mass during the quench; and if they are applied to the small mass, the large mass may not be adequately quenched so as to produce the desirable acceleration in the austenite transformation rate. In instances where the invention is applied to the large mass, the small mass may be quenched and tempered in the prior art manner, the tempering occurring during the time the austenite of the large mass is transforming in the desired manner.

The accompanying drawings illustrate heat treating apparatus that has been developed to carry out the method that has been described, the various figures being as follows:

Figure 1, a plan;

Figure 2, an elevation in section on the line II—II in Figure 1;

Figure 3, a horizontal section on the line III—III in Figure 2;

Figure 4, a modification of Figure 2;

Figure 5, a chart graphically showing an example of the invention; and

Figure 6, the article treated as shown by Figure 5.

More specifically, these drawings show a heating furnace having a heating chamber 1 and a soaking or temperature adjusting chamber 2, it being in this furnace that the steel is rendered fully austenitic in as even a manner as is possible. This furnace is of the continuous type having an entrance 3 and an exit 4, with a conveyor 5 for continuously conveying steel articles through it. The furnace should be equipped with an adequate temperature controlling system.

A declining chute 6 leads from the exit 4 into a tank 7 for containing the quenching liquid. This liquid may be brine, water or a light oil; that is to say, an oil of low viscosity. The best quenching effect has been found to be obtained by a petroleum oil having a Saybolt viscosity of 100–115 seconds at 100° F., a flash point of from 310–330° F., a pour test of approximately 40 at 0° F. and a fire point of from 350–360° F.

The chute 6 has a perforate portion 6ª below the normal liquid level in the tank 7 and a propeller 8 is positioned opposite this perforate portion to force the quenching liquid through its holes. This propeller is mounted on a drive shaft 9 powered by a motor 10 that is mounted so it can tilt, the angularity of the propeller and its height being adjustable by a mounting 11 which raises or lowers the drive shaft 9. Furthermore, the mounting 11 and the motor 10 are arranged so that they can be slid back and forth over the top of the tank 7 so that the propeller 8 can be spaced any distance desired from the perforate portion 6ª of the chute 6.

The motor 10 is extremely powerful and the propeller 8 is large and of relatively heavy pitch, the arrangement being such that the propeller can move the quenching liquid with substantially the same force that it would be moved by the

propeller of a 30 foot motor boat capable of driving this boat at least 30 miles an hour. In other words, the propeller 8 is capable of moving the liquid in the tank 7 at terrific velocity and with extreme force and to give agitation other than direct impingement.

As the steel articles move from the exit 4 down the chute 6 and particularly down the perforate portion 6ª of the chute, the quenching action occurs. Since this must exceed the critical cooling rate of the steel and since no appreciable amount of martensite should be produced during the quenching, it is necessary to vary the cooling action, and this is done by adjusting the spacing of the propeller 8 from the perforate portion 6ª and the angularity of this propeller, as well as the propeller speed, the motor 10 being a variable speed motor or geared head motor to obtain the propeller speed and desired adjustment. The rate at which the articles fall down the declining chute 6 also may be adjusted, this being done by adjusting the angularity of the chute, it being hinged at its top and provided at its bottom with adjustable supports 12 for this purpose. In all cases a very violent quenching action giving uniform wiping and wetting is necessary so that in all instances the steel will be uniformly quenched at a rate exceeding or at least equaling its critical cooling rate.

A further feature is the provision of baffles 13 forming a channel extending longitudinally of the propeller 8 and on the outside of which the quenching liquid reversely passes after it has once been driven through the holes of the perforate portion 6ª of the chute 6. A liquid cooler 14 receives the liquid from the tank 7 by way of an exit 15 positioned in the end of the tank opposite the chute so as to receive the quenching liquid traveling outside the baffles 13, the cooled liquid leaving the cooler 14 and entering the tank 7 by an entrance 16 directly behind the propeller 8. The cooler 14 may be any of the conventional types but must, of course, have sufficient capacity to keep the liquid sufficiently cool to properly perform its quenching function. Since the propeller 8 moves such a terrific volume of liquid it is impossible for the exit 15 to handle all the flow outside of the baffles 13, the latter, therefore, being open, as at 13ª so that the propeller action driving the liquid from the channel bounded by these baffles 13 will not result in emptying this channel or driving the liquid over the tank top.

A continuous conveyor 17 having a loading portion beneath the chute 6 catches the articles dropping from the end of the chute and quickly carries them continuously from the tank, this conveyor having an unloading portion outside the tank for dropping them on the receiving end of the conveyor 18 of a continuous reheating furnace 19. In this fashion the quenched steel is quickly transferred to the reheating furnace 19, the latter being operated at a temperature causing the temperature of the steel to rise to that where its austenite quickly transforms directly to the structure providing the physical properties desired. The furnace 19 need not be made unduly long since the transformation of the austenite proceeds extremely rapidly after the quenching phase of the method. The steel leaving the furnace 19 drops into a cooler 20.

The modification shown by Figure 4 is mainly featured by the use of a short conveyor 21 between the chute 6 and the conveyor 17, this prolonging the quenching period to allow time for proper cooling of sections which might be so heavy that they could not be adequately cooled otherwise. Normally this modification is not needed, the extreme quenching action obtained by the violent driving of the quenching liquid around the steel articles and through the holes of the perforate portion 6a being adequate in most instances.

Before concluding the description of this apparatus, attention is called to the fact that one of the things which retards the quenching of steel is scale on the steel's surface. Due to the tumbling action of the articles falling down the chute 6, a large amount of the scale is dislodged, it falling to the bottom of the tank 7. To aid in this action the atmosphere of the furnace having the chambers 1 and 2 may consist of a suitable gas producing a more easily dislodged scale, such as an oxidizing atmosphere. In the actual operation of apparatus similar to that disclosed herein, the hardened steel articles leaving the furnace 19 are very nearly scale free, this being obviously an advantage in connection with further processing as well as indicating that quenching of the articles was not retarded by scale on their surfaces during much of the time they were in the quenching liquid.

Since the critical cooling rate of steel, its austenite transformation temperature, etc. vary according to the chemical composition of the steel and other factors, the use of specific temperature and time factors have been avoided in this specification. However, the chart graphically shows a specific example of the invention as it has been commercially applied.

Figure 5 represents the cooling and heating curve for hardening fine-grain open-hearth plain-carbon steel of from .90 to 1.00% carbon content in accordance with the principles of the present invention. The articles treated are rail anchor springs such as illustrated by Figure 6, the section being 1¼ inch x $\frac{3}{32}$ of an inch and the microscopic structure produced being finely dispersed carbide in alpha iron with a hardness of Rockwell C45. In most instances, quenching to temperatures of from 250 to 450° F. are best, the steel being immediately reheated to higher temperatures.

In addition to the already described advantages, connected with the use of the disclosed apparatus, there are others, equally inherent and of equal importance. Thus, the large amount of scale dislodged by the tumbling of the articles, down the chute 6, is to a large degree picked up and held in suspension by the violent agitation of the quench medium and dashed against the articles so as to break more scale from them and, of great importance, so as to eliminate surface vapor from them which would prevent the drastic quenching action disclosed by preventing their direct contact with the quench. Any light objects may be substituted for the scale providing they can be picked up by the quench and turned into projectiles which hit the articles tumbling down the chute.

Furthermore, the violence of the quench flow is so great as to actually lift the articles, tumbling down the chute, as the quench flow is deflected where it impinges the flat surfaces of the chute between the perforations. That is to say, the flow is turbulently reflected and deflected with such force as to actually lift, whirl, turn, agitate, roll, etc. the articles whereby the quench contacts them on all sides and at the same time with a violent wiping and wetting action and, as explained already, in direct contact with them the chute sides, functioning as guides, forcing the articles to remain in the path of the most forcible quench flow. Naturally, the liquid flow must be in the direction against the chute surface carrying the articles, since, if otherwise, they would be thrown from the chute.

I claim:

1. Apparatus for quenching steel articles, the apparatus including a tank for the quenching liquid and a chute declining into said tank with a perforate portion beneath the normal quenching liquid level, the chute being for carrying the articles to be quenched into the tank, a marine-type propeller being positioned adjacent to and opposite said chute and adapted to direct a powerful stream of liquid towards a generally upwardly facing surface of said chute for producing a forced agitation of the quenching liquid through said perforate portion, means for withdrawing said liquid at the end of said tank remote from said chute, the said tank having baffles for directing the quenching liquid that has passed through said perforate portion to said remote end of the tank.

2. Apparatus for quenching steel articles, the apparatus including a tank for the quenching liquid and a chute declining into said tank with a perforate portion beneath the normal quenching liquid level, the chute being for carrying the articles to be quenched into the tank, a marine-type propeller being positioned adjacent to and opposite said chute and adapted to direct a powerful stream of liquid towards a generally upwardly facing surface of said chute for producing a forced agitation of the quenching liquid through said perforate portion, means for withdrawing said liquid at the end of said tank remote from said chute, the said tank having baffles for directing quenching liquid that has passed through said perforate portion to said remote end of the tank, and means for introducing cooled liquid to said tank at the inlet side of and adjacent to said propeller.

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