C. P. SANDBERG.

METHOD OF TREATING STEEL.

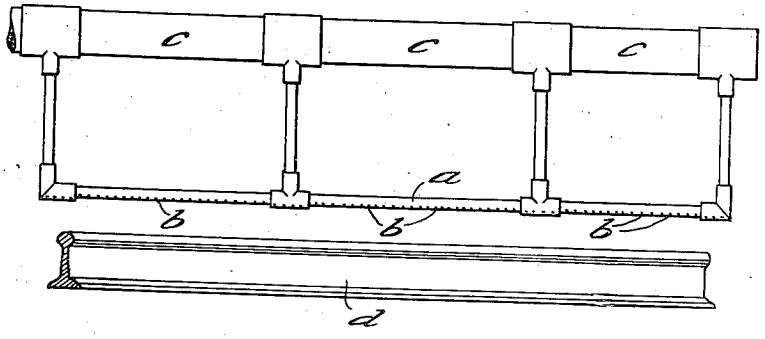
APPLICATION FILED AUG. 9, 1915.

1,178,352.

Patented Apr. 4, 1916.

2 SHEETS—SHEET 1.

Fig. 1.



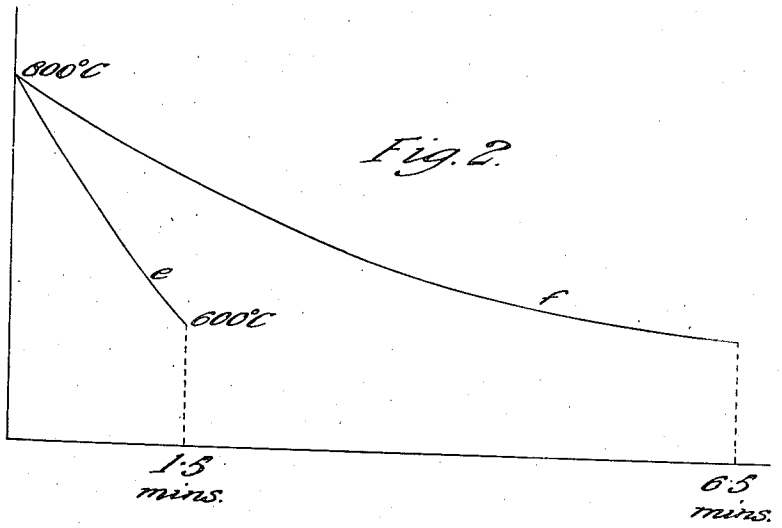




Fig. 2.

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2 SHEETS—SHEET 2.

Fig. 3.

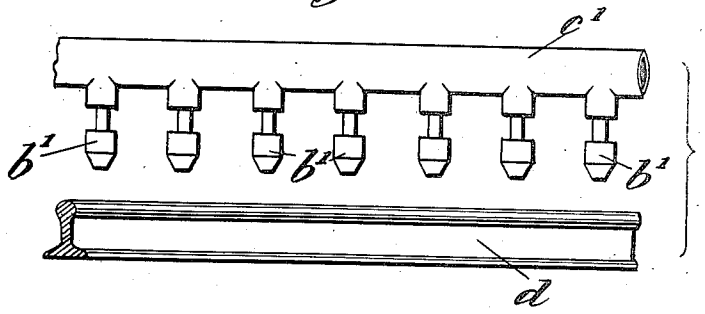



Fig. 4.

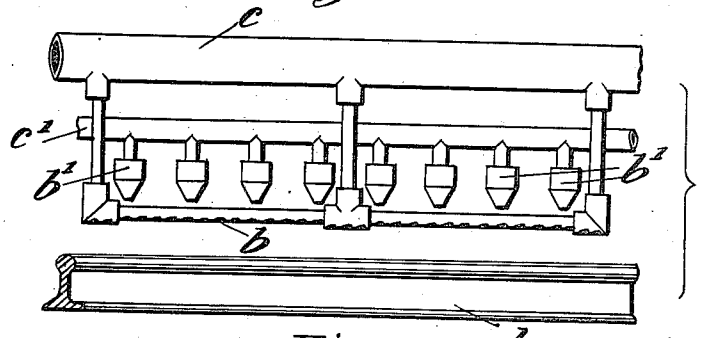
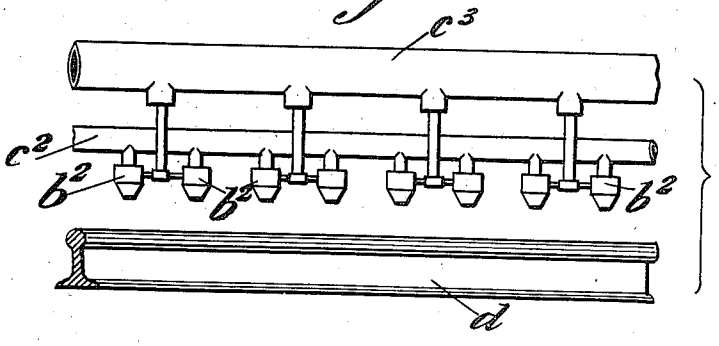



Fig. 5.




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# UNITED STATES PATENT OFFICE.

CHRISTER PETER SANDBERG, OF LONDON, ENGLAND.

## METHOD OF TREATING STEEL.

1,178,352. Specification of Letters Patent. Patented Apr. 4, 1916.

Continuation in part of application Serial No. 28,805, filed May 17, 1915. This application filed August 9, 1915. Serial No. 44,570.

*To all whom it may concern:*

Be it known that I, CHRISTER PETER SANDBERG, a subject of the King of Great Britain, residing in London, England, have invented a certain new and useful Improved Method of Treating Steel, of which the following is a specification.

This application is filed as a substitute for my co-pending application Serial No. 28,805, filed May 17, 1915, and, as regards the application of the process which constitutes the present invention to the treatment of railway or tramway rails, embodies, in the specification, claims and drawings, the subject matter of my said co-pending application.

It is well known that steel may be hardened without altering its ultimate chemical composition, by quenching it from above a certain critical temperature which varies with the composition of the steel. This quenching has been carried out by submerging the heated steel in a tank of water, oil or other liquid medium, by spraying with jets of water, or by means of a blast of air. The hardness of the steel thus produced is due to the prevention of the change in microstructure which steel undergoes during slow cooling, and steel having this hard structure is generally known as martensitic. Steel having this structure, or in which this structure occurs, is decidedly brittle, and owing to this brittleness there are many purposes for which it is dangerous to employ such steel. To correct this brittleness, without losing greatly in the way of hardness, the quenched steel has been reheated to a temperature somewhat below the critical temperature and then allowed to cool slowly. As a result of this reheating and slow cooling, the structure of the steel undergoes another change, resulting in a steel which combines both hardness and toughness. This last named structure of the steel is generally described as sorbitic.

In some cases it is necessary that the metal should be hard and tough throughout, but in others it is only necessary that the surface of the steel shall resist wear and it suffices if the hardness and toughness is limited to a superficial layer of comparatively small depth. Hence it has been suggested that water or other liquid should be sprayed upon the surface of the metal when the latter is at a temperature above the critical temperature so as to quench the superficial layer to the required depth. It might be expected that this procedure would be very satisfactory in the case of pieces or articles of any considerable mass, because the heat in the portion of the article not quenched, would be conducted to the quenched portion and would reheat the latter, so that if the latter were allowed to cool slowly, there would be no brittleness. In my experience, however, this expectation is not fulfilled in practice, because the quenching by sprays of liquid is so rapid that the temperature of the superficial layer in general falls below that from which it can be re-heated to a sufficiently high temperature by the heat remaining in the mass, brittleness being the result. The method, therefore, is quite unreliable. Even if the heat remaining in the mass should be sufficient to reheat the hardened layer to the necessary extent, fine cracks are liable to form in the hardened layer previous to the reheating. Further, in connection with steel rails (and similar difficulties arise with other articles), owing to the varying temperatures at which the rails leave the rolls, the great and varying speed at which they travel, and the variation in the weight and, consequently, the mass which is to be cooled, none of the methods referred to has in practice been under sufficient control to produce regularly the desired structure.

The method of hardening so-called "self" or "air-hardening" tool steel by means of an air blast is also well known, but such steels are alloy steels of special composition and the process is alone applicable to them and not to carbon steel, the structure obtained being quite different to that obtained in carbon steel by the herein described process.

I have found that if carbon steel, while at a temperature above the critical, is treated with an elastic fluid such as air or steam, or very finely divided or atomized water or brine, or both elastic fluid and liquid together, which are blown or delivered upon the surface of the steel so as to cool it moderately rapidly, *i. e.* more quickly than would take place normally, but not so suddenly as to produce a brittle or martensitic structure, that the hard and tough or sorbitic structure can be produced in the steel without double heating or re-heating

and that the formation of fine cracks in the steel is entirely obviated.

My invention, therefore, consists in treating steel to produce a hard and tough or sorbitic structure therein by directing or impinging against the surface of the steel, while at a temperature above the critical, a flow of an elastic fluid, or of very finely divided or atomized liquid, or of both elastic fluid and atomized liquid together so as to quickly cool the steel either superficially or throughout, but not so rapidly as to form martensite.

The invention is applicable for producing the hard and tough or sorbitic structure desired, either superficially in the steel or to any depth, or entirely throughout the mass.

It will be hereinafter described, by way of example, as applied to a railway or tramway rail, but it is to be understood that the process may be employed for treating carbon steel in any form or of any carbon content above .3% and may be applied whether other cooling of the steel has taken place during rolling or in connection with any other operation the steel may have been subjected to.

The drawings show diagrammatically various methods of applying the invention to a track rail and a curve illustrating the cooling effect according to one example.

Figure 1 illustrates one arrangement for cooling the rail by an elastic fluid. Fig. 2 is a curve illustrating the cooling effect according to one example. Figs. 3, 4 and 5 illustrate modified arrangements for cooling the rail according to the invention.

In general, as applied to rails, I avail myself of the heat existing in the rail after the completion of the rolling operation, and after a rail has been rolled and while it is still above the critical temperature, steam or air, or a mixture of air and steam or other elastic fluid, is caused to impinge on the head of the rail for a predetermined time varying with the weight and section of the rail and its temperature, the operation being so conducted that the rate and degree of cooling are such that when the cooled upper portion of the head is reheated by any heat retained in the upper portion of the rail which has not been cooled, or has been more slowly cooled, the hard and tough structure produced is retained, and the said upper portion is of great hardness combined with toughness, while the other portions of the section remain practically unaffected. No re-heating of the rail, either before or after the rapid cooling, is, therefore, necessary in practising my invention. Such re-heating of long lengths of rail is known to be an exceedingly difficult and expensive operation to carry out with any uniformity throughout the length.

Another great advantage of my invention is that the rail may be allowed to cool in the ordinary way to the desired temperature at which the quick cooling operation should begin, so that the treatment in no way interferes with the speed at which the mill normally operates or depends on the temperature at which the mill finishes the rail. Moreover, again without interfering with the mill, the rate and degree of cooling may be varied within any required limits by increasing or decreasing the duration of the cooling operation, by increasing or decreasing the pressure of the cooling medium or varying its temperature, or by increasing or decreasing the quantity of the medium impinging upon the head of the rail in unit time, so as to suit the different compositions, sections and weights of rails.

The rails, when cooled in the manner herein described on the hot bank, may be cooled either separately or in a batch.

It is impossible to prescribe conditions of working which will provide for all cases. Metallography affords a satisfactory method of establishing the conditions for the practice of any particular rolling mill, namely the degree and rate of cooling proper for the composition of the steel rolled, the weight of section of the rail produced, and the temperature from which the cooling is to start. The microstructure of the upper portion of the head of the rail, after it has been hardened and toughened should preferably be that known as sorbitic, and the volume and speed of the elastic fluid delivered against the head of the rail should be such as to produce a structure having as great a degree of hardness combined with toughness as is possible. Obviously, mechanical tests for hardness and toughness may be used instead of microscopic examination, for determining the physical properties of the steel.

As an example of conditions suitable for a rolling mill producing from a steel containing say 0.50 per cent. C., 0.90 per cent. Mn., 0.08 per cent. Si., flange rails of 90 lb. section which leave the mill at about 850° C., the accompanying diagrams illustrate in Fig. 1 an elevation of a pipe *a* about two inches diameter having on its under side perforations *b* about $\frac{1}{16}$ inch diameter and about $\frac{3}{4}$ inch apart, fed with air at ordinary temperature and under 80 lbs. pressure from a main *c*. This pipe *a* is situated at a distance about 1 inch above the head of the rail *d*.

The curve *e* in Fig. 2 shows the rate of cooling of the rail under the action of the air jets, while the curve *f* shows the rate for a rail under precisely similar conditions cooling by ordinary exposure to the atmosphere; the abscissæ represent times and the ordinates temperatures. As indicated by the curve *e*, the upper portion of the head of the rail is in this example quickly cooled

from a temperature of about 800° C. to about 600° C. in about 1½ minutes (the same rail if allowed to cool normally, would, in the same time as indicated by curve *f*, only have cooled from a temperature of about 800° C. to about 720° C.)

The cooling of the head of the rail in the example given and in all other cases in which the invention may be usefully applied is effected at a "moderately rapid" rate; and I use the expression, "moderately rapid", in this description and in the appended claims to define a rate of cooling which is dependent upon the mass and composition of the article treated but in all cases will be substantially more rapid than normal air cooling (*i. e.* as by mere exposure to the atmosphere) but not sufficiently rapid or sudden to produce a brittle or martensitic structure and which will invariably produce a hard and tough or sorbitic structure in the steel without double heating or re-heating. It will be understood that this "moderately rapid" rate of cooling cannot be absolutely set forth with reference to all cases, since its degree will be dependent upon, and hence will vary with the differences in, the mass and composition of the various articles or products of carbon steel in connection with which the invention may be practised. It is noted that one instance of a definite "moderately rapid" rate of cooling has already been given, viz: in the example above of the application of the invention for the production of a hard and tough or sorbitic structure in the head of a railway or tramway rail.

The maximum temperature down to which the upper portion of the head of the rail should be cooled cannot be stated definitely, as this may vary according to circumstances, and among other things naturally depends upon the weight and shape of the section, but the essential point is that the quick cooling action of the elastic fluid directed against the surface of the head should be such that the temperature of the upper part of the head is rapidly reduced to such a degree that it will not be raised again to the critical temperature by any redistribution of the heat contained in the whole mass during natural cooling.

When my method is used, excessive chemical hardness of the steel for the rails is not necessary in order to arrive at good wearing results, and it is well known that in the endeavor to obtain rails sufficiently hard to resist modern heavy traffic conditions resort has been had to a high degree of chemical hardness. This, with the segregation and other troubles that must occur in the economical production of steel rails on a commercial scale, has led to brittleness, large numbers of rail fractures and accidents. On the other hand, the lower chemical hardness which suffices in steel rails made by my process, insures tougher and safer rails, while the structure in the upper portion of the head withstands the wear even better than the ordinary chemically harder rails.

The treatment of other steel articles is in general similar to that for rails, the elastic fluid being caused to impinge upon the surface of the article, or that portion of the article, which is to be made hard and tough.

The treatment with finely divided or atomized water or other liquid, or with such liquid and air or other elastic fluid combined, is also similar to that above described and the liquid should preferably be atomized to such a degree that the particles, as they impinge on the hot steel, are directly evaporated and do not coalesce before such evaporation, so that no liquid flows over the steel and the process becomes equivalent to treatment with an elastic fluid. The apparatus employed as applied to rails as illustrated in Fig. 3 may be very similar to that shown in Fig. 1, the perforations in the air pipe being replaced by atomizers $b'$ of any suitable form arranged on a liquid supply pipe $c'$. Where both atomized liquid and elastic fluid are employed, as shown in Fig. 4, the elastic fluid pipe $c$ and the liquid pipe $c'$ may be arranged side by side with either separate or a common regulating device of any known type. Or where an elastic fluid is employed for atomizing the liquid, as shown in Fig. 5, the liquid may be fed by a supply pipe $c^2$ to the atomizers $b^2$, and the elastic fluid may be led to the atomizers $b^2$ from a supply pipe $c^3$, so that the atomized liquid and the elastic fluid issue together from the atomizers.

Where the hard and tough or sorbitic structure is only required to be produced superficially in the steel, or a portion of it, as is, for instance, the case with railway or tramway rails of wheels or tires, the quick cooling should continue till the temperature of the surface to be treated is reduced, to the depth desired, to such a degree that it will not be raised again to the critical temperature by any redistribution of the heat remaining in the mass of the steel during natural cooling.

Where the hard and tough structure is to be produced throughout the steel, the treatment should be continued till the temperature of the whole mass is reduced below the critical temperature, when the steel may be allowed to cool naturally. It is, however, no disadvantage to continue the treatment till the steel is cold.

The invention is applicable to any steel article such, for instance, as rails, wheels, tires, axles, laminated or coil springs, steel castings, steel forgings, steel plates, steel tubes, steel screw bolts, or other articles in which it is desired to produce the

structure referred to more or less throughout the section of the article.

Throughout the claims, by the term "elastic fluid" is meant a gas or vapor or an atomized liquid so finely divided that it is in fact an elastic fluid and has the properties thereof as hereinbefore described.

Having thus described the nature of the said invention and the best means I know of carrying the same into practical effect, I claim:—

1. A process for producing a hard and tough or sorbitic structure in carbon steel, which consists in cooling it moderately rapidly by means of an elastic fluid, from a temperature above the critical to such a temperature below the critical, that it will not again be raised to the critical temperature by any heat remaining in the mass.

2. A process for producing a hard and tough or sorbitic structure superficially in carbon steel, which consists in cooling the surface of the steel moderately rapidly by means of an elastic fluid, from a temperature above the critical to such a temperature below the critical, that it will not be again raised to the critical temperature by any redistribution of the heat contained in the whole mass of the steel.

3. The process which consists in subjecting the upper portion of the head of a steel track rail after rolling, while the temperature of the rail is above the critical temperature, to the cooling action of elastic fluid, directed against the surface of the head until the temperature of the upper part of the head has fallen moderately rapidly to such a degree that it will not be raised to the critical temperature by any redistribution of the heat contained in the whole mass.

4. The process, which consists in subjecting the upper portion of the head of a steel track rail, when the temperature of the rail is above the critical temperature, to the cooling action of elastic fluid, directed against the surface of the head until the temperature of the upper part of the head has fallen moderately rapidly to such a degree that it will not be raised to the critical temperature by any redistribution of the heat contained in the whole mass.

5. The process which consists in subjecting the head of a steel track rail, when the temperature of the rail is above the critical temperature, to the cooling action of an elastic fluid directed against the head until the temperature of the upper part of the head has fallen moderately rapidly to such a degree that it will not be raised to the critical temperature by any re-distribution of the heat contained in the whole mass.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

CHRISTER PETER SANDBERG.

Witnesses:

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