This invention is a ferrous metal article having a controlled heterogeneity of composition, and the method of producing it.

The accompanying drawing shows diagrammatically in Figure 1 a side elevation of an axe embodying one form of the invention, a sufficient area being shown in longitudinal section to illustrate the invention so far as it can be illustrated; and show diagrammatically in Figure 2 the heat treating step.

To render the detailed description to follow easier to understand, it may be said by way of introduction that an article such as an axe is first made as a casting of conventional malleable iron, and then selected parts such as the cutting edge of an axe are transformed into what is essentially a high carbon tool steel. There is thus produced an article with the softness, toughness and resistance to crystallization characteristic of malleable iron, but selected parts of which have the desirable characteristics of high carbon steel.

In practicing the invention, the first step is making the usual white iron casting of the composition of conventional black heart malleable iron. As is well known, the composition may vary somewhat with the size of the casting and the time it will take to cool in the mold. It will generally contain from 2 to 2½% of carbon, which, in the original unannealed casting, will all be combined carbon.

The casting may next be annealed in the conventional way so that all the carbon is precipitated within the body of the casting in minute irregular particles sometimes called rosettes, thus providing a typical black heart malleable casting.

However, as the free carbon particles may impair the appearance of a finely finished surface without materially affecting utility, it is sometimes desirable to anneal the casting in a packing containing an oxidizing agent, such as mill scale, in sufficient quantity to decarburize only a very thin superficial film, but to reduce the carbon in the region, where free carbon might be objectionable, to from 1 to 1.3%.

The amount and concentration of the oxidizing agent would vary somewhat with the composition of the casting and the time spent in annealing, but the requisite factors for controlled operation can quite readily be determined for any given casting by very few analyses of the annealed castings.

The next step in the process is to cold work the annealed casting, preferably by hammering so as to compact the granular structure. For some purposes, this step may be omitted, but it will improve the quality of the finished article.

The next step is to reheat, at least to the critical temperature, the part of the article to be modified, and, to hold it at the critical temperature until the precipitated carbon becomes combined to the amount of 1 to 1.3%, as may be desired. The remainder of the article should not be allowed to rise in temperature sufficiently to alter its composition.

To accomplish these results, the part to be modified should be heated very quickly under conditions which will provide extremely rapid heat transfer, so that the part to be modified reaches the desired temperature so quickly that not much heat is conducted to the body of the article. It is also desirable to insulate the body of the article from extraneous heat, so as to keep its temperature as low as possible.

It has been found that the most satisfactory method of providing this localized reheating is to immerse that part of the article to be modified in a bath of molten salt, as shown in Figure 2. To prevent the body of the article from being heated either by convection currents from the surface of the bath or by radiation therefrom, there is floated upon the bath a layer perhaps ½ inch thick of finely divided carbon.

The composition of the bath is not particularly important, except that it is generally undesirable to employ an oxidizing bath. Excellent results have been obtained by using a commercial fused salt bath containing some cyanide and commonly sold under the name "Perliton." This particular material is designed for case hardening, but, in the brief time employed in the present process, the addition of carbon to the casting is insignificant. This particular bath is commonly available, and, of course, has no tendency to produce either an oxid scale or any oxid discoloration.

It is obviously impossible to give precise directions as to time and temperature for carrying out this reheating step of the process. The recombination of free carbon proceeds more rapidly at higher temperatures than at lower ones. Therefore, if temperature is varied, the time limit of treatment must also vary.

The temperatures selected must be determined for the various types of castings which may be treated and the portions thereof to be modified. If the temperature is too high, the re-dissolving of the carbon may be so rapid that it cannot be stopped with any accuracy at the right point, which is when there is from 1 to 1.3% combined
carbon. On the other hand, if the temperature is too low, there is a greater opportunity for heat to be conducted into the body of the casting, so that modification occurs beyond the desired area. Generally speaking, it is desirable to use the highest temperature consistent with accurate control of the combined carbon.

While with an axe of the type illustrated, satisfactory results have been obtained with a bath at 1557°F. and a treatment of about 5 minutes, these figures may require considerable variation to accomplish the same result with another of a different nodular, however, it is quite easy for a metallurgist to determine a correct time temperature combination for any particular job by analyzing the treated part of a test casting for combined carbon.

If the combined carbon is too high, either the temperature should be reduced or the time shortened, or both, and conversely, if the combined carbon is too low, either the time or temperature, or both, should be increased.

Obviously, too, the temperature of the bath, which is the factor which the operator must employ for his control, is not a direct indication of the temperature of the article, and it is obviously very difficult, if not impossible, to determine the actual temperature of the article. It would seem probable that in the case of the axe illustrated the temperature of the treated part is probably 1000° or more below the bath temperature.

Furthermore, in the case of massive articles, the temperature of the bath may be very markedly reduced by the introduction of the article. For example, if it is desired to modify the surface of a malleable iron roll, the entire roll would have to be immersed, and the immersion would have to be for so short a time that the interior of the roll is not greatly heated.

The introduction of the entire roll into the bath would doubtless lower the temperature very greatly, and, therefore, the best results would doubtless be obtained with a bath very much hotter than that above mentioned for modifying the cutting edge of an axe. However, correct conditions can be very quickly determined by examining test castings. Any combination of time and bath temperature can be developed to produce the desired re-dissolving of carbon in the area desired.

When the heat treatment step has been carried to the extent determined to be correct, the casting is immediately removed and quenched as rapidly as possible, so as to preserve the steel structure in the most desirable form. It has been found desirable to quench in brine, and even refrigerated brine is desirable for the purpose.

After this quenching, the temper of the treated area is drawn as in the case of ordinary tool steel to the desired point. In the case of the axe selected as a representative casting, it has been found desirable to heat to 600°F. and quench.

When the invention is practiced on ordinary conventional black heart malleable castings, it is quite evident that the carbon nodules or rosettes will be reduced, in size and somewhat in number (the smaller ones going wholly into the solution) by the heat treating process. In that case, the modified part of the article, while of tool steel characteristics, will have scattered through it the residual portions of the original carbon nodules, and these will be readily distinguishable under microscopic examination. For practical purposes, the presence of these nodules is quite unimportant. The modified section has the operating characteristics of tool steel.

However, if it is desired to provide a highly polished surface which gives the article a certain sales appeal, some of these nodules rather on the surface or even in the ground edge of an axe, causing very small but nevertheless visible blemishes. While such a nodule in the cutting edge of an axe produces a very small nick, it is much smaller than the irregularities produced by ordinary methods of grinding or on a grind-stone or on a dry wheel. But when the cutting edge of the axe is given a high polish for sales purposes, such a practically insignificant irregularity in the edge might be visible.

It is for that reason that the modified process of annealing above described may be used. In that case, the structure will have the general characteristics which the section portion of Figure 1 is intended to represent. The body of the article will be of the usual black heart malleable composition with carbides of iron and of small amounts of free carbon, the amount of the latter being from 2 to 2 1/2% or thereabouts. Throughout the heat treated part the nodules will be smaller and somewhat less numerous, because of the complete solution of the smaller nodules.

As the margin of the article is approached, the portion partially decarburized in annealing will show still less free carbon, and very close to the margin all the carbon will have been redissolved. This condition is diagrammatically illustrated in Figure 1 by showing the body of the axe heavily stippled to indicate conventional black heart malleable. The stippling is reduced in density toward the margin close to which it entirely disappears to represent the gradual lessenings of free carbon and its absence immediately adjacent to the margin.

While the process and product have been described in the preferred form wherein the modified portion is in effect a high grade tool steel, it is evident that if one desires, for some special reason, to modify the portion to give it the characteristics of a lower carbon steel, it is only necessary to adjust the heating step to produce the desired re-solution of carbon.

I claim as new and desire to secure by letters patent:

1. The process of making a malleable casting, the selected surface of which has the characteristics of high carbon steel, consisting in making the conventional white iron casting, annealing in a decarburizing pack to produce a body part of conventional black heart iron, and a surface part wherein the free carbon is reduced to the amount desired as combined carbon in the selected part, reheating the selected part at least to the critical temperature, holding it at the selected temperature for a time adjusted to cause the recombination of such part of the free carbon as to give the desired carbon content, and quenching.

2. The process of claim 1, in which the selected portion is subsequently tempered.

3. The process of claim 1, in which the casting is cold worked before reheating.

4. The process of claim 1, in which the heating of the selected portion is accomplished by immersing it in a fused salt bath.

5. The process of making a malleable casting, the selected surface of which has the characteristics of steel, consisting in making the conventional white iron casting, annealing in a decarburizing pack to produce a body part of conventional black heart iron, and a surface part
wherein the free carbon is reduced to the amount desired as combined carbon in the selected part, reheating the selected part at least to the critical temperature, holding it at the selected temperature for a time adjusted to cause the recombination of such part of the free carbon as to give the desired carbon content, and quenching.

6. The process of imparting high carbon steel characteristics to a selected surface portion of a blackheart malleable iron casting, consisting in heating the selected portion at least to the critical temperature by immersing it in a fused salt bath, holding this portion at the selected temperature for a time adjusted to cause the recombination of such part of the free carbon as to give the desired carbon content while the remainder of the casting is insulated by a layer of granular material floating on the bath, and quenching.

7. The process of making a malleable casting, a selected surface of which has the characteristics of high carbon steel, consisting in making the conventional white iron casting, annealing in a de-carburizing pack to produce a body part of conventional blackheart iron, and a surface part wherein the free carbon is reduced to the amount desired as combined carbon in the selected part, reheating the selected part at least to the critical temperature by immersing it in a fused salt bath, holding it at the selected temperature for a time adjusted to cause the recombination of such part of the free carbon as to give the desired carbon content while the remainder of the article is insulated by a layer of granular insulating material floating on the bath, and quenching.

8. The process of imparting high carbon steel characteristics to a selected portion of a blackheart malleable iron casting, consisting in heating the selected portion at least to the critical temperature by immersing it in a molten bath, holding this portion at the selected temperature for a time adjusted to cause the recombination of such part of the free carbon as to give the desired carbon content while the remainder of the casting is insulated by a layer of material floating on the bath, and quenching.

9. The process of imparting carbon steel characteristics to a selected portion of a blackheart malleable iron casting, consisting in heating the selected portion at least to the critical temperature by immersing it in a molten bath, holding this portion at the selected temperature for a time adjusted to cause the recombination of such part of the free carbon as to give the desired carbon content while the remainder of the casting is insulated by a layer of carbon floating on the bath, and quenching.

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