

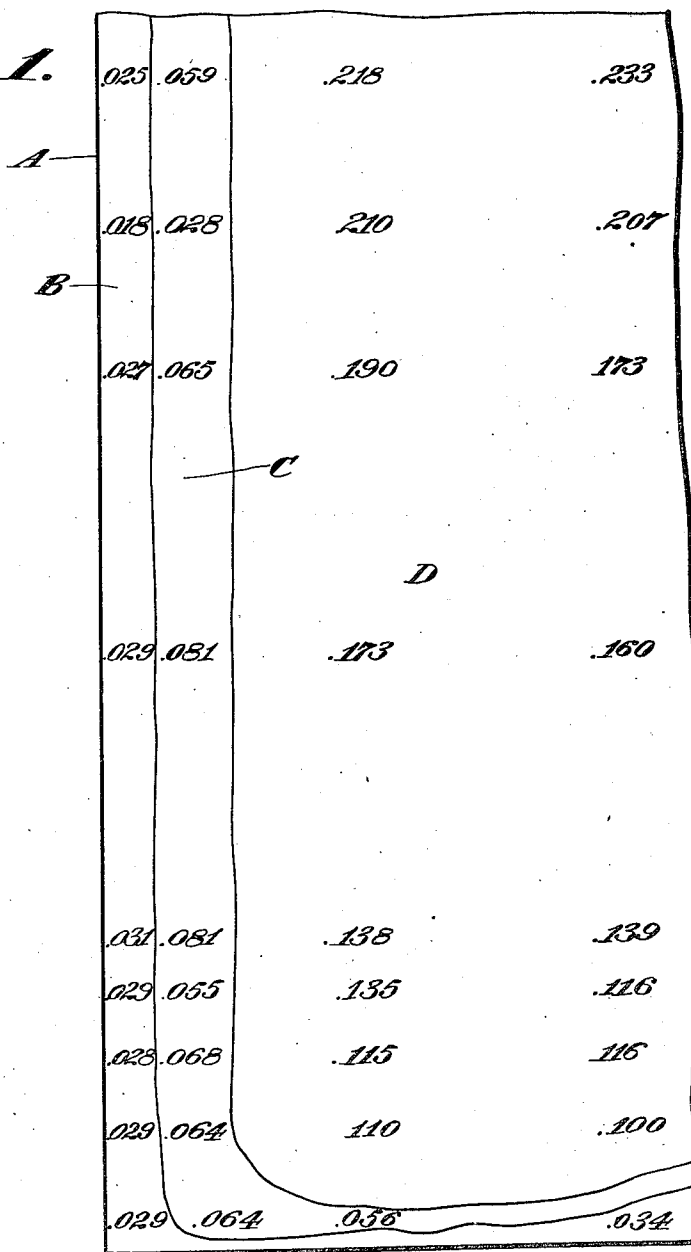
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C. H. HERTY, JR
MANUFACTURE OF STEEL
Filed July 28, 1938

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2 Sheets-Sheet 1

Fig. 1.



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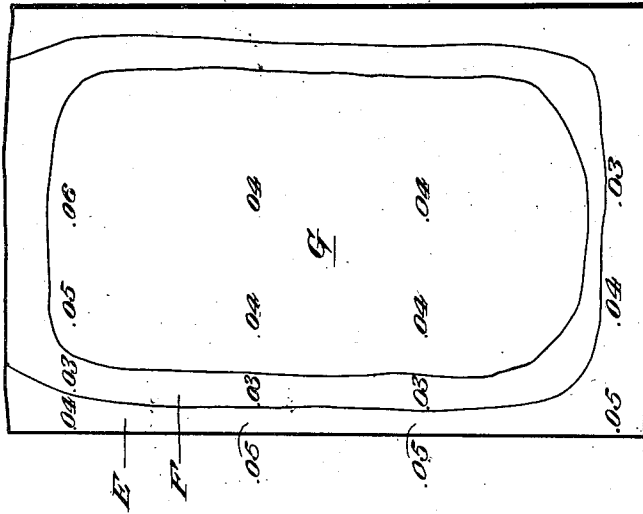
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Fig. 2.



Decarbonized Ingot

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UNITED STATES PATENT OFFICE

2,236,504

MANUFACTURE OF STEEL

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Application July 28, 1938, Serial No. 221,696

16 Claims. (Cl. 75—45)

My invention is directed to processes for the manufacture of steels. It more particularly relates to the manufacture of steel in which the metal is treated to modify the composition or structure after it has been poured in the mold. It especially relates to the modification of rimming steel.

My process comprises the steps of pouring steel in a mold and adding thereto substances which will modify the composition or structure. It comprises the steps of pouring a rimming steel in a mold and adding a substance or substances at the proper time to produce a desired distribution of a constituent or constituents in the steel. More particularly my invention comprises the steps of pouring a rimming steel in a mold, allowing the steel to cool therein until a solid layer of steel has formed about the sides of the mold, and then adding a modifying substance to the molten metal in the mold, this addition being made while the molten metal is still vigorously effervescing. By this process I am enabled to produce ingots of steel in which the composition and properties of the metal are controlled in various desirable ways. Such ingots may then be rolled into the desired shapes, the articles thus produced having the desired composition and the desired distribution of the constituents of the steel.

My invention has a wide range of application. It is applicable, for example, to the production of steels in which it is desired that the metal be readily machined and yet be easily worked as by rolling, forging, or upsetting. To this end my invention may be utilized to produce an ingot having a substantial amount of an embrittling agent, such as sulphur, phosphorus, or nitrogen throughout a goodly part of the interior metal while the outer portion is practically free from these agents, or contains them only in such amounts as do not cause appreciable or serious embrittlement of the outer surface, thus permitting production of steel which may be readily worked by rolling, forging or like operations and yet be freely machineable throughout a major portion of its mass.

Another field of application is in the control of segregation of certain steel constituents, which segregation occurs during rimming, by adding to the steel, while it is still effervescing in the mold, substances which are reactable with the segregating constituents. For example, I may add oxidizing agents to steel in the mold at predetermined stages to effect a reduction in the amount of carbon in those portions of the ingot

which would otherwise have too high a carbon content. As another example, fluxes, reactable with certain segregating steel constituents, such as sulphur and phosphorus, may be added to reduce the content of these constituents in those regions of the ingot where they would otherwise be present in undue amount.

My invention may also be applied in situations where it is desired to secure a desired distribution of an alloying constituent in the steel, as, for example, by adding an alloying constituent to rimming steel, while it is still vigorously effervescing, and after a "skin" is formed on the ingot, to produce an ingot having its interior provided with the alloying constituent and its exterior free from such constituent, or at least low in such element.

The principles of my invention will be apparent from a consideration of the following illustrations of various embodiments thereof.

My first illustration is in the field of free machining steels. It is old to use various embrittling constituents to render steels easily machineable. Sulphur, phosphorus, and nitrogen have been used as embrittling constituents, sulphur having been the most common. Such steels, as heretofore produced, have certain disadvantages, the principal one being that steels containing these embrittling constituents are difficult to work mechanically, cracking or rupturing easily when subjected to rolling, upsetting, forging and kindred operations. By my invention it is possible to effect such a distribution of the embrittling constituent as to permit of these operations without danger of cracking or rupturing the material. I introduce sulphur, or other embrittling constituent, into the steel under conditions to provide a substantial amount of the embrittling constituent within its interior and but little in the exterior portion. An ingot of this character may then be worked by rolling, upsetting, or the like, without cracking, and articles produced from the ingot may be machined, particularly interiorly, by virtue of the increased content of the embrittling constituent in the interior metal. I produce ingots of this character by casting rimming steel, having a relatively low content of embrittling constituents, in a mold, allowing a layer of solid metal of desired thickness to form, and then adding an embrittling constituent to the molten metal while it is still effervescing to give the interior metal the desired content of the embrittling constituent.

The following, given in some detail, is a spe-

cific example of the manufacture of nut stock in which it is desired to have the steel of such characteristics that it may be subjected to severe distortion in mechanically forming the nuts but which may be readily machined to form the interior thread. In this specific illustration sulphur is the embrittling constituent employed.

I proceed by making a heat of free rimming steel having a composition at the time it reaches the ladle substantially as follows: carbon preferably not in excess of .08%, manganese .30 to .40%, phosphorus preferably not in excess of .04% and a sulphur content preferably not in excess of .035%. This steel is poured in an ingot mold and allowed to cool sufficiently long to produce a layer of solid metal around the sides of the mold. The length of time necessary for this cooling will, of course, vary with the size of the ingot. Where the mold is 22 x 25, cross-sectional dimensions, one minute will usually be sufficient. I then add sulphur in some form to the molten metal in the mold while the liquid metal is still effervescent. The sulphur may be conveniently added in the form of iron pyrites. Sufficient sulphur is added to give the liquid metal a sulphur content of from .08% to .12%. The metal circulation, due to the effervescence, will effect the desired distribution of the sulphur throughout the molten metal. The cast metal is then allowed to solidify.

The resulting ingot will have an outer portion of metal with a relatively low sulphur content, this content not exceeding that of the steel as first cast, that is the sulphur, in this particular instance, will not be in excess of .035%. The inner metal, however, due to the addition of sulphur, will have a relatively high content, in this instance, being between .08 and .12%.

The ingot thus produced may be rolled in the ordinary way, the low sulphur content of the exterior metal allowing the rolling man to shape the metal without the special precautions which would be required if ordinary free machining high sulphur steel were involved. The resulting rolled metal may then be subjected to the regular shaping operations for preparing nut stock, following which the blanks are punched in the regular way to furnish the interior opening and then are threaded, the high sulphur content of the inner metal being freely machineable.

By my invention I am thus enabled to combine the free workability of steels which lack embrittling compositions, and at the same time have all of the advantages, so far as the portion to be machined is concerned, of the presence of the embrittling agent.

In making effervescent steels, certain substances, sulphur, for example, tend to segregate. Sulphur, during the rimming operation, tends to concentrate toward the center and toward the top of the ingot. In a normal operation of rimming, the metal which first solidifies, the outer metal of the ingot, is lowest in sulphur, but as solidification advances the sulphur increases in percentage, until when solidification is complete the sulphur is at its maximum. Not only does the sulphur tend to increase inwardly of the ingot, but it increases upwardly thereof. It is frequently important to take this effect of rimming into consideration in carrying out my invention. In carrying out my process of producing free machining, high sulphur steels, after allowing the outer portion to solidify and then adding the additional sulphur or sulphur bearing material, I allow the rimming operation to proceed for

awhile and then cap the ingot to stop the further evolution of gas and thus stop the rimming action. This results in a more nearly even distribution of sulphur in the inner metal of the ingot.

Fig. 1 of the drawings diagrammatically represents the sulphur distribution in an ingot produced by my process, this figure schematically representing a vertical section of one-half of a portion of an ingot. The line A represents the outer surface of the ingot. Space B represents the section of the metal which first solidifies after pouring the metal into the ingot and before the addition of sulphur or sulphur bearing material to the metal in the mold, the numerals in this space indicating the percentages of sulphur in the metal which first solidifies. It will be noted that the sulphur content of this metal is relatively low. Space C indicates the metal which solidifies after the addition of sulphur or sulphur bearing material to the effervescent metal and which solidifies during the rimming operation. It will be noted that the sulphur content of this space C is considerably higher than that of space B, due to the added sulphur. Space D represents the metal which solidifies subsequent to the capping of the ingot, which capping stops the effervescent action. It will be noted that the sulphur content of space D is considerably higher than that of space C, as the sulphur content of the liquid metal, at the time of capping, was considerably higher than that of the metal which had previously solidified, during rimming, due to the segregating effect of rimming earlier referred to.

An ingot of steel prepared like that illustrated in Fig. 1, because of the low sulphur content of the outer metal, is capable of being worked by rolling, forging, upsetting, and the like, without danger of cracking or the production of surface imperfections. At the same time the greater part of the ingot contains sulphur in a comparatively uniformly distributed form and in high enough amount to permit of easy machineability.

As indicated earlier in this application, I may utilize my invention for producing an alloy of the inner metal of the steel ingot. For instance, I may pour rimming steel in the mold, allow a portion to solidify, and then, while the metal is still effervescing, add an alloying metal to the molten steel in the mold. Rimming is then allowed to continue as long as desired and then the mold may be capped, if desired. Copper, for example, may be alloyed with steel in this manner, particularly where it is desired to produce bodies from steel where it is important to have the inner portion resistant to certain corrosive agencies, such as mine waters and the like.

As indicated earlier in this specification, I may utilize my invention for controlling the effects of segregation by adding a substance to the molten metal which is reactable with a segregating constituent of the steel. In producing rimming steel, certain substances tend to segregate in the inner part of the ingot, and especially in the upper part thereof, to such an extent, as to greatly reduce the value of the metal in the regions of greatest segregation. In some cases the segregation is so great as frequently to require the scrapping of a considerable amount of the ingot.

Carbon is one of the constituents which segregates to a considerable extent in the inner and upper portions of the ingot. In preparing steels for certain purposes this may involve very sub-

stantial disadvantages. Rimmed steel of low carbon content is used extensively for purposes requiring steel having deep drawing characteristics. Ordinarily in preparing steel having a ladle composition of the desired low carbon content for deep drawing operations, the carbon segregates in the inner and upper portions of the ingot to such an extent as to make the steel of the upper portion of the ingot practically useless for this type of application. Consequently, it is necessary to crop off a substantial amount of the upper part of the ingot, as ordinarily produced.

My invention finds an especially valuable application in overcoming the effects of this carbon segregation. In this application of my invention the steel, having the desired low carbon ladle analysis, is poured into the ingot, the solidification is allowed to proceed until a layer of solid metal of the desired thickness is produced, and the liquid metal, while still effervescing, is treated with a decarbonizing agent in sufficient amount to effect the reduction of the desired amount of carbon. This addition of an oxidizing substance is carried out while the liquid metal is still actively effervescent in order to secure the desired distribution of the decarbonizing agent. After the reactions, due to the use of the oxidizing agent, are completed, the ingot may be capped to stop further rimming action.

Fig. 2 is a diagrammatic representation longitudinally of an ingot treated in accordance with my process. The space designated E represents the steel which solidifies prior to the addition of the decarbonizing agent. Space F represents the metal which solidifies after the addition of the decarbonizing agent but before the capping operation. Space G represents the metal which solidifies subsequent to the capping operation.

The numerals on this figure indicate the carbon contents in various parts of the ingot. It will be noted that the carbon content of the steel is relatively low throughout the entire ingot. It is especially to be noted that the carbon content in the upper and inner portion of the ingot are much lower than the carbon content of this region of the corresponding ingot produced by the ordinary method of rimming. It will thus be apparent that by means of my invention it is possible to control the effects of the segregation of carbon during rimming so as to bring the upper-inner portion of the ingot to a carbon content which is sufficiently low to render the upper part of the ingot usable for deep drawing purposes.

Various decarbonizing or oxidizing agents may be employed. I have been very successful in using roll scale for this purpose. Illustrating my invention, somewhat specifically, I may cast rimming steel from the ladle to the mold, the ladle composition, for instance, being:

	Per cent
Carbon	.09
Manganese	.41
Phosphorus	.008
Sulphur	.025

This is cast, for example, in an ingot mold 22" x 34". The steel is allowed to rim for some time, say of the order of seven minutes, until a solid outer layer of steel is produced of about 2½ inches thick. While the steel is still effervescent the desired amount of scale is added. In the particular instance this may amount to about nine pounds of scale, the scale containing about

26% of available oxygen for decarbonizing. This scale is preferably added in installments. Upon adding a portion of the scale a brisk reaction ensues between the carbon and the oxygen of the scale. As soon as the steel becomes relatively quiet, more scale is added. The steel is then allowed to continue its rimming action and then may be capped in the ordinary manner, if desired. When employing scale it is important to have a scale free from substances which might contaminate the steel. Preferably it should be clean and crushed so as to have it in form for easy introduction into the steel and so that it will react evenly and uniformly with the carbon therein.

Usually it is very desirable to have the metal in the mold free, or substantially free, from slag. Occasionally, however, I find it advantageous to have some slag upon the surface of the metal as the vigor of the reaction may thereby be somewhat moderated.

Other decarbonizing agents may be employed. Any suitable oxide, or oxidizing substance, whose oxygen is reactable with the carbon of the steel may be used, care, of course, being exercised not to introduce any substances which may contaminate the steel.

Oxygen gas, either in the pure form, or as air, may be utilized. I have obtained very successful results by the use of air or air mixed with some steam. In the use of air, I proceed as outlined above, first allowing a layer of solid metal to form about the sides of the ingot and then blowing air upon the upper surface of the metal in the mold. The oxygen of the air immediately combines with the iron which is quickly disseminated through the molten steel as a result of the effervescence due to the rimming action, the iron oxide thus formed reacting with the carbon to reduce the carbon content.

The utilities of my invention as applied to the production of an ingot with the desired carbon distribution will be readily apparent. The metal which it is necessary to discard is far less than that produced by the usual practice. Furthermore, when using my operation, it is frequently possible to start with a steel having a ladle analysis somewhat higher in carbon than that which would be necessary to use with the standard practice, thereby avoiding the necessity of producing as low a carbon content in the furnace, this operation reducing the cost of producing the steel. This is so because of the fact that in rimming steel the steel which first solidifies has a less carbon content than that of the ladle analysis, and the addition of the oxidizing agent to the molten steel greatly reduces the carbon which would otherwise segregate in the upper part of the mold. This operation also decreases somewhat the tendencies of phosphorus and sulphur to segregate in the upper part of the ingot, since these elements tend to be less where there is less segregation of carbon. Furthermore, my process permits the use of larger molds and the consequent production of larger ingots, as it is well known that the larger the ingot the slower the solidification, therefore the greater the segregation. By the use of my process the segregation is controlled thus permitting the use of larger molds.

My invention finds utility in controlling the effects of segregation with other constituents than carbon in rimming steels. For example, phosphorus and sulphur sometimes tend to be present in objectionable amounts in the inner

and upper part of the ingot. By the use of suitable fluxes at the proper stage substantial amounts of these elements may be removed and appreciably lower the content of these elements in the upper part of the ingot. My general procedure for this purpose is similar to that outlined in regard to carbon; the rimming steel is cast in the mold, solidification about the sides of the mold allowed to proceed until a layer of the desired thickness is secured, and a suitable flux added to the steel while it is still effervescing. This may or may not be followed by capping, depending upon the exigencies of the particular heat. As an example of a suitable flux, may be given the following: calcium oxide, 50%, fluor-spar, 12%, cryolite, 38%.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. In a process of treating steel, the steps of preparing a heat of rimming steel, casting in a mold, allowing the steel to cool sufficiently to form a solid layer of metal of desired thickness about the sides of the mold, then adding a substance incapable of stopping the rimming action to the molten steel while it is still effervescing to modify the composition of the molten steel, and allowing the rimming action to proceed for a desired interval.
2. In a process of treating steel, the steps of preparing a heat of rimming steel, casting in a mold, allowing the steel to cool sufficiently to form a solid exterior of the desired thickness, then adding a substance incapable of stopping the rimming action to the molten steel reactable with a constituent of the steel.
3. In a process of treating steel, the steps of preparing a heat of rimming steel, casting in a mold, allowing the steel to cool sufficiently to form an external solid layer of metal of desired thickness, adding a substance incapable of stopping the rimming action to the molten steel reactable with a constituent of the steel while the steel is still effervescing and capping the mold after a desired interval of time to stop the rimming action.
4. In a process of treating steel, the steps of casting a rimming steel in the mold, allowing the rimming to proceed until a skin of the desired thickness is formed, adding a solid oxidizing agent in predetermined amounts to effect the desired decarbonization of the steel, and employing a slag upon the surface of the metal in the mold to moderate the vigor of the reaction between the oxidizing agent and the carbon in the steel.
5. In a process of treating steel, the steps of preparing a heat of rimming steel, casting in a mold, allowing rimming to proceed until a skin of the desired degree of thickness is produced, then adding an oxidizing agent to the steel while it is still effervescing to secure the desired reduction of carbon content of the steel.
6. A process for making steel articles, comprising the steps of pouring a free rimming steel in a mold, allowing the steel to cool sufficiently to form an external layer of solid metal, and adding an alloying substance incapable of stopping the rimming action to the steel in the mold while the liquid metal is still effervescing.
7. A process for making steel articles, comprising the steps of pouring a free rimming low sulphur steel in a mold, allowing the steel to cool sufficiently to form an outer layer of solid metal, and adding sulphur to the liquid metal while it is still effervescing.
8. A process for making steel articles, comprising the steps of pouring a free rimming low sulphur steel in a mold, allowing the steel to cool sufficiently to form an outer layer of solid metal, and adding pyrites to the liquid metal while it is still effervescing.
9. A process for making steel articles, comprising the steps of pouring a free rimming steel in a mold, allowing the steel to cool sufficiently to form an outer layer of solid metal, adding an embrittling agent to the liquid metal while the liquid metal is still effervescent.
10. A process for making steel articles, comprising the steps of pouring a free rimming steel in a mold, allowing the steel to cool sufficiently to form an outer layer of solid metal, adding an embrittling agent to the liquid metal while the liquid metal is still effervescent, allowing the entire metal to solidify, rolling the resulting product, and subjecting the interior of the rolled body to a machining operation.
11. In a process for treating steel the steps of preparing a heat of rimming steel, casting in a mold, allowing rimming to proceed until a skin of the desired degree of thickness is produced, then adding a decarbonizing agent to the steel while it is still effervescing to reduce the carbon content of the steel the desired degree.
12. In a process of treating steel, the steps of preparing a heat of rimming steel, casting in a mold, and adding an oxidizing agent to the steel after the pouring into the ingot has been completed and while it is still effervescing to effect a desired degree of decarbonization of the steel.
13. In a process of treating steel, the steps of preparing a heat of rimming steel, casting in a mold, and adding an oxide in solid form to the steel after the pouring into the ingot has been completed and while it is still effervescing to produce a desired degree of decarbonization of the steel.
14. In a process of treating steel, the steps of casting a rimming steel in a mold, allowing the steel to rim to form a skin of desired thickness, then while the steel is still effervescing adding a predetermined amount of iron oxide to the steel to obtain a desired degree of decarbonization of the steel.
15. In a process of treating steel, the steps of casting rimming steel in a mold, allowing the rimming to proceed until a skin of desired thickness is formed, adding oxygen to the steel while it is still effervescing to produce a desired degree of decarbonization, and adding a flux to scavenge the steel.
16. In a process of treating steel, the steps of casting a rimming steel in a mold, allowing a layer of solid metal to form about the sides of the mold, and adding a flux to the molten steel while it is still effervescing to remove impurities in the steel.

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