May 6, 1952 H. A. REECE 2,595,294

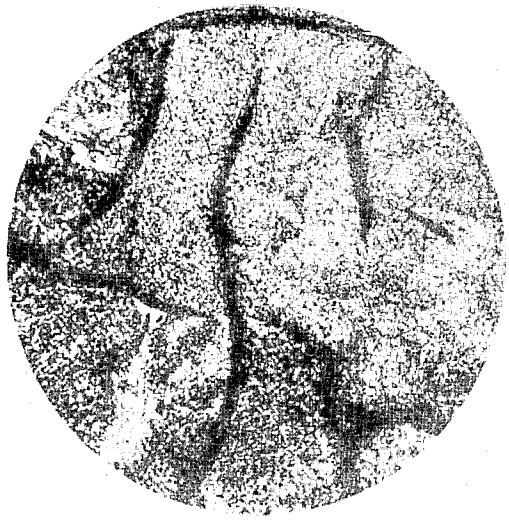
PRODUCTION OF IRON FOR USE IN THE MANUFACTURE OF CAST IRON PRODUCTS

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FIG. 1



FIG. 2



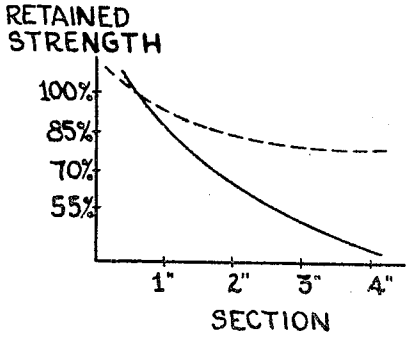


FIG. 3

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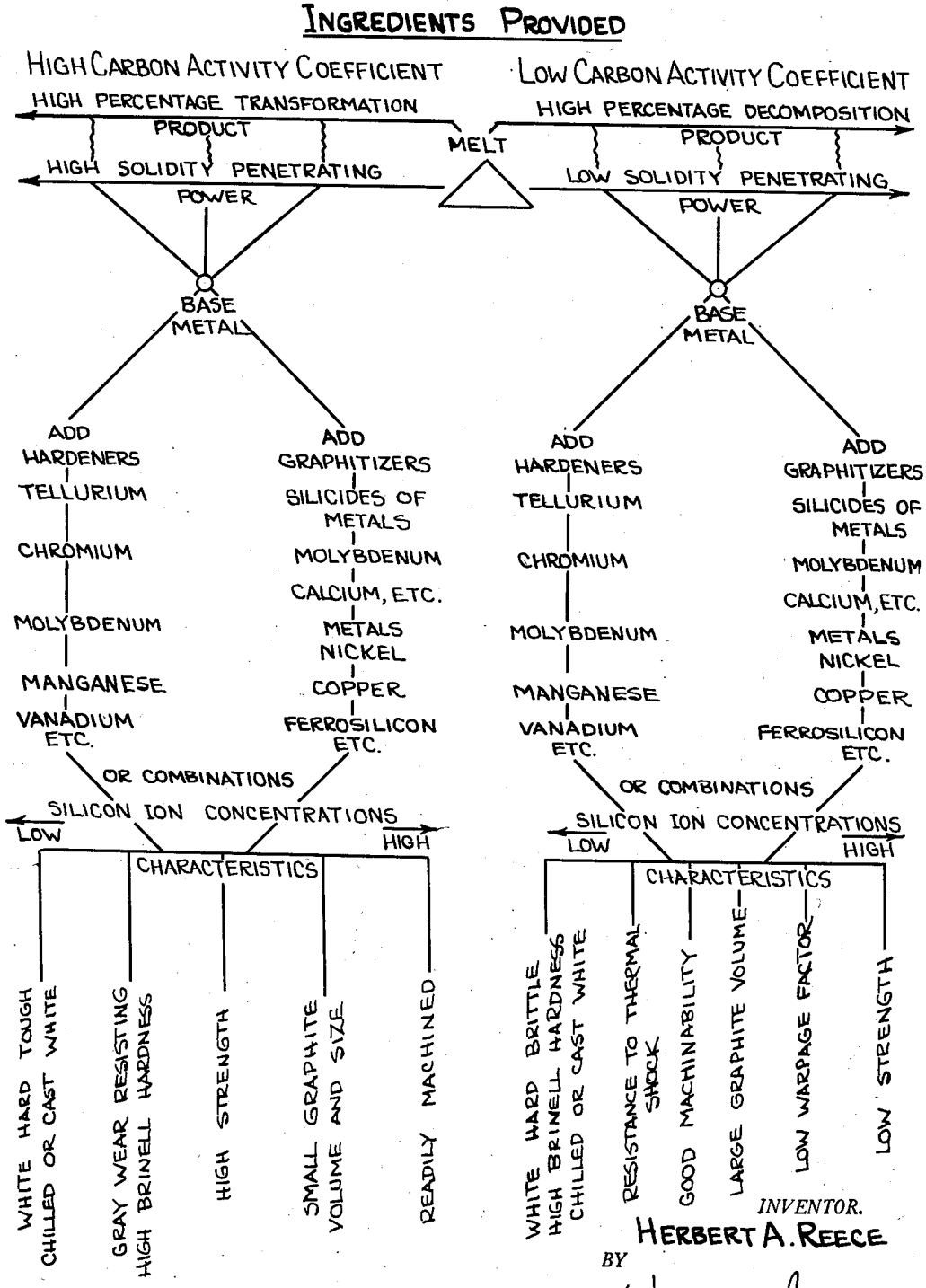


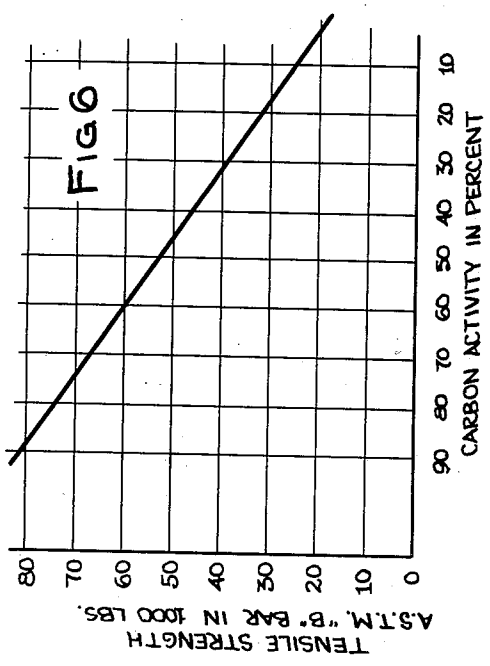
FIG. 4

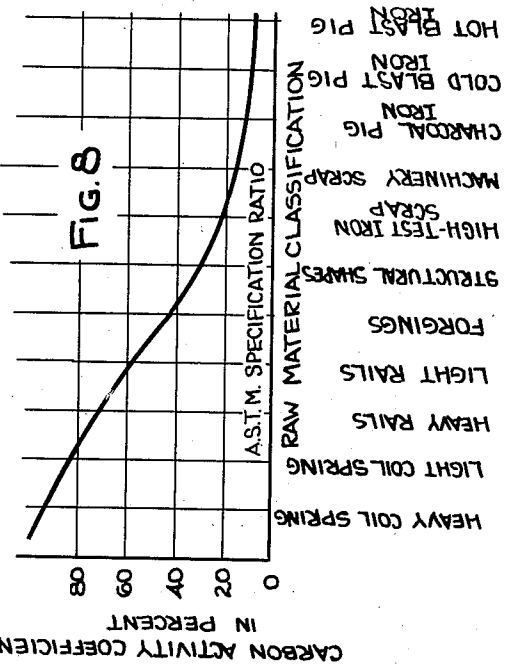
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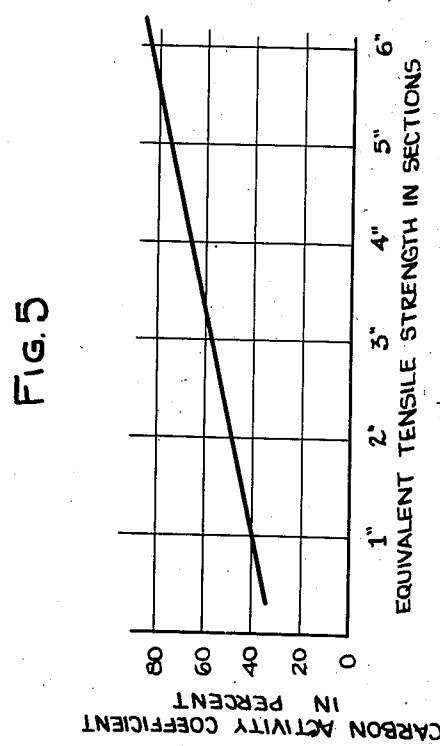
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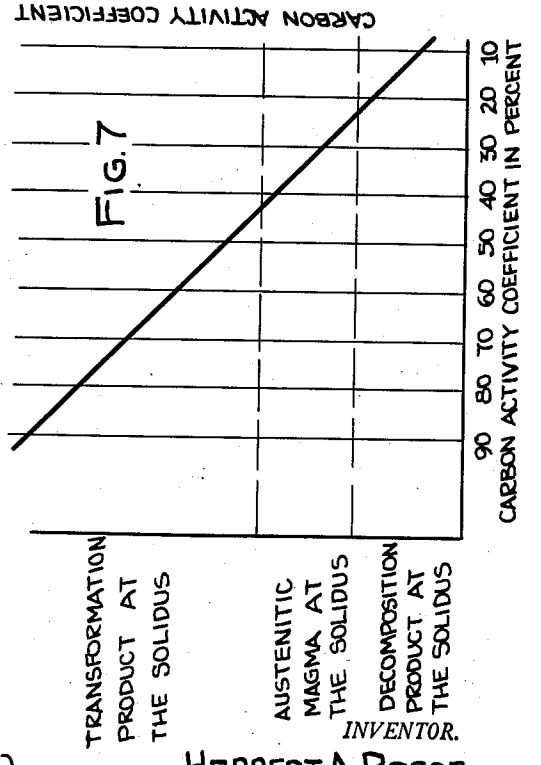
PRODUCTION OF IRON FOR USE IN THE MANUFACTURE OF CAST IRON PRODUCTS

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2,595,294

PRODUCTION OF IRON FOR USE IN THE MANUFACTURE OF CAST IRON PRODUCTS

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Application May 16, 1950, Serial No. 162,292

4 Claims. (Cl. 75—43)

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This invention relates, as indicated, to the production of iron for the use in the manufacture of cast iron products.

The iron-carbon system, stable and metastable, as proposed by Portevin, and shown on page 140 of "The Elements of Ferrous Metallurgy," by Rosenholtz and Oesterle, second edition, is of interest in showing that eutectic cast iron contains about 4.3% carbon, that the eutectic moves to the left, or lower carbon content, with silicon additions to the metal, and as illustrating the percentage of cementite (Fe_3C) possible in relation to the eutectic.

The mathematical procedure of calculating the constituent percentages is illustrated in many books, both from the straight iron-carbon diagram, and with the introduction of various amounts of silicon where specific properties or characteristics are desired in the metal. It is generally agreed that the austenitic magma content of ordinary cast iron, containing from 1.25% silicon to 2.25%, is relatively in the maximum of 40%–50%, where the total carbon content is 2.50% to 3%; 30%–40%, where the total carbon content is 3.00% to 3.15%; 20%–30%, where the total carbon content is 3.15% to 3.35%; and less than 20%, where the total carbon content is greater than 3.35%.

The tensile strength of products cast from ordinary melts in the above classification, is of the order of 20,000 p. s. i. for the lowest percentage of austenitic magma to about 40,000 p. s. i. for the highest percentage of austenitic magma, at the solidus.

It has long been known that the introduction of steel to a cupola charge results in an increase in the austenitic magma content of the metal, as well as an increase in the strength of castings poured from such charges.

The theory of carbon-silicon ratios, saturation value methods, the Maurer rectangle and other methods for the control of the physical properties of iron through methods involving control of the chemical analysis, have all been exploited, with results which in general are unsatisfactory. The recent development of so-called "nodular" irons is a striking example of this, for with carbon-silicon ratios based on the existing standards for obtaining lowest strength castings, these same ratios, through rearrangement of the constituents

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of the casting, have produced strengths heretofore unknown in iron castings.

I have discovered that by utilizing various carbon activity coefficients in molten iron, and controlling the amounts of such carbon which are introduced into the melt or cupola charge, I am able to control the proportions of austenite and cementite at the solidus, and thereby control the physical properties of the iron, including its strength, fluidity, machinability, damping capacity, etc.

By increasing the amounts of austenite at the solidus, the strength and solidity penetrating power of the metal are improved, whereas by increasing the amounts of the decomposition product, cementite, at the solidus, the machinability and damping capacity of the metal are improved. As the one constituent increases, the other decreases, for only the two make up the metallic whole.

Through this method of control, I am enabled to obtain two groups of castings, as follows:

1. Castings derived from a predominating decomposition product at the solidus (Fe_3C or cementite).

2. Castings derived from a predominate transformation product at the solidus ($Fe_{24}C$ or austenite).

By introducing carbon of various activity coefficients in the molten iron in appreciable amounts, the susceptibility of the molten iron to the formation of austenite at the solidus is increased, resulting in an iron, which, when subjected to further graphitization treatments utilizing, for example, molybdenum silicide, calcium silicide, ferrosilicon, or the like, has improved strength and toughness. In this manner, I have been able to produce cast irons having tensile strengths of up to 80,000 p. s. i., without the graphite being in nodular form.

Similarly, by decreasing the amounts of such carbon in the molten iron, the metal becomes a decomposition product at the solidus, and while the strength and toughness thereof are decreased, the damping capacity, machinability and lack of distortion are improved.

The term or expression "carbon activity coefficient" is difficult to define, and must be defined in terms of the effect produced by the components of the melt. On this basis, it is possible to divide

the components or raw materials used for the manufacture of iron castings, whether steel pig iron, or cast iron scrap, as to their carbon activity coefficient. The following table includes virtually every raw material, i. e., steel, pig iron and cast iron scrap, used in the manufacture of iron castings in major amounts, and lists the approximate carbon activity coefficient of each.

Raw Material	Carbon Activity Coefficient
	Per Cent
File Steel—Tool Steel	100
Coil Springs (heavy)	91
Coil Springs (light)	83
Heavy Rails—7"–90/120#	71
Medium Rails—6"–60/90#	60
Light Rails—4½"–Up to 60#	50
Forged Products (miscellaneous)	42
Structural Products	35
High Test Iron Scrap	23
C. I. Scrap	16
Charcoal and Virgin Pig Iron	13
Cold Blast Pig Iron	10
Hot Blast Pig Iron	6

By using a mixture of materials selected from the foregoing list, I can obtain a metal at the solidus, which contains austenite in amounts necessary to obtain the desired physical properties, and by controlling the silicon ion concentration, I can retard or accelerate the precipitation of graphite in amounts necessary to produce a casting of the required physical properties.

In order to obtain a product of high physical properties, i. e., having strength and toughness, I start with a charge of selected carbon activity value and with a sufficiently low silicon ion development potential to prevent breakdown of the carbon before addition of a graphitizer, which may include ferro silicon, molybdenum silicide, calcium silicide, nickel, copper, etc., and thereby produce gray machinable iron castings.

In order to produce hard irons of greater strength and toughness than would ordinarily be obtainable without the use of the present invention, I add hardeners, such as chromium, tellurium, molybdenum, etc. Rapid cooling results in a decrease of the silicon ion mobility, and the carbon ions produced do not tend to form graphite nodules. Thus, sufficiently fast cooling, as on chill work, may entirely prevent graphite formation.

In order to obtain the other class of castings, i. e., those which are distortionless, and have low strength, but good damping capacity, I introduce into the melt components, selected from the above list, having low carbon activity values, and preserve in the casting undissolved graphite molecules which results in a decomposition product at the solidus, due to the fact that I have not saturated the liquid with such carbon and have left the graphite to promote the rapid breakdown of Fe_3C during cooling.

In the accompanying drawings, which form a part of this specification,

Fig. 1 is a photomicrograph, illustrative of the first class of products, and showing an austenite-sorbite structure derived from a melt in which materials having high carbon activity coefficients have been introduced. The quenching rate used in making this material exceeded the critical cooling velocity of the metal, and at the solidus, more than 70% austenite was present (as compared with maximums of 40%–50% austenite obtained through the use of existing methods). The chemical analysis of this sample showed a total carbon content of 3.15%, silicon 1.61%, manganese .95%, phosphorus .12%, and sulphur .09%.

Fig. 2 is a photomicrograph illustrative of the other class of products, and showing a pearlite structure, derived from a melt in which materials having low carbon activity coefficients have been introduced. The quenching rate, in this case, was unable to exceed the critical cooling velocity of the metal, since the melt was predominantly a decomposition product, rather than a transformation product. The chemical analysis of this sample showed a total carbon content of 3.28%, silicon 1.90%, manganese .82%, phosphorus .14% and sulphur .08%.

For high strength castings, the carbon activity content of the liquid metal should be high, resulting in enriched austenite at the solidus.

A typical charge for obtaining such a high strength casting, that is to say, a charge at the upper end of the scale of carbon activity coefficients, conducive to high transformation product recovery, is as follows:

780# coil springs
220# gates, risers, return scrap, etc.
7 silicon briquettes
2 manganese briquettes

The above charge is melted, and in order to obtain the desired or proper grayness of the casting, the melt has added thereto a graphitizing addition, such as molybdenum silicide, calcium silicide, ferro silicon, copper, nickel, etc.

High carbon activity coefficient liquid melts are readily attacked by the silicon ion and rarely require more than 100 ounces of graphitizer per ton of the liquid metal, in order to effect the desired grayness.

The solidity penetrating power of the high carbon activity coefficient melt is greatest when the graphitizing treatment is light, and least where the graphitizing treatment is heavy, as illustrated by the fact that 25 ounces of the graphitizer are sufficient for a 12 inch section casting, whereas 125 ounces are necessary for a ½ inch section casting.

The solidity penetrating power of the metal increases with the increase in carbon activity coefficient, the percentage of the mix ingredients being otherwise the same. This is illustrated by Fig. 3 of the accompanying drawing, wherein the abscissa represents the thickness of a casting in inches, and the ordinate the percentage of retained strength in the casting in ratio to the strength of the test specimen. The solid line curve is the result of many tests and published results, and the broken line curve represents values obtained by the use of the process of the present invention.

A common supposition of cast iron metallurgy is that the carbon content of the iron decreases, the strength of the resultant castings will increase. This is analogous to another "principle" of cast iron metallurgy, that as the steel content of the charge increases, the strength of the resultant product increases.

This inventor has long disagreed with these premises and regards liquid iron as a solution containing carbon of various activity coefficients, wherein the carbon activity value of the charge is the controlling measure of the product, that is to say, the control of the physical properties of the resultant casting is based on the ability to control the carbon activity value of the liquid.

For example, in a charge composed of

50% steel
15% pig iron
35% returns
11 FeSi bricks
4 Mn bricks

having a calculated analysis of

Si	Mn	P	S
1.73	1.18	.19	.089

the carbon activity value of the charge is

50% steel × .50	=	.250
15% pig × .10	=	.015
35% returns × .23	=	.081
Carbon activity value	=	.346
(Carbon activity value)	=	34.6%

Now, if we change the activity value of the charge and even use a lower steel content, viz:

40% steel × .83	=	.332
15% pig × .10	=	.015
45% returns × .23	=	.104
Carbon activity value	=	.451
(Carbon activity value)	=	45.1%

with the same chemistry, the higher carbon activity value iron will have higher physical properties, even though the steel content is less.

As the carbon activity value of the solution increases, a higher silicon ion potential is required to effect the same degree of graphitization and resultant physical properties, viz:

Carbon Activity Value	Graphitization Value in Percentage Silicon
Per Cent	
30	.10
35	.15
40	.20
45	.25
50	.30

Where a tough, hard casting is desired, a hardening treatment with hardening alloys or elements (tellurium, chromium, molybdenum, manganese, etc.) should be employed, this treatment being relatively on the order of less than 2%.

Similarly, it would require a lesser amount of a carbide forming element to advantageously effect the structure and resultant physical properties, viz:

Carbon Activity Value	Percent Molybdenum
Percent	
30	.30
35	.25
40	.20
45	.15
50	.10

Tensile strengths of the casting made from the high carbon activity coefficient liquids, which have been subjected to a graphitizing treatment, are on the order of 70,000/85,000 p. s. i.

Hardnesses of the castings made from the high carbon activity coefficient liquids, which have been subjected to a hardening treatment, are on the order of 450/600 BHN, with the casting possessing a high degree of toughness, whether in the chilled or white cast condition (low silicon ion potential).

At the other end of the scale, a low carbon

activity coefficient, high decomposition product, is obtained. A typical charge for such a product is as follows:

780# hot blast pig iron
220# gates, risers, return scrap, etc., from similar melts

The above charge is melted, and is then graphitized or hardened, depending upon the properties desired in the casting.

As an example of a treatment for a specific problem of eliminating warpage in a casting, the treatment, after melting, consisted in the addition of ½ per cent of 30–70 ferro silicon, which resulted in a plate $\frac{9}{32}$'' thickness, 32'' square, fully enclosed in a frame 1⅜'' thick, which was less than $\frac{2}{32}$'' out of true.

Various combinations of the use of carbon activity coefficient metal and its treatment are illustrated in Fig. 4 of the drawings. Castings of any specific service application can be produced by relating the application to the service desired in the casting.

Fig. 5 of the drawings is a diagram illustrating the relationship between the carbon activity coefficient and equivalent tensile strengths in various sections, the tensile strength remaining uniform as the carbon activity coefficient increases with the section. This illustrates the solidity penetrating power of increases in the carbon activity coefficient. As shown in Fig. 6, 33% carbon activity value has a tensile strength of 40,000 p. s. i. Thus, to obtain 40,000 p. s. i. tensile strength in the 2'' section, the carbon activity value must be 44%, and in the 6'' section for 40,000 p. s. i. tensile strength, the activity must be 82%.

Fig. 6 of the drawings is a diagram illustrating the relationship between carbon activity and the tensile strength of A. S. T. M. "B" bar, the tensile strength increasing uniformly as the carbon activity increases.

Fig. 7 of the drawings is a diagram illustrating the condition of the product at the solidus, as the carbon activity coefficient factor increases. The metal at the solidus passes from a decomposition product, to an austenitic magma product, to a transformation product.

Fig. 8 of the drawings is a diagram illustrating the relationship between the raw material classification and the carbon activity coefficients.

It will be understood that various changes may be made in the steps of the method as described, and in other details of the process, without departing from the scope of the appended claims.

Having thus described my invention, I claim:

1. The method of producing cast iron of controlled physical properties including desired tensile strength, which comprises charging into a melting furnace a mixture of ferrous materials having a total carbon activity coefficient in percent substantially as indicated in Figure 6 of the drawings with the total carbon activity coefficient of the charge plotted against tensile strength on said Figure 6, the carbon activity coefficient in percent being substantially as indicated for various ferrous materials in Figure 8 of the drawings.

2. The method as set forth in claim 1 modified for castings of different cross sections wherein the carbon activity coefficients in percent are plotted against equivalent tensile strength in sections of different sizes substantially as indicated in Fig. 5 of the drawings.

3. The method of producing cast iron of controlled physical properties in which the base molten iron of the character described in claim 1 is treated by incorporating a graphitizing material therein.

4. The method of producing cast iron of controlled physical properties in which the base molten iron of the character described in claim 1 is treated by incorporating a stable or metastable carbide forming element therein.

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The following references are of record in the file of this patent:

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Number	Name	Date
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