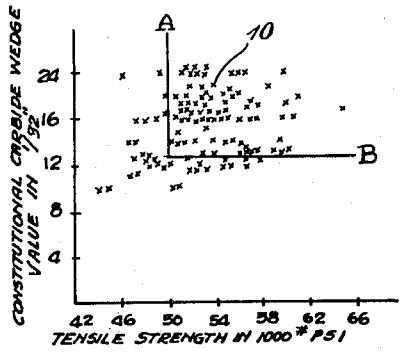
April 19, 1949. H. A. REECE 2,467,406

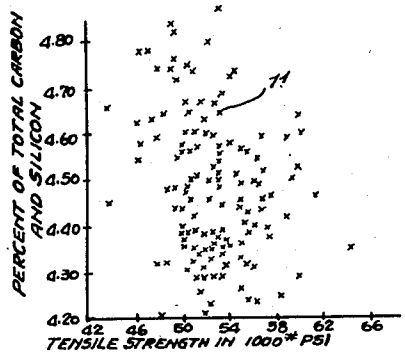
METHOD OF OBTAINING PREDETERMINED PHYSICAL CONSTITUTION IN IRON

Filed Sept. 25, 1946



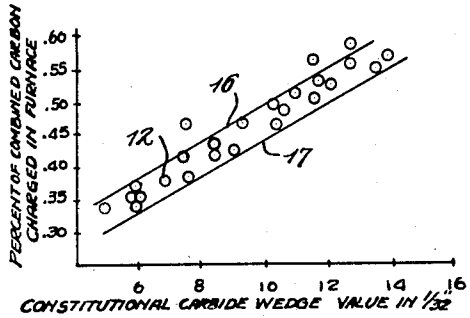
CHARGED IN FURNACE
STEEL APPROXIMATELY 65 To 80 PERCENT
SILICON APPROXIMATELY 1.20 To 1.90 PERCENT
TOTAL CARBON APPROXIMATELY .98 To 1.89 PERCENT

FIG. 1



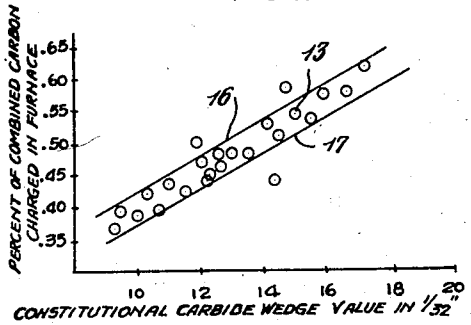
CHARGED IN FURNACE
STEEL APPROXIMATELY 65 To 80 PERCENT
SILICON APPROXIMATELY 1.20 To 1.90 PERCENT
TOTAL CARBON APPROXIMATELY .98 To 1.89 PERCENT

FIG. 2



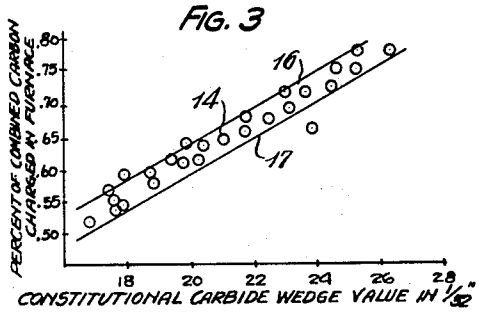
CHARGED IN FURNACE
STEEL APPROXIMATELY 35 To 50 PERCENT
SILICON APPROXIMATELY 1.50 To 2.00 PERCENT
TOTAL CARBON APPROXIMATELY 1.60 To 2.65 PERCENT

FIG. 3



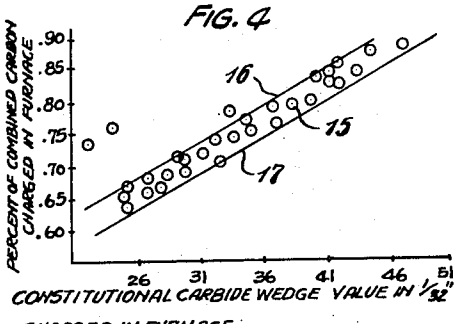
CHARGED IN FURNACE
STEEL APPROXIMATELY 50 To 65 PERCENT
SILICON APPROXIMATELY 1.40 To 2.00 PERCENT
TOTAL CARBON APPROXIMATELY 1.10 To 1.90 PERCENT

FIG. 4



CHARGED IN FURNACE
STEEL APPROXIMATELY 65 To 80 PERCENT
SILICON APPROXIMATELY 1.20 To 1.90 PERCENT
TOTAL CARBON APPROXIMATELY .98 To 1.89 PERCENT

FIG. 5



CHARGED IN FURNACE
STEEL APPROXIMATELY 60 To 80 PERCENT
SILICON APPROXIMATELY .80 To 1.20 PERCENT
TOTAL CARBON APPROXIMATELY .96 To 1.58 PERCENT

FIG. 6

INVENTOR.

Herbert A. Reece

Patented Apr. 19, 1949

2,467,406

UNITED STATES PATENT OFFICE

2,467,406

METHOD OF OBTAINING PREDETERMINED PHYSICAL CONSTITUTION IN IRON

Herbert A. Reece, Cleveland Heights, Ohio

Continuation of application Serial No. 617,747, September 21, 1945. This application September 25, 1946, Serial No. 699,200

6 Claims. (Cl. 75—130)

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This invention relates to the production of iron for use in the manufacture of cast iron products and, as one of its objects, aims to provide a method by which a base iron having a predetermined physical constitution can be uniformly obtained.

It has been recognized that when a base iron of a given physical constitution is subjected to graphitization or other known process steps and castings are poured from the treated or processed iron, they will have a desired tensile strength and certain other desirable physical properties but, so far as I am aware, there has never been heretofore any known way of obtaining a base iron for such subsequent treatment which will uniformly have a desired predetermined physical constitution. Because of the inability heretofore to control the physical constitution of the base iron, the castings obtained from the processed iron did not uniformly possess the desired physical properties.

By the present invention it is possible to uniformly obtain a predetermined physical constitution in a base iron and since this physical constitution of the iron is retained through subsequent graphitization steps, or other process steps, the castings poured from the processed iron will inherit the desired physical constitution and will therefore possess corresponding desirable physical properties. In accordance with this invention the predetermined physical constitution is obtained in the base iron by controlling the combined carbon content of the materials charged into the melting furnace.

Another object of the invention is, therefore, to provide a method for controlling the physical construction in a base iron by controlling the amount of combined carbon charged into the melting furnace.

Other objects and advantages of the present invention will be apparent from the following description and the accompanying drawing.

This application is a continuation of my earlier application Serial No. 617,747, filed September 21, 1945, now abandoned.

In the accompanying drawing

Fig. 1 is a diagram illustrating the resultant tensile strength in iron castings where the physical constitution of the base iron is not controllable.

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Fig. 2 is another diagram illustrating the resultant tensile strength in iron castings when the physical properties as regards tensile strength are based on total carbon and silicon percentage values, and

Figs. 3–6, inclusive, are diagrams showing the uniformity of results obtainable in the physical constitution of base irons by controlling the combined carbon content of the mixture of ferrous materials charged into the furnace.

As already indicated in a general way above, a feature of prime importance in the present invention is the discovery by this applicant that the relationship of the combined carbon content of the ferrous materials of the furnace charge and not the total carbon content in the resultant analysis controls the physical constitution of the base iron. It is shown hereinafter that the control of this factor, namely, the combined carbon content of the charge, makes it possible to obtain a predetermined physical constitution for a base iron.

Before proceeding further with the detailed description it should be explained that the physical constitution of the base iron can be definitely predetermined and can be conveniently designated by values expressed in terms of the measurement of the carbide formation of the iron. In obtaining this measurement a casting of wedge-shaped cross section is first poured from a base iron whose physical constitutional value is to be determined. The wedge-shaped casting has an acute angle at its apex defining a knife-edge and which angle may range approximately from 20° to 30°. The back face of the wedge-shaped casting can be of any convenient width such as 1", 2", 3" or 4". This wedge-shape has been found to be very convenient for obtaining the desired measurement but obviously this invention contemplates that other shapes could be employed.

After the wedge-shaped casting is poured and has cooled, it is broken in two transversely so that the carbide balance may be observed on the broken surface of the casting at the line of demarcation between the metal of white apearance and the metal of grey appearance. The width measured across the broken surface of the wedge-shaped casting at the line of demarcation is taken as an indication of the physical constitution of the base iron and the indication or value

thus obtained is usually expressed in 1/32" for convenience and is referred to as the constitutional carbide wedge value of the iron.

Generally speaking, a melter operating a metallurgical furnace has at his disposal a variety of raw materials such as those represented by the following tabulation and which contain the percentages of combined carbon, graphitic carbon and total carbon specified therein.

Raw Material	Approximate Percentages		
	Combined Carbon	Graphitic Carbon	Total Carbon
S, Low, Med. and High Carbon Splice Bars, etc.	.30 to .90		.30 to .90
T, Structural and Plate-Fish Plates, etc.	.12 to .25		.12 to .25
E, Bar Stock and Shafting, etc.	.10 to .50		.10 to .50
E, Coil Springs and Spring Stock, etc.	.80 to 1.15		.80 to 1.15
L Rail Stock, etc.	.30 to .70		.30 to .70
L Steel Castings, etc.	.15 to .45		.15 to .45
Malleable:			
Malleable Castings	.02 to .20	1.80 to 2.25	1.80 to 2.45
Pearlitic Malleable	.65 to .90	1.70 to 2.35	1.85 to 2.60
Cupola Malleable	.30 to .45	1.90 to 2.70	1.90 to 3.10
Pig Iron:			
#1-#5	.25 to 1.40	2.50 to 3.70	3.45 to 4.20
Silvery	.35 to 1.60	.90 to 2.40	1.60 to 3.50
Spiegeleisen	.60 to 3.00	.40 to 2.50	3.00 to 6.00
Cast Scrap:			
Automotive, etc.	.25 to .80	2.60 to 3.10	3.20 to 3.50
No. 1 Machinery	.25 to .75	2.65 to 3.15	3.15 to 3.60
Car Wheels	.30 to .90	2.60 to 3.60	3.30 to 3.90
Agricultural	.20 to .70	2.60 to 3.40	3.20 to 3.80
Fittings and textile	.20 to .80	2.65 to 3.45	3.20 to 3.90
Heavy Cast	.30 to .80	2.40 to 3.40	3.10 to 3.65
Alloys and other materials of like nature.	Percentage varies with alloy		

The diagram of Fig. 1 of the drawing illustrates the lack of uniformity in the physical properties of iron castings when the physical constitution of the base iron from which they are obtained has not been controlled or is not controllable. In this diagram tensile strength values expressed in 1000# p. s. i. are plotted against constitutional carbide wedge values expressed in 1/32". These tensile strength values are indicated by the plotted points 10. The tensile strength values plotted in Fig. 1 were obtained from tests made on standard 1.21" section test bars conforming to the specifications of the American Society for Testing Materials and known thereunder as "B" bars.

The iron on which the tests of Fig. 1 were made was obtained from furnace charges which, as indicated in the legend of Fig. 1, contained steel approximately 65% to 80%, silicon approximately 1.20% to 1.90% and total carbon approximately .98% to 1.89%. The distribution of the plotted points 10 shows that in most cases an iron having a constitutional carbide wedge value above 12/32 will have a tensile strength above 50,000# p. s. i. and this is represented in the diagram by the fact that the majority of the plotted points lie within the area defined by the angular line AB. It is important to note, however, that the plotted points lying within this area are scattered and do not conform to any definite pattern. This shows that tensile strengths above 50,000# p. s. i. are consistently obtainable when the physical constitution of the base iron is controlled.

The diagram of Fig. 2 illustrates the lack of uniformity in the physical properties if iron castings when the iron from which they are obtained is controlled on the basis of the total carbon and silicon analyses in the resultant castings or test bars. In this diagram tensile strength values expressed in 1000# p. s. i. are plotted against the total carbon and silicon content of the test bars expressed as a percentage. The tensile strength values corresponding with certain percentages of the total carbon and silicon content are indicated by the plotted points 11. The tensile strength values plotted in Fig. 2 were also obtained from tests made on standard 1.21" section test bars conforming to the specifications of the American Society for Testing Materials and known thereunder as "B" bars.

The iron on which the tests of Fig. 2 were made was in the form of castings or test bars having a total carbon and silicon analysis ranging from about 4.30% to about 4.85% and which charges, as indicated in the legend of Fig. 2, contained steel approximately 65% to 80%, silicon approximately 1.20% to 1.90% and total carbon approximately .98% to 1.89%. The wide dispersion of the plotted points 11 shows that there is no correlation between the tensile strength of an iron and the percentage value of its total carbon and silicon content.

Previous to this invention consideration has been given only to the total carbon content in the making up of the furnace charge. Under that practice it has generally been assumed that when the various charges all have the same total carbon content, the physical constitution of the castings obtained would be the same providing that the recarburization value remains the same for all of the melts and that the cupola is operated in a normal manner. That the same physical constitution is not obtained in different irons having substantially the same total carbon content is clearly indicated by the following examples designated 1 and 2.

Example 1

Steel, 1203#=61%
Auto cast, 363#=18%
Returns, 317#=16½%
Speigel 85#=4½%
Total carbon charged=1.52%
Total carbon of melt=3.02%
Constitutional carbide wedge values varied from 12/32 to 30/32.

Example 2

Steel, 1050#=70%
Pig iron 350#=23.33%
Silvery, 100#=6.67%
Total carbon charged=1.53%
Total carbon of melt=3.00%
Constitutional carbide wedge values varied from 10/32 to 24/32.

The result given above in Example 1 were obtained over a period of a month's operation of the cupola during which a large number of tests were made and the results of Example 2 were obtained from a corresponding number of tests performed during a like period of time. From the tabulations given in these two examples it will be seen that the total carbon content of the charges are almost identical in value but that the constitutional carbide wedge values of the irons differ widely which shows definitely that the physical constitutions of the melts are not the same and that the control of the total carbon content of the charge did not provide an accurate control for the physical constitution of the melt.

The reason for the variance in the constitutional carbide wedge values obtained in Examples 1 and 2 was found to be due to the inclusion of various types of steels in the materials constituting the charge. These examples demonstrate that the total carbon content of the charged materials is not the controlling element in securing a desired predetermined physical constitution in the iron.

In analyzing the relationship of the graphitic carbon content to the physical constitution of a base iron numerous tests were made and the results set out in the following tabulation, designated Example 3, are illustrative thereof.

Example 3

Constitutional Carbide Wedge Values in 1/32"	Graphitic Carbon Content of Charges, percent		
30/32	.68	.56	.49
25/32	.87	1.10	.61
29/32	1.37	1.01	.83
18/32	1.04	.92	1.13
15/32	.57	.84	.72
12/32	.81	1.03	1.01
19/32	.62	.84	.97

The foregoing tabulation of Example 3 lists the constitutional carbide wedge values given by base irons obtained from charges having the percentages of graphitic carbon which are indicated in the example. The wide variation in the graphitic carbon content for charges which produced base irons having the same constitutional carbide wedge value shows clearly that the graphitic carbon content has no important bearing on the matter of controlling the physical constitution of the base iron.

When the combined carbon content of the materials of the charge was determined and controlled in accordance with the teachings of this invention the relation of the combined carbon content to the physical constitution of the iron became apparent and is illustrated in the following examples designated Example 4 and Example 5.

Example 4

Charge consisting of:

	Pounds
Pig iron	100
Silvery	80
Spiegel	20
Returns	195
Rail steel	500
Misc. steel	305
Total	1200

Calc. combined carbon .61%; calc. graphitic carbon .76%; silicon 1.43%.

Example 5

Charge consisting of:

	Pounds
Pig iron	150
Silvery	65
Spiegel	15
Returns	370
Rail steel	300
Misc. steel	300
Total	1200

Calc. combined carbon 60%; calc. graphitic carbon 1.20%; silicon 1.64%.

In Example 4 the charge consisted of the ferrous materials listed in this example which aggregated 1200# and had a calculated combined carbon content of approximately .61%, a calculated graphitic carbon content of approximately .75% and a silicon content of approximately 1.43%. In Example 5 the charge consisted of the same kinds of ferrous materials having the same aggregate weight but with the weights of the individual materials differing considerably from the weights of the corresponding individual materials in Example 4. The materials constituting the charge of Example 5 had a calculated combined carbon content of approximately .60%, a calculated graphitic carbon content of approximately 1.20% and a silicon content of approximately 1.64%.

An important factor to be noted in Examples 4 and 5 is the fact that the materials have been so selected that the combined carbon content is substantially the same in both examples even though the other percentages and the amounts of the individual materials vary widely. Charges as represented by Example 4 yielded regularly a base iron with a constitutional carbide wedge value of 19/32 and charges corresponding with Example 5 yielded regularly a base iron with a constitutional carbide wedge value of 16/32. The results represented in these examples therefore clearly show that by controlling the combined carbon content of the materials of the charge a desired predetermined physical constitution is uniformly obtainable for the iron of the melt.

The diagrams of Figs. 3–6, inclusive, further illustrate the consistently uniform results obtainable for the physical constitution of a base iron by controlling the combined carbon content of the materials of the charge in accordance with the teachings of this invention. In the diagram of Fig. 3 the plotted points 12 represent constitutional carbide wedge values expressed in 1/32" which were obtained for a base iron having typical calculated percentages of approximately .30% to .60% for the combined carbon content of the materials charged in the furnace when using in the charge approximately 35% to 50% of steel, approximately 1.50% to 2.00% of silicon, and approximately 1.60% to 2.65% for the total carbon content.

The diagram of Fig. 4 illustrates the use of typical calculated percentages of approximately .35% to .65% for the combined carbon content of the materials charged in the furnace and the resulting constitutional carbide wedge values as represented by the plotted points 13 when using in the charged materials approximately 50% to 65% steel, approximately 1.40% to 2.00% of silicon, and a total carbon content of approximately 1.10% to 1.90%.

The diagram of Fig. 5 illustrates the use of typical calculated percentages of approximately

.50% to .80% for the combined carbon content of the materials charged in the furnace and the resulting constitutional carbide wedge values as represented by the plotted points 14 when using in the charged materials approximately 65% to 80% steel, approximately 1.20% to 1.90% silicon, and a total carbon content of approximately .98% to 1.89%.

The diagram of Fig. 6 illustrates the use of typical calculated percentages of approximately .60% to .90% for the combined carbon content of the materials charged in the furnace and the resulting constitutional carbide wedge values as represented by the plotted points 15 when using in the charged materials approximately 60% to 80% steel, approximately .80% to 1.20% of silicon, and a total carbon content of approximately .96% to 1.58%.

Obviously, if the total carbon content of a charge of metal is a fixed value, any decrease in the graphitic carbon content results in an increase in the combined carbon content, with a resultant increase in the constitutional carbide value as shown in Figures 3–6. This can be illustrated, by referring to Figure 5, using a fixed total carbon content of the metal charge of 1.25%:

	Per cent
Total carbon	1.25
Graphitic carbon	.60
Combined carbon	.65

Constitutional carbide wedge value=$^{21}/_{32}$.

	Per cent
Total carbon	1.25
Graphitic carbon	.50
Combined carbon	.75

Constitutional carbide wedge value=$^{25}/_{32}$.

In the diagrams of Figs. 3 to 6 inclusive the plotted points have a definite pattern in which substantially all of the points lie between a pair of parallel sloping lines 16 and 17 which show that the physical constitution of the base iron is directly related to and dependent upon the combined carbon content of the materials of the charge. The upper line 16 corresponds with a low steel-high silicon value for the percentages specified for the materials of the charges in Figs. 3 to 6 inclusive and the lower line 17 corresponds with a high steel-low silicon value for the specified percentages. The slope of the lines 16 and 17 can be varied by altering the silicon content or the steel percentages of the charge but the principle of the invention will remain the same.

From the drawing and the foregoing specification it will now be understood that this invention provides a practical and workable method by which a predetermined physical constitution can be readily and uniformly obtained in a base iron, and hence, iron castings having desired physical properties can be uniformly produced when the base iron is processed.

The term "cast iron" as used herein is intended to mean iron products as distinguished from steel products, that is, iron products containing 1.8% to 4.5% carbon and more than .25% silicon, and which include all of the commonly known cast irons such as gray cast iron, white cast iron, air furnace iron, chilled iron, alloy iron, mottled iron, semi-steel and the various trade name irons.

Although the invention has been disclosed herein in a detailed way it should not be regarded as being correspondingly limited since it is intended to include all changes and modifications coming within the scope of the appended claims.

I claim as my invention:

1. The method of producing cast iron of controlled physical properties which comprises charging into a cupola a mixture of ferrous materials which will provide a predetermined approximate percentage of 35 to 50 percent for the steel content of the materials charged, 1.50 to 2.00 percent for the silicon content and 1.60 to 2.65 percent for the total carbon content, and said selected ferrous materials also providing a predetermined approximate percentage of .30 to .60 percent for the combined carbon content of the materials charged such that said mixture will substantially uniformly give corresponding approximate constitutional carbide wedge values of $^{4}/_{32}$ to $^{16}/_{32}$, the steel charge, the silicon charge, the combined carbon, and constitutional carbide wedge values being related as shown in Figure 3 of the drawing, the relationship of the steel and silicon charges being shown by lines 16 and 17 of said figure with line 16 being low steel and high silicon value and line 17 being high steel and low silicon value, melting said charge, and casting the molten iron.

2. The method of producing cast iron of controlled physical properties which comprises charging into a cupalo a mixture of ferrous materials which will provide a predetermined approximate percentage of 50 to 65 percent for the steel content of the materials charged, 1.40 to 2.00 percent for the silicon content and 1.10 to 1.90 percent for the total carbon content, and said selected ferrous materials also providing a predetermined approximate percentage of .35 to .65 percent for the combined carbon content of the materials charged such that said mixture will substantially uniformly give corresponding approximate constitutional carbide wedge values of $^{8}/_{32}$ to $^{20}/_{32}$, the steel charge, the silicon charge, the combined carbon, and constitutional carbide wedge values being related as shown in Figure 4 of the drawing, the relationship of the steel and silicon charges being shown by lines 16 and 17 of said figure with line 16 being low steel and high silicon and line 17 being high steel and low silicon, melting said charge, and casting the molten iron.

3. The method of producing cast iron of controlled physical properties which comprises charging into a cupola a mixture of ferrous materials which will provide a predtermined approximate percentage of 65 to 80 percent for the steel content of the materials charged, 1.20 to 1.90 percent for the silicon content and .98 to 1.89 percent for the total carbon content, and said selected ferrous materials also providing a predetermined approximate percentage of .50 to .80 percent for the combined carbon content of the materials charged such that said mixture will substantially uniformly give corresponding approximate constitutional carbide wedge values of $^{16}/_{32}$ to $^{28}/_{32}$, the steel charge, the silicon charge, the combined carbon, and constitutional carbide wedge values being related as shown in Figure 5 of the drawing, the relationship of the steel and silicon charges being shown by lines 16 and 17 of said figure with line 16 being low steel and high silicon and line 17 being high steel and low silicon, melting said charge, and casting the molten iron.

4. The method of producing cast iron of controlled physical properties which comprises charging into a cupola a mixture of ferrous materials which will provide a predetermined approximate percentage of 35 to 80 percent for the

steel content of the materials charged, .80 to 2.00 percent for the silicon content and .96 to 2.65 percent for the total carbon content, and said selected ferrous materials also providing a predetermined approximate percentage of .30 to .90 percent for the combined carbon content of the materials charged such that said mixture will substantially uniformly give corresponding approximate constitutional carbide wedge values of $\frac{4}{32}$ to $\frac{48}{32}$, the steel charge, the silicon charge, the combined carbon, and constitutional carbide wedge values being related as shown in Figures 3 to 6 of the drawing, the relationship of the steel and silicon charges being shown by lines 16 and 17 of said figures with line 16 being low steel and high silicon and line 17 being high steel and low silicon, melting said charge, and casting the molten iron.

5. The method of producing cast iron of controlled physical properties in which the base molten iron of the character described in claim 4 is treated by dissolving a graphitizing material therein.

6. The method of producing cast iron of controlled physical properties in which the base iron of the character described in claim 4 is treated by dissolving a hardening material therein.

HERBERT A. REECE.

REFERENCES CITED

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

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Number	Name	Date
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