

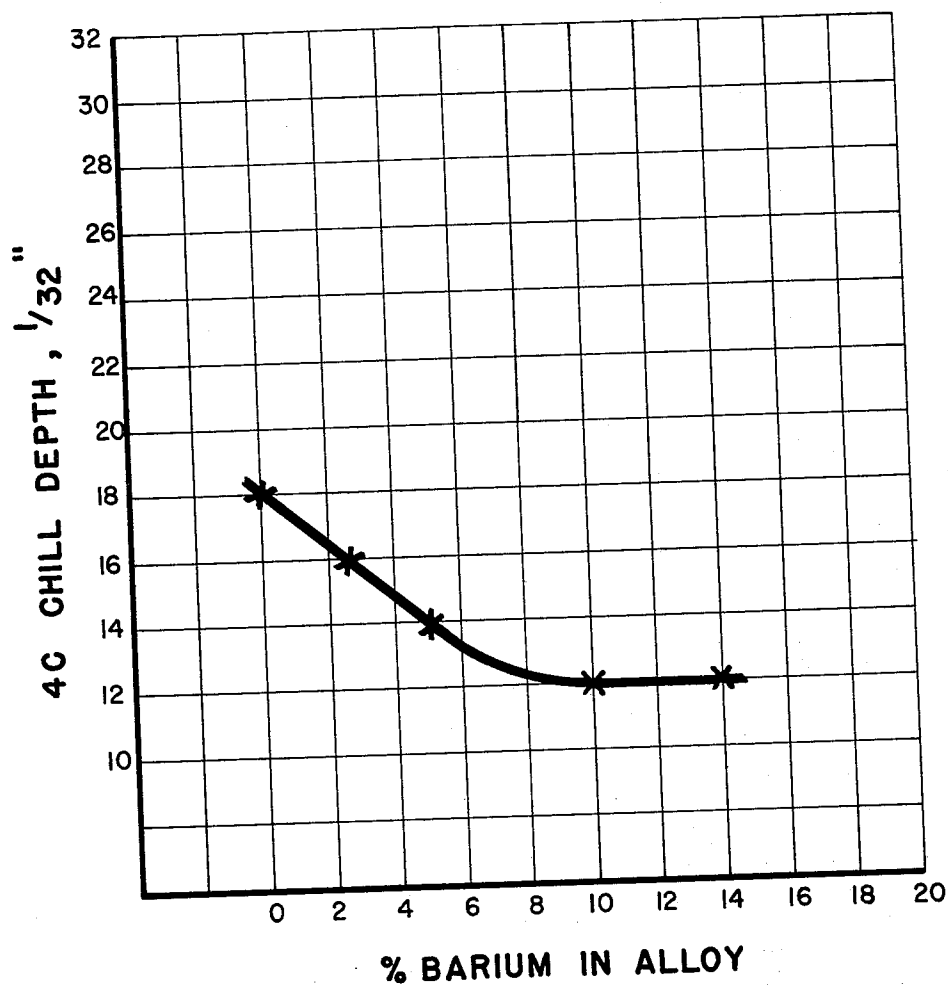
June 16, 1964

R. L. MICKELSON

3,137,570

INOCULATING ALLOY

Filed Aug. 10, 1962



INVENTOR.

Robert L. Mickelson

BY

Wells, Mackay & Bunker

HIS ATTORNEYS

1

3,137,570

INOCULATING ALLOY

Robert L. Mickelson, Cambridge, Ohio, assignor to
Vanadium Corporation of America, New York,
N.Y., a corporation of Delaware

Filed Aug. 10, 1962, Ser. No. 216,099

2 Claims. (Cl. 75-124)

This invention relates to a composition of matter which is capable of graphitizing cast iron in a highly effective manner.

Numerous compositions have been described in the art to cause cast iron which would ordinarily solidify white, i.e., to solidify with a high percentage of carbides, to dissociate these carbides so that the iron solidifies grey, i.e., contains carbon in the form of graphite.

The actual mechanism underlying the change from a white solidification to a grey solidification is as yet incompletely understood although numerous theories and explanations have been advanced.

Numerous metals and alloys have been proposed for use as inoculating agents in the production of grey iron castings. The standard inoculating agents are silicon, calcium-silicon, ferro-silicon, or other silicon alloys, as well as graphite. Various degrees of efficiency are achieved by the use of these agents, and it has been attempted over the years to improve their performance. One measure of the efficiency of an inoculating agent is the degree to which the iron carbide (cementite) is dissociated, resulting in the production of graphite. The direct effect of this conversion can be seen in the depth of chill produced when the metal is cast: the deeper the chill, the greater the residual cementite in the metal; the shallower the depth of chill, the greater the conversion of cementite carbon to graphite.

A variety of problems have been encountered in connection with the use of these alloys. In some cases the use of inoculants engenders surface porosity which may be the result of aluminum when present in relatively substantial proportions in the silicon alloy. Variations in the cooling rate that occur in castings of nonuniform section size cause structural differences that are minimized to different degrees by standard inoculants. Some inoculants, while causing dissociation of massive carbides, allow an undesirable type of interdendritic graphite to precipitate. Some inoculants tend to decrease the percentage of combined carbon in pearlitic structures and thereby weaken the matrix. Also, it has been observed that certain inoculants promote undesirably large, coarse graphite flake structures in heavy sections that are slowly cooled. Iron that has relatively low percentages of carbon and silicon is generally more difficult to inoculate properly than iron that contains higher carbon and silicon levels. The low carbon, low silicon irons are usually more prone to have massive carbides in castings of small sections. Large additions of some presently used inoculants are required to dissociate these carbides. These large additions often affect adversely the pearlitic structure and graphite size.

It is an object of this invention to provide an inoculating agent which causes the cementite in the iron to be substantially dissociated and the graphite to be evenly distributed in a beneficial manner throughout the section of the resultant casting.

It is another object of this invention to provide castings having a greatly reduced depth of chill as an indication of the effectiveness of the inoculant of this invention.

It is a further object of this invention to provide an inoculating agent which produces the desired effects under the addition of very small amounts of this agent.

It is a further object of this invention to provide an inoculating agent which does not impair the surface quality of the castings produced.

2

Other useful objects will become apparent in the course of the following specifications.

The drawing is a graph in which the percent of barium in the alloy is plotted against the chill depth in $\frac{1}{32}$ ".

5 The alloy of this invention is designed to provide a satisfactory inoculant which does not impair the surface quality of the casting and which provides satisfactory results over a wide range of sections. It is furthermore designed to develop a high strength cast iron which can be used in applications where the mechanical stresses to which the castings are exposed are considerable. Minimal additions of the inoculating agent will provide a casting which does not contain massive carbides, but which has largely graphitic carbon, along with combined carbon in a pearlitic structure. It is, however, not only important that the carbon be present as graphite, but that the graphite be present in a beneficial form. The graphite produced by the addition of the alloy of this invention is in a fine, randomly dispersed condition throughout the casting.

20 The effect of inoculating agents thus becomes apparent by graphitization which is amenable to measurement. Generally the effect of graphitization is measured in grey iron foundry technology by determining the amount of chill that develops during the solidification of the grey iron. This test may be performed in a number of ways. In the following specifications the test method employed has been identified by the industry-wide standard established by ASTM. In these tests, the depth of chill is inversely proportional to the effectiveness of the graphitizing treatment, i.e., the less the chill, the more effective the treatment, and vice versa. Chill is usually measured in $\frac{1}{32}$ ". The alloy of this invention when added to grey irons containing around 3% C, 2% Si, 0.75% Mn, 0.1% S in amounts of between two and four pounds per ton of iron, produced a very satisfactory reduction of chill when compared with either the untreated iron or with iron treated by the more conventional graphitizing agents.

40 The metallic matrix developed in grey irons produced by using the alloy of this invention can be either ferritic or pearlitic in character, and thus such castings exhibit high strength, depending on the composition of the iron. In addition, the alloy renders the matrix structure less sensitive to the effects of section size. Accordingly, the mechanical characteristics of the casting are more uniform and consistent.

45 The alloy of this invention is a silicon-based composition containing auxiliary inoculating elements in a carefully balanced relationship.

50 The constituents of the alloy of this invention are as follows: 58-68% Si, 9-12% Mn, 1.5-4% Ca, 2.5 min. Ba, 0.8-1.8% Al, balance iron and incidental impurities.

55 In the above composition the limits of barium have been defined merely as a minimum. It has been determined as a result of extensive tests that barium above a minimum content of about 2.5% in alloys of the above composition contributes markedly to its graphitizing power and there is actually no specific upper limit to the effectiveness of this constituent. However, for reasons of economics, I may indicate an upper limit in the order of 60 15 to 20% barium in the alloy of this invention.

65 This point of effectiveness of barium with respect to graphitizing is shown in FIGURE 1 attached hereto. FIGURE 1 plots the barium content against a 4C chill depth in $\frac{1}{32}$ " as specified by ASTM standards. For the preparation of this graph, additions of 4 pounds per ton of iron were made of an alloy containing 62% Si, 10% Mn, 1.8% Ca, 1.0% Al, balance iron and barium. The base iron used in these tests analyzed as follows: 3.15% C, 2.0% Si, 0.5% Mn, 0.08% S. The tapping temperature was 2850° F., the treating temperature 2775° F., and the pouring temperature, 2650° F. As is evident

from FIGURE 1, the base iron had a chill depth of $\frac{3}{32}$ ".

The graph indicates that the alloy composition without barium reduced the chill depth to $\frac{1}{32}$ ". The addition of 2.5% barium brought the chill down to $\frac{1}{32}$ ", 5% to $\frac{1}{32}$ ", and 10% lowered the chill depth to $\frac{1}{32}$ ". Further increases in barium apparently had no additional beneficial effect, but neither was there a reversal in effectiveness. In view of these data, the barium level in the alloy of this invention is best defined as 2.5% minimum and a maximum of between 15 and 20%.

The alloy of this invention is added generally in amounts of between 2 and 4 pounds per ton of iron. Occasionally the addition may range up to 15 pounds per ton. Conversely, additions on a smaller scale than 2 pounds per ton may also be made under some practices.

The following particulars will provide data relating to the performance in service of the alloy of this invention which is compared to a standard inoculating alloy designated as alloy "X" which is well established in the industry as a superior product.

Table I below gives the chemical composition of the two alloys used. In the following text the alloy of this invention has been designated as "No. 63."

TABLE I

Composition of Inoculants

Alloy	Si	Mn	Ca	Ba	Zr	Al	Fe
X-----	59.56	7.02	3.49	Nil	5.96	1.01	Bal.
63-----	63.16	9.87	1.20	4.94	Nil	1.07	Bal.

The above described inoculating alloys have been tested by inoculating an iron having the approximate composition of 3% C, 2% Si, .75% Mn, 0.1% S. This iron was produced as a 300 lb. heat in an induction furnace from which 100 lbs. taps were made and the inoculating alloy was added to the stream as the iron entered the ladle. The metal in the ladle had a chemical composition as shown in the following Table II.

TABLE II

Base Iron Composition, Percent

Iron Heat	C	Si	Mn	S	C Eq.
1-----	2.90	2.05	0.79	0.10	3.58
2-----	2.95	1.86	0.76	0.09	3.57
3-----	3.10	1.83	0.76	0.09	3.71
4-----	3.46	2.35	0.59	0.10	4.24
5-----	3.03	1.87	0.74	0.09	3.65
6-----	2.91	1.95	0.78	0.09	3.56

The irons described in the above table were then poured into two ladles and tested. A number of ASTM type 4C chill specimens were obtained which yielded the results as shown in Table III below.

TABLE III

Iron Temperature and Treatment

Iron Heat	4C Base Chill $\frac{1}{32}$ "	Inoc. Temp., ° F.	Inoculation, Percent		Pouring Temp., ° F.		4C Chill Depth, $\frac{1}{32}$ "	
			Ladle 1	Ladle 2	Ladle 1	Ladle 2	X	#63
1-----	32	2,700	0.20 X	0.20 #63	2,610	2,610	18.0	16.0
2-----	30	2,750	0.20 X	0.20 #63	2,650	2,620	16.5	12.5
3-----	30	2,750	0.20 #63	0.20 X	2,670	2,640	17.0	14.0
4-----	27	2,700	0.20 #63	0.20 X	2,620	2,600	9.0	5.5
5-----	30	2,750	0.10 #63	0.10 X	2,570	2,540	22.5	21.5
6-----	32	2,750	0.10 X	0.10 #63	2,640	2,590	19.0	19.0

It will be seen from the Table III that a very substantial reduction in the chill depth is achieved by both alloy X and alloy 63. However, the alloy of this invention shows a superiority of up to 38%, although in some cases only marginal advantages were observed.

As indicated above, the chill depth is the accepted measure of the effect produced by inoculating alloys upon the carbon contained in a cast iron. A complementary index of the quality is provided by mechanical tests.

Table IV provides information concerning these tests by offering data on the transverse strength and deflection of 1.2" arbitration bars and the tensile strength of 0.750" diameter specimen.

TABLE IV

Transverse and Tensile Data

Iron Heat	Transverse Strength, Lbs. (1.2" Arb. Bar)			Deflection, in. (1.2" Arb. Bar)			Tensile Strength, p.s.i. (0.750" Dia. Specimen)		
	Base	X	#63	Base	X	#63	Base	X	#63
1-----	2,150	2,870	2,900	17	34	35	24,900	41,100	40,400
2-----	1,950	2,600	2,700	17	34	35	30,100	38,500	38,700
3-----	1,850	2,600	2,640	16	34	34	30,700	38,000	37,200
4-----	1,900	1,870	1,940	21	33	33	21,200	24,900	26,500
5-----	1,800	2,100	2,230	16	22	25	30,000	30,600	33,400
6-----	1,900	2,600	2,580	15	30	29	31,900	38,300	36,500

From these tables again the beneficial effect of the inoculation is apparent, an effect which is most clearly demonstrated by the improvement in the deflection, i.e., the elasticity of the product. Here the improvement by the addition of inoculants is generally a factor of two, except where only a .10% addition of inoculant was made. Also in this instance, the alloy of this invention shows a marginal superiority over the standard alloy, a superiority which is reflected, with a single exception, also in the transverse strength. In the tensile test data there is on balance a distinct advantage on the side of the alloy of this invention, although in some instances its performance was not superior to alloy X.

Table V below offers data on the Brinell hardness readings obtained on step castings. These castings are made to provide different section sizes and thus to give information on hardness development in depth. Since lower hardness readings are a measure of graphitization effectiveness of an inoculating alloy, these data clearly show the excellent performance of the alloy of this invention.

TABLE V

Brinell Hardness of Step Castings

Iron Heat	Brinell Hardness of Sections									
	1/16"		1/8"		1/4"		1/2"		1"	
	X	#63	X	#63	X	#63	X	#63	X	#63
1-----	474	357	252	248	226	215	218	218	208	217
2-----	540	*	264	235	230	234	218	214	202	184
3-----										
4-----	455	455	242	239	224	226	209	206	206	209
5-----	520	470	252	270	243	240	224	230	215	212
6-----										

* Section was broken off and lost in handling.

In addition to the laboratory tests, a foundry test was made using the alloy of this invention having the following composition: 63.22% Si, 10.12% Mn, 2.44% Ca, 5.37% Ba, 1.42% Al, balance Fe. Tests were carried out on acid cupola iron that had nominally 3.40% C, 2.05% Si, 0.75% Mn, 0.11% S, and 0.07% P. The base iron contained also 0.15% Cr, which was increased by the addition of some chromium to 0.30%.

The iron was tapped continuously into an 8-ton forehearth, poured into 2-ton transfer ladles and then distributed into 1-ton pouring ladles. Inoculation took place in the transfer ladle, using a -0.4'+32 mesh alloy.

The temperatures were as follows: 2840-2860° F. for the

cupola spout, 2750-2770° F. into the transfer ladle, 2630-2660° F. at the end of the pour. Each ton of iron required 10 minutes for pouring. Alloy X is usually used in this foundry and here it was compared with alloy #63. The results of these tests are set forth in Table VI below.

TABLE VI

Test	Type Inoculant	Percent Addition	Base Chill, 1/16"	Final Chill, 1/16"		
				Transfer Ladle	Start of Pour	End of Pour
A.....	X.....	0.075	4	2.5	2.5	3.0
B.....	Alloy #63.....	0.070	6	2.5	2.0	2.0
C.....	do.....	0.070	3	1.0		
D.....	do.....	0.038	7	3.0		

The above results confirm the experimental results described earlier.

I claim:

1. An inoculating alloy for grey iron, said alloy consisting essentially of 58 to 68% silicon, 9 to 12% manganese, 1.5 to 4% calcium, a minimum of 2.5% barium, and 0.8 to 1.8% aluminum, the balance being iron and incidental impurities.
2. An inoculating alloy for grey iron, said alloy consisting essentially of 58 to 68% silicon, 9 to 12% manganese, 1.5 to 4% calcium, 2.5 to 20% barium, and 0.8 to 1.8% aluminum, the balance being iron and incidental impurities.

References Cited in the file of this patent

UNITED STATES PATENTS

2,266,123	Kinzel	Dec. 16, 1941
3,000,731	Ototani	Sept. 19, 1961
3,033,676	Cox	May 8, 1962