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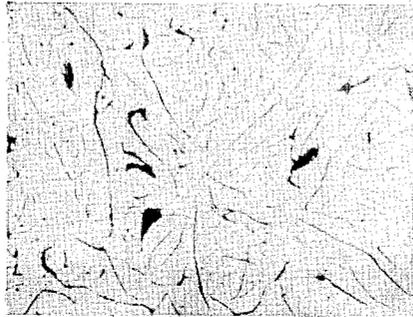
K. D. MILLIS ET AL

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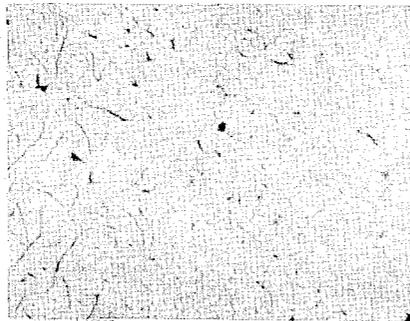
GRAY CAST IRON HAVING IMPROVED PROPERTIES

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2 Sheets-Sheet 1



*Fig. 1.*



*Fig. 2.*

KEITH DWIGHT MILLIS  
ALBERT PAUL GAGNEBIN  
NORMAN BODEN PILLING

INVENTORS

BY *a. d. Deller*  
ATTORNEY

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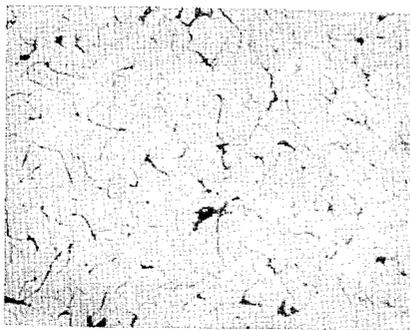
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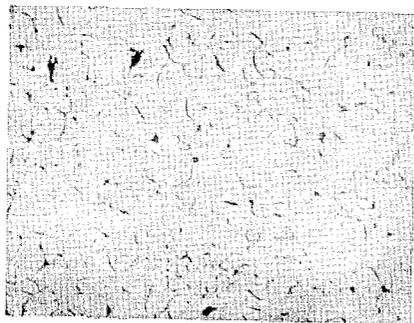
GRAY CAST IRON HAVING IMPROVED PROPERTIES

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2 Sheets-Sheet 2



*Fig. 3.*



*Fig. 4.*

KEITH DWIGHT MILLIS  
ALBERT PAUL GAGNEBIN  
NORMAN BODEN PILLING

INVENTORS

BY

*A. P. Weller*  
ATTORNEY

# UNITED STATES PATENT OFFICE

2,485,761

## GRAY CAST IRON HAVING IMPROVED PROPERTIES

Keith Dwight Millis, Rahway, Albert Paul Gagnebin, Red Bank, and Norman Boden Pilling, Westfield, N. J., assignors to The International Nickel Company, Inc., New York, N. Y., a corporation of Delaware

Application March 20, 1948, Serial No. 16,106  
In Great Britain March 22, 1947

8 Claims. (Cl. 75-123)

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The present invention relates to an improved gray cast iron and more particularly to a new gray cast iron having an improved and unusual combination of properties, including founding properties and mechanical and physical properties.

Gray cast iron has been one of the most widely used ferrous engineering materials. It is easily made, is soft and machinable and has physical properties which make it useful in a wide number of applications. Gray cast iron is a ferrous alloy containing graphitic carbon, i. e., gray cast iron is a ferrous alloy containing uncombined carbon in excess of that carbon required to form the ferrous matrix. This excess uncombined carbon appears in the form of elongated, warped, thin plates or flakes which are disseminated throughout the matrix of the iron. Ordinary gray cast iron has been recognized to be a weak, brittle material as compared to materials having compositions and structures substantially the same as the matrix of the gray cast iron. The comparatively poor mechanical properties possessed by gray cast iron are generally attributed to the effect produced by the presence of the elongated flake graphite particles. Because of the great effect of flake graphite in lowering the strength, toughness and ductility of gray cast iron, it has been found that, when it is attempted to improve the properties of gray cast iron through improving the strength of the matrix thereof, large improvements in the strength of the matrix have produced only relatively minor overall improvements in the properties of the gray cast iron. Similarly, advances in the melting, founding and processing techniques have produced only relatively small improvements in the properties of gray cast iron. Although many attempts have been made to provide a solution to these and the other problems relating to the manufacture of improved gray cast iron, none, as far as is known, has been entirely successful when carried into practice on an industrial scale.

It has now been discovered that through a simple treatment of gray cast iron melts, e. g., in a ladle, the mode of occurrence of the graphite flakes in gray cast iron can be materially affected in a beneficial manner to improve markedly the properties of the cast iron.

It is an object of the present invention to provide a gray cast iron containing graphite having a compacted flake form, and a method of producing the same.

It is a further object of the present invention to provide a gray cast iron having an improved

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combination of founding properties together with improved mechanical and physical properties.

It is a still further object of the present invention to provide a gray cast iron having an improved combination of mechanical and physical properties even in the presence of relatively high carbon contents.

Other objects and advantages of the present invention will become apparent to those skilled in the art from the following description, taken in conjunction with the drawings in which:

Figure 1 is a reproduction of a photomicrograph taken at 100 magnifications showing the structure of a plain gray cast iron devoid of the special element contemplated by the present invention;

Fig. 2 is a reproduction of a photomicrograph taken at 100 magnifications and depicting the structure of the same gray cast iron as shown in Fig. 1 but containing the special element in an amount within the range contemplated by the present invention;

Fig. 3 is a reproduction of a photomicrograph taken at 100 magnifications showing the structure of another plain gray cast iron devoid of the special element contemplated by the present invention; and

Fig. 4 is a reproduction of a photomicrograph taken at 100 magnifications and depicting the effect of the special element contemplated by the present invention upon the structure of the gray cast iron shown in Fig. 3.

Broadly stated, the present invention provides a gray cast iron containing at least about 50% iron, carbon and silicon within the cast iron range and containing a controlled amount of retained magnesium within the range of from at least about 0.02% up to 0.04%. The product of the invention is characterized by a microstructure in which the graphite appears in the form of compacted flakes, i. e., the flake graphite in the alloy of the invention appears as particles which are shorter and thicker than the flakes which occur in gray cast irons having a similar composition but which are devoid of magnesium. Magnesium has a progressive effect on the size and form of the graphite. Small quantities within the ranges contemplated by the present invention shorten the flakes, while larger quantities of the order of about 0.03% promote further reduction in the length of the flakes besides tending to curl and thicken them. With 0.035% and more magnesium, there is considerable compacting of the graphite in the form of thick short flakes, irregular masses, some more rounded masses and possi-

bly occasional spheroids. At least about 75% of the graphite present in the gray cast iron of the invention will be present in the compacted flake form.

The magnesium-free base composition of the gray cast iron of the invention is one which would be a gray cast iron if cast in an inoculated condition. Thus, the product of the invention can have any matrix structure found in gray cast iron. For example, a matrix may be pearlite, ferrite, martensite, austenite, an acicular constituent (e. g., bainite or other transformation products of austenite explained by the S-curve), tempered martensite or sorbite, etc., or the known combinations thereof. The application of the invention to high strength acicular irons increases the strength, toughness, modulus and fatigue resistance. In general, the process is applicable to any cast iron containing flake graphite. The influence of composition upon the structural constituents and properties of the matrix and the control of these structural constituents and properties of the matrix are known to those skilled in the art of gray cast iron.

A feature of the present invention in obtaining the novel gray cast iron product containing the shorter, thicker or compacted graphite flakes and having high properties is the introduction of magnesium into the molten bath from which the gray cast iron is made and the retention in the final product of amounts of magnesium within the ranges set forth herein. It is not sufficient merely to add magnesium to the molten bath. The presence of retained magnesium in the gray cast iron of the invention is essential in order to obtain the improved properties which characterize the magnesium-containing gray cast iron product. It has been found that magnesium has a powerful whitening effect on gray cast iron. Thus, a gray cast iron melt containing magnesium in accordance with the invention will usually produce castings having a carbidic network structure unless inoculation is employed as contemplated by the invention. It has been found that carbidic network structures must be avoided because they have a deleterious effect upon the properties obtainable in alloys of the invention. However, where special properties such as wear resistance, heat resistance, etc., are desired, primary carbides may be present. Thus, cast irons containing chromium for heat resistance are improved by the present invention. This is believed to be due to the fact that oxide penetration along the graphite particles is reduced as compared to the oxide penetration that occurs in ordinary gray cast irons having longer flakes. Likewise, cast irons such as the nickel-chromium cast irons used for dies in forming sheet metal are improved by the present invention. The improved properties of these cast irons are attributed to their greater modulus of elasticity, strength and hardness when produced in accordance with the present invention. The gray cast irons produced in accordance with the invention are especially useful in heavy sections where the graphite flakes normally tend to be quite large when made in a conventional manner.

A graphitizing inoculation of the magnesium-containing melt shortly before casting is an important feature of the invention and effectively prevents the formation of the aforementioned harmful carbide network structures. The graphitizing inoculation is preferably made shortly after the magnesium introduction, but may be made simultaneously therewith, and

shortly before casting the cast iron. A preferred graphitizing inoculation comprises a late addition of silicon in amounts between about 0.3% up to about 2.5%, more preferably between about 0.4% and 1.2%. The magnesium-containing inoculated bath should be cast very quickly after the inoculation, for example, within about 3 minutes after inoculation, as it has been found that magnesium is lost if the bath is held for a substantially longer time and that the inoculating effect wears off and is lost if the bath is held much longer after inoculation. This can be compensated for by another inoculating addition which may incorporate a smaller amount of the inoculant, e. g., as little as about 0.1% or 0.15% silicon may be sufficient. Silicon may be introduced in the form of ferro-silicon, e. g., an iron alloy containing about 50% to about 95% silicon, although other metallic silicon-containing agents or alloys such as nickel-silicon alloys or nickel silicide, calcium-silicon alloys or calcium silicide, silicon metal, and various proprietary inoculating alloys commonly used for reducing dendriticism and chill in foundry gray cast irons may be employed. Aluminum and its alloys are not as preferred as the silicon-containing inoculating agents.

As indicated hereinbefore, the magnesium-containing gray cast iron contemplated by the invention can be produced from any molten bath which would be a gray cast iron when cast in an inoculated condition. This includes molten baths having such high graphitizing power that they would be gray cast irons when solidified regardless of whether or not they were inoculated. Satisfactory results have been obtained from molten baths which contain 1.7% to 5% carbon and 0.5% to 5.5% silicon and which provide a final product containing the same amount of carbon in combination with 1% to 6% silicon, in addition to the amounts of retained magnesium contemplated by the invention. It is preferred to maintain the carbon content of the bath within the range of about 2% to 4.5%, especially about 2.5% to 4%, in combination with silicon within the aforementioned range, preferably within the range of 1% to 4.7% and more preferably 1.2% to 4.2%.

The magnesium-containing improved gray cast iron of the invention will generally contain over 1.7% to less than about 5% carbon. More preferably, the carbon content will fall within the range of about 2% to about 4.5%, especially about 2.5% to about 4% carbon. As will be obvious to those skilled in the art, some of the carbon present in the cast iron is usually required to produce the matrix structure. For example, if the matrix is pearlite, the cast iron will contain about 0.8% combined carbon. Other microconstituents of the matrix are also usually deemed to contain combined carbon, and the combined carbon present in the cast iron of the invention will usually be within the range of about 0.3% to 1.2% when the cast iron is in the as-cast condition. The excess carbon not required to produce the matrix will be mainly uncombined carbon. As pointed out hereinbefore, over 75% of the uncombined carbon will be present in the compacted form of graphite described hereinbefore. The silicon content of preferred gray cast irons produced in accordance with the invention will be at least 1% of the cast iron and will usually fall within the range of 1.3% to about 5%, preferably within the range of 1.5% to 4.5%. An important effect attributable to magnesium in gray cast irons produced in accordance with the

invention is that of causing the graphite to occur in the compacted forms described hereinbefore. The retained magnesium content of the cast iron will usually be within the range of 0.02% to 0.04%. It is preferred that the magnesium content be relatively high when the carbon content is relatively high, i. e., exceed about 0.03% as the carbon content reaches 3% or more. Thus, when the carbon content is about 3% a magnesium content of about 0.035% produces good results, when the carbon content is 3.5% a magnesium content of about 0.039% is satisfactory, and when the carbon content is about 4% a magnesium content of about 0.043% is highly effective. None of the common alloying elements employed in gray cast irons, with the possible exception of large amounts of copper, have been found to prevent the results of the invention from being obtained. Thus, the gray cast iron may contain usual amounts of alloying elements such as nickel, molybdenum, chromium, manganese, aluminum, etc. Nickel may be present in amounts up to about 40%. As those skilled in the art know, nickel has an important influence on the matrix structure; for example, when nickel is present in amounts of about 2%, the matrix will be pearlitic, when nickel is present in amounts of about 5% the matrix will be martensitic, and when the nickel content exceeds about 20% the matrix will be austenitic. Chromium may be present in amounts up to about 3.5%, e. g., 0.01% to 3.5%, and manganese in amounts up to about 2.5%, e. g., 0.01% to 2.5%. Preferably, the manganese content is within the range of about 0.4 to 0.9%. Molybdenum may be present in amounts up to about 2%, e. g., 0.01% to 2%. It is preferred that copper not be present in amounts exceeding about 3%, e. g., 0.01% to 3%. Certain elements, including tin, lead, antimony, bismuth, arsenic, selenium, tellurium, etc., have been found to be subversive to the effect of magnesium in controlling the form of flake graphite in the cast iron, and it is preferred that these elements be avoided although small amounts, preferably less than about 0.1%, may be tolerated in some instances. It is preferred that phosphorus (usually considered an impurity) be low, for example, below about 0.25% and more preferably below about 0.15%, although amounts as high as 0.5% may be present if high properties, especially impact properties, are not the primary consideration. The sulfur content of cast irons made in accordance with the invention is usually low, i. e., below about 0.08%. The sulfur content depends upon the original sulfur content of the base irons and the amount of retained magnesium. When 0.03% or more magnesium is retained, the sulfur level is usually less than about 0.02%, regardless of the initial quantity in the base iron. With less retained magnesium, the sulfur level may be as high as 0.08% and, in general, the final sulfur content will vary inversely with the amount of retained magnesium. The foregoing applies to base irons with normal sulfur contents of the order of 0.10% to 0.14%; obviously, in low sulfur base irons, no relation exists between the sulfur content and the retained magnesium. In general, the sulfur content will usually be within the range of 0.015% to 0.08%. The balance of the composition is iron (including small amounts of impurities, preferably less than a total of about 0.5%). The iron content is generally at least 50% or more, usually at least 55% by weight of the alloy, and in the case of unalloyed or low-alloyed products will be

at least about 90% or 87% of the total composition.

Figures 1 to 4 illustrate the influence of magnesium in shortening and/or compacting the graphite flakes. Fig. 1 depicts the structure of a magnesium-free cast iron containing about 3.5% carbon and about 2.25% silicon, while Fig. 2 shows the microstructure of the same gray cast iron after the introduction of 0.039% magnesium. The effect of magnesium upon the shape and size of the graphite particles is apparent from a comparison of the two microstructures. Similarly, Figs. 3 and 4 show the respective microstructures of a magnesium-free and a magnesium-containing gray cast iron comprised of about 3% carbon and 1.75% silicon. The magnesium-containing gray cast iron had a retained magnesium content of 0.033%. Again, the effect of magnesium upon the size and shape of the graphite flakes is apparent from these structures.

For general purposes, it is preferred that products having a pearlitic matrix be employed; and for this purpose, it is preferred to employ a composition containing the amounts of elements set forth in Table I.

Table I

Element	Range
Carbon.....	Per cent 2.5 to 3.2
Silicon.....	1.6 to 2.5
Magnesium.....	0.02 to 0.04
Nickel.....	0 to 3
Manganese.....	0.4 to 0.9

The balance of the composition will be essentially all iron except for incidental small amounts of impurities, etc. Up to about 1% of molybdenum may be present, e. g., 0.01% to 1.0%. The nickel content will usually fall within the range of 0.01% to 3%. The nickel content is preferably at least 0.25%, and more preferably at least 0.5%. Magnesium-containing gray cast irons made in accordance with the invention will have higher mechanical and physical properties than the corresponding magnesium-free base composition.

Magnesium-containing cast irons having a pearlitic matrix and compositions within the ranges set forth in Table I will usually be stronger than similar cast irons devoid of magnesium, e. g., the magnesium-containing cast irons will have tensile strengths at least about 5000 and up to 30,000 pounds per square inch higher than a comparable magnesium-free gray cast iron. In addition, the magnesium-containing cast irons will usually have improved ductility, impact resistance, modulus of elasticity and fatigue properties in combination with this greater strength. The properties of magnesium-containing gray cast irons having compositions within the ranges set forth in Table I will usually be within the ranges set forth in Table II.

Table II

Transverse properties: <sup>1</sup>	
Defl., inches.....	0.15 to 0.20
Load, pounds.....	4,500 to 7,500
Tensile strength, p. s. i.....	45,000 to 75,000
Brinell hardness number.....	200 to 300
Impact resistance, ft.-lbs.....	35 to 65

<sup>1</sup>Determined on 1.2-inch diameter arbitration bar over 12-inch span.

The influence of magnesium upon the properties and structure is particularly notable in gray cast irons having carbon, silicon and magnesium contents within the ranges set forth in Table I, and

small increases in the percentage of retained magnesium within said range have a marked effect upon the properties, especially the strength.

The properties of magnesium-containing cast iron compositions having matrices other than pearlitic matrices will also be higher than the properties of similar cast iron compositions devoid of magnesium. For example, it can be said that cast iron compositions containing amounts of magnesium as defined by the present invention will have tensile properties at least 3000 pounds per square inch greater than similar magnesium-free gray cast irons, and this increase in tensile strength will usually be accompanied by an increase in impact, ductility, heat resistance and compressive strength. Usually, the improvement will be at least 5000 pounds per square inch in tensile strength for matrices other than austenitic ones where the minimum improvement may be less, e. g., 3000 pounds per square inch. In order to insure the high order of improved properties in cast irons made in accordance with the invention, it is essential that the cast irons contain amounts of retained magnesium as set forth herein and that these cast irons be substantially devoid of any carbide network structure, for example, the network that can be seen with the naked eye in the fractures of cast irons, such as magnesium-containing cast irons which have not been effectively inoculated.

The necessity for having the required retained magnesium content in the as-cast product made in accordance with the present invention is illustrated by the data in Table III setting forth the mechanical properties of similar iron-base compositions devoid of magnesium and containing various amounts of magnesium. The properties set forth in Table III are the properties of the product in the as-cast condition determined from standard unmachined arbitration bars having a diameter of 1.2 inches, except for the tensile strength which was determined from a tensile specimen machined out of the arbitration bar. All cast irons, except No. 4 and No. 5, were inoculated with a ladle addition of 0.5% silicon as ferrosilicon. The magnesium-containing cast irons Nos. 2 and 3 were inoculated shortly after the magnesium addition and shortly before casting.

Table III

[Composition: 3.1% C; 1.6% Si; 0.8% Ni; 0.7% Mn; 0.02% P.]

No.	Per cent Mg.*	Transverse		T. S.	BHN	Impact
		Defl.	Load			
1	0	0.155	3,610	39,940	216	28
2	0.019	0.197	4,590	47,880	222	39
3	0.033	0.176	6,160	69,400	269	56
4	0	0.147	3,910	38,220	213	27
5	0.023	0.155	3,880	32,840	222	22

\*Mg introduced as 80% nickel-20% magnesium alloy.  
 Defl. = Deflection in inches in transverse test determined on arbitration bar over 12-inch span.  
 Load = Pounds required to fracture arbitration bar transversely over 12-inch span.  
 T. S. = Tensile strength in pounds per square inch.  
 BHN = Brinell hardness number.  
 Impact = Foot pounds required to break full-sized unnotched standard arbitration bar in Izod (120 ft.-lb.) impact testing machine.

It will be observed from the foregoing table that a notable improvement in properties is obtained in the magnesium-containing gray cast irons made in accordance with the invention. In addition, the importance of avoiding a carbide network and of inoculating the cast iron melt after the introduction of the required amount of retained magnesium is illustrated by comparing the properties of No. 5 with the properties of No. 2.

No. 5 had a definite carbide network which was apparent upon inspection of the fractured test bar with the naked eye or a low-powered hand lens. This cast iron, although of the same hardness as No. 2, was weaker, more brittle and less ductile than the corresponding No. 2 which had been inoculated and, accordingly, was substantially devoid of a carbide network.

In order that those skilled in the art have a better understanding of the properties which can be obtained by the present invention, the compositions of some as-cast gray cast irons made in accordance with the invention and containing the compacted form of flake graphite are set forth in Table IV and their properties in the as-cast condition are set forth in Table V. The balance of the composition of the gray cast irons set forth in Table IV was iron except for small amounts of impurities. The transverse properties and impact properties were determined from unmachined standard arbitration bars having a diameter of 1.2 inches, and the tensile properties were determined on machined test specimens.

Table IV

No.	Per cent C	Per cent Si	Per cent Mg	Per cent Mn	Per cent Ni	Per cent P
6	2.6	1.9	0.038	0.6	2.0	0.05
7	3.1	2.0	0.036	0.8	1.1	0.09
8	3.4	2.4	0.033	0.7	2.8	0.063
9	3.4	2.3	0.037	0.2	0.87	0.02
10	3.5	2.3	0.032	0.15	0.35	0.047
11	3.5	2.3	0.031	0.2	0.75	0.02
12	3.7	3.7	0.033	0.7	0.4	0.073
13	4.1	2.7	0.033	0.5	1.1	0.027

Table V

No.	Transverse Props.		BHN	Impact	T. S.	Improvement in T. S.*
	Defl.	Load				
6	0.211	8,120	289	62	76,000	25,000
7	0.156	6,320	262	46	64,000	19,000
8	0.124	3,780	227	23	40,000	18,600
9	0.377	6,850	208	120+	58,700	31,000
10	0.157	4,030	202	n. d.	44,840	23,000
11	0.400	5,930	174	120+	39,240	17,000
12	0.146	3,360	171	18	34,260	5,740
13	0.194	2,830	126	25	23,680	6,240

\*Improvement over comparable magnesium-free gray cast iron. n. d. = not determined.

Tables IV and V illustrate the application of the invention to cast irons of varying composition over a wide range of carbon contents. These data illustrate the improved properties obtained in accordance with the invention. A feature of the invention is that cast irons ordinarily considered to be soft, weak, gray irons can be markedly improved by a simple ladle treatment with magnesium and an inoculant while the cast iron is in the molten condition.

As pointed out hereinbefore, it is essential that amounts of magnesium within the ranges defined herein be present in the novel product of the invention. If any undesirable elements which tend to combine with and/or counteract the effect of magnesium are present in the molten cast iron bath from which the magnesium-containing product of the invention is to be produced, the amount of magnesium introduced into the bath should be increased by the amount required to counteract the effect of the presence of such elements or impurities by removing the elements or by otherwise overcoming their effects. Sulfur is the magnesium-counteracting element which is most likely to be present, and when sulfur is

present in the molten bath, it is necessary to introduce into the bath an amount of magnesium which is sufficient not only to produce the desired retained magnesium content but also to react with sulfur. Many baths that can be treated in accordance with the invention will contain amounts of sulfur as high as even 0.3% or more. It is therefore necessary to add an amount of magnesium which is sufficient to introduce magnesium to combine with this sulfur and to provide an excess sufficient to give the retained magnesium content required by the invention. The introduction of about three parts by weight of magnesium is required to react with about four parts by weight of sulfur. In actual practice, it is preferred to introduce one part by weight of magnesium for each part by weight of sulfur to be removed.

The introduction of the essential amounts of magnesium required by the present invention can be accomplished in a number of ways. The amount of magnesium to be added to the bath will depend upon a number of factors including the retained magnesium content desired, the additional amounts of magnesium required to overcome the presence of interfering elements such as sulfur, etc., the amount of magnesium lost by delaying the casting of the bath after the introduction of magnesium, and the proportion of magnesium recovered in the bath from the magnesium addition agent. This last factor presents considerable difficulties, as it has been found that in many cases no magnesium can be recovered from the addition agent employed or only a small amount recovered, e. g., 3% of the amount added. The art has taught that magnesium does not alloy with iron, and as a matter of fact, when it has been attempted to introduce metallic magnesium in elemental form into a molten bath of iron when the latter was at the ordinary elevated temperature required for satisfactory casting, a reaction of such explosive violence took place that the molten iron was blown from the receptacle in which it was held. In addition, it is known that the temperatures of molten iron baths usually exceed the boiling temperature of magnesium. The fact that the introduction of elemental magnesium into molten iron baths produces a reaction of explosive violence has been well recognized in the art heretofore, and the introduction of magnesium into molten iron has been generally regarded as being impossible on a practical scale. It is preferred to add the magnesium as a metallic agent, such as an alloy containing about 2% to about 40% magnesium, the balance preferably being nickel and/or copper. It is more preferred to employ a nickel-base alloy containing the foregoing amounts of magnesium, especially 4% to 20% magnesium. A detailed description of suitable addition alloys which have been employed in producing the magnesium-containing cast iron products of the present invention can be found in our corresponding United States patent application, Serial No. 787,420.

The product containing compacted flake graphite in the as-cast condition has been satisfactorily produced by a method which comprises establishing a molten bath of such composition that it would be a gray cast iron if inoculated (including those cast irons which would be gray even though not inoculated) and cast in a sand mold or in the mold in which it is to be cast, regulating the temperature of the molten bath to a proper casting temperature, e. g., a temperature within the range of about 2450° to 2850° F., but preferably within the range of 2650° to 2750° F., trans-

ferring all or part of the molten metal of the bath to a ladle, adding a nickel-rich magnesium alloy to the molten metal in the ladle in an amount sufficient to provide a retained magnesium content in the solidified metal of about 0.02% to 0.04%, inoculating the magnesium-containing molten metal with at least about 0.3%, e. g., 0.4% to 1.2%, of silicon, preferably as ferrosilicon, and then quickly casting the inoculated magnesium-containing molten metal into molds, preferably within three minutes after the last inoculation. The treated inoculated metal can be cast in accordance with accepted foundry technique for gray cast iron.

An unusual feature of the invention is that the magnesium treatment very effectively removes sulfur from the molten ferrous bath even when it is under the influence of acidic conditions such as created by furnace linings, ladle linings, slags, etc., of a siliceous nature or other acidic nature as well as under neutral or basic conditions created by the furnace lining, the ladle lining, the slag, etc. Another unusual feature of the invention is that the removal of sulfur by the magnesium treatment does not require the presence of any slag and takes place regardless of whether a slag is or is not present. For example, sulfur can be removed by the magnesium treatment from a molten ferrous bath while it is not covered by a slag and while it is being held in an acid-lined ladle or other acid-lined container.

As indicated hereinbefore, alloys which are cast without inoculation or which have been ineffectively inoculated, may contain a carbide network structure which prevents the realization of improved properties. However, properties of such improperly made castings can be improved by a heat treatment above the temperature at which the alpha-gamma transformation takes place in the alloy. The treating time, at temperatures above the critical temperature, will generally be at least about one hour but less than about 15 hours, e. g., about 3 to 5 hours. A suitable treatment comprises subjecting a casting to temperatures between about 1750° and 1500° F., although temperatures within the range of about 1800° and 1400° F. may be used.

The present invention may be applied to the manufacture of a wide variety of ferrous products which will be apparent to those skilled in the art from the properties and structure of the ferrous alloy provided by the invention. The cast iron provided by the invention is particularly useful where so-called high-quality cast irons of the prior art have been employed. Illustrative products and articles include crank shafts; stamping dies; heat- and oxidation-resistant parts such as furnace parts, stove parts, grate bars, etc.; machine tool beds and frames, particularly those having heavy sections; frames for other machinery, including punching presses etc.; railroad and farm machinery castings; internal combustion engine castings; etc.

Although the present invention has been described in conjunction with preferred embodiments, it is understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Variations and modifications apparent to those skilled in the art are considered to be within the purview and scope of the invention and appended claims.

We claim:

1. As an article of manufacture, a casting

comprised of a gray cast iron containing about 2.5% to 4% carbon, about 1.5% to 4.5% silicon, about 0.01% to 2.5% manganese, at least 0.02% and up to 0.04% magnesium, and the balance essentially iron, said gray cast iron being characterized by a microstructure containing at least 75% of the graphite in a compacted flake form.

2. As an article of manufacture, a casting containing 0.02% to 0.04% magnesium, the balance being a gray cast iron composition.

3. A gray cast iron containing about 2% to 4.5% carbon, about 1.3% to 5% silicon, at least about 0.02% and up to 0.04% magnesium, and the balance essentially all iron and alloying elements.

4. A gray cast iron containing about 1.7% to about 5% carbon, less than 1.2% carbon being in the combined form, about 1% to 6% silicon, at least about 0.02% and up to 0.04% magnesium, up to 40% nickel, up to 3.5% chromium, up to 2.5% manganese, up to 2% molybdenum, up to 3% copper and the balance essentially all iron.

5. A method for producing an improved gray cast iron which comprises establishing a bath of molten metal containing at least about 87% iron, 1.7% to 5% carbon and 0.5% to 5.5% silicon and having such a composition as to be a gray cast iron when inoculated and cast, introducing into said bath an amount of magnesium sufficient to provide a retained magnesium content in castings made from said bath of at least 0.02% and up to 0.04% magnesium, inoculating metal in the bath containing said amount of magnesium with at least about 0.3% of silicon and casting the inoculated metal to obtain a gray cast iron containing the aforesaid amounts of retained magnesium, at least about 87% iron, 1% to 6% silicon and 1.7% to 5% carbon.

6. A method for producing an improved gray cast iron which comprises establishing a bath of molten metal having such a composition as to be a gray cast iron when inoculated and cast, introducing into said bath an amount of magnesium sufficient to provide a retained magnesium content in castings made from said bath of at least 0.02% and up to 0.04% magnesium, inoculating metal in the bath containing said amount of magnesium in such a manner that

the inoculation does not precede the magnesium introduction, and casting the inoculated metal to obtain a gray cast iron containing the aforesaid amounts of retained magnesium.

7. A casting having a microstructure containing in the as-cast condition uncombined carbon in the form of compacted particles, said casting comprising about 0.03% to about 0.04% magnesium with the balance a gray cast iron composition containing at least 87% iron and being devoid of subversive amounts of elements materially interfering with the occurrence of the aforesaid form of uncombined carbon.

8. As a new article of manufacture, an iron casting characterized by a microstructure containing compacted particles of uncombined carbon in a matrix of the group consisting of pearlite and ferrite and containing about 0.02% to about 0.04% magnesium to promote the occurrence of uncombined carbon as compacted particles with the balance a gray cast iron composition normally containing uncombined carbon in the form of elongated flakes in the matrix, said gray cast iron composition being devoid of subversive amounts of elements which materially interfere with the aforesaid occurrence of uncombined carbon.

KEITH DWIGHT MILLIS.  
ALBERT PAUL GAGNEBIN.  
NORMAN BODEN PILLING.

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