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GRAY CAST IRON

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The present invention relates to a novel method for the production of gray cast iron containing spheroidal graphite and to the novel hypoeutectic gray cast iron product produced thereby.

It is an object of the present invention to provide a novel method for the production of hypoeutectic gray cast iron containing graphite in a spheroidal form.

Another object of the invention is to provide a novel hypoeutectic gray cast iron having a greatly improved combination of properties.

The invention also contemplates providing a novel hypoeutectic gray cast iron containing a special combination of elements to control the occurrence of graphite in a spheroidal form.

Generally speaking, the present invention contemplates a novel process for producing hypoeutectic gray cast iron containing uncombined carbon or graphite in a substantially spheroidal form in the as-cast condition and the product produced thereby. The novel process contemplated by the present invention comprises incorporating in a molten iron bath having such a composition as to be a hypoeutectic gray cast iron when inoculated and cast an amount of magnesium sufficient to provide a retained magnesium content of at least about 0.015% but less than about 0.035% or 0.04% in castings made from said bath, an amount of cerium sufficient to provide a retained cerium content of at least about 0.015% and up to about 0.16% in castings made from said bath with a total content of magnesium and cerium in said castings being at least about 0.035% or 0.04% up to about 0.2% and casting metal from said treated bath in an inoculated condition to produce castings of hypoeutectic cast iron containing uncombined carbon or graphite in a spheroidal form in the as-cast condition. Very satisfactory results are obtained when the retained content of magnesium plus cerium is about 0.05% to about 0.075%, although retained contents of magnesium plus cerium of up to about 0.1% can be employed especially in compositions having high graphitizing power, e. g., those cast in heavy sections such as about four inches. The cerium content is usually less than about 0.1%, e. g., up to 0.06% or 0.08%.

As those skilled in the art know, cast irons are eutectiferous alloys whose principal constituents

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are iron and carbon and hypoeutectic cast irons are those containing less carbon than the eutectic amount. The eutectic amount of carbon in any particular composition varies depending upon the amounts of other elements in the composition, e. g., silicon. Hypoeutectic gray cast irons are those containing carbon, silicon and phosphorus in such amounts that the carbon content plus one-third the silicon content plus one-third the phosphorus content is less than 4.3, e. g., 4.2 or less, with the carbon in excess of that required to form the matrix being predominantly in the uncombined form. In general, the gray cast iron compositions produced according to the present invention contain, in addition to the aforesaid amounts of magnesium and cerium, about 1.7% to about 3.9% carbon with the excess carbon not required to form the matrix being predominantly uncombined, about 1.2% to about 7% silicon, about 0.05% to about 2% manganese, up to about 0.5% phosphorus, up to about 10% nickel, e. g., about 0.05% to about 3% nickel, up to about 2% copper, e. g., about 0.05% to about 1.5% copper, and the balance essentially iron to provide a ferrous matrix. The iron content is usually at least about 85% or 80% of the total composition and the iron is in the alpha form at atmospheric temperatures. The carbon content in castings produced in accordance with the invention is controlled such that it is always less than the value represented by the formula 4.3 minus ⅓ (Si+P). Particularly satisfactory results are obtained when the carbon content is about 2.5% to about 3.7% and the silicon content is about 1.5% to about 3%. Such castings usually contain at least about 1.3% or 1.5% uncombined carbon or usually about 2% uncombined carbon in the as-cast condition.

Within the ranges of composition set forth hereinbefore, the retained magnesium and cerium contents contemplated by the invention cooperate to produce a new result, i. e., the production of a hypoeutectic gray cast iron containing graphite or uncombined carbon in a spheroidal form although the retained magnesium content is insufficient by itself to control the occurrence of a large proportion of the graphite in a spheroidal form. This result is unexpected in view of the fact that cerium, in the absence of magnesium, is not effective by itself in hypoeutectic cast iron

compositions to provide the results obtained by the present invention but acts as a desulfurizer and carbide stabilizer or whitener even when inoculation is employed after the introduction of cerium.

In the process contemplated by the invention for producing spheroidal graphite in a hypoeutectic gray cast iron composition, inoculation is an essential feature required to produce uncombined carbon or graphite in the solidified product provided by the invention. Inoculation of the hypoeutectic cast iron bath is accomplished along with or subsequent to the incorporation therein of the amounts of magnesium and cerium contemplated by the invention. Inoculation is accomplished by a late addition of an inoculant, e. g., silicon. Preferably, the graphitizing inoculation is carried out after the incorporation of magnesium and cerium into the molten hypoeutectic cast iron bath. Very satisfactory results have been obtained using ferrosilicon, e. g., an iron alloy containing a major proportion up to about 95% silicon as the inoculating agent 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 reducing chill in foundry gray cast irons may be employed. As those skilled in the art know, commercially available ferro-silicon and various proprietary inoculants usually contain calcium, e. g., up to about 1% or so, and the presence of this element has been recognized to increase the effectiveness of the inoculant in many instances. It is also known that ferrosilicon and various proprietary inoculants often contain aluminum. It is preferred to employ silicon in amounts between about 0.3% and about 2% or 2.5%, more preferably between about 0.4% and about 1.2%, as the late addition to effect inoculation. Since the aforesaid amounts of silicon are added to effect inoculation in the process embodying the present invention, the initial silicon content of the hypoeutectic cast iron bath to be treated in accordance with the present invention is usually about 0.8% to about 2%.

In carrying out the process contemplated by the invention to produce hypoeutectic gray cast iron containing spheroidal carbon and having high ductility, it is preferred that the manganese content be low as this element detrimentally affects the ductility. Thus, it is preferred that the manganese content not exceed about 0.3% to provide good ductility. When high strength, rigidity and wear resistance are desired, a pearlitic matrix containing about 0.5% to about 0.9% manganese is employed. Phosphorus, which is usually considered an impurity but which in the usual amounts does not materially interfere with the formation of spheroidal graphite, is also preferably maintained at a low level as phosphorus detrimentally affects the ductility. Although the phosphorus content may be as high as about 0.5% or more, phosphorus preferably does not exceed approximately 0.25% and more preferably does not exceed about 0.1%. The sulfur content in hypoeutectic cast iron products produced in accordance with the invention is low, usually not exceeding about 0.02%, e. g., about 0.01% to about 0.018%. Certain other elements not usually found in cast iron should be avoided or should be present only in traces or in very small amounts because these elements interfere with the formation of spheroidal graphite. These subversive elements include tin, lead, antimony, bismuth, arsenic, selenium, tellurium, etc. These elements preferably are not present in a total amount over about 0.05%. Other alloying elements which may be present in the composition to provide specific effects upon the matrix structure include up to about 1% chromium, up to about 1% molybdenum, up to about 0.5% vanadium, etc.

Magnesium can be introduced into the molten hypoeutectic gray cast iron in metallic form provided proper precautions are observed or it can be introduced in the form of an alloy. Nickel, copper and/or silicon are the preferred metals with which magnesium is alloyed to form an addition agent. Very satisfactory alloys include nickel-magnesium alloys containing about 4% to about 20% magnesium; nickel-magnesium-carbon alloys containing about 10% to about 15% magnesium, and about 1.5% to about 3% carbon; nickel-magnesium-silicon alloys containing about 13% to about 20% magnesium and about 20% to about 30% silicon; and iron-magnesium-silicon alloys containing about 12% to about 16% magnesium and about 30% to about 60% silicon. Cerium is added to the molten cast iron in the form of cerium metal or as an alloy or a mixture, e. g., mischmetal.

In carrying out the process contemplated by the invention, particularly when the sulfur content of the hypoeutectic cast iron bath to be treated is about 0.05% or 0.06% to 0.15% or more, e. g., up to about 0.3% sulfur, magnesium in an amount sufficient to reduce the sulfur content of the bath, e. g., to a value below about 0.03% or 0.02%, and to provide the required retained magnesium content in castings made from the bath is incorporated in the bath; thereafter the required amounts of cerium are incorporated in the bath, the bath is inoculated at least once and metal from this treated inoculated bath is cast to obtain hypoeutectic gray cast iron containing spheroidal graphite. Alternatively, other means may be used to reduce the sulfur below about 0.05% or even below about 0.02% prior to the introduction of magnesium and/or cerium, e. g., by means of a basic slag, etc., and this practice is beneficial and advantageous. When the sulfur content of the hypoeutectic cast iron bath is low, e. g., below about 0.05%, the cerium addition can be made simultaneously with the magnesium addition, or even prior thereto. Magnesium is a very powerful desulfurizer in cast iron baths, even baths which are held under acid conditions, as in an acid-lined ladle, etc. About one part by weight of magnesium is introduced into the cast iron bath for each part by weight of sulfur to be removed and the magnesium consumed in removing sulfur is not effective to promote the formation of graphite in a spheroidal form. Of course, sufficient magnesium must be added not only to compensate for the losses of magnesium encountered in removing sulfur from the cast iron bath, in the addition reactions, in holding the bath after the incorporation of magnesium, etc., but also to incorporate the required amounts of magnesium in the bath to provide the required retained magnesium content in the final casting. Moreover, losses are similarly encountered in introducing and retaining cerium in the cast iron melt, and these losses also must be compensated for in incorporating the required amounts of cerium in the cast iron bath to provide the re-

quired retained cerium content in the final casting.

In the novel gray cast iron product provided by the invention in the as-cast condition, some or practically all of the uncombined carbon or graphite appears as compact, soft, gray-colored, rounded particles or spheroids, or as agglomerates or groups of such particles. These rounded particles or spheroids of uncombined carbon or graphite visible in properly polished and etched sections have a well-defined radial or radiating structure. The particle has the appearance of a plurality of crystals radiating from approximately the center, i. e., a radiating and polycrystalline appearance. At least some, e. g., usually about 25 or more, of the uncombined carbon or graphite is in a spheroidal form in the novel gray cast iron provided by the invention. When some of the uncombined carbon or graphite is in the spheroidal form, the use of a slightly higher amount of retained magnesium and/or cerium, e. g., about 0.01% or 0.02% additional retained magnesium and/or cerium, is sufficient in most cases to cause the uncombined carbon or graphite to appear predominantly in a substantially spheroidal form.

The novel product provided by the invention containing spheroidal graphite in the as-cast condition possesses a very remarkable combination of properties and characteristics. In general, the tensile strength of the as-cast product will be 50% or more greater than would be obtained in the same composition devoid of magnesium, and usually the improvement in tensile strength will be 100% or much more. Tensile strengths on the order of 85,000 pounds per square inch or more are obtained in the pearlitic (i. e., generally preferred) compositions. The high tensile strengths are obtained in combination with improved ductility, e. g., elongations in tension as high as 5% or more, in compositions having pearlitic matrices. The novel as-cast product is characterized by a consistently high tensile modulus of elasticity of about 25,000,000 pounds per square inch and other improved or high properties. Castings made of the novel material have a light-colored or steely fracture as compared to the gray fracture of gray cast iron and have the unexpected characteristic that when struck with or against a hard object they emit a definite steel-like ring rather than the duller sound emitted by gray cast iron. A highly useful property possessed by castings manufactured in accordance with the invention is that the hardness within a particular casting is very uniform even though the section size of the casting varies considerably.

As indicated hereinbefore, the generally preferred matrix structure in the as-cast product provided by the invention is a pearlitic matrix. However, the spheroidal form of uncombined carbon or graphite which characterizes the novel as-cast product provided by the invention can be obtained in any matrix obtainable in gray cast irons of similar composition. Thus, the ferrous matrix may be pearlite, ferrite, martensite, an acicular constituent (e. g., bainite or other transformation products of austenite explained by the S-curve), etc., or the known combinations thereof. When it is desired to enhance certain properties or to modify the combination of properties, the as-cast alloy may be subjected to known heat treatments, surface treatments, etc., for stress relief, hardening, strengthening, toughening, etc. Illustrative heat treatments include quenching and drawing, normalizing and drawing, austempering, annealing at temperatures both above and/or below the critical temperature, slow cooling from the casting temperature, etc.

For the purpose of giving those skilled in the art a better understanding of the invention, the following illustrative examples are given:

Example 1

A hypoeutectic cast iron bath containing about 2.8% carbon, about 1.5% silicon, about 0.06% manganese, and about 0.07% phosphorus was established. To one portion of the bath, sufficient magnesium was incorporated to provide a retained magnesium content of about 0.016%, and sufficient cerium was incorporated to provide a retained cerium content of about 0.031% in the final casting. The treated metal was inoculated with about 0.5% silicon as ferrosilicon and cast. This casting, made in accordance with the present invention, was a gray cast iron, had graphite in a spheroidal form and had a transverse load in a 1.2-inch arbitration bar tested over 12-inch centers of about 9300 pounds, an impact value of 78, and a Brinell hardness of 269. The fracture of this casting was steely. To another portion of the said bath 0.06% cerium (but no magnesium) was incorporated. The portion was inoculated with about 0.5% silicon as commercial ferrosilicon and cast. This casting, not made according to the invention, was a white cast iron and had a transverse load of 5700 pounds, an impact value of 24, and a Brinell hardness of 430. The fracture of this casting was white.

Example 2

A hypoeutectic cast iron melt containing about 3.3% carbon, about 1.8% silicon, about 0.6% manganese, about 0.05% phosphorus, and about 0.03% sulfur was established. To one portion of the bath, sufficient magnesium was incorporated to provide a retained magnesium content of 0.014%, and sufficient cerium was incorporated to provide a final retained cerium content of about 0.016% in the final casting, i. e., the final casting had a magnesium plus cerium content of about 0.03%. The treated metal was inoculated with about 0.5% silicon as commercial ferrosilicon and cast. This casting, not made according to the invention, had a gray fracture and, when tested under the same conditions as in Example 1, had a transverse load of about 3480 pounds, impact value of about 29, and a Brinell hardness of about 179. Into another portion of the aforesaid bath, sufficient cerium to provide a final retained cerium content of about 0.019% and sufficient magnesium to provide a final retained magnesium content of about 0.016% were incorporated, i. e., the final casting had a magnesium plus cerium content of about 0.035%. This portion was likewise inoculated with about 0.5% silicon as commercial ferrosilicon and cast. This casting, made in accordance with the invention, was a gray cast iron containing a substantial portion of the graphite as spheroids. The fracture of this casting was steely, and, when tested under the same conditions as in Example 1, the casting had a transverse load of about 6770 pounds, an impact value of 70, and a Brinell hardness of about 215. To another portion of the aforesaid bath, sufficient magnesium was incorporated to provide a final magnesium content of about 0.017% in the final casting and sufficient cerium was incorporated to provide a final cerium content of about 0.033% therein, i. e., the

casting had a magnesium plus cerium content of about 0.05%. The thus-treated metal was inoculated with about 0.5% silicon as commercial ferrosilicon and cast. The resulting casting, made in accordance with the invention, was a gray cast iron containing substantially all the graphite as spheroids. The fracture of the casting was steely and, when tested under the same conditions as Example 1, the casting had a transverse strength of about 8770 pounds, an impact value greater than 120, and a Brinell hardness of about 268.

It is recognized that magnesium and cerium determinations of the order involved herein are difficult to make. The values given herein for these elements are based upon analyses which have been checked and are reproducible within about 0.005% and the values given for cerium are reproducible within about 10%.

The present invention may be applied to the manufacture of a wide variety of ferrous products and articles. For example, engine crankshafts, machinery parts such as roll mill housings and run-out tables for steel mill equipment, ingot molds, railroad castings, marine castings, castings for agricultural implements, automotive castings, etc., can be made of the alloy provided by the invention.

It is to be noted that the present invention is not to be confused with the teachings and disclosures of Morrogh et al. (for example, in the article published in the March 1948 issue of the Journal of the Iron and Steel Institute at pages 306 et seq., in the article published in the April 1948 issue of American Foundryman at pages 91 et seq., etc.) since the cerium treatment process disclosed by Morrogh et al. must be applied to a hypereutectic cast iron composition and is applied to low-sulfur content cast iron melts. Thus, at page 92 of the aforesaid American Foundryman article, Morrogh et al. state that a compositional requirement for the treatment of cast irons by their process is that the iron "must be of hypereutectic carbon content, that is, the carbon content should exceed the value 4.3—⅓ (percent Si+percent P)." The requirement that the cast iron be of hypereutectic composition is a serious limitation since hypereutectic cast irons are not commonly used in commercial practice. The present process, on the other hand, is applied specifically to the treatment of hypoeutectic cast iron melts more commonly employed in commercial practice and is not restricted to the treatment of cast iron melts of very low sulfur content.

Although the present invention has been described in conjunction with preferred embodiments, it is to be 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 understand. Such modifications and variations are considered to be within the purview and scope of the invention and of the appended claims.

We claim:

1. The improved process for producing hypoeutectic gray cast iron containing spheroidal graphite which comprises establishing an iron bath having such a composition as to be a hypoeutectic gray cast iron when inoculated and cast, incorporating in said bath sufficient magnesium to provide a retained magnesium content of at least about 0.015% but less than about 0.04% and insufficient by itself to control the occurrence of substantially spheroidal graphite in castings made from said bath and sufficient cerium to provide a retained cerium content of at least about 0.015% in castings made from said bath, inoculating said bath with about 0.3% to about 2.5% silicon and casting the metal from the inoculated bath in an inoculated condition to obtain a hypoeutectic gray iron casting containing about 0.05% to about 0.075% magnesium plus cerium and containing graphite in a substantially spheroidal form.

2. The improved process for producing hypoeutectic gray cast iron containing spheroidal graphite which comprises establishing an iron bath having such a composition as to be a hypoeutectic gray cast iron when inoculated and cast, incorporating in said bath sufficient magnesium to provide a retained magnesium content of at least about 0.015% to about 0.035% and insufficient by itself to control the occurrence of substantially spheroidal graphite in castings made from said bath and sufficient cerium to provide a retained cerium content of at least about 0.015% in castings made from said bath, and casting the metal from the bath in an inoculated condition to obtain a hypoeutectic iron casting containing about 0.035% to about 0.1% magnesium plus cerium and containing graphite in a substantially spheroidal form in the as-cast condition.

3. The improved process for producing hypoeutectic gray cast iron containing spheroidal graphite which comprises establishing a molten cast iron bath having such a composition as to be a hypoeutectic gray cast iron bath when cast in an inoculated condition, incorporating in said bath an amount of magnesium sufficient to provide a retained magnesium content of at least about 0.015% but less than about 0.04% and insufficient by itself to control the occurrence of a substantial amount of graphite in a substantially spheroidal form in castings made from said bath and an amount of cerium sufficient to provide a retained cerium content of at least about 0.015% to about 0.1% in castings made from said bath, and casting metal from the thus-treated bath to obtain hypoeutectic gray cast iron castings containing a substantial amount of graphite in a substantially spheroidal form and characterized by an improved combination of properties as compared to the properties of a similar gray iron casting not containing both magnesium and cerium in the aforesaid amounts.

4. The improved process for producing hypoeutectic gray cast iron containing uncombined carbon in a substantially spheroidal form which comprises incorporating in a molten cast iron bath having such a composition as to be a hypoeutectic gray cast iron bath when cast in an inoculated condition an amount of magnesium sufficient to provide a retained magnesium content of at least about 0.015% but less than about 0.04% and insufficient by itself to control the occurrence of a substantial amount of uncombined carbon in a spheroidal form in castings made from said bath and an amount of cerium sufficient to provide a retained cerium content of at least about 0.015% but less than about 0.16% in castings made from said bath, and casting metal from said bath in an inoculated condition to obtain hypoeutectic gray cast iron castings containing a substantial amount of the uncombined carbon in a substantially spheroidal form and characterized by an improved combination of properties as compared to the proper-

ties of a similar gray iron casting devoid of magnesium.

5. The improved process for producing hypoeutectic gray cast iron containing substantially spheroidal graphite which comprises establishing a molten iron bath having such a composition as to be a hypoeutectic cast iron when inoculated and cast, incorporating and retaining in said bath at least about 0.015% but less than about 0.04% magnesium and at least about 0.015% cerium, the sum of the retained magnesium and retained cerium contents being at least about 0.035%, and casting metal from said bath containing the aforesaid amounts of magnesium and cerium in an inoculated condition to obtain a hypoeutectic gray cast iron casting containing graphite in a substantially spheroidal form and having an improved combination of properties as compared to a similar casting devoid of magnesium.

6. The process for producing an improved hypoeutectic gray cast iron which comprises establishing a bath of molten iron of such a composition as to be a hypoeutectic gray cast iron when inoculated and cast and containing over about 0.06% sulfur, reducing the sulfur content to a value less than about 0.05%, incorporating into said bath an amount of magnesium sufficient to provide a retained magnesium content of at least about 0.015% to about 0.035% and insufficient by itself to control the occurrence of graphite in a spheroidal form in castings made from said bath, incorporating into said bath an amount of cerium sufficient to provide a retained cerium content of at least about 0.015% up to about 0.08% in castings made from said bath, inoculating said bath with about 0.3% to about 2.5% silicon and casting metal from said bath in an inoculated condition to obtain a hypoeutectic gray cast iron casting containing graphite in a spheroidal form and containing at least about 0.035% magnesium plus cerium.

7. The process for producing an improved ductile hypoeutectic gray cast iron which comprises establishing a bath of molten iron of such a composition as to be a hypoeutectic gray cast iron when cast in an inoculated condition and containing more than about 0.06% sulfur, incorporating into said bath an amount of magnesium sufficient to reduce the sulfur content thereof below about 0.03% and to provide a retained magnesium content of at least about 0.015% up to about 0.04% in castings made from said bath, incorporating into said magnesium-treated bath an amount of cerium sufficient to provide a retained cerium content of at least about 0.015% up to about 0.1% in castings made from said bath, and casting metal from said bath in an inoculated condition to obtain a hypoeutectic gray cast iron casting containing uncombined carbon in a spheroidal form, and containing at least about 0.04% magnesium plus cerium.

8. An iron casting containing about 2.5% to about 3.7% carbon, with the excess carbon not required to form the matrix being predominantly uncombined, about 1.5% to about 3% silicon, up to about 0.5% phosphorus, the carbon, silicon and phosphorus contents being so related that the sum of the carbon content plus one-third the silicon content plus one-third the phosphorus content is less than 4.3, magnesium from about 0.015% to about 0.035% and insufficient by itself to control the occurrence of a substantial amount of graphite in a spheroidal form, at least about 0.015% cerium, with the magnesium plus cerium content being about 0.05% to about 0.075% to control the occurrence of a substantial amount of the uncombined carbon in a substantially spheroidal form, and the balance essentially iron to provide a ferrous matrix in which the substantially spheroidal uncombined carbon particles are dispersed.

9. A hypoeutectic gray iron casting containing about 2.5% to about 3.7% carbon, about 1.5% to about 3% silicon, magnesium from about 0.015% to less than about 0.04% and insufficient by itself to control the occurrence of graphite in a spheroidal form in the casting, at least about 0.015% cerium, with the total quantity of magnesium plus cerium being about 0.04% to about 0.1% to control the occurrence of graphite in a spheroidal form, and the balance essentially iron.

10. A gray iron casting containing about 1.7% to about 3.9% carbon, with the excess carbon not required to form the matrix being predominantly uncombined, about 1.2% to about 7% silicon, up to about 0.5% phosphorus, with the carbon, silicon and phosphorus contents being so related that the carbon content plus one-third the silicon content plus one-third the phosphorus content is less than 4.3, up to about 10% nickel, up to about 2% copper, at least about 0.015% but less than about 0.04% magnesium, at least about 0.015% cerium, with the sum of the magnesium and cerium contents being about 0.05% to about 0.075%, and the balance essentially iron, said casting being characterized by uncombined carbon in a substantially spheroidal form and by an improved combination of properties as compared to those of a similar casting devoid of magnesium.

11. A gray iron casting containing about 1.7% to about 3.9% carbon, with the excess carbon not required to form the matrix being predominantly uncombined, about 1.2% to about 7% silicon, up to about 0.5% phosphorus, with the carbon, silicon and phosphorus contents being so related that the carbon content plus one-third the silicon content plus one-third the phosphorus content is less than 4.3, up to about 10% nickel, up to about 2% copper, at least about 0.015% to about 0.04% magnesium, at least about 0.015% cerium, with the sum of the magnesium and cerium contents being about 0.035% to about 0.1%, and the balance essentially iron, said casting being characterized by uncombined carbon in a substantially spheroidal form and by an improved combination of properties as compared to those of a similar casting devoid of magnesium.

12. A gray iron casting containing magnesium from about 0.015% to about 0.035% and insufficient by itself to control the occurrence of graphite in a spheroidal form in the casting and at least about 0.015% cerium, with the total quantity of magnesium plus cerium being about 0.035% to about 0.1% to control the occurrence of graphite in a substantially spheroidal form, with the balance being a hypoeutectic cast iron composition.

13. An iron casting containing at least about 0.015% up to about 0.04% magnesium, at least about 0.015% and up to about 0.16% cerium, with the total quantity of magnesium plus cerium being about 0.04% to about 0.2%, and containing uncombined carbon in a substantially spheroidal form with the balance being a hypoeutectic gray cast iron composition.

14. An improved gray iron casting containing the carbon not required to form the matrix predominantly in an uncombined form, at least

about 0.015% up to about 0.06% cerium, a small but effective amount up to about 0.035% of magnesium insufficient by itself to control the occurrence of uncombined carbon in a spheroidal form in said casting but effective in combination with the aforesaid amounts of cerium to control the occurrence of uncombined carbon in a spheroidal form in said casting, and the balance a hypoeutectic cast iron composition devoid of subversive amounts of elements which materially interfere with the formation of uncombined carbon in a spheroidal form.

ALBERT PAUL GAGNEBIN.
WARREN McLELLAN SPEAR.

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