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ART OF USING MAGNESIUM-CONTAINING ADDITION AGENTS TO PRODUCE SPHEROIDAL GRAPHITE CAST IRON

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The present invention relates to the art of magnesium-containing addition agents for cast iron and, more particularly, to an improved process of producing spheroidal graphite cast iron with magnesium-containing addition agents.

It is well known that many addition agents, including magnesium-containing addition agents, have been proposed for deoxidizing, degasifying, desulfurizing, purifying, and/or otherwise refining molten metals by removing impurities through reactions which consume the magnesium or other refining ingredient added to the molten metals, especially iron and steel, to improve the quality of the final solidified product. Thus, Becket in U. S. Patent No. 1,322,158 proposed an alloy, for deoxidizing and purifying iron and steel, which contained magnesium and silicon and which could also contain iron as a result of the use of ferro-silicon to introduce silicon in the alloy bracket attempted, by the use of this alloy, to moderate the violence of the reaction which occurs when magnesium is introduced in the pure or un-alloyed state in steel or the like. In U. S. Patent No. 1,376,113, Pistor et al. proposed the use of an iron-silicon-magnesium alloy for deoxidizing iron and steel. The alloy was made by adding magnesium to ferro-silicon at a temperature near the melting point thereof so that the ferro-silicon was in a pasty or semi-fluid state. Hunt proposed, in U. S. Patent No. 1,555,978, that a mixture of comminuted or powdered ferro-silicon and magnesium be employed for deoxidizing and purifying molten metals such as iron and steel. Hunt referred specifically to a briquette made up of 10 to 20 parts of magnesium and 90 to 80 parts of ferro-silicon. Hunt attempted, by the use of his addition agents, to diminish the violence of the reaction which takes place when elemental magnesium is added to iron and steel. In U. S. Patent No. 1,461,643, Becket proposed an alloy for deoxidizing and purifying iron and steel which contained magnesium, silicon and iron and/or its equivalent, manganese. With this alloy Becket attempted to render less energetic the reaction which took place when the high-magnesium alloys described in his earlier U. S. Patent No. 1,322,158 were employed. It was disclosed that the magnesium content could fall within the range of 10 to 50% and that the presence of iron

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was incidental to the use of ferro-silicon as a convenient means of introducing silicon in the alloy. A wide variety of other magnesium-containing addition alloys have been proposed and have been described in various patents and publications. As indicated by the aforementioned prior art, one of the problems encountered in the use of magnesium for treating iron and steel is presented by the violent nature of the reaction which occurs when elemental magnesium is introduced into iron and steel. Other proposals have been made by the prior art to solve an analogous problem encountered in the addition of various highly reactive and/or volatilizable elements into molten baths. For example, U. S. Patent No. 1,931,144 disclosed the introduction of sodium as sodium vapors into a molten bath to purify the bath.

The use of magnesium to produce spheroidal graphite cast iron involves many difficulties presented by the requirement that the final solidified casting contain retained magnesium and that the amount of retained magnesium be carefully controlled. These difficulties mainly involve the nature and amounts of the addition agent employed to secure retained magnesium in the final casting and to control the amounts thereof. As a result of extended investigations, it has been found that certain magnesium-containing addition agents function more satisfactorily than others when used on a commercial scale. Thus, when some magnesium-containing addition agents were used, only a small proportion of the magnesium added was introduced or recovered in the molten metal. In some instances as little as 3% or even less of the magnesium contained in the addition agent was actually introduced into or recovered in the molten metal. Those inefficient addition agents which provided a low recovery of magnesium were uneconomic and required the use of large amounts of the addition material which tended to chill excessively the molten metal and to present other difficulties with regard to handling, casting, etc. Other addition agents which were quite satisfactory from the viewpoint of magnesium introduction and recovery were not desirable in that they introduced undesirable elements or in that they introduced costly elements which were not necessary to meet the properties required in the final product.

Furthermore, certain addition agents which were satisfactory in introducing magnesium into the molten bath were unsatisfactory in that they also introduced subversive amounts of elements which interfered with the function of magnesium in producing the spheroidal form of graphite in cast iron in the as-cast and/or heat treated condition.

Although prior investigators, including Hunt, Pistor et al., and Becket, proposed using magnesium-containing addition agents for deoxidizing and otherwise purifying the molten iron and steel by reactions which consumed the magnesium, they did not produce or obtain a new spheroidal graphite cast iron and did not encounter or envisage the problems encountered in producing spheroidal graphite cast iron and/or in retaining controlled amounts of magnesium in the solidified cast iron and did not propose or suggest any solution for these problems.

It has been discovered that, when certain magnesium-containing addition agents are employed in producing spheroidal graphite cast iron from a molten metal bath of such composition as to be a gray cast iron when inoculated and cast, magnesium can be introduced effectively and satisfactorily into the molten metal and can be retained in the solidified casting produced therefrom in the required controlled amounts on a commercial scale economically and practically.

It is an object of the present invention to provide an improved process for producing spheroidal graphite cast iron on a commercial scale in an economical and practical manner.

It is another object of the invention to provide an improved process of using magnesium-containing addition agents economically and practically to produce spheroidal graphite cast iron.

The invention also contemplates the provision of an improved process for simultaneously incorporating controlled amounts of magnesium in molten cast iron and inoculating the said cast iron by means of a single addition agent to obtain castings of cast iron containing graphite in spheroidal form and/or other compacted form.

It is a further object of the invention to provide an improved process for producing spheroidal graphite cast iron by means of a magnesium-containing addition agent which does not require the use of strategic or costly metals.

It is also an object of the invention to provide an improved process for economically and practically producing cast iron containing retained magnesium in controlled amounts which promote the occurrence of uncombined carbon in a substantially spheroidal form.

Another object of the invention is to provide an improved process for producing cast iron containing compacted graphite and having a ferritic matrix.

Other objects and advantages will become apparent from the following description.

The present invention contemplates a process which involves introducing a magnesium-containing agent, e. g., in the form of an alloy or mechanical mixture, into a molten cast iron bath to incorporate in said bath retained magnesium in a controlled amount, and casting metal from said bath to obtain an iron casting containing controlled amounts of magnesium retained therein and/or containing uncombined carbon or graphite in a compacted form, particularly a spheroidal form, with the carbon not required to form the matrix being present predominantly in the uncombined or graphitic

form. In our copending applications Serial No. 737,420, now U. S. Patent 2,485,760, Serial No. 16,106 now U. S. Patent 2,485,761 and Serial No. 115,088, we disclosed suitable procedures for obtaining such castings and disclosed that in order to obtain uncombined carbon in a compacted form it was essential that the solidified cast iron contain a small but effective amount, preferably at least about 0.03%, up to about 0.5% of retained magnesium. Retained magnesium contents controlled within the range of about 0.02% to 0.035% or 0.040% produce compacted uncombined carbon or graphite but where it is desired to assure that a substantial portion of the uncombined carbon or graphite appear in the more perfectly compacted form of spheroidal particles the retained magnesium is preferably controlled within the range of about 0.035% to about 0.3% or 0.4% or more when the cast iron is cast in the more usual section sizes encountered in gray cast iron practice. In our co-pending application Serial No. 737,420 filed November 21, 1947 now U. S. Patent No. 2,485,760, we disclosed that alloys which can satisfactorily be employed as magnesium-containing addition agents for the purpose of introducing magnesium into molten cast iron baths in the required amounts to provide the controlled amounts of retained magnesium in the solidified castings include an addition agent containing about 5% to about 10% magnesium, about 30% nickel, about 20% silicon, with the balance iron; an addition agent containing about 11% magnesium, about 28% nickel, about 18% silicon, with the balance iron; and an addition agent containing about 10% magnesium, about 40% silicon, with the balance iron.

In general, the satisfactory agents employed in the process embodying the present invention contain about 5% to about 20% magnesium, up to about 45% iron, up to about 40% nickel, up to about 30% copper, with the balance essentially silicon and the silicon content being at least about 15% of the composition. Preferably, the magnesium content is about 7% to about 17%, e. g., about 8% to about 15%, of the agent. It has been found that the magnesium should not be considerably higher than about 20% because high magnesium contents detrimentally affect the addition characteristics of the agent and detrimentally affect the quality of the product produced by using the addition agent. These undesirable effects become excessively detrimental when the magnesium content exceeds about 40%. Thus, when agents containing such high magnesium contents are added to molten iron, large quantities of magnesium oxide smoke are produced, high losses of the agent are encountered, excessively large additions of the agent are required, and entrapment in the molten metal of the refractory materials produced in the addition reactions leads to the production of "dirty" castings having poor quality. The silicon content is at least about 15% to as much as about 95% of the agent, e. g., about 25% to about 60% or 75%, and the silicon plus magnesium content is at least about 25% or 30%. When nickel is present it is in amounts up to about 40%, e. g., about 5% to about 30%, preferably about 10% to about 15% or 20%. Nickel improves the addition characteristics of magnesium-containing agents. When copper is present it preferably does not exceed about 30%, e. g., about 5% to 20%. The iron content is usually at least about 5%, e. g., about 10% to about 35% or 45%. The

iron content of the agent may be replaced with manganese up to about 45% of the agent, although the manganese content of the agent preferably does not exceed about 25%, e. g., about 5% to 15%. The manganese content of the magnesium-containing addition agent is preferably low as it has been found that manganese detrimentally affects the ductility of the spheroidal graphite cast iron provided by the invention, although manganese is sometimes added to the cast iron to obtain specific effects, e. g., improved strength and hardness. The agents may contain up to about 1% calcium, e. g., about 0.25% to about 1% calcium, particularly when an enhanced inoculating effect is desired, and may also contain up to about 0.5% of impurities such as phosphorus, chromium, etc., which may unavoidably be included during the manufacturing operations, etc. The agents employed in the process embodying the present invention are preferably devoid of subversive amounts of certain elements not usually found in cast iron as these elements interfere with the desired effect of magnesium in controlling the production of graphite in a compacted form, e. g., as substantially spheroidal particles, in the cast iron produced in accordance with the invention. These elements include tin, lead, antimony, bismuth, arsenic, selenium, tellurium, etc. Alloys of the following compositions have given very satisfactory results: about 10% magnesium, about 50% silicon, with the balance essentially iron and the iron content being about 40% of the alloy; about 13% to about 17% magnesium, about 14% to about 22% iron, with the balance essentially silicon; and about 13% to about 17% magnesium, about 30% to about 45% iron, up to about 20% nickel, with the balance essentially silicon, e. g., alloys containing about 13% to about 17% magnesium, about 38% to about 44% iron, with the balance essentially silicon and containing about 13% to about 17% magnesium, about 31% to about 36% iron, about 15% to about 20% nickel, with the balance essentially silicon.

It is not sufficient merely to add the magnesium-containing agent to the cast iron bath. It is essential in carrying out the process embodying the invention that the aforedescribed required amounts of magnesium be incorporated in the bath and be retained in the final product. As indicated hereinbefore, losses of magnesium are encountered when magnesium-containing agents are added to molten iron and these losses must be compensated for in carrying out the invention. If any undesirable elements which tend to combine with and/or counteract the effect of magnesium, for example, sulfur, oxygen, etc., are present or subsequently combine with the magnesium, the amount of magnesium introduced in the molten metal should be increased by the amount required to counteract the effect of the presence of these elements in consuming magnesium by removing the elements or by otherwise overcoming their effects. Sulfur is the magnesium-counteracting element which is most likely to be present in the molten metal. Since many baths that can be treated in accordance with the invention will usually contain sulfur in various amounts 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 the 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, about one part by weight of magnesium is introduced for each part by weight of sulfur to be removed. Thus, sufficient magnesium must be added to the molten cast iron bath to compensate for the losses encountered in addition reactions, to reduce the sulfur content of the bath to a low level, preferably about 0.02% or less, e. g., about 0.015% or about 0.012% or less, and to provide the required retained magnesium content in the bath and in the final castings produced therefrom. However, the total addition of the magnesium-containing agent must not be too large or difficulties are encountered due to chilling of the metal, in handling the addition material, etc. To conform with good foundry practice, the amount of the magnesium-containing addition used preferably should not exceed about 2.5% or about 3% by weight of the molten metal treated, e. g., it should be about 1% or 1.5% to about 2% of the metal treated. Alternatively, the amount of addition agent required is reduced by a separate desulfurization prior to the magnesium introduction which provides the required retained amounts of magnesium, e. g., through the use of a basic-lined cupola to melt the metal, through the treatment of the molten metal with a basic slag to provide a desulfurizing treatment, through the treatment of the molten metal with desulfurizing agents, etc., or combinations of the foregoing. When the sulfur content of the bath is above about 0.08%, e. g., about 0.1% to 0.15% or more; the magnesium content of the agent preferably is about 13% to about 17%; while, when the sulfur content of the bath is low, e. g., about 0.02% to about 0.04%, the magnesium content of the agent preferably is about 8% to about 12%.

The magnesium-containing molten cast iron is cast in an inoculated condition to insure the presence of graphite in the solidified casting. By employing an agent containing both magnesium and the inoculating element, e. g., silicon, it is possible to introduce the magnesium and the inoculant by means of a single addition agent. Magnesium-containing agents which provide the important advantage of introducing magnesium into a molten cast iron bath and, at the same time, of providing an improved inoculating effect, contain about 3 parts of silicon for each part of magnesium contained and preferably contain about 30% or 50% or more silicon. Although the aforesaid agents containing about 3 parts of silicon or more for each part of magnesium provide an improved simultaneous inoculating effect, supplemental inoculation may be employed if desired along with or subsequent to the addition of the aforesaid magnesium-containing agents to the cast iron bath to enhance the inoculation and/or to insure effective inoculation. When supplemental inoculation is employed, ferro-silicon, e. g., an iron alloy containing a major part up to about 95% silicon, gives satisfactory results as an inoculant. However, 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, commercial inoculants frequently contain calcium in amounts up to about 1% or so and the presence of calcium is considered to improve the inocu-

lating effect of such inoculants. When supplemental inoculating effects are desired, about 0.1% to about 1% or more silicon, e. g., about 0.2% to about 0.3% or about 0.5% silicon, is usually used as an inoculant along with or subsequent to the introduction into the cast iron bath of the magnesium-containing agent employed in carrying out the invention.

The addition agents contemplated by the present invention are manufactured in the form of alloys or in the form of mechanical mixtures, e. g., briquettes with binders and/or the like, to decrease the burning of the magnesium and to allow the magnesium to become incorporated more quietly and with greater recovery of the magnesium in the bath. In the manufacture of briquettes, numerous combinations of ingredients in comminuted form, etc., may be employed to provide mixtures containing silicon, e. g., commercial ferro-silicon or commercial silicon, and containing magnesium in a form available to react with sulfur, e. g., a metallic form. For example, mixtures of ferro-silicon with nickel-magnesium alloys or copper-magnesium alloys, of nickel-magnesium-silicon alloys with ferro-silicon, of nickel-magnesium-carbon alloys with ferro-silicon, etc., are very satisfactory. Suitable nickel-magnesium-carbon material and nickel-magnesium-silicon materials which may be incorporated in briquettes are disclosed in our co-pending applications U. S. Serial No. 88,494 filed April 19, 1949 now U. S. Patent No. 2,529,346 and U. S. Serial No. 108,424 filed August 3, 1949, now U. S. Patent No. 2,563,859 respectively.

The magnesium-containing addition agents described herein may be added in a ladle although the agent preferably is incorporated into a stream of hot metal running into a container or the like. Very satisfactory results have been obtained through the use of a mechanical device providing for contact of a descending stream of the magnesium-containing agent with a descending stream of molten iron converging therewith, both of said streams being in motion at moderate to high velocity. The object of such an addition device is to incorporate the addition agent into the moving molten metal stream and to dissolve the agent into the metal moving into a ladle or the like before any undissolved agent can rise to the molten metal surface after the moving metal is conducted into a ladle, etc. For example, a refractory device having approximately the shape of a cast iron pipe fitting known to the art as a "lateral" has proven satisfactory in commercial foundry practice when used to incorporate a magnesium-containing agent being conducted through one leg of the device into a moving stream of molten iron being conducted through the converging leg. In commercial practice the agent is added in the form of lumps or granules, etc., of relatively small size, e. g., in pieces about one-half inch in diameter or less. In order to secure the highest possible recoveries of magnesium from a given magnesium-containing agent, the temperature of the metal to which the agent is added should not be too high, since the efficiency of magnesium introduction decreases rapidly as the metal temperature is increased. Thus, for best results, the metal temperature when the magnesium-containing agent is added thereto usually should be about 2500° F. to about 2850° F., preferably about 2650° F. to about 2750° F.

For the purpose of giving those skilled in the art a better understanding of the invention, the following table is presented which sets forth the approximate composition of some magnesium-containing agents which can be employed in the form of alloys, briquettes, etc., for the purpose of introducing magnesium into a molten cast iron bath in accordance with the invention:

No.	Percent Mg	Percent Fe	Percent Si	Percent Ni	Percent Others
1	5–10	Bal.	20	30	
2	6.5	Bal.	40.6		
3	6.9	Bal.	18	28	
4	10	Bal.	50		
5	10–12	Bal.	40–45		0.5–1% Ca.
6	11	Bal.	18	28	
7	11	39	Bal.		
8	12.2	Bal.	23	30	
9	12.7	Bal.	47		
10	13	35	Bal.		16% Cu.
11	14.0	20.6	Bal.		
12	14.5	Bal.	31.8	16.3	
13	15		40		45% Mn.
14	15	Bal.	65		
15	15.1	17.2	Bal.		
16	15.5	36	Bal.		
17	17	30	23	28	
18	20		40		40% Mn.
19	20		30	20	30% Mn.

The agents provided by the invention are adapted to the treatment of cast iron baths to improve the properties of castings obtained therefrom. Particularly high properties are obtained when cast iron melts are treated with about 1% to about 2.5% or 3% of the magnesium-containing agent provided by the invention.

Cast iron baths which may be treated according to the process embodying the invention are eutectiferous iron-carbon alloy baths usually containing about 1.7% to about 5% carbon and up to about 5.5% or 6% silicon, e. g., about 0.5% or 1% to about 4% silicon, with the balance essentially iron to provide a ferrous matrix, the iron content being at least about 50% or 55% or more of the total composition. The preferred products produced in accordance with the present invention have matrices of alpha iron at atmospheric temperatures and contain about 85% or 87% or 90% or more iron. The aforesaid baths are those which will produce gray iron castings when cast in an inoculated condition. Preferably, the baths to be treated according to the process embodying the invention contain about 2% to about 4.5% carbon or about 2.5% to 4% carbon. The silicon content of the bath to be treated is such that the final silicon content of castings made according to the process embodying the invention will be at least about 1%, usually about 1.3% to about 5% or 6%, preferably about 1.5% to about 4.5%. The molten cast iron compositions to be treated may contain the common alloying elements in the amounts usually found in cast iron, e. g., the cast iron compositions may contain up to about 36% nickel, up to about 0.6% molybdenum, up to about 1% chromium, up to about 2.5% manganese, up to about 3% copper, etc., as disclosed more fully in our co-pending applications U. S. Serial No. 787,420 now U. S. Patent No. 2,485,760 and U. S. Serial No. 115,088. In order to realize the preferred effects obtainable through the introduction of magnesium into cast iron, the copper content of the final product is usually kept below about 2%, especially in cast irons having the iron present in the alpha form at atmospheric temperatures. The cast iron bath to be treated is preferably practically devoid of subversive amounts of tin, lead, antimony, bismuth, arsenic, selenium and tellurium, etc., as these elements have been found to be subversive to the desired effects of magnesium on the graphite form. The

impurities phosphorus and sulfur may be present in the molten bath to be treated in the usual amounts found in various grades of commercial cast iron. Thus, the bath to be treated may contain up to 0.5% or more phosphorus, although it is preferred that the phosphorus content be below about 0.15%, e. g., about 0.02% to 0.06%. Similarly, the sulfur content of the bath to be treated may be as high as 0.3% or more, e. g., 0.05% to 0.3%, although it is preferred that the sulfur content be below 0.15%, e. g., 0.03% to 0.1%.

When it is desired to produce cast iron containing a small but effective amount of retained magnesium and containing graphite in a substantially compacted form, such as a spheroidal form, dispersed in a matrix containing a substantial amount of ferrite in the as-cast condition through the treatment of a cast iron bath with a single addition of the preferred agents provided by the invention containing about three parts of silicon or more for each part of magnesium, the bath preferably contains about 3.4% to about 3.7% or even about 4.2% carbon, about 0.1% to about 0.5% manganese, about 0.03% to about 0.1% sulphur, about 0.02% to about 0.15% or about 0.25% phosphorus, at least about 1.5% silicon, and the balance essentially iron. The aforesaid bath is treated with about 1.5% to about 3% of the agent provided by the invention and castings made by adding to the aforesaid bath the aforesaid amounts of addition agent will usually contain about 2% to about 4.5% silicon. When a cast iron bath of the foregoing composition is employed, no other inoculating additions are required to produce cast iron containing graphite in a spheroidal form although other inoculating additions may be employed if desired to obtain supplemental inoculating effects or to assure inoculation.

The cast iron product produced in accordance with the present invention can be heat treated in various manners, including the heat treatments described in our co-pending U. S. applications Serial No. 787,420, now U. S. Patent No. 2,485,760, Serial No. 16,106 now U. S. Patent No. 2,485,761 and Serial No. 115,088.

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

Example 1

A cast iron bath containing about 4% carbon, about 0.35% manganese, about 0.06% phosphorus, and about 0.04% sulfur, was established and brought to the proper temperature for successful casting. A 2% addition of an alloy containing about 15% magnesium, about 65% silicon, balance iron, was made and thereafter metal from the bath was cast without further inoculation. A casting made in the aforedescribed manner contained graphite in a substantially spheroidal form and had in the as-cast condition a hardness of 170 Brinell, a tensile strength of 73,000 pounds per square inch and an elongation of about 14%. The casting contained about 2.9% silicon in addition to the aforementioned amounts of carbon, manganese and phosphorus.

Example 2

A cast iron bath containing about 4% carbon, about 1.7% silicon, about 0.5% manganese, and about 0.06% sulfur, was established. When the temperature of the bath was about 2550° F., a 1.5% addition was made of the same magnesium-containing addition alloy as employed in Example 1. The bath was given a supplemental inoculating effect by adding about 0.6% silicon as ferro-silicon and metal from the bath was cast. A 1.2-inch diameter arbitration bar casting made in the aforedescribed manner contained about 2.6% silicon, the foregoing amounts of carbon and manganese, about 0.05% retained magnesium, contained graphite in a substantially spheroidal form, had a hardness of 207 Brinell, a very high impact strength and, when tested transversely across 12-inch centers, withstood a load of about 7910 pounds with a deflection of about 0.54 inch.

Example 3

A cast iron bath was established which contained about 3.7% carbon, about 1.6% silicon, about 0.5% manganese, about 0.12% phosphorus, and about 0.03% sulfur. A portion of the aforesaid bath was treated with a 1.8% addition of the same magnesium-containing alloy as employed in Example 1. A first part of the metal from the aforesaid magnesium-treated portion of the bath was cast into a step bar casting without further additions being made. A second part of the magnesium-treated portion was given a supplemental inoculation with about 0.5% silicon as ferro-silicon and metal from this second part of the bath was likewise cast into a step bar casting. Each casting contained about 0.087% magnesium. In the one-half inch section, the step bar made from the first part of magnesium-treated metal contained graphite in a spheroidal form, had the typical steely fracture, and had a hardness of 269 Brinell, while the step bar made from the second part of magnesium-treated metal given a supplemental inoculation likewise had graphite in the spheroidal form, a steely fracture and a hardness of 212 Brinell. In the two inch section, both castings contained graphite in the spheroidal form and the casting made from the first magnesium-treated portion had a hardness of 205 Brinell while the casting made from the second magnesium-treated portion had a hardness of 196 Brinell.

Agents in alloy form contemplated by the invention can be manufactured by a process which comprises melting, e. g., in an induction furnace, ferro-silicon with or without the other alloying agents contemplated to establish a melt, incorporating the required amounts of magnesium in said melt and casting metal from the melt to obtain alloy castings containing the required amounts of magnesium. It is preferred to reladle the melt between the melting operation and final casting to insure good distribution of magnesium, etc., throughout the casting.

The present application is a continuation-in-part application of our co-pending U. S. applications Serial No. 787,420 filed November 21, 1947, now U. S. Patent No. 2,485,760, Serial No. 16,106 filed March 20, 1948, now U. S. Patent No. 2,485,761 and Serial No. 108,424 filed August 3, 1949 now U. S. Patent No. 2,563,859.

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 a new

alloy having a cast iron composition and containing graphite in a spheroidal form which comprises establishing a bath having such a composition as to be a gray cast iron when cast in an inoculated condition and being devoid of subversive amounts of elements materially interfering with the occurrence of graphite in a spheroidal form, conducting metal from said bath to a container in a descending stream through a leg of a pipe-like conduit having converging legs, contacting the descending metal stream with a stream of an alloy descending through another leg of said pipe-like conduit, said alloy containing about 7% to about 17% magnesium, about 10% to about 45% iron, up to about 20% nickel, with the balance essentially silicon, the amount of said alloy being about 1% to about 3% by weight of said metal and being sufficient to provide a content of at least about 0.04% magnesium in said metal; and thereafter casting the magnesium-containing metal in an inoculated condition to obtain an improved casting having a cast iron composition, containing about 0.04% to about 0.4% retained magnesium, being characterized by the presence of graphite in a spheroidal form, and being devoid of subversive amounts of elements materially interfering with the effect of magnesium in controlling the occurrence of graphite in a spheroidal form.

2. The improved process for producing a new alloy having a cast iron composition and containing graphite in a compacted form which comprises establishing a bath having such a composition as to be a gray cast iron when cast in an inoculated condition and being devoid of subversive amounts of elements materially interfering with the occurrence of graphite in a compacted form, conducting metal from said bath to a container in a descending stream through a leg of a pipe-like conduit having converging legs, contacting the descending metal stream with a stream of an alloy descending through another leg of said conduit, said alloy containing about 13% to about 17% magnesium, about 14% to about 45% iron, up to about 20% nickel, with the balance essentially silicon, the amount of said alloy being about 1% to about 3% by weight of said metal and being sufficient to provide a content of at least about 0.02% magnesium in said metal; and thereafter casting the magnesium-containing metal in an inoculated condition to obtain an improved casting having a cast iron composition containing at least about 0.02% retained magnesium, being characterized by the presence of graphite in a compacted form, and being devoid of subversive amounts of elements materially interfering with the effect of magnesium in controlling the occurrence of graphite in a compacted form.

3. The improved process for producing a new alloy having a cast iron composition and containing graphite in a spheroidal form which comprises establishing a bath having such a composition as to be a gray cast iron when cast in an inoculated condition and being devoid of subversive amounts of elements materially interfering with the occurrence of graphite in a spheroidal form, conducting metal from said bath to a container in a descending stream through a leg of a pipe-like conduit having converging legs, incorporating a magnesium-containing alloy into said descending stream by conducting said alloy through another leg of said pipe-like conduit into said descending stream to dissolve said alloy in said metal and to provide a magnesium content of at least about 0.04% in said metal, said alloy containing about 5% to about 20% magnesium, up to about 45% of metal selected from the group consisting of iron and manganese, up to about 40% nickel, up to about 30% copper, up to about 1% calcium, and the balance essentially silicon, the silicon content being at least about 15% of said alloy, and thereafter casting the magnesium-containing metal in an inoculated condition to obtain an improved casting having a cast iron composition, containing about 0.04% to about 0.5% retained magnesium, being characterized by the presence of graphite in a spheroidal form and being devoid of subversive amounts of elements materially interfering with the effect of magnesium in controlling the occurrence of graphite in a spheroidal form.

4. The improved process for producing an alloy having a cast iron composition and containing graphite in a substantially compacted form which comprises establishing a bath having such a composition as to be a gray cast iron when cast in an inoculated condition and being devoid of subversive amounts of elements materially interfering with the occurrence of graphite in said substantially compacted form; conducting metal from said bath to a container in a descending stream through a leg of a pipe-like conduit having converging legs; contacting the descending metal stream with a stream of an alloy descending through another leg of said pipe-like conduit, said alloy containing about 5% to about 20% magnesium, up to about 45% iron, up to about 40% nickel, up to about 30% copper, up to about 1% calcium, and the balance essentially silicon with the silicon content being at least about 15% of said alloy, the amount of said alloy being about 1% to about 3% by weight of said metal and being sufficient to provide a content of at least about 0.02% magnesium in said metal; and thereafter casting the magnesium-containing metal in an inoculated condition to obtain an improved casting having a cast iron composition, containing about 0.02% to about 0.5% retained magnesium, being characterized by the presence of graphite in a substantially compacted form and being devoid of subversive amounts of elements materially interfering with the effect of magnesium in controlling the occurrence of graphite in said substantially compacted form.

5. The improved process for producing an alloy having a cast iron composition and containing graphite in a compacted form which comprises establishing a bath having such a composition as to be a gray cast iron when cast in an inoculated condition and being devoid of subversive amounts of elements materially interfering with the occurrence of graphite in a compacted form, conducting metal from said bath to a container in a descending stream through a leg of a pipe-like conduit having converging legs, incorporating a magnesium-containing alloy into said descending stream by conducting said alloy through another leg of said pipe-like conduit into said descending stream to dissolve said alloy in said metal and to provide a magnesium content of at least about 0.02% in said metal, and thereafter casting the magnesium-containing metal in an inoculated condition to obtain an improved casting having a cast iron composition containing about 0.02% to about 0.5% retained magnesium, said casting being characterized by the presence of graphite in a compacted form and being devoid of subversive amounts of elements materially inter-

fering with the effect of magnesium in controlling the occurrence of graphite in a compacted form.

6. As a new article of manufacture, an addition agent adapted for treating molten cast iron to produce cast iron products containing at least a small but effective amount of retained magnesium which comprises about 5% to 20% magnesium, about 10% to 45% iron, about 5% to 30% nickel and the balance essentially silicon.

7. A composition of matter for addition to cast iron, said composition comprising about 5% to about 20% magnesium, up to about 45% iron, about 5% to about 20% copper, and the balance essentially silicon, the silicon content being over about 15% of the composition.

8. A composition of matter for addition to cast iron, said composition comprising about 5% to about 20% copper, about 15% to about 60% silicon, about 10% to about 45% iron and the balance essentially magnesium, said magnesium being at least about 5% but less than about 40% of said composition.

9. A composition of matter for addition to cast iron, said composition comprising about 5% to about 20% copper, about 15% to about 60% silicon, about 10% to about 45% iron and the balance essentially magnesium, said magnesium being at least about 5% but not considerably higher than about 20% of said composition.

10. A composition of matter for addition to cast iron, said composition comprising about 5% to about 20% copper, about 10% to about 45% iron, at least about 5% magnesium and the balance essentially silicon, the silicon content being about 15% to about 75% of said composition and being at least three times the magnesium content of said composition.

11. A composition of matter for addition to cast iron, said composition comprising about 13% magnesium, about 16% copper, about 35% iron and the balance essentially silicon.

12. As a new article of manufacture, an addition agent adapted for treating molten cast iron to produce cast iron products containing at least a small but effective amount of retained magnesium which comprises about 5% to 20% magnesium, about 5% to 30% of metal from the group consisting of nickel and copper, up to about 45% iron, and the balance essentially silicon.

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