

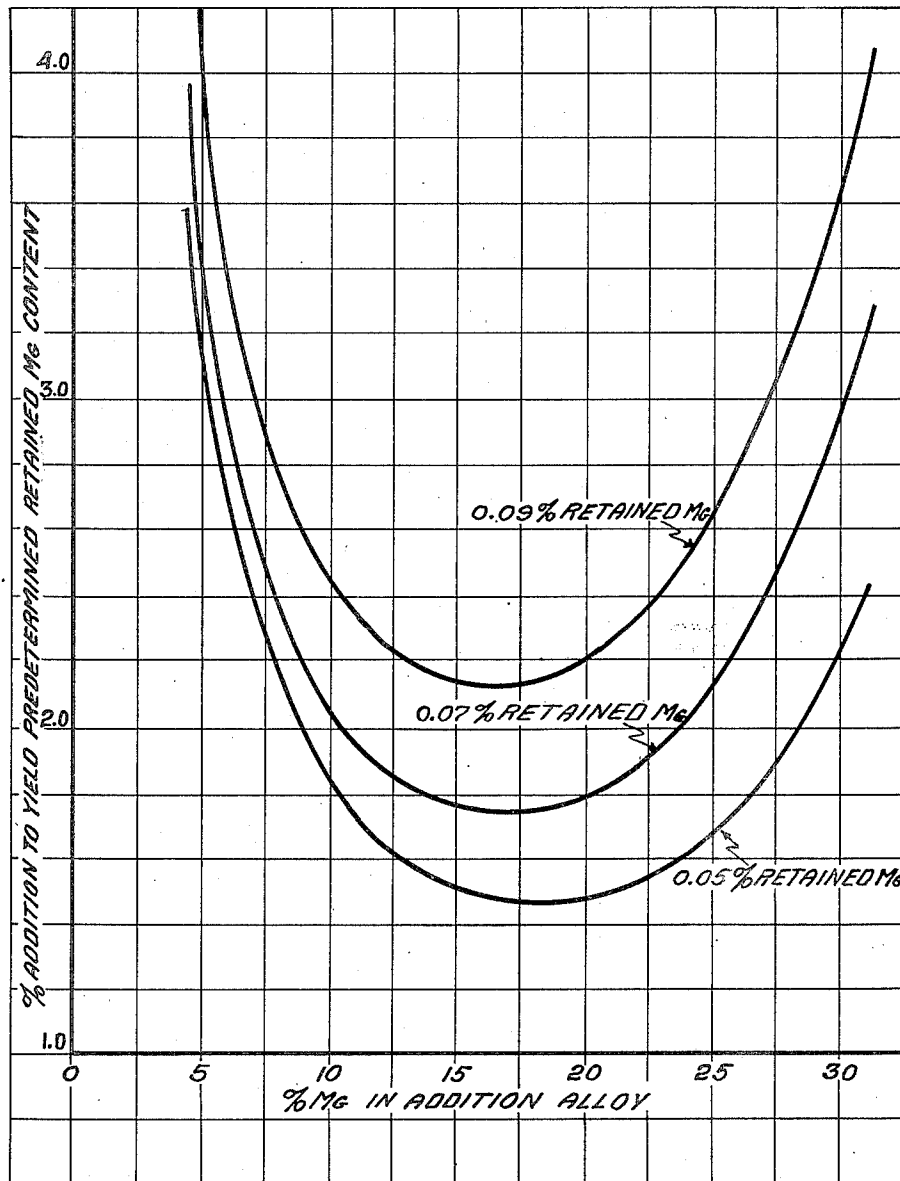
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K. D. MILLIS ET AL

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PROCESS FOR PRODUCING IMPROVED CAST IRON

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INVENTORS
KEITH DWIGHT MILLIS
ALBERT PAUL GAGNEBIN
NORMAN BODEN PILLING
BY
G. Dr. Jeller
ATTORNEY

UNITED STATES PATENT OFFICE

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PROCESS FOR PRODUCING IMPROVED
CAST IRON

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

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The present invention relates to an improved process for introducing magnesium into cast iron melts to produce cast iron products with improved properties and characteristics, especially a process for obtaining with smaller total additions a desired amount of retained magnesium in cast iron.

Heretofore, the art has taught that magnesium does not alloy with iron and, in fact, when attempts were made to introduce metallic magnesium into cast iron baths a reaction of such explosive violence took place that the molten iron was blown from its receptacle. It is known that the boiling point of magnesium is about the same as the eutectic temperature of cast iron and is below the melting point of most cast iron baths. The problem of introducing magnesium into a bath of molten cast iron, and particularly of incorporating and retaining magnesium in said cast iron without explosive results, was a difficult one to overcome.

An improved method has now been discovered whereby magnesium can be incorporated controllably and successfully into cast iron melts.

It is an object of the present invention to provide a process for treating cast iron melts to improve the recovery of magnesium in castings produced from such melts.

Another object of the invention is to provide an improved process for producing cast iron containing spheroidal graphite which comprises the treatment of molten cast iron baths with special magnesium-containing addition agents whereby special cooperative effects are obtained.

The invention also contemplates providing an improved process for producing magnesium-treated cast iron containing spheroidal graphite or other compacted forms of graphite wherein the introduction of magnesium in and an inoculating effect on the cast iron are accomplished simultaneously.

It is a further object of the invention to provide a process which enables high recovery of contained magnesium from the addition agent in a cast iron melt.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawing which depicts graphically special cooperative effects obtained in carrying out the process embodying the present invention.

Generally speaking, the present invention contemplates a process which involves treating molten cast iron baths with cooperating mag-

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nesium-containing agents having special compositions to incorporate magnesium in said baths, to substantially remove sulfur present therein and to provide retained magnesium in castings made therefrom. The aforesaid cooperating agents, usually in the form of alloys, contain about 12% to about 22% magnesium, about 25% to about 50% silicon, with or without up to about 12% or 15% iron, and the balance essentially nickel and, when added to the cooperating cast iron baths, provide in the resulting cast iron castings a small but effective amount, e. g., about 0.02%, up to about 0.3% or 0.4% retained magnesium. Preferably, the cooperating agents employed in the process embodying the present invention contain about 12% or about 14% to about 20% magnesium, with the foregoing amounts of silicon and nickel. A preferred range of silicon is from about 25% to about 30% or about 35%.

The accompanying drawing illustrates the cooperative effects obtained in the process embodying the present invention. The drawing is based upon the results of a number of tests conducted at a treating temperature of about 2700° F. upon a base iron containing 0.11% sulfur with additions made through a refractory-lined tube. By reference to the drawing, it will be seen that when the process embodying the present invention is carried out, lower and substantially constant quantities of the magnesium-containing agents may be employed to produce a predetermined magnesium content in cast irons produced according to the invention when the magnesium contents of these agents fall in the range of about 12% to about 22% contemplated by the invention. Thus, by employing in the process magnesium-containing agents having magnesium contents within the range of about 12% to about 22%, the control over the amount of retained magnesium in the resulting castings is markedly improved and is practically independent of variations in the magnesium content of the agent as compared to the control obtainable when the magnesium content is either above or below this range. Furthermore, when magnesium contents either above or below this range are employed, the additions of magnesium-containing agent required to produce a predetermined retained magnesium content in the resulting cast iron increase rapidly as shown in the drawing. Other undesirable effects are also found when the magnesium content of the agent is substantially outside the aforesaid range. Thus, as the magnesium content of the agent is increased, the violence of the

addition reaction markedly increases with resulting spattering of metal and with consequent high losses of magnesium and markedly lower recovery of magnesium; and, for these reasons, the magnesium contents of the agents employed in accordance with the present invention preferably do not substantially exceed about 20%. When the magnesium content of the agents is substantially below about 12% or substantially above about 22%, disproportionately large additions are required which result in an undesirable cooling effect in the bath. The cooling effect in the former case, but not in the latter case, can be compensated to some extent by proper increase in the bath temperature and is not as critical as the effects associated with high reactivity which are encountered when the magnesium content of the agent becomes too high. The relationships illustrated by the shapes of the curves in the accompanying drawing depict generally the critical co-operative effects obtained in carrying out the process embodying the present invention although it will be appreciated that the amount of addition agent required will be affected by the amount of sulfur in the bath and by other factors to be described hereinafter.

There are a number of factors which influence the amount of magnesium retained in the cast iron from a given addition of the agent and also influence the amount of agent to be added. These factors include the sulfur content of the bath, the temperature of the bath, the manner in which the addition is made, the time during which the reaction is carried out, the agent particle size and rate of solution, etc. The influence of sulfur has been described in U. S. Patent No. 2,485,760. Sufficient agent must be included in the total addition to eliminate substantially all the sulfur and at the same time provide sufficient excess magnesium to insure the desired retained magnesium content. For ease in calculating the amount of alloy required under practical conditions, sulfur and magnesium are considered to react in approximately equal weight ratios. This may be modified by other factors such as the method of addition, alloy size, etc. Temperature is an extremely important factor in magnesium recovery and, therefore, in the amount of agent to be added. The higher the addition or treating temperature the less the magnesium recovered in the bath. For example, at a temperature of 2900° F. magnesium recovery (after sulfur removal) may be as low as 15% or 20%, at 2700° F., it may be approximately 35%, and at 2500° F. it may be as high as 60% or 70%. With reference to the manner of addition, it must be borne in mind that magnesium is a volatile element with strong tendencies to escape during the addition procedure. For this reason, adding the agent to the surface of molten iron usually results in low recovery. The better procedures for adding the agent introduce and maintain the agent beneath the surface of the iron during its solution in the molten iron. At any given temperature, therefore, there may be widely different quantities of magnesium introduced and/or retained from the same addition depending on the manner of addition. A practical procedure consists of placing the agent or alloy in the bottom of a ladle and reladling the iron from a second ladle onto the addition agent or alloy. Another practical procedure consists in using an addition device such as a refractory tube which intermixes the molten iron and the addition agent on their way into the ladle. For large

volumes of iron, e. g., those over 5000 pounds, the agent may be fed into the stream while the iron is being reladled from one ladle to another. The length of time involved in reacting any given particle of addition agent with the molten iron is another important factor governing magnesium recovery in the iron. For example, if the iron is tapped directly from the cupola into a ladle containing the agent and the cupola is equipped with a small tap hole so that several minutes are required for filling the ladle, the magnesium recovery will be considerably less than if a large tap hole is used and the ladle filled in a minute or less. A superior procedure consists in collecting the iron in a holding ladle and then reladling into a second ladle containing the agent since this reladling operation can be conducted much more quickly and the reaction brought to an end more rapidly than by tapping directly from the cupola. The main object of any addition procedure is to mix the iron and the agent as quickly as possible. The agent particle size should harmonize with the procedure being used so that complete solution of the agent occurs when the transfer of the iron is complete. If reladling is used, the particle size of the agent should be smaller for 500-pound ladles than for 10,000-pound ladles. For example, an agent ranging from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch in size has been found practical in ladles ranging up to 1000 pounds' capacity. For larger ladles, better recovery has been obtained by using an agent approximately 1 to 3 inches in size. In very small ladles, such as hand shanks, of 30 pounds' capacity, it is sometimes preferred to use an agent of about $\frac{1}{16}$ -inch size. If an addition device is used such as a refractory-lined tube, the alloy should be of such size that the individual particles will react as completely as possible before the iron emerges from the lower end of the tube. In any case, particles should not be so large as to rise to and continue dissolving at the surface of the metal in the receiving ladle.

From the foregoing, it will be appreciated that the process may vary within wide limits depending on the conditions and also on the requirements of the products being made, the casting temperature, the section size, etc. For example, if very thin sand castings are being produced, they are usually cast or poured at relatively high temperatures, and it is necessary to make the addition of the agent at a high temperature even though at the expense of magnesium recovery. If the products being made are cast at low temperatures, e. g., pressure pipe, ingot molds, or very heavy castings, then the addition agent can be added to the bath at a low temperature and thus utilize the fact that the magnesium recovered varies inversely with the treating temperature. For example, in making ingot molds which are normally cast in the range of 2300° F. to 2400° F., the agent is ordinarily added at a temperature of about 2500° F., and thus a higher recovery of magnesium is secured. Furthermore, irons treated in this manner can be desulfurized with sodium carbonate or some other agent since there is adequate temperature leeway between melting and casting, and this further reduces the amount of magnesium agent required. It is axiomatic, of course, that all irons, regardless of casting temperature, should be heated sufficiently hot (e. g., between 2750° F. and 2850° F. which are normal operating temperatures for cupolas) to make certain that all the primary constituents of the melt, including graphite, are completely dissolved. The addition agent has been suc-

cessfully used with irons melted in the air furnace where the temperatures of the iron in the furnace rarely exceeded 2650° F. to 2700° F. All the primary constituents of the melt were dissolved under these circumstances, in spite of the fact that the irons were not melted as hot as in the case of cupola melting, because of the long interval that the irons were in the molten condition in the furnace. In other words, time can be a partial substitute for temperature to dissolve the primary constituents provided that the primary constituents of the melt are completely soluble at the temperature attained.

The addition agents described hereinbefore represent practical compositions useful for carrying out the process embodying the present invention. In addition to nickel, magnesium and silicon, the agents may also contain up to about 12% or 15% iron, e. g., 0.01% to 15%, up to about 2% or even 20% copper, e. g., 0.01% to 20%, up to about 1% cobalt, e. g., 0.01% to 1%, up to about 1% manganese, e. g., 0.01% to 1%, up to about 1% calcium, up to about 0.3% or 0.5% aluminum, etc. The sum of the nickel and copper contents is at least about 40% of the agent. In addition to the foregoing, the agent provided by the invention may contain small amounts of incidental impurities. The cooperating agents contemplated by the invention preferably are devoid of the elements lead, tin, antimony, arsenic, bismuth, selenium, tellurium, etc.

The agents contemplated by the invention are adapted to the treatment of cast iron baths for the general improvement thereof, e. g., for deoxidation, desulfurization, etc., leading to the production of improved properties in castings made from said baths. Improved properties are obtained when cast iron melts are treated with about 0.25% to about 3% of the aforesaid magnesium-containing agents. Usually the amount added will be at least about 0.5% or 0.8%.

In producing graphitic cast iron, the process comprises establishing a bath having such a composition as to be a gray cast iron when inoculated and cast, adding to said bath the special cooperating addition agent having a composition within the aforementioned ranges, and casting the metal from said bath in an inoculated condition to obtain gray iron castings having improved properties. The process is applicable to the production of castings containing at least a small but effective amount of retained magnesium and having the graphite present in a compacted form, especially graphite in a spheroidal form.

Magnesium retained in cast iron has been found to have by itself a very powerful whitening or carbide-stabilizing effect which is usually undesirable in graphitic iron castings. Accordingly, a foundryman accustomed to gray iron will find that for comparable conditions, it will usually be necessary to have a higher inherent graphitizing tendency in the base metal in order to avoid chilled edges and carbide structures in light sections. In the production of magnesium-containing gray cast iron, it is usually necessary in the great majority of cases to cast the magnesium-containing baths in an inoculated condition to insure that the resulting castings will be graphitic. While the agent employed in carrying out the invention simultaneously introduces magnesium and promotes an inoculating effect, the extent of the inoculating effect will depend on the composition of the iron being treated, the mass of the casting made, its cooling rate, etc. If

the casting is light in section and the inherent graphitizing power of the base iron is low, then the resulting product with, for example, 0.05% retained magnesium will tend to be a white iron. On the other hand, with a composition having a strong graphitizing tendency, e. g., one containing 3.8% carbon and 2.5% silicon, the inoculating effect of the agent may be appreciable in castings heavy in section. For average conditions, it is preferred to add a supplemental inoculating agent after the addition of the special magnesium-containing agent. The supplemental inoculants may be ferrosilicon, nickel silicide, calcium silicide, etc. When inoculants such as the foregoing are also employed in the treatment of cast iron melts, amounts of from about 0.2% to about 1% or 1.5% by weight of the bath may be employed. When silicon-containing inoculants are employed, the common quantities of silicon introduced for supplemental inoculation of magnesium-containing irons usually range from about 0.35% to about 1% silicon. Magnesium-containing irons are generally subjected to heavier inoculation than is common for magnesium-free gray irons. It might be said that the principal effect of the inoculating tendency of the special magnesium-containing agent is to reduce the amount of supplementary inoculant required. A comparison with a magnesium agent free of silicon discloses that more supplemental inoculation is required under these circumstances than in the case of the special silicon-containing magnesium agent described herein. One practical illustration of where the supplemental inoculation has not been required is the casting of heavy parts, e. g., machinery parts weighing 50,000 pounds and having a cross section of more than 12 inches. Another practical instance where the supplemental inoculant has been omitted occurs when the section is so light in relation to the inherent graphitizing power of the base iron that complete graphitization of massive carbides cannot be made to occur in the cast condition even when supplemental inoculation is employed. Such light castings are subsequently annealed for graphitization, and it is believed that the inoculating tendency of the agent assists graphitization during annealing.

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% to about 5%, with the balance essentially iron, said balance usually being 85% or 87% or more iron. The aforesaid baths include 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 have gray iron compositions containing about 2% to about 4.5% carbon or about 2.5% to 4% carbon and containing silicon in such an amount that the final silicon content of castings made according to the process embodying the invention is usually 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, etc. In order to realize the preferred effects obtainable through the introduction of magnesium into cast iron, the copper content of the cast iron bath is kept below about 2%. The cast iron bath to be

treated is preferably practically devoid of subversive amounts of tin, lead, antimony, bismuth, arsenic, selenium, tellurium, etc., as such elements have been found to be subversive to the desired effects of magnesium, for example, on the graphite form. The impurities phosphorus and sulfur may be present in the 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 0.01% or about 0.02% to 0.06%. Similarly, the sulfur content 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., 0.01% or 0.03% to 0.1%. Generally speaking, when sufficient magnesium is introduced into a cast iron containing more than about 0.02% sulfur (e. g., 0.03% to 0.1% or more) to produce a retained magnesium content of 0.03% or more, the sulfur content will be reduced below 0.02%.

In the process provided by the present invention wherein gray cast iron is produced containing a small but effective amount of magnesium to cause the occurrence of graphite in a substantially compacted form, including the spheroidal form, the initial bath preferably contains about 3.4% to about 4% carbon, about 0.1% to about 0.4% manganese, about 0.01% or about 0.03% to about 0.1% sulfur, about 0.01% or about 0.02% to about 0.12% phosphorus, at least about 1% or about 1.25% silicon, and the balance essentially iron. Castings poured from a molten bath treated by adding to the aforesaid bath the amounts of addition agent contemplated by the invention will contain about 1.5% or about 2% to about 2.5% or about 4.5% silicon.

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 gray cast iron melt containing about 4% carbon, about 1.4% silicon, about 0.35% manganese, about 0.06% phosphorus and about 0.04% sulfur was established and the temperature of the bath was adjusted to permit successful casting. To a portion of said bath held in a ladle, a 1.5% addition of an alloy containing about 18% magnesium, about 27% silicon, about 47% nickel and about 8% iron was made. The thus-treated metal was then cast. In 1-inch keel sections, the castings had hardness values of 215 to 230 Brinell, tensile strengths of 87,000 to 92,000 pounds per square inch and elongations of 5% to 7.5% in the as-cast condition.

Example 2

A cast iron melt containing about 3.3% carbon, about 1.3% silicon, about 0.3% manganese, about 0.03% phosphorus, and about 0.11% sulfur was established. About 2,000 pounds of the melt held in a ladle were reladled upon lumps of an alloy containing about 14.7% magnesium, about 30% silicon, about 41% nickel, about 5% copper, and about 5.7% iron, said agent amounting to about 2.25% by weight of said reladled melt. The thus-treated metal was then inoculated with an addition of about 0.75% silicon as ferrosilicon and was then cast. A test specimen taken from a 1-inch keel block thus produced contained about 0.09% retained magnesium and exhibited in the as-cast condition a tensile strength of about 85,500 pounds per square inch and an elongation of about 14%. The graphite in the casting was

wholly in the spheroidal form and was dispersed in a matrix which was about 75% ferritic.

The magnesium addition agent employed in carrying out the invention can be prepared as an alloy by a method which comprises melting down nickel and ferrosilicon (e. g., an alloy containing about 75% silicon, balance essentially iron), introducing magnesium into the resulting bath, and casting the metal from said bath. Care should be exercised in preparing the alloy. Nickel and silicon under certain conditions of melting react exothermically, and this reaction can attain violent proportions. With proper precautions, the alloy can be manufactured on a commercial scale.

The present application is a continuation-in-part of our copending application U. S. Serial No. 108,424 filed August 3, 1949, now U. S. Patent No. 2,563,859, which is a continuation-in-part of our application U. S. Serial No. 787,420 filed November 21, 1947, now U. S. Patent No. 2,485,760.

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. The improved method for producing gray cast iron which comprises establishing a gray cast iron bath containing about 3.4% to about 4% carbon, about 0.1% to about 0.4% manganese, about 0.03% to about 0.1% sulfur, about 0.02% to about 0.12% phosphorus, at least about 1.25% silicon and at least about 85% iron, adding to said bath about 0.8% to about 3% of an agent containing about 25% to about 30% silicon, about 14% to about 20% magnesium, up to about 12% iron, up to about 1% calcium and the balance essentially nickel to desulfurize the metal of said bath below about 0.02% sulfur and to incorporate at least a small but effective amount of magnesium in said metal and to provide in said metal an improved graphitizing propensity, and casting said magnesium-containing metal from said bath to obtain gray iron castings containing a small but effective amount of magnesium and containing graphite in a compacted form, whereby small, substantially constant additions of said agent under similar conditions provide predetermined retained magnesium contents in said castings independent of variations in the magnesium content of said agent within the aforesaid magnesium range.

2. The improved method for producing gray cast iron which comprises establishing a bath having such a composition as to be a gray cast iron when inoculated and cast, adding to the metal in said bath about 0.25% to about 3% of an agent containing about 25% to about 30% silicon, about 14% to about 20% magnesium, up to about 12% iron and the balance essentially nickel to incorporate and retain in said metal of said bath at least a small but effective amount of magnesium and to provide in said metal an improved graphitizing propensity, and casting said magnesium-containing metal in an inoculated condition to obtain improved gray iron castings containing a small but effective amount of magnesium and containing graphite in a compacted form, whereby small, substantially con-

stant additions of said agent under similar conditions provide predetermined retained magnesium contents in said castings independent of variations in the magnesium content of said agent within the aforesaid magnesium range.

3. The improved method for producing gray cast iron which comprises establishing a bath having such a composition as to be a gray cast iron when inoculated and cast, adding to said bath about 0.8% to about 3% of an agent containing about 25% to about 50% silicon, about 12% to about 20% magnesium, up to about 12% iron and the balance essentially nickel, and casting the metal from said bath in an inoculated condition to obtain gray iron castings having improved properties as compared to the properties of similar gray iron castings not treated with the aforesaid agent, whereby small, substantially constant additions of said agent under similar conditions provide predetermined retained magnesium contents in said castings independent of variations in the magnesium content of said agent within the aforesaid magnesium range.

4. The improved method for producing cast iron which comprises establishing a bath having such carbon and silicon content as to be a gray cast iron when inoculated and cast, adding to said bath about 0.8% to about 3% of an agent containing about 12% to about 20% magnesium, about 25% to about 35% silicon, up to about 20% copper, up to about 15% iron, and the balance essentially nickel, with the sum of the copper and nickel contents being at least about 40% of the agent, to incorporate in the metal of said bath at least a small but effective amount of magnesium and to provide in said metal an improved graphitizing propensity, and thereafter casting metal from said bath in an inoculated condition to produce gray cast iron castings containing at least a small but effective amount of magnesium and containing graphite substantially in a spheroidal form, whereby small, substantially constant additions of said agent under similar conditions provide predetermined retained magnesium contents in said castings independent of variations in the magnesium content of said agent within the aforesaid magnesium range.

5. The improved method for producing cast iron which comprises establishing a bath having such a composition as to be a gray cast iron when inoculated and cast; adding to said bath about 0.25% to about 3% of an alloy containing about 14% to about 20% magnesium, about 25% to about 50% silicon, up to about 15% iron, up to about 20% copper, and the balance essentially nickel, with the sum of the nickel and copper contents being at least about 40% of the alloy, to incorporate in the metal of said bath at least a small but effective amount of magnesium and to provide in said metal an improved graphitizing propensity; and thereafter casting metal from said bath in an inoculated condition to produce graphitic cast iron containing at least a small but effective amount of magnesium and containing

graphite in a compacted form, whereby small, substantially constant additions of said alloy under similar conditions provide predetermined retained magnesium contents in said castings independent of variations in the magnesium content of said alloy within the aforesaid magnesium range.

6. The improved method for producing graphitic cast iron containing magnesium and spheroidal graphite which comprises adding to a molten cast iron bath having such a composition as to produce a gray cast iron when inoculated and cast about 0.5% to about 3% of an agent containing about 12% to about 22% magnesium, about 25% to about 50% silicon, up to about 15% iron, up to about 20% copper, with the balance essentially nickel, with the sum of the nickel and copper contents being at least about 40% of the alloy, to incorporate at least a small but effective amount of magnesium into said molten bath and to provide in said metal an improved graphitizing propensity; and thereafter casting metal from said bath in an inoculated condition to produce a graphitic cast iron containing at least a small but effective amount of retained magnesium and containing graphite predominantly in a spheroidal form, whereby small, substantially constant additions of said agent under similar conditions provide predetermined retained magnesium contents in said castings independent of variations in the magnesium content of said agent within the aforesaid magnesium range.

7. The improved method for incorporating magnesium in cast iron which comprises establishing a molten cast iron bath, and adding to said bath about 0.25% to about 3% of an agent containing about 12% to about 22% magnesium, about 25% to about 50% silicon, up to about 15% iron, up to about 20% copper and the balance essentially nickel, with the sum of the copper and nickel contents being at least about 40% of the agent, thereby obtaining cast iron having an improved combination of graphitizing propensity and magnesium recovery for a given addition of magnesium-containing agent and whereby small, substantially constant additions of said agent under similar conditions provide predetermined retained magnesium contents in said castings independent of variations in the magnesium content of said agent within the aforesaid magnesium range.

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