This invention relates to a process for malleableizing iron and to an alloy for effecting the same. Malleable iron is a heat-treated product having greater strength and ductility than ordinary gray cast iron. This type of iron is cast in the form of white iron having carbon present in the form of massive carbides of iron and manganese. Hard and brittle white iron is softened and toughened by an extended heat treatment at high temperature during which the iron carbide is dissolved and the carbon content precipitates in the form of temper carbon consisting of groupings of very fine graphite flakes. It is known that a small addition of boron to such iron makes possible its softening by annealing in a reduced period of time. This addition also makes possible the production of a more consistent and uniform malleable iron having improved characteristics of micro-structure, machinability and hardness. In addition, boron also increases the number of graphite nodules in the structure of the iron. Boron is also added to malleable iron for the purpose of neutralizing the carbide stabilizing effects of certain residual metals such as chromium, which may be introduced into the iron by steel or iron scrap in the furnace or cupola charge from which the iron is produced, the presence of which renders very difficult the annealing of iron.

Hitherto the conventional practice to add boron to malleable iron and other cast irons in the form of alloys of iron and boron. In this process the ferroboron alloy is added to molten metal as tapped into a ladle or alternatively to metal in an air or electric furnace. The criticality of the amount of boron addition necessitates a great care in operation. This is because the iron is likely to be adversely affected. It is, furthermore, not practical to use ferroboron alloys in the cupola charge because of high losses occurring therein, which would render the boron treatment prohibitively expensive.

It is, therefore, the primary object of this invention to provide a ferrosilicon alloy containing boron, which alloy can be put through the cupola without subsequently treating the iron with costlier ferroboron alloy.

Another object of this invention is to produce malleable iron through the use of a boron-containing ferrosilicon alloy, in which the boron content is controlled within certain limits. Another object is to provide improved control of annealing by the use of boron-containing ferrosilicon, and to simplify the production of consistently high quality malleable irons of both the ferritic and pearlitic grades. This means that these objects are attained based on the discovery that boron can be more easily and accurately introduced in cast iron to produce malleable iron of high quality when it is alloyed with both iron and silicon, which element also promotes malleableizing, than when added with iron alone.

Ferroboron alloys containing between 15 percent and 90 percent silicon with 0.01 percent to 0.20 percent boron are satisfactory for use in the production of malleable iron, and in the practice of this invention. The compositions of the alloys in regard to silicon and boron must be such that the silicon to boron ratio would permit the addition of between 0.0005 percent and 0.003 percent boron without simultaneously adding too much silicon. In general, the boron content of the alloy must approach the lower end of the range specified in the alloys having the lower silicon contents. In cases where the silicon contents of the alloys are high, the boron content must be proportionately increased. Thus, by adjusting the composition of the alloy-containing ferrosilicon, it is always possible to add sufficient silicon and boron to permit the addition of between 0.0005 percent and 0.003 percent boron to the iron.

The preferred range for the alloys is about 25 percent and 90 percent silicon, with 0.01 percent to 0.20 percent boron. Because of this higher silicon content an improved recovery of boron can be obtained. Satisfactory results, however, may also be obtained with iron alloys containing the lower percentages of silicon hereinbefore mentioned. As an example of the practice of this invention, 140 pounds of 0.041 percent silicon, 49.24 percent silicon ferroalloy was used per 10,000 pound cupola charge of duplex malleable iron, thereby introducing 0.00057 percent boron. A high recovery of boron was obtained, and the product annealed satisfactorily.

Conventionally, the temperature used in malleableizing iron is in the range of 1600° to 1750° F. As is well known, the practice is to gradually heat the iron to this temperature, hold it there for the required time, and then slowly to cool it through the transformation range at a rate of less than 10° F. per hour to produce malleable iron free of the pearlitic constituent. In production, the annealing of malleable iron is carried on in cycles which vary extensively, depending upon the tonnage of metal being annealed, and upon the type of article so treated. The annealing cycle in some instances may be as short as 18 to 30 hours, while in others it may be protracted to 72 or more hours. By the careful control of the boron level, which is made possible by the method of this invention, it is possible to cool the treated iron article at a faster rate.

No particular form of apparatus for preparing the molten mix for pouring it, and no one particular type of annealing furnace are herein described by diagrams, inasmuch as any suitable prior art means for these purposes may be used.

The exact mechanism whereby the alloys of this invention operates to achieve the effects indicated is not known. The insoluble boron present in the annealed iron may be one of a number of compounds, but is believed to be in the form of either a nitride or carbide. It is thought that the insoluble boron compounds are rejected early during heat treatment of the iron, and act as nuclei for the growth of temper carbon during the annealing cycle. The presence of such a nucleus promotes the precipitation of temper carbon, thereby reducing the time necessary to maintain the process at the annealing temperature to obtain substantially complete precipitation of the carbide in the form of temper carbon.

The ferrosilicon alloy containing boron is used in lump form, or in the form of briquets. Briquets of the alloys produced from crushed ladle have been found to be especially suitable for malleable iron production. These can be prepared from a single ferrosilicon alloy.
containing boron, or may be prepared from ferrosilicon alloys or ferroboron alloys mixed prior to briquetting.

In summary, the economy involved in using a ferro-
silicon boron alloy of the type herein disclosed is of great
importance, because boron can be introduced at a much
lower cost. That this alloy may be added to the cupola
carbon or to ferrosilicon or ferroboron alloys mixed prior to...substantially convert and precipitate in the form of temper carbon, the carbon contained in said white iron.

What is claimed is:

1. The process of producing malleable iron, which
  comprises adding to a cupola charge of iron, silicon and
  manganese, containing carbon and incidental impurities, an
  alloy consisting of silicon in the range between 15 per-
cent and 90 percent, between 0.01 percent and 0.20 per-
cent boron, the remainder iron; said boron thus intro-
duced comprising between 0.0005 percent and 0.003 percent
  of said charge, forming a cast iron article and annealing
  said article at the annealing temperature to substan-
tially convert and precipitate in the form of temper carbon the
  carbon present in said cupola iron.

2. The process of producing malleable iron, which
  comprises adding to a cupola charge of iron, silicon con-
  taining carbon and incidental impurities, an alloy con-
  sisting of silicon in the range between 25 percent and 90
  percent, between 0.01 percent and 0.20 percent boron, the
  remainder iron; said boron thus introduced comprising
  between 0.0005 percent and 0.003 percent of said charge,
  forming a cast iron article and annealing said article at the
  annealing temperature to substantially convert and
  precipitate in the form of temper carbon, the carbon
  present in said cupola iron.

3. The process of producing malleable iron, which
  comprises adding to a cupola charge of iron an alloy
  consisting of 49.2 percent silicon and 0.04 percent
  boron, the remainder iron; forming a cast iron article
  and annealing said article at the annealing temperature
  to substantially convert and precipitate in the form of
  temper carbon the carbon contained in said cupola iron.

4. A process for producing malleable iron, which
  process comprises adding to a cupola charge of white iron
  briquets of an alloy consisting of silicon in the range be-
tween 25 percent and 90 percent, with between 0.1 per-
cent and 0.2 percent of boron, the remainder iron, said
  briquets being prepared from mixtures of ferroboron and
  ferrosilicon alloys; forming a cast iron article and anneal-
ing said article at the annealing temperature to substan-
tially convert and precipitate in the form of temper carbon
  the carbon contained in said white iron.

5. A process for producing malleable iron, which proc-

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