

UNITED STATES PATENT OFFICE

2,331,886

ALLOY MALLEABLE IRON

Alfred L. Boegehold, Detroit, Mich., assignor to
General Motors Corporation, Detroit, Mich., a
corporation of Delaware

No Drawing. Application September 10, 1938,
Serial No. 229,291

19 Claims. (Cl. 148—3)

This invention has to do with alloy compositions for making malleable iron castings and the manufacture thereof.

My invention comprises alloys and processes of producing the same to provide castings having a white fracture commonly known as "white iron castings." The alloys forming the subject matter of this invention contain as essential alloying constituents carbon, silicon, manganese, copper and tellurium in comparatively small amounts with a large amount of iron. In addition to the above mentioned elements, the compositions include ordinary impurities such as small amounts of sulphur, phosphorous, etc. These impurities are usually present in amounts from a trace up to around .10% of each. In certain applications of the invention small amounts of molybdenum are added. The white iron castings are adapted to be annealed to produce what is known as "malleable iron," or they may be specially annealed or heat treated to obtain higher physical properties than possessed

The elements carbon, silicon, manganese, copper, tellurium, etc. in accordance with my invention are present in amounts such that the iron upon solidification will have the fracture typical of white cast iron. The compositions are such that grey iron rather than white iron would be produced without the inclusion of tellurium. In general, the amounts of the several elements will be within the following ranges: 1.00–3.50% carbon, .50–2.50% silicon, .35–1.75% manganese, .25–2.00% copper, .002–.02% tellurium added, balance iron plus minor amounts of ordinary impurities. Greater amounts of tellurium may be added if desired. For example, up to .2%, tellurium may be added, or even greater amounts if desired, in particular applications of my invention. Usually the higher amounts are unnecessary and are not preferred.

I have found that the addition of small amounts of copper to irons containing tellurium prevents the formation or occurrence during the annealing operation of widely separated temper carbon spots of large size which tend to form in heavy sections when tellurium is added to the metal. The occurrence of the widely separated temper carbon spots of large size is more apparent in larger sections than in the case of smaller sections. In the larger sections the presence of the large temper carbon spots greatly retards the carbide decomposition during the annealing operation. One important object of my invention is to prevent the formation of the

widely separated temper carbon spots during the annealing of white iron castings of large size which contain tellurium by providing a white iron of a particular composition. For these large size castings the ranges of percentages of the several essential elements are preferably approximately as follows: 2.00–3.25% total carbon, 1.00–2.50% silicon, .25–2.00% copper, .35–.45% manganese, .002–.02% tellurium added, balance iron. The specific percentages of the several elements will vary somewhat with the different sized castings and different cooling rates, for example, in order to obtain white iron castings. In those cases in which the carbon content is on the high side of the range mentioned, an adjustment of the silicon, copper and tellurium is made. This means that the percentages of the silicon and/or copper are toward the lower side of the ranges disclosed, or more of the tellurium may be added. The composition is such in any case that the alloy without the tellurium has the fracture typical of grey iron but is such that the inclusion of tellurium results in a white fracture as cast, whereby the casting may be annealed to obtain malleable iron castings.

As heretofore mentioned I have found that the addition of copper to the white iron tends to prevent the formation of large, widely separated temper carbon spots during the annealing of large sections. In order to obtain the greatest benefit in this direction in the irons containing copper I prefer that a special annealing cycle be followed. This special annealing cycle includes heating the castings to around 900° F. for about four hours before heating to a temperature of around 1700° F. at which primary graphitization takes place. The treatment at about 900° F. for approximately four hours causes the formation of a greater number of small temper carbon spots and in this way accelerates the primary graphitization stage. While the special annealing cycle is preferred, the castings may be annealed by following the usual or standard annealing cycle, or in any convenient manner. The usual annealing cycle is to heat to approximately 1700° F. at a suitable rate, hold at this temperature until massive cementite is eliminated (usually about eight hours), cool to about 1400° F. at about 150° F. per hour, cool from 1400° to approximately 1300° F. at around 7° F. per hour. The special annealing cycle differs from the usual cycle in the treatment at around 900° F. for approximately four hours.

For sections having a rate of solidification similar to that of a two-inch round bar four inches

or more in length the several essential constituents may be approximately as follows:

	Per cent
Carbon	2.50-2.85
Silicon	1.45-1.60
Manganese	.35-.45
Copper	.45-.60
Tellurium added	.003-.006
Iron plus usual amounts of ordinary impurities	Balance

A specific example for a section having a rate of solidification similar to a round bar of 2" diameter is 2.75% carbon, .40% manganese, 1.50% silicon, .50% copper with about .006% tellurium added. The balance is iron with ordinary impurities such as sulphur, phosphorous, etc. in small amounts.

A specific example for an extra large section having a rate of solidification similar to that of a round bar four inches in diameter may be as follows: 2.00% carbon, 1.75% silicon, .40% manganese, 1.75% copper, .02% tellurium added, balance iron plus usual impurities.

The addition of small amounts of molybdenum to the iron enables malleable iron castings having extremely good physical properties to be readily obtained. In attempting to obtain high physical properties by heat treating ordinary malleable iron, or ordinary pearlitic malleable iron, in heavy sections it has been found that even with drastic quenching the heavy sections do not harden satisfactorily throughout. The addition of small amounts of molybdenum to irons containing copper and tellurium in addition to carbon, manganese, and silicon provides a suitable alloy composition which can be readily hardened after the annealing or malleabilizing operation in sections of large size by oil or air quenching depending on the proportions of the alloying elements used.

In general, the alloys having good properties of hardenability in heavy sections by means of air or oil quenching after the annealing operation in accordance with my invention may be composed as follows: 1.00-3.50% total carbon, .50-2.50% silicon, .35-1.75% manganese, .25-2.00% copper, .10-.75% molybdenum, .002-.02% tellurium added, balance iron plus usual impurities. The amounts of each element within the above ranges is so chosen that white iron castings result. It is to be understood also that without the tellurium the composition selected for any casting would result in a grey or mottled iron. The function of the tellurium is to permit the use of a composition ordinarily too high in graphitizing elements to obtain a white iron without it. The white iron castings may be annealed to produce malleable or pearlitic malleable iron as desired. The malleabilized castings of large section in accordance with my invention can be readily hardened without drastic quenching operations. If desired, the composition may be so adjusted that castings given the regular annealing cycle for malleabilizing will retain a hard martensitic structure. Any degree of hardenability between this extreme and that of ordinary malleable iron may be obtained by proper adjustment of the elements silicon, manganese, copper and molybdenum.

The following specific examples of white iron compositions which may be malleabilized and heat treated in sections of large size, as for example a 2" round bar at least 4" long, by air or oil quenching are given. A composition which may be malleabilized and thereafter air

quenched from a temperature of around 1600° to produce a martensitic structure in the bar is as follows: 2.50% carbon, 1.50% silicon, 1.20% manganese, 1.00% copper, .25% molybdenum, .003% tellurium added, the balance iron plus usual impurities.

A composition similar to that first given containing .75% manganese in place of 1.20% will upon air cooling have a structure which is largely martensitic with some pearlite. Oil quenching instead of air quenching provides sufficient cooling velocity to cause this alloy to be fully martensitic. A range of the several components for this purpose is as follows: 2.40-2.75% carbon, 1.45-1.60% silicon, .70-.80% manganese, .90-1.10% copper, .20-.30% molybdenum, .003-.006% tellurium added, balance iron plus usual impurities.

An example of a casting where high strength after annealing and heat treatment is desired when used in a heavy section where flake graphite would form without the addition of tellurium is as follows: 1.00-1.50% carbon, 2.25-2.50% silicon, .80-1.00% manganese, 1.50-2.00% copper, .25-.35% molybdenum, .005-.010% tellurium added, balance iron plus ordinary impurities.

The following is an example of a high carbon, high silicon cast iron modified by tellurium, copper and molybdenum additions to convert it into a heat treatable, annealable white iron casting for light and medium sections: 3.25%-3.50% carbon, 2.40-2.50% silicon, .60-.80% manganese, .40-.50% copper, .20-.25% molybdenum, .003-.006% tellurium added, balance iron plus usual amounts of ordinary impurities.

The following is a composition which even after an annealing cycle that would completely anneal ordinary malleable iron in which the cooling rate from 1400° to 1300° F. is 10° an hour, will have a martensitic structure of about 440 Brinell: 2.40-2.75% carbon, 1.45-1.60% silicon, 1.40-1.60% manganese, .90-1.10% copper, .45-.55% molybdenum, .003-.006% tellurium added, balance iron. The above alloy when heated to 1600° F. and air cooled becomes harder and has a hardness of over 500 Brinell.

The alloys with medium manganese and molybdenum contents after the standard annealing cycle for ordinary malleable iron possess varying proportions of ferrite, pearlite and martensite having hardnesses ranging from 146 to 235 Brinell, depending upon the amounts of manganese and molybdenum used. The following table gives examples of compositions, structures and hardness:

Table

C	Si	Mn	Cu	Mo	Te added	Annealed like regular malleable iron—cooled thru critical range @ 7° F. per hour	
						Structure	Hardness
2.70	1.50	.38	1.06	.28	.003	Ferrite and temper C.	146
2.56	1.50	.74	1.02	.27	.003	Ferrite, pearlite and temper C.	187
2.62	1.50	.98	1.08	.26	.003	Ferrite, pearlite and temper C.	217
2.40	1.50	1.18	1.06	.26	.003	Pearlite, temper C, trace of ferrite.	235
2.66	1.71	.78	1.02	.26	.003	Ferrite, pearlite and temper C.	197
2.49	1.71	1.19	1.07	.25	.003	Ferrite, pearlite and temper C.	229

The hardness of the above compositions may be readily increased by air or oil quenching from a temperature of around 1600° F.

The several alloying constituents may be added in any desired manner. In the case of the tellurium it may be added to the molten iron coming from the cupola or electric furnace, or if desired, tellurium oxide may be added, although the oxide is slightly less effective than the metal. Other alloys or compounds containing tellurium may be added. With the continued use of tellurium it will be found that the scrap returned to be remelted will contain small amounts of tellurium and this must be taken into account in determining the amount of tellurium which it is necessary to supply to the molten iron in any case.

The amount of tellurium in the solidified white iron casting is not known definitely, since quantitative tests for this element in the small amounts present are not accurate. In each case the amount in the white iron casting is thought to be somewhat less than that supplied to the iron. This is due to volatilization, etc. of the tellurium. Qualitative tests indicate that when the tellurium is supplied to the iron as described the solidified white iron casting contains tellurium.

In some of the descriptions of the alloy or casting herein the language "tellurium added" is used defining the amount of tellurium in the solidified iron alloy. This language is meant to describe the amount of tellurium that remains in the white iron casting upon solidification when the tellurium is supplied to the molten metal coming from the cupola, electric furnace, or other melting furnace, in the amounts stated. It is meant, also, to include by the term "tellurium added" equivalent amounts in the solidified white iron regardless of how the tellurium is supplied. In other words a portion of the tellurium may be supplied in the scrap to be remelted and this must be taken into account in determining the amount which is supplied to the molten iron coming from the melting furnace. So long as the amount of tellurium in the casting is present in amount equivalent to that which results from supplying the tellurium to the molten metal coming from the cupola in the amounts described it is intended to be included.

The term "white iron casting" as used herein means a carbon containing iron free of appreciable amounts of carbon in flake form that characterizes ordinary grey iron castings. I do not intend the term to exclude castings that may contain some nodular or temper carbon but contain substantially no flake carbon. White iron as used commercially for the manufacture of malleable iron may have a small percentage of the structure containing flake graphite without detriment to the properties of the annealed product. These small areas are known as mottles and are similar to grey iron in structure.

It will be understood that various modifications and changes may be made by skilled metallurgists in the embodiments of my invention disclosed herein without departing from the principle and spirit of my invention and I do not desire to limit the patent granted thereon except as necessitated by the prior art.

I claim:

1. An annealable white iron casting composed largely of iron and containing small amounts of carbon, silicon, manganese, .25 to about 2% copper, and a small but effective amount of tellurium up to about .02%, the composition without the tellurium being such that a grey or mottled iron would be formed on solidification and the tellurium being sufficient to obstruct formation

of flake graphite during solidification of the casting.

2. An annealable white iron casting as in claim 1 containing .10-.75% molybdenum.

3. An annealable white iron casting especially adapted for heavy sections which consists of the following elements as essential constituents in approximately the amounts given:

	Percent
Carbon-----	2.50-2.85
Silicon-----	1.45-1.60
Manganese-----	.35-.45
Copper-----	.45-.60
A small but effective amount of tellurium up to about-----	.006
Iron-----	Balance

4. An annealable white iron casting adapted after annealing to form castings having good properties of hardenability in heavy sections which consists of the following elements as essential constituents within the ranges given:

	Percent
Carbon-----	1.00-3.50
Silicon-----	.50-2.50
Manganese-----	.35-1.75
Copper-----	.25-2.00
Molybdenum-----	.10-.75
A small but effective amount of tellurium up to about-----	.02
Iron-----	Balance

5. An annealable white iron casting composed of the following elements as essential constituents in approximately the percentages given:

	Percent
Carbon-----	2.40-2.75
Silicon-----	1.45-1.60
Manganese-----	.70-.80
Copper-----	.90-1.10
Molybdenum-----	.20-.30
A small but effective amount of tellurium up to about-----	.006
Iron-----	Balance

6. An annealing white iron casting composed of the following elements as essential constituents in approximately the proportions given:

	Percent
Carbon-----	2.40-2.75
Silicon-----	1.45-1.60
Manganese-----	1.40-1.60
Copper-----	.90-1.10
Molybdenum-----	.45-.55
A small but effective amount of tellurium up to about-----	.006
Iron-----	Balance

7. The steps in a process of making an annealable white iron casting which comprises, providing a molten composition containing as essential elements iron, carbon, silicon, manganese, .25-2.00% copper, a small but effective amount of tellurium up to about .02%, and pouring said molten composition into the form of the desired casting, the molten composition without the tellurium being such that a grey or mottled iron casting would be formed upon solidification.

8. A process as in claim 7 in which the molten composition includes .10-.75% molybdenum.

9. A process of making a malleable iron casting which comprises; providing a molten composition composed largely of iron and containing small amounts of carbon, silicon, and manganese, said composition also containing .25-2.00% copper and a small but effective amount of tellurium up to about .02%; pouring said mol-

ten composition into the form of the desired casting and annealing said casting, the composition without tellurium being such that a grey or mottled iron casting would be formed upon solidification and the tellurium content being sufficient to cause at least substantially all of the carbon to be in combined form after solidification, said annealing operation breaking down at least a portion of the combined carbon to form temper carbon.

10. A process as in claim 9, in which the annealing operation includes heating the casting to about 900° F. for about four hours and thereafter heating to a higher temperature sufficient to break down the massive cementite.

11. A process as in claim 9 in which the molten composition includes .10-.75% molybdenum.

12. An annealable white iron especially adapted for castings of heavy section composed substantially as follows:

	Percent
Carbon	2.00-3.25
Silicon	1.00-2.50
Manganese	.35-.45
Copper	.25-2.00

a small but effective amount of tellurium up to about .02%, balance substantially all iron.

13. An annealable white iron casting composed largely of iron and containing 1.00-3.50% carbon, .50-2.50% silicon, .35-1.75% manganese, .25-2.00% copper, and a small but effective amount of tellurium up to about .02%, the composition without the tellurium being such that a grey or mottled iron casting would be formed upon solidification.

14. A malleableizable white iron casting composed substantially as follows:

	Percent
Carbon	1.00-3.50
Silicon	.50-2.50
Manganese	.35-1.75
Copper	.25-2.00

a small but effective amount of tellurium up to about .02%, balance substantially all iron.

15. A process of making a malleable iron casting which comprises; providing a molten composition composed substantially as follows:

	Percent
Carbon	1.00-3.50
Silicon	.50-2.50
Manganese	.35-1.75
Copper	.25-2.00

a small but effective amount of tellurium up to about .02%, balance substantially all iron; pouring said molten composition into the form of the

desired casting; and thereafter annealing said casting, the molten composition without the tellurium being such that a gray or mottled iron casting would be formed upon solidification and the tellurium content being sufficient to cause a white iron casting containing massive cementite to be formed upon solidification, said annealing operation breaking down at least a portion of the combined carbon to form temper carbon spots of small size as compared with generally similar compositions free of copper.

16. A process of making a malleable iron casting of heavy section which includes providing a molten composition composed substantially as follows: 2.00-3.25% carbon, 1.00-2.50% silicon, .35-.45% manganese, .25-2.00% copper, a small but effective amount of tellurium up to .02%, and the balance substantially all iron; pouring said molten composition into the form of the desired casting; and thereafter annealing the casting to break down combined carbon to form temper carbon spots of relatively small size, the molten composition without the tellurium being such that a grey or mottled iron casting would be formed upon solidification and the tellurium being effective to cause a white iron casting containing massive cementite to be formed upon solidification and the annealing operation causing at least a portion of the massive cementite to be broken down to form temper carbon spots of small size as compared with generally similar compositions free of copper.

17. A process as in claim 16, in which the annealing operation includes heating the casting to about 900° F. for about four hours and thereafter heating to a higher temperature sufficient to cause breakdown of massive cementite.

18. An annealed or malleableized iron casting composed largely of iron and containing 1.00-3.50% carbon, .50-2.50% silicon, .35-1.75% manganese, .25-2.00% copper, and a small but effective amount of tellurium up to about .02%, said annealed casting having at least a portion of its carbon in the form of temper carbon spots of small size as compared with generally similar compositions free of copper.

19. An annealed or malleableized iron casting of heavy section composed largely of iron and containing about 2.00-3.25% carbon, 1.00-2.50% silicon, .35-.45% manganese, .25-2.00% copper, and about .002-.02% tellurium, said annealed or malleableized casting having at least a substantial amount of its carbon in the form of temper carbon spots, the temper carbon spots being characterized by their small size as compared with generally similar compositions free of copper.

ALFRED L. BOEGEHOLD.

CERTIFICATE OF CORRECTION.

Patent No. 2,331,886.

October 19, 1943.

ALFRED L. BOEGEHOLD.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, first column, line 22, after "possessed" insert "--by ordinary malleable iron.--"; page 3, second column, line 44, claim 6, for "annealing" read "--annealable--"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of December, A. D. 1943.
