

## UNITED STATES PATENT OFFICE

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## ALLOYS FOR MAKING CAST IRON

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1

The present invention relates to improved addition alloys for cast irons and to a method involving the use thereof for producing improved cast irons consistently possessing superior mechanical properties and soundness.

It is well known that general commercial practice in the manufacture of cast irons has been to make whatever alloying additions were considered necessary directly into the molten furnace charge or at the spout, usually in the form of ferro-alloys, and then to inoculate, usually in the ladle. Many cast iron foundries, due to scrap or other operating limitations such as personnel, technology and/or equipment, found it necessary to confine themselves to producing cast irons of a narrow range of properties from a single base composition. Although the foundries have desired to produce a wide variety of cast irons, they have encountered difficulties in modifying the single base composition by varying the additions of alloying and other elements to accomplish this aim. Attempts to produce these various composition ranges of cast irons to meet a variety of property specifications were found to involve a complexity of alloying and other procedures which rendered such production so difficult as to be uneconomical. As a result, the production versatility of each foundry was seriously limited and the foundry could not, or was reluctant to, produce the wide variety of cast irons continually demanded by the trade. Ease and flexibility of control necessary for the commercial production of the above-mentioned variety of irons were not feasible in any except a few specially-equipped foundries. No simple method providing such ease and flexibility of control was known to the art which might be employed regardless of the base composition and/or the section size of the cast iron product to be made. Although many attempts were made to overcome the above-mentioned problems, none, as far as we are aware, was entirely successful when applied to a commercial operation on an industrial scale in producing consistently satisfactory results.

2

We have discovered an improved method of making cast irons which is notably suited to the production of a wide variety of compositions and properties and is not limited by the base composition and/or section size, and which not only provides all foundries with ease and flexibility of control but which also unexpectedly imparts to the cast iron mechanical properties consistently superior to those possessed by similar cast irons in which the alloying additions and inoculations are made separately as in conventional practice; and a simple, unitary or singly contained alloying addition agent for use in said method whereby these improved properties are consistently obtained.

It is an object of the present invention to provide an improved method of producing cast irons of superior quality and mechanical properties, said method involving the use of a novel addition alloy.

It is another object of the present invention to provide a simple method of producing cast irons, the application of which is unrestricted with regard to the cast iron base composition and/or section size of the final product, and involving the use of a new addition alloy.

A further object of the present invention is to provide a method of producing improved cast irons, the very nature of said method promoting ease and flexibility of control of the manufacture of said cast irons and, by reason of this, simplifying the art of producing high quality cast irons.

The invention likewise contemplates providing a simple method of producing improved cast irons possessing mechanical properties consistently superior to those of similar cast irons made by conventional methods, and involving the use of a novel addition alloy.

Moreover, the invention also has the object of providing cast iron foundries with a simple method involving the use of a novel addition alloy whereby cast irons are produced having mechanical properties superior to those of cast irons made by prior art practice in that unex-

pectedly superior mechanical properties are imparted to said cast irons.

Furthermore, the present invention also has as an object, the provision of an improved method of producing cast irons involving the use of an addition agent within a novel range of composition.

It is also within the contemplation of the invention to provide a simple, unitary or singly-contained addition alloy which can be used in the production of high quality cast irons of any base composition and/or section size and to provide an addition alloy which can be employed in the process of the present invention to accomplish the foregoing objects.

Other objects and advantages of the invention will become apparent to those skilled in the art from the following description.

In general, the invention provides a method of producing cast irons of improved quality, regardless of character, section size and/or base composition, in which a novel alloy within the following range of composition is added to the molten metal bath in small amounts, for example, about 0.5% to about 5% of the molten metal bath, preferably about 1% to about 3%, as a late addition, preferably in the ladle:

|                  | Per cent |
|------------------|----------|
| Silicon .....    | 6 to 35  |
| Chromium .....   | 0 to 20  |
| Molybdenum ..... | 10 to 30 |
| Calcium .....    | 0.1 to 2 |
| Iron .....       | 0 to 30  |
| Nickel .....     | Balance  |

In practice, the addition alloy will usually contain at least a small amount of chromium and/or iron, and the nickel content will usually be at least 30%, for example, within the range of about 30% to about 66%. It is preferred, however, that the alloy composition be maintained within the limits of about 11% to about 17% silicon, about 9% to about 11% chromium, about 14% to about 17% molybdenum, about 0.4% to about 1.0% calcium, up to about 11% iron (in practice usually between about 6% and about 11% iron), and the balance

substantially nickel (in practice usually within the range of about 48% to about 53% nickel). While chromium is not essential, it is preferably present. These addition alloys can be prepared by methods obvious to those skilled in the art. The alloys may contain small amounts of incidental elements and impurities, such as carbon, manganese, titanium and/or aluminum, which may be present as a result of the raw materials, the operations, etc., employed in making the alloys; and when the term "balance" is employed, it is not intended to exclude such small amounts of incidental elements and impurities.

In practicing this invention, addition alloys having the compositions given in the following Table No. 1 were used and gave satisfactory results.

TABLE NO. 1

| Addition Alloy No. | Chemical Compositions |            |            |            |            |            |
|--------------------|-----------------------|------------|------------|------------|------------|------------|
|                    | Percent Si            | Percent Ni | Percent Cr | Percent Mo | Percent Ca | Percent Fe |
| 1.....             | 8.2                   | 53.4       | 10.6       | 16.0       | 1.0        | 10.8       |
| 2.....             | 13.8                  | 49.5       | 9.9        | 14.8       | 0.5        | 11.5       |
| 3.....             | 29.0                  | 39.2       | 7.7        | 11.8       | 0.5        | 12.0       |
| 4.....             | 20.3                  | 45.2       | 9.08       | 13.12      | 0.47       | 10.45      |
| 5.....             | 10.9                  | 51.5       | 10.3       | 15.6       | 0.5        | 11.2       |
| 6.....             | 12.3                  | 50.2       | 10.1       | 15.1       | 0.99       | 9.9        |
| 7.....             | 10.9                  | 50.2       | 10.3       | 15.6       | 2.0        | 11.2       |
| 8.....             | 11.0                  | 50.0       | 0          | 26.0       | 1.0        | 13.0       |
| 9.....             | 15.0                  | 51.0       | 11.0       | 17.0       | 1.0        | 5.0        |
| 10.....            | 15.0                  | 51.0       | 11.0       | 9.6        | 1.0        | bal.       |
| 11.....            | 14.52                 | 50.0       | 11.0       | 10.5       | 1.0        | 8.36       |
| 12.....            | 12.08                 | 50.0       | 11.0       | 15.86      | 1.0        | 10.27      |
| 13.....            | 19.5                  | 45.5       | 9.1        | 13.6       | 0.5        | 11.8       |
| 14.....            | 8.0                   | 53.0       | 10.0       | 16.0       | 1.0        | bal.       |
| 15.....            | 11.0                  | 51.0       | 10.0       | 16.0       | 1.0        | bal.       |
| 16.....            | 14.0                  | 51.0       | 10.0       | 15.0       | 0.7        | 9.0        |

In order to illustrate the superiority of the new method over the conventional practice of separate alloying, generally in the form of ferro-alloys introduced either into the furnace and/or the ladle, and inoculation, usually in the ladle, there were produced melts of cast irons of various carbon contents having the "as cast" compositions given in Table No. 2 and possessing the corresponding mechanical properties given in Table No. 3.

TABLE NO. 2

| Cast Iron No.  | "As Cast" Chemical Compositions |             |             |             |             | Method                     |
|----------------|---------------------------------|-------------|-------------|-------------|-------------|----------------------------|
|                | Per Cent C                      | Per Cent Si | Per Cent Ni | Per Cent Cr | Per Cent Mo |                            |
| A-1 (Old)..... | 2.60                            | 2.10        | 0.50        | 0.10        | 0.15        | C. F. additions.           |
| A-2 (New)..... | 2.60                            | 2.10        | 0.50        | 0.10        | 0.15        | No. 6 alloy 1% in Ladle.   |
| B-1 (Old)..... | 2.50                            | 2.24        | 1.02        | 0.21        | 0.26        | C. F. additions.           |
| B-2 (New)..... | 2.58                            | 2.22        | 1.06        | 0.21        | 0.28        | No. 6 alloy 2% in Ladle.   |
| C-1 (Old)..... | 2.88                            | 2.16        | 1.60        | 0.33        | 0.48        | C. L. additions.           |
| C-2 (New)..... | 2.89                            | 2.16        | 1.60        | 0.33        | 0.48        | No. 1 alloy 3% in Ladle.   |
| D-1 (Old)..... | 3.15                            | 1.95        | 0.50        | 0.10        | 0.15        | C. F. additions.           |
| D-2 (New)..... | 3.15                            | 1.95        | 0.50        | 0.10        | 0.15        | No. 6 alloy 3% in Ladle.   |
| E-1 (Old)..... | 3.18                            | 2.08        | 0.99        | 0.21        | 0.29        | C. F. additions.           |
| E-2 (New)..... | 3.17                            | 2.06        | 0.92        | 0.19        | 0.27        | No. 6 alloy 2% in Ladle.   |
| F-1 (Old)..... | 3.14                            | 1.90        | 0.25        | 0.05        | 0.08        | C. L. additions.           |
| F-2 (New)..... | 3.15                            | 1.90        | 0.25        | 0.05        | 0.08        | No. 2 alloy 0.5% in Ladle. |
| G-1 (Old)..... | 3.69                            | 2.63        | 1.36        | 0.10        | 0.12        | C. F. additions.           |
| G-2 (New)..... | 3.62                            | 2.60        | 1.40        | 0.12        | 0.13        | No. 4 alloy 1% in Ladle.   |
| H-1 (Old)..... | 3.68                            | 3.11        | 2.35        | 0.30        | 0.36        | C. F. additions.           |
| H-2 (New)..... | 3.63                            | 2.92        | 2.35        | 0.30        | 0.38        | No. 4 alloy 3% in Ladle.   |
| I-1 (Old)..... | 3.70                            | 2.62        | 1.46        | 0.09        | 0.14        | C. L. additions.           |
| I-2 (New)..... | 3.71                            | 2.62        | 1.46        | 0.09        | 0.14        | No. 4 alloy 1% in Ladle.   |

C. F. additions=conventional furnace additions.  
C. L. additions=conventional ladle additions.

TABLE No. 3

## Mechanical properties

| Cast Iron No.  | Chill Depth, in. |       | Transverse Str. |            | Tensile Str., p. s. i. | Ized Impact, ft. lbs. | Hardness B. H. N. |
|----------------|------------------|-------|-----------------|------------|------------------------|-----------------------|-------------------|
|                | Clear            | Total | Load, Lbs.      | Defl., in. |                        |                       |                   |
| A-1 (Old)..... | 0.51             | 1.25  | 5,150           | .138       | 52,800                 | 31                    | 254               |
| A-2 (New)..... | 0.14             | 0.80  | 5,880           | .185       | 56,200                 | 41                    | 254               |
| B-1 (Old)..... | 0.12             | 0.40  | 5,950           | .155       | 58,400                 | 42                    | 266               |
| B-2 (New)..... | 0.10             | 0.40  | N. D.           | N. D.      | 61,100                 | 47                    | 269               |
| C-1 (Old)..... | 0.17             | 0.60  | 5,930           | .170       | 61,200                 | 39                    | 279               |
| C-2 (New)..... | 0.05             | 0.18  | 7,200           | .192       | 68,300                 | 58                    | 286               |
| D-1 (Old)..... | 0.58             | 1.30  | 4,530           | .181       | 43,000                 | 24                    | 216               |
| D-2 (New)..... | 0.80             | 0.75  | 4,990           | .197       | 43,100                 | 24                    | 212               |
| E-1 (Old)..... | 0.24             | 0.57  | 5,150           | .193       | 48,000                 | 38                    | 228               |
| E-2 (New)..... | 0.18             | 0.61  | 5,240           | .200       | 48,300                 | 40                    | 227               |
| F-1 (Old)..... | 0.30             | 0.62  | 4,330           | .159       | 46,300                 | 35                    | 217               |
| F-2 (New)..... | 0.33             | 0.86  | 4,830           | .196       | 46,300                 | 38                    | 224               |
| G-1 (Old)..... | 0.05             | 0.07  | 2,740           | .187       | 22,300                 | 22                    | 155               |
| G-2 (New)..... | 0.15             | 0.19  | 2,960           | .173       | 25,400                 | 23                    | 173               |
| H-1 (Old)..... | 0.04             | 0.02  | 3,120           | .183       | 27,900                 | 19                    | 181               |
| H-2 (New)..... | 0.04             | 0.05  | 3,690           | .191       | 28,000                 | 23                    | 196               |
| I-1 (Old)..... | 0.08             | 0.12  | 2,780           | .181       | 24,200                 | 23                    | 170               |
| I-2 (New)..... | 0.07             | 0.14  | 2,940           | .186       | 26,200                 | 22                    | 176               |

Three groups of melts were made to illustrate the applicability of the invention to the production of low (A to C), medium (D to F), and high (G to I) carbon cast irons. For each of the three pairs in each group, one heat, designated by the number "1," was alloyed and inoculated in the conventional manner, e. g., ferro-alloyed and inoculated in multiple additions; the other heat of each pair, designated by the number "2," was treated in the ladle with one of the new alloys given in Table No. 1. The amounts of additions in both cases were so calculated that each pair of melts coded with the same letter, e. g., A, B, etc., had closely similar "as cast" or final chemical compositions. In each group of three pairs, the "1" heat of the third pair (C-1, F-1, and I-1) was produced with the conventional additions and inoculants being made entirely in the ladle in-

stead of in the furnace. From an examination of the data given in Table No. 3, it can be seen that the method of the invention has produced superior overall mechanical properties in comparison to the properties of the conventionally made cast irons. It is also to be noted that this superiority is maintained over the conventional practice regardless of whether the conventional methods involve furnace or ladle additions. In addition, the beneficial effects of the method of the invention are apparent over a wide range of cast iron compositions, e. g., low, medium, and high carbon cast irons.

The effects of using different amounts of the new alloy in the method of the invention in producing cast irons of varying carbon contents are shown by the data given in Tables No. 4 and No. 5.

TABLE No. 4

| Cast Iron No.  | "As Cast" Chemical Compositions |             |             |             |             | Method                                                 |
|----------------|---------------------------------|-------------|-------------|-------------|-------------|--------------------------------------------------------|
|                | Per Cent C                      | Per Cent Si | Per Cent Ni | Per Cent Cr | Per Cent Mo |                                                        |
| J-1 (New)..... | 2.87                            | 2.66        | 0.80        | 0.10        | 0.15        | No. 2 alloy 1% in Ladle.<br>No. 2 alloy 2% in Ladle.   |
| J-2 (New)..... | 2.86                            | 2.20        | 1.00        | 0.20        | 0.30        |                                                        |
| J-3 (New)..... | 2.85                            | 2.35        | 1.50        | 0.30        | 0.45        | No. 2 alloy 3% in Ladle.<br>C. L. Additions.           |
| J-4 (Old)..... | 2.88                            | 2.16        | 1.60        | 0.33        | 0.48        |                                                        |
| K-1 (New)..... | 3.35                            | 2.49        | 0.50        | 0.10        | 0.15        | No. 2 alloy 1% in Ladle.<br>No. 2 alloy 2% in Ladle.   |
| K-2 (New)..... | 3.34                            | 2.63        | 1.00        | 0.20        | 0.30        |                                                        |
| K-3 (New)..... | 3.33                            | 2.77        | 1.50        | 0.30        | 0.45        | No. 2 alloy 3% in Ladle.<br>C. L. Additions.           |
| K-4 (Old)..... | 3.32                            | 2.77        | 1.50        | 0.30        | 0.45        |                                                        |
| L-1 (New)..... | 3.73                            | 2.52        | 1.23        | 0.05        | 0.07        | No. 4 alloy 0.5% in Ladle.<br>No. 4 alloy 1% in Ladle. |
| L-2 (New)..... | 3.71                            | 2.62        | 1.46        | 0.09        | 0.14        |                                                        |
| L-3 (New)..... | 3.69                            | 2.82        | 1.92        | 0.18        | 0.28        | No. 4 alloy 2% in Ladle.<br>C. L. Additions.           |
| L-4 (Old)..... | 3.68                            | 2.82        | 1.92        | 0.18        | 0.28        |                                                        |
| L-5 (New)..... | 3.67                            | 3.02        | 2.38        | 0.27        | 0.42        | No. 4 alloy 3% in Ladle.                               |

TABLE NO. 5  
Mechanical properties

| Cast Iron No.  | Chill Depth, in. |       | Transverse Str. |            | Tensile Str., p. s. i. | Izod Impact, ft. lbs. | Hardness B. H. N. |
|----------------|------------------|-------|-----------------|------------|------------------------|-----------------------|-------------------|
|                | Clear            | Total | Load, Lbs.      | Defl., in. |                        |                       |                   |
| J-1 (New)..... | 0.25             | 0.47  | 5040            | .170       | 56,600                 | 53                    | 242               |
| J-2 (New)..... | 0.17             | 0.40  | 6340            | .197       | 61,000                 | 42                    | 261               |
| J-3 (New)..... | 0.10             | 0.29  | 6590            | .198       | 63,000                 | 53                    | 271               |
| J-4 (Old)..... | 0.17             | 0.60  | 5930            | .170       | 61,200                 | 39                    | 279               |
| K-1 (New)..... | 0.07             | 0.14  | 4540            | .190       | 43,800                 | 30                    | 217               |
| K-2 (New)..... | 0.03             | 0.08  | 5320            | .217       | 47,600                 | 45                    | 228               |
| K-3 (New)..... | 0.07             | 0.12  | 6140            | .232       | 55,700                 | 47                    | 286               |
| K-4 (Old)..... | 0.09             | 0.14  | 5180            | .177       | 50,100                 | 28                    | 248               |
| L-1 (New)..... | 0.07             | 0.03  | 2800            | .175       | 25,700                 | 20                    | 171               |
| L-2 (New)..... | 0.07             | 0.14  | 2940            | .186       | 26,200                 | 22                    | 176               |
| L-3 (New)..... | 0.09             | 0.15  | 3070            | .179       | 27,800                 | 19                    | 190               |
| L-4 (Old)..... | 0.03             | 0.07  | 3020            | .172       | 26,800                 | 18                    | 185               |
| L-5 (New)..... |                  | 0.02  | 3870            | .199       | 33,200                 | 25                    | 228               |

In each of the three carbon range groups, i. e., J, K and L., there is one melt, designated by the number "4," which was made conventionally with ladle additions of nickel and ferro-alloys and inoculated with a nickel-silicon-calcium alloy. Comparing the mechanical properties of these melts numbered "4" with those of heats of similar chemical compositions produced by the method of the invention with a ladle addition of one of the alloys contemplated by the invention and numbered "3," it is evident that the invention promotes unexpectedly superior mechanical properties regardless of the carbon range involved. In fact, the overall mechanical properties of cast irons produced by the invention method and of comparatively lower alloy content (see "1" and "2" of each group) are at least equal to and in many cases superior to those cast irons made by conventional methods and of comparatively higher alloy content.

It is to be observed that this invention provides a novel method for producing a wide range of cast irons of superior mechanical properties to meet a variety of high quality specifications, a procedure heretofore restricted to a few specially equipped foundries. The use of the method disclosed by the invention will, in general, definitely and consistently improve the quality of cast irons over the conventional methods heretofore used, regardless of the base composition and/or section size, by reducing chill depth and therefore improving the machinability, by increasing wear resistance and reducing the galling tendencies, and by improving mechanical properties, such as transverse and tensile strengths and toughness. In practicing said method, the invention provides a novel, simple, all-purpose alloy which can be incorporated as a late addition to cast iron melts, regardless of the carbon content and the section size of the final casting. The present invention provides a unitary or singly-contained alloy for late additions in small amounts to cast iron melts, whereby improved quality and consistently superior mechanical properties are obtained. The novel alloy provided by the invention assists greatly in the production of high-quality gray cast iron and provides a more effective means of alloying and inoculating the same that is more efficient in the method of the present invention than the conventional means.

Although the present invention has been described in conjunction with certain 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 readily understand. Such variations and modifications are to be considered within the purview of the application and the scope of the appended claims.

We claim:

1. An addition alloy for the production of improved cast irons comprising about 11% to about 17% silicon, about 9% to about 11% chromium, about 14% to about 17% molybdenum, about 0.4% to about 1.0% calcium, about 6% to about 11% iron, and the balance essentially nickel and constituting about 48% to about 53% of the alloy.

2. An addition alloy for the production of improved cast irons comprising about 11% to about 17% silicon, about 9% to about 11% chromium, about 14% to about 17% molybdenum, about 0.4% to about 1.0% calcium, a small amount up to about 11% iron, and the balance essentially nickel and constituting about 43% to about 65% of the alloy.

3. An addition alloy for the production of improved cast irons comprising about 6% to about 35% silicon, a small amount up to about 20% chromium, about 10% to about 30% molybdenum, about 0.1% to about 2.0% calcium, a small amount up to about 30% iron, and the balance essentially nickel and constituting about 30% to about 66% of the alloy.

4. An addition alloy for the production of improved cast irons comprising about 6% to about 35% silicon, a small amount up to about 20% chromium, about 10% to about 30% molybdenum, about 0.1% to about 2.0% calcium, a small amount up to about 30% iron, and the balance essentially nickel.

5. As an article of manufacture, an addition alloy for treating molten cast irons and improving the "as cast" properties thereof, comprising about 8% to about 35% silicon, up to about 20% chromium, about 10% to about 30% molybdenum, about 0.1% to about 2.0% calcium, up to about 30% iron, and the balance essentially nickel.

6. An addition alloy for the production of improved cast irons comprising about 6% to about 35% silicon, up to about 20% chromium, about 10% to about 30% molybdenum, about 0.1% to about 2.0% calcium, and the balance essentially nickel and constituting about 30% to about 66% of the alloy.

7. An addition alloy for the production of improved cast iron comprising about 6% to about 35% silicon, about 10% to about 30% molybdenum, about 0.1% to about 2.0% calcium, up to about 30% iron, and the balance essentially nickel and constituting about 30% to about 66% of the alloy.

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5

10

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