

1

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FOUNDRY PRACTICE

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This invention relates to the metallurgic sciences and is more particularly directed to a process for the volume production of low oxygen, low sulphur iron at the lowest possible over-all cost.

In the course of extensive experimentation and production runs covering over one hundred thousand tons, we have established that practically all commercial melting apparatus may be employed to give a base metal suitable for deoxidizing and desulphurizing outside of the melting instrumentality. In this work we have employed the acid electric furnace, the basic electric furnace, the acid cupola, basic cupola and various duplex combinations of the cupola followed by the electric furnace. In the course of this work it became very apparent that nodular iron could be produced with a much smaller magnesium addition and a much smaller magnesium residue i. e., a magnesium residue of 0.005% to 0.030%, if the base metal were desulphurized and deoxidized to the proper degree prior to the addition of magnesium. Similarly, savings of other nodularizing agents such as titanium, zirconium, nitrogen, cerium and their mixtures with each other or magnesium may be obtained. This is in accordance with views held by the art since the commercial production of nodular iron began. The need for a drastically deoxidizing and desulphurized iron in large volumes and at low cost indicates primarily one melting apparatus; that is, a basicy operated cupola.

Attempts to operate in a conventional basic cupola were not acceptable. The results were erratic, and only a slight reduction was made in the amount of nodularizing additive required. The erosion of the cupola refractory was so severe that it was often impossible to complete the usual sixteen hour cupola campaign. To alleviate this condition the exterior of the cupola shell adjacent the melting zone and well was arranged to be cooled by directly impinging thereupon a vigorous spray of water. In place of the ordinary thick refractory basic lining in the melting zone and well, a very thin basic lining was used in the melting zone and a neutral lining such as carbon used in the well and permitted to reach an equilibrium with the molten slag on the interior of the cupola. In some instances the basic lining may be omitted entirely. The water cooling insures preeminently satisfactory service in each case despite the use of highly corrosive calcareous slags containing large amounts of fluor spar and calcium carbide by which the basic operation of the cupola is effected.

To obtain a metal consistently low in oxygen and sulphur it has been found necessary to change the arrangement of the cupola tuyeres. In the ordinary cupola the combustion air is injected into the mass of incandescent carbon at a point adjacent the wall of the cupola. This practice has been found to permit a preferential flow of the air up the cupola in a zone immediately adjacent the comparatively cold refractory wall and hence to permit unreacted oxygen to ascend well up into the cupola. In this way a long vertical oxidizing zone is produced which is inimical to the consistent production of an iron very low in oxygen. To avoid this difficulty it has been found necessary to project the tuyeres about eight to

2

twenty inches into the cupola proper past the wall when working with a nominally 100 inch cupola. By this expedient all of the air must flow through a comparatively long path over incandescent coke before it can be subjected into the chilling action of the refractory wall or the descending melt.

In the conventional operation of a basic cupola approximately 5% of limestone based on the weight of metallics is the usual flux together with sufficient fluor spar to insure the necessary liquidity. This flux charge has been found inadequate for the production of low oxygen and sulphur metal suitable for conversion to nodular iron. However, satisfactory results have been obtained by the use of a very high limestone comprising 10% limestone based upon metallics to which is added 3% of fluor spar and calcium carbide periodically as indicated by melting conditions. To insure the proper rate of the oxidation a relatively high coke ratio must be employed. It has been found that a ratio of slightly more than one part by weight of coke to five of metallics is most satisfactory. A typical charging schedule is tabulated below.

- Steel, 0-1500 lbs.—preferred, 1000 lbs.
- Bessemer pig iron, 0-1500 lbs.—preferred, 520 lbs.
- Returns, 500-2000 lbs.—preferred, 1400 lbs.
- Limestone, 9-12%—preferred, 10%
- Fluor spar, 2-5%—preferred, 3%
- Coke, 575-650 lbs.—preferred, 625 lbs.
- Calcium carbide, 0-40 lbs. per hr.—added each 1½ to 2 hours
- Blast volume, 8,000-12,000 C. F. M.—preferred 11,000 lbs.
- Blast pressure, 10-30 ounces—preferred, 18.

Even when operating with the very drastically deoxidizing and desulphurizing conditions outlined above, it has been found that the results are often erratic if the cupola is controlled by observation of the slag color, consistency and iron oxide content as dictated by conventional practice. The inventors have discovered that the only reliable indicator which will consistently indicate low oxygen and low sulphur metal and hence the susceptibility of the metal being produced to nodularization by magnesium additions, is the manganese oxide content of the slag. In the range of 0.1% to 0.4% manganese oxide consistently good nodular iron can be produced with a minimum of nodularizing additions and residues. This manganese oxide content is in a slag containing 50 to 70% calcium oxide, 5 to 20% magnesium oxide, 3 to 15% aluminum oxide, .5 to 1½% sulphur, .25 to 1.25% iron oxide, 13 to 30% silica and 5 to 20% calcium fluoride. However, if the manganese oxide is allowed to go substantially above four tenths of 1% the presence of substantial quantities of oxygen and/or sulphur is a certainty. Such iron can only be nodularized by the use of large and costly alloy additions and the results are at best erratic. This is clearly illustrated by the following tabulation:

Slag MnO	Alloy Added, lbs.	No. of Cranks, Scrapped (Grey Iron)
.27-1.38	24-42	480
.21-1.27	27-40	260
.10-.40	28-36	20
.10-.23	26-36	20
.14-.35	32-35	0
.10-.43	30-36	60
.13-1.32	24-35	380
.14-.38	26-35	20

In the above tabulation the second column indicates the weight of 8% magnesium ferrosilicon added to a 2500 lb. ladle. The final tabulation indicates the number of scrapped cranks in a total daily production of about 9,000. A study of this chart will disclose that high scrap and high manganese oxide are coexistent.

Castings made from nodular iron in which there are sharp changes of section are plagued with two closely related defects known as cope defect and graphite flotation. The cope defect comprises inclusion of carbon coated magnesium oxide plates which float to the upper or cope portion of the casting and cause mechanical weakness. The second effect, graphite flotation, is caused by the presence of excessive amounts of silicon in a high carbon casting. Graphite flotation produces results similar to the cope defect in that the lighter graphite floats to the cope portion of the casting and renders it mechanically weak. Graphite flotation is controlled by carefully regulating the silicon content of the final metal to the absolute minimum sufficient to produce the requisite graphite, pearlite balance.

The occurrence of cope defect may be prevented by the addition to the ladle of basic cupola slag analyzing from 5 to 20% by weight of calcium fluoride. This fluoride containing flux at the same time acts as a scouring agent and prevents the accumulation of the oxides of the nodularizing and graphitizing additions in the ladle. Although cupola flux is preferred for this purpose cost wise, any suitable fluoride bearing material may be used, or resort may be had to commercially available magnesium type fluxes.

To insure commercially acceptable results it has been found necessary to add a forehearth to the pouring apparatus to insure a supply of metal of uniform temperature and chemical analysis despite variations in the operation of the cupola. In the ordinary practice this forehearth is unfired except to heat it up for the initial reception of metal.

Despite the most meticulous care in the operation of cupola it has been found that occasionally the manganese oxide content of the slag will rise beyond the desired upper limit of four tenths of a percent and prompt corrective treatment must be taken if the consumption of magnesium alloy and the production of scrap is not excessive. The logical corrective measure would appear to be a decrease in the wind volume and an increase in the rate of coke charging. This has been tried and is successful after a lapse of about the forty minutes which is required for the additional coke to descend to the melting zone. To avoid this undesirably long period of only partial deoxidized metal an addition of about forty pounds of calcium carbide has been found to effect an almost immediate reduction in the manganese oxide content of the slag thereby preventing the production of excessive amounts of scrap. The same rapid correction may be obtained by the addition in the blast and through the tuyeres of any readily available low sulphur content fuel. For example, natural gas or coke oven gas or low sulphur fuel oil may be injected through the tuyeres to re-establish the desired strongly deoxidizing conditions at the bottom of the cupola. If sufficiently sulphur free pulverized coal is at hand it may also be injected as an alternative to or in conjunction with the fluid fuels just mentioned.

We claim as our invention:

1. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce a slag having

a manganese oxide content of from 0.1% to 0.4%, tapping the cupola into ladles to which has been added granulated basic cupola slag containing 5 to 20% by weight calcium fluoride, adding a magnesium bearing alloy in an amount to leave a magnesium residual of from 0.005% to 0.030%, inoculating and casting the metal.

2. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce a slag having a manganese oxide content of from 0.1% to 0.4%, tapping the cupola into ladles to which has been added a fluoride containing flux, adding a magnesium bearing alloy in an amount to leave a magnesium residual of from 0.005% to 0.030%, inoculating and casting the metal.

3. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce a slag having a manganese oxide content of from 0.1% to 0.4%, tapping the cupola into ladles to which has been added a magnesium flux, adding a magnesium bearing alloy in an amount to leave a magnesium residual of from 0.005% to 0.030%, inoculating and casting the metal.

4. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce a slag having a manganese oxide content of from 0.1% to 0.4%, correcting irregularities in the operation of the cupola by the periodic charging of small amounts of calcium carbide, and adding a magnesium bearing alloy in an amount to leave a magnesium residual of from 0.005% to 0.030%.

5. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce a slag having a manganese oxide content of from 0.1% to 0.4%, correcting irregularities in the operation of the cupola by the periodic charging through the tuyeres of small amounts of calcium carbide, and adding a magnesium bearing alloy in an amount to leave a magnesium residual of from 0.005% to 0.030%.

6. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce a slag having a manganese oxide content of from 0.1% to

5

0.4%, correcting irregularities in the operation of the cupola by the periodic charging through the charging door of small amounts of calcium carbide, and adding a magnesium bearing alloy in an amount to leave a magnesium residual of from 0.005% to 0.030%.

7. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce a slag having a manganese oxide content of from 0.1% to 0.4%, correcting irregularities in the operation of the cupola by the periodic charging of a low sulphur carbonaceous fuel through the tuyeres, tapping the cupola into ladles to which has been added a fluoride containing flux, adding a magnesium bearing alloy in an amount to leave a magnesium residual of from 0.005% to 0.030%, inoculating and casting the metal.

8. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce

6

a slag having a manganese oxide content of from 0.1% to 0.4%, cooling the cupola shell at the melting and well level by externally applied streams of water, tapping the cupola into ladles to which has been added a fluoride containing flux, adding a magnesium bearing alloy in an amount to leave a magnesium residual of from 0.005% to 0.030%, inoculating and casting the metal.

9. The process of producing nodular iron castings comprising charging into a basically operated cupola a ferrous charge, limestone to the extent of 9 to 12%, fluor spar to the extent of 2 to 5% and coke to the extent of 575 to 650 pounds to each 2920 pounds of metallics, injecting air into the cupola at a plurality of points which are substantially removed from the wall of the cupola, regulating the blowing rate to produce an iron substantially saturated with carbon and to produce a slag having a manganese oxide content of from 0.1% to 0.4%, tapping the cupola into ladles to which has been added a fluoride containing flux, adding a nodularizing alloy sufficient to leave a magnesium residual of from 0.005% to 0.030% and casting the metal.

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