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[54] **METHOD FOR PROMOTING METALLURGICAL REACTIONS IN MOLTEN METAL**

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[52] **U.S. Cl.** .... **75/61,** 75/93 R, 75/129, 266/34 A, 423/348
[51] **Int. Cl.** **C21c 7/00**
[58] **Field of Search** ...... 75/61, 93 R, 129; 423/350, 423/348, 349; 266/34 A

[56] **References Cited**

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Cervinka et al., Brutcher Trans. No. 7892, from Hutnicke Listy, Vol. 20, 1965, No. 6, pp. 394–400.

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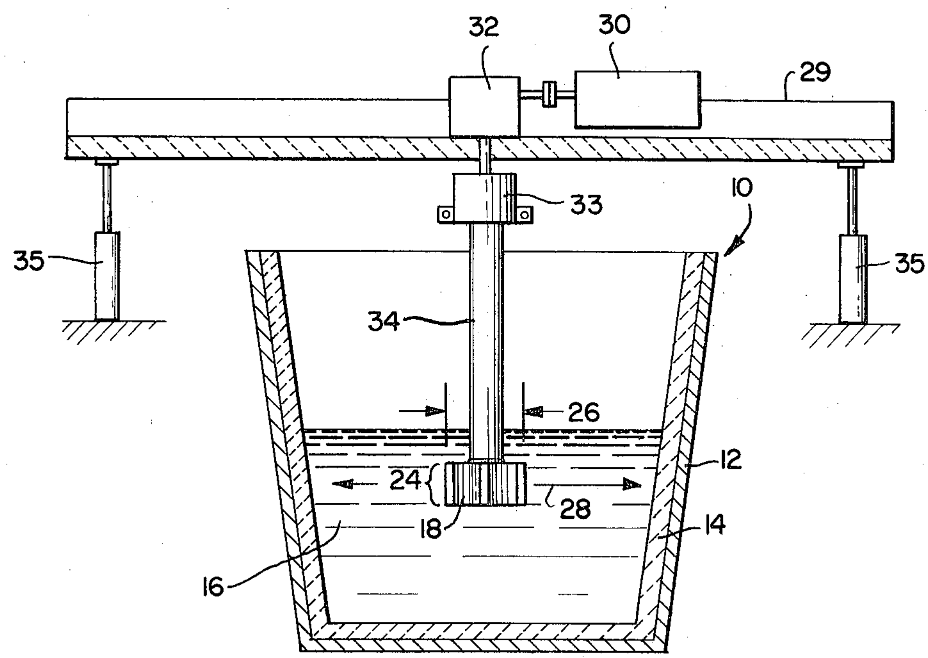
[57] **ABSTRACT**

Method and apparatus for promoting metallurgical reactions in molten metal employing high speed stirring.

3 Claims, 4 Drawing Figures



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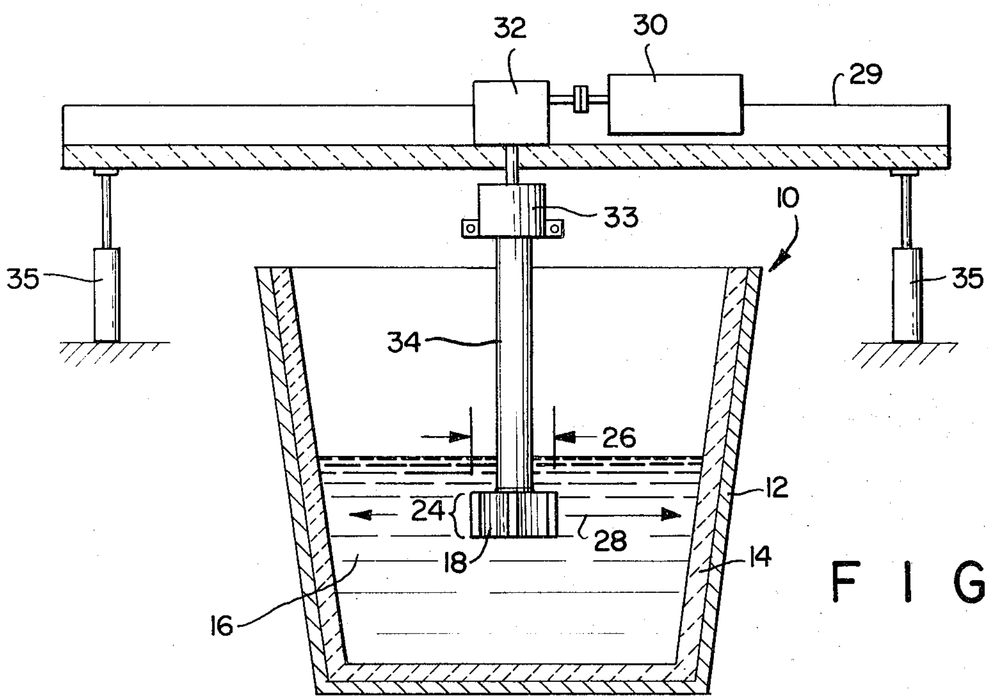


FIG. 1

FIG. 2

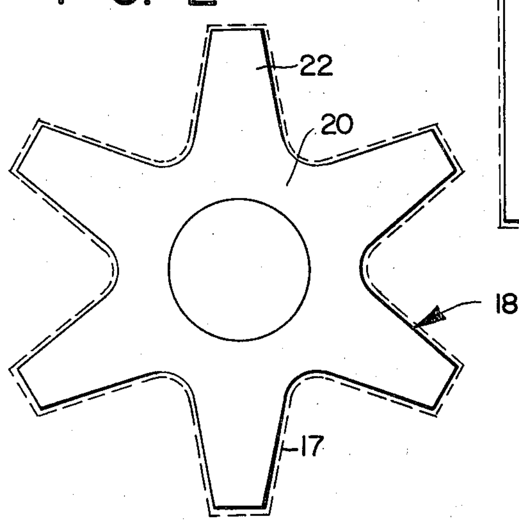


FIG. 3

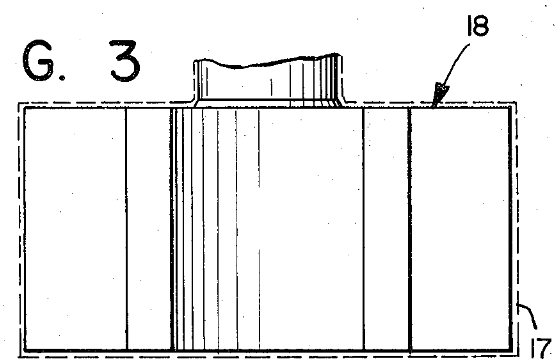
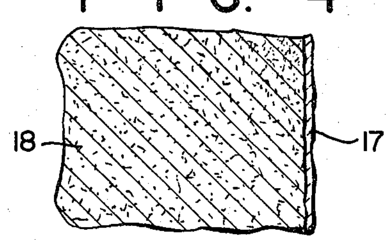


FIG. 4



METHOD FOR PROMOTING METALLURGICAL REACTIONS IN MOLTEN METAL

The present invention is directed to an apparatus and method for promoting metallurgical reactions. More particularly, the present invention is directed to a method and apparatus whereby molten metal is agitated in such a manner as to efficiently expose the molten metal to solid, gaseous, or liquid reactants so as to rapidly complete metallurgical reactions with the molten metal.

It is an important industrial practice to react molten metal product with various substances to alter the chemical composition of the molten metal in order to obtain a final desired composition. For example, gases, such as air, oxygen, and chlorine, have been introduced into molten ferrosilicon baths for the purpose of reducing the calcium and aluminum contents thereof. These practices have been effective but have had the disadvantage in some cases of undesirably chilling the molten metal bath and of requiring relatively long processing times and relatively expensive process equipment.

It has also been proposed to stir molten metal with various apparatus such as described in U.S. Pat. Nos. 3,664,826 and 3,592,629 to promote metallurgical reactions. The practices disclosed in the afore-mentioned patents require either complicated mechanical stirring equipment or close control of stirring patterns in the molten metal.

It is therefore an object of the present invention to provide an uncomplicated process and apparatus for promoting and rapidly completing metallurgical reactions involving molten metal.

Other objects will be apparent from the following description and claims taken in conjunction with the drawing wherein

FIG. **1** shows an elevational view of an apparatus in accordance with the present invention,

FIGS. **2** and **3** show a plan and elevational view of the agitating mechanism of the apparatus of the present invention and

FIG. **4** shows a fragmented peripheral portion of the agitating mechanism of the apparatus of the present invention having a protective coating in accordance with the present invention.

The present invention can be illustrated in connection with the drawing wherein a conventional ladle is indicated in FIG. **1** at **10** having an iron shell **12** and a refractory lining **14.** The molten metal to be treated, indicated at **16,** is held in the ladle **10** and an agitating member **18** is immersed in the molten metal. The material composition of the agitating member and its configuration are important in the practice of the present invention. The agitating member **18** is machined from graphite to the shape as shown in FIGS. **2** and **3,** more fully described herein below.

Agitating member **18,** machined from high-density graphite, can be provided at its metal contacting surfaces with a thin adherent coating layer **17** of silica based slag formed from contact of the graphite surfaces with a molten mixture of silica, lime, alumina, and magnesia. The slag for this purpose consists essentially of about 45 to 70 percent by weight SiO_2, 10 to 35% CaO, up to 30% MgO and up to 15% Al_2O_3. In the case of aluminum and calcium removal from silicon or silicon-base alloys with the aid of a molten synthetic slag as hereinafter described, treatment with such slag will provide the desired coating. It has been observed that the portion of the agitating member **18,** and the portion of supporting shaft **34,** which were immersed in the molten metal and slag and had an adherent coating did not suffer appreciable oxidation whereas the portion of shaft **34** which was not so immersed showed oxidation attack which led to ultimate failure. The slag layer **17** is typically on the order of 0.03–2.5 mm. in thickness. This thickness can be obtained by immersing the graphite member **18** in the molten slag for about one minute or more. As long as the slag is molten the temperature is not critical.

The configuration of the agitating device **18** is also important in the practice of the present invention. With reference to FIGS. **2** and **3,** the graphite agitating member comprises a hub portion **20** having from three to eight and preferably six substantially identical radial extensions **22** having a length of from about 25 to about 85 percent of the diameter of hub portion **20.** The average width of the extension **22** is about 40 to 80 percent of their length. The height of agitating member **18,** indicated at **24,** is from about 75 to 200 percent of its hub diameter. It has been found that the foregoing configuration is important, together with the abovementioned adherent coating in the high speed agitation practice of the present invention.

For example, in the practice of the present invention high rotation speeds are employed to rapidly complete the metallurgical reactions involved thus avoiding long operating times and undesired chilling of the bath. The configuration of the agitating member of the present invention can accommodate the high mechanical stresses involved with high rotation speeds while providing a high order of turbulence. It has been found that the coating previously described is remarkably adherent to the graphite agitating member and its thickness remains essentially constant during operation in which a silica-base slag is employed and in which calcium and aluminum impurities are being removed. The reason for this is not fully understood but may be due to the renewal of the coating by the slag constituents present. In the case when a silica base slag is not being used, or calcium and aluminum are not being removed by oxidation, it may be desirable to periodically recoat the agitation member with silica base slag as described herein.

With further reference to FIG. **1,** agitating member **18** is constructed so that it outside diameter **26** is from about 25–40 percent of the average diameter of the metal bath indicated at **28.** Also, agitating member **18** is arranged so that it is immersed in the molten metal bath with the bottom portion thereof located in the upper 50 percent of height of the metal bath. With agitating member **18** arranged as indicated, and with reference to FIG. **1** of the drawing, motor **30** acting through speed reducer **32** and clamp **33** drives shaft **34** and hence agitating member **18** at a speed of from about 120 to 225 rpm. At rotation speeds as specified, and with the agitating member configured as indicated, the metal bath is vigorously and turbulently agitated. A rotation speed of at least about 120 rpm is important to enable rapid completion of the metallurgical reaction involved; rotation speeds above about 225 rpm result in excessive splashing and possible loss of metal. When the molten metal to be treated is a silicon containing alloy and it is desired to remove calcium and aluminum impurities, the exposure of the molten metal to the surrounding air provided by the above-mentioned agitation is sufficient to rapidly reduce the calcium content from about 0.20 to 0.02 percent and the aluminum content from about 0.5 to 0.3 percent in less than **8** minutes. For such operations, the agitating member is preferably located in the upper 10 percent of the molten bath. In instances where solid metal additions are to be added to the molten metal, e.g., finely particulated ferrosilicon is added to a ferrosilicon metal bath, the agitating member is preferably in the upper 20 to 40 percent of the metal bath.

In instances where aluminum and calcium impurities are to be removed from silicon or ferrosilicon using a synthetic slag, the agitating member is preferably in the upper 10–20 percent of the metal bath. As illustrated, motor **30** and speed reducer **32** are supported on refractory protected support member **29** which can be raised and lowered by hydraulic pistons **35** to adjust the position of agitating member **18**.

Particular advantages of the present invention is the rapidity obtained for the metallurgical reactions involved and the long life of the agitating member. The rapidity of the reactions avoids the undesirable effects which can occur on account of cooling of the melt during prolonged agitation.

The following examples will further illustrate the present invention.

EXAMPLE I

5970 lb. of 75% FeSi having a composition of 0.54% Al and 0.22% Ca were placed in a ladle having an average inner diameter of 4.1 feet to a depth of 2.8 feet. The initial temperature of the metal was 1510°C. A graphite agitating member of the type shown in the drawing having a hub diameter of 8 inches and a height of 8 inches and six extensions having an average thickness of 2½ inches was immersed in the molten metal with the bottom thereof about 10 inches below the surface. A blended mixture of 105 lb. lime, 200 lb. sand, and 32 lb. magnesia was added to the ladle. The agitating member was rotated at 120 rpm for 25 minutes. The metal was tapped from the ladle and analyzed 0.07% Al and 0.04% Ca.

EXAMPLE II

8725 lb. of 50% FeSi having a composition of 0.60% Al and 0.07% Ca were placed in a ladle having an average inner diameter of 4.1 feet to a depth of 3.0 feet. The initial temperature of the metal was 1600°C. A graphite agitating member of the type shown in the drawing having a hub diameter of 8 inches and a height of 8 inches and six extensions having an average thickness of 2½ inches was immersed in the molten metal with the bottom thereof about 11 inches below the surface. A blended mixture of 100 lb. lime, 200 lb. sand and 45 lb. magnesia was added to the ladle. The agitating member was rotated at 120 rpm for 30 minutes. The metal was tapped from the ladle and analyzed 0.05% Al and 0.04% Ca.

EXAMPLE III

23,980, lb. of 50% FeSi having a composition of 0.91% Al and 0.26% Ca were placed in a ladle having an average inner diameter of 5.0 feet to a depth of 4.7 feet. The initial temperature of the metal was 1477°C. A graphite agitating member of the type shown in the drawing having a hub diameter of 8 inches and a height of 8 inches and six extensions having an average thickness of 2½ inches was immersed in the molten metal with the bottom thereof about 12 inches below the surface. A blended mixture of 492 lb. lime, 800 lb. sand, and 250 lb. magnesia was added to the ladle. The agitating member was rotated at 175 rpm for 21 minutes. The metal was tapped from the ladle and analyzed 0.08% Al and 0.01% Ca.

EXAMPLE IV

3990 lb. of silicon having a composition of 0.54% Al and 0.20% Ca were placed in a ladle having an average inner diameter of 3.4 feet to a depth of 2.7 feet. The initial temperature of the metal was 1430°C. A graphite agitating member of the type shown in the drawing having a hub diameter of 8 inches and a height of 8 inches and six extensions having an average thickness of 2½ inches was immersed in the molten metal with the bottom thereof 8 inches below at the surface. The agitating member was rotated at 120 rpm for 7 minutes. The metal was tapped from the ladle and analyzed 0.22% Al and 0.01% Ca.

EXAMPLE V

3665 lb. of silicon having a composition of 0.79% Al and 0.12% Ca were placed in a ladle having an average inner diameter of 3.3 feet to a depth of 2.6 feet. The initial temperature of the metal was 1500°C. A graphite agitating member of the type shown in the drawing having a hub diameter of 8 inches and a height of 8 inches and six extensions having an average thickness of 2½ inches was immersed in the molten metal with the bottom thereof about 12 inches below the surface. A blended mixture of 76 lb. lime, 146 lb. sand, and 31 lb. magnesia was added to the ladle. The agitating member was rotated at 150 rpm for 15 minutes. The metal was tapped from the ladle and analyzed 0.08% Al and 0.01% Ca.

EXAMPLE VI

22,450 lb. of 50% FeSi were placed in a ladle having an average inner diameter of 5.0 feet to a depth of 4.6 feet. The intial temperature of the metal was 1521°C. A graphite agitating member of the type shown in the drawing having a hub diameter of 8 inches and a height of 8 inches and six extensions having an average thickness of 2½ inches was immersed in the molten metal with the bottom thereof about 16 inches below the surface. 1150 lb. of fine particulated 50% FeSi were added to the ladle. The agitating member was rotated at 145 rpm for 11 minutes. The particulated metal was thoroughly melted by the bulk metal.

In the practice of the present invention, calcium and aluminum impurities can be rapidly removed from molten silicon and alloys containing about 50 percent or more silicon, e.g., the various ferrosilicon alloys with the use of a synthetic slag of the following composition

45 – 70%	SiO_2
10 – 35%	CaO
9 – 30%	MgO

The amount of slag with respect to molten metal is from about 3.5 to 9 percent of the weight of the metal bath with higher amounts of slag in this range being employed with higher silicon contents in the metal being treated. With the use of the aforementioned range of slag, lowering of the aluminum impurity level to 0.1 percent can be achieved. If higher aluminum levels can be tolerated lesser amounts of slag can be used.

The present invention may also be utilized in a wide variety of metal treatments such as additions of calcium carbide to iron for purposes of desulphurization, the dissolving of metal additions in molten metal, and in lowering the total carbon content of silicon-manganese alloys, e.g., silico-manganese using by-product slag with the molten metal.

What is claimed is:

1. A method for refining molten metal containing impurities which comprises

i. introducing molten metal into a substantially cylindrically shaped vessel

ii. agitating the molten metal in said vessel by means of a graphite rotating agitating member substantially centrally and axially aligned within said vessel with the bottom portion of said agitating member being in the upper 50 percent of the height of the metal bath, said agitating member being rotated at a speed of from about 120 to 225 r.p.m. to provide turbulent agitation at least at the surface of the

metal bath and said agitating member comprising a substantially cylindrical hub portion having from three to eight radial extensions, the length of said radial extensions being from about 25 to 85 percent of the diameter of the hub, the width of said radial extensions being about 40 to 80 percent of their length, and the height of said radial extensions being from about 75 to 200 percent of the hub diameter and the diameter of a circle circumscribing said radial extensions being about 25 to 40 percent of the diameter of said vessel containing said molten metal.

2. A method in accordance with claim **1** wherein the surface of the agitating member is provided with a thin adherent coating consisting essentially of about 45 to 70% SiO_2, 10 to 35% CaO, up to 30% MgO, and up to 15% Al_2O_3.

3. A method in accordance with claim **1** wherein the molten metal contains at least 50 percent silicon and calcium and aluminum impurities and wherein a slag is introduced into the molten metal containing vessel, said slag consisting essentially of about 45 to 70% SiO_2, **10–35%** CaO, **9–30%** MgO.

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