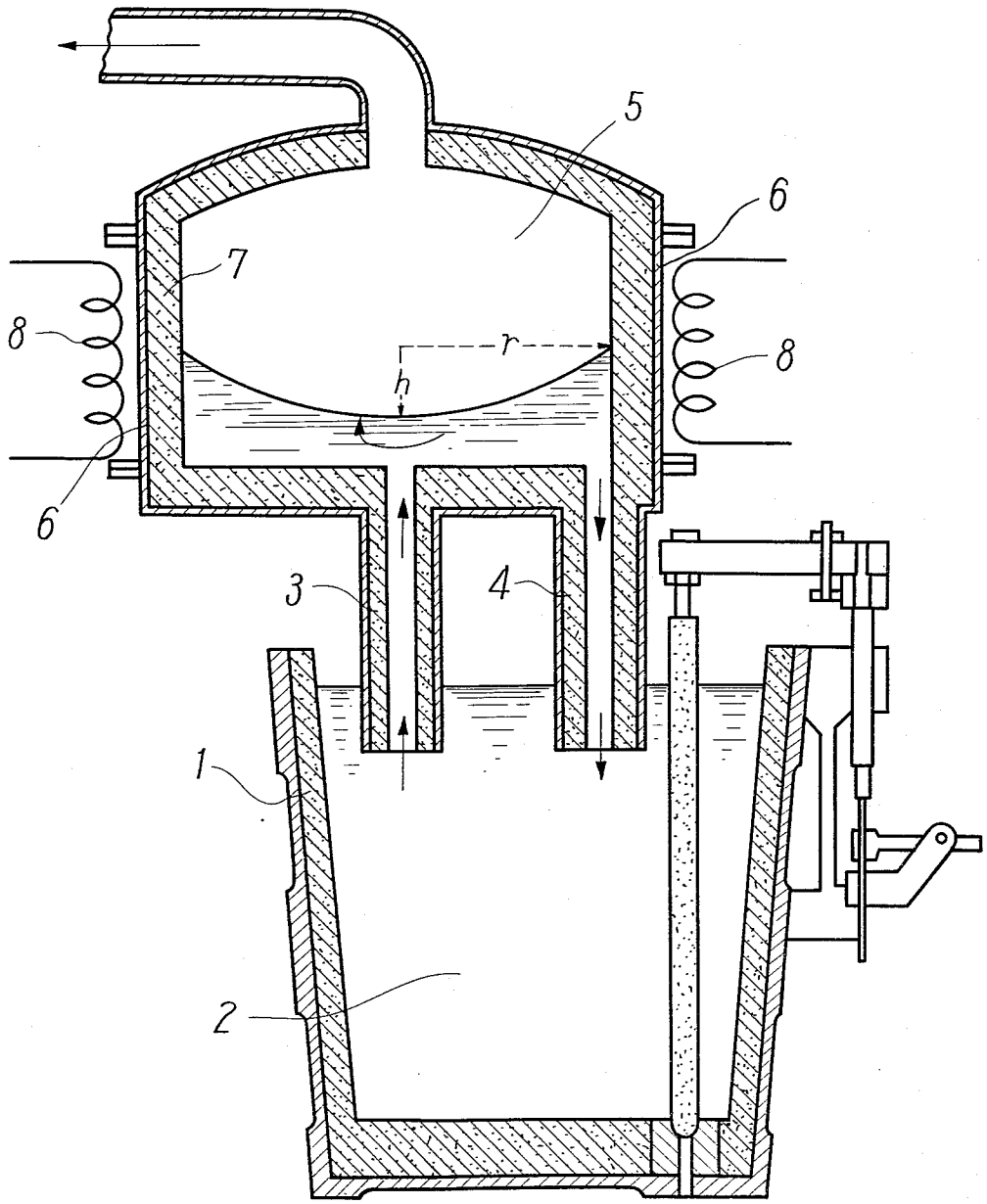
Aug. 1, 1961 KAMEMATSU MATSUDA 2,994,602

METHOD OF VACUUM DEGASIFYING MOLTEN STEEL BY CIRCULATION

Filed Sept. 30, 1959



INVENTOR.

KAMEMATSU MATSUDA

BY Wenderoth, Lind & Ponack Attys.

United States Patent Office 2,994,602
Patented Aug. 1, 1961

2,994,602

METHOD OF VACUUM DEGASIFYING MOLTEN STEEL BY CIRCULATION

Kamematsu Matsuda, Yawata City, Japan, assignor to Yawata Iron and Steel Co., Ltd., Tokyo, Japan, a corporation of Japan

Filed Sept. 30, 1959, Ser. No. 843,395
Claims priority, application Japan Oct. 3, 1958
2 Claims. (Cl. 75—49)

The present invention relates to a method of vacuum degasifying the molten steel in which the molten metal is continuously introduced into a vacuum chamber and subjected to circulation therein.

The steel melted and refined in the open atmosphere contains an appreciable amount of various gases, such as, hydrogen, oxygen and nitrogen, etc. These occluded gases of the steel will remain in a steel ingot cast therefrom as blowholes which result in many defects of the rolled steel product. Accordingly, several methods of degasification have been well known to industry. To this end, a method of degasifying steel in which the molten metal is subjected to pouring and diffusing under vacuum has been recently introduced and carried out.

However, this method of degasification is not satisfactory, because the period of time during which the molten steel is exposed to vacuum is a very short one. Further, it is considered that it is chiefly hydrogen which is to be removed by the above degasifying treatment. The removal of hydrogen gas is thought to be beneficial in reducing white spots of the forged steel product. In addition, this degasification does not involve an effective deoxidization, hence, with a view to preventing the formation of blowholes resulting from oxygen occluded in the steel, a deoxidizing agent is usually employed to convert the oxygen into an oxide of such an element as aluminum, silicon and manganese, etc.

After this deoxidization, the steel free from oxygen is subjected to the vacuum treatment. Hence a steel free from impurities could not be obtained due to the remains of such oxides resulting from the deoxidization treatment therein, even though the complete degasification has been effected. The rolled steel product, therefore, could not derive a beneficial effect from the above treatment.

Recently, another method of degasification by which the effect of degasification is much improved by subjecting the molten steel to exposure to vacuum repeatedly has been reported in West Germany. According to this method of degasification, the molten steel is drawn up in a vacuum or degasifying chamber through an elongated pipe leading from the ladle filled with the molten metal, then allowed to come in and out of the vacuum or degasifying chamber repeatedly by moving either the ladle or the vacuum chamber upwardly or downwardly. By this treatment, the molten steel in the ladle is exposed to vacuum little by little repeatedly in order to be fully degasified for a sufficiently extended period of time, whereby oxygen in the steel, next to hydrogen, is completely removed in accordance with the following formula:

$$C+O=CO$$

However, when the above degasifying process is performed on a relatively large scale, the vacuum or degasifying vessel or the ladle filled with the molten metal provided with an evacuating apparatus will result inevitably in a considerably immense equipment weighing hundreds of thousands of pounds so that the construction of the overall equipment in which the molten metal is allowed to come in and out of the vacuum vessel with an upward and downward movement thereof will become an

impractically enormous one, which should be a disadvantage. In addition, the provision of a heating means is required to prevent the molten metal from cooling within the vacuum degasifying chamber.

To overcome the above disadvantages, the present invention provides an improved method of degasifying the molten metal in which either the provision of an elevating means for the ladle or the vacuum chamber or of a heating means within the vacuum degasifying chamber is not required.

Briefly stated, the invention comprises drawing up the molten steel into the upper vacuum chamber through one of at least two pipes dipped into the molten metal contained in the lower ladle, allowing the molten metal in the vacuum chamber to start into a revolving motion by means of a rotary magnetic field imparted thereto, whereby the cooling of the molten metal is prevented simultaneously due to the heating effect thereof, accelerating the drawing up of the molten metal through the central pipe inserted at the bottom of the vacuum chamber by the aid of the revolving motion, dropping the degasified molten steel down through the other pipe provided on the same bottom but near the side of the vacuum chamber into the ladle, and carrying out the complete degasification by circulating the molten steel in the ladle through the vacuum chamber in a successive manner described above.

Thus, the present invention is characterized by that degasification is effectively performed in a predetermined degree of vacuum by the continuous circulation of the molten steel and that the heating effect is enhanced by the revolving motion owing to the rotary magnetic field resulting from the magnetic coil provided on the outside of the vacuum chamber, all of which results in the same quality steel free from impurities as obtained from the degasifying method mentioned hereinbefore which comprises repeated drawing up the molten metal. Furthermore, the present invention is advantageous in that such an exceedingly heavy equipment including an elevating means as employed in the above method is not required.

Referring more particularly to the accompanying drawing which illustrates an embodiment of the invention, a vacuum chamber **5** having two pipes **3** and **4** lined with refractory, the ends of which being dipped into the molten steel **2** contained in the ladle **1**, is exhausted by an evacuating pump (not shown) to vacuum, then the molten metal is drawn up into the vacuum chamber to the height corresponding to the atmospheric pressure and higher than the level of the molten steel therein. One pipe **3** is provided on the central part of the bottom of the vacuum chamber while the other **4** near the side wall thereof. The vacuum chamber is constructed of a cylindrical shell **6** made of a nonmagnetic metal lined with a suitable refractory **7** and surrounded with the coil **8** of a rotary magnetic field. When this coil **8** is supplied with electric current to energize the rotary magnetic field, the molten steel starts into a rotary motion to the direction of an arrow with the result that the level of the molten steel in the vacuum chamber turns into a parabolic plane depending upon the angular velocity of revolution thereof.

This parabolic plane can be expressed as follows:

$$h=\frac{A^2r^2}{2g}$$

where h: distance between the center of the molten steel bath level at its standstill and the center of the parabolic plane of the molten steel in motion; A: angular velocity; r: distance between the pipes **3** and **4** on the same level; g: accelerated velocity of gravity.

If N presents the number of revolutions per minute, then we have

$$N=\frac{60A}{2\pi}$$

$$\therefore A=\frac{2\pi N}{60}$$

Hence

$$h=\left(\frac{2\pi N}{60}\right)^2 r^2\times\frac{1}{2g}$$

$$=\frac{4\pi^2N^2r^2}{3600\times 2g}$$

$$=\frac{\pi^2N^2r^2}{1800g}$$

The difference P between static pressures of molten steel of the pipes **3** and **4** at their respective levels is expressed as follows:

$$P=Dgh$$

(D: density of molten steel.)

Then, we substitute h of the above expression

$$P=\frac{\pi^2N^2r^2}{1800g}\times Dg$$

$$=\frac{\pi^2N^2r^2}{1800}D$$

Consequently, the molten steel in the ladle rises up through the pipe **3** continuously depending upon the velocity proportional to the above static pressure, and falls down through the pipe **4** after the complete degasification in the vacuum chamber.

Thus, after the completion of degasification, the addition of an alloying element may be effected in vacuum from an alloying element introducing means (not shown) provided in the vacuum chamber as desired, and thereafter the molten steel added with the alloying element is subjected to the subsequent circulation and agitation. Then the vacuum chamber is open to the atmosphere, and the molten steel is collected in the ladle. Thus, the degasified molten steel free from impurities is poured into an ingot mold in the open atmosphere.

An apparatus which is a preferred embodiment of this invention is not only simple in its construction, but also the revolution and heating of the molten steel in the vacuum chamber can be effected in this apparatus by supplying electric current to the coil provided in the open atmosphere, whereby the continuous circulation of molten steel from the ladle in the open atmosphere to the vacuum chamber can be carried out, which is more effective and more advantageous than the degasifying method of prior art which consists of drawing up the metal repeatedly in that the molten steel can be degasified more quickly by this invention than by the process of prior art by the time required for dropping it.

While one embodiment of my invention has been shown and described, it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. A method of degasifying molten steel comprising providing a vacuum vessel above an open ladle of the molten steel to be gasified, said vacuum vessel having a central pipe depending from the center of the bottom thereof into the ladle and having at least one discharge pipe depending from the periphery of the bottom thereof into the ladle, applying a vacuum to the vacuum vessel and drawing the molten steel up into the vessel through the pipes, and while maintaining the vacuum, causing the molten steel in the vessel to rotate around a substantially vertical axis, whereby the surface of the molten steel assumes a parabolic shape due to the centrifugal forces produced during rotation, and a difference in static head is produced between the central pipe and the discharge pipe causing the degasified molten steel to flow out of the vessel back into the ladle through the discharge pipe and the molten steel from the ladle to flow upwardly into the vessel through the central pipe.

2. A method as claimed in claim 1 in which said molten steel is caused to rotate by applying thereto a rotating magnetic field.

References Cited in the file of this patent

UNITED STATES PATENTS

2,397,737	Heuer	Apr. 2, 1946
2,893,860	Lorenz	July 7, 1959