618686

COMMONWEALTH of AUSTRALIA
Patents Act 1952

APPLICATION FOR A STANDARD PATENT

I/We

Nippon Steel Corporation

of

6-3, Ohtemachi 2-chome, Chiyoda-ku, Tokyo, Japan

hereby apply for the grant of a Standard Patent for an invention entitled:

Method of and apparatus for detecting level of molten metal

which is described in the accompanying complete specification.

Details of basic application(s):-

Number	Convention Country	Date
01-243117	Japan	19 September 1989
01-260690	Japan	5 October 1989
01-277667	Japan	25 October 1989

The address for service is care of DAVIES & COLLISON, Patent Attorneys, of 1 Little Collins Street, Melbourne, in the State of Victoria, Commonwealth of Australia.

DATED this TWELFTH day of SEPTEMBER 1990

To: THE COMMISSIONER OF PATENTS

Keith [signature]

a member of the firm of
DAVIES & COLLISON for
and on behalf of the
applicant(s)

Davies & Collison, Melbourne

57

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

DECLARATION IN SUPPORT OF CONVENTION OR NON-CONVENTION APPLICATION FOR A PATENT

Insert title of invention.

In support of the Application made for a patent for an invention entitled: "METHOD OF AND APPARATUS FOR DETECTING LEVEL OF MOLTEN METAL"

Insert full name(s) and address(es) of Declarant(s) being the applicant(s) or person(s) authorized to sign on behalf of an applicant company.

I, ~~We~~ Fumio KODAMA, c/o NIPPON STEEL CORPORATION, of 6-3, Ohtemachi-2-chome, Chiyoda-ku, Tokyo, Japan,

Cross out whichever of paragraphs 1(a) or 1(b) does not apply.

1(a) relates to application made by individual(s).

1(b) relates to application made by company; insert name of applicant company.

do solemnly and sincerely declare as follows :-

1. (a) ~~I am / We are the applicant for the patent~~

or (b) I am authorized by NIPPON STEEL CORPORATION,

the applicant............ for the patent to make this declaration on its ~~their~~ behalf.

Cross out whichever of paragraphs 2(a) or 2(b) does not apply.

2(a) relates to application made by inventor(s)

2(b) relates to application made by company(s) or person(s) who are not inventor(s); insert full name(s) and address(es) of inventors.

2. (a) ~~I am / We are the actual inventor of the invention~~

or (b)

Yoichi NAGANUMA, c/o Setsubigijutsuhonbu, NIPPON STEEL CORPORATION, 1-1, Edamitsu-1-chome, Yahatahigashi-ku, Kitakyushu-shi, Japan.

Masaki MOTOMURA, c/o Setsubigijutsuhonbu, NIPPON STEEL CORPORATION, 1-1, Edamitsu-1-chome, Yahatahigashi-ku, Kitakyushu-shi, Japan.

~~is~~ are the actual inventor..S....... of the invention and the facts upon which the applicant........... is ~~are~~ entitled to make the application are as follows :-

State manner in which applicant(s) derive title from inventor(s)

The applicant is the assignee of the invention from the inventors.

Cross out paragraphs 3 and 4 for non-convention applications. For convention applications insert basic country(s) followed by date(s) and basic applicant(s).

3. The basic applicationS......... as defined by Section 141 of the Act ~~was~~ were made

in Japan on the September 19, 1989
by NIPPON STEEL CORPORATION
in Japan on the October 5, 1989
by NIPPON STEEL CORPORATION
in Japan on the October 25, 1989
by NIPPON STEEL CORPORATION

4. The basic applicationS........ referred to in paragraph 3 of this Declaration ~~was~~ were the first applicationS....... made in a Convention country in respect of the invention the subject of the application.

Insert place and date of signature.

Declared at Tokyo, Japan this 3rd day of September, 1990.

Signature of Declarant(s) (no attestation required).

NIPPON STEEL CORPORATION

Fumio Kodama

Fumio KODAMA, General Manager
Intellectual Property Div.

Note: Initial all alterations.

DAVIES & COLLISON, MELBOURNE and CANBERRA.

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(56) Prior Art Documents
US 4529029
US 4441541
US 4279149

(57) An apparatus is also claimed.

CLAIM

1. A method of detecting a level of molten metal existing within a mold, comprising the steps of:

disposing a transmission coil and a receiving coil to oppose to each other with the mold interposed therebetween;

applying a first AC voltage to said transmission coil to produce alternating magnetic flux so that at least a part of the magnetic flux passes through said mold and the molten metal, if any, and reaches said receiving coil;

processing a second AC voltage, which is induced in said receiving coil by the part of the magnetic flux, by a synchronous-detection or a phase detection with reference to a phase of said first AC

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voltage thereby producing a processed signal;

determining the level of said molten metal on the basis of a voltage value of said processed signal.

2. A method according to claim 1, further comprising the step of applying said processed signal to a low-pass filter thereby producing a filtered processed signal so that the level of the molten metal is determined on the basis of a voltage value of said filtered processed signal.

3. A method according to claim 1, further comprising the steps of determining a sine or cosine of a phase difference between a phase of said second AC signal and the phase of said first AC voltage and producing a product of the sine or cosine of the phase difference and the voltage value of said processed signal, said product being used for determining the level of said molten metal.

4. A method according to claim 1, further comprising the step of applying said second AC signal to a band-pass filter for removing undesired frequency components of said second AC signal before said second AC signal is processed by the synchronous-detection or the phase detection.

618686

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PATENTS ACT 1952

COMPLETE SPECIFICATION

NAME & ADDRESS
OF APPLICANT:

Nippon Steel Corporation
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NAME(S) OF INVENTOR(S):

Yoichi NAGANUMA
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ADDRESS FOR SERVICE:

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COMPLETE SPECIFICATION FOR THE INVENTION ENTITLED:

Method of and apparatus for detecting level of molten metal

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a method of and an apparatus for detecting the position of the level of molten metal, and particularly to, but not limited to, a method of and an apparatus for detecting the position of the level of molten metal within a mold in operation of a continuous casting apparatus.

Description of the Related Art

There are known the following methods of detecting the position of the level of molten metal:

1) Use of a float

A float is floated on a molten metal surface and the position of this float is detected by a bar, a chain or the like.

2) Use of optical (optoelectric conversion) technique

Since the brightness changes at a boundary between the molten metal surface and the container such as a mold, this boundary is measured by triangulation technique using for example, a sensor array, television cameras or the like.

3) Use of ultrasonic wave

The distance to a surface of molten metal is measured by a time required for an ultrasonic wave irradiated on the surface of the molten metal to return an original position after reflected by the surface of the molten metal.

4) Use of radioactive ray

A radioactive ray is transmitted through the molten metal in a diagonal direction, and the surface level of the molten metal is detected from the amount in attenuation of the radioactive ray during transmission through the molten metal.

5) Use of immersed electrode

The level of the molten metal is detected by turning on or off of an electric circuit provided by the molten metal and an immersed electrode.

6) Use of thermocouple

Several thermocouples are buried in the outer surface of the wall of the container of the molten metal, and the level of the molten metal is indirectly detected from the changing point in the temperature distribution measured by the thermocouples.

7) Use of electromagnetic induction

For example, in the Japanese Patent Publication No. 55-16749, a coil which is long in the depth direction of the container is provided on the outer surface of the wall of the mold and connected to one side of an impedance bridge circuit. Since the temperature of the mold wall changes with the change of the level of the molten metal within the mold, resulting in change of the specific resistance of the mold wall, the level of the molten metal is detected from the change of the eddy current produced in the mold wall due to the change of the specific resistance of the mold wall.

The conventional methods for detecting the level of the molten metal, however, involve the following problems:

1) Use of a float

The float is subjected to corrosion by the high-temperature molten metal, and also the slug, molten metal or the like is sometimes adhered to the float, thereby changing the specific gravity of the float, resulting in the necessity of the calibration.

2) Use of optical (optoelectric conversion) technique

When a smoke, dust or the like is present or when the slug (which generally provides a low brightness and looks black) is floated on the surface of the molten metal, the measurement is difficult. Further when the optical sensor portion is soiled by this smoke or the like, or when the molten metal is at a high temperature and the light is refracted by the heat waves, the measurement may involve errors.

3) Use of ultrasonic wave

When the molten metal is at a high temperature, the air is waved (changed in its density) by the heat, causing complicated refraction of sound to disable the measurement.

4) Use of radioactive ray

There is a problem with safety, and the

radiation source and the detector must be placed in a special space.

5) Use of immersed electrode

The electrode is consumed greatly in the high-temperature molten metal and thus cannot be used for a long time.

6) Use of thermocouple

Since the container for the high-temperature molten metal is made of firebricks, its heat conduction is poor. Thus, not only is delayed the measurement but also the detection precision is poor. Moreover, it is difficult to bury the thermocouples in the container wall, or to exchange a broken thermocouple with a new one.

7) Use of electromagnetic induction (Japanese Patent Publication No. 55-16749)

The temperature change at the molten metal surface is indirectly measured as the temperature change on the mold wall. However, the temperature change on the mold wall at the molten metal surface is less sharp, thus causing measurement errors.

Moreover, since the mold is cooled, it is more difficult to detect this temperature change as an impedance change, thus inevitably causing measurement errors.

Further, in a recently developed continuous casting apparatus using a belt drive type mold, as disclosed in, for example, Japanese Patent laid-open No.

JP-A-60-152347, it is required to continuously detect the level of the molten metal within the mold during operation. However, any of the conventional methods as above-mentioned is difficult to be used for the purpose, because the surface of the molten metal exposed to the top of this type of mold is small and various auxiliary devices for operation of the mold are disposed on the outside of the mold, resulting in insufficient physical space.

SUMMARY OF THE INVENTION

According to one aspect of the present invention a method of detecting a level of molten metal existing within a mold, comprising the steps of:

disposing a transmission coil and a receiving coil to oppose to each other with the mold interposed therebetween;

applying a first AC voltage to said transmission coil to produce alternating magnetic flux so that at least a part of the magnetic flux passes through said mold and the molten metal, if any, and reaches said receiving coil;

processing a second AC voltage, which is induced in said receiving coil by the part of the magnetic flux, by a synchronous-detection or a phase detection with reference to a phase of said first AC voltage thereby producing a processed signal;

determining the level of said molten metal on the basis of a voltage value of said processed signal.

According to another aspect of the present invention, an apparatus for detecting a level of molten metal existing within a mold comprising:

a transmission coil and a receiving coil disposed to oppose to each other with said mold interposed therebetween;

means for applying a first AC voltage to said transmission coil to produce alternating magnetic flux so that at least a part of the magnetic flux passes through said mold and the molten metal, if any, and reaches said receiving coil;

means for processing a second AC voltage, which is induced in said receiving coil by the part of the magnetic flux, by a synchronous-detection or a phase detection with reference to a phase of said first AC voltage thereby producing a processed signal; and

means for determining the level of said molten metal on the basis of a voltage value of said processed signal.

The method and apparatus mentioned above may be particularly used for detecting a level of a molten metal within a metal mold of a continuous casting apparatus during operation thereof.

Methods and apparatus of the invention may be applied for detecting the level of a high-temperature molten metal in a mold from outside of the mold without directly contacting the molten metal, without being much affected by the atmospheric conditions such as smoke, dust or heat and without the necessity of relatively large space.

The methods and apparatus may be applied for continuously detecting the level of the molten metal in a mold of a continuous casting apparatus during operation thereof.

BRIEF DESCRIPTION OF THE DRAWINGS A

Fig. 1 is a block diagram of a first embodiment of this invention.

Fig. 2 is a block diagram of a modification of the first embodiment of the invention.

Fig. 3 is a graph showing the relation between the voltage induced in the receiving coil and the level of the molten metal in the arrangement of Fig. 1.

Fig. 4 is a graph showing the relation between the voltage induced in the receiving coil and the level of the molten metal in the arrangement of Fig. 2.

Fig. 5 is a block diagram of a second embodiment of the invention.

Fig. 6 is a graph showing the relation between the output of the phase detector and the level of the molten metal.

Fig. 7 is a graph showing the comparison between the output of the low-pass filter and a value of the output multiplied by the cosine of the phase difference in the arrangement of Fig. 5.

Fig. 8 is a block diagram of a third embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The first embodiment of the invention concerning with the detection of the level of the molten metal within a mold will be described with reference to Fig. 1. Referring to Fig. 1, there are shown side walls 2, 3 of a mold made of a thin steel plate in, for example, a continuous casting apparatus, and a molten steel 1. In the continuous casting apparatus, as is well known, the molten steel is poured into the mold from a tundish (not shown), and the molten steel is cooled within the mold to a half-solid steel which is drawn through a bottom opening of the mold. In this case, in order to maintain the level of the molten steel within the mold constant, it is necessary to detect the level of the molten steel.

As illustrated in Fig. 1, a transmission coil 4 wound on a ferrite core is provided on the outside of the side wall 2 of the mold, and an AC voltage is applied to the coil 4 from an AC power supply 5 so as to produce alternating magnetic flux. A part of the alternating magnetic flux is distributed over and under the coil 4 and a part thereof enters into the side wall 2 of the mold made of a steel plate and transmits through the side wall 2 at its upper and lower portions. In addition, a very small part of the magnetic flux of which the density is small, penetrates the side wall 2 and passes through the molten steel 1 or air 6 or an intermediate portion including a boundary therebetween as shown in Fig. 1 depending on the level of the molten steel to reach the side wall 3 of the mold. Part of the magnetic flux which has reached the side wall 3 enters into the side wall 3 and passes through the side wall 3 at its upper and lower portions. Then, a very small part of the magnetic flux reaches the receiving coil 7 thereby inducing a voltage signal in the coil 7. The value of the induced signal is very small because a very small amount of the magnetic flux reaches the receiving coil 7. According to an experimental study by the inventors, the value of the induced voltage in the receiving coil 7 is about 1/1000 of the voltage value of the AC power supply 5. Therefore, the measurement in the field is easily affected by detrimental noise components which are irrelevant to the measuring signal of the molten steel level. Thus, detrimental noise components are removed. That is, the output of the receiving coil 7 is first passed through a band-pass filter 8 which allows only the same frequency as that of the AC power supply 5 to pass therethrough so that the detrimental noise components can be removed by the filter.

The signal passed through the band-pass filter 8, however, may sometimes include a noise component of substantially the same frequency as that of the power supply. Thus, the phase of the AC power supply 5 is adjusted by a phase adjuster 11 to produce a signal having an adjusted phase matching that of the useful signal passed through the band-pass filter 8. The outputs of the band-pass filter 8 and the phase adjuster 11 are applied to a well-known synchronous detector 9 to extract from the output of the band-pass filter 8 only a component synchronized with the adjusted phase and to convert the component into a DC voltage signal. The components which are not synchronized with the adjusted phase (or undesired signals) are produced as AC voltages from the synchronous detector 9 and removed by a low-pass filter 10 which is

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capable of passing only a DC voltage and very low frequency components, so that only the useful signal of the DC signal component can be obtained. The phase adjuster 11 and the synchronous detector 9 may be any of well known types as disclosed, for example, in "Method of measurement of minute signal" in a catalogue of NF circuit design block, March, 1983.

When the molten metal 1 is filled in the mold, part of the magnetic flux penetrated through the side wall 2 of the mold passes through the molten metal 1, thereby producing an eddy current within the molten metal. Since this eddy current is partially consumed in a form of Joule heat within the molten metal, the magnetic flux reaching the receiving coil 7 is very small.

When no molten metal 1 is present within the mold, but only an air 6 is filled within it, no eddy current is produced in the molten steel unlike the above case. Thus, the magnetic flux is less attenuated within the mold, or is not lost in a form of joule heat, so that the amount of the magnetic flux reaching the receiving coil 7 is larger than that in the case in which the molten metal 1 is filled in the mold. Fig. 3 shows the relation between the measured value of the induced voltage in the receiving coil 7 and the level of the molten steel. In this graph, the width W of the mold is about 50 mm, the height (the dimension in the vertical direction) D of the rectangular cross-section of the transmission coil is about 40 mm, the mid point M in the graph indicates the induced voltage obtained when the level H2 of the molten steel coincides with the upper side of the transmission coil, and the maximum point A and the minimum point B in the graph indicate the induced voltages obtained when the molten metal is at a level H1 50 mm higher than H2 and at a level H3 50 mm lower than H2, respectively. In other words, the induced voltage is continuously changed as the level of the molten steel changes over the range of about 100 mm. Therefore, the change of the level of the molten steel over the range of about 100 mm can be detected by measuring this induced voltage. In the field of actual measurement, noise independent of the level of the molten steel is of course picked up, and hence the level of the molten steel is measured based on an output of a low-pass filter 10 shown in Fig. 1.

When the level of the molten steel is greatly shifted from the position of the transmission or receiving coil, for example, separated by 50 mm or more, the position of the level cannot be detected by the above method even though it is possible to detect whether the level is above or below the transmission or receiving coil position. In that case, as shown in Fig. 2, a plurality of sets of transmission coils 4a, 4b, ..., 4n and the receiving coils 7a, 7b, ..., 7n are oppositely disposed on the outsides of the mold walls 2 and 3 within which the molten metal 1 is filled, at intervals in the vertical direction in which the level of the molten steel changes. The voltages of different frequencies from AC power supplies 5a, 5b, ..., 5n are supplied to the transmission coils 4a, 4b, ..., 4n, respectively. Parts of the alternating magnetic flux produced by the coils are transmitted through the molten steel 1 or air 6 and the mold walls 2, 3 so as to reach the receiving coils 5a, 5b, ..., 5n, thereby inducing AC voltages in the coils in the same manner as mentioned above. The induced voltages are respectively supplied through band-pass filters 8a, ..., 8n, and synchronous detectors 9a, ..., 9n to low pass filter 10a, 10b, ..., 10n in the same way as described above. In the circuit arrangement shown in Fig. 2, phase adjusters corresponding to the phase adjuster 11 shown in Fig. 1 are also provided for the respective coil sets, but for the sake of simplicity they are not shown.

Moreover, the outputs of the low-pass filters 10a, 10b, ..., 10n are connected to binary encoders 12a, 12b, ..., 12n, respectively. Each of the binary encoders produces a logical value of "1" when the output voltage of the corresponding low-pass filter is lower than a value corresponding to point M in Fig. 1, and a logical value of "0" when it is equal to or higher than the value corresponding to point M. As a result, it is determined from the outputs of the binary encoders whether the level of the molten steel is higher or lower than the upper edge of the corresponding transmission coil, or the position H2 of the level of the molten steel in Fig. 3. By providing a plurality of sets of transmission and receiving coils at proper intervals to cover a range in which the level of the molten steel is possibly changed, which region of the range where the level of the molten steel is positioned is determined based on the outputs of the binary encoders.

This method is able to determine which one of the regions, each corresponding to half the interval between adjacent two sets of transmission and receiving coils, the level of the molten steel is located, but unable to continuously detect the change of the level of the molten steel. If it is desired to continuously detect the change of the level of the molten steel over a wide range, a plurality of sets of transmission and receiving coils are disposed in such a manner that the interval between every two adjacent sets is equal to or slightly smaller than a distance between the points H1 and H3 in Fig. 3. Then the position of the level of the molten steel can be precisely detected from the output voltages of the low-pass filters of adjacent two sets of transmission and receiving coils of which the outputs of the corresponding binary encodes are, respectively, "1" and "0". Fig. 4 is a graph showing the relation between the level of the molten steel and the output (induced voltage in the receiving coil) of each of the low-pass filter 10a, 10b, 10c, 10d of 4 sets of transmission and receiving coils arranged in this way.

While in this embodiment the mold is made of a steel plate, it may be made of other metal or a material such as firebrick.

Moreover, the molten metal to be measured may be other metal than steel, for example, aluminum.

A second embodiment of this invention will be described with reference to Figs. 5 to 7. In the arrangement shown in Fig. 5, the elements other than a phase difference detector 13, a cosine calculator 14 and a multiplier 15 are substantially the same as those in the first embodiment of Fig. 1. The second embodiment is an improvement in the detection sensitivity of the first embodiment. The phase of the AC power supply 5 is adjusted by a known phase adjuster 11 so that when no molten steel 1 is present within the mold, the phase of the useful AC signal, i.e. an output of the band-pass filter 8 is equal to that of the output of the phase adjuster 11, and hence the output of the phase difference detector 13 which converts the phase difference between them into a voltage signal is zero. When the output value of the phase difference detector 13 is zero, i.e. the phase difference $\Delta\phi = 0$, Cos $\Delta\phi = 1$ is produced from a cosine calculator 14. Thus, the output of a known multiplier 15 which produces a product of the value of cos $\Delta\phi$ and the output of the low-pass filter 10 is equal to the output of the low-pass filter 10. On the other hand, when the molten steel 1 is filled within the mold, part of the magnetic flux having penetrated the side wall 2 of the mold causes an eddy current within the molten steel during passing through the molten steel 1, and it thus lost as joule heat. Consequently, the impedance of the receiving coil 7 equivalently represented by L (inductance) and R (resistance) is changed so that the phase of the voltage induced in the receiving coil is deviated by $\Delta\phi$ as compared with the case in which no molten metal 1 is present within the mold or only air is present. According to the experimental study by the inventors, when the frequency of the AC voltage of the AC power supply 5 is 600 Hz, the phase difference $\Delta\phi$ is 72 degrees. A signal corresponding to this phase difference $\Delta\phi$ is outputted from the phase difference detector 13 and converted into a value of Cos $\Delta\phi$ by the cosine calculator 14 as mentioned above. In case of $\Delta\phi$ being 72 degrees, Cos $\Delta\phi$ is 0.309 smaller than "1". As a result, the multiplier 15 produces a product of this value and the output value of the low-pass filter 10. Thus, the output value of the low-pass filter 10, which is smaller than a value of its output obtained when the molten metal is filled in the mold, is made further smaller by use of the multiplier 15. Generally, the value of the phase difference $\Delta\phi$, or the output voltage of the phase difference detector 13 continuously increases as shown in Fig. 6, or decreases, as the level of the molten steel becomes higher in the vicinity of the position of the set of the transmission and receiving coils. In the above embodiment using the product of a value of Cos $\Delta\phi$ and the output value of the low-pass filter 10, the difference between the output of the low-pass filter 10 produced when the molten steel is filled in the mold and that produced when no molten steel exists is magnified by using the multiplier 15 as shown by solid line in Fig. 7 as compared with the case using no multiplier as shown by broken line, thus resulting in increasing the sensitivity.

When the band width (frequency band) of the band-pass filter 8 is decreased, the noise signal detrimental to the measurement can be effectively decreased, but when it is too narrow, an error occurs in the measurement because a slight change of the frequency of the AC power supply 5 due to drift or the like may cause great shift in phase of the output of the band-pass filter when the frequency of the AC power supply 5 is changed from the center frequency of the band-pass filter 8. To avoid this effect, it is desired to make the band width wider or make the center frequency of the band-pass filter 8 slightly higher or lower than the frequency of the AC power supply 5.

Moreover, when the time constant of the low-pass filter 10 is increased, more stability is achieved against the undesired noise signal, but the measurement time delay is increased. Thus, the desired time constant will be about 1/3 the allowable delay time (in this embodiment, the time constant is 30 msec).

While in this embodiment the output of the phase difference detector 13 is zero when no molten steel 1 is present within the mold as described above, the same effect can be achieved by an arrangement in which the output of the phase difference detector 13 is made zero when the mold is filled with the molten steel 1, and a sine calculator is used in place of the cosine calculator 14.

A third embodiment of this invention will be described with reference to Fig. 8. While in the first embodiment the level of the molten steel is detected on the basis of the value of the voltage induced in the receiving coil, in the third embodiment the level of the molten steel is detected on the basis of the phase of the voltage signal induced in the receiving coil. While in the second embodiment the cosine of the output of the phase difference detector is used for improving the detection sensitivity in which case the output of the phase difference detector is continuously changed with change of the level of the molten steel as shown in Fig. 6, the third embodiment utilizes the change of the phase difference.

In Fig. 8 showing the third embodiment, like elements are designated by the same reference numerals as those in Fig. 5. The phase adjuster 11 adjusts the phase of the power supply so that the phase difference $\Delta\phi$ between the output of the low-pass filter and the output of the phase adjuster is 90° or 0° in electrical angle, when the level of the molten steel is, for example, below the transmission coil. In this case, the only one set of transmission and receiving coils is used as shown in Fig. 8, the phase adjuster is not always necessary, but when a plurality of sets of transmission and receiving coils are arranged as in Fig. 2, a phase adjuster must be provided for each set in order to adjust the outputs in the respective sets.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A method of detecting a level of molten metal existing within a mold, comprising the steps of:

disposing a transmission coil and a receiving coil to oppose to each other with the mold interposed therebetween;

applying a first AC voltage to said transmission coil to produce alternating magnetic flux so that at least a part of the magnetic flux passes through said mold and the molten metal, if any, and reaches said receiving coil;

processing a second AC voltage, which is induced in said receiving coil by the part of the magnetic flux, by a synchronous-detection or a phase detection with reference to a phase of said first AC voltage thereby producing a processed signal;

determining the level of said molten metal on the basis of a voltage value of said processed signal.

2. A method according to claim 1, further comprising the step of applying said processed signal to a low-pass filter thereby producing a filtered processed signal so that the level of the molten metal is determined on the basis of a voltage value of said filtered processed signal.

3. A method according to claim 1, further comprising the steps of determining a sine or cosine of a phase difference between a phase of said second AC signal and the phase of said first AC voltage and producing a product of the sine or cosine of the phase difference and the voltage value of said processed signal, said product being used for determining the level of said molten metal.

4. A method according to claim 1, further comprising the step of applying said second AC signal to a band-pass filter for removing undesired frequency components of said second AC signal before said second AC signal is processed by the synchronous-detection or the phase detection.

5. Apparatus for detecting a level of molten metal existing within a mold comprising:

a transmission coil and a receiving coil disposed to oppose to each other with said mold interposed therebetween;

means for applying a first AC voltage to said transmission coil to produce alternating magnetic flux so that at least a part of the magnetic flux passes through said mold and the molten metal, if any, and reaches said receiving coil;

means for processing a second AC voltage, which is induced in said receiving coil by the part of the magnetic flux, by a synchronous-detection or a phase detection with reference to a phase of said first AC voltage thereby producing a processed signal; and

means for determining the level of said molten metal on the basis of a voltage value of said processed signal.

6. Apparatus according to claim 5, further comprising means for applying said processed signal to a low-pass filter for removing high frequency components of said processed signal thereby producing a filtered processed signal so that the level of the molten metal is determined on the basis of the filtered processed signal.

7. Apparatus according to claim 5, further comprising means for determining a sine or cosine of a phase difference between a phase of said second AC signal and the phase of said first AC voltage and prodcuing a product of the sine or cosine of the phase difference and the voltage value of said processed signal said product being used for determining the level of said molten metal.

8. Apparatus according to claim 5, further comprising means for applying said second AC signal to a band-pass filter for removing undesired frequency components of said second AC signal before said second AC signal is processed by the synchronous-detection or the phase detection.

9. A method of detecting a level of molten steel existing within a mold having at least two side walls of continuous casting equipment, comprising the steps of:

disposing a transmission coil and a receiving coil at outsides of said two side walls so as to oppose to each other with the mold interposed therebetween;

applying a first AC voltage to said transmission coil to produce alternating magnetic flux so that at least a part of the magnetic flux passes through said mold and the molten steel, if any, and reaches said receiving coil;

processing a second AC voltage, which is induced in said receiving coil by the part of the magnetic flux, by a synchronous-detection or a phase detection with reference to a phase of said first AC voltage thereby producing a processed signal; and

determining the level of said molten steel on the basis of a voltage value of said processed signal.

10. Apparatus for detecting a level of molten steel existing within a mold having at least two side walls of continuous casting equipment comprising:

a transmission coil and a receiving coil disposed at outsides of said two side walls so as to oppose to each other with the mold interposed therebetween;

means for applying a first AC voltage to said transmission coil to produce alternating magnetic flux so that at least a part of the magnetic flux passes through said mold and the molten steel, if any, and reaches said receiving coil;

means for processing a second AC voltage, which is induced in said receiving coil by the part of the magnetic flux, by a synchronous-detection or a phase detection with reference to a phase of said first AC voltage thereby producing a processed signal; and

means for determining the level of said molten steel on the basis of a voltage value of said processed signal.

11. A method of detecting the level of molten metal substantially as hereinbefore described with reference to the drawings.

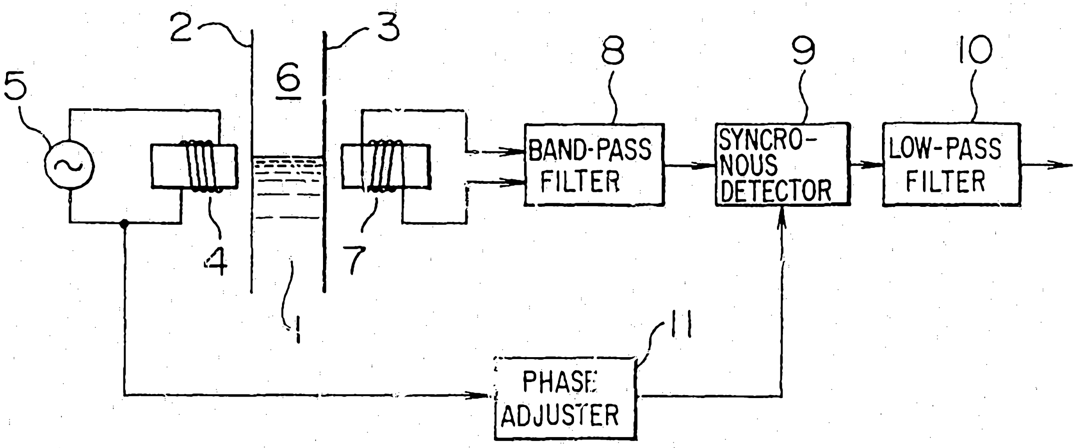
12. An apparatus for detecting the level of molten metal substantially as hereinbefore described with reference to the drawings.

Dated this 11th day of September, 1991

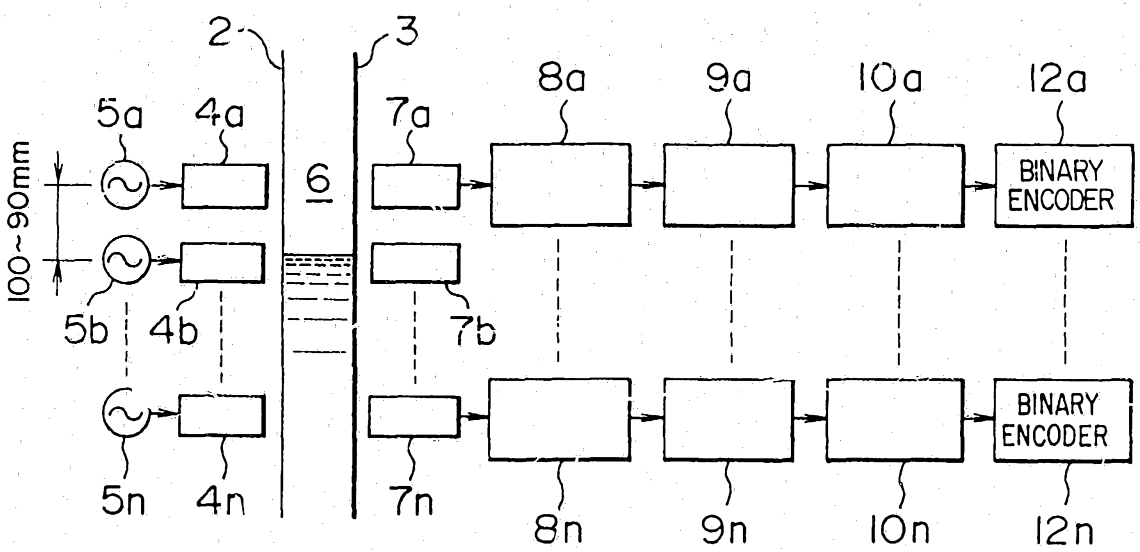
NIPPON STEEL CORPORATION
by its Patent Attorneys
DAVIES & COLLISON

62429/90

F I G. 1



F I G. 2



62429/90

FIG. 3

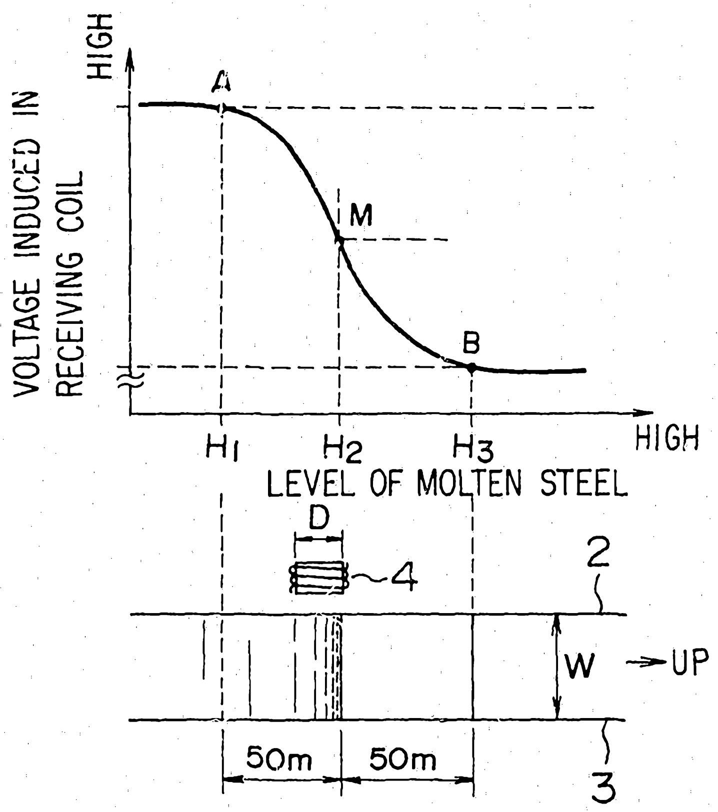


FIG. 4

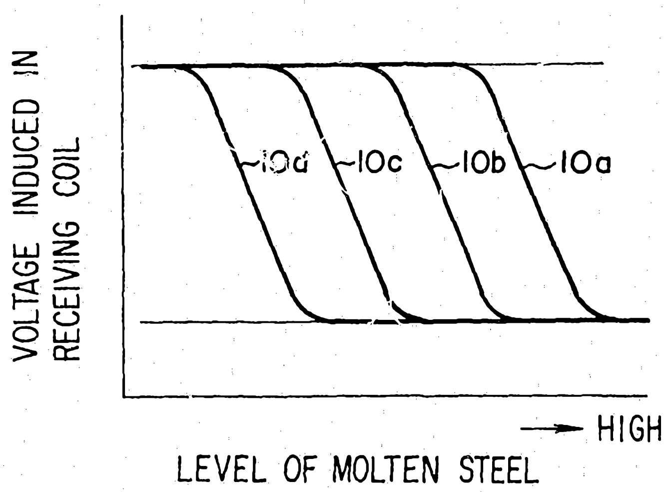
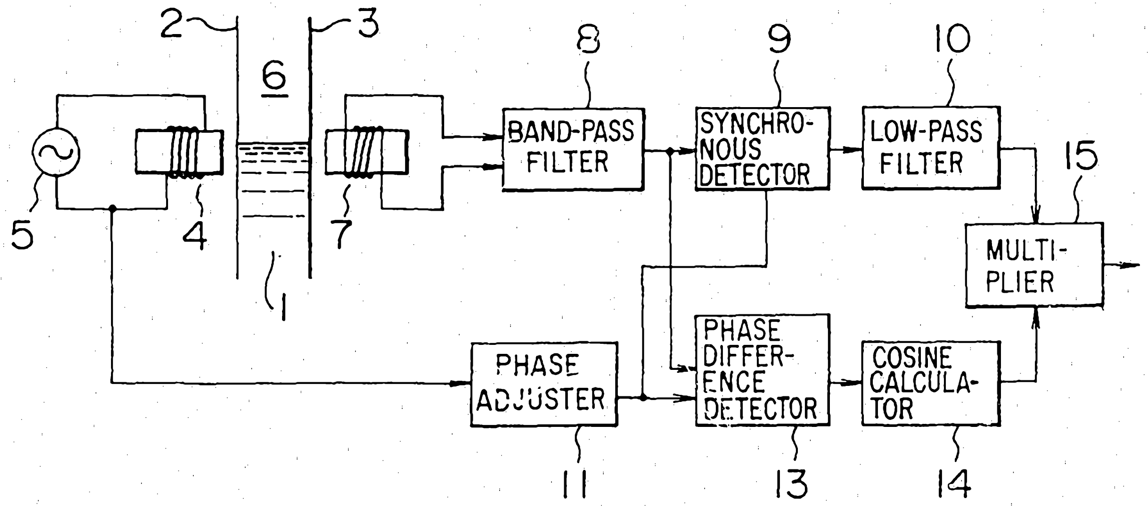
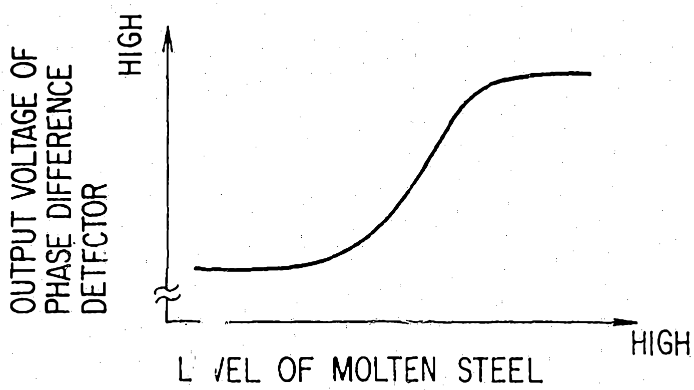


FIG. 5



2
3
6
8
9
10
BAND-PASS FILTER
SYNCHRO-NOUS DETECTOR
LOW-PASS FILTER
15
MULTI-PLIER
5
4
7
1
PHASE DIFFER-ENCE DETECTOR
COSINE CALCULA-TOR
PHASE ADJUSTER
11
13
14

FIG. 6



OUTPUT VOLTAGE OF PHASE DIFFERENCE DETECTOR
HIGH
HIGH
L VEL OF MOLTEN STEEL

FIG. 7

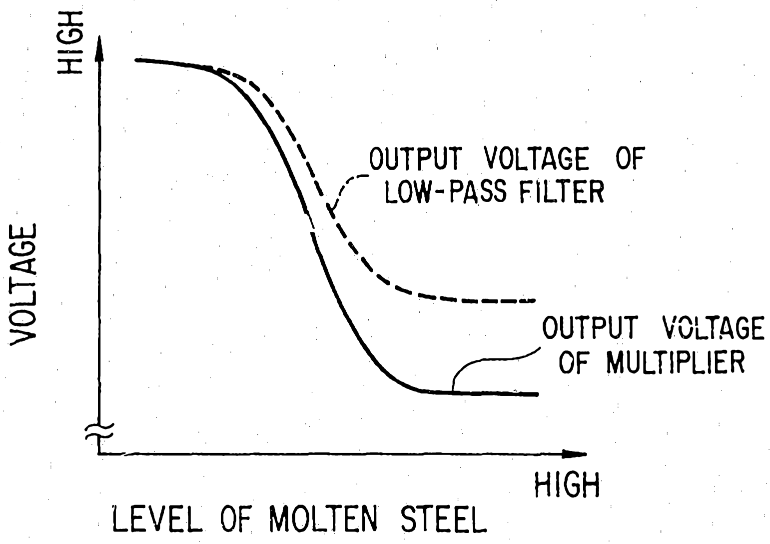
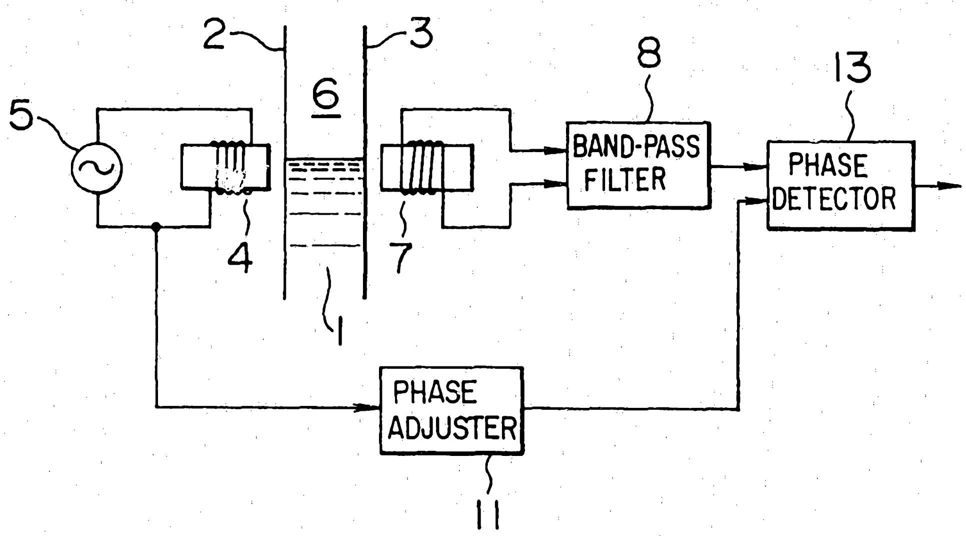

HIGH
VOLTAGE
OUTPUT VOLTAGE OF
LOW-PASS FILTER
OUTPUT VOLTAGE
OF MULTIPLIER
HIGH
LEVEL OF MOLTEN STEEL

FIG. 8


2
3
6
5
8
13
BAND-PASS
FILTER
PHASE
DETECTOR
4
7
1
PHASE
ADJUSTER
11