Title: PHASE LEVEL SYSTEM

Abstract: System to determine the height in liquid or molten metal levels or phases within a mat or slag converter or pyrometallurgical furnace, whereby it comprises a signal generator and a signal processor, where such generator sends an electrical signal to such processor, being such processor connected to a group of electrodes placed in the converter's shell or pyrometallurgical furnace, in which such electrodes are disposed crossing the shell in electrical contact with the phases so that they are installed in height zones of the slag and metal levels or phases, so that once such electrodes are installed configuring serial resistance groups through which such electrical signals circulate.
PHASE LEVEL SYSTEM

The following invention is directed towards a method and system to determine the level height of liquid or molted metals inside metal, mat or slag converters or furnaces. It is specifically directed towards a method and system that by the application of a sign external to the melting bath is possible to determine the height of phases on line, being able to obtain the height from the slog-mat interface and the total level of the bath.

Previous Art

In pyrometallurgical converters or furnaces, basically three immiscible products coexist, composition and different physicochemical properties; Gas, Mat (high grade phase) and slag (low grade phase). These are separated by phases, thus presenting a Gas-Slag interface and another Slag-Mat interface which height with respect to the converter or furnace’s bottom is denominated total level and mat level, respectively.

Currently, it is particularly difficult to estimate those levels with an acceptable precision during pyrometallurgical processes. However, these constitute fundamental parameters regarding decision making of operations and metallurgical accounting. In effect, the inadequate control of the phase’s levels, resulting from a poor measurement, will always result in fewer metal recoveries due to losses of mat or slag, or else, insufficient consumption of
energy in the operation. This makes monitoring and control of the total level and mat level an essential tool to obtain an optimum operation and thus reduce losses.

In the previous art, different useful technologies are known for the measurement of levels within converters or furnaces.

Currently, the most widely used method consists in estimating the phase levels starting from visual inspections of steel rods at carbon-20, of greater length than the converter or furnace's diameter, periodically submerged in the metallurgical bath vertically through an opening in the converter or furnace's upper part and removed after a time of residence of a few minutes in the metallurgical bath. A strong chemical deterioration can thus be observed in these rods in the zone exposed to the mat phase, which permits to estimate the mat level and slag adhesion up to the height corresponding to the maximum level.

This method is fairly simple in its implementation, but conveys a risk to the operator. Likewise, the sampling precision and frequency that this method offers is low, therefore the timely and precise knowledge of each phase during operation continues to be a problem without solution or only a partial solution in the pyrometallurgical processes.
Another method used in the previous art corresponds to a densimeter or Floating Buoy. By having each liquid a different density within the inside of the converter or furnace, it is feasible to think of a method that detects the heights upon which they vary, and thus, know each of the existent phase changes. Its operation would be greatly similar to the use of a spear, considering the introduction of the instrument in the converter or furnace supported by a spear that serves as a height measuring tool of the respective level heights.

The high temperatures existent in the interior of the converter or furnace force for the use of a densimeter capable of resisting operation temperatures greater than 1250°C (2282°F), to which the liquids to be measured are subject to. Without a doubt, this inconvenience hampers even more the operation and the life of the instrument to be utilized.

The inconveniences that the previous art methods present lie, firstly, in their poor precision, given that the metallurgical bath is in constant movement producing widespread marks over the rods which are hard to accurately interpret, therefore the estimation so obtained represents only another threshold for the continuance of the conversion process in the converter or furnace. Secondly, the relative frequency that such measurements may be carried out, diminish the timely information inferred from them.
Additionally, the previous art has also described a system of discreet and continuos measurement of levels, based on the application of mechanical waves (ultrasonic). For example, the following patent publications can be mentioned:


Rojas et al: "System for a non-invasive online continuos measurement of phase levels in converters or pyrometallurgical furnaces". US 6,792,358 B2, Dec. 28, 2004

Additionally, the previous art has also described a discrete and continuos measurement of levels, based on electro-resistant principles. For example, the following patent publications can be mentioned:


Both publications mention the development of detectors able to perform continuos measurements of phase levels, based on spear type assembly. However, this type of system does not allow to carry out online measurements.
Notwithstanding the above, the previous art nearest this invention, is represented in the publication by Usher John D. "Refractory material sensor for determining level of molten metal and slag and method using". US 6.309.442, since it is mentioned in this patent publication the disposition of electrodes at different heights in which the proposed device contemplates piercing the refractory with electrodes, in this case wire conductors (not solid electrodes as in this application) which at the beginning does not necessarily come into contact with the metallurgical bath. Notwithstanding, the operational principle of the sensor is based on the Seebeck effect (commonly utilized in thermocouples) and the "Double layer" effect which is the propeller electromotive force (EMF) between the volume of an ionic phase conduction such as slag and the layer which is produced in the interface with an electronic conduction material such as metal. This principle, is far from the electro-resistant principle applied in this application, since in the mentioned publication small potentials are measured which are generated by putting into contact two materials of different electronic nature. On the other hand, in this application, the electronic response in a metallurgical bath is studied at a controlled and external electronic stimulation.

It must also be considered that the Usher system does not deliver a continuos level measurement, but rather a discrete measurement, therefore the level measurements corresponds to a discrete level.
In this sense, the basic advantage of the current application, discrete as well as continuous measurement, with respect to the systems developed by Woodcock and Tenberg is the possibility to be implemented online. Further to the already mentioned surface exposed to chemical corrosion which in the present invention is much less.

Moreover, the advantage of the proposed invention compared to the Usher system and method, is based on the ability to measure the levels in a wide range, along the converters or furnaces and not in a specific manner to a certain specific height of the container, which only serves to identify when the slag-mat interface passes along that specific height or, at the most in a discrete manner, thus needing a great amount of probes (or electrodes) to reach an acceptable height resolution. But even more importantly, the system and method herein proposed allows to vary, in a wide range, the intensity of the stimulating signal and thus the amplitude of the responses. This capacity is crucial in the acquisition of signals in industrial environments, where the high level of noise may widely exceed the amplitudes of smaller signals comprised in the chemical interactions proposed by Usher.

**Brief Description of the Figures**

Figure 1: represents a scheme which illustrates the operation of the invention system with sensors measuring the phase levels.
Figure 2 represents a scheme which illustrates the measuring system composed by a stimulating branch, another branch of acquisition and a sequence device that coordinates both branches.

Figure 3: represents a scheme of the resistance measuring mechanism. (a) corresponds to the scheme of a pair of electrodes submerged in one of the metallurgical bath phases with the purpose of exemplifying the method of the invention, (b) Corresponds to a circuit equivalent to a pair of submerged electrodes whereby the way in which the measuring is performed in such invention method is illustrated.

Figure 4: represents a scheme of electrode configurations for discrete measuring, specifically in an option of co-lineal electrodes.

Figure 5: represents a scheme of electrode configurations for discrete measuring, specifically in a configuration option of co-lineal electrodes.

Figure 6a: represents a scheme which illustrates a configuration to perform the discrete estimation method.

Figure 6b: represents a circuit equivalent to the configuration of a method of discrete estimation.
Figure 7a: represents a scheme which illustrates a configuration to perform the continuous estimation method.

Figure 7b: represents a circuit equivalent for the configuration of a continuous estimation method.

**Detailed Description of the Embodiments**

The method of the invention is based on the measurement of electrical resistance through the phases present within a pyrometallurgical converter or furnace. To this effect, it is known that measurements of specific electrical conductance (opposite to the resistivities), show differences of various nature of magnitude, between mat and slag, for example, for white metal and slag, the studies carried out by Pound, G.M., Degre, G. and Osuch, G. (1955) "Electrical conduction in molten Cu-Fe sulphide mattes". Trans A.I.M.E. 203, 481-484, show values of 300 to 1000 $\Omega^{-1}cm^{-1}$ in white metal and 0.5 $\Omega^{-1}cm^{-1}$ in slag. Similar results were obtained by Otero, A. and Garcia, M. (1992) "Study of height level measurement of molten phases in copper concentrated converter furnaces". CIMM, Extractive Metallurgical Division, P-833, in which studies of electric properties of molten phases coexistent in the interior of copper concentrated converter furnaces, upon which the method of invention proves that it is possible to take advantage of these electrical differences in said phase, for the construction of a method and system capable of...
measuring the total level of the metallurgical bath as well as the slag-white metal interface.

The method consists in performing sequenced measurements of potential falling between electrodes (1) immersed at certain heights of the bath represented by phases (3) (4) and (5), as illustrated in figure 1. To generate these measurements, a system composed of two branches is prepared; stimulating branch and acquisition branch, duly synchronized through a sequence device (8), showed in figure 2.

The stimulating branch is made up of an current source (6), of variable intensity $I_0$. The electricity so generated is modulated by a sequence device (8) of adjustable synchronization which alternately and sequentially closes the contacts between the current source (6) and electrodes (1) for adjustable and relatively short periods of time $\tau$, during which an electrode (9) will be the transmitter, sending a pulse of electricity of $I_0$ intensity through the phase in which it is immersed and which shall be received by the other electrode (10), closing the circuit.

Furthermore, the acquisition branch, made up of a voltmeter (7), which measures during time $\tau$, the potential difference between the transmitting electrode (9) and the receptor (10), assigned by the same sequence device, which closes the contact between the receptor electrode (10) and Voltmeter (7).
Starting from these measurements, the electric resistance \( R_m = \frac{V}{I_0} \), that some regions between electrodes (9) and (10) offer may then be inferred, such regions being composed by phases.

The electric behavior of the system composed by a pair of electrodes (9) and (10) submerged in a specific phase of the metallurgical bath, as illustrated in figure 3a, in which said electrodes an \( I_0 \) current is made to circulate, can be described as a serial resistance group, just as it is shown in figure 3b.

The resistance of phase \( (R_f \text{ in figure } 3b) \) can always be expressed in terms of the specific electric resistivity of the phase and geometrical parameters of the electrodes and their availability. However, whichever the geometry and separation of the electrodes, this resistance will always be directly proportional to the specific electric resistivity which characterizes the phase between the electrodes. Therefore, the measured resistance \( R_m \) is a product of the resistive contributions of the electrodes and wiring plus the phase's resistance, this is:

\[ R_m = R_{em} + R_{re} + 2R_c + RF \]

With, \( RF = p \cdot G(r, d, a) \)

Where, \( R_{em} \) and \( R_{re} \) represent the resistance of the transmitting and receptor electrode, respectively.

\( R_c \) represents the wiring resistance of an electrode.
RF represents the phase’s resistance

\[ G(r, d, a) \]

corresponds to an independent function of the geometry and disposition of the electrodes.

Therefore, the resistances so measured will be much higher for measurements executed in slag than for those executed in white metal and practically infinite for measurements performed in gas. This way, in conjunction with the fact that the height of the electrodes is known, real time information will be achieved with respect to the levels of the phases in the interior of converters or furnaces.

The system of the invention contemplates two preferred embodiments of execution. The first preferred embodiment contemplates a continuous and online determination system of phase levels and the second embodiment contemplates a discrete and online determination system of such levels. Both embodiments are based on the above mentioned method, differing amongst them only by the arrangement of immersed electrodes in the phases and interpretation criteria of the signals, as explained below.

In the case of the discrete determination embodiment, the system contemplates electrodes densely disposed around historic height zones of total and mat level which is known by experience, for example, of the spear introduced in the previous art as shown in figure 4 where pairs of electrodes are placed in a collinear manner. Such manner is not strictly necessary,
being able to place the electrodes even in zigzag, as shown in figure 5, so long as the height in which they are placed is known. This way, if a pair of electrodes immersed in the gaseous phase is considered, another in the slag phase and another in the mat phase, as shown in figure 6, so long as the sequence device activates the reading between the electrode pairs, it will be observed that $R_{m12} > R_{m34}$ and $R_{m34} > R_{m56}$, from which it can be inferred that between the height of electrodes E2 and E3 the Gas-Slag interface is found and between the height of electrodes E4 and E5 the Slag-Mat interface can be found. Thus, the levels can be estimated upon the sudden variations observed and the measured resistances and the heights known by construction of the electrodes, in which these variations may be observed, with an uncertainty given by half of the separation between these electrodes, without determining the exact height in which the phases may be found, therefore the levels are determined only discretely by knowing that the interface is found between two particular electrodes, but not at which height. In this manner, the density of the electrodes around the historic heights of the slag-mat levels, will depend of the discrete resolution wished to be obtained.

In the continuous determination embodiment, the dense disposition of electrodes is not required, since the criteria of level estimation is capable of determining the interface height between two particular electrodes.

For the case of Total Level, the estimation criteria supposes the existence of an accretion layer in the wall of the converter or furnace through
which the electrodes are installed. These electrodes shall be disposed in such a way that at least one electrode is at all times immersed in each phase, as shown in figure 7a. In this way, the electric behavior of this system can be modeled as the resistance configurations illustrated in figure 7b.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

In the foregoing and in the examples, all temperatures are set forth uncorrected in degrees Celsius and, all parts and percentages are by weight, unless otherwise indicated.

The entire disclosures] of all applications, patents and publications, cited herein are incorporated by reference herein.

The preceding examples can be repeated with similar success by substituting the generically or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.
CLAIMS

1. System to determine the height in liquid or molten metal levels or phases within a mat or slag converter or pyrometallurgical furnace, whereby it comprises a signal generator and a signal processor, where such generator sends an electrical signal to such processor, being such processor connected to a group of electrodes placed in the converter's shell or pyrometallurgical furnace, in which such electrodes are disposed crossing the shell in electrical contact with the phases so that they are installed in height zones of the slag and metal levels or phases, so that once such electrodes are installed configuring serial resistance groups through which such electrical signals circulate.

2. System to determine the height of phases according to claim 1, whereby a set of electrodes is installed above a certain phase level and another set of electrodes is installed under such phase level.

3. System to determine the height of phases according to claim 2, whereby, each electrode set is composed by at least two electrodes in case the determination of phase heights is discrete.

4. System to determine the height of phases according to claim 2, whereby, each electrode set is composed by at least one electrode in case the determination of phase heights is continuous.
5. System to determine the height of phases according to claim 2, whereby in a preferred embodiment, such electrodes are installed in a coliinear manner.

6. System to determine the height of phases according to claim 2, whereby in a preferred embodiment such electrodes are installed in zigzag.

7. System to determine the height of phases according to claim 1, whereby such electric signal is an electric current which circulates through such electric circuit.

8. Method to determine the height of liquid or molten metal within metal, mat or slag converters or pyrometallurgical furnaces whereby the method consists in measuring the electric resistance of such liquid metal and/or slag phases present in such converter or pyrometallurgical furnace, so that through the differences in such electric resistances detected in each phase the height in which each one of the is places is determined; in that such measurement consists in determining the potential fall between a group of electrodes placed at different heights in the shell of such converter or furnace, being such electrodes submerged in contact in such phases, and conforming a serial group of resistance, by which through such electrodes a circular current is made to circulate, such current coming from a signal generator system and modulated by a signal processor, so that once such current circulates, the electric resistances of the regions comprised between
such electrodes are inferred, so as to obtain a real time measurement of the height levels of such phases inside said converter or furnace.

9. Method to determine the height of phases according to claim 8 whereby the resistance of each phase is directly proportional to the specific electric resistivity that characterizes each phase between electrodes.

10. Method to determine the height of phases according to claim 9 whereby the measured resistance is obtained by the electrode resistance plus the wire resistance, through which such resistances are connected, plus the resistance phase.
Figura 7