

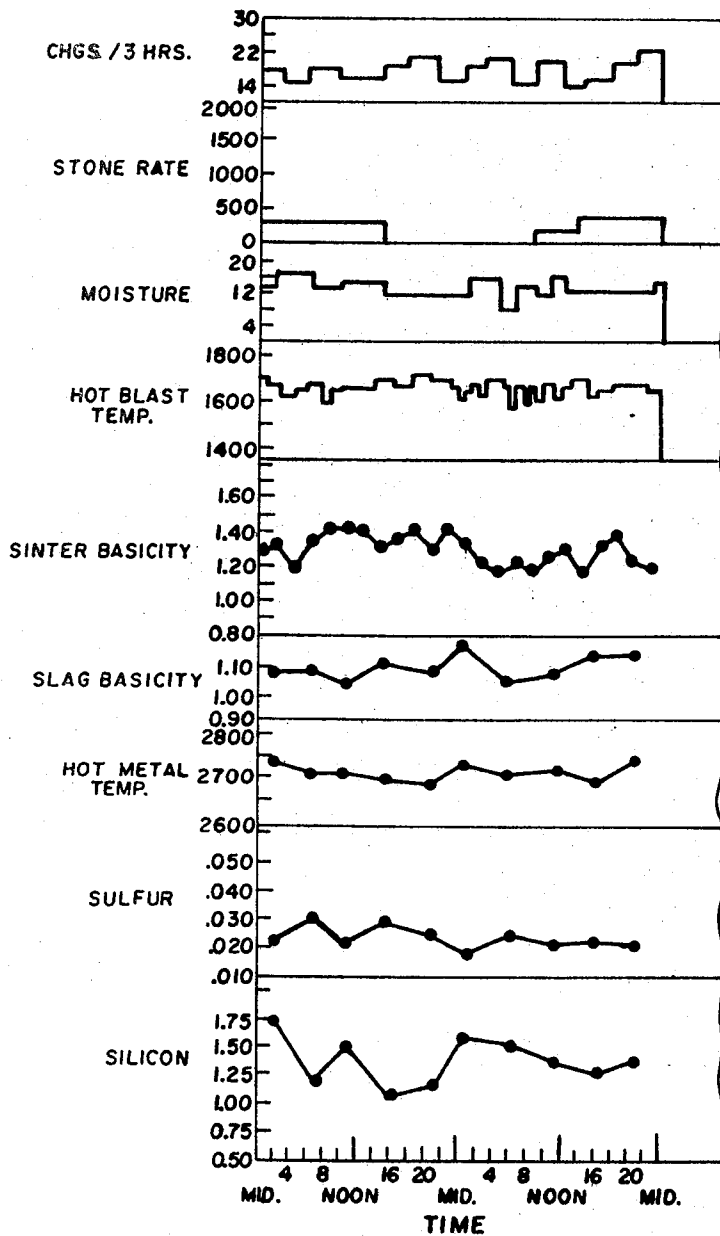
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METHOD OF BLAST FURNACE CONTROL

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METHOD OF BLAST FURNACE CONTROL

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4 Claims

ABSTRACT OF THE DISCLOSURE

The operation of a blast furnace is controlled by changing the moisture level of the hot blast in response to variations in the peak hot metal temperature from cast to cast with relation to an aim peak hot metal temperature. Burden ratio changes are made as the hot blast moisture level reaches predetermined maximum and minimum values along with equivalent moisture changes in order to maintain the moisture level within a predetermined range without affecting the hot metal temperature.

This invention relates generally to a method for controlling the operation of a blast furnace and more specifically to a control method where the peak hot metal temperature is the control guide, and the blast moisture level is the primary control variable.

In controlling the operation of a blast furnace, the operator seeks to produce maximum iron tonnage of specific grade and quality while maintaining a smoothly running furnace. Control of the hearth temperature is of great importance in accomplishing these objectives. It is well known, for example, that a cold furnace generally produces iron low in silicon and high in sulfur, while a hot furnace produces iron with a high silicon and low sulfur content. The present invention utilizes the peak hot metal temperature during each cast from the furnace, which temperature reflects the hearth temperature, as a control guide in bringing about smooth blast furnace operation. By maintaining the peak hot metal temperature near an aim value consistent operation is established.

The hot metal temperature is a function of many variables, including the nature and amount of the iron-bearing materials charged, the amount of coke charged, the amount of fluxes such as limestone and dolomite used and the moisture content of the hot blast. In addition, these variables, except for blast moisture content, have their own independent effect on the quality and grade of the hot metal produced and on slag basicity. It will therefore be understood that it is difficult for an operator to evaluate all these factors and others in attempting to keep the iron temperature at an aim value, especially since changes to the burden are not manifested at the hearth for at least six hours, or until the burden change essentially reaches the hearth.

The present invention obviates this difficulty by using iron temperature as the control guide and changes in hot blast moisture as the primary control variable in controlling the iron temperature and consequently furnace operation and by maintaining all other variables as constant as possible. Controlling iron temperature by effecting changes in the moisture content of the hot blast has the advantage that corresponding changes in the iron temperature are brought about relatively quickly so that the operator in a short time learns what effect a particular moisture change has had. In addition, blast moisture changes do not directly influence iron quality or slag basicity. By comparing the peak hot metal temperature of a particular cast in progress with the peak hot metal temperature of the previous cast and by relating these

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temperatures to the aim hot metal temperature, a determination is made as to the change in blast moisture required to maintain the furnace temperature at or near the desired value. In order that the cumulative effect of blast moisture changes does not cause the furnace to drift too far from optimum operating conditions, the blast moisture level is maintained within a predetermined range. When the minimum and maximum values of that range are reached, changes are made in the burden ratio along with subsequent and equivalent moisture changes so that the moisture level can be maintained within the range at or near an aim level.

As a further aspect of the invention, where swings in burden basicity occur tending to result in corresponding swings in slag basicity, changes in the stone rate are made concurrent with the changes in burden basicity to maintain the slag basicity constant. A change in the burden weight equal but opposite to the stone change is made to compensate for the thermal effect of the stone change. This eliminates the need for a subsequent moisture change to maintain the furnace temperature at the desired level.

An object of this invention is to provide a method for controlling a blast furnace so as to bring about a smooth and consistent operation. Another object of this invention is to provide a method of controlling the operation of a blast furnace by controlling the peak hot-metal temperature. Yet another object of this invention is to provide such control by effecting changes in the hot blast moisture level. Another object of the invention is to maintain the moisture level within a desired range to provide smooth and efficient furnace operation. A further object of this invention is to provide a method of controlling the operation of a blast furnace where the effects of different operating conditions on the furnace are readily determined.

While the present invention is applicable to blast furnaces generally, reference is made in the following description to a particular furnace for the purpose of fullness, clearness, conciseness and exactness in enabling those skilled in the art to practice the invention. The figure of the drawing sets forth in a graphical manner operating data for said furnace.

Typically, a blast furnace operator is charged with producing hot metal having a prescribed silicon and sulfur content and slag basicity. By reviewing and analyzing past operating data, he can determine the hot metal temperature required to produce iron having the desired specifications and slag basicity for a particular burden. Thus, he looks at past performance for a period of smooth operation where iron of the quality desired was produced at a good tonnage and a fairly constant iron temperature and attempts to duplicate the conditions prevailing at that time.

The nature of the operating data which is important to the control method of the present invention and is available to an operator is shown in the figure. Along the abscissa of the chart of the figure is plotted time. The chart of the figure is for a two-day period, starting at midnight and continuing for forty-eight hours. Along the ordinate of the chart, reading from top to bottom, is plotted the number of burden charges delivered to the furnace every three hours, the stone rate in pounds per charge, the moisture level of the hot blast in grains per standard cubic foot of gas, the hot blast temperature in degrees Fahrenheit, the sinter basicity every two hours, the slag basicity of each cast of hot metal, the peak hot metal temperature of each cast in degrees Fahrenheit, the sulfur content of each cast of hot metal and the silicon content of each cast of hot metal. Obviously, the operator analyzes several weeks of data of the type shown in the figure in arriving at the aim hot metal temperature required to produce the desired quality iron.

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For the furnace from which the chart of the figure was obtained, it was determined that to produce hot metal from that furnace with a silicon content within the range of 1.0 to 1.3% and a .040% maximum sulfur content at a slag basicity of 1.10, an aim peak hot metal temperature of 2700° F. is required. That is, the peak temperature of each cast of hot metal should be 2700° F. Of course, many of the operating variables listed on the figure influence iron temperature and some can be employed to control that temperature. However, indiscriminate changes in these variables are ill-advised since it is difficult to evaluate the effect of such changes. Also, burden changes and changes in the burden ratio, that is, the ratio of the weight of iron-bearing burden materials per charge to the total weight of coke per charge, besides effecting changes in iron temperature can change the hot metal composition and slag basicity. Increased amounts of coke, for example, greatly increase the sulfur input to the furnace while increased amounts of ore and sinter change slag basicity. Changes in the burden are also difficult to evaluate, because their effect is not manifested at the furnace hearth for at least six hours.

We have found that a reliable control of the iron temperature can be brought about by using the moisture level of the hot blast as the control variable while maintaining the other variables as constant as possible, except under circumstances discussed below. This permits desired changes in the hot metal temperature to be made rapidly since changes in blast moisture quickly affect that temperature. In addition, moisture changes have no direct affect on iron composition or slag basicity.

We have also found that in using iron temperature as a control guide, it is not sufficient to compare only the peak temperature of a cast in progress with the aim temperature and adjust the blast moisture level so as to cause the furnace to heat up when the peak temperature of a cast in progress is below the aim temperature and to cool down when the peak temperature of a cast in progress is above the aim temperature. This sort of control scheme does not take into account the momentum effect of the furnace where its temperature is trending either upwardly or downwardly over a number of casts.

According to the present invention, the peak temperature of a cast in progress is compared with the peak temperature of the previous cast, and these two temperatures are related to the aim peak temperature in determining what change if any should be made in the blast moisture level. Based on these first two temperatures, it is possible to note whether the furnace temperature is trending upwardly or tending to stay constant. By taking into account the temperature trend of the furnace and relating the absolute values of the peak hot metal temperatures of the cast in progress and the previous cast to the aim hot metal temperature, an appropriate change is made in the blast moisture level to bring the furnace temperature to the aim.

For example, generally, a change of one grain of moisture per cubic foot of hot blast changes the furnace hearth and hot metal temperature about 20° F. Therefore, where the aim temperature is 2700° F. and the peak temperatures of the hot metal of a cast in progress and the previous cast are 2720° F. the blast moisture level is increased by one grain per cubic foot of gas to bring the peak hot metal temperature of the next cast to 2700° F. Similarly, where the aim temperature is 2700° F. and the peak temperatures of the hot metal of a cast in progress and the previous cast are 2660° F., the blast moisture level is decreased by two grains per cubic foot of gas to bring the peak hot metal temperature of the next cast to 2700° F.

In each of these examples, the temperature of two consecutive casts is the same so that the momentum effect of the furnace is negligible, and consequently, changes in peak hot metal temperature could be considered solely on the basis of a change of one grain of moisture per cubic foot of hot blast effecting a 20° F. change in hot

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metal temperature. However, when the peak hot metal temperatures of a cast in progress and the previous cast are different, changes in the hot blast moisture level are made giving consideration to furnace temperature momentum. Thus, when the aim peak hot metal temperature is 2700° F. and the peak hot metal temperatures of a cast in progress and the previous cast are 2720° F. and 2750° F., respectively, no change in the blast moisture level is made, because the momentum of the furnace in going from 2750° F. to 2720° F. is sufficient to normally carry it to about 2700° F. on the next cast. At the same time where the temperature of the previous cast is 2800° F., the moisture content of the hot blast is decreased by one grain per cubic foot even though the temperature of the cast in progress is 2720° F., 20° F. above the aim temperature, because the momentum of the furnace in going from 2800° F. to 2720° F. will carry the temperature below the aim value of 2700° F. unless the moisture level is decreased. Similar consideration is given to the effect of the momentum of the furnace when the hot metal temperatures are below the aim temperature.

While a change in the blast moisture level of one grain per cubic foot of hot blast generally effects a 20° F. change in the hot metal temperature, the exact temperature change varies from furnace to furnace and burden to burden. In addition, the influence of the furnace temperature momentum is different for different furnaces. However, for any particular furnace and burden, a given change in the blast moisture level under a given set of temperature conditions will normally effect the same change in hot metal temperature whenever those same temperature conditions are encountered. By noting the performance of a particular blast furnace under varying operating temperatures, sufficient data is obtained to enable one to predict the change in blast moisture required to bring the hot metal temperature to a desired value based on the peak hot metal temperature of a cast in progress and the previous cast. This predictable relationship enables close control of the furnace to be exercised by basing the furnace control primarily on the single control guide of peak hot metal temperature and the single control variable of hot blast moisture while maintaining the other operating variables as constant as possible.

The present invention also provides for maintaining the blast moisture level within a predetermined range to avoid wide fluctuations from optimum furnace operating conditions. Because of economic considerations, it is desirable to obtain high tonnage from a blast furnace and generally the higher the flame temperature, the higher the iron production rate. Obviously, however, there is an upper limit on the flame temperature which can be employed, and experienced operators seek to maintain a maximum flame temperature commensurate with smooth furnace operation. Concomitant with such a maximum flame temperature is a particular blast moisture level, and with the very high hot-blast temperatures routinely employed, this level is generally above the moisture content of the ambient air.

Because blast furnace control is accomplished according to the present invention by changing the blast moisture level, that level will deviate from the level concomitant with the maximum flame temperature from time to time during the course of operation. As long as the deviation is small, the furnace continues to operate in an efficient manner. However, should the controlled blast moisture level be decreased significantly, rough operation could be encountered. If the controlled blast moisture level is increased, a higher than necessary coke rate results. Therefore, the moisture level is maintained within a particular range of an aim operating level to insure smooth operation, and maintenance is accomplished by making thermally equivalent but opposite changes in the burden ratio and moisture level in a manner as described below. The aim moisture level may or may not be the same as

the moisture level concomitant with the maximum flame temperature depending on the ambient air moisture level.

In arriving at an aim moisture level, consideration is also given to the fact that where the moisture level accompanying the maximum flame temperature is only a few grains above ambient, it is preferable to operate with a moisture level somewhat above the accompanying level. Such operation insures controllability of the furnace where it is necessary to remove moisture from the hot blast to prevent the furnace from going cold. As will be understood, since the minimum moisture level obtainable is the ambient level, by operating at or near ambient one risks the possibility of not being able to stop a furnace from going cold by blast moisture control.

We have found that, generally, best control results when the aim moisture level is three grains per standard cubic foot of gas greater than the level concomitant with the maximum flame temperature and at least five grains per standard cubic foot of gas above the ambient moisture level. This provides a safety margin so that significant amounts of moisture can be removed from the hot blast when such action is necessary to prevent the furnace from going cold and at the same time the aim level is close to the level accompanying the maximum flame temperature. Naturally, with the moisture level constituting the primary control variable, it is not possible to keep that level at the aim value at all times, but we have found that good control and smooth operation are possible by maintaining the blast moisture within $+2$ and -3 grains/s.c.f. of the aim. This can be done by proper manipulation of the burden ratio. Thus, where the cumulative effect of changes in blast moisture dictated by a comparison of the peak hot metal temperature of a cast in progress and the previous cast with the aim hot metal temperature as discussed above results in the hot blast moisture level being at a maximum $+2$ or more grains from the aim for two consecutive casts, the burden ratio is increased the equivalent of 2 grains of moisture. The immediate effect of the burden ratio change is negligible. Two casts after the change is made, however, or at the approximate time the change begins to exert an influence on the hearth and hot metal temperatures, the moisture level is reduced by 2 grains/s.c.f. to compensate for the thermal effect of the burden ratio change. This reduction in the moisture level is in addition to any change called for by a comparison of the peak hot metal temperature of a cast in progress and the previous cast with the aim hot metal temperature. The decrease in the moisture level increases the flame temperature and brings it back into the desired range and the furnace temperature is maintained near the aim temperature at a lower moisture level approximating the aim moisture level.

In a similar manner, where the cumulative effect of changes in blast moisture results in the hot blast moisture level falling to a minimum level of 3 or more grains from the aim, the burden ratio is decreased the equivalent of 2 grains of moisture. Two casts later or at the approximate time the change begins to exert an influence on the hearth and hot metal temperatures, two grains are added to the blast in addition to any change called for otherwise. These changes drive the operation toward the aim hot metal temperature and a higher moisture level approximating the aim moisture level.

The burden ratio changes are preferably made by increasing or decreasing the amount of each iron-bearing material equally while maintaining the coke charge constant since changing any one material could have a pronounced effect on slag basicity. An alternative to this procedure would be to change the amount of coke charged.

It will be realized that because blast furnace operations differ from furnace to furnace, different control moisture ranges and safety margins can be employed. For example, where a very uniform burden is used and a relatively constant dry carbon to iron ratio is maintained, a very smooth operation results. Under such circumstances the moisture

range can be narrowed to $+1$ and $\frac{1}{2}$ and -2 grains/s.c.f. of the aim moisture level and the safety margin can be reduced to only 3 grains/s.c.f. above ambient. Alternatively with a widely varying burden, the moisture range would preferably be widened to $+3$ and -4 grains/s.c.f. of the aim level and the safety margin increased to 7 grains/s.c.f. above ambient. In any case, changes in the burden ratio and moisture level are made in the manner described above except that instead of using a 2 grains/s.c.f. equivalent change in burden and change in moisture, a change which is equivalent thermally to the difference between either the maximum and minimum moisture levels and the aim moisture level is employed. Thus, under the first set of conditions set out above, a burden change equivalent to a moisture change of 1 and $\frac{1}{2}$ grains/s.c.f. is made when the moisture level is $+1$ and $\frac{1}{2}$ or -2 grains/s.c.f. from the aim and thereafter a 1 and $\frac{1}{2}$ grains/s.c.f. change in the blast moisture level is made. Similarly, under the second set of conditions a burden change equivalent to a moisture change of 3 grains/s.c.f. is made when the moisture level is $+3$ or -4 grains/s.c.f. from the aim and thereafter a 3 grains/s.c.f. change in the blast moisture level is made.

As has been noted, the present invention provides for keeping constant as many of the variables of blast furnace operation as possible so that the changes that are made can be readily evaluated. To this end changes in slag basicity caused by changes in burden basicity are counteracted by a compensating change in stone rate at the same time the high or low basicity burden is entering the furnace. A change in the burden weight equal but opposite to the stone change is made to compensate for the thermal affect of the stone change. Thus, no subsequent moisture change is required.

To further maintain the constancy of furnace operation, coke blanks are kept to a minimum. Coke blanks represent drastic changes in burden ratio which significantly increase hot metal temperature, and they confuse the evaluation of furnace operation from cast to cast because they are temporary in nature. Coke blanks also greatly increase the sulfur load on the furnace.

It will be apparent that various changes and modifications may be made in the invention as described above without departing from the spirit and scope thereof as defined in the following claims.

We claim:

1. A method of controlling the operation of a blast furnace comprising:

- (a) measuring the temperature of the hot metal issuing from said furnace during a successive number of casts to determine the peak hot metal temperature of each cast,
- (b) changing the moisture level of the hot blast in response to the peak hot metal temperatures so measured by an amount required to drive the hot metal temperature to an aim peak temperature,
- (c) increasing the burden ratio when the hot blast moisture level reaches a maximum value of between 1 and $\frac{1}{2}$ to 3 grains per standard cubic foot of hot blast above an aim moisture level of between 3 to 7 grains per standard cubic foot of hot blast, respectively, above the ambient moisture level as a result of changes made in the hot blast moisture level during step (b), thereafter, as the increased burden ratio begins to influence the hot metal temperature, decreasing the moisture level of the hot blast an amount thermally equivalent to the increase in burden ratio, and
- (d) decreasing the burden ratio when the hot blast moisture level reaches a minimum value which is substantially above the ambient moisture level and is between 2 to 4 grains per standard cubic foot of hot blast below an aim moisture level of between 3 and 7 grains per standard cubic foot of hot blast, respectively, above the ambient moisture level as a

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result of changes made in the hot blast moisture level during step (b), thereafter, as the decreased burden ratio begins to influence the hot metal temperature, increasing the moisture level of the hot blast an amount thermally equivalent to the decrease in burden ratio,

so as to maintain said moisture level within a range defined by said maximum and minimum values at or near the aim level.

2. The method of claim 1 wherein the aim moisture level is 5 grains per standard cubic foot of hot blast above the ambient air moisture level, the maximum moisture level is 2 grains per standard cubic foot of hot blast above the aim moisture level, the minimum moisture level is 3 grains per standard cubic foot of hot blast below the aim moisture level, the burden ratio is increased the thermal equivalent of 2 grains of moisture when said maximum value is reached and decreased the thermal equivalent of 2 grains of moisture when the minimum value is reached.

3. The method of claim 1 wherein the aim moisture level is 3 grains per standard cubic foot of hot blast above the ambient air moisture level, the maximum moisture level is 1 and 1/2 grains per standard cubic foot of hot blast above the aim moisture level, the minimum moisture level is 2 grains per standard cubic foot of hot blast below the aim moisture level, the burden ratio is increased

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the thermal equivalent of 1 and 1/2 grains of moisture when said maximum value is reached and decreased the thermal equivalent of 1 and 1/2 grains of moisture when the minimum value is reached.

4. The method of claim 1 wherein the aim moisture level is 7 grains per standard cubic foot of hot blast above the ambient air moisture level, the maximum moisture level is 3 grains per standard cubic foot of hot blast above the aim moisture level, the minimum moisture level is 4 grains per standard cubic foot of hot blast below the aim moisture level, the burden ratio is increased the thermal equivalent of 3 grains of moisture when said maximum value is reached and decreased the thermal equivalent of 3 grains of moisture when the minimum value is reached.

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