

gen, by heat alone. A slag rich in lime is irretentive of lime in the sense that its excess of lime is held but feebly by the silica, and because of the feebleness of this hold this lime is readily deoxidized by reaction (30).

The silica and lime of the slag are bound together chemically, and the strength of this bond opposes the removal of the silica or the lime by deoxidation. But if there is an excess of lime, this excess is bound less powerfully to the silica than if there is but little lime. Because the bond between the excess of lime and the silica is thus relatively feeble, the opposition which the bond offers to the deoxidation of the calcium is the feebler, and the calcium is consequently the more easily deoxidized the richer in lime the slag is.

Conversely, if the slag is deficient in lime, or in other words has an excess of silica, then for like reasons silicon is the more readily deoxidized.

This then is the reason why the blast-furnace charge is habitually so made up that the slag may be rich in lime, in order that it may thereby be irretentive of lime, and so that in turn this irretentiveness may favor the deoxidation of calcium by reaction (30), and thereby the removal of sulphur from the iron. Of course, if very little sulphur is present, or if for any cause desulphurization is not sought, then this reason for having our slags rich in lime no longer exists. Hence we often find that the slags of charcoal blast-furnaces are not rich in lime, for the simple reason that the charcoal lacks the sulphur which coke and anthracite always contain, so that there is no need of desulphurizing, unless the ore or limestone introduces sulphur into the charge.

Now since our slags are habitually on the lime side of the greatest fusibility, any addition of lime will carry them farther in composition from that of the greatest fusibility, and so make them more infusible; and conversely diminishing the lime-content will make them more fusible. The rubric in line *C* of column 1 of Table 19 is based on this principle.

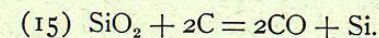
Having thus seen that increasing the lime-content of the slag or in other words increasing the proportion of limestone charged, should tend to raise the hearth temperature, we record this fact by means of the plus sign in line *C* of column 2; and since this tendency to raise the hearth temperature should, for the same

reasons as before, tend to increase the silicon-content of the pig iron but to lower the sulphur-content, we accept the plus and minus signs in columns 3 and 4 respectively of line *C*.

308. DIRECT CHEMICAL EFFECT OF THE LIME-CONTENT OF THE SLAG. — Having now seen how an increase of the lime-content of the slag raises its melting-point, through this raises the hearth temperature, through this strengthens the reducing action, and through this raises the silicon-content and lowers the sulphur-content of the iron; in short, having seen what the thermal aspect of such an increase is, let us now consider what the direct chemical influence is.

For the reason which we have just considered, an increase in the lime-content by favoring the reaction (30) clearly promotes desulphurization. Therefore we may accept the minus sign (—), in line *C*, column 6 of Table 19.

But for the same reason, when we increase the lime-content of a lime silicate, the decrease which we thereby (by difference) cause in its silica-content makes it more retentive of silica. In other words, in a slag containing less silica and more lime, the silica is more tenaciously held by that excess of lime than in a lime silicate rich in silica; or an increase in the percentage of lime, while making a slag irretentive of lime, increases in proportion its retentiveness of silica, and proportionally opposes the deoxidation of silicon by the reaction:



In short, increasing the lime-content opposes the deoxidation of silicon, and so tends to lessen the silicon-content of the iron, and thereby to make the iron less gray. This justifies us in accepting the minus sign (—) placed in line *C*, column 5.

Considering now the thermal and the direct chemical influence jointly we see that, as regards sulphur, these two influences are alike, both of them favoring desulphurization; hence the minus mark (—) in line *C* column 8; but that as regards silicon the thermal effect of an increase in lime-content (column 3), is opposite to its chemical effect (column 5). Hence, the plus or minus sign (±) entered in line *C*, column 7.

The marks which we have now entered in columns 2 to 8 of line *C* lead directly to the marks which are now entered in columns 9 to 11 of that line.

309. THE EFFECT OF MOST VARIABLES ON THE SILICON-CONTENT IS THE OPPOSITE OF THAT ON THE SULPHUR-CONTENT. — Now looking back on Table 19 as a whole we notice that, with the exception of the direct chemical influence of the lime-content of the slag, the influence of each variable on the silicon-content is the opposite of its effect on the sulphur-content. In other words, those changes in the management of the furnace which tend to desulphurize and thus to make the iron grayer, simultaneously increase the silicon-content and thereby also tend to make the iron grayer.

From this fact arises the difficulty of making cast iron at once low in silicon and low in sulphur. Of the principles here tabulated only an increase in the lime-magnesia-content of the slag tends to decrease both the silicon and sulphur. In case we are called upon to make an iron low in both silicon and sulphur this then would be the principle on which we should chiefly rely.

310. RELATIVE PROMPTNESS OF DIFFERENT METHODS OF RAISING THE HEARTH TEMPERATURE. — We may recognize two kinds of considerations which may demand that the hearth temperature shall be raised. Thus, first, we may wish to change permanently or for a long period the condition of affairs, wishing to make an iron grayer than that which the furnace has normally been making, grayer either through containing more silicon or less sulphur or both, than the present product. Or, second, we may need to raise the temperature to meet a temporary and abnormal trouble, a temporary cooling due to the leaking of a tuyere or a bosh-plate, which is sending a stream of water into the hearth, and cooling it abnormally and indeed intolerably. To meet the latter state of affairs it is important that the remedy applied shall take effect promptly. Of the three means which we have been considering of raising the temperature of the hearth, *viz.*,

- (1) increase in blast temperature,
- (2) increase in fuel ratio (*i. e.*, lightening the burden), and
- (3) raising the melting-point of the slag,

the first one will give much the quickest relief. Our fuel, flux and ore are introduced only through the top of the furnace, and many hours must elapse between the time when we change the burden or the limestone ratio, and the time when the extra fuel or the extra lime will reach the hearth of the furnace. On the other hand, increasing the temperature of the blast immediately

throws an increased quantity of heat into the hearth. A difficulty in the way, however, often is that just at the time when we are in need of a hotter blast, the furnace gases on which we have to rely for heating that blast are from the same cause lean in carbonic oxide, *i. e.*, of low heating power. Hence the importance of so arranging matters that a deficit of gas can be met by firing our boilers with coal or other fuel, so that we may be free to turn into our hot blast stove a larger quantity of gas.

But though many hours must elapse between the time of increasing our fuel ratio and that in which this increase in fuel actually reaches the hearth so as to generate there an increased quantity of heat; nevertheless, this increase in fuel ratio gives relief much more quickly than might be expected, for the reason that the fuel is in large angular lumps which mechanically open up the charge in the upper part of the furnace, thus lessening the frictional resistance to the upward travel of the gas, and thus hastening the operation as a whole. In particular, since the blast can enter at the bottom of the furnace only so fast as the gases escape from its top, this opening action of our extra fuel has the same effect as an increase in the blast pressure, and permits us to blow in more air per second with the consequence that we burn more fuel per second, and hence generate more heat per second, while the abstraction of heat by conduction through the furnace walls remains substantially constant. In short, it increases the heat development per second without corresponding increase of the heat removal.

### CHAPTER XIII. — METALLURGICAL GAS FURNACES

311. GAS-FIRING AND DIRECT-FIRING. — In a sense all reverberatory furnaces are gas furnaces, because they are heated by a flame, and a flame is only burning gas; so that in every case they are heated by burning gas.

312. BY DIRECT-FIRING is meant burning coal or other solid fuel in a fire-box close to the working chamber of the reverberatory furnace, and in a layer so thin that enough free atmospheric oxygen passes through some of the wider crevices between the lumps of fuel, both to burn the carbonic oxide generated by the incomplete