CALCULATION OF BLAST FURNACE SLAGS AS PRACTISED IN CERTAIN WORKS IN EUROPE.

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In another paper (this journal, Vol. 12, **6, 7**) we have described a practical method of calculating the charges of a blast furnace in order to obtain a slag of a given type, which does not require the use of any formula or chemical symbol. It may be interesting to compare it with the method followed in certain works, in Eastern France, to arrive at the same result.

What is called "a charge" is this certain weight of ore, limestone and fuel, in relative proportion to each other, which are charged in a furnace at regular intervals of time during twenty-four hours. Technically, it is more properly the calculated weights of the relative qualities of limestone and ore necessary to obtain a given composition of slag, the quantity of fuel per ton of iron smelted, or per charge, being, as a rule, a factor which is assumed and which practice has taught, but subject to ulterior corrections as may be required.

The coal is supplied to furnish, by its combustion, the heat and the elements necessary for the chemical reactions which take place and only its ash contributes to the ultimate composition of the slag. In France, the charge is called "*lit de fusion*," an expression, it seems to us, having a more appropriate meaning than the vague term "charge." The total amount of ore and stone constitutes "*a lit de fusion*," "a charge," with an assumed quantity of fuel and the proportion of the two materials, ore and stone, are the elements to be calculated, bearing in mind the character of the slag desired as indicative of a special grade of pig iron and the percentage of ash of the fuel and its composition.

Calculation of a Slag at the Works X.

The formula of the slag expected was that of a "Seisgulo-Silicate" (monosilicate of Percy), $3RO, SiO_3$ or $2RO, SiO_2$ (ortho-silicate, bibasic slag); oxygen of acid = oxygen of base.

Two different kinds of ore were used, of which the composition is given below, the calculations being based on the determination of the *free* oxygen in the materials, demand a certain technical knowledge.

1.—Gangue of Ore A.

SiO_3 8.50 Equiv. SiO_3 = 45.3 .. Oxygen of $SiO_3 = 8.50 \times \frac{24}{45.3} =$ 4.50

$$\left.\begin{array}{llll} Al_2O_3\ 5.50 & \text{Equiv. } Al_2O_3 = 51.5 & \text{Oxygen of } Al_2O_3 = 5.50 \times \frac{24}{51.5} = 2.56 \\ CaO\ 5.00 & \text{Equiv. } CaO = 28. & \text{Oxygen of } CaO = 5. \times \frac{8}{28} = 1.43 \\ MgO\ 0.90 & \text{Equiv. } MgO = 20. & \text{Oxygen of } MgO = 0.9 \times \frac{8}{20} = 0.31 \end{array}\right\} 4.40$$

2.—Gangue of Ore B.

SiO_3 29.55, CaO 0.15, Al_2O_3 3.40 on an average it was taken to be: SiO_3; 25.00 .. O of Acid SiO_3 13.24; Al_2O_3; 3.50 .. O of Base Al_2O_3 1.63

Free oxygen, acid 11.61

3.—Ash of Coal.

SiO_3 = 47.80	O of SiO_3		25.32
Al_2O_3 = 33.00	" Al_2O_3	15.37	
CaO = 6.00	" CaO	1.71	18.36
MgO = 3.20	" MgO	1.28	
	Free oxygen, acid		6.96

4.—Limestone.

SiO_3 = 2.50	O of SiO_3 =		1.32
Al_2O_3 = 2.00	" Al_2O_3 =	1.10	16.10
CaO = 52.50	" CaO =	15.00	
	Free oxygen, basic		14.78

Resume.

Free O, acid, in ore A 0.20
" " " B 11.61
" " in ash of Coke 6.96
" O, basic, in limestone 14.78

Assume 360 kilos. of good coke at 10% of ash, a quantity judged sufficient for "a charge" or "*lit de fusion*," taken to be = 880 kilos. stone and ore. This gives 36 kilos. of ash corresponding to

$$36 \times \frac{6.96}{100} = 2.50 \text{ free oxygen of acid in the ash.}$$

Let m be the weight of ore A to be used, in kilogrammes.
" f " " " B " "
" c " " of limestone " "

Then: The total free oxygen acid $= 0.20\ m + 11.61\ f + 2.50$..

Total free oxygen, basic$=14.78$ c, and since we want to obtain a bibasic slag, that is one in which oxygen, acid=oxygen, basic.

$0.20\ m + 11.61\ f + 2.50 = 14.78\ c$, but we have also the equation of condition, total charge: $\underbrace{f + m}_{\text{Ore.}} + \underbrace{c}_{\text{Stone.}} = 880$; we have then two equations containing three unknown quantities. Eliminating c between the two we come to the final equation:

$14.98\ m + 26.39\ f = 13003.90$, an equation which is indeterminate, as it should be, since the proportions of ore A and ore B, within the above limits, are evidently optional. Assuming for m certain values we find:

m= 50	f=464.50	c=365.50
m=100	f=436.00	c=344.00
m=200	f=379.25	c=300.75
m=300	f=322.45	c=257.55

and the charges will be:

$$\left.\begin{array}{ll} \left.\begin{array}{ll}\text{Ore A} & 50.\\ \text{Ore B} & 464.50\end{array}\right\} & 514.50 \text{ kilos.}\\ \text{Limestone} & 365.50 \quad \text{"}\\ \text{Coke} & 360.00 \quad \text{"}\end{array}\right\}$$
Or such others based on the other values of m, f, c. Coke always=360 kilos.

The ores had about 35% metallic iron, hence 514.50 kilos. of ore would yield $514.50 \times 0.35 = 180$, iron, and taking the first solution, the relative proportions of the different materials in one charge for one of iron must be:

$$\left.\begin{array}{ll}\text{Ore} & 2.85\\ \text{Stone} & 2.03\\ \text{Coke} & 2.00\end{array}\right\} \text{for } m=50.$$

Adopting the first solution let us calculate the composition of the slag and verify its bibasic character.

	Ore A = 50 Kgs.	Ore B = 464.50.	Coke = $\left(\frac{\text{Ash}}{10\%}\right)$ 36.00 Kgs.	Stone = 365.50.	Totals in Slag.
Silica	$\frac{8.50}{100}\times50=24.5$	$\frac{25.00}{100}\times464.50=116.12$	$\frac{49.80}{100}\times36=17.20$	$\frac{2.50}{100}\times365.50=9.13$	146.70 Kgs.
Alumina	$\frac{5.50}{100}\times50=2.75$	$\frac{3.50}{100}\times464.50=16.26$	$\frac{33.00}{100}\times36=11.88$	$\frac{2.00}{100}\times365.50=7.31$	38.20 "
Lime	$\frac{5.00}{100}\times50=2.50$	....	$\frac{6.00}{100}\times36=2.16$	$\frac{52.50}{100}\times365.50=191.89$	196.55 "
Magnesia........	$\frac{0.90}{100}\times50=0.45$	....	$\frac{3.30}{100}\times36=1.15$	....	1.60 "
Totals........	9.95	132.38	32.39	208.33	383.05

Reducing to lime:

$$\begin{array}{llll}
\text{Silica} & =146.70 \ldots\ldots\ldots\ldots\ldots\ldots\ldots & & 146.70 \text{ Silica.} \\
Al_2O_3 & = 38.20\times1.631 = & 62.27 \ CaO & \multirow{3}{*}{$\left.\begin{array}{l}\\ \\ \\ \end{array}\right\} 261.06 \text{ Lime.}$} \\
CaO & =196.55 & 196.55 \ CaO & \\
MgO & =1.60\times1.40 = & 2.24 & \\
 & & & \overline{407.76}
\end{array}$$

Reducing to a percentage, we find:

$SiO_2 = 35.90$ The type, exactly bibasic, has the composition $\left\{\begin{array}{l} SiO_2 = 34.88 \\ CaO = 65.12 \end{array}\right.$

$CaO = 64.10$

$\overline{100.00}$

The slag is practically a bibasic slag, as closely as possible using two decimals or only one, as in the analyses.

Let us calculate this same slag by the method of reduction to *lime*, adopting the same data and two indeterminate quantities of the ores A and B.

Ore A:

SiO_2	$=8.50$		8.50
Al_2O_3	$=5.50\times 1.63=8.95$	}	CaO 15·21
CaO	$=5.00\times 1. \quad =5.00$	}	
MgO	$=0.90\times 1.49=1.26$	}	

The saturation for a bibasic slag is 0.538 SiO_2 for 1 lime. 15.21 lime will take then: $15.21\times 0.53=8.18$ SiO_2, leaving 0.32 to 0.33% free silica to be saturated for 1 of ore.

Ore B:

SiO_2	$=25.00$	25.00
Al_2O_3	$=3.50\times 1.63$	2.71 CaO

571 CaO will saturate 3.07 SiO_2, leaving 21.93% free silica for 1 of ore.

Ash of Coke ($10\%\times 360=36$ Kilos.)

SiO_2 47.80	$=47.80$		
Al_2O_3	$=33. \quad \times 1.63+=53.79$	}	64.27 CaO
CaO	$=6. \quad = 6.00$	}	
MgO	$=3.20\times 1.40 \quad = 4.48$	}	

64.27 CaO will saturate $64.27\times 0.538=34.58$ silica, leaving in ash 13.22% free silica. For 36 ash $\frac{13.22}{100}\times 36=4.76$ free silica.

Stone:

Silica	$=2.50$		2.50
Al_2O_3	$=2.00\times 1.63+ \quad 3.26$	}	55.76
CaO	$= \quad 52.50$	}	

1 silica takes up 1.858 lime to make a basic slag. Hence: 2.50 silica will take 2.50×1.858 lime$=4.65$ lime, leaving as free lime in the stone 51.11%.

Let m be the amount of ore A taken as before, f that of ore B, c that of stone. We have then:

Free Silica in Ore A	....	m × 0.33
" " in ash of Coal	....	c × 4.76
" " in Ore B	....	f × 21.93

Total free *silica* in ores and coal: 0.33 m + 21.93 f + 4.76

Total free *lime* in stone: 51.11 c

and since the free lime of the stone must saturate the free silica of the ores, stone and ash, at the rate of 0.538 silica for 1 of lime the 51.11 c of free lime in stone will take up 51.11 × 0.538 c = 27.50 c of *silica*. We have then this equation free silica to saturate 0.33 m + 21.93 f + 4.76 = 27.50 c silica saturated by stone. All the terms being expressed in *silica*, SiO_2, if we multiply them *all* by $\frac{8}{15}$, which does not change the equation, we shall have the relation of equality of the oxygen found previously by the other method as near as the difference of the numbers expressing the equivalents of silica formerly, and now (taking only one or two places of decimals) we have the differences appearing only in hundredths as already observed. 0.18 m + 11.68 f + 2.15 = 14.66 c, instead of 0.20 m + 11.61 f + 2.50 = 14.78 c. We have a second equation of condition the same as in the first method: f + m + c = 880. By combining these two equations and taking m = 50, 100, etc., we shall find the same figures as already calculated or differing only in hundredths.