I do not know that I can profitably add anything further in explanation of the table now submitted to the Institute. That my classification will be found in all respects satisfactory I do not expect, but I hope that it may be found serviceable in some degree until superseded by a better. I am also sanguine enough to believe that some of my fellow-members may, by using it, ascertain at a glance what otherwise might occasion them several hours' study.

WYANDOTTE, MICH., April 12th, 1879.

ON THE USE OF DETERMINING SLAG DENSITIES IN SMELTING.

BY THOMAS MACFARLANE, WYANDOTTE, MICH.

IN smelting copper, lead, and silver ores, it is scarcely possible in every case to make analyses of the various parcels of ore, with the view of combining these and the fluxes so accurately as to yield, in the furnace, slags of exactly the most favorable composition. This is even more difficult with ores which require previous calcination, or with mattes which have been roasted in heaps. Even in cases where the greatest pains have been taken and the most elaborate calculations made beforehand, it frequently happens that variations in the working of the furnace interfere with the result so much desired. Generally, the practical metallurgist must be content with ascertaining the average composition of his ores and fluxes, making a calculation once for all as to the most advantageous mixture, and leaving slight changes in its composition to be taken care of as it is passing through the furnace. The various products then afford him the best material whereon to base his judgment as to the manner in which his smelting mixture is working. Of course the character of the slag is one of his chief guides, but it is not always possible from its outward characters alone to form a correct judgment as to its composition. Neither would it be possible or practicable to apply chemical analysis for this purpose, as it would be impossible to wait for its results while working a furnace.

Abich was, I believe, the first to point out the relation existing between the composition of volcanic rocks and their densities, and to show that, the latter being ascertained, very correct conclusions

might be drawn as to their contents in silica. The general rule is that the most siliceous rocks are the lightest, and the most basic have the highest specific gravity. It occurred to me that by determining the density of slags it might be possible to judge more accurately of their nature than by observing merely their superficial appearance. This plan was first applied at the Wyandotte Silver Smelting and Refining Works in September, 1877, when siliceous silver ores and galenas from Georgetown, Colorado, were being treated. Mr. F. H. Williams determined the following densities and silica contents of the slags from these ores:

Sp. Gr.	Per cent. SiO_2.
3.44	37.60
3.48	36 35
3.50	36.30
3.51	35.80
3.56	35.15
3.57	33.90
3.63	31.15
3.88	30.40

In July and August, 1878, Mr. S. B. Wight made the following examinations of three slags from one and the same smelting campaign, during which Western ores were being treated:

Sp. gr.	Per cent. SiO_2	Al_2O_3.	FeO.	CaO.
3.47	35.05	Undetermined.	31.51	15.77
3.52	32.56	"	37.70	14.68
3.60	31.96	"	36.97	12.71

The gradual increase of density as the silica decreases in both these series of examinations will be apparent. But the rule is not absolute, and is only applicable where the relative quantity of the different bases in a slag remains the same. In smelting ferruginous ores and lead and copper mattes the quantity of protoxide of iron in the slag in proportion to the other bases is usually greater, and this increases the density, although the percentage of silica may remain the same. A slag from smelting lead matte gave, on examination by Mr. S. B. Wight, as follows:

Specific gravity,	3.65
Silica,	34.67
Alumina,	14.85
Ferrous oxide,	39.04
Lime,	7.54

If this example is compared with the first in the last-mentioned

series it will be found that an increase of 7.53 per cent. in the ferrous oxide, while the silica remains nearly the same, causes a considerable increase in density. The following determinations are further generally illustrative of the increase of density in slags as their percentage of silica decreases:

Where produced.	Sp. gr.	SiO_2.	Al_2O_3.	FeO.	CaO.
Iron Blast Furnace, Wyandotte, . .	2.85	55	Undetermined.		
Copper Works, Detroit, ...	3.04	43.31	26.22	——	27.40
Germania Works, Utah, ...	3.81	28.01	Und.	48.10	12.37
Eureka Consolidated Works, Nevada, .	4.18	26.47	"	61.62	2.73
Wyandotte Rolling-Mills (" heating slag"),	4.29	25.49	"	75.06	——

Some of these determinations are by Dr. Hermann Hahn, others by Mr. S. B. Wight.

In practically making use of the slag densities for regulating the smelting at Wyandotte Silver Smelting and Refining Works, Jolly's spring balance (described at page 59 of Brush's *Determinative Mineralogy*) was found of great service. Five minutes only are used in making, by its use, two determinations of the density of a slag, and then it is found easy to decide whether any change in the smelting charge is necessary. The smelting of ore goes on regularly and cleanly when the specific gravity of the slag is kept between 3.6 and 3.8. Water-jacket furnaces are used, with six tuyeres, and a height from these to the charging-door of 12 feet. The crucible of each furnace is 18 inches deep, and furnished with a tapping-hole at the bottom, besides the usual lead-well and slag-spout. The tapping occasions no difficulty, and so long as the slag is not allowed to become too heavy no incrustations are deposited in the furnace, which is easily cleaned out at the end of each campaign. The charging is managed in the following way: The smelting mixture is made up of ore and fluxes, and is calculated to yield a slag containing 32 per cent. silica. The slag necessary to keep the charge open is added separately in the proportion of about one-third of the smelting mixture. The slag used is unclean slag from previous campaigns and puddling slag or heating slag (*frischschlacke*) from the rolling mills. When the furnace yields a slag of greater density than 3.8 the proportion of rolling-mill slag is decreased. The latter is on the other hand increased when the slag produced is lighter than 3.6. By ascertaining the specific gravity of the slags frequently, and altering the charge in the manner described, the furnaces are found to work regularly and satisfactorily.

It is not supposed that the exact figures above given will be found

of great value in other smelting works, or that by attending only to the composition of slags in smelting it will be possible to do the best of work. The metallurgist has very many points to consider at one and the same time while conducting smelting operations, and the object of this paper is merely to direct his attention to one of these points and to indicate a mode of ascertaining approximatively the amount of silica in slags with comparative ease and accuracy.

WYANDOTTE, MICH., April 21st, 1879.

PHOSPHORUS IN BITUMINOUS COAL AND COKE.

BY ANDREW S. McCREATH, HARRISBURG, PA.

THE manufacture of pig iron for conversion into steel by the Bessemer and open-hearth processes, is now one of the most important industries of the United States. It is necessary that iron intended for this purpose should be very pure, and especially must it be comparatively free from phosphorus. Great care must therefore be exercised in the selection of proper ores, flux, and fuel. Only such ores as are practically free from phosphorus can be used, and pure fuel is as much a necessity as pure ores; though hitherto iron men have paid comparatively little attention to this point.

During the course of my work as chemist for the Second Geological Survey of Pennsylvania, I had occasion to examine some of the bituminous coals of the State for phosphorus, and the results obtained are so interesting that I venture to present them to the notice of the members of the Institute.

The coals are arranged in geological order according to the different beds, and the table shows the percentage of phosphorus in the coal and also in the coke.

The greatest number of specimens have been selected from the Pittsburgh bed, because it is the principal coal-bed of Southwestern Pennsylvania, and most of the mineral fuel which is mined along the Youghiogheny and Monongahela rivers, to be used in the coke ovens of the Connellsville region and in the blast furnaces and mills of Pittsburgh and its vicinity, and to be shipped to Western and Southern markets, comes from this bed.

It will be noticed that many of the specimens examined contain