THE VALUE OF COAL-MINE SAMPLING.

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INTRODUCTION.

It is always satisfactory to have one's conclusions verified, especially when they were originally based on scanty, or insufficient data and are confirmed by more refined methods of work and by a great mass of evidence that makes them irrefutable. This statement applies particularly to some provisional conclusions which the writer published regarding the value of coal-mine sampling for the purpose of determining the commercial value of a coal, and to its verification by recent work along the same line.

At the close of the St. Louis Exposition the writer endeavored, in a short paper read before the Washington meeting of the American Institute of Mining Engineers,¹ to sum up the results of mine sampling as compared with carload sampling after the coal had been shipped to the Fuel-Testing Plant of the United States Geological Survey at St. Louis. Comparisons were made of the amounts of impurities contained in the samples taken by these two methods, and certain conclusions were provisionally reached.

At the close of the year 1904 the writer ceased to be connected with the Fuel-Testing Plant, but the work was continued on about the same lines and samples were taken in the same manner as in the previous year. A larger number of samples were tested, however, and more care was exercised in their selection and treatment than was possible during the Exposition, and consequently the results are regarded as more reliable than those obtained during the previous year. The results obtained in 1905 are now available,² and, together with those obtained dur-

¹ "The Commercial Value of Coal-Mine Sampling," *Trans. Am. Inst. Min. Eng.*, Vol. XXXVI., pp. 341-353.

² Preliminary Report of the Operations of the Fuel-Testing Plant of the United States Geological Survey at St. Louis, Mo., 1905; U. S. Geological Survey Bull., 290.

ing the previous year, they constitute a large mass of data upon which it seems possible to base final conclusions. The object of the present paper is to present a brief résumé of these results and to compare them with the provisional conclusions which the writer published a year ago.

MOISTURE.

The provisional conclusions regarding the variations in the amount of moisture in car and mine samples, based on the work of 1904 were as follows:

"The gains in the amount of moisture in the coal are about equally balanced. In the entire lot of 50 samples, 26 show a gain of moisture in the average of the car analyses and the average amount of gain expressed in per cent. is 1.35. In 24 cases there was an excess of moisture in the mine sample over the car sample, and the average percentage of excess was 1.11. Thus, considered as a whole, there was no perceptible gain or loss of moisture in transit or in the car samples as compared with the mine samples."

Notwithstanding this apparent balance of the amount of moisture in the two classes of samples, certain differences were noted as follows:

1. "Lignites and lignitic coals are apt to show a greater percentage of moisture in the car sample than in the mine sample, but the amount of gain is small."
2. "Bituminous coals, having a high moisture content, (more than 5 per cent.), are apt to show less moisture in the car sample than in the mine sample, and the amount of loss is about 1.5 per cent."
3. "Bituminous and semibituminous coals with a small moisture content (less than 5 per cent.), generally show a gain in moisture in the car sample of about 1.5 per cent."

When the analyses made during 1905 are combined with those made during the year previous, the differences noted above disappear to a great extent. The figures showing the amount of moisture in the mine and car samples for the two years vary considerably. In some cases the former is in excess while in

others the reverse is the case. There does not appear to be any definite law governing the variation in the amount of moisture in the two classes of samples, but taken in a broad way the analyses fall into large groups which seem to be well enough marked to deserve consideration. In the previous work the only distinctions observed were in those having less than 5 per cent. moisture in the car sample and those having more than 5 per cent. In the larger number of analyses, this difference is not noticeable, but, as stated above, it is possible to divide the results into four great groups which have certain but different relations in their moisture content, as follows:

Group A.—This group includes all coals in which the average moisture content of the car sample is less than 3 per cent. Of this group 18 samples show an excess of moisture in the coal from the mines and 6 samples show an excess in the coal from the car. The total excess in the mine samples is 9.47 per cent. and in the car samples 5.48 per cent. The difference is 3.99 per cent. This divided by 24, the total number of samples, gives an average excess in the mine sample of 0.17 per cent.

Group B.—In this group are included all samples having an average moisture content in the commercial coal of from 3 to 8 per cent. Of this group 18 samples show an excess of moisture in the commercial coal and the other 18 samples show an excess in the coal from the mine. The number of samples are the same in both cases, but the total amounts are quite different, the excess in the car samples being 24.60 and in the mine samples 10.23 per cent. The difference between these amounts, or 14.37, divided by 36, the total number of samples, gives .40 per cent. as the average excess in the car samples.

Group C.—This group includes all samples having a moisture content in the average car sample of from 8 to 10 per cent. Of this group 4 samples show an excess in the commercial coal and 11 samples an excess in coal from the mine. The total amount of excess in the car samples is 2.24 per cent., and in the mine samples 10.69 per cent. The difference, 8.45 per cent., divided by 23, the number of samples, gives an average excess in the mine sample of .56 per cent.

Group D.—This group includes all samples having a greater amount of moisture in the car sample than 10 per cent. The mine samples show an excess in moisture over the car samples as in the previous group, but the excuse for considering it separately is that the average amount of excess is much greater than that of the preceding group.

Of group D, 8 samples show an excess in coal from the car, and 22 samples show an excess in coal direct from the mine. The total excess in the former case is 10.50 per cent. and in the latter 48.56 per cent., the difference, 38.06 per cent. divided by 30, the number of samples, give 1.27 per cent. as the average excess in the mine samples.

Tabulated, the results are as follows:

TABLE OF COAL GROUPS ARRANGED ACCORDING TO THE EXCESS OF MOISTURE IN MINE AND CAR SAMPLES.

Groups of Coal.	Excess in Mine Samples; Per Cent.	Excess in Car Samples; Per Cent.
A. Coals having less than 3 per cent. in car samples	.17	
B. Coals having from 3 to 8 per cent. in car samples	—	.40
C. Coals having from 8 to 10 per cent. in car samples	.56	
D. Coals having over 10 per cent. in car samples	1.27	

The meaning of the above-described groups is not well understood, especially the reason why an intermediate group B, should show an excess of moisture in the car samples when coals of both larger and smaller content show less moisture in the car lot than in the mine samples. The reasons for groups C and D are evident. They include coals having a high moisture content, and it is only reasonable to suppose that coal, of this character would lose some of its moisture in transit, especially when the shipment occurred in midsummer, as was the case with most of these samples. It is possible that the coals of class B were shipped in bad weather and hence gained moisture in transit, or it may be possible that coals of this intermediate grade are in such a condition that they will absorb moisture from the atmos-

phre more readily than those having either a higher or lower moisture content. It is possible also that group B is not a natural group, but merely due to fortuitous circumstances. If that is the case, a larger series of tests would probably show that no such group exists. The apparent disagreement with the groups recognized in 1904 seems to indicate that many of the variations are due to conditions not inherent in the coal itself, and hence are irregular in their occurrence.

SULPHUR.

In general the results of the first year showed that the percentage of sulphur in the car samples was greater than that in the mine samples, and the result was stated thus:

"The general average of the sulphur in all analyses shows an excess in the car sample above that contained in the mine sample. The coefficient of increase in the 50 samples at hand is 1.04; therefore, in mine sampling, for the purpose of determining the probable amount of sulphur in the commercial output of the mine, it is necessary to multiply the amount of sulphur in the mine sample by this coefficient of 1.04."

The results obtained during the second year serve to confirm in great measure the conclusions stated above. Of the 105 samples analyzed during the two years, 75 show an excess of sulphur in the commercial coal; 28 show an excess in coal direct from the mines; and 2 show an equal amount in each. The total excess in car samples is 261.67 per cent. and in mine samples 246.25 per cent.; 261.67 divided by 246.25 equals 1.06, the coefficient of excess of sulphur in the car samples over the mine samples. If, therefore, the amount of sulphur shown in any analysis of coal direct from the mines be multiplied by 1.06, the result will be approximately the amount of sulphur that may be expected in commercial coal from the same mines. In the report for 1904 this coefficient was given as 1.04 on a basis of 50 samples analyzed, but the additional samples tested during 1905 have given it a slightly larger amount and probably greater value.

ASH.

The relation of the percentages of ash in the two classes of samples analyzed in 1904 was found to be far more constant than either the moisture or the sulphur. "Of the 50 analyses compared, 46 show a greater amount of ash and 4 show a smaller amount of ash in the car sample than in the mine sample." The total percentage of ash in the car samples (545.35) divided by the total percentage for the mine samples (418.36) gave 1.3 as the coefficient of increase; "if, therefore, the amount of ash in any given mine sample be multiplied by this coefficient (1.3), the result will be approximately the amount of ash that may be expected in the commercial output of the mine."

The results of the combined work of 1904 and 1905 show the same regularity in excess of ash in the mine samples as was noted in the previous paper.

The total excess in the car samples is 1,062.66, and in the mine samples 825.95 per cent.; 1,062.66 divided by 825.95 equals 1.29. This may be called the coefficient of increase and can be used in converting the ash in analyses of mine samples into analyses of commercial coal; thus, if the ash in the analysis of the mine sample be multiplied by the coefficient, 1.29, the result will be approximately the amount of ash that may be expected in commercial coal from the same mine.

The coefficient determined in 1904 is 1.3, which is practically the same as 1.29, the coefficient determined by the results of 1904 and 1905. The agreement is remarkably close and certainly shows that careful sampling, even by different persons, will give approximately the same results.

Personal Equation.—As noted in the previous report, the personal element of the collectors enters largely into the results obtained; thus during the two years A collected 34 samples, and the ash in the car samples obtained by him exceeds the ash in his mine samples by an average of 2.17 per cent., whereas the average excess for the whole, 105 samples, is 1,062.66 minus 825.95 equals 236.71, divided by 105 equals 2.25 per cent. In 1904 the average for this collector was 2.4 per cent. The reduction in the average amount of excess shows that in 1905 the

sampling by this man was more accurately done; that is, more of the impurities were included in the mine sample and it was more nearly typical of the commercial output of the mines than was the case in his sampling of 1904.

B collected a total of 40 samples, and the ash in his car samples exceeded the ash in his mine samples by 2.77 per cent. In 1904 his average was 3.49 per cent. Therefore, he made a decided improvement in approximating commercial coal in his mine work. In 1904 his mine samples were entirely too clean to be representative, but the average for the two years was fair, although still above the average excess (2.25) for the whole.

C collected 12 samples and the ash in his car samples exceeded the ash in his mine samples by 2 per cent. In 1904 his average excess was 1.66 per cent.; therefore, his work in 1905 was not quite so good as it was in 1904.

D collected 3 samples and his average excess in the car samples was only .79 per cent.

E collected 8 samples and the ash in his car samples exceeded the ash in his mine samples by an average of 1.58 per cent.

D and E made the best sampling record in approximating commercial coal.

F collected 3 samples, but his work was of an entirely different character from that of any other collector, as in 2 cases out of 3 his mine samples contained more impurities than the carload lots which he shipped to St. Louis. The ash in his car samples fell below the ash in his mine samples by 2.13 per cent. There is nothing in the report to explain this anomaly, and so it must be attributed to accident or to his personal opinion as to what constituted commercial coal from those mines.

As stated in the previous paper the object of this mine sampling was to secure coal representative of the commercial output of the mine, but this was not accomplished. After a year's experience the excesses were reduced, but not to a very great extent and it is very doubtful if under this plan it is possible to secure the same grade of coal as reaches the market. There are several reasons for this which under present conditions can not well be changed.

Summed up and tabulated the results are as follows:

TABLE SHOWING RELATIVE AMOUNTS OF ASH IN CAR AND MINE SAMPLES OF THE DIFFERENT COLLECTORS.

Collector.	Work of 1904.			Work of 1904-5.		
	Number of Samples.	Average Excess in Car Samples.	Average Excess in Mine Samples.	Number of Samples.	Average Excess in Car Samples.	Average Excess in Mine Samples.
A.....	23	2.40	.....	34	2.17	.....
B.....	16	3.49	.....	40	2.77	.....
C.....	8	1.66	.....	12	2.00	.....
D.....	3	.79	.....	3	.79	.....
E.....	.....	.....	.....	8	1.58	.....
F.....	.....	.....	.....	3	.....	2.13
Av. Excess.....	.....	2.54	.....	.....	2.25	.....

Perhaps the most important is that the consumers do not demand clean coal and consequently the operator makes little or no attempt to keep his coal free from shale and bone during the process of mining and loading. In the second place, even if the operator is willing and anxious to improve the output of his mine, the carelessness and indifference of the miners will not permit him to do so. Positive instructions may be issued to throw out certain partings, but unless pickers are employed and suitable machinery installed, the chances are about 10 to 1 that all the partings are loaded with the coal and also a large percentage of dirt from roof or floor.

In view of this seeming impossibility of approximating commercial coal, the writer has recommended an arbitrary system of sampling which would reduce to the minimum the effect of the personal equation of the sampler and also obviate the necessity of trying to imitate the miner who not only leaves in the natural impurities of the coal, but through his carelessness adds more from an outside source. This can be done only by adopting regulations covering each step of the operation. A method of coal-mine sampling was recommended in a previous paper, which will be repeated here with such changes as have been suggested by recent work. All geologists and mining engineers are urgently requested to conform to this proposed method so that the results of analyses may be compared. At present this

is generally impossible since no information is given as to the method of sampling or of analysis.

PROPOSED METHOD OF MINE-SAMPLING.

1. Never accept weathered coal, but select a fresh face of coal at the point where the sample is to be obtained, and clean it of all powder-stains and other impurities.

2. Spread a piece of oil-cloth or rubber-cloth upon the floor so as to catch the particles of coal as they are cut and to keep out impurities and excessive moisture where the floor is wet. Such a cloth should be about $1\frac{1}{2}$ by 2 yards in size and spread so as to catch all the material composing the sample.

3. Cut a channel perpendicularly across the face of the coal bed from roof to floor, with the exceptions noted in paragraph 3 and of such a size as to yield at least 5 pounds of coal per foot of thickness of coal bed; that is, 5 pounds for a bed 1 foot thick, 10 pounds for a bed 2 feet thick, 20 pounds for a bed 4 feet thick, et cetera.

4. All material encountered in such a cut should be included in the sample, except partings or binders more than $\frac{3}{8}$ inch in thickness and lenses or concretions of sulphur or other impurities greater than 2 inches in maximum diameter and $\frac{1}{2}$ inch in thickness.

5. If the sample is wet it should be taken out of the mine and dried until all sensible moisture has been driven off.

6. If the coal is not visibly moist, it should be pulverized and quartered down inside the mine to avoid changes in moisture which take place rapidly when fine coal is exposed to different atmospheric conditions. The coal should be pulverized until it will pass through a sieve with $\frac{1}{2}$ inch mesh, and then, after thorough mixing, it should be divided into quarters and opposite quarters rejected. The operation of mixing and quartering should be repeated until the desired size of sample is obtained. When the work has been properly done a quart sample is sufficient to send for chemical analysis. This should be sealed in either a glass jar or a screw-top can with adhesive tape over the joint, and sent to the chemical laboratory for analysis.

7. The analysis of such a sample will show the grade of coal that may be obtained by careful mining and picking. In a majority of cases the sulphur and ash in the commercial output of the mine will exceed the amount shown by the analysis, but the former can be approximated from the latter by multiplying by the coefficients given above: 1.06 for sulphur and 1.29 for ash. These coefficients will only hold for general results, but it seems probable, that when more detailed work of this character has been done, specific coefficients may be determined for each field or for each important coal bed.

8. Each sample should be accompanied by a complete description stating definitely how the sample was obtained and what it represents so that the reader may judge for himself of its value, and when analyses are recalculated the coefficients of increase should be given together with the authority for their use or the data upon which they were determined.

9. In publishing analyses, full descriptions should be given as noted above, together with the name of the collector, date of collection, name of analyst, and care of sample after it was collected.