Method of Least Squares Applied to Estimating Errors in Coal Analysis

Technical Paper No. 171 of the U. S. Bureau of Mines. Paper binding; 9 x 6 in.; 36 pages; one halftone illustration and numerous photographs, tables, etc. Authors, J. D. Davis and J. G. Fairchild. Obtainable from Superintendent of Documents, Washington, D. C. Price, 5 cents. Published September, 1918.

As a contribution to the increase of efficiency in the utilization of fuel, the authors have sought to describe a definite method for estimating the probable limits of error in analyzing samples of coal and to show how this method, that of least squares, should be applied. According to Messrs. Davis and Fairchild, E. G. Bailey has shown that the method of least squares is applicable to the problem of sampling coal; it can be used to determine the limits of accuracy of sampling and for preparing standardized methods of sampling, but apparently the accuracy of the ordinary methods of analyzing coal had not heretofore been investigated by a mathematical method.

It is customary to estimate the limits of accuracy of analysis by observing the agreement of duplicate determination; that is, from general experience with a given kind of analysis. Hence, as some sets of duplicates are found to agree more closely than others, this question arises: What is the widest variation and what is the average variation reasonably to be expected? Or, in other words, the question is: What is the magnitude of the "probable error" of a single determination and what is the maximum error to be expected, say, once in 1,000 determinations?

The writers have tackled the problem by first carefully working out the limits for a few coals that were selected as typical, and then comparing the results so obtained with data compiled with numerous check determinations taken consecutively from the laboratory records. The number of check determinations was usually 1,000, and the experimental work was all done by the same analyst; hence the effect of the "personal equation" was eliminated from the results. On the other hand, the data taken from the records included the work of several analysts, so that the personal equation was here involved. Moreover, the experimental work for a given result took only a day or two, whereas the data represented in the compilation from the records represented at least a month's analyses, so that the variations chargeable to changing conditions in the laboratory probably were involved in the recorded results used. The subject matter of this publication takes up in detail the preparation of the sample of coal for analysis, the error of the ash determination, the error of moisture determination, the error in volatile-matter determination and the error in heating-value determination.

According to conclusions drawn by the authors, the results obtained through the application of the theory of probabilities would seem to indicate rather clearly what degree of precision may be expected with the coal analysis when the quantities determined are defined by the actual methods used for the analysis. When the error corresponding to a probability of one-half is taken, the errors involved in sampling and analyzing coal may be taken to be as follows: In taking the 5-lb. gross sample, about 0.04 per cent of sample, because of failure to include or exclude impurities represented is ash in the analysis; in the

ash determination, 0.08 per cent; in the moisture determination, 0.04 per cent; in the volatile-matter determination, 0.15 per cent, and in the heating-value determination, 0.15 per cent. Combining these possible errors makes a possible error in calculating the heating value of coal substance of about 0.18 per cent of the total heating value.

The limit determining rejection is often taken as the error whose probability is 1 in 1,000, which is 4.9 times (or, roughly, five times) the probable error of a single determination; the outside limit for error in the above determinations may be easily calculated. The limits of error, the authors conclude, would then be as follows: For sampling, 0.20 per cent; for the ash determination, 0.40 per cent; for the moisture determination, 0.20 per cent, and for the heating-value determination, 0.75 per cent. The writers believe, in view of this, that the limits allowed by the committee on coal analysis of the American Society for Testing Materials are not limits outside which, with ordinary care, determinations would never fall, but rather that the committee means to designate limits within which a large percentage of the errors will fall.
