USING PUBLISHED WYOMING COAL ANALYSES

by
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Increased interest in Wyoming coals has prompted inquiries into the quality of various potentially strippable Wyoming coal seams. Since published analyses must provide these data, 473 proximate analyses, sulfur contents, and heat values of selected Wyoming coals were examined to appraise their value in characterizing the strippable deposits of each of the seams. The Wyodak and Monarch coals of Northeastern Wyoming and the Hanna Formation coals of Southcentral Wyoming were chosen because (1) there were many analyses of each, and (2) unlike many Wyoming coals, both strip and deep mine analyses were available for comparison — a necessary attribute. By way of further explanation, all 215 analyses of the Hanna Formation coals were treated as if they were one seam. In this way analytical variations within a formation were comparable with variations individually exhibited by the Wyodak and Monarch coal analyses. Apparently, variations are similar in these three cases at least.

By comparing analyses of each of the selected coals by sample type (channel, tipple, and delivered) as well as by mine type (strip and underground), predictable but small variations are seen. When analyses of all these different samples are averaged, however, mean values characterize the moisture, volatile matter, fixed carbon, ash, sulfur, and heat values of a strippable coal at least in the vicinity of the sampled area. But in all the coals examined, there are not enough strip or underground mines, hence not enough analyses to reliably characterize the quality of a coal beyond the area of a couple of townships (36-72 square miles). Coal quality between distant mines often far exceeds mean values. For this reason, characterization of a coal beyond heavily sampled areas is questionable and must await the availability of a large number of analyses over much wider areas. Unfortunately the numerical definition of "a large number" is still not certain. Tentatively, analyses of as many as 100-200 samples per township (six square miles) may be needed.

Coming back to the variations between sample types and mine types, let us look at how each analytical parameter behaves. First, we will examine the as-received moisture content (Figure 1). For any given seam, four variations are noted:

1. At least for underground mines, channel samples exhibit the highest moisture contents.
2. Delivered samples from either mine type exhibit the lowest moisture contents.
3. At least for tipple and delivered samples, strip mine samples exhibit higher moisture contents than underground mine samples.
4. Mean values between these sampling types and/or mine types differ by no more than 3% by weight.

Turning now to the volatile matter on a moisture-free basis, three observations are made in respect to any given seam:

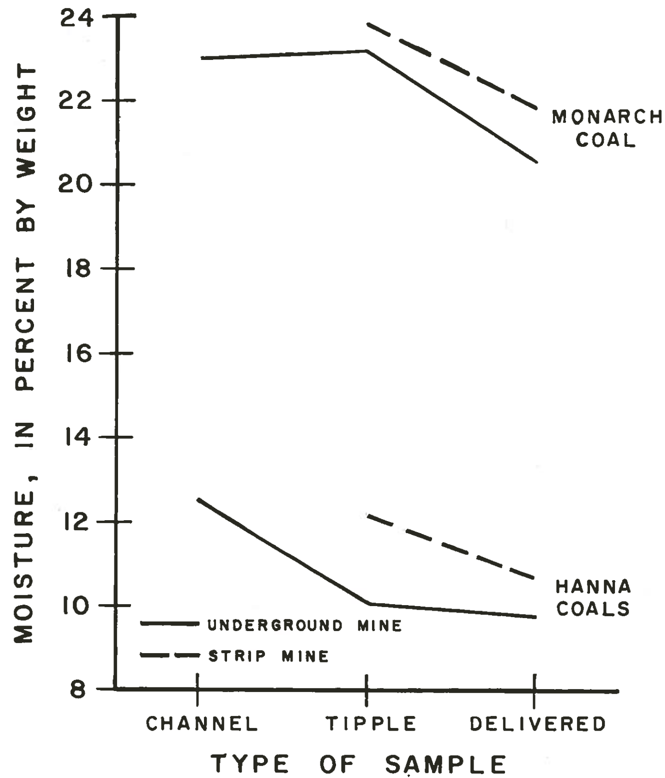

FIGURE 1
Variation in as-received moisture contents for the Monarch and Hanna Formation coals.

1. In underground mine samples, volatile matter decreases from channel to tipple to delivered samples.
2. Analyses of the Monarch and Hanna Formation coals suggest that delivered samples exhibit more volatile matter than tipple samples from strip mines. This relationship must be used cautiously since the Wyodak analyses did not substantiate it.
3. The difference in mean values between sample and/or mine types does not exceed 2% by weight, however.

The converse of the volatile matter observations are true for the fixed carbon contents (moisture-free) of a given seam.

For these seams there are also 4 predictable variations in ash content (moisture-free basis) (Figure 2).

1. At least for deep mines, ash contents increase from channel to tipple to delivered samples. The strip mine samples, however, did not behave as predictably.
2. Strip mine samples tend to exhibit greater ranges in ash content than deep mine samples.
3. Ash contents of strip mine samples are generally higher than underground mine samples.

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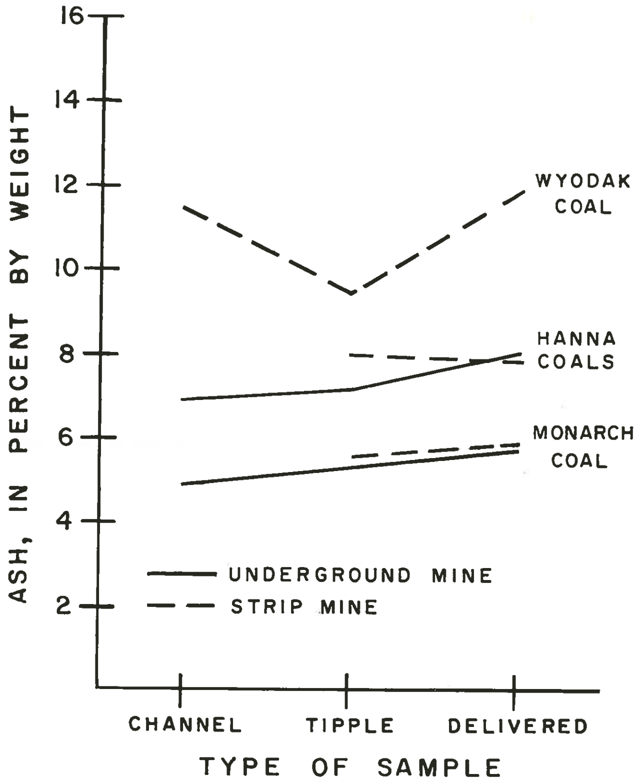

FIGURE 2
Variation in moisture-free ash contents of the Wyodak, Hanna Formation, and Monarch coals.

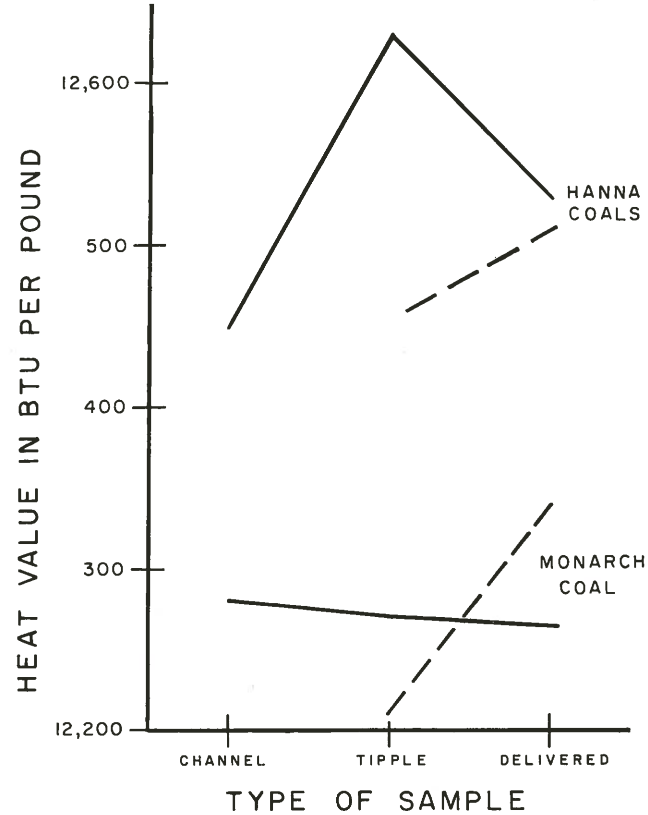

FIGURE 3
Variation in moisture-free heat values of the Hanna Formation and Monarch coals.

4. With the exception of the Wyodak seam where the mean ranges 3% by weight between sample types, mean ash contents generally differ less than 1% by weight between sample types and/or mine types.

Although the heat values of the examined coals exhibit no firm tendencies, several observations may be valid for heat values on a moisture - free basis (Figure 3).

1. Delivered strip mine samples generally exhibit higher heat values than tipple samples.
2. Delivered underground mine samples generally exhibit lower heat values than tipple samples.
3. Ranges in heat values generally increase from channel to tipple to delivered samples in both types of mines.
4. The range in mean heat values for different types of samples and/or mines is no more than 203 Btu/lb.

Because the sulfur content of all these coals is very low, there is little difficulty in characterizing it from any type of sample or mine. In fact, when the average as-received sulfur contents of all these widely separated coals are plotted on a single graph, the range in their mean values is only 0.55% by weight. Additionally, for any given seam, no predictable variations in sulfur content between sample types and mine type were evident.

As noted, there are small predictable variations between the analyses of various types of samples and various types of mines. These variations are not particularly significant when a large enough number of analyses can be averaged. If only a few analyses are available, however, which is frequently the case, detailed background information into each analysis will be an invaluable aid in judging the value of that analysis.

Assuming that a sample has been collected and analyzed by acceptable methods, there are at least 8 background items or variables besides sample types and mine types that are important in evaluating a coal analysis:

1. Mine name and/or location
2. Seam thicknesses and sampled intervals
3. Coal and overburden description
4. Size fractions
5. Dates of sampling and analysis
6. Type of mining equipment
7. Processing and preparation facilities at the mine
8. Customer identification

All these variables are deemed important since analyses and value judgments on the analyses can be directly or indirectly affected by one or more of them. In fact, many of the observations already discussed may be related to these variables also. Incidentally, this preliminary investigation was not intended to determine real cause - and - effect relationships, but rather to point out various possibilities and precautions that should be considered.

Before going into each of these background items, it should be mentioned that although channel samples eliminate many of the variables above, only 14.2% of the investigated analyses were of this type (Table 1). Instead, 84.3% were analyses of tipple and delivered samples. Because these latter samples are very de-

	CORE	CHANNEL		TIPPLE		DELIVERED		NUMBER OF SAMPLES	
		Strip	Deep	Strip	Deep	Strip	Deep	Strip	Deep
Wyodak Coal	7	2	8	35	0	3	0	40	8
Monarch Coal	0	0	33	22	21	32	95	54	149
Hanna Coals	0	0	24	50	22	114	5	164	51
Subtotal	7	2	65	107	43	149	100	258	208
Total All Seams	7	67		150		249		473	
Percent of Total	1.5	14.2		31.7		52.6		100	

TABLE 1
Number of examined analyses by sample type, mine type, and seam name

pendent on the mining methods, mining equipment, preparation and processing facilities, and contract specification, analyses of these samples cannot be considered as characteristic of a coal in its natural state as a channel sample. The remaining 1.5% of the analyses were core samples. Unfortunately, too few core analyses were available to make any meaningful comparisons.

An isolated or atypical analyses may be as much a consequence of the above variables as it may reflect a true stratigraphic variation in coal quality; therefore, we need to find out as much about that analysis' origin as possible. The mine name and/or location are two of the most valuable items in this search because they provide keys to finding information on all the other items. For this reason analyses not identified by mine or location are practically worthless. Then too, an accurate sample location provides insight into the potential value of an analysis because the location shows its proximity to other analyses with which it can be compared.

The relationship of sampled intervals to seam thicknesses is an important item to consider also. Often, sampled intervals are far from representative of a given seam. For example, most underground samples (channel, tipple and delivered) of the Monarch coal represent only 31% or 8.9 feet of the total seam thickness, which averages 29 feet (Figure 4). The same holds true for samples of other thick coals like the Wyodak seam, which averages 90 feet thick. Most samples of this coal represent 1/4 to 1/3 of the total seam thickness simply because (1) underground mines have extracted no more than 21 feet of the seam and (2) strip mines remove the coal in 25-35 foot thick benches rather than in its entirety (Figure 5). Consequently analyses from both types of mines only represent the mined portions of the seam. What is more important, deep mine samples may high-grade the coal's quality since deep mines are seldom developed on the poor quality portions of a seam. In strip mines, however, this handicap can be offset by averaging even a few analyses collected over a period of many months or

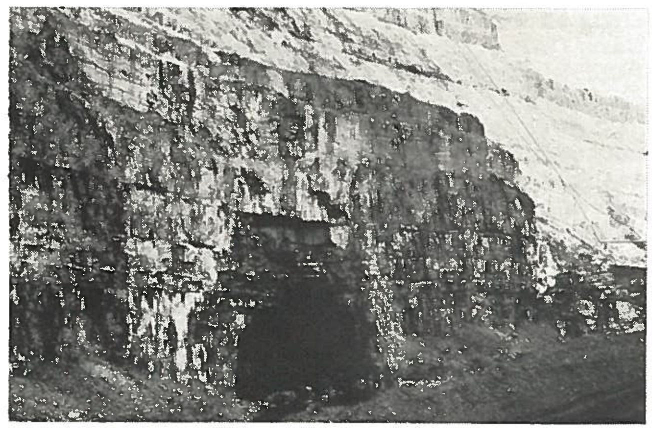

FIGURE 4
Underground mines seldom extracted more than the lower third of the Monarch coal as evidenced by this abandoned portal in the Big Horn No. 1 strip mine near Acme, Wyoming.

FIGURE 5
Because Wyoming's thick coal seams must be strip mined in 20-30 foot lifts like these in the Big Horn No. 1 mine, a single tipple or delivered sample seldom reflects the composition of the entire seam.

perhaps years. If the sampling is done over a long enough period of time, the entire seam thickness will be mined and analyzed.

In a similar vein, it should be noted that even a channel sample may not precisely represent the entire thickness of a seam. In this type of sample, partings or binders of non-coaly material greater than 3/8 inches thick and concretions more than 1/2 inch by 2 inches must be excluded. One should take note of these exclusions since a mining operation is not going to be as efficient at their removal as the individual who collects the channel sample.

Coal and overburden descriptions can be important for several reasons. Firstly, the physical description of a sampled coal can give clues to its reported quality. Badly weathered coals, for example, are occasionally analyzed simply because they were the only exposures available. Weathering can certainly affect almost all the analytical parameters we have examined to varying degrees. As another example, dirty or bony coals can explain anomalously high ash contents. Secondly, the thickness of the overburden or cover above a sample is an important variable. Heat values, in particular, increase with rather small increases in overburden thickness. A 300 Btu/lb. increase with a 110 foot thickening of overburden has been reported in the Hanna Basin (Unfer, 1951). In that basin many samples are from depths in excess of 1000 feet. These deeper underground mine samples tend to exhibit higher heat values that nearby analyses of strip mine samples on the same seam. This tendency is not as noticeable in analyses of the Monarch seam, perhaps because the underground mines were much shallower on that seam than those on the Hanna coals. Thirdly, analytical parameters, especially sulfur, may vary in response to the overburden material immediately above a coal. Although to date no such relationships are specifically noted in Wyoming, some Pennsylvanian bitituminous coals exhibit their highest sulfur contents where they are overlain by thick fluvial sandstones.

Washability studies of Wyoming coals show that the size fractions sampled and analyzed have a very important bearing on analytical results. For instance, analyses of various size fractions of the Monarch coal show that ash contents vary as much as 2% between fractions and moisture contents as much as 3% (Figure 6). For this reason one should attempt to ascertain what size fractions were analyzed. Although most coal now marketed in Wyoming is simply crushed without washing, fines from older washed tipple and delivered samples may not be included in some analyses. One should also be alert to the possibility that published analyses of specific size fractions may be quoted without reference to their special nature.

Sampling and analysis dates are valuable aids to deducing or tracking down information about the other variables. For example, equating a sampling date to a mine map can not only reveal where the sample was collected but also the thickness of the sample. Dates and coal thicknesses are often annotated on such maps. Both these dates can also give insight into the probable type of mine, mining equipment and processing that the sample represents. The date of an analysis can also qualify its reliability. Because very old analyses were not done under ASTM standards, those done before 1904 cannot be used for certain purposes such as the determination of rank. One should also note the time

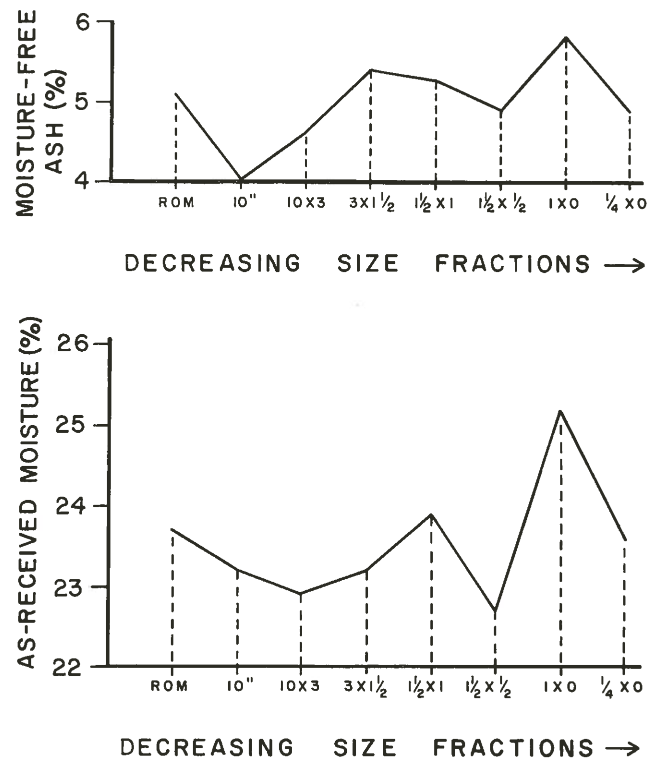

FIGURE 6
Different size fractions of the Monarch coal vary in moisture and ash contents.

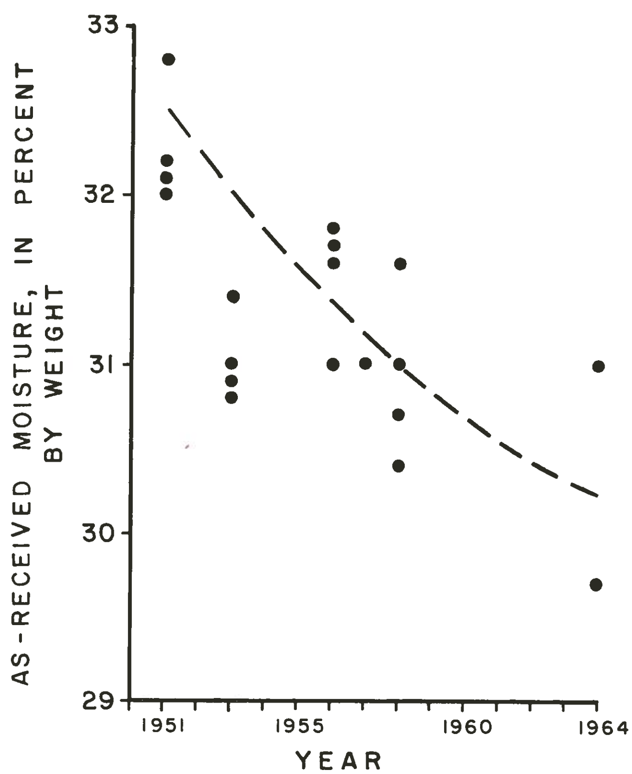

FIGURE 7
Wyodak coal analyses show an apparent gradual decrease in moisture content between 1951 and 1965 (U.S. Bureau of Mines, unpublished).

	WYODAK COAL ANALYSES (48)		
	As-received (Range)	Moisture-free (Range)	Average (as-received)
MOISTURE	23.4 - 36.9		30.2
VOLATILE MATTER	26.5 - 32.7	39.0 - 46.7	30.0
FIXED CARBON	29.6 - 41.4		33.8
ASH	2.9 - 12.2	3.9 - 17.0	6.0
SULFUR	0.2 - 1.2		0.3
BTU PER POUND	7,420 - 9,306	10,840 - 12,380	8,411
	MONARCH COAL ANALYSES (203)		
MOISTURE	14.5 - 26.0		21.5
VOLATILE MATTER	30.3 - 38.4	40.2 - 49.7	34.5
FIXED CARBON	34.9 - 44.0		39.6
ASH	3.1 - 8.2	4.0 - 10.7	4.4
SULFUR	0.3 - 0.7		0.4
BTU PER POUND	9,000 - 10,410	11,740 - 12,640	9,600
	HANNA FORMATION COAL ANALYSES (215)		
MOISTURE	6.0 - 17.5		11.0
VOLATILE MATTER	33.2 - 44.9	39.2 - 48.1	39.2
FIXED CARBON	38.8 - 47.0		43.1
ASH	3.6 - 13.2	4.1 - 14.3	6.7
SULFUR	0.2 - 2.3		0.5
BTU PER POUND	9,740 - 11,770	11,460 - 13,200	11,370

TABLE 2
Summary of the analytical data for the Wyodak, Monarch, and Hanna Formation coals without differentiation by sample types or mine types

lapse between the dates of sampling and analysis. This should be kept to a minimum. The greater this time lapse, the more questionable the analytical results. Another value in keeping track of the date of various analyses is evident in published tipple analyses from the Wyodak strip mine (Figure 7). Moisture contents between 1951 and 1964 gradually decreased from about 32.5% to 30.5%. Although one can only speculate on the reasons for this decrease (deeper overburden, different sampling intervals, change in coal quality, processing, etc.), it is significant that such a trend exists. Had this data not been examined from the standpoint of time, the variation would have gone undetected.

The last three items, mining equipment, processing facilities, and customer identification, are important to consider when dealing with tipple and delivered samples. Since coal has been mined underground by hand, blasting and mechanical methods, variations in a coal's quality may be a result of the differing ability of these various machines or methods to produce coal with consistent characteristics. The same holds true with strip mining techniques and equipment and, of course, would also apply to a comparison of the two mining types with one another.

Likewise, coal preparation facilities can alter a coal's quality. Washing plants, for instance, can raise moisture contents as well as reduce ash. Because various types of plants can be more efficient at ash removal than others, an analysis of a processed coal may vary between such plants as well. Since the quality of a processed coal is as much a function of the efficiency of the preparation plant as it is the coal itself, just knowing that a coal has been processed can be a meaningful piece of information. For example, it was already noted that some size fractions can be lost in processing.

Customer identification is becoming more important as we enter an era of strict contract specifications where a mining company penalizes itself if it provides too good a product and gets penalized by its customer if its product falls below specifications. Mining is now geared to reduce the variability in ash, sulfur, moisture and heat values to a minimum. This can be accomplished by blending and/or selective mining if necessary. The problem is then one of knowing exactly what coal or coals were sampled from a tipple or railroad car. If the customer is known, one may gain insight into the reliability of using analyses of his tonnages to characterize a particular seam.

In conclusion, if one averages enough proximate, sulfur, and heat value determinations of channel, tipple, delivered, underground, and strip mine samples of a given coal, those average values can be used to characterize that coal with a fair degree of reliability at least in the vicinity of the sampling (Table 2). On the other hand, the quality of thick, potentially strippable Wyoming coals should not be stringently characterized from a small number of analyses without consideration of detailed background information on each analysis. Minimally, the type of sample, type of mine, mine name and/or location, seam and sample thickness, coal and overburden description, size fractions, dates of sampling and analysis, types of mining equipment, processing facilities, and customer identification should be known to adequately appraise an analysis fully.

REFERENCES

Dobbin, C. E., 1931, Analyses of Wyoming coals: U.S. Bureau of Mines Technical Paper 484, 159 pp.

Lord, N. W., 1913, Analyses of coal in the United States: U.S. Bureau of Mines Bulletin 22, p. 295-321.

Unfer, L., Jr., 1951, Study of factors influencing the rank of Wyoming coals: M.A. Thesis, University of Wyoming, Laramie, 54 pp.

U.S. Bureau of Mines, unpublished, computer printout of analyses of tipple and delivered samples from Wyoming (1901-1971).

U.S. Geological Survey and Montana Bureau of Mines and Geology, 1973, Preliminary report of coal drill-hole data and chemical analyses of coal beds in Sheridan and Campbell Counties, Wyoming, and Big Horn County, Montana: Open File Report, 57 pp.