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COMPOSITION OF THE ASH OF ILLINOIS COALS

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ABSTRACT

Analyses of the ashes of various Illinois coals, many of which have been available in the analytical files of the Illinois State Geological Survey, are presented in this report. Inasmuch as some of the ash analyses were made on prepared coals, some information is presented on the effects of preparation (sizing and washing) on ash composition. The relation of ash composition to ash softening temperatures has been indicated in three ways. While all three show a general relation between composition and softening temperatures, none are adequate to permit estimating softening temperatures within desirable tolerances. It is suggested that the necessary oversimplification when dealing with a complex multicomponent system such as coal ash prevents such predictions.

INTRODUCTION

Over a period of about 32 years, the Analytical Chemistry Section of the Illinois State Geological Survey has analyzed ashes from various Illinois coals. While some of these analyses have appeared as supporting data in certain publications, and other reports dealing with various considerations of coal ash and mineral matter have been published, the ash analyses have never been assembled into a single report. The purpose of this summary, therefore, is to make available information on the composition of Illinois coal ashes.

The data represent face channel samples, raw coal (commercially mined), and prepared coals, both sized and washed. Since preparation influences ash composition, each analysis must be considered representative only of the specific sample described. Information on the effect of preparation on ash composition and some discussion of the relation between ash composition and ash fusion are included.

SAMPLES

The coal samples described in this report were obtained, for the most part by Survey personnel. The majority of sized and washed coals represented in table 1 were commercial plant products, but in certain instances, the preparation was done in the Survey laboratory. For example, the washing of samples A, B, and C has been described by Helfinstine and Boley (1946). All sized and gravity samples shown in tables 2 and 3 were prepared in the Survey laboratory and described by McCabe and Rees (1939). The gravity samples, for which ash analyses are shown in tables 2 and 3, were individual samples rather than cumulative gravity samples.

ANALYTICAL METHODS

Coal analyses (ash and sulfur) and ash fusion values were determined by the American Society for Testing Materials procedures. The three commonly determined values, i.e. the initial deformation (I. D.), softening (S), and fluid (F) temperatures, were obtained in a mildly reducing atmosphere. In all cases, the softening temperature shown is the spherical one.

Ash samples were prepared from minus 60-mesh coal as follows. About 100 grams of coal were spread in a thin layer in fire clay dishes, which were about 5 inches in diameter, and ashed in an air atmosphere in a muffle furnace at 750-800 °C. The ashes then were ground to pass a 200-mesh sieve, placed in a small evaporating dish, and burned further in an oxygen atmosphere at 850 °C. Methods used for the ash analyses were, for the most part, wet chemical methods for silicate analysis as described by Hillebrand (1919), Hillebrand and Lundell (1953), and H. S. Washington (1930). SiO_2, Al_2O_3, MgO, CaO, SO_3, and loss on ignition were gravimetric determinations. TiO_2 was determined colorimetrically. In many instances, TiO_2 was not determined separately and is included in the Al_2O_3 value. Fe_2O_3 was determined volumetrically. In the earlier analyses (lower laboratory numbers), the iron in the ferrous state was titrated with standard potassium permanganate; in the later analyses, the iron in the ferric state was titrated with standard titanium trichloride. Sodium and potassium oxide values, where actually determined, were obtained in the earlier analyses by the classical J. Lawrence Smith method and in later analyses by flame photometer. Where sodium and potassium were not actually determined, an estimate of Na_2O+K_2O was made by difference. For this purpose the SO_3 value, not the loss on ignition value, was included in the sum subtracted from one hundred.

RESULTS

Table 1 is a tabulation of analyses and sample descriptions assembled from the analytical files of the Survey. The table is arranged by the counties from which the coal samples were collected. Where available, analyses of ashes from face samples are shown first, followed by analyses of various prepared products. Since the analyses for each county represent samples of coals of different size, gravity, etc., and since coal preparation influences the ash composition, it is not possible to arrive at reliable county averages.

The data in tables 2 and 3 show the effect of coal preparation, both sizing and washing, on the composition of the ashes of the prepared products. Two coals, one from the No. 5 Coal in Sangamon County and the other from the No. 6 Coal in Williamson County, were obtained for this work. Both coals were $1\frac{1}{4}$" x 0 screenings. Each was screened into 5 sizes, and each size was separated into 6 fractions by gravity separation. Both the original samples and the five sized and 6 gravity products were ashed. The ashes were analyzed. Ash and sulfur values for all coals and ash softening temperature data for all ashes were obtained. Table 2 presents the data for the Sangamon County series, and table 3 presents the data for the Williamson County series. The influence of sizing on the four major components of the ash of the Sangamon County coal is shown graphically in figure 1A and of gravity separation in figure 1B-F. The same influences for the Williamson County coal are shown in figure 2A and figure 2B-F.

ANALYSES OF ILLINOIS COAL ASHES

The prime purpose of table 1 is to make information available on the composition of the ashes of Illinois coals, which were prepared according to the procedure described earlier in this report. The principal parent material of the ash is the mineral matter of the coal of which clayey or shaley material, pyrite or marcasite, and carbonates, principally calcite, are the main consistuents. All of these undergo changes during ashing. The clayey or shaley materials lose water of hydration; the pyrite and marcasite are converted to Fe_2O_3 and sulfur oxides, parts of which are retained in the ash as sulfate; and the carbonates lose CO_2. The clayey or shaley portion is composed of hydrous aluminum silicates, varying amounts of quartz, and possibly other minerals. The common aluminum silicates, or clay minerals, contain two moles of SiO_2 to one mole of Al_2O_3. It is interesting to note that analyses of the ashes of coals from all counties, except one, show an excess of SiO_2 over the ratio of two to one. The exception is in Will County, where the ratio of SiO_2 to Al_2O_3 is definitely less than two to one. As reported, the SO_3 values should not be taken as indicative of the occurrence of sulfates in the coals. Actually, the sulfate sulfur of coal is normally less than 0.1 percent. In the ashing procedure, part of the coal sulfur is oxidized to SO_3 and retained in the ash as sulfate. The amount that is retained depends upon the ashing procedure and the composition of the ash. For these reasons, ash analyses sometimes are calculated to the SO_3 free basis for better comparison.

EFFECT OF COAL PREPARATION ON ASH COMPOSITION

Since the analyses in table 1 represent mine, sized, and cleaned samples of coal, it is desirable to present some information of the effect of preparation, both sizing and gravity separation, on ash composition.

By way of comparing the two $1\frac{1}{4}$" to 0 coals used in this work, it will be seen from tables 2 and 3 that the No. 5 Coal is a higher ash, higher sulfur coal than is the No. 6 Coal. Analyses of the ashes from the two coals show higher percentages of Fe_2O_3 and CaO and lower percentages of SiO_2 and Al_2O_3 in the No. 5 Coal than in the No. 6 Coal. The percentage of SO_3 in the No. 5 Coal ash is higher than in the No. 6 Coal ash. The content of MgO is typically low and similar for both ashes. The alkalies (Na_2O+K_2O - By difference) are the same for the two ashes.

Effect of Sizing

The effect of sizing on the ash composition of the two coals is shown in figures 1A and 2A. Concentrations of the four major ash constituents, SiO_2, Al_2O_3, Fe_2O_3, and CaO, are plotted on the vertical axis, and size is plotted on the horizontal axis. For reference, the concentrations of these constituents in the ash of

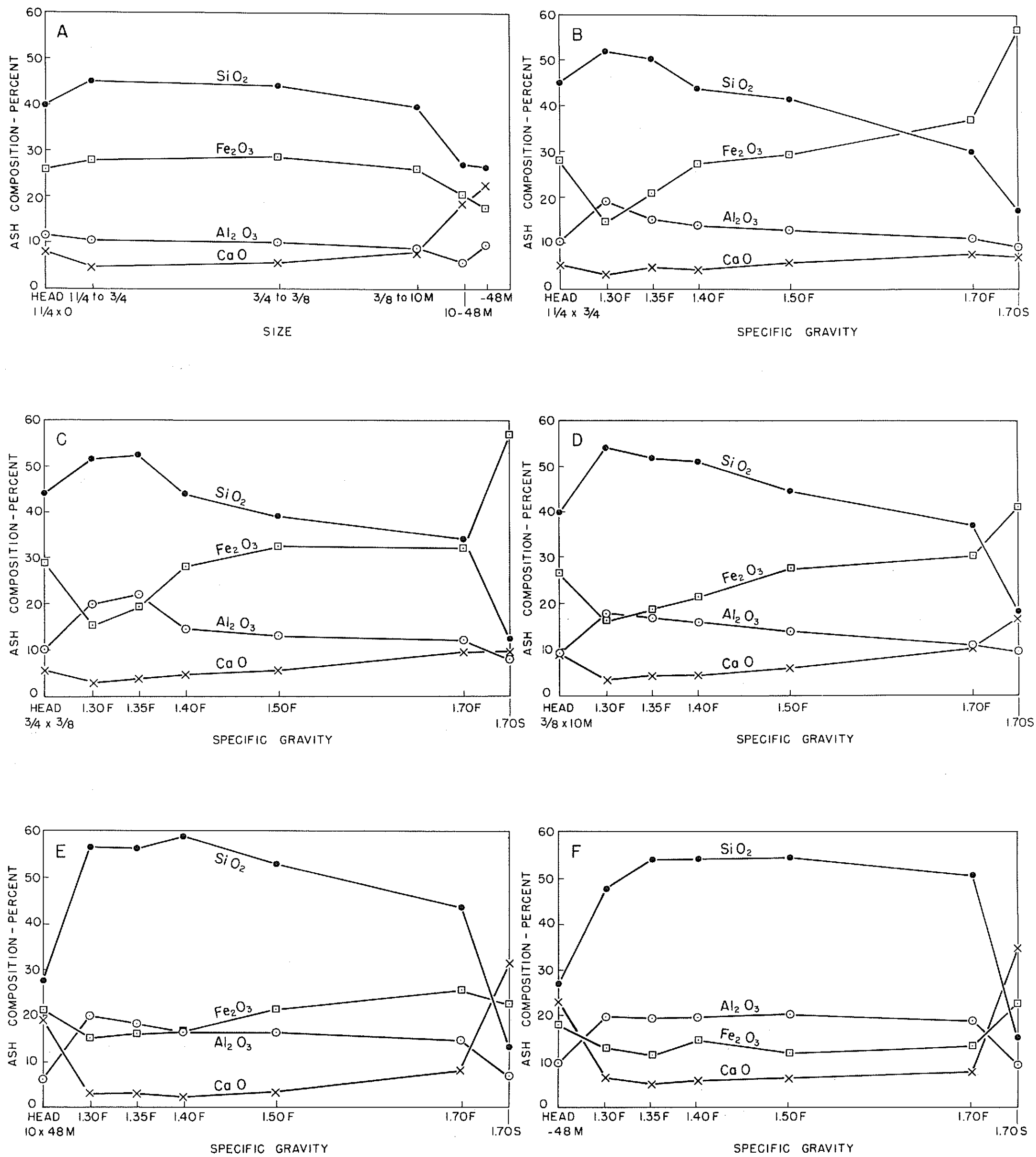

Figure 1 - Effect on ash composition of No. 5 Coal, 1 1/4" x 0, by (A) sizing and by gravity separation, (B) 1 3/4" x 3/4", (C) 3/4" x 3/8", (D) 3/8" x 10 mesh, (E) 10 mesh x 48 mesh, and (F) minus 48 mesh.

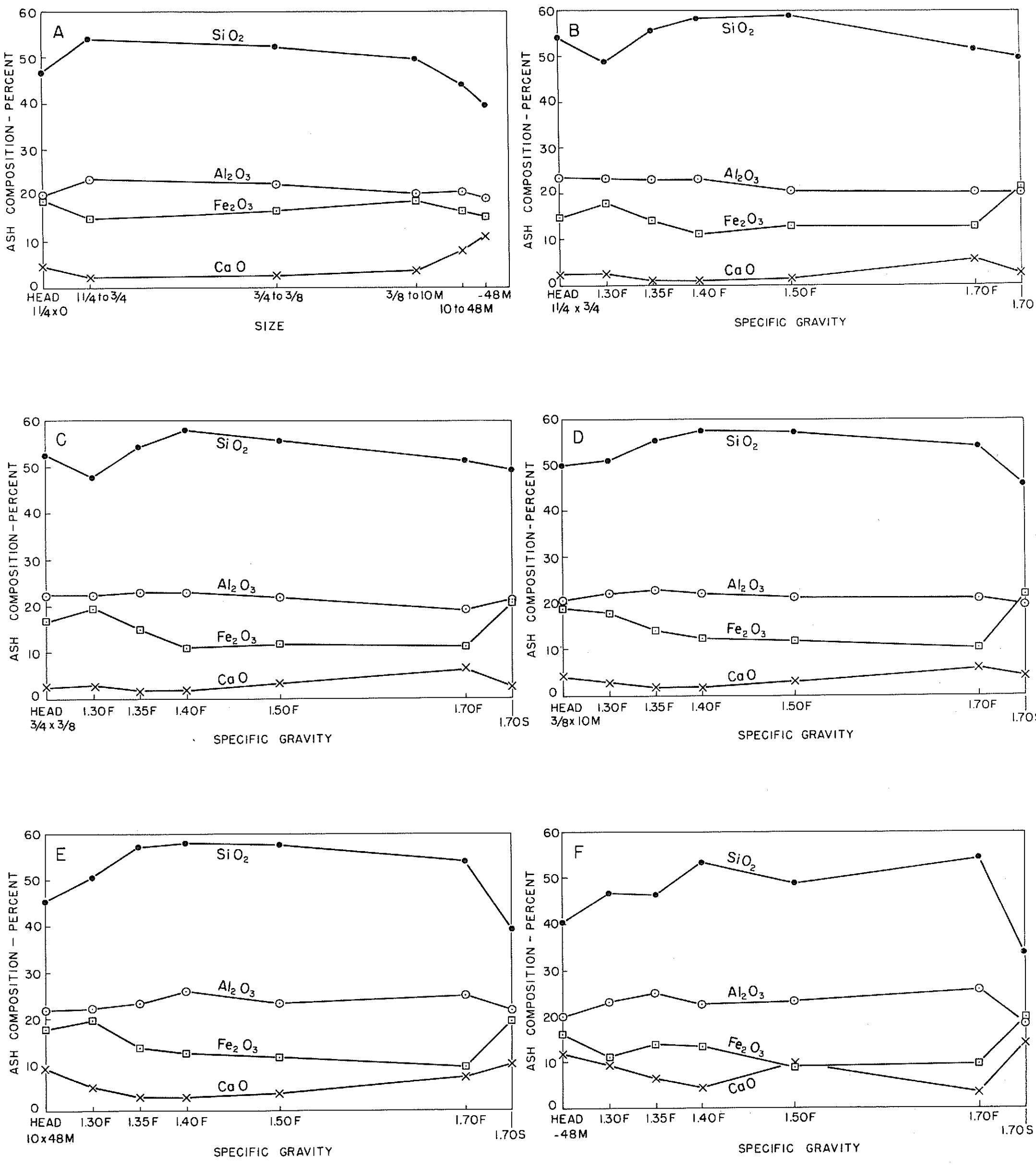

Figure 2 - Effect on ash composition of No. 6 Coal, 1 1/4" x 0, by (A) sizing and by gravity separation, (B) 1 3/4" x 3/4", (C) 3/4" x 3/8", (D) 3/8" x 10 mesh, (E) 10 mesh x 48 mesh, and (F) minus 48 mesh.

the head sample ($1\frac{1}{4}$" x 0) are shown at the left of the graphs. Concentrations of MgO and Na_2O+K_2O are not shown in the figures as they are both low in the ash. However, they are given in tables 2 and 3.

For a clear picture of the effect of sizing on the No. 5 Coal, the reader is referred to figure 1A and table 2. Briefly, the percentages of SiO_2 and Fe_2O_3 are highest in the ashes of the larger sizes of coal and lowest in the smaller sizes. Al_2O_3 is not greatly affected by size; but it is lowest in the 10 to 48M size. CaO is lowest in the larger sizes and highest in the smaller sizes.

The effects of sizing on the composition of the ash of the No. 6 Coal are shown in figure 2A and table 3. In general, they are similar to those shown in figure 1A for the No. 5 Coal.

EFFECT OF GRAVITY SEPARATION

In all the composition vs. gravity graphs, the percentages of the four major constituents are plotted on the vertical axis and the specific gravities on the horizontal axis. Percentages of these constituents in the sized or head sample are plotted at the left of the graph for comparison.

Table 2 and figure 1B through 1F show the effects of gravity separation on the ash composition of the five sizes of No. 5 Coal. Briefly, SiO_2 and Al_2O_3 are highest in the low gravity fractions and lowest in the heavy fractions, indicating concentration of the clayey or shaley part of the mineral matter in the light fractions. Fe_2O_3 and CaO are lowest in the 1.30 float (1.30F) fractions and highest in the 1.70 sink (1.70S) fractions, indicating concentration of pyrite and calcite in the heavy fractions.

The effects of gravity separation on the ash composition of the five sizes of No. 6 Coal are shown in table 3 and figure 2B through 2F. For the most part, the effects are similar to those on the No. 5 Coal. The chief exception is the lower SiO_2 and the somewhat higher Fe_2O_3 in the 1.30F fractions of the two largest sizes of the No. 6 Coal.

RELATION OF ASH COMPOSITION TO ASH SOFTENING TEMPERATURE

Several investigators have attempted to relate the composition of coal ash to such things as clinkering, slagging of boilers, and viscosity of coal ash slags and to ash softening temperature. No attempt is made here to present a complete summary of published work on this subject. The establishment of a relation between ash composition and viscosity of coal ash slags has been more successful than the establishment of a relation between ash composition and softening temperature. However, some relation between composition and softening temperature has been demonstrated by certain investigators. Three of the approaches used have been tried on the data at hand.

Relation of Acid to Base Ratio to Ash Softening Temperature

The first approach to be considered here is the relation of the acid to base ratio to the softening temperature. The acid used in this approach is SiO_2+Al_2O_3 and the base Fe_2O_3+MgO+CaO+(Na_2O+K_2O). This was tried by Nicholls and

Selvig (1932), who found that "...in general, ashes having large amounts of alumina and silica as compared to the bases had high softening temperatures and that those having relatively low amounts of alumina and silica had low softening temperatures."

This approach was tried, using the data in tables 2 and 3. The results are shown in figure 3. There is a relation between ash composition and ash softening temperature, which is, in general, in accord with the findings of Nicholls and Selvig. However, the relation is not precise enough to permit making reliable estimates of ash softening temperatures. The data show a few exceptions even to a general relation. Figure 3 shows four points that represent ashes of low acid to base ratios (less than 0.5) but which have ash softening temperatures much higher than might be expected. These ashes are designated in table 2 by laboratory numbers C-1224, C-1230, C-1197, and C-1513. All of these ashes are from 1.70S gravity samples of No. 5 Coal, and all are characterized by relatively low SiO_2 and Al_2O_3 values. In addition, the ashes of C-1224 and C-1230 are unusually high in Fe_2O_3; the ashes of C-1197 and C-1513 are unusually high in CaO. Another exception to even a general relation is shown in figure 3 where three points that represent No. 6 Coal ashes have acid to base ratios from 4.0 to 4.37 and have ash softening temperatures which are considerably higher than might be expected. These three ashes are designated in table 3 by laboratory numbers C-1248, C-1259, and C-1242. They have high SiO_2 and Al_2O_3 and low Fe_2O_3 and CaO contents. Although these facts explain the relatively high acid to base ratios, there is no apparent explanation for these high ash softening temperatures. Other ashes with higher acid to base ratios have softening temperatures that are lower and more closely fit the relation displayed in figure 3. These anomalies emphasize the fact that the relation of ash composition to fusibility is complex.

Relation of Silica Ratio to Ash Softening Temperature

The second approach relates the silica ratio to ash softening temperature. This ratio is calculated by the following formula:

$$\text{Silica Ratio} = \frac{SiO_2 \times 100}{SiO_2 + Fe_2O_3 + MgO + CaO}$$

Other investigators have used this silica ratio to relate ash composition to slagging tendencies and ash viscosity. For example, Hoy, Roberts, and Wilkins (1958) reported that slagging conditions could be established in an experimental cyclone combustor, provided that the silica ratio of the ashes of the bituminous coals used did not exceed 75.

For this report, an attempt was made to relate silica ratios to ash softening temperatures using the data in tables 2 and 3. The results in figure 4 show a general relation between the silica ratio and the softening temperature, i.e., as the the silica ratio increases the softening temperature increases. Again there are four points, representing ashes with low silica ratios and high softening temperatures, and three points, representing ashes with high silica ratios and high softening temperatures, that do not agree with the general relations. These exceptions are the same as those shown in figure 3. Therefore, the relation in figure 4 is similar to that in figure 3.

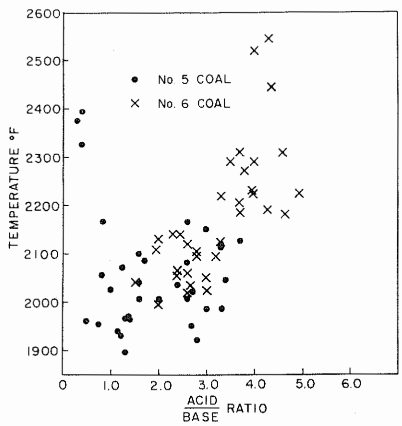

Figure 3 - The acid to base ratio versus ash softening temperatures.

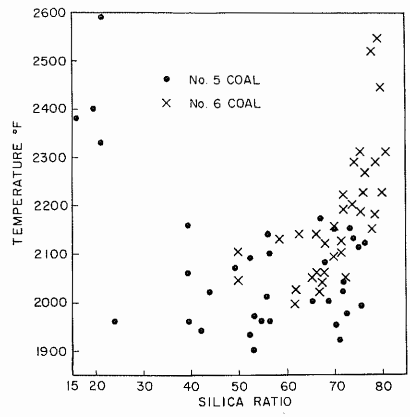

Figure 4 - The silica ratio versus ash softening temperatures.

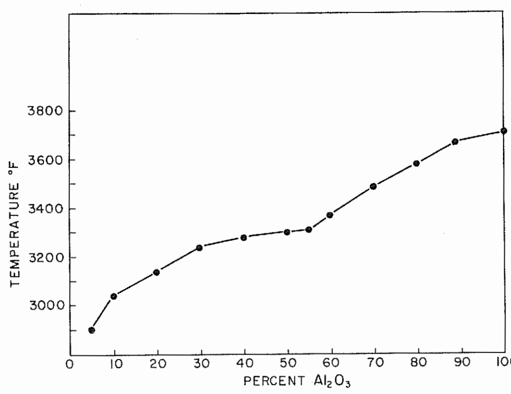

Figure 5 - Melting point versus composition of two component system, SiO_2-Al_2O_3.

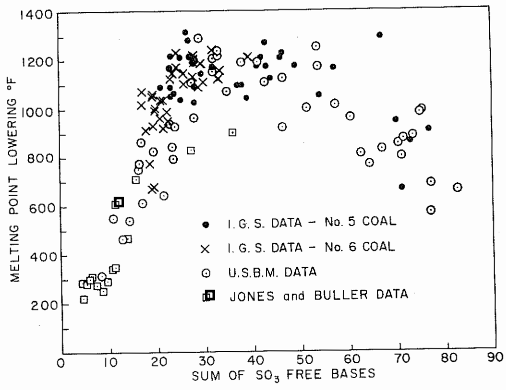

Figure 6 - Lowering by ash bases of melting point of two component system, SiO_2-Al_2O_3.

Relation of Composition to Softening Temperature Based on Lowering Effect of Bases on Assumed Two Component System, SiO_2 - Al_2O_3

A third approach was used by Jones and Buller (1936) to relate the composition of anthracite ashes to their softening temperatures. The first step in this approach is to assume a two component system, SiO_2 - Al_2O_3, for which melting point data are available (see fig. 5). For the purpose of this correlation, the ash softening temperatures are assumed to be liquidus temperatures. The next step is to calculate the relative percentages of SiO_2 and Al_2O_3 from the ash analyses. Using these values, it is possible to determine the melting point of this two component system from the curve in figure 5. The determined softening temperature of each ash is subtracted from the value obtained from the curve (fig. 5) and the difference is plotted against the sum of the bases in the ash, i.e., Fe_2O_3 + MgO + CaO + (Na_2O + K_2O). This plot is shown in figure 6. In preparing figure 6, data in tables 2 and 3 were supplemented by the analyses of anthracite ashes, reported by Jones and Buller, and some of the analyses of ash from United States coals, reported by Selvig and Gibson (1956). Values, calculated to the SO_3 free basis, were compared with values, not calculated to the SO_3 free basis, to see if the change would affect the relation. Comparison of the two showed no appreciable influence on the relation. This may indicate that the SO_3 in the ash has virtually no influence on softening temperature. The following discussion is based on SO_3 free values (fig. 6).

It will be seen that, as the bases increase, their lowering effect on the melting point of the assumed two component system (SiO_2-Al_2O_3) also increases up to about 25 percent of the total bases. The average effect appears to be approximately the same up to about 55 percent. Beyond this, the lowering effect decreases appreciably. There is considerable scatter of points so the relation shown is only a general one and is not precise enough to predict softening temperatures within desirable tolerances.

Why bases, beyond 55 percent of the ash, exhibit a reverse trend in their lowering effect is unknown. It is possible that the SiO_2 - Al_2O_3 system may no longer be the controlling one.

GENERAL DISCUSSION OF ASH COMPOSITION - ASH SOFTENING TEMPERATURE RELATIONSHIP

Three approaches that show a general relation between ash composition and ash softening temperature have been presented. However, none provides a reliable means of estimating softening temperatures. It is suggested here that this lack of demonstrated precise relation may be due to oversimplification—i.e., the practice of lumping together in a group certain ash constituents as reported in an ash analysis (oxides), with the assumption that each of the constituents included in the group has the same influence on ash softening temperature. This assumption does not seem very logical because the constituents, which may be included in a group, have different fundamental characteristics. Furthermore, the usual analytical report shows various constituents as oxides. Undoubtedly, they are present in other chemical combinations. To complicate the situation even further, it is probable that interactions between ash constituents take place during heating and result in the formation of other compounds that have different characteristics and behaviors. Thus, to arrive at a more precise relation between ash composition and softening temperature, it would be necessary to identify, by X-ray diffraction or other means, the inorganic constituents both qualitatively and quantitatively. In a multicomponent system such as coal ash, it would be virtually impossible to achieve this.

TABLE 1 - ANALYSES OF

Lab No.	Coal No.	Description	Coal Analysis Moisture Free Ash%	Sulfur%	SiO_2	Al_2O_3	TiO_2
CHRISTIAN							
C-10142	6	Face channel sample	10.9	4.42	34.76	18.12	0.80
C-10143	6	Face channel sample	12.1	4.06	32.10	18.44	0.75
C-10144	6	Face channel sample	10.9	4.45	31.58	18.25	0.85
C-10291	6	Face channel sample	12.1	4.56	39.73	16.71	0.83
C-10292	6	Face channel sample	12.0	4.45	44.58	18.20	0.95
C-10293	6	Face channel sample	11.2	4.72	42.70	16.96	0.98
C-10160	6	Core sample	14.2		34.70	18.63	0.83
C-10161	6	Core sample	15.2		33.39	19.21	0.90
C-10162	6	Core sample	15.9		40.74	16.71	0.70
C-10163	6	Core sample	12.8		39.60	15.88	0.65
C-10237	6	Core-total channel	16.2	5.73	30.66	14.10	0.68
C-10254	6	Represents 91" of coal	18.1	6.54	36.73	13.52	0.75
C-10294	6	1 1/4" x 0 screenings	14.7	4.77	41.11	15.95	0.97
C-10246	6	Minus 1 1/4"-unwashed	17.4	4.65	35.39	17.90	0.88
C-1302	6	1.30 fl. of size 3/4" x 3/8"	4.4	3.45	20.00	7.98	
C-3257	6	14A: 1½" screenings	13.7	4.26	43.03	20.04	
C-3286	6	14B: first washing of 14A	9.2	3.90	45.81	21.42	
C-3304	6	14C: first washing of 14B	8.2	3.68	46.71	21.69	
C-5738	6	3/4" x 28 mesh washed stoker coal	13.6	4.08	44.25	19.04	
FRANKLIN							
C-92	6	Column sample			40.89	32.48	
C-10603	6	Face channel sample	9.9	3.19	42.18	17.54	0.74
C-10604	6	Face channel sample	9.0	1.40	41.31	17.36	0.79
C-10605	6	Face channel sample	9.9	3.12	34.18	15.44	0.73
C-11621	6	Face channel sample	11.4	4.44	32.29	18.67	0.89
C-11622	6	Face channel sample	11.5	4.46	30.53	17.61	0.98
C-3470	6	1½" x 3/4" washed coal	8.0	0.87	54.49	26.12	
C-3778	6	2" x 3/8"	6.8	1.17	50.88	24.75	
C-4375	6	1½" x 28 mesh washed coal	10.2	2.84	43.42	19.40	
C-4380	6	C-4875 dedusted at 10 mesh	9.3	2.73	46.93	20.76	
C-4439	6	2" x 1½" (No. 2 nut)	9.7	2.48	47.67	21.95	
C-5618	6	Stoker coal	8.4	0.97	49.64	22.75	
C-10637	6	6" x 1" clean coal	7.9	2.09	50.50	22.98	1.03
C-10638	6	¼" x 48 mesh clean coal	11.9	2.94	35.93	14.65	0.65
C-10639	6	48 mesh x 0 clean coal	17.6	2.42	35.58	14.26	0.56
C-10640	6	7/8 " x 10 mesh clean coal	13.1	2.70	52.42	20.77	0.96
C-10641	6	1" x ¼" clean coal	7.4	2.23	49.73	21.52	1.03
FULTON							
C-91	5	Raw coal - 66"	14.4	4.93	57.20	5.61	
C-5638	5	3/4" x ¼" stoker coal	11.2	2.96	48.38	15.62	
GRUNDY							
C-5576	7	1" x ¼" stoker coal	6.0	2.07	32.73	18.28	
C-5712	7	Stoker coal	10.0	3.23	48.23	20.98	
HENRY							
C-14	6	Face channel sample	18.18	5.88	25.26	13.83	0.66
JACKSON							
UI-17062	6	Face sample			40.98	22.72	

ILLINOIS COAL ASHES

Ash Analysis (percent)								Ash Fusion °F		
Fe_2O_3	MgO	CaO	Na_2O	K_2O	Na_2O + K_2O by Diff.	SO_3	Loss on Ignition	Initial Deformation	Softening	Fluid
23.38	1.12	6.75	3.97	1.38		8.95	8.06	1684	1821	1878
22.68	2.91	7.63	3.50	1.54		9.67	8.50	1754	1862	1968
23.44	2.04	7.16	3.70	1.43		10.81	9.70	1713	1842	1898
21.86	0.97	7.70	2.89	1.40		8.19	2.12	1711	1856	1894
22.17	0.98	4.06	3.13	1.55		4.43	2.28	1696	1876	2018
27.33	1.00	2.92	3.18	1.55		3.30	2.25	1755	1876	2018
28.23	1.01	5.21	3.97	1.53		6.32	4.57			
26.49	1.40	6.06	2.53	1.46		8.10	5.20			
22.50	0.97	6.80	2.02	1.34		7.95	6.11			
26.50	1.04	5.53	2.20	1.55		6.77	5.92			
27.28	0.85	11.76	1.15	1.10		12.75	1.49	1669	1767	1859
32.70	0.87	6.40	1.27	1.23		6.63	1.23	1753	1835	1859
21.83	0.93	7.30	2.84	1.40		8.01	2.75	1755	1876	1930
19.60	1.51	8.15	2.90	1.80		11.17	7.98	1669	1859	2382
37.58	0.52	16.13			1.96	15.83				
23.85	1.04	3.54			5.20	3.30	3.32	2016	2054	2359
20.03	1.11	2.86			6.38	2.39	1.38	2026	2094	2357
18.65	1.20	2.70			6.35	2.70	1.87	2048	2106	2339
19.01	0.54	5.19			6.57	5.40	2.13	2032	2109	2140
7.68	0.07	9.63			0.72	8.53				
14.86	0.77	10.56	1.00	1.60		10.40	3.48	1897	2032	2126
11.23	0.81	12.39	1.27	1.33		13.18	6.86	1807	2014	2110
17.88	0.58	13.69	0.98	1.33		15.22	6.11	1816	2014	2110
27.74	0.70	8.63	1.10	1.50		8.75	1.52	1977	2054	2208
27.00	0.62	10.04	0.80	1.44		11.52	2.17	1972	2046	2204
7.77	1.11	3.71			4.35	2.45	1.57			
10.78	1.06	4.20			4.27	4.06	3.05			
17.63	0.89	7.95			2.29	8.42	0.08	2004	2053	2124
18.63	0.91	5.01			2.78	4.98	0.52	2016	2102	2183
16.68	0.40	4.46			3.91	4.93	3.24	2019	2092	2225
8.91	1.04	8.17			3.55	5.94	0.65	2182	2264	2311
13.11	0.83	4.20	1.18	2.10		3.47	1.66	2098	2170	2270
12.49	0.76	17.50	0.88	1.50		15.50	2.00	1961	2038	2050
10.63	0.90	17.59	1.18	1.55		17.28	4.21	2038	2082	2114
13.09	1.00	4.31	0.83	2.45		3.67	1.00	2098	2126	2196
13.95	0.89	4.88	1.15	1.62		4.09	1.41	2038	2126	2151
27.25	0.57	4.68			2.93	1.76	1.01			
12.89	0.73	10.19			1.45	10.74		2039	2105	2169
28.47	0.89	8.46			3.75	7.42	0.35	2026	2107	2149
17.33	0.58	4.55			3.89	4.44	0.00	2079	2156	2205
38.71	0.86	10.44			2.47	7.77	0.00		1905	
1.02	0.76	4.72			4.92	4.88				

TABLE 1 –

Lab No.	Coal No.	Description	Coal Analysis Moisture Free				
			Ash%	Sulfur%	SiO_2	Al_2O_3	TiO_2
JEFFERSON							
C-10288	6	Face sample	10.1	0.77	51.54	25.79	1.32
C-10289	6	Face sample	7.5	0.80	55.24	27.89	1.35
C-10290	6	Face sample	9.7	0.81	47.97	22.30	1.12
C-10463	6	Minus 48 mesh	17.5	0.97	42.98	21.05	0.58
C-10464	6	Over product from slurry vibrator	22.8	1.36	42.83	21.10	0.62
C-10465	6	Through product from slurry vibrator	30.2	1.28	48.01	21.51	0.64
KNOX							
C-15	1	Face channel sample	16.70	6.51	33.94	17.04	0.78
C-3463	1	16A: 1" x ¼" screened	13.2	5.21	31.40	18.67	
C-3507	1	16B: First washing of 16A	8.9	3.75	36.42	23.09	
C-3520	1	16C: First washing of 16B	5.1	2.94	34.95	25.56	
C-5663	6	1" x ½" stoker coal	8.0	2.68	48.20	25.33	
LASALLE							
C-21	2	Face channel sample	9.5	4.71		11.09	0.75
C-22	2	Face channel sample	15.6	4.55		5.24	0.54
C-2527	2	Stoker coal ½" x 8 mesh	14.3	5.47			
C-4652	2	1¼" screenings – washed	10.1	3.97	27.01	13.69	
C-4709	2	2" x 1¼" raw coal with minus 1" removed	9.8	4.61	26.72	13.41	
MACOUPIN							
UI-17053	6	Mine sample			46.04	16.31	
UI-17054	6	Mine sample			45.58	16.67	
UI-17055	6	Mine sample			46.88	20.25	
MADISON							
C-16	6	Face channel sample	17.4	5.12	46.20	21.01	0.96
C-3775	6	3" x 1½" raw coal	13.6	1.49	49.10	23.01	
C-4512	6	1¼" screenings – washed	12.6	3.88	51.34	21.35	
C-4578	6	2" x 1¼" – washed	10.7	4.02	50.86	22.05	
C-11093	6	Composite of two channel samples	9.1	2.26	42.78	21.83	
PERRY							
C-922	6	Face channel sample	13.3	3.78	40.09	17.54	1.00
C-923	6	Face channel sample	12.6	4.13	40.60	16.73	0.84
C-924	6	Face channel sample	12.0	4.10	41.59	18.64	1.00
C-925	6	Face channel sample	10.6	4.20	39.70	17.74	0.86
RANDOLPH							
C-3204	6	13A: 1½" x 3/4"	17.6	4.08	48.90	19.93	
C-3229	6	13B: First washing of 13A	12.6	3.20	51.53	20.94	
C-3246	6	13C: First washing of 13B	10.1	2.99	51.78	21.46	
SALINE							
C-10617	5	Channel sample	8.4	1.41	39.14	23.76	0.92
C-11203	Davis	Composite of channel samples	8.6	3.44	41.34	20.81	
C-18	Davis	Face channel sample	9.7	3.77	36.91	20.81	0.98
C-3024	5	19A: ½" x 10 mesh	10.4	2.63	39.99	20.05	
C-3048	5	10B: First washing of 10A	7.6	2.06	41.57	21.58	
C-3072	5	10C: First washing of 10B	6.3	1.84	44.16	23.49	
C-3515	5	6" x 28 mesh – washed	6.4	1.01	48.76	29.23	
C-5757	6	1" x 28 mesh stoker coal	10.1	2.98	48.14	24.12	

Continued

Ash Analysis (percent)								Ash Fusion °F		
Fe_2O_3	MgO	CaO	Na_2O	K_2O	Na_2O + K_2O by Diff.	SO_3	Loss on Ignition	Initial Deformation	Softening	Fluid
25.31	1.51	5.48	2.17	2.12		4.46	1.99	2112	2233	2279
7.14	1.27	1.43	2.10	2.62		0.50	0.60	2259	2448	2500
6.04	0.96	8.92	2.38	1.75		8.15	2.49	1993	2183	2295
11.44	1.71	10.36	1.51	1.86		7.28	1.44	1902	2171	2351
13.77	2.19	8.71	0.78	1.95		7.12	0.90	1902	2113	2351
12.63	1.74	6.60	0.70	2.18		5.19	0.97	2087	2195	2219
32.75	0.69	6.58			2.85	5.37	0.59		1950	
34.71	0.56	6.23			1.53	6.90	0.37	2044	2099	2289
29.82	0.63	4.16			2.36	3.52	0.21	2055	2158	2534
26.25	0.58	4.04			5.67	2.95	3.13	2036	2173	2565
17.92	1.23	1.74			4.46	1.12	0.86	1980	2105	2254
35.87									1865	
24.04									2035	
37.16								1969	2105	2209
33.40	0.25	10.27			2.68	12.70	7.64	2068	2172	2443
40.33	0.15	7.79			2.62	8.98	4.83	2103	2193	2589
21.65	1.01	6.74			4.25	4.00				
29.29	0.94	3.40			0.81	3.31				
23.07	0.36	4.00			2.29	3.15				
20.61	0.92	3.99			2.46	3.85	1.05		1920	
10.97	1.01	6.12			3.94	5.85	2.51			
14.96	0.81	3.85			4.31	3.38	3.30	2008	2071	2377
17.44	0.88	2.26			5.14	1.37	1.47	1913	2093	2363
17.98	1.13	6.89	1.20	1.73		6.03	2.43			
18.60	1.03	11.16	0.33	1.92		8.85			2113	
22.37	0.82	10.10	0.68	0.67		7.48			2043	
22.48	1.20	7.10	1.29	0.86		6.28			2070	
25.20	0.98	7.72	0.91	1.38		6.12			2022	
18.83	1.00	4.17			3.07	4.10	2.17	1880	1995	2213
14.12	0.97	4.05			4.21	4.18	2.75	2003	2081	2389
13.97	0.97	3.62			4.40	3.80	3.25	2058	2131	2396
15.40	1.16	11.56	0.63	2.18		5.23	0.39	2101	2168	2194
33.09	0.94	1.44	0.54	1.78		0.75	0.93			
35.07	0.71	1.27			2.45	1.80	2.09		1945	
24.35	0.98	6.18			3.20	5.25	2.40	1920	1940	2287
23.59	0.78	4.85			3.71	3.92	2.41	1873	1958	2280
22.02	0.94	3.78			3.19	2.42	2.75	1857	1983	2291
11.28	1.21	3.66			3.78	2.08	1.44			
21.01	0.49	1.22			4.15	0.87	1.16	2064	2265	2304

TABLE 1

Lab No.	Coal No.	Description	Coal Analysis Moisture Free				
			Ash%	Sulfur%	SiO_2	Al_2O_3	TiO_2
SANGAMON							
C-3132	5	12A: 1" x 0 coal	16.1	5.06	46.74	12.84	
C-3151	5	12B: First washing of 12A	11.1	4.49	47.00	13.49	
C-3183	5	12C: First washing of 12B	13.9	3.98	48.93	14.67	
SHELBY							
C-10159	6	Core sample	13.1		31.97	16.72	0.75
C-11680	6	Composite of 2 core samples	6.1	3.07	10.25	7.56	0.32
ST. CLAIR							
C-3032	6	Second washing of mine run coal with considerable fine coal included	5.3	3.35	51.25	21.85	
TAZEWELL							
C-17	5	Face sample	11.0	3.61	36.00	13.50	0.84
VERMILION							
C-3079	7	11A: 1" x 8 mesh stoker coal	19.5	4.36	41.88	19.96	
C-3088	7	11B: First washing of 11A	11.4	3.53	38.59	18.51	
C-3113	7	11C: First washing of 11B	9.1	3.25	38.39	18.01	
C-4129	7	1¼" washed screenings	10.0	1.76	43.99	24.04	
C-4189	7	1¼" washed screenings - dedusted	9.8	1.80	45.26	24.93	
C-4206	7	1¼" washed screenings	10.5	1.81	43.94	23.92	
C-4207	7	1¼" washed screenings - dedusted	9.7	1.70	45.43	24.79	
C-4235	7	Equal parts of coals C-4206 & C-4207	10.2	1.76	43.62	23.76	
C-4294	7	2" x 1¼" washed coal - crushed to 1¼ x 0	12.1	1.69	43.42	23.35	
C-4306	7	Coal C-4294 - dedusted at 10 M.	11.7	1.62	45.94	24.16	
C-4336	7	Coal C-4294 - crushed to ¼" x 0 deducted at 10 M.	11.6	1.59	46.01	24.50	
WILL							
C-19	2	Face sample	6.0	2.16	16.40	26.53	0.84
C-20	2	Face sample	6.4	2.17	7.72	26.98	0.00
WILLIAMSON							
C-11216	6	Composite of 3 face channel	10.4	2.61	47.59	20.42	
C-10602	6	Industrial mix coal	10.6	1.96	50.77	20.69	0.84
C-3319	6	15A: 1½" dedusted screenings	8.6	0.99	58.07	25.37	
C-3389	6	15B: First washing of 15A	7.4	0.92	58.84	25.90	
C-3462	6	15C: First washing of 15B	3.0	0.86	50.52	26.21	

Continued

Ash Analysis (percent)								Ash Fusion °F		
Fe_2O_3	MgO	CaO	Na_2O	K_2O	Na_2O + K_2O by Diff.	SO_3	Loss on Ignition	Initial Deformation	Softening	Fluid
25.56	0.78	5.81			2.82	5.45	1.07	1873	1935	2327
25.53	0.63	5.55			2.37	5.43	0.87	1868	1922	2077
24.58	0.74	5.06			2.60	3.42	1.10	1906	1950	2119
30.61	1.51	6.30	2.65	1.23		7.91	7.59			
26.96	0.89	25.97	1.07	0.36		25.84	1.65			
17.20	1.02	3.20			4.40	1.08	1.39			
16.86	0.83	16.04			5.65	10.28	3.79		2000	
21.62	0.79	6.05			3.91	5.79	3.28	1892	1985	2338
24.33	0.93	6.62			4.34	6.68	2.10	1911	1985	2336
26.68	1.00	5.62			3.62	5.68	2.97	1888	1970	2380
14.87	0.70	6.05			4.87	5.48	0.98			
14.75	0.66	5.52			5.35	3.53	0.84	2180	2220	2243
14.68	0.72	6.55			5.40	4.79	0.86	2164	2211	2240
14.44	0.71	5.14			4.22	5.27	1.04	2197	2229	2409
14.71	0.61	6.38			4.55	6.37	0.91	2183	2232	2263
12.23	0.98	8.31			3.86	7.85	0.60	2230	2286	2325
11.83	0.90	6.70			4.09	6.38	0.71	2203	2275	2333
11.47	0.90	6.52			4.31	6.29	1.00	2238	2270	2296
									1905	
									1960	
13.59	0.97	8.26	0.38	2.02		7.66	1.72			
11.28	1.08	6.46	0.48	2.87		5.75	1.63	1998	2060	2194
9.20	0.78	1.59			3.81	1.18	1.58	2321	2530	2653
8.59	1.04	1.28			3.63	0.72	0.72	2463	2550	2650
13.18	1.00	2.79			4.47	1.83	1.95	2130	2304	2532

TABLE 2 - ANALYSES OF NO. 5

Lab No.	Description	Coal Analysis Moisture Free		Ash Analysis (percent)				
		Ash%	Sulfur%	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO
C-1085	Head (1¼" to 0)	13.8	5.3	40.15	11.81	26.20	0.88	8.37
C-1086	1 1/4" to 3/4"	12.8	5.2	45.28	10.58	28.22	1.41	5.15
C-1087	3/4" to 3/8"	14.1	5.5	44.45	10.36	28.98	1.60	5.97
C-1088	3/8" to 10 mesh	13.8	5.3	40.07	9.34	26.72	1.15	8.65
C-1089	10 to 48 mesh	17.3	5.4	27.61	6.16	20.98	2.12	19.00
C-1090	Minus 48 mesh	20.2	5.0	27.09	9.82	18.00	1.00	23.00
	1 1/4" to 3/4"							
C-1086	Sized sample	12.8	5.2	45.28	10.58	28.22	1.41	5.15
C-1219	1.30 Float	7.0	3.5	52.16	19.36	14.88	2.34	3.29
C-1220	1.30 - 1.35	12.0	4.2	50.48	15.34	21.04	0.70	4.93
C-1221	1.35 - 1.40	16.3	5.8	44.02	13.92	27.52	2.12	4.33
C-1222	1.40 - 1.50	22.1	7.1	41.83	13.14	29.60	1.50	5.83
C-1223	1.50 - 1.70	31.0	11.6	30.55	11.42	37.38	1.35	7.95
C-1224	1.70 sink	51.2	25.0	17.47	9.52	57.24	0.59	7.28
	3/4" to 3/8"							
C-1087	Sized sample	14.1	5.5	44.45	10.36	28.98	1.60	5.97
C-1225	1.30 Float	6.2	3.4	51.88	20.24	15.60	3.00	3.36
C-1226	1.30 - 1.35	11.0	4.0	52.70	17.40	19.62	2.28	3.99
C-1227	1.35 - 1.40	16.0	5.7	44.39	14.84	28.42	2.00	4.80
C-1228	1.40 - 1.50	21.6	7.5	39.36	13.32	32.72	2.00	5.81
C-1229	1.50 - 1.70	31.9	10.0	34.54	12.26	32.40	2.17	10.00
C-1230	1.70 sink	54.4	25.6	12.75	8.20	57.36	0.74	9.85
	3/8" to 10 mesh							
C-1088	Sized sample	13.8	5.3	40.07	9.34	26.72	1.15	8.65
C-1198	1.30 Float	6.5	3.5	54.40	17.94	16.52	0.72	3.44
C-1199	1.30 - 1.35	9.2	3.9	52.02	16.80	18.86	0.36	4.35
C-1200	1.35 - 1.40	12.8	4.6	51.41	16.24	21.52	0.38	4.40
C-1201	1.40 - 1.50	18.1	6.1	44.79	14.14	27.76	0.96	5.73
C-1202	1.50 - 1.70	29.4	8.5	37.34	11.08	30.48	0.48	10.74
C-1203	1.70 sink	60.3	15.5	18.55	9.72	41.20	0.28	16.60
	10 to 48 mesh							
C-1089	Sized sample	17.3	5.4	27.61	6.16	20.98	2.12	19.00
C-1192	1.30 Float	3.5	3.2	56.26	19.92	14.76	0.44	3.00
C-1193	1.30 - 1.35	5.7	3.3	55.95	18.18	16.08	0.38	2.98
C-1194	1.35 - 1.40	10.4	3.9	58.61	16.48	16.52	0.72	2.27
C-1195	1.40 - 1.50	15.8	4.9	53.05	16.40	21.36	0.42	3.40
C-1196	1.50 - 1.70	27.5	7.1	43.55	14.60	25.36	0.54	7.84
C-1197	1.70 sink	61.7	12.7	13.31	6.72	22.46	0.84	31.40
	Minus 48 mesh							
C-1090	Sized sample	20.2	5.0	27.09	9.82	18.00	1.00	23.00
C-1508	1.30 Float	2.2	3.1	47.68	19.76	12.80	0.44	6.28
C-1509	1.30 - 1.35	2.5	3.0	54.10	19.50	11.28	0.38	5.12
C-1510	1.35 - 1.40	5.2	3.1	54.23	19.67	14.58	0.58	6.08
C-1511	1.40 - 1.50	10.7	2.9	54.69	20.40	11.91	1.16	6.36
C-1512	1.50 - 1.70	18.8	3.2	50.90	19.10	13.44	0.98	7.63
C-1513	1.70 sink	58.6	11.6	15.37	9.40	22.60	1.06	34.55

[1] Acid = $SiO_2 + Al_2O_3$
Base = $Fe_2O_3 + MgO + CaO + (Na_2O + K_2O)$

[2] Silica ratio = $\frac{SiO_2 \times 100}{SiO_2 + Fe_2O_3 + MgO + CaO}$

COAL ASHES (SANGAMON COUNTY)

$Na_2O + K_2O$ By Diff.	SO_3	$\frac{Acid}{Base}$ Ratio[1]	Silica Ratio[2]	Ash Fusion °F Initial Deformation	Ash Fusion °F Softening	Ash Fusion °F Fluid
3.50	9.09	1.33	53.1	1890	1900	2040
4.34	5.02	1.43	56.6	1920	1960	2040
4.42	4.22	1.34	54.9	1930	1960	2030
5.01	9.06	1.19	52.3	1910	1930	1980
2.93	21.20	0.75	39.6	1910	1960	1970
2.07	19.02	0.84	39.2	1980	2060	2080
4.34	5.02	1.43	56.6	1920	1960	2040
5.53	2.44	2.75	71.8	1710	2020	
4.91	2.60	2.08	65.4	1860	2000	2200
3.09	5.00	1.56	56.4	1880	2140	2330
3.36	4.74	1.36	53.1	1850	1970	2130
2.41	8.94	0.85	39.6	2100	2160	2430
0.68	7.22	0.41	21.2	1910	2590	2640
4.42	4.22	1.34	54.9	1930	1960	2030
4.56	1.36	2.72	70.3	1680	1950	2510
1.33	2.68	2.58	67.1	1950	2170	2430
1.75	3.80	1.60	55.8	1900	2010	2270
1.61	5.18	1.25	49.3	1930	2070	2410
0.47	8.16	1.04	43.7	1890	2020	2260
0.44	10.66	0.31	15.8	1880	2380	2470
5.01	9.06	1.19	52.3	1910	1930	1980
3.64	3.34	2.97	72.5	1830	1980	2430
3.37	4.24	2.55	68.9	1880	2000	2210
1.95	4.10	2.39	66.2	1900	2040	2540
0.68	5.94	1.68	52.6	2000	2090	2220
0.32	9.56	1.15	42.1	1860	1940	1960
0.00	13.66	0.49	24.2	1890	1960	1960
2.93	21.20	0.75	39.6	1910	1960	1970
4.66	0.96	3.33	75.6	1840	1990	2490
5.39	1.04	3.09	73.2	2020	2150	2680
3.40	2.00	3.28	75.0	1860	2110	2470
1.75	3.62	2.58	67.8	1930	2080	2350
1.51	6.60	1.65	56.4	1990	2100	2220
0.00	26.56	0.37	19.6	2090	2400	2550
2.07	19.02	0.84	39.2	1980	2060	2080
4.88	8.16	2.77	71.0	1750	1920	2180
5.40	4.22	3.32	76.3	1880	2120	2640
0.53	4.33	3.39	71.9	1910	2040	2260
0.86	4.62	3.70	73.8	1910	2130	2380
0.29	7.66	3.13	69.8	1980	2150	2420
0.62	16.40	0.42	20.9	2010	2330	2360

TABLE 3 - ANALYSES OF NO. 6

Lab No.	Description	Coal Analysis Moisture Free		Ash Analysis (percent)				
		Ash%	Sulfur%	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO
C-1689	Head (1¼" to 0)	10.4	1.9	46.94	20.19	18.82	1.24	4.62
C-1163	1 1/4" to 3/4"	9.8	1.7	54.16	23.59	14.91	1.59	2.36
C-1164	3/4" to 3/8"	9.9	1.9	52.55	22.51	16.73	1.52	2.63
C-1165	3/8" to 10 mesh	10.8	2.2	49.92	20.48	18.79	1.47	3.73
C-1166	10 to 48 mesh	14.4	2.3	44.38	20.83	16.70	1.55	8.28
C-1167	Minus 48 mesh	14.6	2.2	39.91	19.52	15.55	1.32	11.31
	1 1/4" to 3/4"							
C-1163	Sized sample	9.8	1.7	54.16	23.59	14.91	1.59	2.36
C-1245	1.30 Float	4.4	1.3	48.77	23.36	18.10	2.30	2.57
C-1246	1.30 - 1.35	8.7	1.6	55.48	23.06	14.24	2.42	1.23
C-1247	1.35 - 1.40	14.9	1.7	58.32	23.16	11.20	1.62	1.08
C-1248	1.40 - 1.50	21.1	2.1	58.88	20.48	13.12	1.94	1.50
C-1249	1.50 - 1.70	34.3	3.5	51.57	20.26	12.56	1.64	5.48
C-1250	1.70 sink	67.5	10.3	49.81	20.14	21.26	1.56	2.41
	3/4" to 3/8"							
C-1164	Sized sample	9.9	1.9	52.55	22.51	16.73	1.52	2.63
C-1257	1.30 Float	3.7	1.3	47.80	22.37	19.63	2.19	3.19
C-1258	1.30 - 1.35	8.8	1.6	54.45	22.97	15.05	1.83	1.92
C-1259	1.35 - 1.40	14.5	1.7	57.96	22.94	11.24	1.94	1.94
C-1260	1.40 - 1.50	20.7	2.2	55.94	22.03	11.84	2.10	3.61
C-1261	1.50 - 1.70	35.2	3.1	51.48	19.28	11.32	2.27	6.48
C-1262	1.70 sink	67.7	10.4	49.47	21.18	20.60	1.38	2.55
	3/8" to 10 mesh							
C-1165	Sized sample	10.8	2.2	49.92	20.48	18.79	1.47	3.73
C-1502	1.30 Float	4.6	1.4	50.94	22.12	17.74	1.34	2.63
C-1503	1.30 - 1.35	11.8	1.8	55.23	22.66	13.78	1.42	1.60
C-1504	1.35 - 1.40	16.5	2.0	57.28	21.98	12.20	1.38	1.93
C-1505	1.40 - 1.50	22.3	2.0	57.05	21.34	11.66	1.42	2.80
C-1506	1.50 - 1.70	35.2	2.9	54.14	21.10	10.20	1.52	5.87
C-1507	1.70 sink	67.9	12.1	45.94	19.56	21.92	1.95	4.67
	10 to 48 mesh							
C-1166	Sized sample	14.4	2.3	44.38	20.83	16.70	1.55	8.28
C-1239	1.30 Float	3.5	1.1	49.76	21.24	18.60	0.40	4.04
C-1240	1.30 - 1.35	10.1	1.5	56.29	22.54	12.68	0.42	2.05
C-1241	1.35 - 1.40	14.1	1.7	57.06	24.98	11.60	0.60	1.99
C-1242	1.40 - 1.50	18.1	1.7	56.86	22.60	10.32	1.18	3.02
C-1243	1.50 - 1.70	30.3	2.1	53.46	24.30	9.00	0.84	6.51
C-1244	1.70 sink	71.1	10.5	38.73	21.20	18.80	0.70	9.74
	Minus 48 mesh							
C-1167	Sized sample	14.6	2.2	39.91	19.52	15.55	1.32	11.31
C-1427	1.30 Float	1.7	0.89	46.44	22.63	10.68	0.21	8.91
C-1428	1.30 - 1.35	3.8	1.1	46.07	24.51	13.45	0.32	5.92
C-1429	1.35 - 1.40	6.4	1.1	53.18	22.40	13.20	1.67	3.98
C-1430	1.40 - 1.50	8.6	0.90	48.72	23.00	8.78	1.20	9.39
C-1431	1.50 - 1.70	10.4	0.92	54.59	26.14	9.58	1.14	4.31
C-1432	1.70 sink	62.5	9.3	34.13	18.64	19.08	0.91	14.22

[1] Acid = $SiO_2 + Al_2O_3$
Base = $Fe_2O_3 + MgO + CaO + (Na_2O + K_2O)$

[2] $$\text{Silica ratio} = \frac{SiO_2 \times 100}{SiO_2 + Fe_2O_3 + MgO + CaO}$$

COAL ASHES (WILLIAMSON COUNTY)

				Ash Fusion °F		
$Na_2O + K_2O$ By Diff.	SO_3	Acid/Base Ratio[1]	Silica Ratio[2]	Initial Deformation	Softening	Fluid
3.50	4.69	2.38	65.5	1920	2050	2260
1.95	1.44	3.73	74.2	2080	2210	2450
2.46	1.60	3.22	71.5	1950	2100	2450
2.53	3.08	2.66	67.5	1890	2040	2310
1.55	6.71	2.32	62.7	2010	2140	2410
0.77	11.62	2.05	58.6	2010	2130	2380
1.95	1.44	3.73	74.2	2080	2210	2450
4.90	0.00	2.59	68.0	1860	2120	2460
3.39	0.18	3.69	75.6	2000	2310	2500
3.98	0.64	4.56	80.8	1890	2310	2630
2.82	1.26	4.09	78.1	2310	2520	2700
3.39	5.10	3.11	72.4	1900	2050	2430
3.32	1.50	2.45	66.4	2050	2140	2330
2.46	1.60	3.22	71.5	1950	2100	2450
4.23	0.59	2.40	65.7	1830	2060	2420
3.42	0.36	3.48	74.3	1890	2290	2550
3.72	0.26	4.29	79.3	2040	2550	2740
1.73	2.75	4.04	76.1	1920	2220	2440
1.29	7.88	3.31	72.0	2050	2220	2410
3.13	1.69	2.55	66.9	1880	2020	2370
2.53	3.08	2.66	67.5	1890	2040	2310
4.19	1.04	2.82	70.1	1870	2090	2310
4.13	1.18	3.72	76.6	1890	2270	2560
3.85	1.38	4.09	78.7	1850	2290	2450
3.19	2.54	4.11	78.2	1940	2150	2550
2.91	4.26	3.67	75.5	1910	2190	2270
2.36	3.60	2.12	61.7	1880	1990	2230
1.55	6.71	2.32	62.7	2010	2140	2410
4.50	1.46	2.58	68.4	1860	2060	2270
4.80	1.22	3.95	77.5	1870	2230	2590
2.41	1.36	4.94	80.1	1920	2220	2430
3.66	2.36	4.37	79.7	2050	2450	2580
1.63	4.26	4.32	72.2	2020	2190	2450
1.11	9.72	1.97	49.9	2040	2110	2360
0.77	11.62	2.05	58.6	2010	2130	2380
2.57	8.56	3.09	62.1	1860	2030	2190
5.21	4.52	2.83	70.1	2050	2150	2500
4.15	1.42	3.29	73.8	—	—	—
2.11	6.80	3.34	71.6	1940	2130	2400
2.30	1.94	4.66	78.4	1980	2180	2560
0.00	13.11	1.54	49.9	1900	2040	2220

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