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Coal is not composed of the same mixture of materials throughout; the composition and texture of the mixes of organic portions and mineral portions can vary. This variation exists not only between different coal seams but also vertically and horizontally within the same seam. This heterogeneous aspect of coal influences the physical properties that determine how the coal will be utilized and also how the coal will be beneficiated. Designers of coal utilization facilities sometimes overlook the inherent variability of raw coal, both geographically and overtime for the same mine. Coal preparation can eliminate, or at least minimize, this variability.

The purpose of this paper is to review the basic coal properties that are commonly analyzed in coal testing and to present how these properties relate to utilization as well as how the properties of the coal amenable to coal cleaning relate to the selection of the appropriate coal-cleaning process. Four different coals will be compared for their utilization and cleaning characteristics.

The two most common uses for coal are for steam generation (or thermal use) and for producing metallurgical-grade coke for steel refining. For these two uses, a set of generalized coal analyses has been developed that determines the characteristics of the coal critical for that use. These characteristics are also important in selecting the appropriate coal and coal-cleaning process for other uses, such as synthetic fuels production. Figures 1 and 2 cover the basic coal analyses that are performed for thermal and metallurgical coal.

#### THERMAL COAL

In Figure 1 there are six main blocks: proximate analysis, ultimate analysis, the fusion temperature of the ash, the analysis of the ash, sulfur forms, and general characteristics.

#### Proximate Analysis

Moisture affects the overall coal flowability in material handling systems and the theoretical air required for the combustion of the coal in the combustion or utilization stage. Moisture is made up of both surface moisture that clings to the surface of the coal and inherent moisture in the molecular structure of the coal or in its interstitial spaces. The combination of surface and inherent moisture gives a total moisture.

Ash is the noncombustible residue left after complete combustion of the coal and consists of varying proportions of elements as outlined on the analysis of the ash. The weight of the ash is slightly less than the total mineral matter originally present before burning because some elements are volatilized during combustion.

Volatile matter is the portion of the coal which is distilled off in gas or vapor when coal is heated during a standardized time/temperature test or when it is burned. It consists of hydrocarbons and other gases resulting from distillation and decomposition. This constituent has high energy value per unit weight and is of particular importance for establishing ignition

and maintaining stable fires in thermal operations. In metallurgical coal, it is desirable to have as little volatile matter as possible consistent with strong coke formation, while for thermal coal it is desirable to have a high content of volatile matter.

Fixed carbon is a combustion residue left after distillation of the volatile matter. It is not all carbon and represents that portion of the fuel which must be burned in a solid state. It can include other oxidizing elements besides carbon. Fixed carbon is usually the major component of proximate analysis of coal and hence represents the major source of heat energy when combusted. The ash residue from the furnace or combustion usually contains some fixed carbon which is lost as far as its heat content is concerned.

#### Ultimate Analysis

The analysis of coal into its various chemical elements of carbon, hydrogen, nitrogen, oxygen, sulfur, ash, and moisture is called the ultimate analysis and is required primarily in order to calculate the overall heat losses during combustion and to determine the weights of products from combustion. For producing thermal coals, ultimate analysis is important in general boiler design for computing air requirements and hence, the size of fans, etc.

Moisture is the same as moisture content under the "Proximate Analysis."

Total carbon includes both the carbon in the fixed carbon and the carbon in the volatile matter. When combustion is complete, all this carbon burns to carbon dioxide and monoxide.

All hydrogen in the fuel burns to water ( $H_2O$ ) and together with the moisture initially in the fuel, appears as water vapor in the gases. The weight of water vapor in the products of combustion is nine times the weight of hydrogen plus original water in the fuel.

Nitrogen is present in most solid fuels owing to its vegetable origin. Its value is low, and except where  $NO_x$  levels are critical, it is of little importance because it is incombustible.

Oxygen is present in coal combined with carbon and hydrogen. The amount present gives a guide to the rank of the fuel: low-ranked fuels like lignites, for example, have high oxygen contents. The oxygen value is the sum of all the other ultimate analysis values subtracted from 100 and includes all errors in mineral matter lost in ashing.

#### Fusion Temperature of the Ash

The fusion temperature of the ash measures the temperatures required under both reduction and oxidation conditions for the ash to form a liquid slag. When ash in coal is heated, it first deforms, and then, as the temperature is increased, it becomes soft and sticky. With further increases of temperature, it fuses into a fluid. The temperature and conditions at which this occurs varies with each coal. Coals with ash that soften and fuse at comparatively low temperatures can cause problems in thermal use, except in relatively cyclonic firing.

In the laboratory, the initial deformation temperature is the temperature at which a prepared standard cone of ash just begins to fuse or show evidence of deformation at the top of the cone as it is being heated in a standard test furnace. This temperature will correspond to the operation temperature to which the particles of coal ash can cool and still retain a slight tendency to stick together or slowly to build up on heat-absorbing surfaces.

When the temperatures in the operating furnace are such that ash particles cool to a temperature lower than their initial deformation temperature, they tend to accumulate as a dry product.

The softening temperature, commonly called the fusion temperature of an ash, corresponds to an observed condition between initial deformation and fluidity. To the laboratory technician, the softening temperature is the temperature at which the test cone under observation has deformed to a shape where the height equals the width.

The hemispherical temperature is read when the cone is further deformed to the point where it assumes a hemispherical shape and its height equals one-half of its width. To the operating engineer, both softening and hemispherical temperatures are related to a point at which the fuel shows a greatly accelerated tendency to mass together and stick in large quantities to heat-absorbing surfaces.

In a laboratory determination, the fluid temperature is the temperature at which the test cone flattens out to pancake shape. To the operating engineer, the fluid temperature is related to the temperature at which the coal ash can be expected to flow in streams or drip from heat-absorbing surfaces or to the temperature at which heavy clinker forms in the grate under a fuel bed. Generally speaking, coals with high ash fusion temperatures can be used in dry-bottom furnaces, while coal with low ash fusion temperature values require wet-bottom operations.

#### Sulfur Forms

Sulfur in coal exists in either a pyritic, sulfate, or organic form. This value becomes important only when one is attempting to produce a particular sulfur level in the clean coal product. Sulfate or organic sulfurs cannot be removed from the coal with conventional coal preparation technology. Their removal requires liquid or solvent extraction methods.

#### Analysis of Ash

The control of steam and metal temperatures in boiler operation is affected by the extent of ash or slag deposits on heat-absorbing surfaces and will be severely limited by the corrosive characteristics of some types of ash and reaction products. Quantitative evaluation of mineral species is difficult, so composition of coal ash is determined by chemical analysis of the ash obtained by slow combustion of the coal under oxidizing conditions in a laboratory furnace. Although reported as oxide of the principal elements, the constituents of the ash are actually present as silicates, oxides, sulfates, or other compounds and may differ appreciably from the original forms of the mineral matter in the coal as well as from eventual compounds that may be developed by complex reactions in the operating furnace.

Phosphorus occurs in coal primarily as the mineral "apatite" and is detrimental to utilization for several reasons. It is responsible for metal corrosion in steam boilers and for causing the refractory brick utilized in some boiler fire boxes to become brittle. A high phosphorus coal would be eliminated from consideration for coke production since the phosphorus can cause extensive damage to byproduct oven walls, and if carried over into molten iron, it renders the steel difficult to roll. Silica is considered acidic and primarily refractory in a high temperature melting component of the ash.

Iron is considered basic chemically and in the ferrous state, acts as a fluxing agent in the coal ash by forming complex silicates having lower melting temperatures than iron oxides.

Alumina and titanium are acidic. Alumina also is primarily refractory in character.

Calcium and magnesium are basic and act as fluxes in the ash. These elements react readily with sulfates, limiting their reactivity with alkaline elements to form the undesirable low temperature alkali salts known to be responsible for slagging, fouling, and corrosion of boilers. The mechanism of clinker formations is very complex and not amenable to precise definition.

The alkali metals, sodium and potassium, are basic and act as fluxes. Even in small percentages, they play an important role in bank fouling by volatilization of low temperature eutectics and later deposition in certain boiler areas. Accumulation of ash or slag on steam-generating and superheating surfaces retards heat transfer, obstructs gas flow through the tubes, and may lead to maldistribution of flow and temperature, thereby reducing capacity and forcing shutdown. Corrosive compounds may attack pressure parts and supporting structures.

Increased effort is being spent to identify those characteristics of the ash which cause difficulties in boiler operation.

#### Other Coal Characteristics

The Hardgrove Grindability Index (HGI) of coal is a measure of the ease with which coal can be ground to the required size. High values, 70-90+, represent soft coal; low values, 30-40, represent a very hard coal. A general index of 100 has been designated as a standard; coals whose indices are higher than 100 are soft and those with indices below 100 are hard. The farther from 100 the HGI for a coal is, the harder the coal.

The  $T_{250}$  temperature is that temperature at which the viscosity of the slag is 250 poise when 20% of the iron in the slag is present in the ferric form. It can be determined by direct measurement but seldom is because of the difficulty and expense of running the test. Unless specified, the value given is assumed to be an estimated value determined by taking the hemispherical temperature  $H = W$  at oxidation and adding 105°. (If  $H = W$  is 2,000°F,  $T_{250} = 2150$ °F.) The maximum viscosity of molten slag that can readily be tapped from a boiler is about 250 poise. This test to determine  $T_{250}$  temperature was originally designed to determine what temperature would be required to obtain the necessary viscosity in a wet-bottom furnace. It is also used by some manufacturers to indicate the degree of slagging problems for which they must allow in the design of dry-bottom units. On dry-bottom units, high values are desired.

The temperature of critical viscosity (CVT) is that temperature at which the viscosity properties of the molten slag change in cooling from those of the plutonium fluid to those of a Bingham plastic. As the slag is cooled, the logarithm of its viscosity increases linearly with decreasing temperature. At some point, the progression deviates from a straight line, and viscosity tends to increase more rapidly as temperature is decreased. The point at which this deviation takes place has been termed the temperature of critical viscosity and is believed to be the temperature where solid phases start to crystallize from the melt. If the true CVT in the furnace is known, it allows prediction of the temperature at which molten slag will run freely from the furnace walls and tubes. Since the value is a function of the state of oxidation of iron in the slag and thus of furnace operating conditions and since values reported are generally estimated from the initial deformation temperature under reducing conditions, the CVT value has no

advantage for this purpose over ash fusion results. The CVT does provide a guide to the minimum temperature below which the slag viscosity cannot be determined.

Fouling Index (Rf) is a relative indicator of fouling in the boiler, fouling being the undesirable deposition of ash on heat-absorbing surfaces which hinders heat transfer and increases air draft pressures, thus reducing overall boiler efficiency. The deposit may be corrosive to metals at temperatures between 100 and 1,300°F.

The Rf is base-to-acid ratio times the sodium oxide in the ash. The fouling factor is used to indicate the relative propensity of coals with "eastern," or ashes with high sodium content to cause fouling of convection section surfaces. "Western," or lignite ashes (low sodium) have an advantage, in addition to their content, over "eastern" coals due to their relatively low water sodium content. Sodium content is determined by the water soluble forms and the actual level for a western coal can be above that of an eastern coal. The term "western" is used only because most of the low sodium coals are in the West. Just because a coal comes from the West does not mean it has a western-type ash. An analysis of the sodium content must be made to determine whether it is classed as a "western-" or "eastern-" type ash coal.

Slagging Index (Rs) is a relative indicator of the slagging in the fire box. Slag is the molten ash suspended from the walls in the bottom of the boiler which hinders heat transfer in the primary heaters. The Rs is calculated from the base-to-acid ratio times the total dry sulfur in the coal. The slagging index has no theoretical basis; however, its developers report that it has a reasonable correlation with slagging problems, particularly for dry-bottom furnaces.

The base-to-acid ratio is the percent of total basic material to total acidic material in a coal ash. Since it is a ratio, its lower limit can approach but never reach zero, and its upper limit approaches infinity. It is generally used only on a range of 1.0 to 0.1. The base-to-acid ratio has been empirically correlated with ash melting and viscosity problems, as listed above. At values less than 0.75, the melting temperature and viscosity of the ash and given temperature decreases as the base-to-acid ratio increases. A maximum ratio is frequently specified for coal intended for dry-bottom furnaces to guard against slag buildup problems.

#### METALLURGICAL COAL

Figure 2 presents the results of analyses performed for metallurgical coal that are not normally performed for thermal coal, these being plastic properties and petrographic analyses.

#### Plastic Properties of Coal

Coals within the bituminous range tend to be thermoplastic. The optimum development of these properties occurs within the ranges of about 88 to 89% carbon and about 25 to 30% volatile matter. The importance of the quantitative measurement of the plastic behavior of coal has long been recognized by those involved in the assessment of coals for coking purposes. To this end, a variety of techniques ranging from the simple to the complicated have been devised; these include the free swelling index, Gray-King coke type, Roga index, the microscope hot stage, and a variety of penetrometer, dilatometer, and plastometer tests. Some of these will be described briefly in this section.

The Free Swelling Index (FSI) test quantifies the plastic behavior of coal when a 1-gram sample is rapidly heated in a small crucible to 820°C in 2-1/2 minutes. The cross-sectional profile of the resulting coke bottom is compared to standard profiles numbered from 1 to 9 in half units.

Although intended primarily to provide some indication of the caking and swelling behavior of coal under the rapid heating of combustion processes, the test is often used as a very rough method of assessing the potential of coal for metallurgical coke making. The test is highly empirical, and the size and the shape of the crucible, the heating rate, and other test details have been carefully specified. Results can be invalidated by too fine a size consist of the coal sample or too high a temperature gradient from the bottom to the top of the crucible.

Geisler plasticity and other similar tests are used for a more accurate reading of the plastic properties of the coal. In the coking process, coal passes through the plastic state when it is heated over the temperature range of approximately 400° to 500°C. Above this range, both fusion and decomposition of the fusible constituents of coking coals occur, and the degree of plasticity is determined by the relative rapidity of these processes. It is believed that the degree of plasticity is an important factor in determining the coking power of coal because the most pronounced chemical and physical changes of the coking process take place while it is plastic. Accordingly, a number of laboratory methods have been devised for measuring plasticity, among which those involving resistance of the plastic coal to passage of gases, resistance to stirring, and relative swelling are perhaps the most widely used.

The Bureau of Mines has studied these methods of measuring plasticity and has attempted to correlate the results of the tests with the coking properties of 30 coking coals. The correlation obtained was not close enough to make predictions of small differences in coking power possible. Perhaps this result is not surprising when the rapidity of the changes taking place and their high sensitivity to temperature and rate of heating are considered.

Furthermore, plasticity develops in a coke oven in layers from the walls to the middle of the charge as coking progresses, and the conditions under which it develops are imperfectly known. It is probable that these conditions are not simulated closely in the empirical laboratory plastic range where the charge passes through the plastic range as a whole.

#### Petrographic Analyses

The petrographic analysis of a coal was originally used to study coal as a rock and to identify the various dull and bright bands that occur. Two methods were used: the thin section method and the polished surface method. By studying the various lithotypes and microlithotypes present under a microscope, more or less homogeneous constituents were found which are called macerals (similar to minerals in inorganic rocks). These macerals were called vitrinite, fusinite, semifusinite, resinite, and micrinite. Each of the various macerals have definite characteristics which, in turn, determine the characteristics of the particular coal. By knowing the amount of the various macerals present, the present-day petrographer can predict the behavior of a particular coal under certain conditions. This knowledge is used in determining blends of coals for use in making coke. Other uses are being investigated, such as coal liquification.



## BENEFICIATING COAL

The preceding sections dealt with how coal is analyzed to determine variables such as percentage of ash, volatility, fixed carbon content, and heating values not uniformly distributed in the coal. These variables can be removed by a physical beneficiation process.

All coals exhibit a gradation between the lightest and the heaviest materials they contain, with no distinct, sharp division between clean coal and impurities.

As a mixture of comparatively light organic compounds and heavy mineral matter, coal exhibits a quality versus specific gravity relationship. Depending on the rank of the coal, various values ranging between 1.2 and 1.7 have been used as the specific gravity of "pure coal." The common impurities (mineral matter) associated with coal have specific gravities above this range. Shale, clay, and sandstone, if pure, have a specific gravity of about 2.6. Carbonaceous shale ranges in specific gravity from 2.0 to less than 2.6 depending on the amount of carbonaceous material present. Gypsum, kaolin, and calcite have specific gravities of 2.3, 2.6, and 2.7, respectively.

The specific gravity analysis, made by immersing a sample of coal in a series of float-and-sink baths of increasing specific gravity and recovering and analyzing the gravity fractions recovered, is the standard method of evaluating the washability characteristics of coal.

All of the coal-cleaning methods in general use, except froth flotation, employ methods of gravity concentrating. Consequently, the specific gravities of the impurities associated with coal are very important. Everything else being equal, the heavy, dense impurities can be removed in the cleaning operation more easily than the light impurities.

### Plant Performance Prediction

What percentage of the raw coal will be recovered, and what will be the coal quality of a washed coal from this raw coal? The answers to these questions must be provided by the coal preparation engineer when forecasting the performance of a coal preparation plant.

Fortunately, relatively simple calculations can take the guesswork out of predicting washery performance. The information required is indicated by performance curves for the coal washing equipment. Equipment performance is available from the original work done by the Dutch State Mines Research Institute, U.S. Bureau of Mines publications, manufacturers' data, and publications by other research organizations.

Each type of washing equipment has its own characteristic performance curve, commonly referred to as a partition curve. (The term "partition" derives from the fact that the equipment separates or partitions the coal into two fractions  $\pm$  the specific gravity of separation.) Each curve is substantially independent of the density composition of the coal being washed. The curve is dependent upon the size distribution of the feed coal.

There are two basic philosophies in dealing with the effect of different size feeds. One philosophy requires a unique partition curve for each size feed and each separating gravity. This procedure becomes very cumbersome and requires a large file of curves. A new or changed feed size is handled by recombining the sizes to match the partition curves available. This is the test followed by the U.S. Bureau of Mines which has sampled and tested various plants and process equipment and published the results.

The second philosophy is based upon the work of the Dutch State Mines Research Institute which specified that each type of gravity separating device has one generalized partition curve which is transformed to a curve for each feed size distribution and separating gravity by modifying the slope of the midsection on the general curve. This is generally referred to as a normalized curve and is based on  $\pm$  x specific gravities from a separating point referenced as zero (see Figure 3).

A variation of this second method is used by Kaiser Engineers and several other engineering firms. As such, we have a set of curves for processing equipment as well as adjustment factors (called  $E_p$ 's) for the center sections.  $E_p$  is an abbreviation for Ecart Probable Error and is a measure of the precision of separation. A low  $E_p$  (.02) indicates a very precise separation, and a high  $E_p$  (.20) indicates a very imprecise separation.

The process used for a given coal depends mainly on the following factors:

- o Capability of the process to meet the required clean coal specifications.
- o Yield of clean coal at a given quality: ash, sulfur, etc.
- o Capital and operating costs.

Water-only process plants (jigs, tables, and water-only cyclones) are generally less expensive to install and operate than heavy-media circuits (heavy-media vessels and cyclones). They have the added advantage that, quite commonly, they do not require separation of the feed into various size fractions. On the negative side, however, they all have the following disadvantages compared to the heavy-media circuits:

- o They produce lower yields for a given clean coal quality even in the case of coals which are "easy" to clean.
- o They generally do not operate well, if at all, at separation gravities below 1.60.
- o In case of "difficult" coals, they do not operate effectively.

The ease or difficulty of cleaning a coal is defined in terms of near gravity material. This is the amount of coal present within  $\pm 0.1$  specific gravity units of the selected separation (which in turn depends on the desired clean coal quality).

On the basis of experience gained with a large number of coals over many years, coal preparation engineers have devised the following scale of ease or difficulty of cleaning a coal (See Coal Preparation edited by J. Leonard and D. Mitchell):

Near Gravity Material Wt %	Separation Problem
0-7	Simple
7-10	Moderately Difficult
10-15	Difficult
15-20	Very Difficult
20-25	Exceedingly Difficult
Above 25	Formidable

Kaiser Engineers makes use of two computer programs to assist in the prediction of clean coal quality. The first program takes the washability data, adds dilution material as required, and composites the data into a form that can be used in the second program. This program can develop various raw coal qualities depending on mining conditions and seam mixes. The second program expands the raw coal composite data into more gravity fractions based on the statistical relationship of the fractions. Expansion is performed to make all data conform to a similar base. These expanded washability data are then applied to various partition curves, and the clean coal quality is calculated at different separating gravities.

The first datum calculated is the yield, because the partition curve is based on the percent weight reporting to each gravity. From the weight calculation, the ash is then calculated based on the overall direct weight versus ash distribution. The Btu per pound is calculated from the knowledge that for any coal, the Btu per pound versus cumulative ash is a straight line. Sulfur is calculated based on the sulfur and direct ash values.

To show the wide variation in coals and what can be done in beneficiating them for utilization, I have selected four very different coals from various parts of the North American continent: two thermal coals used for steam generation and two metallurgical coals.

The first coal, a thermal coal, is Illinois No. 6 from central Illinois (Tables 1 and 2). The clean coal analysis shows low ash, high sulfur, high heating (Btu) values, high volatile matter content, and a high as-received moisture content. One of the most significant drawbacks for this coal is the high sodium ash analysis. This coal is relatively easy to clean with 7% near gravity materials, as can be seen in Table 2 and Figure 4. By cleaning at 1.6 specific gravity, this coal can be reduced in total ash content by almost 50% and still reach almost 80% weight yield. Illinois No. 6 coal is mined because it is within 300 to 400 feet of the surface and is found in a wide thick seam averaging 5 to 7 feet in thickness, and it can be cleaned using water-based processes (baum jigs) with a very high yield and Btu recovery.

The strongest negative factors for Illinois No. 6 coal are that it has a high sulfur content, commonly approaching 5% in the raw coal and 3 to 3-1/2% in the clean coal. The majority of the sulfur is organic and cannot be removed by conventional coal-cleaning technology. Illinois No. 6 coal has a HGI of 56; it requires more horsepower to crush than do softer coals but not as much as some of the other coals. The overall ash analysis of the coal indicates that there can be some problems, particularly with fouling and slagging, but due to the capability to reduce the ash level by 50% in cleaning, this difficulty can be minimized. Illinois No. 6 coal from Central Illinois has a high inherent moisture added to a surface moisture of 3 to 7%, giving a total moisture that can run from 14% to as high as 17% or higher in some cases. This high moisture that can cause problems in handling and transportation as well as some problems in utilization due to the increased heat required. The volatile matter content allows for good flame stability and ease of ignition. The fusion temperatures of the ash require monitoring the temperature and the burning conditions in the bottom of the boilers or a fluid slag may develop, especially if reducing conditions are allowed to exist.

The second coal, Winifred seam, is a high-grade thermal coal from West Virginia that is sometimes used for coking (see Tables 3 and 4 and Figure 5). This coal has a high volatile matter content with a potential for gasification. It has a higher Btu and lower sulfur content than the Illinois No. 6. Winifred coal is fairly easy to clean with 7% near gravity material, an excellent yield, and a reduction in the overall ash content of

75% (9% down from 37%). A look at the ash analysis shows that Winifred coal would not be likely to cause fouling and slagging problems in the boiler. Due to the silica and aluminum content, this coal could cause wear problems in the pulverizing and ash handling systems. The low HGI of 38.6 indicates that this coal would be extremely difficult to pulverize, thus requiring the use of a great deal of energy. The fusion temperatures of the ash indicate that it never really fuses and would fire in a dry-bottom boiler with few problems. This coal lies in a very difficult-to-mine region; mining costs are significantly higher than those in the midwest. Because of a large amount of extraneous material due to partings in the coal and soft roof and floor, a heavy-media based system would be required to maximize recovery and grade. The high volatile matter content that can be increased from 25.3% to 36.8% by cleaning the coal makes this coal a possible candidate for synthetic fuel feed stock. The net reduction of ash would also be a benefit in developing synthetic fuel use.

The third coal is a metallurgical coal from British Columbia (see Tables 5 and 6 and Figure 6). The geological conditions are such that local names are the most prevalent. This coal is called the No. 8 seam because it is the eighth seam reached during mining at this locale. No. 8 seam coal is a low volatile, low ash, high fixed carbon metallurgical coal, the key indicator being that the FSI of 7 is well over the minimum of 4-1/2. The coal lies in rather thick seams, approaching 16-1/2 feet in thickness, relatively close to the surface in a remote area. The plasticity reading shows that this coal has good plastic properties; at the same time it will form a stable coke with a minimal amount of inerts in the product. No. 8 seam coal is cleaned at a low gravity and is classified as a very difficult coal to clean based on the amount of near gravity material. A heavy-media process is used to assure a maximum recovery and grade with a good yield. This coal is well suited for metallurgical purposes due to the low volatile matter. It would not be very well suited for thermal coal because of the amount of extra energy required to ensure combustion.

The last coal is called C seam coal (Tables 7 and 8 and Figure 7). It is also a metallurgical coal from British Columbia. It can be cleaned to a low ash, medium-to-high volatile content; it has an excellent free swelling index which approaches the maximum of 9. The heating values for the C seam coal are not as high as those for the other coals, but the petrographic characteristics show higher content of total reactivities than for the 8 seam coal. The C seam coal with 12% near gravity material is easier to clean than the 8 seam coal with 18% near gravity material.

The optimum cleaning method and the cleaning gravity for each of the coals can be selected. Illinois No. 6 coal would be used primarily as a thermal coal. We can make a significant upgrade in the overall quality of a coal by cleaning. A look at the washability analysis on Table 2 indicates that Illinois No. 6 coal should be cleaned at about 1.6 specific gravity. At a gravity of 1.6, it has a low amount of new gravity material. Based on this fact, we can consider low efficiency of cleaning devices such as the jig or other water processes. Experience has shown that this coal can be clean at relatively coarse sizes with a reduction in crushing requirements. A water-based process (baum jigs) is commonly used to clean only the coarse sizes of this coal, with all material being run through the jig and then the fines that were not cleaned (commonly minus 1/4 inch) dewatered and reclaimed with the coarse coal (plus 1/4 inch). To date it has not been considered economical to clean the fine sizes, but in light of increased environmental concerns and given increased plans for synthetic feed stock, cleaning of the fines to enhance the overall clean coal character probably has some merit. This process would be done in water-based processes for the 1/4-inch by 28-mesh of minus-1/4-inch by 60-mesh material, and froth flotation would be used on the fine (minus-60-mesh) sizes.

To reach acceptable ash levels, Winifred seam coal needs to be cleaned at a gravity of 1.7. Again, there is little near gravity material. A preliminary selection of a water-based process would be feasible; even the same flowsheet as recommended for the Illinois coal could possibly be used. Further allowance for problems associated with the partings and roof and floor may dictate a heavy media system. An economic analysis would need to be performed before making the final selection. This coal shows the effect of why cleaning prior to utilization has strong advantages. A look at the washability shows that 40% of the raw feed at 80% ash can be rejected with a minimal loss of total Btu's.

The specific gravity of cleaning of the 8 seam coal is 1.5 and the amount of near gravity material is 20%, making this an extremely difficult, even formidable coal to clean with anything but very high efficiency cleaning devices. Not shown in these tables is the fact that this coal becomes progressively easier to clean in the finer sizes. A general selection of a heavy-media system, perhaps multistage, is what would be expected.

The C seam coal is a much easier coal to clean than the 8 seam. A heavy-media process is also indicated for this coal in order to maximize the ash reduction and at the same time minimize the total coal losses to the tails or refuse.

The overall coal analysis helps determine how the coal will be used. The washability analysis determines how it will be cleaned. The interplay of the two determines how and to what extent the coal can and should be benefited to maximize the overall characteristics. The above examples should not be taken as representative of more than a specific coal from a particular mine and locale. Coal by its very nature has a high variability from one seam or locale to another. Understanding of these variations and their import on utilization can assure the coal consumer of more satisfactory results. All else being equal, coal preparation can lead to a more uniform product.

#### BIBLIOGRAPHY

- Cassidy, S. M., editor, Elements of Practice Coal Mining, AIME, 1973.  
 Leonard, J. W. and D. R. Mitchell, editors, Coal Preparation, AIME, 1966; 1978.  
 Mitchell, David R., editor, Coal Preparation, AIME, 1950.  
 U.S. Department of Energy, Scientific Problems of Coal Utilization, 1978.

## Coal Analysis

FIGURE 1

Client \_\_\_\_\_ Date \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam \_\_\_\_\_  
 Type of Sample \_\_\_\_\_  
 Purpose \_\_\_\_\_  
 Remarks \_\_\_\_\_

### PROXIMATE

Percent of	As Received	Dry
Moisture	_____	_____
Ash	_____	_____
Volatile	_____	_____
Fixed Carbon	_____	_____
BTU	_____	_____
Sulfur	_____	_____
Alkalies as Na <sub>2</sub> O	_____	_____

### FUSION TEMPERATURE OF ASH

	Reduction	Oxidation
Initial Deform.	_____	_____
Softening (H = W)	_____	_____
Softening (H = 1/2 W)	_____	_____
Fluid Temperature	_____	_____

### SULFUR FORMS

	As Received	Dry
Pyritic	_____	_____
Sulfate	_____	_____
Organic	_____	_____
Total	_____	_____

HGI

T<sub>800</sub>

CVT

R<sub>f</sub>

R<sub>s</sub>

B/A

### ULTIMATE

Percent of	As Received	Dry
Moisture	_____	_____
Carbon	_____	_____
Hydrogen	_____	_____
Nitrogen	_____	_____
Chlorine	_____	_____
Sulfur	_____	_____
Ash	_____	_____
Oxygen	_____	_____

### ANALYSIS OF ASH

	Ignition Basis
Phosphorus pentoxide (P <sub>2</sub> O <sub>5</sub> )	_____
Silica (SiO <sub>2</sub> )	_____
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )	_____
Alumina (Al <sub>2</sub> O <sub>3</sub> )	_____
Titanium (TiO <sub>2</sub> )	_____
Lime (CaO)	_____
Magnesia (MgO)	_____
Sulfur trioxide (SO <sub>3</sub> )	_____
Potassium oxide (K <sub>2</sub> O)	_____
Sodium oxide (Na <sub>2</sub> O)	_____
Undetermined	_____

### COMMENTS

## Coal Analysis

FIGURE 2

Client \_\_\_\_\_ Date \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam \_\_\_\_\_  
 Type of Sample \_\_\_\_\_  
 Purpose \_\_\_\_\_  
 Remarks \_\_\_\_\_

## PROXIMATE

Percent of	As Received	Dry
Moisture	_____	_____
Ash	_____	_____
Volatile	_____	_____
Fixed Carbon	_____	_____
BTU	_____	_____
Sulfur	_____	_____
Alkalies as Na <sub>2</sub> O	_____	_____

## GEISLER PLASTICITY

Maximum Fluidity	(dd/min)	_____
Maximum Fluidity	°C	_____
Start	°C	_____
End	°C	_____
Range	°C	_____

## SULFUR FORMS

	As Received	Dry
Pyritic	_____	_____
Sulfate	_____	_____
Organic	_____	_____
Total	_____	_____

## PETROGRAPHIC ANALYSIS (Vol. in %)

Inertinite Suite	_____
Exinite Suite	_____
Inertinite Suite	_____
Minerals	_____

FSI	_____
HGI	_____
	_____
	_____
	_____

## ULTIMATE

Percent of	As Received	Dry
Moisture	_____	_____
Carbon	_____	_____
Hydrogen	_____	_____
Nitrogen	_____	_____
Chlorine	_____	_____
Sulfur	_____	_____
Ash	_____	_____
Oxygen	_____	_____

## ANALYSIS OF ASH

	Ignition Basis
Phosphorus pentoxide (P <sub>2</sub> O <sub>5</sub> )	_____
Silica (SiO <sub>2</sub> )	_____
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )	_____
Alumina (Al <sub>2</sub> O <sub>3</sub> )	_____
Titanium (TiO <sub>2</sub> )	_____
Lime (CaO)	_____
Magnesia (MgO)	_____
Sulfur trioxide (SO <sub>3</sub> )	_____
Potassium oxide (K <sub>2</sub> O)	_____
Sodium oxide (Na <sub>2</sub> O)	_____
Undetermined	_____

## COMMENTS

	_____
	_____
	_____
	_____
	_____

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TABLE 1

## Coal Analysis

Client \_\_\_\_\_ Date \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam \_\_\_\_\_  
 Type of Sample Illinois No. 6  
 Purpose \_\_\_\_\_  
 Remarks Clean @ 1.60 Sp. Gr.  
6" x 0

## PROXIMATE

Percent of	As Received	Dry
Moisture	15.5	—
Ash	7.9	9.4
Volatile	33.7	39.9
Fixed Carbon	42.9	50.7
BTU	10850	12840
Sulfur	3.1	3.7
Alkalies as Na <sub>2</sub> O	0.2	0.3

## FUSION TEMPERATURE OF ASH

	Reduction	Oxidation
Initial Deform.	1995	2271
Softening (H = W)	2067	2370
Softening (H = 1/2 W)	2100	2411
Fluid Temperature	2165	2487

## SULFUR FORMS

	As Received	Dry
Pyritic	1.0	1.0
Sulfate	0.02	0.02
Organic	2.1	2.5
Total	3.1	3.7

HGI	56.0
T <sub>1st</sub>	2421
CVT	2300
R <sub>1</sub>	.6
R <sub>5</sub>	1.5
B/A	0.4
FSI	N.A.

## ULTIMATE

Percent of	As Received	Dry
Moisture	15.5	—
Carbon	60.3	71.4
Hydrogen	4.1	4.9
Nitrogen	0.9	1.1
Chlorine	0.1	0.1
Sulfur	3.1	3.7
Ash	7.9	9.4
Oxygen	8.0	9.4

## ANALYSIS OF ASH

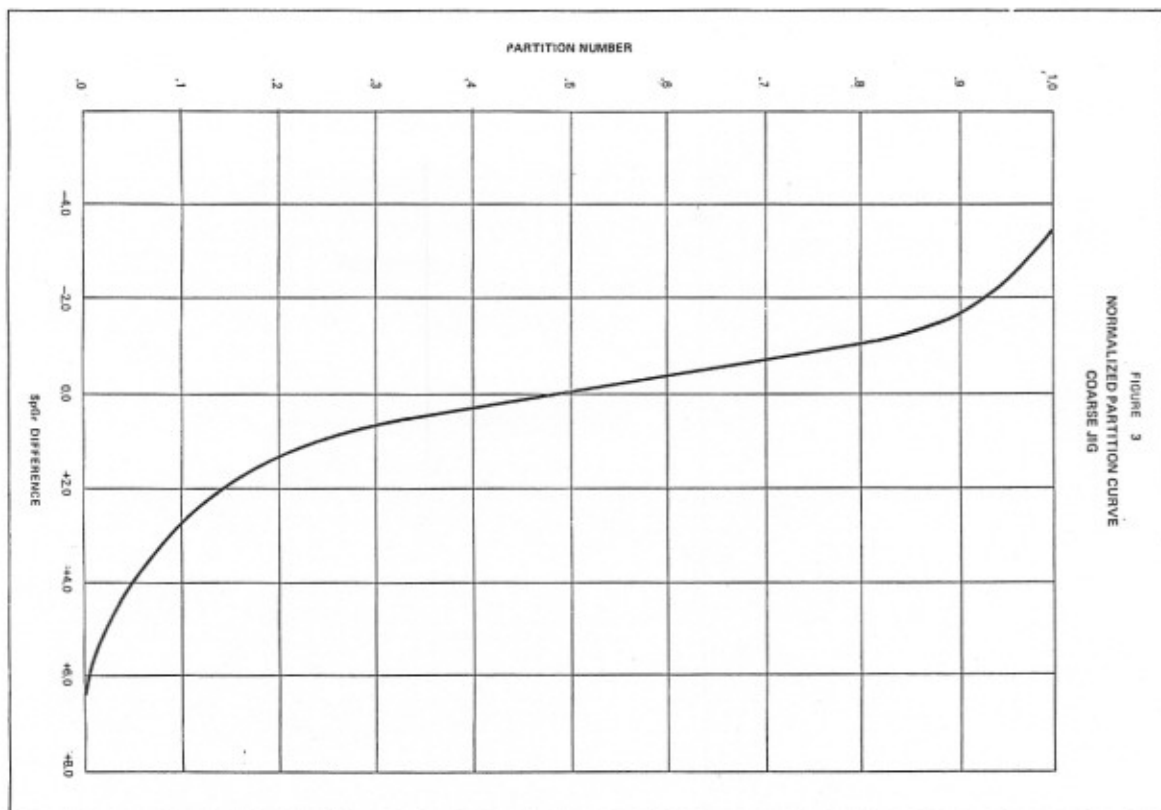
	Ignition Basis
Phosphorus pentoxide (P <sub>2</sub> O <sub>5</sub> )	0.1
Silica (SiO <sub>2</sub> )	46.9
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )	18.1
Alumina (Al <sub>2</sub> O <sub>3</sub> )	19.9
Titanium (TiO <sub>2</sub> )	0.9
Lime (CaO)	5.0
Magnesia (MgO)	0.9
Sulfur trioxide (SO <sub>3</sub> )	3.6
Potassium oxide (K <sub>2</sub> O)	1.9
Sodium oxide (Na <sub>2</sub> O)	1.6
Undetermined	1.2

## COMMENTS

	_____
	_____
	_____
	_____
	_____

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FORM 3

TABLE 2

## Float and Sink Tables

Client \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam Illinois No. 6  
 Type of Sample \_\_\_\_\_  
 Purpose \_\_\_\_\_  
 Remarks \_\_\_\_\_

Date \_\_\_\_\_  
 Percent of Total \_\_\_\_\_  
 Size 6" x 0

Specific Gravity		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	Percent Weight	Percent Ash	Percent Sulfur	BTU/LB.	Percent Weight	Percent Ash	Percent Sulfur	BTU/LB.	Percent Weight	Percent Ash	Percent Sulfur	BTU/LB.
	1.30	41.74	5.56	4.10	14173	41.74	5.56	4.10	14173				
1.30	1.35	11.62	9.78	4.70	14003	53.36	6.48	4.23	14136				
1.35	1.40	8.25	11.68	4.86	13432	62.21	7.22	4.32	14107				
1.40	1.45	6.51	14.26	5.10	13962	68.78	7.88	4.39	14081				
1.45	1.50	4.73	17.20	5.01	13708	73.51	8.48	4.43	14057				
1.5	1.60	2.21	21.41	5.47	13303	79.02	9.56	4.50	14014				
1.60	1.70	.61	44.81	5.80	12578	79.63	9.83	4.51	14003				
1.70	1.80	1.00	46.07	6.47	12559	80.64	10.28	4.54	13985				
1.80		19.36	63.90	6.14	11851	100.00	20.66	4.85	13572				

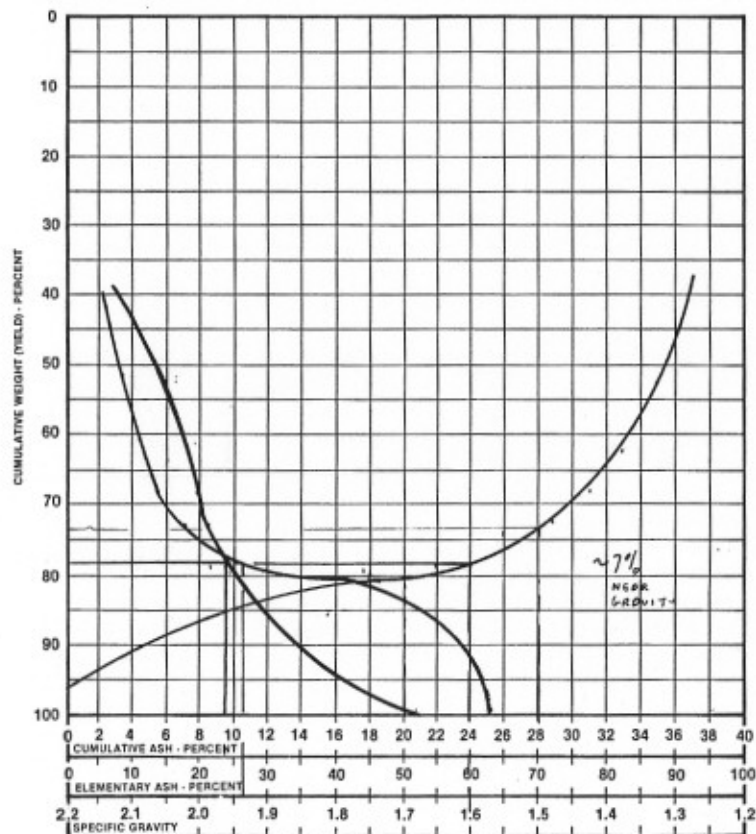
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FIGURE 4

## Washability Curves

Client \_\_\_\_\_ Date \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam Illinois No. 6  
 Type of Sample 6" x 0 7% near gravity  
 Purpose \_\_\_\_\_ 1.60 separating gravity  
 Remarks \_\_\_\_\_



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TABLE 3

## Coal Analysis

Client Illinois No. 6 Date \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam Winifred  
 Type of Sample \_\_\_\_\_  
 Purpose \_\_\_\_\_  
 Remarks Clean @ 1.70 Sp. Gr.

## PROXIMATE

Percent of	As Received	Dry
Moisture	8.0	—
Ash	8.1	8.8
Volatile	33.9	36.8
Fixed Carbon	50.0	54.4
BTU	12907	13486
Sulfur	0.8	0.9
Alkalies as Na <sub>2</sub> O	0.1	0.1

## FUSION TEMPERATURE OF ASH

	Reduction	Oxidation
Initial Deform.	2820 +	2820 +
Softening (H = W)	2820 +	2820 +
Softening (H = 1/2 W)	2820 +	2820 +
Fluid Temperature	2820 +	2820 +

## SULFUR FORMS

	As Received	Dry
Pyritic	0.2	0.2
Sulfate	0	0
Organic	0.6	0.7
Total	0.8	0.9

## ULTIMATE

Percent of	As Received	Dry
Moisture	8.0	—
Carbon	68.9	74.8
Hydrogen	4.8	5.2
Nitrogen	1.4	1.5
Chlorine	0.2	0.2
Sulfur	0.8	0.9
Ash	8.1	8.8
Oxygen	7.9	8.7

## ANALYSIS OF ASH

	Ignition Basis
Phosphorus pentoxide (P <sub>2</sub> O <sub>5</sub> )	0.2
Silica (SiO <sub>2</sub> )	56.0
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )	6.1
Alumina (Al <sub>2</sub> O <sub>3</sub> )	37.0
Titanium (TiO <sub>2</sub> )	1.4
Lime (CaO)	1.2
Magnesia (MgO)	0.1
Sulfur trioxide (SO <sub>3</sub> )	0.9
Potassium oxide (K <sub>2</sub> O)	1.4
Sodium oxide (Na <sub>2</sub> O)	0.2
Undetermined	1.0

## COMMENTS

HGI	38.6
T <sub>SH</sub>	2970 +
CVT	N/A
R <sub>I</sub>	.02
R <sub>S</sub>	.09
B/A	.10

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TABLE 14

## Float and Sink Tables

Client \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam Winifrede  
 Type of Sample \_\_\_\_\_  
 Purpose \_\_\_\_\_  
 Remarks \_\_\_\_\_

Date \_\_\_\_\_  
 Percent of Total \_\_\_\_\_  
 Size 6" x 0

Specific Gravity		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	Percent Weight	Percent Ash	Percent Sulfur	BTULB.	Percent Weight	Percent Ash	Percent Sulfur	BTULB.	Percent Weight	Percent Ash	Percent Sulfur	BTULB.
1.30	1.30	31.4	3.20	.74	14411	31.4	3.20	.74	14411	100.0	37.33	.69	8785
1.30	1.40	19.4	9.34	.98	13325	50.8	5.54	.83	13996	68.6	52.95	.66	6210
1.40	1.50	4.1	20.73	1.16	11425	54.9	6.68	.86	13804	49.2	70.15	.54	3405
1.50	1.60	2.4	30.73	1.04	9900	57.3	7.69	.86	13641	45.1	74.64	.48	2676
1.60	1.70	2.0	39.61	.98	8339	59.3	8.76	.87	13462	42.7	77.11	.45	2270
1.70	1.80	1.9	49.34	.74	6767	61.2	10.02	.86	13254	40.7	78.95	.43	1972
1.80		38.8	80.40	.41	1737	100.0	37.33	.69	8785	38.8	80.40	.41	1737

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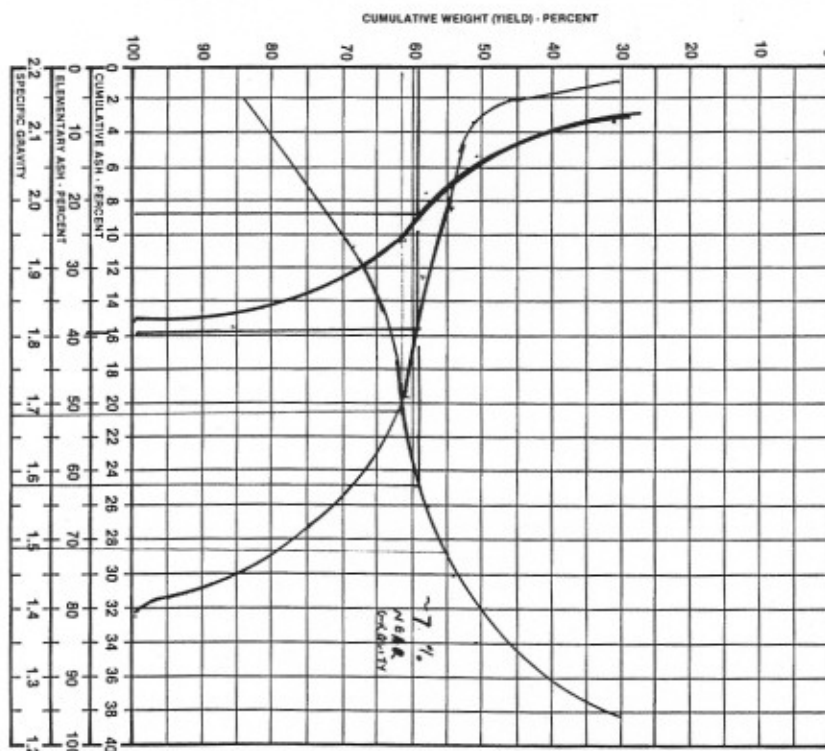
FIGURE 5

## Washability Curves

Client \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam Winifrede  
 Type of Sample 6" x 0  
 Purpose \_\_\_\_\_  
 Remarks \_\_\_\_\_

Date \_\_\_\_\_

7% near gravity  
 1.58 separating gravity



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FORM 9

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TABLE 5		Coal Analysis																																																							
Client _____		Date _____																																																							
Job Number _____		Canadian Low Vol.																																																							
Mine/Plant/Seam _____		8 seam																																																							
Type of Sample _____		Clean																																																							
Purpose _____		Remarks _____																																																							
<div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <h3>PROXIMATE</h3> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Percent of</th> <th>As Received</th> <th>Dry</th> </tr> </thead> <tbody> <tr> <td>Moisture</td> <td>7.0</td> <td>-</td> </tr> <tr> <td>Ash</td> <td>10.0</td> <td>10.8</td> </tr> <tr> <td>Volatile</td> <td>18.8</td> <td>20.2</td> </tr> <tr> <td>Fixed Carbon</td> <td>64.2</td> <td>69.0</td> </tr> <tr> <td>BTU</td> <td>13023</td> <td>14004</td> </tr> <tr> <td>Sulfur</td> <td>0.5</td> <td>0.5</td> </tr> <tr> <td>Alkalies as Na<sub>2</sub>O</td> <td>N/A</td> <td>N/A</td> </tr> </tbody> </table> </div> <div style="width: 48%;"> <h3>GEISLER PLASTICITY</h3> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Maximum Plasticity</th> <th>(dmm)</th> <th>125.0</th> </tr> </thead> <tbody> <tr> <td>Maximum Plasticity</td> <td>°C</td> <td>475</td> </tr> <tr> <td>Soft</td> <td>°C</td> <td>363</td> </tr> <tr> <td>End</td> <td>°C</td> <td>508</td> </tr> <tr> <td>Range</td> <td>°C</td> <td>60</td> </tr> </tbody> </table> </div> </div>				Percent of	As Received	Dry	Moisture	7.0	-	Ash	10.0	10.8	Volatile	18.8	20.2	Fixed Carbon	64.2	69.0	BTU	13023	14004	Sulfur	0.5	0.5	Alkalies as Na <sub>2</sub> O	N/A	N/A	Maximum Plasticity	(dmm)	125.0	Maximum Plasticity	°C	475	Soft	°C	363	End	°C	508	Range	°C	60															
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TABLE 6													
Float and Sink Tables													
Client <u>Canadian Metallurgical Coal</u>										Date _____			
Job Number _____										Percent of Total <u>82.9%</u>			
Mine/Plant/Seam _____										Size <u>-4" x 60 M</u>			
Type of Sample _____													
Purpose _____													
Remarks _____													
Specific Gravity		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
		Percent Weight	Percent Ash	Percent Sulfur	BTU/LB.	Percent Weight	Percent Ash	Percent Sulfur	BTU/LB.	Percent Weight	Percent Ash	Percent Sulfur	BTU/LB.
Sink	Float												
1.30	1.30	13.0	3.3	-	-	13.0	3.3	-	-				
1.35	1.35	14.5	6.9	-	-	27.5	5.2	-	-				
1.40	1.40	14.2	10.7	-	-	41.6	7.1	-	-				
1.45	1.45	10.0	15.7	-	-	51.7	8.8	-	-				
1.50	1.50	6.3	20.6	-	-	58.0	10.0	-	-				
1.55	1.55	4.3	25.1	-	-	62.3	11.1	-	-				
1.60	1.60	2.2	30.8	-	-	64.5	11.8	-	-				
1.65	1.65	3.8	36.8	-	-	68.3	13.1	-	-				
1.70	1.70	1.7	44.3	-	-	70.0	13.9	-	-				
1.80	1.80	30.0	80.8	-	-	100.0	33.8	-	-				

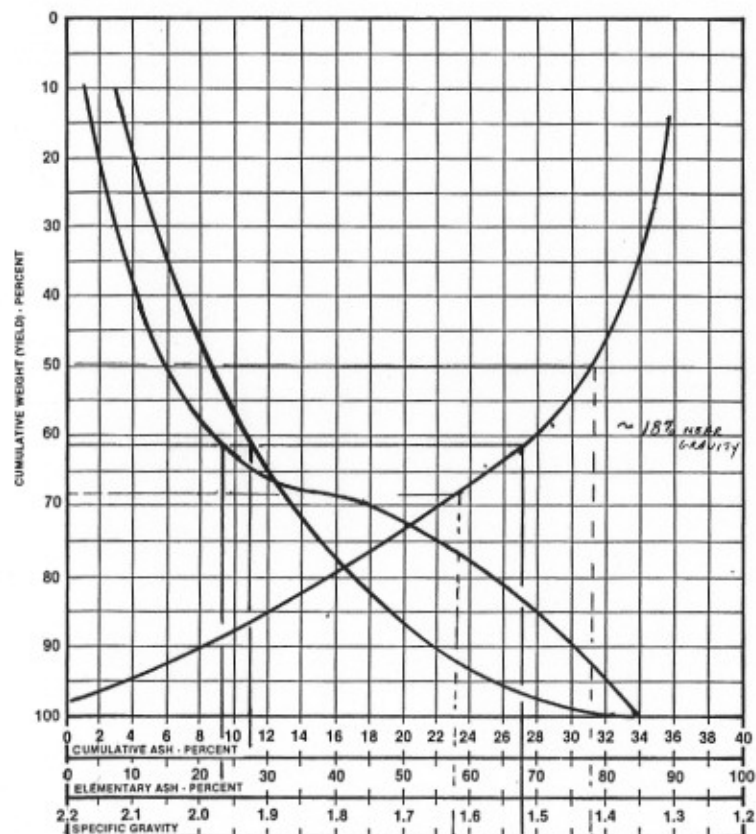
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FIGURE 6

## Washability Curves

Client \_\_\_\_\_ Date \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam Canadian High Vol.  
 Type of Sample C seam  
 Purpose 4" x 60 M  
 Remarks \_\_\_\_\_

18% near gravity  
 1.52 separating gravity



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## Coal Analysis

TABLE 7

Client \_\_\_\_\_ Date \_\_\_\_\_  
 Job Number \_\_\_\_\_  
 Mine/Plant/Seam Canadian High Vol.  
 Type of Sample C seam  
 Purpose \_\_\_\_\_  
 Remarks clean

## PROXIMATE

Percent of	As Received	Dry
Moisture	8.0	—
Ash	5.0	5.4
Volatile	26.8	29.1
Fixed Carbon	60.5	65.8
BTU	13351	14512
Sulfur	.5	0.5
Alkalies as Na <sub>2</sub> O	N/A	N/A

## GEISLER PLASTICITY

Maximum Fluidity	(dd/min)	430.0
Maximum Fluidity	°C	439
Start	°C	362
End	°C	487
Range	°C	75

## SULFUR FORMS Not Analyzed

	As Received	Dry
Pyritic	—	64.7
Sulfate	—	55.2
Organic	—	17.1
Total	—	3.3

## PETROGRAPHIC ANALYSIS (Vol. in %)

Inertinite Suite	—
Exinite Suite	—
Inertinite Suite	—
Minerals	—

FSI	8.
HGI	85.0

## ULTIMATE Not Analyzed

Percent of	As Received	Dry
Moisture	—	—
Carbon	—	—
Hydrogen	—	—
Nitrogen	—	—
Chlorine	—	—
Sulfur	—	—
Ash	—	—
Oxygen	—	—

## ANALYSIS OF ASH Not Analyzed

	Ignition Basis
Phosphorus pentoxide (P <sub>2</sub> O <sub>5</sub> )	—
Silica (SiO <sub>2</sub> )	—
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )	—
Alumina (Al <sub>2</sub> O <sub>3</sub> )	—
Titanium (TiO <sub>2</sub> )	—
Lime (CaO)	—
Magnesia (MgO)	—
Sulfur trioxide (SO <sub>3</sub> )	—
Potassium oxide (K <sub>2</sub> O)	—
Sodium oxide (Na <sub>2</sub> O)	—
Undetermined	—

## COMMENTS

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TABLE 8  
Float and Sink Tables

Client: \_\_\_\_\_  
Job Number: \_\_\_\_\_  
Manufacturer: \_\_\_\_\_  
Material: \_\_\_\_\_  
Purpose: \_\_\_\_\_  
Remarks: \_\_\_\_\_

Date: \_\_\_\_\_  
Percent of Total: \_\_\_\_\_  
Size: 4" x 6 1/2"

Sample Size, Lbs.	DIRECT			SIMULATED			CUMULATIVE SINK		
	Net Weight	Net Sink	Net Float	Net Weight	Net Sink	Net Float	Net Weight	Net Sink	Net Float
3.20	54.1	2.7	.88	54.1	2.7	.84	-	-	-
1.35	13.3	4.4	.60	71.4	2.6	.78	-	-	-
1.35	1.40	9.3	15.3	58	-	88.8	4.4	.76	-
1.40	1.45	4.5	14.7	.52	-	85.2	4.9	.74	-
1.45	1.50	2.9	14.6	.48	-	88.1	5.4	.74	-
1.50	1.55	3.6	24.5	.53	-	89.7	5.7	.73	-
1.55	1.60	3.3	26.4	.60	-	91.8	6.0	.73	-
1.60	1.70	3.4	34.2	.68	-	92.2	6.5	.72	-
1.70	1.85	.9	41.3	.82	-	93.2	6.8	.73	-
1.80	6.8	69.3	.45	100.0	12.1	.71	-	-	-

