Labuan Coal Characteristic

by

Muhammad Izzat Bin Abd Rahman

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

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CERTIFICATION OF APPROVAL

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Chemical Engineering Programme
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(CHEMICAL ENGINEERING)

Approved by,

(Dr. Zuhar Zahir Tuan Harith)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(MUHAMMAD IZZAT BIN ABD RAHMAN)

ABSTRACT

The characterization of Labuan Coal has been completed. The moisture content is determined using oven at 104-llO°C for three hours. The ash and the fixed carbon of the coal was determined using furnace at temperature 815 °C and 900 °C respectively at different time, 3 hours for ash content and 10 minutes for the fixed carbon content determination. The determination of Hydrogen, Nitrogen, and Sulfur content in Labuan Coal is done by using CHNS equipment while the calorific value of Labuan Coal was done by using Oxygen Bomb Calorimeter. The characterization shows that the Labuan Coal I actually the Bituminous Coal and it is suitable to use for electricity generation power plant in Malaysia.

ACKNOWLEDGEMENT

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CHAPTER 1: INTRODUCTION

Coal is a readily combustible black or brownish-black sedimentary rock normally occurring in rock strata in *layers or veins* called **coal beds**. The harder forms, such as anthracite coal, can be regarded as metamorphic rock because of later exposure to elevated temperature and pressure. It is composed primarily of carbon along with variable quantities of other elements, chiefly sulfur, hydrogen, oxygen and nitrogen.

Coal starts as layer upon layer of annual plant remains accumulating slowly that were protected from biodegradation by usually acidic covering waters that gave a natural antiseptic effect combating microorganisms and then later mud deposits protecting against oxidization in the widespread shallow seas — mainly during the Carboniferous period — thus trapping atmospheric carbon in the ground in immense peat bogs that eventually were covered over and deeply buried by sediments under which they metamorphosed into coal. Over time, the chemical and physical properties of the plant remains (believed to mainly have been fern-like species antedating more modern plant and tree species) were changed by geological action to create a solid material.

Coal, a fossil fuel, is the largest source of energy for the generation of electricity worldwide, as well as one of the largest worldwide anthropogenic sources of carbon dioxide emissions. Gross carbon dioxide emissions from coal usage are slightly more than those from petroleum and about double the amount from natural gas. Coal is extracted from the ground by mining, either underground or in open pits. ((Brian H. Bowen, Marty W. Irwin, 2007)

Basic characterization of coal

Types of coal

As geological processes apply pressure to dead biotic matter over time, under suitable conditions it is transformed successively into

- **Peat**, considered to be a precursor of coal, has industrial importance as a fuel in some regions, for example, Ireland and Finland.
- **Lignite**, also referred to as brown coal, is the lowest rank of coal and used almost exclusively as fuel for electric power generation. Jet is a compact form of lignite that is sometimes polished and has been used as an ornamental stone since the Iron Age.
- **Sub-bituminous** coal, whose properties range from those of lignite to those of bituminous coal is used primarily as fuel for steam-electric power generation. Additionally, it is an important source of light aromatic hydrocarbons for the chemical synthesis industry.
- **Bituminous** coal, dense mineral, black but sometimes dark brown, often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make coke.
- **Anthracite**, the highest rank; a harder, glossy, black coal used primarily for residential and commercial space heating. It may be divided further into metamorphic ally altered bituminous coal and *petrified oil*, as from the deposits in Pennsylvania.
- **Graphite**, technically the highest rank, but difficult to ignite and is not so commonly used as fuel: it is mostly used in pencils and, when powdered, as a lubricant.

The classification of coal is generally based on the content of volatiles. However, the exact classification varies between countries (Brian H. Bowen, Marty W. Irwin, 2007)

Coal Typical content

Table 1: Coal contents according to type of coal

(% Weight)	Anthracite	Bituminous	Lignite
Moisture	2.8 – 16.3	2.2 – 15.9	39.0
Fixed Carbon	80.5 – 85.7	44.9 – 78.2	31.4
Ash	9.7 – 20.2	3.3 – 11.7	4.2
Sulfur	0.6 – 0.77	0.7 – 4.0	0.4
Bulk Density (lb/ft^3)	50 - 58	42 - 57	40 - 54

Early use

Outcrop coal was used in Britain during the Bronze Age (2000-3000 years BC), where it has been detected as forming part of the composition of funeral pyres. The earliest recognized use is from the Shenyang area 4000 BC where Neolithic inhabitants had begun carving ornaments from black lignite, but it was not until the Han Dynasty (206 BC–220 AD) that coal was also used for fuel. In Roman Britain, with the exception of two modern fields, "the Romans were exploiting coals in all the major coalfields in England and Wales by the end of the second century AD". Evidence of trade in coal (dated to about AD 200) has been found at the inland port of Heronbridge, near Chester, and in the Fenlands of East Anglia, where coal from the Midlands was transported via the Car Dyke for use in drying grain. Coal cinders have been found in the hearths of villas and military forts, particularly in Northumberland, dated to around AD 400. In the west of England contemporary writers described the wonder of a permanent brazier of coal on the altar of Minerva at Aquae Sulis (modern day Bath) although in fact easily-accessible surface coal from what became the Somerset coalfield was in common use in quite lowly dwellings locally. Evidence of coal's use for iron-working in the city during the Roman period has been found.

There is no evidence that the product was of great importance in Britain before the High Middle Ages, after about AD 1000. Mineral coal came to be referred to as "seacoal," probably because it came to many places in eastern England, including London, by sea. This is accepted as the more likely explanation for the name than that it was found on beaches, having fallen from the exposed coal seams above or washed out of underwater coal seam outcrops. These easily accessible sources had largely become exhausted (or could not meet the growing demand) by the 13th century, when underground mining from shafts was developed. In London there is still a Seacoal Lane and a Newcastle Lane (from the coal-shipping city of Newcastle) where in the seventeenth century coal was unloaded at wharves along the River Fleet. An alternative name was "pitcoal," because it came from mines. It was, however, the development of the Industrial Revolution that led to the large-scale use of coal, as the steam engine took over from the water wheel.

Uses today

Coal as fuel

Coal is primarily used as a solid fuel to produce electricity and heat through combustion. World coal consumption was about 6,743,786,000 short tons in 2006 and is expected to increase 48% to 9.98 billion short tons by 2030. China produced 2.38 billion tons in 2006. India produced about 447.3 million tons in 2006. 68.7% of China's electricity comes from coal. The USA consumes about 14% of the world total, using 90% of it for generation of electricity.

When coal is used for electricity generation, it is usually pulverized and then combusted (burned) in a furnace with a boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines which turn generators and create electricity. The thermodynamic efficiency of this process has been improved over time. "Standard" steam turbines have topped out with some of the most advanced reaching about 35% thermodynamic efficiency for the entire process, although newer combined cycle plants can reach efficiencies as high as 58%. Increasing the combustion temperature can boost this efficiency even further. Old coal power plants, especially "grandfathered" plants, are significantly less efficient and produce higher levels of waste heat. About 40% of the world's electricity comes from coal, and approximately 49% of the United States electricity comes from coal.

The emergence of the supercritical turbine concept envisions running a boiler at extremely high temperatures and pressures with projected efficiencies of 46%, with further theorized increases in temperature and pressure perhaps resulting in even higher efficiencies.

Other efficient ways to use coal are combined cycle power plants, combined heat and power cogeneration, and an MHD topping cycle.

Approximately 40% of the world electricity production uses coal. The total known deposits recoverable by current technologies, including highly polluting, low energy content types of coal (i.e., lignite, bituminous), is sufficient for many years. However, consumption is increasing and maximal production could be reached within decades (see World Coal Reserves, below).

A more energy-efficient way of using coal for electricity production would be via solid-oxide fuel cells or molten-carbonate fuel cells (or any oxygen ion transport based fuel cells that do not discriminate between fuels, as long as they consume oxygen), which would be able to get 60%–85% combined efficiency (direct electricity + waste heat steam turbine). Currently these fuel cell technologies can only process gaseous fuels, and they are also sensitive to sulfur poisoning, issues which would first have to be worked out before large scale commercial success is possible with coal. As far as gaseous fuels go, one idea is pulverized coal in a gas carrier, such as nitrogen. Another option is coal gasification with water, which may lower fuel cell voltage by introducing oxygen to the fuel side of the electrolyte, but may also greatly simplify carbon sequestration. However, this technology has been criticised as being inefficient, slow, risky and costly, while doing nothing about total emissions from mining, processing and combustion. Another efficient and clean way of coal combustion in a form of coal-water slurry fuel (CWS) was well developed in Russia (since the Soviet Union time). CWS significantly reduces emissions saving the heating value of coal.

Coking and use of coke

Coke is a solid carbonaceous residue derived from low-ash, low-sulfur bituminous coal from which the volatile constituents are driven off by baking in an oven without oxygen at temperatures as high as 1,000 °C (1,832 °F) so that the fixed carbon and residual ash are fused together. Metallurgical coke is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace. The product is too rich in dissolved carbon, and must be treated further to make steel. The coke must be strong enough to resist the weight of overburden in the blast furnace, which is why coking coal is so important in making steel by the conventional route. However, the alternative route to be direct reduced iron, where any carbonaceous fuel can be used to make sponge or pelletised iron. Coke from coal is grey, hard, and porous and has a heating value of 24.8 million Btu/ton (29.6 MJ/kg). Some cokemaking processes produce valuable by-products that include coal tar, ammonia, light oils, and "coal gas".

Petroleum coke is the solid residue obtained in oil refining, which resembles coke but contains too many impurities to be useful in metallurgical applications.

Liquefaction

Coal can also be converted into liquid fuels like gasoline or diesel by several different processes. In the direct liquefaction processes, the coal is either hydrogenated or carbonized. Hydrogenation processes are the Bergius process, the SRC-I and SRC-II (Solvent Refined Coal) processes and the NUS Corporation hydrogenation process. In the process of low temperature carbonization coal is coked at temperatures between 680 °F (360 °C) and 1,380 °F (750 °C). These temperatures optimize the production of coal tars richer in lighter hydrocarbons than normal coal tar. The coal tar is then further processed into fuels. Alternatively, coal can be converted into a gas first, and then into a liquid, by using the Fischer-Tropsch process. An overview of coal liquefaction and its future potential has been done by others

Coal liquefaction methods involve carbon dioxide (CO_2) emissions in the conversion process. If coal liquefaction is done without employing either carbon capture and storage technologies or biomass blending, the result is lifecycle greenhouse gas footprints that are generally greater than those released in the extraction and refinement of liquid fuel production from crude oil. If CCS technologies are employed, reductions of 5-12% can be achieved in CTL plants and up to a 75% reduction is achievable when co-gasifying coal with commercially demonstrated levels of biomass (30% biomass by weight) in CBTL plants. For most future synthetic fuel projects, Carbon dioxide sequestration is proposed to avoid releasing it into the atmosphere. Sequestration will, however, add to the cost of production. Currently all US and at least one Chinese synthetic fuel projects, are including sequestration in their process designs. (Höök, M., Aleklett, K., 2009)

History of Labuan Coal

Coal is a complex mixture of chemical compounds, mostly organic, that results when accumulations of partly decayed plants are subjected to pressure for millions of years. Labuan coal is one of the earliest coals that were found in South East Asia around 1847 to 1911. It was first worked by William Miles between April 1847 to July 1849, under contract for the Eastern Archipelago Company. He picked the surface of seams close to the water's edge. Miles also obtained the concession to import and sell liquor. A light railway track was built from the colliery at Coal Point or Tanjung Kubong to Port Victoria. One persistent problem that faced the coal mining companies was of labors. Often there were riots and strikes. Workers from Brunei and Malaya, and convicts from India, on finishing their contracts or had served their sentences left the island quickly. The lack of basic amenities and the prevalence of malaria were cited as the causes of discontent. There was no shortage of interest in Labuan's coal as seen in the many mining companies. Among them were the Labuan Coal, the Amalgamated China Steamship and Labuan Coal and the Oriental Coal. Generally these companies were poorly managed. Opinion at the time was that Labuan coal was not of the highest quality. It burned more quickly than Welsh coal, made much more smoke, was badly hewn and badly washed. Highest output was about 5000 tons a week. In 1881 only 800 tons were produced. Coal trade soon declined and coal carrying steamers sailed to the China coasts instead. At one time owing to lack of steamers calling at Labuan, the coal at Victoria had accumulated to 8000 tons. The coal station was closed by the navy because of disuse. Today the coal chimney at Tanjung Kubong or Coal Point is a relic of the coal mining days of Labuan. About 500,000 tons of coals were produced during the 60 years that it was mined. Most of the mining land there has now been alienated for other uses. (M. Madon & A Hadi, 2006)

Coal and Electricity

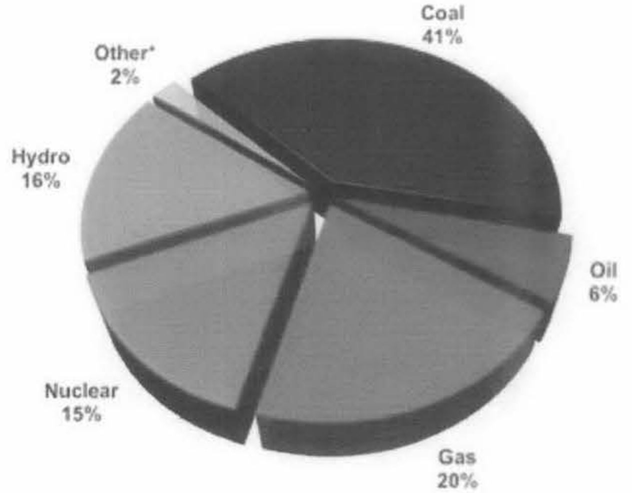


Figure 1: Total World Electricity Generation by Fuel (2006)

Modern life is unimaginable without electricity. It lights houses, buildings, streets, provides domestic and industrial heat, and powers most equipment used in homes, offices and machinery in factories. Improving access to electricity worldwide is critical to alleviating poverty.

Coal plays a vital role in electricity generation worldwide. Coal-fired power plants currently fuel 41% of global electricity. In some countries, coal fuels a higher percentage of electricity. (World coal consumption 1980-2006 October 2008 EIA statistics)

Table 2: Coal in Electricity Generation

Coal in Electricity Generation		
South Africa 94%	**Poland 93%**	**PR China 81%**
Australia 76%	**Israel 71%**	**Kazakhstan 70%**
India 68%	**Czech Rep 62%**	**Morocco 57%**
Greece 55%	**USA 49%**	**Germany 49%**

Source: IEA 2009

The importance of coal to electricity generation worldwide is set to continue, with coal fuelling 44% of global electricity in 2030.

How is Coal Converted to Electricity?

Steam coal, also known as thermal coal, is used in power stations to generate electricity.

Coal is first milled to a fine powder, which increases the surface area and allows it to burn more quickly. In these pulverized coal combustion (PCC) systems, the powdered coal is blown into the combustion chamber of a boiler where it is burnt at high temperature (see diagram below). The hot gases and heat energy produced converts water – in tubes lining the boiler – into steam.

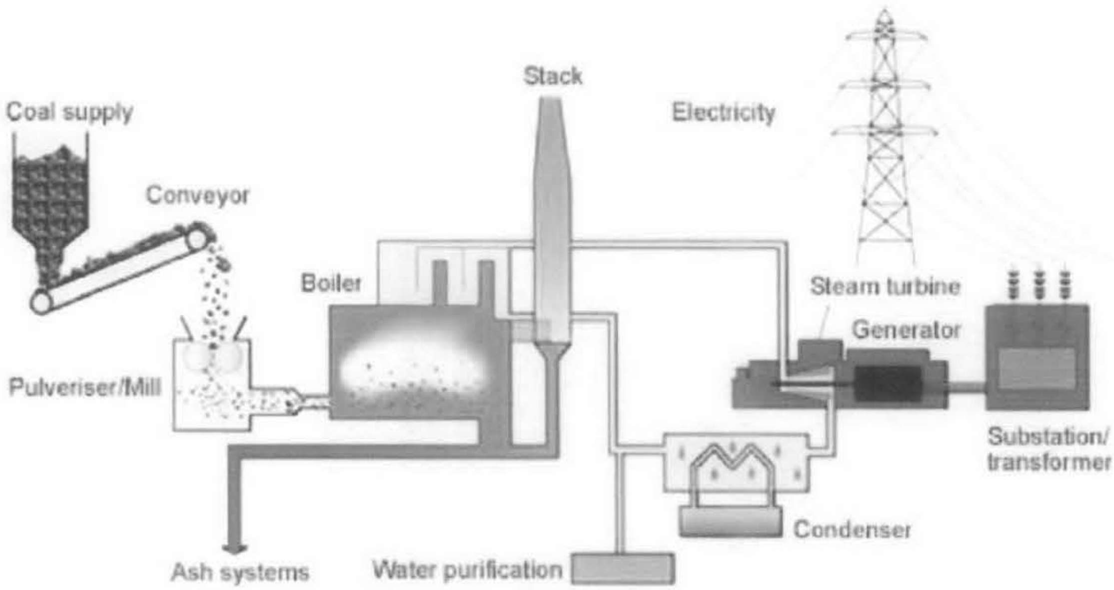


Figure 2: Power Plant Diagram

The high pressure steam is passed into a turbine containing thousands of propeller-like blades. The steam pushes these blades causing the turbine shaft to rotate at high speed. A generator is mounted at one end of the turbine shaft and consists of carefully wound wire coils. Electricity is generated when these are rapidly rotated in a strong magnetic field. After passing through the turbine, the steam is condensed and returned to the boiler to be heated once again.

The electricity generated is transformed into the higher voltages (up to 400,000 volts) used for economic, efficient transmission via power line grids. When it nears the point of consumption, such as our homes, the electricity is transformed down to the safer 100-250 voltage systems used in the domestic market.

Efficiency Improvements

Improvements continue to be made in conventional PCC power station design and new combustion technologies are being developed. These allow more electricity to be produced from less coal - known as improving the thermal efficiency of the power station. Efficiency gains in electricity generation from coal-fired power stations will play a crucial part in reducing CO_2 emissions at a global level.

Efficiency improvements include the most cost-effective and shortest lead time actions for reducing emissions from coal-fired power generation. This is particularly the case in developing countries where existing power plant efficiencies are generally lower and coal use in electricity generation is increasing. Not only do higher efficiency coal-fired power plants emit less carbon dioxide per megawatt (MW), they are also more suited to retrofitting with CO_2 capture systems.

Improving the efficiency of pulverized coal-fired power plants has been the focus of considerable efforts by the coal industry. There is huge scope for achieving significant efficiency improvements as the existing fleet of power plants are replaced over the next 10-20 years with new, higher efficiency supercritical and ultra-supercritical plants and through the wider use of Integrated Gasification Combined Cycle (IGCC) systems for power generation.

A one percentage point improvement in the efficiency of a conventional pulverized coal combustion plant results in a 2-3% reduction in CO_2 emissions.

Advantages and Disadvantages of Coal as Energy Sources

Table 3: Advantages and Disadvantages using Coal as Energy Source

Advantages	Disadvantages
• One of the most abundant energy sources	• Source of pollution: emits waste, SO_2, Nitrogen Oxide, ash
• Versatile; can be burned directly, transformed into liquid, gas, or feedstock	• Coal mining mars the landscape
• Inexpensive compared to other energy sources	• Liquification, gasification require large amounts of water
• Good for recreational use (charcoal for barbequing, drawing)	• Physical transport is difficult
• Can be used to produce ultra-clean fuel	• Technology to process to liquid or gas is not fully developed
• Can lower overall amount of greenhouse gases (liquification or gasification)	• Solid is more difficult to burn than liquid or gases
• Leading source of electricity today	• Not renewable in this millennium
• Reduces dependence on foreign oil	• High water content reduces heating value
• By-product of burning (ash) can be used for concrete and roadways	• Dirty industry—leads to health problems

The Future of Coal

Some countries, those who are signatories to the Kyoto Protocol, have decided to reduce their greenhouse gas emissions. These countries should not increase their consumption of coal but rather reduce it in order to limit their CO_2 discharges. For the others, as a result of oil price increases, it is likely that coal will become a cheaper source of energy, which they will want to use even more. The share of coal in total primary energy consumption (1/3) should remain stable for other one or two decades, and then begin to increase. Certain problems of pollution linked to the use of coal can be solved by treatment of the combustion fumes, but the difficult problem still remains, that of CO_2.

Since 2004, oil prices have increased significantly. And it is by no means certain that they will come back down again to their previous cheap level for a long time. In this context of more expensive energy, decision-makers worldwide have the choice of 3 principal lines of action (none of them mutually exclusive):

- Encouraging energy savings,
- Developing new energy sources, if possible sources which are renewable;
- Reintroducing the use of energy sources already known, but whose use had been reduced or even stopped altogether with the arrival of oil.

Coal is an example of this last type of energy source. Oil is starting to be in short supply? Let's call on coal, among other possibilities, to take its place!

World reserves of coal are very large and will last for 200 years at current rates of consumption. Moreover these reserves are spread more equitably across the world than those of oil. Thus, the most voracious consumer of energy on earth, the United States, is also the country with the largest coal reserves. And a final point: coal should remain a cheap energy source; it is not expensive to extract or to use to produce electricity.

Figure 3: Coal Terminal at Richard's Bay (Richard's Bay - South Africa).

However coal does have certain disadvantages:

- First of all, technical limitations: coal cannot be used for transport purposes, unless we go back to steam machines or, more seriously, if we move to electric vehicles;

- And then, ecological problems: the burning of coal is very polluting. Like oil, coal contains sulphur that gives off sulphur dioxide when it is burnt. In the atmosphere, this becomes sulphuric acid, by oxidation, an irritant for the lungs and the main component of "acid rain", so harmful to forests. The burning of coal also gives off oxides of nitrogen (NOx). Several efficient processes exist for sulphur and nitrogen cleaning of gas emissions from the burning of coal. Action can be taken both upstream, before burning, or downstream, by treating the fumes. In the latter case, the proportion of SO2 can be reduced by 90% and that of nitrogen oxides by 80%. These procedures are gradually being put into operation in all fuel oil and coal power plants throughout Europe, in order to respect the new European norms.

But the burning of coal, like that of gas and oil, produces carbon dioxide (CO_2), the main greenhouse gas. And in this instance, there is no current solution. Even if ideas have been put forward (the injection of CO_2 into the subsurface rock formations or into the major oceanic trenches; a major increase in forested areas to fix a part of the carbon dioxide ...). The signatories of the Kyoto Protocol, who have undertaken to reduce their greenhouse gas emission to 1990 levels, should certainly not increase their coal consumption. Those countries which refuse to make an effort to reduce greenhouse gases and who continue to produce more and more CO_2 because of their needs for economic growth, are without doubt going to increase their coal consumption in the coming years. The future of coal is therefore strongly linked to the commitment, or lack of it, to reducing emissions of greenhouse gases and to making technical progress on the fixing of carbon monoxide in the rock formations or in the oceans.

Lines for technological research are developing rapidly, particularly in the United States, where research programmes exist on:

- The gasification of coal to produce hydrogen for fuel cells;

- The capture and confinement of CO_2 which, once injected into oil wells, contributes to improvement in the hydrocarbon recovery rate.

The future will depend on political decisions to be made in the years to come. But whatever happens, coal is going to remain a major energy source, at least during the 1st half of the 21st century. (Tarka, Thomas J.; Wimer, John G.; Balash, Peter C.; Skone, Timothy J.; Kern, Kenneth C.; Vargas, Maria C.; Morreale, Bryan D.; White III, Charles W.; Gray, David, 2009)

Problem Statement

Coal, a fossil fuel, is the largest source of energy for the generation of electricity worldwide. It also had been used as coke, ethanol production, and some of them are going through gasification and liquefaction to produce syngas and liquid fuels respectively. Different types of coal have different usage. Dr Zuhar Zahir Tuan Harith, a researcher and petroleum engineering expertise recently doing some research on reservoir of Labuan Coal in Labuan, Sabah. This coal has potential to be energy sources to generate electricity plants in Malaysia. However, so far there are no research on Labuan Coal to check its characteristic to determine the type and the usage of the coal. Thus, a research on Labuan Coal must be done.

Objectives

The objective of this project is to study on the characteristic of Labuan Coal to see whether it is suitable to use it as energy resources in Malaysia.

CHAPTER 2: LITERATURE REVIEW

Coal is characterized by a wide variety of properties and composition, because it is a complex and heterogeneous sedimentary rock. The coal properties are characterized by proximate analysis, ultimate analysis, and heating value.

Proximate analysis

Proximate analysis serves as a simple means for analyzing the thermal behavior of coals by determining moisture content, volatile matter content, ash content, and by difference the fixed carbon content

Coal Moisture Content

The moisture content of coal is determined by measuring the percentage of weight loss of approximately a 1-g sample at a temperature of 105-107 °C in an inert atmosphere for 1 hour.

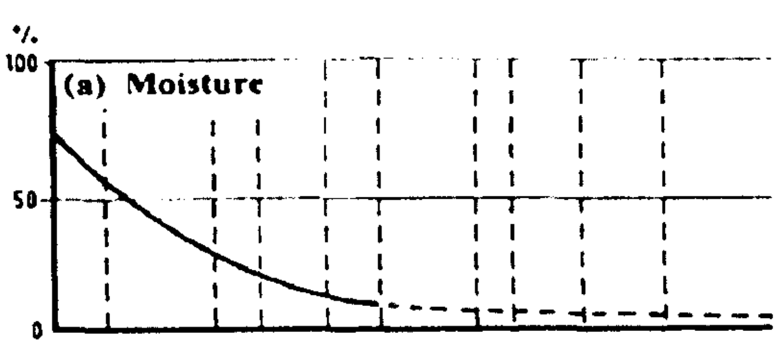


Figure 4: Graph moisture vs. time

Coal Volatile Matter

The volatile matter (VM) content of coal is the percentage of weight loss corrected for moisture that occurs when coal is heated in a specified apparatus in the absence of air under specified conditions at temperature 950°C (1,742°F). It consists mainly of combustible gases such as hydrogen, carbon monoxide, methane, and other hydrocarbons; tar vapor; and incombustible gases such as carbon dioxide and steam. The determination of volatile matter content of coal is important because the data used in coal classification system. It is also an evaluation of the stability of coal for combustion.

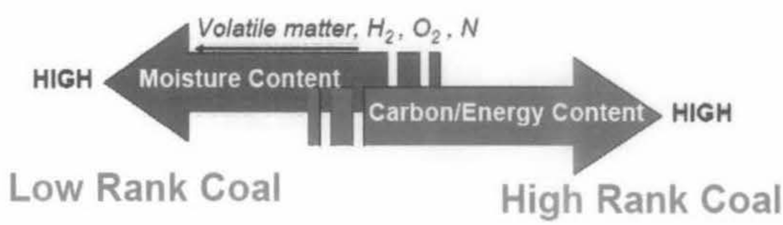


Figure 5: Rank of Coal

Table 4: Coal volatile matter

Class	Volatile matter 1) (weight %)	General description	
101	< 6.1	Anthracites	
102	3.1 - 9.0		
201	9.1 - 13.5	Dry steam coals	Low volatile steam coals
202	13.6 - 15.0	Cooking steams coals	
203	15.1 - 17.0		
204	17.1 - 19.5		
206	19.1 - 19.5	Heat altered low volatile steam coals	
301	19.6 - 32.0	Prime cooking coals	Medium volatile coals
305	19.6 - 32.0	Mainly heat altered coals	
306	19.6 - 32.0		
401	32.1 - 36.0	Very strongly coking coals	High volatile coals
402	> 36.0		
501	32.1 - 36.0	Strongly coking coals	
502	> 36.0		
601	32.1 - 36.0	Medium coking coals	
602	> 36.0		
701	32.1	Weakly coking coals	
702	> 36.0		
801	32.1 - 36.0	Very weakly coking coals	
802	> 36.0		
901	32.1 - 36.0	Non-coking coals	
902	> 36.0		

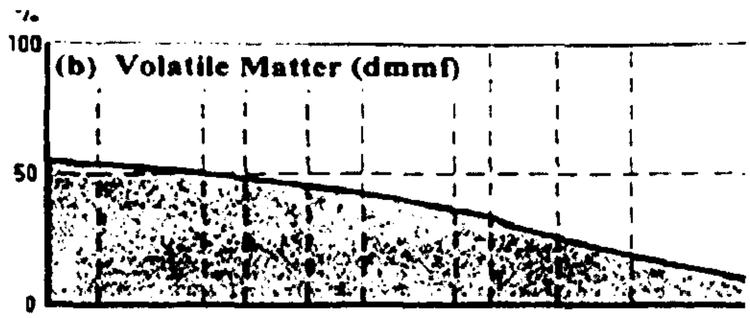


Figure 6: Graph volatile matter vs. time

Ash

Ash content is the residue derived from the mineral matter during complete incineration of coal. Ash content is usually very variable even in the same type of coal and is typically determined by burning 1 to 2 g of coal at temperature range from 700 to 950°C in a ventilated muffle furnace. Ash is normally of sandy, bright yellowish color.

The material remaining after the determination of moisture, volatile matter, and ash is called fixed carbon. It is calculated by subtracting the percentages of moisture, volatile matter, and ash content from 100%. Fixed carbon plus ash represents the approximate yield of coke from coal. Proximate analysis is very frequently handled by an instrument called a proximate analyzer. (Brian H. Bowen, Marty W. Irwin, 2007)

Ultimate analysis

Ultimate analysis determines the composition of carbon, hydrogen, nitrogen, sulfur, ash, and oxygen content by difference, regardless of their origin. Carbon and hydrogen are often considered the most important constituents of coal and account for 70-95% and 2-6% of the organic substance of coal, respectively. Analytical procedures are used to determine carbon and hydrogen by burning an exact amount of coal in closed system with the products of the combustion (CO_2/H_2O) being determined by adsorption. Nitrogen also occurs in the organic matter of coal and accounts for 1-2%. It is measured mainly by use of the Kjeldahl method or the standard method that advocates the Dumas technique and the gasification procedure. Sulfur is an undesirable element in coal. It is an air pollutant in the forms of SO_2, SO_3, H_2S and H_2SO_4 compounds, which cause damage to agricultural crops and corrosion to almost everything (metals, stones, concrete, and clothing) and contribute to acid rain. The sulfur content of coal approximately ranges from 0.2 to 8% and sulfur species are present in coal in the forms of inorganic sulfur (pyrite and marcasite, FeS_2, and sulfate, $FeSO_4$) and organically bound sulfur. Ultimate analysis measures the total sulfur content of coal without distinguishing among the forms in which it occurs. Organic sulfur is usually determined by difference between the total sulfur and the inorganic (pyretic and sulfatic) sulfur measured by use of ASTM methods or by the conventional Powell and Parr method. The amount of oxygen in coal is determined by an indirect method (subtracting the percentages of the other four elements from 100%). The disadvantage of this procedure is that all the experimental errors in the carbon, hydrogen, nitrogen, and sulfur measurements are accumulated into the calculated value of oxygen.

Heating value

Heating value or calorific (CV) of coal is a direct measurement of the chemical energy stored in it. Therefore, it is an important parameter for determining the value of coal as a fuel. The heating values of coals vary widely from less than 600 Btu/lb to more than 14000 Btu/lb. This parameter is used in ASTM rank classification of major coal types. The direct and indirect methods used in determining the calorific value of coals are described in the following subsection.

Calorimetric determination

The use of calorimetric provides a direct measure of the heat of combustion. This determination involves measuring the amount of heat released on a burning a known amount of coal in a closed vessel under pressurized oxygen. An oxygen bomb calorimeter can be used for this measurement.

Dulong's formula.

The calorific value of coal can be estimated from the ultimate analysis by the use of Dulong's equation which states:

$$CV = 145.44X_C + 620.28(X_H - Xo/8.0) + 40.5Xs$$

where CV I the calorific value (Btu/lb) on a dry, ash-free (daf) basis and the X's denote the weight percentages of the element carbons, hydrogen, oxygen, and sulfur as designated by the subscripts. The coefficients of the X's are the calorific values of carbon, hydrogen, and sulfur, respectively, from left to right.

Goutal's formula.

The calorific value of coal can be estimated from the proximate analysis by the use of Goutal's formula

$$CV = 14760 + a\,(VM)$$

Where VM is the percentage of volatile matter and *a* is a parameter that is a function of VM on a dry, ash-free basis.

Ergun's formula.

The calorific value of coal can be estimated from the moisture content by use of Ergun's formula

$$CV = 19000 - 1000(12.0 + 3.1\ M)^{1/2}$$

It is based on a moist, mineral matter-free basis. M is the moisture content of coal.

(Brian H. Bowen, Marty W. Irwin, 2007.)

Study area

In order to study the characteristic of Labuan Coal, author must go to Labuan to get the sample. There the sample can be collect at two sites as mark on the map above.

CHAPTER 3: METHODOLOGY

Standard test methods for routine coal analysis include those of the American Society for Testing and Materials (ASTM) and, with limited application, those of the International Organization of Standardization (ISO). The former consist of national standards used in the United States and Canada, while the latter have been developed by IS0 member nations for international trade . While these methods are used throughout the coal industry and in commerce t o establish coal quality, they may not be applicable in the analysis o f coal samples for research purposes. One problem area is the chemical analysis of coal. This becomes particularly evident when using ASTM methods which were primarily designed for the analysis of bituminous coal t o analyze lignetic and sub bituminous coals

Moisture in the Analysis Sample

Modified ASTM method similar to the **IS0** method 331 (2) is used. The coal sample is heated in an oven at 104-llO°C for three hours. The weight difference of coal sample before enter the oven and after is taken as the moisture content of the coal.

Ash in the Analysis Sample

The ash in coal is the noncombustible residue that remains when coal is burned. In the ASTM method D3174 (3), the coal sample is placed in a cold furnace and heated gradually so the temperature reaches 450 to 500°C in one hour and 700 to 75O°C at the end of the second hour. The **IS0** method 1171 (4) recommends an 815°C final temperature. In both methods the sample is ignited at the appropriate final temperature to constant weight. (American Society for Testing and Materials, 1984.)

Other characterization on coal

X-Ray Diffraction (XRD)

X-ray scattering techniques are a family of non-destructive analytical techniques which reveal information about the **crystallographic structure, chemical composition, and physical properties of materials and thin films**. These techniques are based on observing the scattered intensity of an X-ray beam hitting a sample as a function of incident and scattered angle, polarization, and wavelength or energy.

X-Ray Fluorescence (XRF)

X-ray fluorescence (XRF) is the emission of characteristic" secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays. The phenomenon is widely used for **elemental analysis and chemical analysis**, particularly in the investigation of metals, glass, ceramics and building materials, and for research in geochemistry, forensic science and archaeology.

Sampling the coal

The coal that gathered from Labuan is stored in the container and wrapped with plastic. After removed the plastic, the coal was broke in small pieces. This is to ensure that the grinding process using mortar grinder later will be smooth. The smaller chunk coal is then grinding using the mortar grinder so that it will be fined as powder.

The reason we powdered the coal is because this will increases the surface area and allows it to burn more quickly and this method is used in all electric generation power plant that utilizes coal. Thus, this will gives better result for testing that required the coal to burn such as the determination of ash content of the coal.

Another reason is that equipments such as CHNS and Oxygen Bomb Calorimeter only allow powder sample for testing. Thu, it is important for us to powdered the sample for testing.

Moisture in Labuan Coal

As mentioned above, the coal is heated 104-110°C for three hours. The details procedures are as below:

1. Weight of the silica crucible was measured and the weight of crucible was taken.
2. 2 g of Labuan Coal is measured together with the silica crucible. The total weight of silica crucible and Labuan Coal was taken.
3. Oven temperature was raised until it reached 110°C
4. Sample was inserted in the oven for three hours.
5. After three hours, sample was taken out and weight of sample was measured.
6. Step 1 until 5 was repeated another 2 times to get accurate measurement.

Ash content in Labuan Coal

Ash content is the residue derived from the mineral matter during complete incineration of coal. The sample was gradually heated for three hours until it reached 815°C. Below are the details of the procedures:

1. The silica crucible weight was measured and the weight of the crucible was taken.
2. 2 g of Labuan Coal is measured together with the silica crucible. The total weight of silica crucible and Labuan Coal was taken.
3. The furnace was set to 815°C temperature.
4. The sample was inserted in the furnace and gradually heated from room temperature to set temperature for 3 hours.
5. After 3 hours, sample was taken out and weight of sample was measured.

Note: The experiment could not be repeated since very high temperature was used and the old model furnace could not hold on for long in high temperature as advised by the technician

Fixed Carbon in Labuan Coal

Volatile matter in coal is defined as components of coal, except for moisture, which are liberated at high temperature in the absence of air. Thus the coal needs to be heated at very high temperature. According to *Coal Geology and Coal Technology* Blackwell Scientific Press, 1984, to get the volatile matter, coal sample must be heated to 900 ± 5 °C (1650 ±10 °F) for 7 minutes in a cylindrical silica crucible in a furnace. When the volatile matter, ash and moisture are driven off from the coal, the remaining is fixed carbon. Below are the details of the procedures:

1. The silica crucible weight was measured and the weight of the crucible was taken.
2. 2 g of Labuan Coal is measured together with the silica crucible. The total weight of silica crucible and Labuan Coal was taken.
3. The furnace temperature was raised until it reaches 900°C

Note: The furnace temperature could not be raised more than 900°C since the furnace in UTP is the old model

4. The sample was inserted in the furnace for 10 minutes
5. After 10 minutes, sample was taken out and weight of sample was measured.

Note: The experiment could not be repeated since very high temperature was used and the old model furnace could not hold on for long in high temperature as advised by the technician

Hydrogen, Nitrogen and Sulfur Content

For Hydrogen, Nitrogen and Sulfur content, 1.5-2 mg of samples were measured inside a tin capsule. The capsule is then sealed together with the samples and run in the CHNS equipment. CHNS is equipment that measured Carbon, Nitrogen, Hydrogen and Sulfur of the samples by weight percent.

Heating Value

For Labuan Coal heating value, 0.5-1.0 g sample was measured and the sample was run in the oxygen bomb calorimeter to determine its heating value.

Figure 7: Oxygen bomb Calorimeter

CHAPTER 4: RESULTS AND DISCUSSION

Moisture Content

First Run

Silica Crucible weight: 63.14 g

Labuan Coal weight: 2 g

Total weight: 65.14g

After heated total weight: **64.99 g**

Carbon without moisture = 64.99 g - 63.14 g

= 1.85 g

Moisture content = 2 g – 1.85 g

= **0.15 g**

Second Run

Silica Crucible weight: 63.14 g

Labuan Coal weight: 2 g

Total weight: 65.14g

After heated total weight: **64.96 g**

Carbon without moisture = 64.96 g - 63.14 g

= 1.82 g

Moisture content = 2 g – 1.82 g

= **0.18 g**

Third Run

Silica Crucible weight: 63.14 g

Labuan Coal weight: 2 g

Total weight: 65.14g

After heated total weight: **64.96 g**

Carbon without moisture = 64.96 g - 63.14 g

= 1.82 g

Moisture content = 2 g – 1.82 g

= **0.18 g**

Average moisture content = (0.15 + 0.18 + 0.18)/3

= **0.17 g**

Moisture content weight % = (0.17/2) x 100

= **8.5 %**

<u>Fixed Carbon</u>

Silica Crucible weight: 63.20 g

Labuan Coal weight: 2 g

Total weight: 65.20g

After heated total weight: **63.85 g**

Volatile matter and moisture content loss due to coal burned = 65.85 g - 64.25 g

= 0.95 g

Fixed Carbon = 2 – 0.95

= **1.05 g**

Fixed Carbon weight % = (1.05/2) x 100

= **52.5 %**

Ash Content

Silica Crucible weight: 63.10 g

Labuan Coal weight: 2 g

Total weight: 65.10g

After heated total weight: **63.28 g**

Carbon content loss due to coal burned = 65.10 g - 63.28 g

= 1.82 g

Ash Content = 2 – 1.82

= **0.18 g**

Fixed Carbon weight % = (0.18/2) x 100

= **9 %**

Table 5: Moisture, Fixed Carbon and Ash Content

(% Weight)	Labuan Coal
Moisture	8.5
Fixed Carbon	52.5
Ash	9

Hydrogen, Nitrogen and Sulfur Content

Table 6: Hydrogen, Nitrogen and Sulfur Content

Element	(% Weight)
Carbon	52.43
Hydrogen	5.05
Nitrogen	1.50
Sulfur	0.98

Calorific Value

Result from bomb calorimeter analysis = 29755 J/g

Weight sample = 0.6409 g

Burning thread calorific value
= 50 J/twist

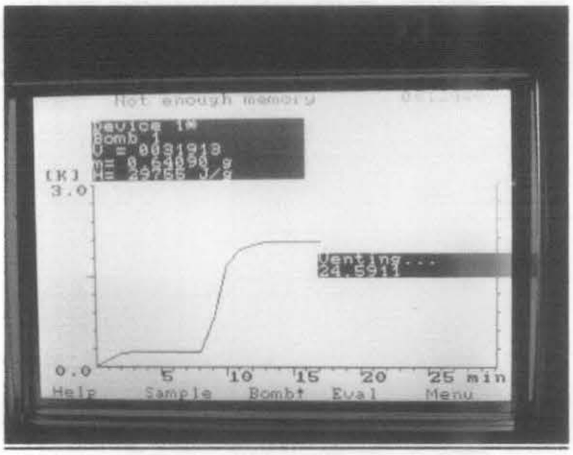


Figure 8: Oxygen Bomb Calorimeter Result

Labuan Coal Calorific Value:

(0.6409 g x 29755J/g) – 50 J

= 19019 J

=19019 J/0.6409 g

=29676 J/g or 12 758.38 Btu/lb

Summary of findings

Table 7: Summary of findings

Composition (%weight)	Labuan Coal	Bituminous type
Moisture	8.5	1.0-10.0
Ash	9	4.0-20.0
Total Sulfur	0.98	0.5-2.2
Fixed Carbon	52.5	50.0-72.0
Hydrogen	5.05	4.8-5.3
Nitrogen	1.50	1.2-1.6
Heating Value	*12 758.38 BTU/lb*	*10 500-15 500 BTU/lb*

All the findings were compared to with all categories of coal such as Lignite, Bituminous, Sub-Bituminous and Anthracite. The table above shows that Labuan Coal has characteristics which are similar with the Bituminous Coal type. Its composition by weight percent and its heating value were all in the range of Bituminous Coal.

Labuan Coal unfortunately not the best out of the best in Bituminous type. The highest value bituminous coals are those which have a specific grade of plasticity, volatility and low ash content, especially with low carbonate, phosphorus and sulfur. From the research that had been done, Labuan Coal ash content is 9 weight percent out of 20 (taking 20 is the maximum ash content for bituminous coal) while its sulfur content is 0.98 weight percent out of 2.2 (taking 2.2 is the maximum sulfur content for bituminous coal). Coal CV5800 from Kalimantan, Indonesia has lower sulfur content which is 0.8-1.0 weight percent.

However, the characteristics were all passed the rejection limit for steam coal (coal that burned in power plant to generate electricity)

Item	Limit	Rejection limit
Total Moisture	8.5%	>32%
Inherent Moisture	*unknown*	>16%
Ash	9%	>14%
Total Sulfur	0.98%	>1%
Fixed Carbon	52.5%	
Calorific Value	7089.68 Kcal/kg	<5600 Kcal/kg

Source from: Global Trade Resources (M) Sdn Bhd

In term of location, Labuan is far more nearer than the other supplier such as Australia and Indonesia. Thus, this will cut a lot of the transportation cost to send coal to the all electricity generation power plant in Malaysia. The potential power plant that going to use Labuan Coal as energy sources as below:

Table 8: Potential power plant that going to use Labuan Coal as energy sources

Plant	State	MW	Owner/Operator
Sultan Salahuddin Abdul Aziz Shah Power Station	Selangor at Kapar	2,420	Kapar Energy Ventures Sdn Bhd
Manjung Power Station	Perak at Manjung	2,295	TNB Janamanjung Sdn Bhd
Tanjung Bin Power Station	Johor at Pontian	2,100	Tanjong Bin Power Sdn Bhd, a subsidiary of Malakoff
Jimah Power Station	Negri Sembilan at Lukut	1,400	Jimah Energy Ventures Sdn Bhd
PPLS Power Generation Plant	Sarawak at Kuching	110	PPLS Power Generation, a subsidiary of Sarawak Energy Berhad
Sejingkat Power Corporation Plant	Sarawak at Kuching	100	Sejingkat Power Corporation Sdn Bhd, a subsidiary of Sarawak Energy Berhad

CHAPTER 5: CONCLUSION AND RECOMMENDATION

Conclusion

As for conclusion, the objective of this project which is the study on the characteristic of Labuan Coal is successful. As the result, the Labuan Coal is determined as Bituminous Coal type and the characteristics limit of the coal is all passed the rejection limit for the coal to be export and use as energy sources for electricity generation power plant.

Recommendation

For this research, student was required by Dr Zuhar Zahir to run the samples in X-Ray Diffraction and X-Ray Diffusion. For these two equipments, the coal needs to be mix with Lithium Tetraborate. However, student could not continue with this two experiment because the Lithium Tetraborate that student ordered could not make it in time. Thus, for the recommendation, student would like this project to be continued by others and test Labuan Coal samples plus Lithium Tetraborate for X-Ray Diffraction and X-Ray Diffusion test.

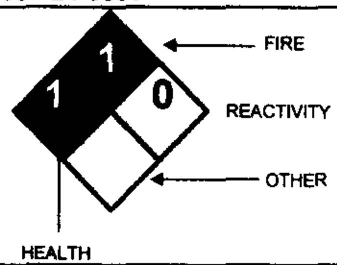
REFERENCES:

1. Dr. AP Zuhar Zahir Tuan Harith, Geosciences and Petroleum Department.
2. Brian H. Bowen, Marty W. Irwin, 2007. Coal Characteristic
3. M. Madon & A Hadi, 2006. Sedimentary geology of Miri, Labuan, and Kota Kinabalu: A field Guide-book. Unpublished
4. Höök, M., Aleklett, K., 2009. A review on coal to liquid fuels and its coal consumption, International Journal of Energy Research
5. Tarka, Thomas J.; Wimer, John G.; Balash, Peter C.; Skone, Timothy J.; Kern, Kenneth C.; Vargas, Maria C.; Morreale, Bryan D.; White III, Charles W.; Gray, David (2009). *Affordable Low Carbon Diesel from Domestic Coal and Biomass*. United States Department of Energy, National Energy Technology Laboratory. p. 21
6. "Shenhua Group Starts China's First Coal-to-Fuel Plant". http://www.bloomberg.com/apps/news?pid=20601072&sid=a3SIXbVZ8JiE&refer=energy. Retrieved August 11, 2009.
7. World coal consumption 1980-2006 October 2008 EIA statistics
8. EIA, World Energy Projections Plus (2009)
9. "Fossil Power Generation". Siemens AG.
10. http://w1.siemens.com/responsibility/en/environment/portfolio/fossil_power_generation.htm. Retrieved 2009-04-23
11. Clean coal facts and figures page by Rising Tide Newcastle
12. American Society for Testing and Materials, "1984 Annual Book of ASTM Standards"; ASTM: Philadelphia, 1984, Vol. 5.05, pp. 398-400.
13. International Organization for Standardization, 1975, IS0 331, 5 p.
14. *Global Trade Resources (M) Sdn Bhd*

APPENDICES

Sprague PUT OUR ENERGY TO WORK FOR YOU.	MATERIAL SAFETY DATA SHEET
Two International Drive, Suite 200, Portsmouth, NH 03801 Tel (603) 431-1000 FAX (603) 430-7290 An Axel Johnson, Inc. Company	***BITUMINOUS COAL*** Content Last Revised 1/94; 10/12/00; 07/26/02; 06/05 4 pages.

SECTION 1 - MATERIAL IDENTIFICATION		**24 HOUR EMERGENCY INFORMATION**
PRODUCT / CHEMICAL NAME:	BITUMINOUS COAL	Sprague: 603-431-1000 Chemtrec: 800-424-9300
PRODUCT / CHEMICAL SYNONYMS:	WASHED COAL, CLEAN COAL, SOFT COAL	**HMIS / NFPA HAZARD RATING**
CHEMICAL FAMILY / FORMULA:	ALIPHATIC AND AROMATIC HYDROCARBONS / VARIABLE	**4=EXTREME** **3=SERIOUS** **2=MODERATE** **1=SLIGHT** **0=MINIMAL**
MATERIAL USE OR OCCURRENCE:	-	



SECTION 2 – INGREDIENTS & RECOMMENDED OCCUPATIONAL EXPOSURE LIMITS

COMPOSITION	**% WEIGHT AS RECEIVED**	**OSHA PEL**	**ACGIH TLV**
MOISTURE	(Typical) 1.0 – 10.0	None established.	None established.
ASH	4.0-20.0	15 mg/M³ as nuisance dust less than 1% quartz	10 mg/M³ as nuisance dust less than 1% quartz
TOTAL SULFUR	0.5-2.2	5.0 ppm as SO_2	2.00 ppm as SO_2
FIXED CARBON	50.0-72.0	None established	None established
VOLATILE MATTER* INCLUDING ELEMENTAL AND COMPOUNDS OF:	17.0-37.0		
HYDROGEN	4.8-5.3	None established	None established
NITROGEN	1.2-1.6	None established	None established
CHLORINE	.08-.19	1.0 ppm	1.0 ppm
COAL DUST		2.4 mg/ M³ respirable fraction, < 5% SiO_2 10 mg/ M³ > 5% SiO_2 % SiO_{2+2}	2 mg/M³ respirable fraction, < 5% SiO_2 10 mg/ M³ > 5% SiO_2 % SiO_{2+2}

SECTION 3 - PHYSICAL DATA

IGNITION TEMPERATURE:	260°-365°F	**% VOLATILITY BY VOLUME:**	Negligible
MELTING POINT:	750° F	**VAPOR DENSITY (AIR = 1):**	N/A
AVERAGE SPECIFIC GRAVITY (H2O = 1):	1.43	**SOLUBILITY IN WATER:**	Non-soluble
HETEROGENOUS - CARBONACEOUS			
APPEARANCE & ODOR: Irregular, rectangular-shaped chunks or particles, dense, grayish-black to black color with slight, minimal dank odor.			

SECTION 4 - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: When exposed to flame of temperatures in excess of 260° F.

EXTINGUISHING MEDIUM: Foam, carbon dioxide, dry chemical, halon, and water fog.

SPECIAL FIRE FIGHTING PROCEDURES: Use washdown and spread out method.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Susceptible to spontaneous combustion. Highly combustible and/or explosive when in dust or powder form.

SECTION 5 - HEALTH DATA

TOXICOLOGICAL TEST DATA: Coal may liberate various polycyclic aromatic hydrocarbons (PAH's) upon thermal decomposition. There is no clear evidence that coal is carcinogenic to man or experimental animals because of their polycyclic aromatic hydrocarbon content. However, there is evidence that these PAH's may play an active role in the generation of lung cancer seen in cigarette smokers or tar-roofing workers.

Coal may release small quantities of methane gas over a period of time. Progression of tuberculosis is greatly increased in pneumoconiosis but susceptibility is apparently not increased.

	ACUTE HEALTH EFFECTS	CHRONIC HEALTH EFFECTS
INHALATION	The principal health hazard associated with coal occurs during its mining and transport. Coal workers' pneumoconiosis (CWP) can occur in miners after as little as 15 years of excessive inhalation of respirable coalmine dust. Respirable quartz particles and free silica may be co-implicated. Coal dust is deposited in the lungs where its site of action is the lung parenchyma, lymph nodes and hila. The severity of the disease is directly related to the amount of coal dust in the lungs. In the simple stages, the disease is detectable by x-ray as round, irregular "macules"of 1-5 mm. This stage typically does not change lung function or shorten life.	The chronic stage of CWP, however, involves massive pulmonary fibrosis that does impair pulmonary function and shorten life. Chronic Bronchitis (lung inflammation, coughing attacks, difficult breathing, etc.) and emphysema can result from excessive coal dust inhalation. Rheumatoid arthritis can be exacerbated by pneumonias leading to rapidly developing lung damage (Caplan's Syndrome).
INGESTION	May cause irritation.	No data available
SKIN CONTACT	May cause irritation.	No data available.
EYE CONTACT	Irritation of the eye.	No data available

FIRST AID PROCEDURES

First aid procedures generally don't apply to this product. Maintain exposure to coal dust according to applicable regulatory standards.

SECTION 6 - REACTIVITY DATA	
STABILITY:	Stable if properly stored to inhibit oxidation.
HAZARDOUS POLYMERIZATION:	Hazardous polymerization has not been known to occur under normal temperatures and pressures. However, coal dust may react slowly with oxygen at room temperature. Heat accelerates the process, which could lead to spontaneous ignition in piles of coal dust.
CONDITIONS TO AVOID:	1. Allowing coal to stand in water. 2. Storing coal on loose or porous ground. 3. Piling coal around upright steel or wooden posts, crane supports, underground drains, steam or hot water lines or areas where there is refuse such as wood, straw, growing vegetation or other organic material. 4. Storage in closed hampers, bins, receptacles, etc. without positive ventilation.
INCOMPATIBLES:	
TYPICAL DECOMPOSITION PRODUCTS:	May liberate hydrogen, methane, carbon monoxide, oxides of sulfur and hydrogen, coal tar pitch volatiles upon thermal decomposition.

SECTION 7 - SPECIAL PROTECTION		
RESPIRATORY PROTECTION:		Use with adequate ventilation.
VENTILATION	**LOCAL EXHAUST:**	MSHA/NIOSH approved dust respirator. Appropriate respirator depends upon type and magnitude of exposure.
	MECHANICAL (General):	Recommended for use in enclosed or semi-enclosed work areas.
EYE PROTECTION:		Splash goggles or shields with safety glasses
PROTECTIVE GLOVES:		Neoprene, PVC
OTHER PROTECTIVE CLOTHING OR EQUIPMENT:		Employee must wear appropriate impervious clothing and equipment to prevent repeated or prolonged skin contact with this substance.

SECTION 8 - SPECIAL PRECAUTIONS	
PRECAUTIONS FOR SAFE HANDLING & STORAGE:	Do not permit accumulation of dust or spillage. See also conditions to avoid, above
SPILL AND LEAK PROCEDURES:	Cleanup by excavation, vacuum collection or washdown.
WASTE DISPOSAL METHOD:	1. Incinerate in combustion device or system. 2. Dispose in approved, regulated landfill.

SECTION 9 - DOT HAZARDOUS MATERIAL INFORMATION		
PROPER SHIPPING NAME: BITUMINOUS COAL		**REQUIRED PLACARDING:** NONE
HAZARD CLASS: Non-Hazardous	**PACKING GROUP (P.G.):** III	**N.A/U.N. NUMBER:** NONE

SECTION 10 - EPA SARA TITLE III INFORMATION			
SECTION 311/312	**ACUTE:** N/A		**CHRONIC:** N/A
HAZARD CLASSIFICATION: Non-Hazardous	**FIRE:** N/A	**PRESSURE:** N/A	**REACTIVE:** N/A

SECTION 11 – REMARKS

This material contains fused polycyclic hydrocarbons. The OSHA interpretation of coal tar pitch volatiles (Section 1910, 1002) is as follows: "Coal tar pitch volatiles include the fused polycyclic hydrocarbons which volatize from the distillation residues of coal, petroleum, wood, and other organic matter." The OSHA PEL and ACGIH TLV for coal tar pitch volatiles is 0.2 mg/M³ (basis one soluble fraction).

SECTION 12 - ADDITIONAL REGULATORY DATA

REPORTABLE COMPONENTS: FEDERAL EPA	%	SARA RQ	CERCLA RQ	RCRA NO.
BITUMINOUS COAL	100	-----	-----	-----

NOTE: OSHA Regulations 29 CFR 1910.1200 (Hazard Communication) do not consider coal as a "hazardous material" and a Material Safety Data Sheet (MSDS) is not required. The information contained herein is based on data available at this time and is believed to be accurate. However, no warranty is expressed or implied regarding the accuracy of these data or the results to be obtained from the use thereof. Since information contained herein may be applied under conditions beyond our control and with which we may be unfamiliar, no responsibility is assumed for the results of its use. The person receiving this information shall make his own determination of the suitability of the material for his particular purpose.