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SPECIAL REPORT 2

Coal Energy: Power From The Past

An Educational Resource for Coal Energy

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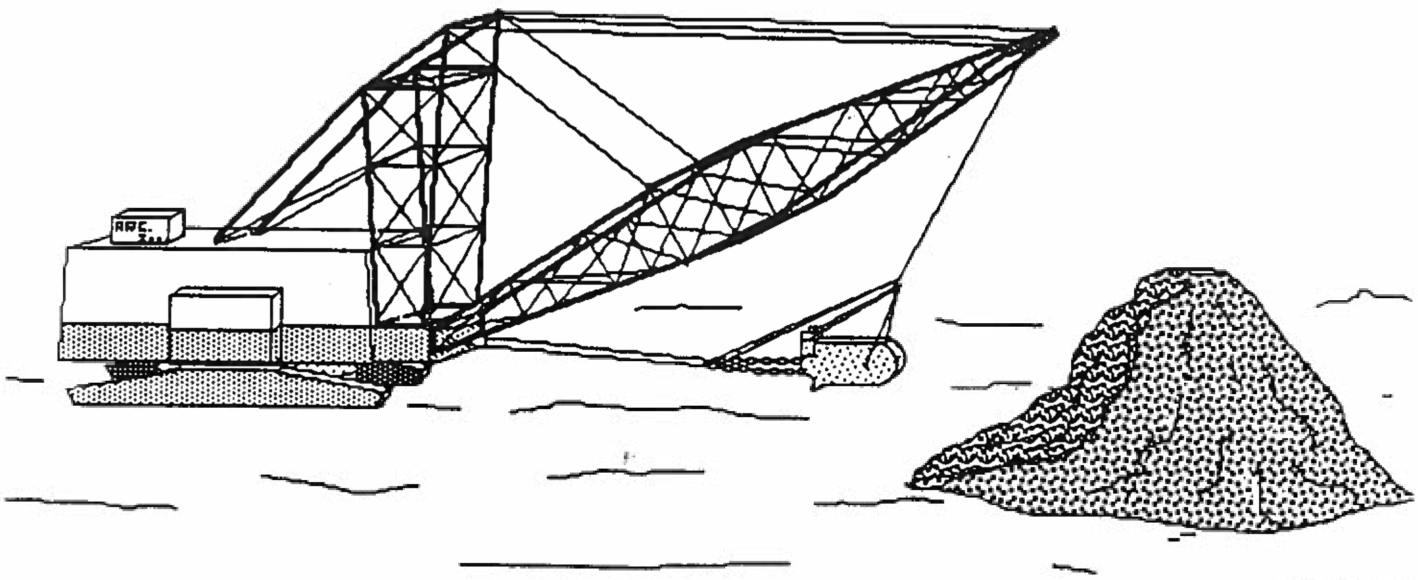
Coal and Hydrocarbon Processing Department



Coal Energy: Power From The Past

An Educational Resource
with
Teacher's Resource Book

Outline of Coal Energy: Power From The Past

The Power of the Past

The steam rose slowly in small wisps from the marsh below. Massive pine trees, some as tall as 30m, stretched skyward as if trying to catch the first rays of sunshine in what was to be another hot and humid day. The stem of an old tree fern glistened with the moisture of the small shower that had just passed over.

A slight breeze caught the fern and stretched it to its limits. The stem could take no more. It snapped suddenly sending a shudder through the whole plant. The fern gracefully bent and landed with a soft plop in the mud. Forgotten, it would be covered in time. Around it, the marsh was awakening to another day of life in the Cretaceous period, 135 million B.C..

The noise is deafening. The huge bowl shaped crusher rotates rapidly as the huge grinding wheels pulverize pieces of what appeared to be black rock. The dust sized particles are now blown directly into the boiler and burned. The 1100°C heat from this reaction heats water, under high pressure, until the molecules of water are moving too fast to be restrained any longer. The water flashs into steam in an instant producing tremendous amounts of pressure. This steam forces its way past the smoothly rotating turbine blades. The power of the past is being converted into the power of the present. The date is July 12, 1990 A.D. and the Genesee power plant is in full operation.

All was dark and quiet but the clock radio continued emitting a soft green glow. Click. The quiet was disturbed with a loud mocking call: "It's 7:00 a.m. July 12th and I'm Bob Lancaster with the news. In traffic there's bee...". The hand hit the snooze button and once again all was silent. The shower, the breakfast, the drive to the office, would all wait for another 15 minutes.

These three seemingly unrelated events are all connected by one thing: their dependance on the same power source. They all rely on the fact that millions of years ago the sun was providing energy to the earth which photosynthesis converted into plant material. The earth then stored this energy in the form of coal.

Coal has been and will continue to be a very important source of energy for the province of Alberta; however coal's importance to our economy and way of life is not fully understood by the majority of Alberta citizens. The goal of this unit is to introduce you to the problems and possibilities of using coal as an energy source.

History of Coal Utilization

Coal has been used as a fuel since the beginning of civilization. The writings of the ancient Greek philosopher Theophrastus mention a black stone that blacksmiths burned instead of charcoal, and the Chinese are said to have used coal for fuel about 100BC. Although European coal industry is known to have existed about AD1200, the use of coal was discouraged because open burning produced objectionable fumes. During the reign of the English king, Edward I(1239-1307) it is said that the death penalty was imposed on anyone found burning coal.

Small coal-mining operations began in Europe in the fifteenth century and grew as coal fired brick kilns came into use. Nevertheless, wood from the abundant forests remained the primary fuel for heat and energy. As the population of European countries grew rapidly in the 1600s the forests became depleted, and coal began to replace wood as a domestic fuel.

A new market for coal arose with the discovery that coal could be made into coke and used to smelt iron. Beginning in the 1700s and throughout the Industrial Revolution, metallurgical and engineering advances produced an insatiable demand for coal.

In North America, the Pueblo Indians in the southwestern United States used coal for firing ceramics long before the arrival of Europeans. The first systematic Canadian coal mine began operations on Cape Breton Island in 1720, to supply coal during construction of the French fortress at Louisbourg. The Cape Breton coal industry grew rapidly as coal began to be exported to American seaport towns. In 1825 the first coal mine opened in New Brunswick.

In western Canada coal was first mined in 1836 on Vancouver Island, to supply coastal steamboats. The gold rush that began in 1849 brought thousands of settlers to the west coast, and new mines were opened through-out Vancouver Island to meet the increased demand for coal. In Alberta coal outcroppings were abundant and easily accessible to early settlers from the beginning of the 1800s. Many small, unlicensed mines supplied coal for domestic heating and cooking before the first official coal mine opened in 1874 in southern Alberta.

By 1867 coal production in Canada had reached 3 million tonnes, most of it coming from Cape Breton. With the arrival of the railroads in western Canada in the early 1900s, the coal industry in Alberta and British Columbia developed rapidly and new mines sprang up throughout the two provinces. Most of the coal went to fuel steam locomotives, which also transported coking coal to metal smelters in the United States and central Canada. By 1911, western Canada had overtaken the Atlantic region as the principal coal producing area.

The use of thermal coal began to decline in 1949 following major new oil discoveries in Canada in 1947. Throughout the 1950s and early 1960s, locomotives were converted from coal to diesel fuel, which was cheaper and convenient. Similarly, residential heating needs were gradually taken over by cleaner oil and natural gas. With the loss of these markets, the coal industry contracted. Nevertheless, coal continued to provide almost 10 per cent of Canada's energy supply.*

Coal usage on a world wide scale recovered as oil and gas prices began to rise with the emergence of the OPEC (Organization of Petroleum Exporting Countries) cartel. Coal exports to Japan, for its' steel industry, have helped to revive interest in western Canadian coal. Although world markets have fluctuated the long term demand for coal seems fairly solid as the reserves of oil and gas are being depleted at a rapid rate.

As the demand for coal increases a greater emphasis is being placed on locating new deposits. One of the keys to finding new deposits is knowing the conditions that must exist in order for coal to form. The source of coal deposits has been the focus of a considerable amount of research. In the following section we will examine the currently held theories of how coal came into being.

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* Source History of Coal Utilization, Coal in Canada, Energy, Mines, and Resources, Canada.

Coal Formation

It is felt that the first **vascular** plant life appeared approximately 440 million years ago. As time progressed plant life slowly evolved into the types commonly associated with coal deposits.

Table 1.1 Geological time Scale

Era	Period	Approximate Age
		(millions of years)
Cenozoic	Quaternary	11
	Tertiary	70
Mesozoic	Cretaceous	135
	Jurassic	180
	Triassic	225
Paleozoic	Permian	270
	Carboniferous	350
	Devonian	400
	Silurian	440

The carboniferous period, approximately 350 million years ago, was the start of the major coal forming period. Vast swamps and forests grew lush with vegetation. The subtropical climate at that point in time was remarkably stable and consistent, with a large annual rainfall. There was such a small yearly variation in temperature that the trees did not form tree rings. In many respects these ancient forests were similar to modern rain forests except that the diversity of the life forms and vegetation types was not as great in these forests.

The plant types associated with coal deposits changed over time. Initially, large ferns, some up to 30m tall, lived and died in the marshes. Later, conifers, cone bearing trees similar to evergreens, became the major source of vegatation for coal deposits. Alberta's coal deposits were formed during the late cretaceous and early tertiary periods, (See table 1.1) and are composed primarily of conifers.

Usually when a plant died it decayed and returned its nutrients to the soil; however plants growing in a marsh often submerged before they could decay completely. Bacteria acted on the plant material and converted into peat. The process of converting this plant material into peat is called **peatification**, also known as the **biochemical** phase of coal formation.

Geological processes were very important in determining how much peat was deposited in the area. If the area was stable and the swamp was able to exist for a very long period of time, the peat layer could become very deep. Some modern swamps have peat layers up to 10m deep. These layers can taken as long as 15,000 years to form. A **geosyncline**, an area where the ground slowly subsides, often allowed the peat to pile up for extended periods of time. As the ground slowly sank, the peat built up at the same rate, thus maintaining the ground at a constant level.

In order for coal to form, these peat forming areas had to be covered. Usually they became flooded with water, and water born sediments were deposited over the top of the peat. As biological activity used up the nutrients and the percolation of water through the peat decreased, the biological activity slowly stopped.

After all the biological activity had ceased the peat layers entered the **geochemical** stage of coal formation. The peat became buried deeper in the crust and the pressure and temperature increased. The high pressures forced water out of the peat and increased its density. The high temperatures (up to 200°C) helped produce chemical changes in the structure of the material, the carbon content increased, and the content of hydrogen and oxygen decreased. Coal was formed.

Chemical Makeup of Coal

As peat is deposited, non-organic materials often become incorporated. Sand and mud, brought into the swamp by floods, may form layers in the peat. This inorganic material is still present after coal is formed. During coal formation high pressures in the crust decrease the amount of H_2O in coal, but are unable to drive all of the water out. For this reason a large percentage of coal by mass is composed of water.

One of the major problems associated with the use of coal is the creation of acid rain. The majority of this problem is caused by the sulfur content of the coal. Peat is often formed in water that contains sulfates. Bacteria takes these sulfates and converts them into hydrogen sulfide, pyrite(Iron Sulfiide), or solid sulfur. This sulfur becomes incorporated into the coal and is later released into the atmosphere as sulfur dioxide when the coal burns.

The Rank of Coal

Coal seams are exposed to very different conditions depending on their location, which leads to considerable variation in coal type. Coal in general has been defined as being composed of more than 50% carbon by mass and more than 70% carbon by volume.

Peat is found in swamps and marshes and it is used in certain areas as fuel. It typically has a high moisture content, but it does not have a high enough carbon content to fit our definition of what coal is.

Brown Coal- Typically brown coals; have a high water content, are easy to ignite, under go **slacking**(break into small weathered pieces if exposed), release low amounts of energy, and may **spontaneously ignite**. Brown coals have either had a short period of development or they have been located in areas where the temperatures were not high enough to create the chemical processes required for complete conversion.

Lignite-Lignite coals have less than 75% carbon, they possess a high moisture content, are soft, and are brown to black in color. It is often easy to see plant remains in this material. Lignites have a large **volatile matter** content and because of this, produce a smoky flame. This coal also slacks and may spontaneously ignite. Lignites are typically used for electrical power generation due to their relatively low heat output as compared to higher quality coals.

Subbituminous Coal- This coal is brown in color and often has a woody texture. It slacks and can undergo spontaneous combustion. Alberta subbituminous coals have a low sulphur content and can be used as a substitute for other types of coal where this is a concern. For example, subbituminous coal is often used in power generation stations to reduce sulphur emissions while still producing reasonable energy production. Much of the thermal coal produced in Alberta is of this type.

Bituminous Coal- This type of coal forms the major type of coal energy in the world. This coal breaks into prismatic blocks, has a lower moisture content than any of the previously mentioned coals, does not weather substantially, and shows very little tendency to spontaneously combust. If this coal is heated in the absence of air it will soften, the remaining volatile gases bubble out, and when the product solidifies, it forms **coke**. Coke is used in blast furnaces to make iron, and its by-products are useful in the production of other chemicals.

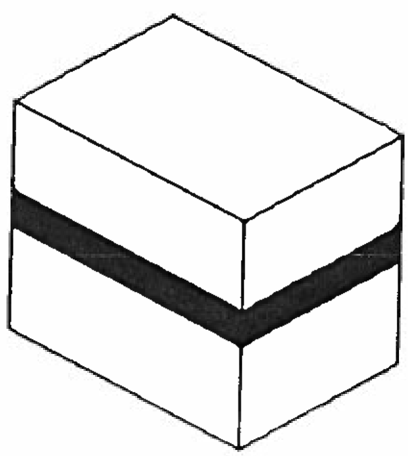
Anthracite- This is the highest ranking coal. It has a very high carbon content and a very low moisture and volatile matter content. It is stable in storage and does not form dust like the other coals. It has a very high heating value and is the hardest and most dense of the coals. Anthracite will not form coke when heated.

Geological Processes Involved in Coal Formation

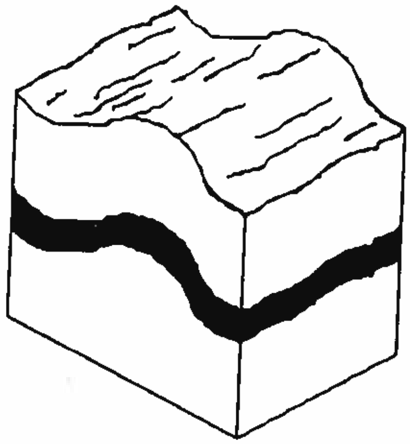
The rank of a coal deposit is not affected by the type of plant material present, but by the factors affecting **geochemical** processes. The major factors influencing coal formation are temperature and pressure. Temperature appears to be the more important of the two, but high pressures are usually found in the same areas.

If a coal deposit has been deeply buried under ground it has experienced high temperatures and pressures. The higher the temperature and pressure the coal has been exposed to the higher the rank of the coal.

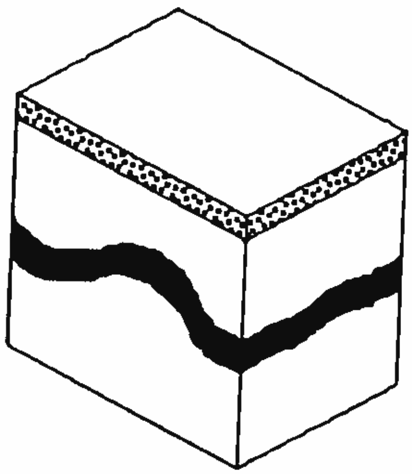
High temperatures can be caused by stress in the earth's crust. While coal is being formed, geological processes continue. If an area of ground is exposed to geological stress, the ground will deform and fault. This means that although a coal seam may start out being flat and level, it will not usually end up that way.



Step one: A coal seam becomes buried under layers of sediment.



Step two: The ground deforms and the coal seam is bent.



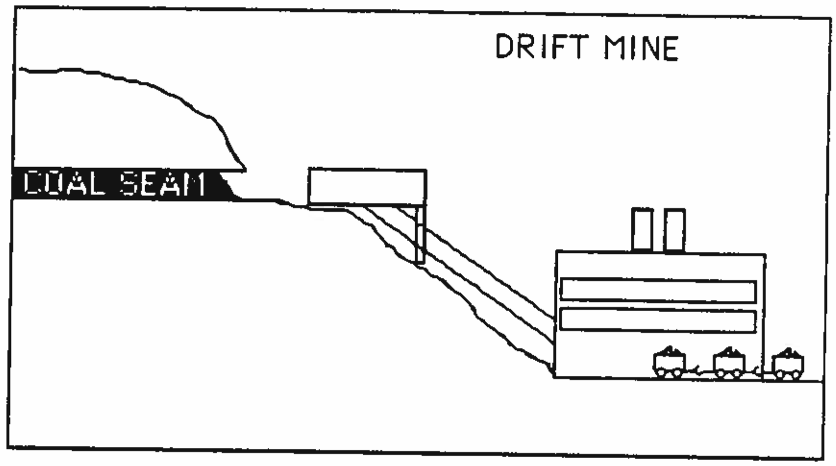
Step three: Glaciers or erosion smooth off the top layer of the ground and sediment levels off the surface of the ground.

Geological factors affect both the type of coal found in a particular deposit and the shape and accessibility of that deposit.

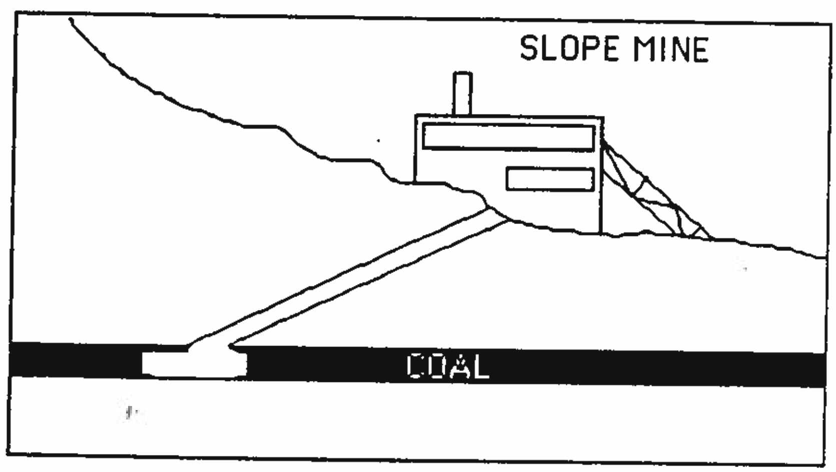
Coal Mining

The type and severity of the geological processes that shape a coal seam also determine how the seam will be mined. Several methods of coal mining are commonly used. These can be broken down into several major types: drift, slope, shaft, and strip mines.

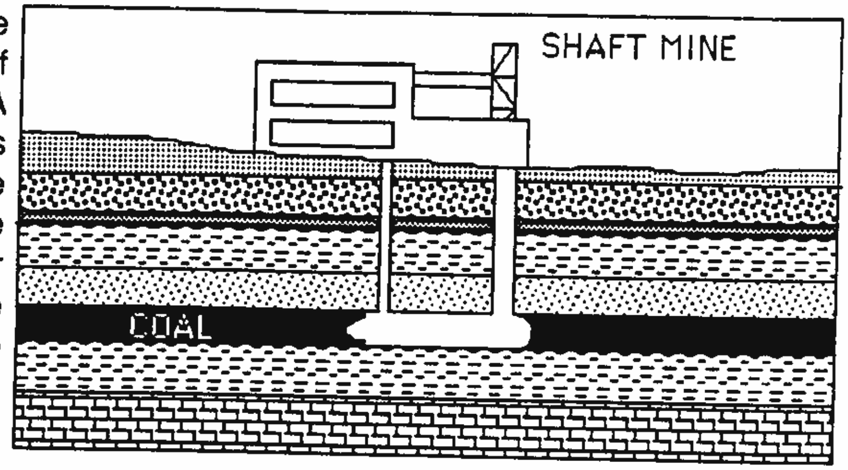
Drift mines are found in areas where horizontal coal seams are exposed on a slope. The mine tunnel is directed horizontally into the seam.



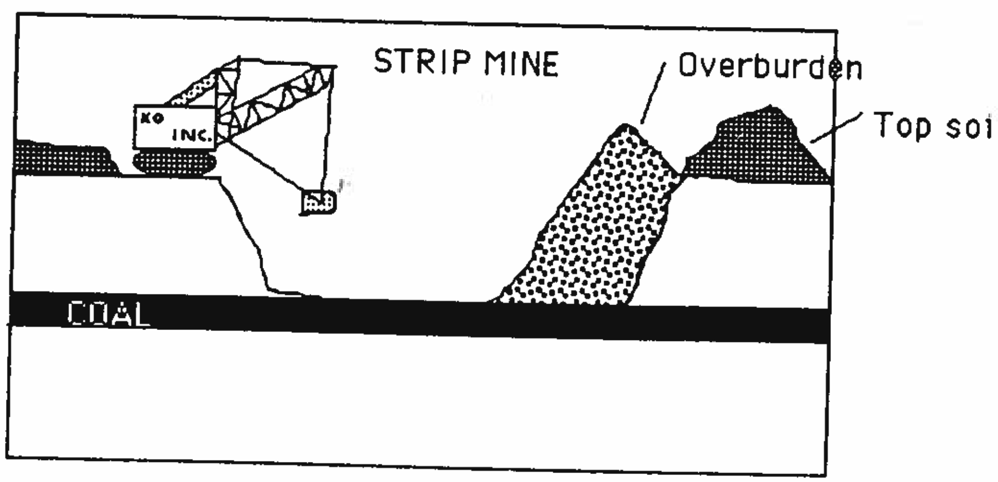
A **slope mine** involves putting a sloping shaft into the coal seam. The sloping shaft allows a conveyor belt to transport coal, and it allows vehicles to transport men and machines. This method is less expensive than a shaft mine at medium depths.



A **shaft mine** is used in areas that have a very large amount of **overburden**. A vertical shaft is drilled down to the coal seam. The miners, their equipment, and the coal they mine, are lifted and lowered in this shaft using elevators. Smaller shafts are used for ventilation.



Strip Mining is used in areas with a relatively small amount of overburden. In strip mining, the overburden is removed, set aside, and then the coal seam is mined. Once all of the usable coal has been removed, the overburden is replaced and the topsoil is put back. Government requires the land be left in as good or better shape than it was before the strip mining operation occurred. In the past, underground mines played a major role in supplying Alberta's coal demands. The development of large earth moving machines has made strip mining more feasible in many areas. In fact 97% of the coal mined in Alberta now comes from strip mines.[1]



[1]ERCB

The Power of a Dragline

A Dragline is an large machine capable of moving extremely large amounts of earth in a short period of time. These machines are used for strip mining operations.

Large draglines are electrically powered using "big" extension cords. These machines move on large tracks like a caterpillar tractor or they can walk. The walking draglines have a large central circular pad and two large feet. In order to move the outer feet are lowered using hydraulics and the central pad is raised and moved forward. The pad is lowered and then the feet are moved forward and the cycle is repeated. These machines typically take 2 m steps.

Draglines used in Alberta coal mines can typically move between 40 m^3 and 70 m^3 of earth in one bucket. (70m^3 would hold 10 Volkswagen Beetles) Large draglines are also used at the Fort McMurray tar sands and other large strip mines. The largest draglines in the world can move up to 176m^3 in one bucket. This would be the typical main floor of a house half filled from floor to ceiling with earth in one bucket.

At Cape Canaveral in Florida they have used dragline technology to develop the large tracked machines which are used to move rockets and the Space Shuttle out to the launching pad. The two machines used here have travelled approximately 1600 km each and have a fuel consumption rating of 45000.L/100.km. (Typical values for a car would be 8.5L/100km)

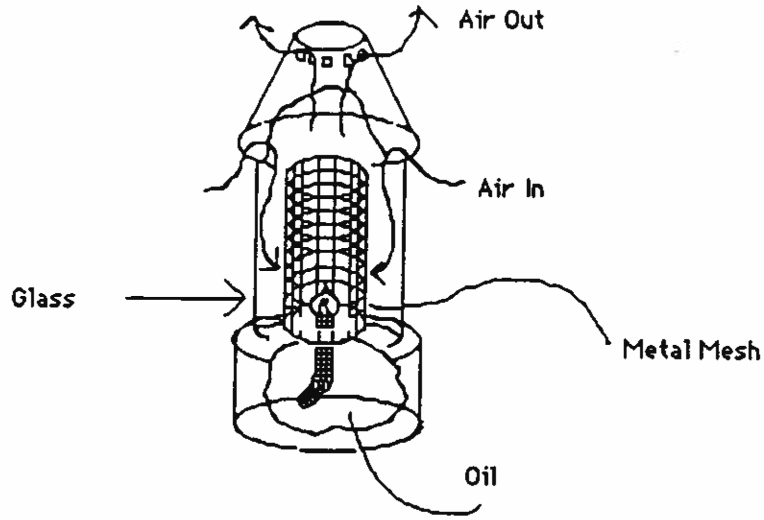
Problems to overcome in mining Coal

Underground mining of coal is a challenging and often dangerous business. One problem associated with underground mining is the build-up of dangerous gases in the poorly ventilated areas of a mine. Several types of gases can create problems.

Carbon dioxide is heavier than air and can accumulate in pockets in the mine. A miner entering these pockets may be overcome by the lack of oxygen before he can get out. Methods of detecting CO_2 (often called chokedamp by miners) include safety lamps and electronic devices.

Carbon monoxide also occurs in coal mines. It is produced by slow coal oxidation, exhaust of diesel mining equipment, and incomplete combustion of explosives. This gas attaches itself to the hemoglobin in the blood and does not allow oxygen to be transported. Typically, victims of CO poisoning will seem to fall asleep. CO is also flammable so if it's ignited, it can contribute to fires and explosions. Safety lamps and electronic devices are used to detect the gas.

Methane is produced during the formation of coal and is often found in coal mines. This gas is one of the components of natural gas and is extremely flammable. Before the invention of the safety lamp, miners' lanterns often acted as an ignition source and set off large explosions in the mines. The safety lamp helped to eliminate these explosions and acted as an indicator that methane was present.



The safety lamp was a major step in advancing mine safety. The flame of this lamp is surrounded by a metal mesh which prevents the flame from igniting an explosion. The flame will get weak or go out in high concentrations of carbon dioxide , and it will burn brighter in high concentrations of methane or carbon monoxide.

Coal dust is another major problem in mines. It can cause explosions if the concentration of the dust in the mine reaches a high level and an ignition source is present. The other concern with large amounts of dust in the mine is the health risk to miners. "Black lung", a common affliction of men who spent much time in coal mines, resulted from inhaling large amounts of coal dust.

In order to counteract the coal dust problem the mine tunnels are often coated with a material that prevents the dust from being released. At the location where the coal is being mined, the coal face is often sprayed with water to keep dust production to a minimum. Powerful ventilation systems help prevent the build up of mine gases and coal dust, and are essential for the safe operation of a modern mine.

Another problem found in underground coal mines is the danger of mine collapse. Thousands of miners have been killed by collapsing tunnels; however, several methods are used to minimize this risk. The room and pillar method leaves large pillars of coal remaining in mined areas in order to support the roof. Tunnels are often braced with beams and heavy steel pillars to support the roof. Another technique allows the roof to collapse, but the machine and operators are protected by temporary hydraulic roof supports.

Strip mining has considerably fewer health and safety concerns than underground mining. The major concern in strip mining is the amount of damage that the environment sustains because of the mine. Strip mines create large scars on the earths surface and unless reclaimed properly, can be devastating to the environment and wildlife in the area. Valuable agricultural land can also be destroyed if care is not taken. If reclamation is done correctly, the reclaimed land can often be in even better shape than it was in to start with.

Electrical Power: How do we Compare

Canada uses an immense amount of electricity. Of all the countries in the world Canada ranks fourth in electrical generating capacity. Only the U.S., U.S.S.R., and Japan generate more electricity. For a country of only 25 million this is amazing. We generate more electricity than countries many times our size. China, France, United Kingdom, and West Germany are all several times larger than Canada in population yet we produce more electricity. In per capita energy consumption only Norway consumes more electricity than Canada does. Canada also exports more electricity than any other country, with our market being the United States.

These facts bring several questions to mind. Does this high consumption of electricity reflect the fact that Canada is a high technology country or is this high consumption rate an indication of the fact that Canada wastes a tremendous amount of energy. You be the judge.

*Information From Energy, Mines, and Resources Canada Electricity Production in Canada 1988.

Uses of Coal Energy

The primary domestic use of coal in the province of Alberta is in the production of electrical power. Two main types of coal fired power plants exist.

Stokers are an early type of steam boiler. Coal is fed onto grates found in the furnace. The grate also removes the ash when the coal has completed burning. Stokers have very limited use in power plants at present because they are inefficient.

Pulverized coal systems are much better than stokers. In a pulverized coal system the coal is put through a crusher which pulverizes the coal until it has the consistency of a fine powder. This powder is then blown into the furnace directly from the crusher using large fans. This increases furnace efficiency and reduce the complexity of coal feeding systems.

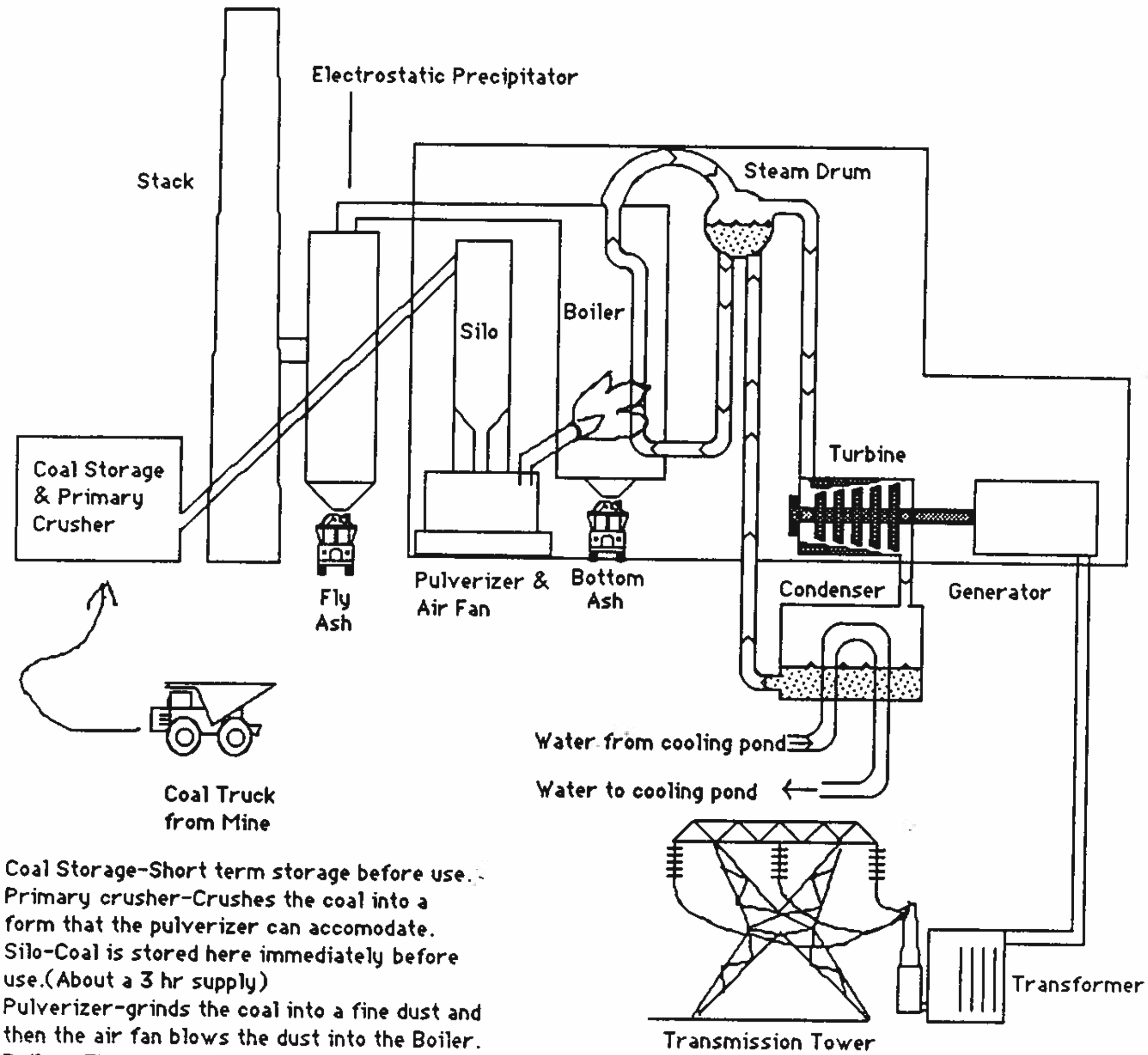
Once the coal has been burnt in the boiler the ash is collected. Two types of ash are produced: bottom ash and fly ash. Bottom ash falls to the bottom of the furnace, is cooled in water, and then collected. The fly ash is composed of very fine particles which attempt to leave the furnace with the other combustion gases. The products of combustion are sent through a device called an electrostatic precipitator. In the precipitator the fly ash particles are charged electrically and then collected using alternately charged sets of parallel metal plates. The ash produced by Alberta power plants is either buried in the coal mine pit or sold for use in concrete.

The heat of coal combustion is used to heat water to a temperature in the neighborhood of 500°C. This steam is sent into the turbines at very high pressure. This immense pressure turns the fan-like turbine at a high rate of speed; 3600 r.p.m. is typical. The turbine is connected to the generator which in turn produces the electrical power by turning large magnets inside a wire coil.

Coal fired plants may increase in importance in the near future. Nuclear power is not considered safe enough for wide spread public acceptance and hydroelectric projects are facing two barriers. Very few good locations for hydroelectric damns remain and public outcry over environmental issues relating to damns is considerable. Another factor increasing the likelihood of coal fired power plants is the very large reserves of coal found in North America and other locations in the world.

The second major use for coal is in the production of iron and steel. Certain grades of coal are known as coking coals. If these coals are heated with no oxygen present they will give off various volatile gases as well as a brownish tar. The remaining coal softens

Electric Power Generation



Coal Storage-Short term storage before use.
Primary crusher-Crushes the coal into a form that the pulverizer can accomodate.
Silo-Coal is stored here immediately before use.(About a 3 hr supply)
Pulverizer-grinds the coal into a fine dust and then the air fan blows the dust into the Boiler.
Boiler- The coal fired flame heats the water in the pipes. The heavy bottom ash is collected at the bottom of the boiler.
Electrostatic Precipitator- These devices use oppositely charged plates to pull the ash particles out of the exhaust gases
Stack- Takes the gases up into the air so they become dispersed before they can come into contact with the ground environment.
Turbine- The turbine uses the steams energy to turn rapidly.
Condenser- the steam is cooled here and turned back into water. It is then pumped back into the steam drum.
Generator- The generator uses the rotation of the turbine to create electric power.
Transformer- raises the voltage from the generator to several hundred thousand volts for transmission.
Transmission Towers- keep the electric lines well above the ground to reduce energy loss.

and reshapes itself. When this substance solidifies upon cooling it has become **coke**, which has a higher carbon content than the original coal and burns hotter. Coke is then dumped into blast furnaces and mixed with either iron ore or pig iron to supply both the heat and the carbon required for production of steel. Coking coals are also called metallurgical coals because of their use in metals production.

The gases and tars given off during coke production can also be used. The gas is most often used to heat the coking ovens to perform the coking process. Although previously coal tar was used to produce many chemical products that is not as true at present. The advent of the petro-chemical industry based on petroleum has considerably reduced the importance of coal tar by-products. At present coal tar is used to produce asphalt and road sealent.

Coal Transportation

Coal fields are seldom located where we need the energy. In Canada 92% of coal production is in western Canada while only 39% of coal usage is in the west. 53% of coal consumption is in Ontario and Quebec where no coal is produced. With this in mind therefore, the costs of transportation play a vital role in coal usage.

Most of the metallurgical coal mined in western Canada is exported to Japan; Quebec and Ontario import most of their coal from the eastern United States. Even though Canada produces enough coal to meet our domestic needs we still import coal because it is cheaper to import it than to transporting it across the country.

In Alberta much of our coal is used on site (Thermal Coal). Thermal coals typically have a lower grade and do not produce as much energy per kg as a higher grade coal. Transportation costs are just as high for this type of coal, however. This means it becomes cheaper to make something using the coal on site and then transport the produced item. At Alberta's coal fired power plants the coal is transported directly from the mine to the plant using large trucks. The produced electricity is then transported using large transmission lines.

Coal is transported from mine to market using a variety of methods. One of the most common transportation methods involves using railways. Railways are a relatively cheap and efficient method of transporting coal.

Rail cars are typically open on top for easy loading, but this can cause a problem with coal dust when the train is moving. To fight this problem the coal is often coated, after loading, with a latex material that reduces the dust that can blow off of the coal car. Alberta coal that is exported out of province is almost exclusively sent by train. Coal bound for Japan will first be sent by rail to a coal terminal on the BC coast, and then loaded onto ships.

Ships are the only practical method available for transporting coal across an ocean. At present coal is transported by ship using bulk dry coal shipments. Bulk coal carrying ships are very efficient. The larger the ship, the more efficient it is at transporting coal. The major limitation on ship size occurs because of the limited size of canals and sea ports.

Pipelines can be used to transport coal. The method currently used is to create a coal-water slurry, a mixture of solid and liquid. This slurry is pumped through the pipeline to its destination. Pipelines have the advantage of being cheaper to build than railways and less expensive to maintain. There are, however, problems to be overcome with coal pipelines:

-the coal slurry may have to be dried before use.

-the water in the slurry may cause corrosion in the pipeline.

-building pipelines in mountainous or rocky regions(Rockies and Canadian Shield) or across large bodies of water can be very difficult.

Another option currently under consideration is using a coal water slurry in a ship similar to an oil tanker. This system would allow coal to be pumped out of the ship and would increase handling efficiency. Problems with the system include the cost of transporting all that water and of drying the coal for certain operations.

Much of what we see when we look at coal is actually waste material. Water and ash make up a significant part of naturally occurring coal; thus when coal is transported over long distances, much of what we transport is waste. Coal preparation techniques are used to treat the coal before it is transported in order to reduce this waste, however, and new technologies are currently being developed to reduce the amount of waste even further.

Methods of Coal preparation

Research on methods of coal preparation is ongoing. The Alberta Research Council: Coal and Hydrocarbon Processing Department is currently studying methods of coal preparation. One method is called agglomeration and it involves mixing ground coal with heavy oil. The oil sticks to the coal but not to the minerals and other matter in the coal. The coal particles then stick to each other and form larger agglomeration particles which can be removed mechanically. The oil is then collected in another process. Both the oil and the coal are in better condition after the process than they were before.

Another method of coal separation being studied involves the use of a device called a cyclone separator. This device uses the fact that coal is lighter than the minerals that are found in the coal. The raw coal is mixed with water and spun very rapidly inside a container. The heavier materials tend to go to the outside where they can be collected and the coal is taken out of the middle. Many high technology solutions are being applied to a very old power source.

Pollution control

One of the major concerns with the use of coal is the amount of pollution that is produced as a by-product of coal combustion. 60% of sulfur emissions and 32% of Nitrous oxide emissions in North America and Europe are due to coal use. Both of these two pollutants contribute to the acid rain problem with the sulfate ion being the more serious problem. Acid rain damages lakes, and plant life such as crops and forests.

What is an Acid?
Acids typically taste sour and are very corrosive to metals. Acids are compared to each other using a scale called the pH scale. The stronger the acid the lower its pH. If the pH is higher than 7 we say the substance is basic. A Base is the opposite of an Acid but both can burn skin and cause other damage. Distilled water has a pH of 7 and is therefore neutral. Tap water is slightly acidic generally because of dissolved materials. Vinegar has a pH of between 2 and 3 and strong acids such as hydrochloric acid have pH values of lower than 1. Acids react with metal to cause metal corrosion and they also damage stone statues and buildings aside from the damage they cause in nature.

In Europe and North America research has indicated a strong link between soil acidification and damage to forested areas. Soil acidification is one effect that acid rain has on the environment. One of the major concerns is that even if we stopped producing acid pollution the acidified soils may not recover on their own. It has been suggested that soil acidity problems can only be corrected with direct human intervention.

Acid rain effects the acid content of lakes and rivers. As the pH of a lake or river decreases it has serious consequences for the animal plant and animal life present in the lake. Large areas of eastern Canada, north eastern United States and large parts of Europe are affected by lake acidification.

Studies have shown that lakes in areas where sulfate and nitrate ion emissions have been reduced are becoming less acidic. Long term damage to an aquatic system through acidification may be stopped by reducing acid rain. Other possible methods of reducing acidification are to drop large quantities of a base into a lake. This neutralizes the acid and helps return the lake to a more normal pH level. This solution, however, only has short-term benefits to the lake.

Another source of pollution from coal combustion is found in the small particles of ash which are emitted into the atmosphere.

The methods of **particulate** control are a known science but have not been uniformly applied. Older electrical power plants in Alberta have very limited particulate control methods while newer plants use a technique called electrostatic precipitation to insure low particulate emissions.

Cyclone separators use the fact that the ash is heavier than air in order to separate the ash. By forcing the exhaust gases into a rapid rotating motion the ash is forced to the outside of the cyclone where it can be collected. Bag cleaning methods are also used for particulate control. Basically a large filter, these systems allows gases to pass through but collect the solid material present in the air. Wet scrubbers, another method, uses water to collect the dust present in exhaust gases. Although other methods of particulate control may be used these are the major types in use today.

The Greenhouse effect is created when carbon dioxide in the earth's atmosphere prevents infrared energy from reflecting into space. This means that the earth's atmosphere is heated up as a result of this extra energy. The potential long term effects of the greenhouse effect are a warmer atmosphere, higher sea levels, increased number of droughts, and larger desert areas. All fossil fuels including natural gas, gasoline, and coal produce carbon dioxide when they are burned, thus the use of these fuels is accelerating the change in temperature of the earth's atmosphere. As coal use becomes more widespread its' contribution to the green house effect will become more pronounced.

Pollution control is a major concern when the options for coal use are considered. In many respects coal use produces a moral dilemma. On one hand it would be nice to reduce the amount of pollution, but on the other hand, would we be prepared to reduce our consumption of electricity and coal related by-products? This dilemma will be looked at in the next section.

The Greenhouse Effect

The earth is in a situation of energy balance. Energy comes into the earth's atmosphere in the form of light and other forms of radiation. Much of this energy is reflected by the clouds and the atmosphere, but a good deal of it reaches the earth's surface. Once the light reaches the earth it warms the ground. Much of this energy is then given off and radiates back into space as infrared radiation. So long as the earth gives off as much energy as it absorbs it will remain at a constant temperature.

Carbon dioxide helps to prevent heat from radiating into space and by doing this, keeps the earth's atmosphere warm. If too much carbon dioxide is present, however, the earth's atmosphere will keep more energy than it gives off and the earth will heat up. This explains the concern felt over the greenhouse effect.

Present predictions vary, but it is predicted that global temperatures will rise by 0.3°C per decade. Although this may seem a small amount it will have major effects. Sea levels will rise due to melting polar ice caps and deserts will form in areas that become dried out.

Carbon dioxide is given off through many of man's activities. Any combustion of fossil fuels produces CO_2. That means that driving cars, heating homes, running trains, as well as a wide variety of industrial operations produce carbon dioxide. The future effects of this raised carbon dioxide level are a source of ongoing study.

The combustion of coal produces 17% of the greenhouse effect.

Deforestation

On a global scale our forests are being depleted at an alarming rate. The destruction of rain forests for agriculture, and northern forests for commercial uses is creating several problems. The major problem created by deforestation is the damage done to the "lungs" of the planet. Plant life, through the photosynthesis reaction, removes carbon dioxide from the atmosphere and releases oxygen. Most other biological reactions create carbon dioxide and use up oxygen. For example, when we breath we produce CO_2 and use O_2.

Natural forests can help to counter-act the build up of carbon dioxide. Not only are we producing large amounts of carbon dioxide but we are destroying one of the few natural systems that reduce the level of carbon dioxide. What can be done to prevent this cycle?

In Canada care must be taken to prevent widespread destruction of our forests. If trees from an area are used they must be replaced. We can incourage foreign governments to conserve their rain forests but we must also be prepared to help out with the finacial burden this will produce. Man has to grow out of the earth user stage and become an earth manager. We only have one earth, there is no second chance!

Future uses of Coal

Coking coal is an essential resource in the production of steel, and will be for many years to come. The use of thermal coal for electrical generation will continue to be secure for at least 30-40 years. As oil and gas reserves become depleted we will require a transition fuel source as we transfer to totally renewable and nonpolluting fuel sources in the future. It will be many years before these other energy sources are capable of taking the place of our nonrenewable resources.

Advanced technologies have been applied to coal use in order to reduce pollution output from coal facilities and to make coal more convenient to use and mine.

Coal liquifaction involves the convertion of coal into a liquid which can be burned in a similar fashion to gasoline. This technolgy has been available since the Second World War when Germany converted a large amount of coal into liquid fuel. South Africa is currently using this same technology to produce synthetic fuel in order to reduce its dependance on imported oil. At present it is more expensive to convert coal into liquid fuel than to produce the liquid fuel from petroleum. As oil and gas reserves become depleted and the price of oil rises coal liquifaction could become much more common.

Coal reserves are considered to be very extensive but not always easy to get at. The current mining techniques available are not suitable for use on some deposits. If a coal deposits is too deep it may not be economically feasible to recover using present techniques.

Coal insitu gasification involves converting coal into a gas and then extracting it. Forcing air into a coal bed will cause the coal to react and heat up. If steam is then forced into a coal bed a reaction occurs that produces a flammable gas. This gas can be enriched with methane and used exactly as natural gas is used today. If desired, the gas can be put through further chemical processes and other useful chemicals can be derived from it.

Coal Energy: Should it be in our Future?

Many environmentalists have legitimate concerns when they look at coal use. Strip mining, if done incorrectly and not monitored closely by government, can damage local ecology and water supplies. The use of coal can produce acid rain which damages not only natural plant growth but also has implications for agricultural production. When burned, coal also produces carbon dioxide, which is a major contributer to the Green House Effect.

People in the coal industry would be quick to point out that energy used to produce the microcomputer the environmentalist used to write his/her letters on required the equivalent of several tons of coal energy to produce. Another point is that it would be impossible for a large percentage of the earth's population to survive if all coal production was stopped now. We depend on electrical energy to such an extent that we would not be able to get clean water or home heating without it. Steel production depends on coal and would stop. This would effect everything from cars to bridges to buildings.

Coal use touches your everyday lives in many ways. Are you prepared to give up your car, your T.V., your bike? Are you willing to use electrical power to a considerably reduced extent? Should we strive to reduce coal use, or should we use advanced technologies to reduce the damage caused by coal use?

Although considerable coal deposits exist they will not last forever, and the long term use of coal will be limited by the extent of our coal reserves. The short term use of coal will continue until reliable alternative energy sources are available. In the mean time it is essential that a concerted effort be made to use advanced technologies to maximize the benifits and minimize the consequences of using coal.

Terminology used in this Unit

Acid Rain- A general term describing precipitation(rain, snow, etc.) that has been acidified by the presence of atmospheric acid pollutants, primarily the sulfates and nitrates.

Anthracite- Coal of the highest rank having a high carbon content and low volatile matter. It has a bright black lustre.

Bituminous Coal- A general term descriptive of coal intermediate in rank between sub-bituminous and semi-anthracite and including coking coals.

Biochemical- Process involving biological organizms and chemical change.

Coke-A hard, dry carbon substance produced by heating coal to a very high temperature in the absence of air. Coke is used in the production of iron and steel.

Conifers- cone bearing tree, eg. Pines, Spruce.

Decrepitate- Break into smaller pieces.

Dragline- a large machine used to remove the overburden from a coal seam in surface mining. A dragline uses a large bucket suspended from cables to scrape up and remove the dirt and rock covering the coal.

Drift Mine- a coal mine entered directly through a horizontal opening.

Exothermic- a chemical reaction that gives off heat.

Geochemical- Process involving geological processes and chemical change.

Geosyncline- Rock bed trough formed geologically

Hydrogen Sulfide- a poisonous chemical, smells like rotten eggs.

Fly Ash- The finely divided particles of ash in the flue gases of burning coal.

Lignite- a brownish-black coal which has been altered more tha peat byt less than sub-bituminous coal.

Metallurgical Coal- The types of coal that can by converted into coke and used in the production of steel.

Methane- A potentially explosive, lighter than air gas which comes out of coal.

Overburden- The rock and soil material covering the coal seam.

Peatification- Process that converts plant material into peat.

Rank- the classification of coal using hardness, moisture and heat production.

Sediments- tiny pieces of clay, sand, soil, and small rocks

Slacking- breaking into small pieces and flaking off in layers

Spontaneous Combustion- A fire is started with no apparent ignition source. In coal this process is not fully understood. A slow reaction between the coal and oxygen may produce sufficient energy to ignite the coal. Coal can also create heat when it absorbs moisture.

Sulfate- a chemical ion composed of sulfur and oxygen.

Thermal Coal- Coal of this type, typically subbituminous and Lignite is primary burned as a heat source (Hence the name thermal coal) for heating or power generation.

Tipple- A structure for cleaning and sizing coal and automatically loading it onto railway cars.

Vascular Plant- Plants characterized by tubes or channels that serve to transport nutrients and water within the plant.

Volatile matter- products given off as gas, vapor, or aerosol when coal is heated in the absents on air or oxygen.

Unit Evaluation

1. Although the majority of the worlds coal deposits where deposited during the carboniferous period the majority of Alberta coals where deposited during which periods? How long ago was that?
2. Electrical power is often taken for granted. In Alberta how are coal and electrical power related?
3. What type of area is best suited to the development of a peat bog.
4. What is a Conifer?
5. The process of plant material being partially decomposed into peat is called peatification. What other name is given to this process?
6. Why is it that the plant material in peat does not decay completely?
7. How are the existence of geosynclines favorable to coal formation?
8. Once all biological activity in the peat has stopped and the peat has been buried under many layers of sediment the formation of coal begins. Chemical changes occur in the peat because of the elevated temperatures and high pressures. What is this stage of coal formation called?
9. How is it possible to tell when the peat has turned into coal?(What is coal?)
10. Several ranks of coal have been discussed. List the coals from highest rank to lowest rank.
11. Often coal miners discover that coal seams can often go up and down even though the ground above them may be flat. Explain how this can occur.
12. How was the steam engine related to coal mining?
13. Has the steam engine effected our history at all.
14. Match the best type of coal mine with each of the following situations.

a) A horizontal coal seam reaches the ground surface on lower face of a very large mountain. Drill samples indicate that the coal seam goes well back into the mountain.

b) Two parallel coal seams are located at 8m and 13m under the ground respectively. They seem to be horizontal and of a fairly uniform thickness.

c) An exploration drilling operation hits a coal seam at a depth of 50 m. It is a large seam and is definitely worth developing.

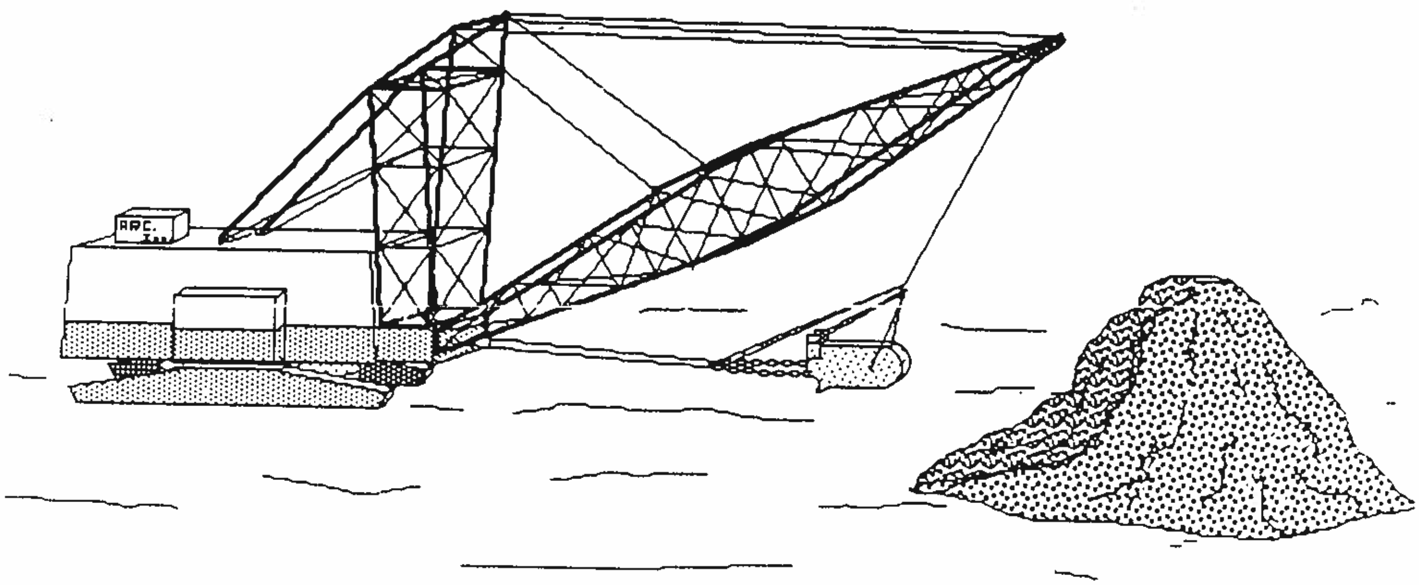
15. Coal miners going into poorly ventilated areas of underground coal mines face many dangers. What technological advancement made detection of dangerous situations easier?
16. Beside each gas describe why the gas in dangerous.
Carbon dioxide (CO_2)
Carbon monoxide (CO)
Methane(CH_4)
What happens to a safety lamp that is put in an area rich in methane gas?
17. What dangers are associated with the build up of coal dust in a coal mine?
18. What methods of controlling coal dust are available to an Engineer designing a ventilation system for a mine?
19. Why have pulverized coal fired power plants replaced stoker power plants?
20. What advantages does a coal fired power plant have over a hydroelectric power plant?
21. What disadvantages does a coal fired power plant have?
22. What advantage would a machine like a dragline have over smaller earth moving machinery?
23. Is a grapefruit acidic or basic?
24. Can soils that become acidic recover by themselves if acid rain stops?
25. What can man do to reduce a lakes acidity without stopping acid rain?
26. What three techniques can be used to separate coal ash before it goes up the stack?
27. The greenhouse effect will seriously effect many parts of the world. What might the effects be in Alberta?
28. According to current predictions how many degrees warmer will the earth be in 45 years?
29. What is coke? How is it produced?
30. What two countries have used or are using coal liquifaction?
31. What use could be made of gasified coal?
32. Should we try to stop coal use?
33. How does coal effect you?

Teacher's Resource Book

Coal Energy: Power From The Past

An Educational Resource for Coal Energy

**Developed by Doug Doran in cooperation with
Sujit Chakrabartty of the Alberta Research Council
Coal and Hydrocarbon Processing Department**



Teaching Resources Content

About the Coal Unit

This resource may be used effectively in several different ways. It will most likely be used for an elective component in a science course. I have completed a cursory examination of the possible overlap that the coal energy unit has with the grade eight science course and these are outlined below. Care must be taken, however, because the resource itself has not been overly tailored to the reading level of a grade eight student. Your judgement will have to be used in order to decide upon the best course of action for your classroom. The unit may be photocopied and distributed as desired to your class or it may simply be used for your own personal resource with class notes being developed from the unit.

Laboratory ideas are just that, ideas. Many other labs could be developed and variations on the ones mentioned are possible. **Safety** should be your overriding consideration. Coal is flammable and so are many of its by-products. **Never** attempt a lab or demonstration in class unless you have successfully completed it on your own beforehand.

Please feel free to distribute copies of the unit to other teachers. **There should be** **no charge** for the unit except for possible photocopy fees.

Grade Eight Science

The grade eight science program of studies specifies 80% core course component and 20% elective. As put forward by Alberta Education in the program of studies "The elective component ... encourages enrichment and remediation consistent with the content and objectives of the required component." [1] A coal energy elective unit would complement the grade eight core component in many ways

The Coal Energy unit focuses on a very important resource in the province of Alberta and uses the skills that have been developed during the required component of the Grade Eight Program. The Coal Unit therefore is recommended as the final unit in the course and will act as a review of many of the concepts which have been developed previously. It also connects many of the independent concepts by focusing on one resource.

Coal is often considered to be an out of date fuel and not widely used anymore. Many people are surprised to discover that 83%[2] of the electrical power used in this province was produced in coal fired power stations. Coal is also very important in producing steel. What role will coal play in our future and how will environmental concerns surrounding coal affect its use. Our students should be informed in order to make decisions.

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[1] Alberta Education Junior High Science Program of Studies

[2] Coal Focus June 1990 information provided by statistics Canada

What is Coal Made Of?

Purpose: To discover the origins of coal deposits
Materials: Coal, newspapers, hammers, chisels, small metal picks, or any device suitable to breaking up coal.
Procedure:
-Place the newspapers on the surface to be used
-examine the coal carefully and see if any evidence of what coal is made of can be found.
-If required break the coal into smaller pieces and examine these for indication of coals make-up.
Questions:
1. Have you found any indication of what coal is made up of?

Results: If possible propose what coal is made out of using information gathered during this lab?
Conclusion: -What information was gained from this experiment?
-What problems came up during the experiment?
-What questions could be looked at in a future experiment?

Demonstration: Separation of Coal into Four Components

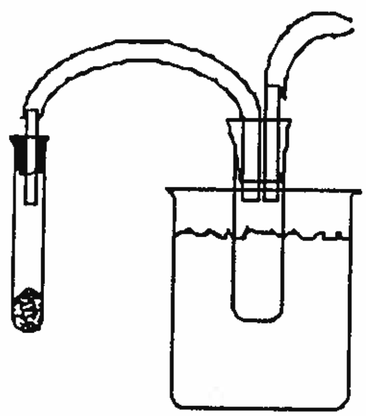
Objective:

-To demonstrate that coal is composed of many different compounds.
-To illustrate that coal is a solid solutions
-To illustrate the existence of volatile matter in coal
-To illustrate the existence of water in coal

Materials:

2-400ml beakers, 2-19mm test tubes,glass tubing, 1-one hole rubber stopper, 1-two hole rubber stopper, ground coal, cold water, Bunsen burner, test tube clamp, 2-ring stands.

Procedure:



-bend the glass tubing as indicated
-create a pointed tip on one piece of tubing
-set up the remainder of the apparatus as pictured.
-Heat the coal gently using a Bunsen burner.
-Tar will begin to be deposited on the sides of the test tube. At this point try to light a flame at the end of the pointed glass tubing. (The flame will not be self supporting immediately so a candle may be of assistance and will reduce the objectionable odour of the coal gas.)
-Let the system run until a noticeable amount of water, gas, and tar have been given off.

Explanation- The gas that is being burnt is highly volatile gases found in the coal. These include methane, carbon monoxide, and hydrogen(H_2). The tars are also volatile compounds. The tar is composed of compounds like benzene, toluene, and phenol. As the molecular motion increases with temperature the larger molecules break down into smaller fragments. These smaller fragments are the gaseous and low boiling component of tar. These escape from the molecular structure of the coal. The compound that remains in the test tube will have a higher percentage of carbon because of the decrease in water and volatile compounds.

Possible Questions-

1. Where do the gas and the tar come from?
2. Is coal a solution?
3. If coal is a solution is it homogeneous or heterogeneous?
4. Why do water droplets form in the glass tubing and in the test tube?
5. If sufficiently large quantities of tar could be collected how might a person separate the tar into its component compounds?

The Effect of Particle Size on Coal Combustion

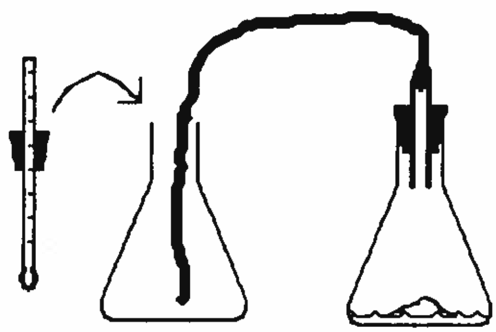
Purpose-to study the effect of particle on the rate of coal combustion.
Materials- lump coal, asbestos pad, ring stand, fume hood(or outside), Bunsen burner, stop watch, weigh scale.
****Combustion of coal produces carbon monoxide and will release sulfates and nitrates**
Procedures:
-Use a mortar and pestle or hammer and flat surface to pulverize some of the lump coal.
-weigh out an equal mass of lump coal and powdered coal
-place the lump coal on the pad and provide heat to the coal using the Bunsen burner. Start the stop watch as soon as Bunsen burner is under the coal.(Do not adjust the Bunsen burner controls between trial, use gas valve to turn gas on and off.)
-Once the coal has been burnt and only ash remains stop the watch and record the time.
-Save the ash for future reference.(place in a labeled container etc)
-Let the stand and pad cool and repeat procedure using the powdered coal.
-Compare the results.
-If time permits several trial could be performed.
Questions:
1. What implications does this experiment have for electric power plants using coal?
2. Is there a difference in the ash left by either method?
3. Can you think of a better method of grinding the coal into small particles?
Results: Which reacted the fastest?
Conclusion: -What information was gained from this experiment?
-Did the experiment work the way you thought it would?
-What problems or concerns came up during the experiment?
-What questions could be looked at in a future experiment?

The Greenhouse Effect

Purpose: to measure the effect of increased levels of Carbon dioxide on heat absorption of a container.

Materials: 2 thermometers, large Erlynmeyer or Florence flasks, rubber hose, spot lamp, sodium bicarbonate, acid solution.(Dry ice may be used to release carbon dioxide into the containers.)

Procedure:



-Put several grams of Sodium bicarbonate into a flask

-Put a piece of glass tubing through a cork and connect a rubber hose to this

-Put a thermometer through a cork

-Add acid to the $NaHCO_3(s)$ and insert the cork and hose as shown

-let the reaction proceed and when near completion remove hose and place thermometer and cork into second flask. (The carbon dioxide will not escape readily from the second flask because it is heavier than air.)

-Put a second thermometer and cork into a second flask of equal size.

-Let the temperatures of the two flasks equalize.

-Place both of the flasks under the same heat lamp so that both of them are exposed to the same amount of light.

-Record the temperature vs. time for both flasks as time progresses.

-Plot a graph of these results if desired.

Questions:

1. Why did the flask containing more carbon dioxide heat up faster?
2. What implications do the results of this experiment have on the earth?
3. What factors are not considered in this experiment but may effect global warming? (What else might happen in the atmosphere as the atmosphere warms and holds more moisture.)
4. What types of things can we do to reduce our production of carbon dioxide?
5. One suggestion to fight carbon dioxide buildup involves dropping large quantities of fertilizer over the oceans. What would this do to reduce the greenhouse effect?

Results: Which flask heated up the fastest?

Conclusion: -Did the results of this experiment match your expectations?

-What application does this research have in the real world?

-What conclusions concerning carbon dioxide in the atmosphere can you make?

-What questions came up that might be answered in a future lab?

Other Laboratory Ideas

1. Compare heat potential of three types of coal.
Materials: scale, crucibles, beakers, ring stand, asbestos pad, thermometer.
2. Distill water from coal. Heat coal to 105
C and collect the steam and condense it. **Do not overheat.
Materials: Florence flask, water jacket, thermometer, graduated cylinder, scale.
3. What effect does methane and Carbon dioxide have on a flame. Methane from gas line, Carbon Dioxide can be made and poured on the flame using Sodium bicarbonate and a weak acid.
4. Grind coal dust to a very fine consistency and place it on a small piece of paper in a funnel in a larger container. Hook a piece of surgical tubing to the end of the funnel and leave the end of the funnel outside the container. Light a candle inside the container and close the container. Force air through the tube and the container will explode.
Caution ** The lid should not be to tight or the container may rupture. Do not use your mouth to provide air pressure as the air may be forced back into your lungs"**
Materials: Hammer, Morter and pessel, funnel, candle, air pump.
5. Design a lamp that while still using a flame will not set off an explosion. Use coal dust and compare a candle with a wire mesh around it with a candle without a wire mesh. Record the temperature at a specific distance from the candle, place the wire gauze over the flame and record temperature at same distance.
Materials: Wire gauze, candle, large pail, thermometer.
6. Burning a candle to demonstrate presents of carbon. Aspirin can also be used to illustrate presents of carbon in all sort of organic compounds.
Materials: Candle, Beaker, aspirin.
7. Make a steam turbine by using a bent piece of glass tubing, cork, Florence flask, fan, small electric motor, meter or very low energy demand instrument.
Materials: Small fan, small electric motor from toy or model, meter or galvanometer.
8. Compare Coke with a sample of the original coal for heating value using a calorimeter.
9. Is it possible to separate coals components using a solvent or simple reactions?
10. Use a microscope to study coal for traces of plant structures.

Information Resources

Many sources of further information are available both from industry sources, educational groups and your local library. Some of these are listed below.

Alberta Energy/Forest, Lands and Wildlife Information Officer - a number of publications are available from the government relating to coal production and usage. Reports on studies of coal liquifaction and gasification as well as mining technologies are available and are suitable resources for reports and assignments.

Alberta Power- a variety of publications for elementary school and information on specific generating plants. Also electrical safety video called Zap Rap.

Alberta Research Council-Each research facility of the Alberta Research Council is equipped with a library that is available for public use. The Devon Coal Research Centre's library is specifically focused on coal but this library's collection can be accessed through the other Research Council libraries.

Edmonton Power -has various pamphlets, educational booklets, and videos that are valuable resources.

Energy, Mines and Resources Canada- Various publications on coal history, production, transportation ,and usage.

Seeds-Society, Environment & Energy Development Studies Foundation.

-This organization is a national organization sponsored by various groups and corporations to promote energy literacy in education. They have produced a full spectrum of resources going from elementary to senior high level. These materials are well suited for use as an elective unit. Their resources are well constructed and well thought out. They often offer seminars at conferences and P.D. days that are well worth attending. The Junior High Resource Natural Resources has 3 chapters on coal energy. This resource has lab ideas and questions plus a teachers guide.

The Coal Association of Canada- This is an association supported by industry and designed to provide a common voice on issues affecting the coal industry. They produce several publications on coal energy in Canada and could be a valuable source of resources.

TransAlta Utilities -produces a variety of resources on electricity production and on their various power plant and mining operations. They publish a booklet called "Educational Resources" which lists a large variety educational resources that are available through them. It is well worth getting. TransAlta also has speakers available who will on request come out and give talks on various subjects.

Coal Energy: Power From the Past Development

The booklet, Coal Energy: Power From the Past, and the accompanying teacher's resource book were produced as part of a six week project through the Alberta Research Council. The project is designed to give classroom teachers an opportunity to experience first hand what scientific research is like in the province. It is also intended to promote the Alberta Research Council and provide a method for encouraging students to choose careers in the scientific disciplines.

If you receive a copy of the booklet and decide to use some or all of this material in your classroom please contact me. Future improvements may be made in the unit and your suggestions and feedback will be invaluable.

Please contact Doug Doran in writing at:

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