The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

# Clean fuel from dirty coal?

Posted by Heading Out on February 27, 2006 - 1:53am
Topic: Supply/Production
Tags: coal, coke, fischer-tropsch, montana, tech talk, town gas, wyoming [list all tags]

Part of the problem with coal is that, when it was first grown (as in the peat bogs back when) the region was occasionally inundated with floods, and, as the Hurricanes showed last year, this carried mud and sand into the bog. Over the passage of time, as the bog turned from peat to brown coal, and then into coal itself, these dirt bands turned into sandstone, mudstones and other rocks. The layers are often found inter-layered within a coal seam, either as very thin stringers, or as partings that can separate a single seam into layers that end up several feet apart. The bedding planes and vertical joints (referred to as cleat) provide the permeable paths through the coal, and are often partially filled with additional minerals that deposit out of the water that percolated through the coal at one time. This can also introduce lenses of pyrite and calcite, so that coal is not the simple carbon lump that people often anticipate.

This is another in the short technical posts that show up at weekends, dealing with one aspect or another of fossil fuel production. Given that, as Super G noted the Governor of Montana was on 60 minutes tonight, it seemed like a good time to return to a coal-related theme. A list of related posts will be appended at the end of this one, and relate to the mining of coal, either on the surface or from underground, though it is the surface mining of coal, that currently entices the Montana Governor. It should be noted that the adjacent state of Wyoming produces around 400 million short tons a year of coal, about ten times the current production from Montana.

---

The way in which the coal was formed gives it a number of impurities, the two of most initial concern being the dirt in the coal (which leaves an ash when the coal is burned and thus is referred to as the ash content), and the amount of sulfur in the coal, because of the sulfur dioxide that is produced, since this will, in turn, generate acid rain. In order to remove these from the coal, it is usually first passed through a coal preparation plant. These plants (known as washeries in the UK) use differences in the density of the coal and the ash particles to separate the two, and this will also remove most of the sulfur that is found in the coal as pyrite and other inorganic forms. The problem, however, is that some of the non-carbon content is part of the original plant life, or related, so that it is bound to the carbon organically and this is more difficult to remove, particularly the organic sulfur. Even relatively clean coal can contain significant ash, and it is this that forms the fused ash or clinker, after coal is burned.

The problems of using coal, particularly unwashed coal, with the pollution it caused have been recognized for decades. Back in the 1960's much of Europe still burned coal in stoves and open fires for heating and cooking, and the resulting fumes and soot meant that buildings were blackened, and, on foggy days a combination of smoke and fog generated smog which reduced visibility to the point that you could not see your hand in front of your face (personal experience), and which had serious health consequences to those caught in one. During the London Smog of

1952 it was estimated that 12,000 people prematurely died. These smogs led to Clean Air Acts, which led to the development and use of smokeless fuels, coal that had been cleaned so that soot was not produced, and the encouragement of gas fires.

At that time in Europe the North Sea Oil and Gas fields were not developed, and so the gas was, particularly in the UK, generated from coal. It was known as town gas and often produced concurrently with coke (which is a smokeless fuel). Coke is made by heating coal, that has been washed and crushed, in larger vertical retorts, but with no air present. This drives off the gases and any volatile matter in the coal (such as hydrocarbons, tars, gasses etc).

> The basic process of coke production is also that used for manufacture of town gas. Bituminous coal of the gasmaking type is perhaps 86% carbon, 5.5% hydrogen, 6% oxygen, and 2.5% or so nitrogen and sulfur. An elemental analysis is all that can be meaningfully given, since coal is a complex substance. When heated in the absence of air, coal produces carbon (coke) and a mixture of many gases, (crude coal gas). The heat for the carbonization of coal is provided by use of some of the the coke product in the strongly exothermic producer gas reaction:
>
> C + O2 --> CO2, DHo = -393.509 kJ/mole
>
> which in the presence of insufficient oxygen drives the endothermic formation of carbon monoxide:
>
> CO2 + C --> 2CO, DHo = +172.459 kJ/mole
>
> Partial use of the endothermic water gas shift reaction equilibrium:
>
> C + H2O(g) <--> CO + H2, DHo = +131.293 kJ/mole
>
> permits control of the temperature of the reaction zone and raises the heating value of the output producer gas slightly. The final composition of producer gas is about 12% hydrogen, 25% carbon monoxide, 7% carbon dioxide, and 56% nitrogen; the nitrogen comes from the air used in the producer gas reaction.
>
> Producer gas is mixed with crude coal gas to give crude town gas. Impurities are condensed out as the gas cools (water, tar, napthalene, ammonium chloride) or by absorption in water (NH3, H2S, CO2). The rest of the H2S is removed by reaction with Fe2O3, and the purified town gas is ready for delivery. A typical composition of town gas would be about 51% hydrogen, 15% carbon monoxide, 21% methane, 10% carbon dioxide and nitrogen, and about 3% other alkanes.

Until the 1950's up to 80% (pdf file) of British homes were connected to the town gas grid. Electricity replaced some of that energy, but it was the advent of North Sea gas that led to the change to natural gas, a change completed in 1974. (It required different burners on stoves and other changes that I was not there to see). Gasification from coal, however, had been the major source of gas in the UK from 1920.

The Fischer-Tropsch process is developed from these gases. As the Bureau of Mines reported

> The catalyst employed in the pilot plant was nickel-manganese-aluminum oxide

> supported on kieselguhr and prepared by precipitating from the nitrates with potassium carbonate. Synthesis gas was prepared by conversion of coke-oven gas with steam over coke and freed from organic sulfur by heating to 400 degC in the presence of an iron catalyst and subsequent scrubbing with alkaline ferrocyanide solution. Operating conditions were specified as 1 atmosphere pressure and a temperature of 190 to 210 deg C. The catalyst was re-activated every 1,000 hours by extraction of the solid paraffin with gasoline. The catalyst chambers, suspended in an oil bath for temperature control, were narrow boxes 1.2 by 10 by 500 cm. The gasoline product of the synthesis consisted mainly of straight-chain hydrocarbons, of which 15 to 38% were olefins. The fraction of the oil product boiling over 220 deg C was better than gas oil for diesel fuel. The solid paraffin had a melting point of 48 deg C. These materials were produced in the ratio of gasoline:oils boiling above 220 deg; paraffin of 4:1:0.2.

The Bureau report goes on

> If and when natural-gas reserves are exhausted, coal could be substituted for natural gas with a gasoline cost of about 10 cents per gallon, exclusive of possible cost-lowering technological advances, according to an estimate by Hydrocarbon Research ,Inc.

Should I mention that this was written in 1946?

Tonight the Montana Governor showed that the fuel produced is hard to distinguish visually from water, and stated that the fuel is more beneficial to engines than petroleum-based fuel. He also commented that the carbon dioxide produced in the process could be used relatively locally to enhance oil recovery, as we have discussed here earlier.

This is a part of a series of talks that has, most recently, dealt with coal mining.

Surface Mining

Longwall Mining

Room and Pillar Mining

As usual any concerns, corrections, or questions, should be addressed in comments.