The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Tech Talk: Burning Coal in Place, or Underground Coal Gasification

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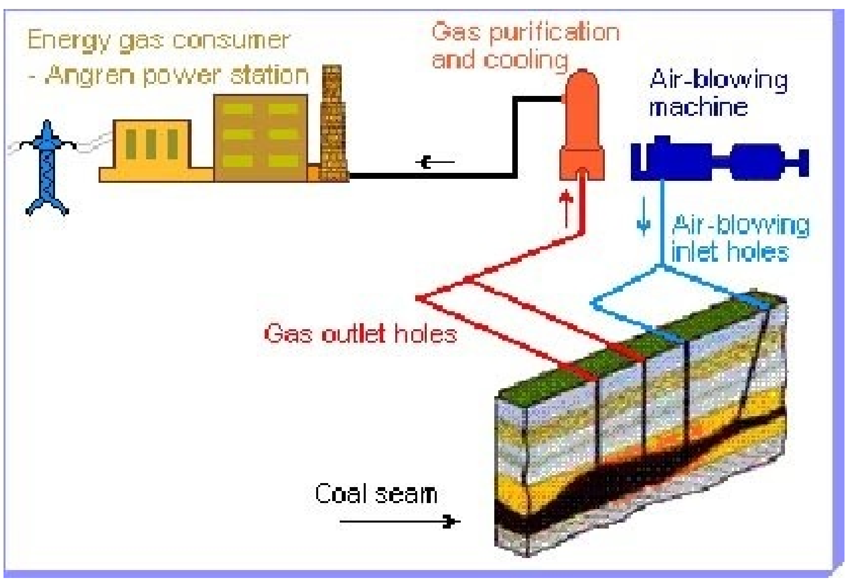
Topic: Supply/Production
Tags: coal, spontaneous combustion, tech talk, underground coal gasification [list all tags]

Last week I wrote about the SAGD process and how it is used to extract the heavy oil/bitumen from the oil sands up in Alberta. What I will write about this week is the more general topic of In Situ ("in place") Combustion. I'll talk about In Situ production as it relates to coal this week. Perhaps next week I'll talk about Toe to Heel Air Injection (THAI), a form of In Situ production which is being tested for use in the oil sands.

This is one in a series of weekly tech talk posts that deal with the technologies of conventional fossil fuel recovery. They are relatively short and so the descriptions are not provided in detail, rather they are meant so that you can understand some of the complexity of the process, and that it is not always easy.



Angren UGC process

The way that we use the majority of the coal, oil and natural gas that comes out of the earth is to burn it so that we can generate heat, which in turn is then used productively, either in the generation of electricity or more directly. But getting the fuel out of the ground can be quite expensive, either in direct cost or in the amount of energy expended. And so the question, why can't we just burn it where it is to get the energy out more easily?

With most deposits, the costs of recovery of the fuel conventionally are still low enough, and the energy recovery at the surface sufficiently high that this would be a losing proposition. But where coal seams are thin, or the oil is thick, using part of the fuel underground to recover a significant portion of what is left can be a winning proposition.

Of course burning coal underground is not always a deliberate act. Coal seams have caught fire for a number of reasons, and in parts of the country have burned for decades with significant environmental problems at the surface. Part of the reason for this is that if the coal seam is relatively close to the surface, then as the coal is burned away, the overlying rock collapses all the way to the surface, opening cracks which allow air to get down to the burning zone, in this way providing oxygen that helps keep the fire burning. If the fire is burning uncontrollably, then it becomes much more difficult to establish control since the cracks to the surface help keep the fire going, and they may not all be that large and easy to detect. (Though I have seen some big enough to hold a cow's carcass).

My own first encounter with underground coal burning was when wandering into a mine that was something like a hundred years old, and being conscious of all the smells in the return air-way. I was told that an old part of the mine had spontaneously caught fire, could not be extinguished, but had been sealed off and left. The fire, in that case, was fed oxygen through the mined out passages around the place now on fire.

This brings up the first point, which is that coal can, on its own, catch fire. The old pit heaps that dotted the landscape around mines were made up of old coal waste, including a fair amount of un-recovered coal. When they were later reclaimed it was often found that the tips had caught fire and burned the clay into a red-brick-like material. This self-ignition is known as spontaneous combustion and occurs because coal reacts with atmospheric oxygen even at ambient temperatures and this reaction is exothermic. If the heat liberated during the process is allowed to accumulate, the rate of the above reaction increases exponentially, and there is a further rise in temperature. When this temperature reaches the ignition temperature of the coal, it starts to burn - hence the term "spontaneous" combustion.

The temperature at which the coal oxidation reaction becomes self sustaining and at which spontaneous combustion occurs varies generally depending on the type (nature and rank) of coal and surrounding conditions of heat dissipation. In poor quality coal and where the heat retention is high, the coal and carbonacous material may start burning at temperatures as low as 30-40° C.

Coal oxidation can occur in coal storage – even on a battleship and, as I mentioned, underground.

The fires are not always spontaneous--perhaps the most famous is the Centralia fire which Joan Quigley has written about in "The Day the Earth Caved in." The coal seam outcropped at the surface where it caught fire, and the fire then moved underground and beneath the town of Centralia, PA. Despite vast amounts of effort, money and time, the fires are still burning.

This brings me to the second point. For a fire to continue to burn it has to have fuel (the coal) and air (oxygen). If the fire is totally cut-off all the air is consumed and the fire goes out. But if there are cracks through which air can reach the fire, then it will continue to burn. Thus, in Centralia, for example, as the coal burned in and under the town, it removed part of the rock holding the town where it was. The ground would then collapse into the burned out cavity, and a crack would run up to the surface along the edge of the opening, allowing air to flow back down to the fire and continue the progression.

Having been once involved in fighting such an event, it is very difficult to tell where the fire front is, and the coal does not burn in a vertical front, but in a very jagged pattern, depending on air flow and relative composition of the different layers of the coal. The air generally flows through the cleat pictured here.

But knowing that coal seams can burn in place, we still have to work out how to make that useful. Short of running water pipes down, and using the steam that comes out for power surely there has to be a better way of getting the energy, and there is.

Before the advent of North Sea gas, British towns were dominated by the Gas Works, old gas-from-coal plants that produced town gas from coal. Simply put, by heating the coal, and passing air and steam across it, one can generate "producer gas" and

> "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." So that if we can get the water and air to the coal fire underground in the right quantities then we can generate a gas that we can extract, and it can be used as an energy source.

Sounds easy, right? It turns out that it is not quite that simple. From the BERR report on the Chinese work written in 2004:

> Underground coal gasification (UCG) experiments have been carried out in many coal mining countries and industrial scale production has been achieved in the former Soviet Union. More than 15Mt of coal has been gasified by UCG and in excess of 50 billion m3 of gas has been produced from UCG projects around the world. Despite research and many trials in different countries, no truly commercially viable UCG project has yet been demonstrated. However, various technologies are now available which could change this situation. A shallow seam, commercial power generation project is currently under development in Australia.

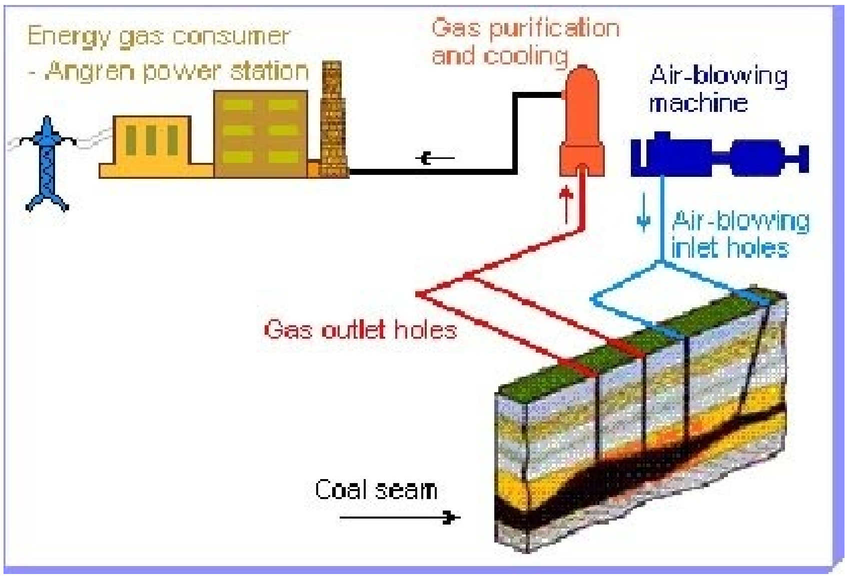
The first major plant was at the YEROSTIGAZ facility in Angren, in Uzbekhistan, which started in 1961, works a brown coal deposit and is now run by Linc Energy. The plant produced 35 million cu ft of synthetic gas a day, which is fed into the local power plant.

Advantages of the process are seen to be:

> * Capital investments in construction of underground coal gasification stations are less by 2.5 times as compared with those in construction of pits and quarries.
>
> * The productivity of labour is the same as in open-cut mining and 4 times as high as in pits while the cost of final product being the same as in open-cut mining is 3 to 4 times as low as in extraction from pits.
>
> * Hard and dangerous underground labour becomes unnecessary, working conditions are much better, and the extraction process can be completely mechanized and automatically controlled.
>
> * Coal transportation, loading and unloading are excluded. No fuel is lost in transportation to the user and the atmosphere is not polluted with coal dust.

> * There is no necessity for large areas for waste and ash dumps, and this allows conservation of fertile soil. The cost of land recultivation is five times as low as that with the conventional method of coal extraction. The mineless method of underground gasification allows exploitation of coal deposits with unfavourable mining conditions unsuitable for underground or open-cut mining. This allows more complete utilization of coal resources because non-conditioned and over-balance coal reserves can be used.
>
> * Unlike coal combustion, the –underground gasification requires no fuel preparation, and consequently, no ash and slag disposal. No environmental pollution occurs because the gas combustion products are free of solid particles, carbon oxide, sulphur and nitrogen oxides.

The process is illustrated:



Angren UGC process

Linc has since opened the Chinchilla UCG operation with initial tests in August of 2008, running only air into the coal and recovering gas.

> During its almost seven months of operation, the generator has operated very stably, producing gas of consistent quantity and quality. Gas has been produced with a typical composition (on a nitrogen-free basis) of H_2 32%; CO 17%; and CH_4 18%. The H_2/CO ratio of 1.81 is ideal for Linc Energy's GTL process. Since commencing operation of the 3rd UCG generator, Linc Energy has gasified approximately 2000 tonnes of coal, producing over 5 million Nm^3 of synthesis gas.

China began building an industrial scale pilot plant in Inner Mongolia in May 2007.

> Seven ignition and production wells reached the coalbed 200 meters below ground by May 23 in the project's $112 million first phase. The project consists of underground drilling and ignition, aboveground coal-gasification power generation, and chemical production.

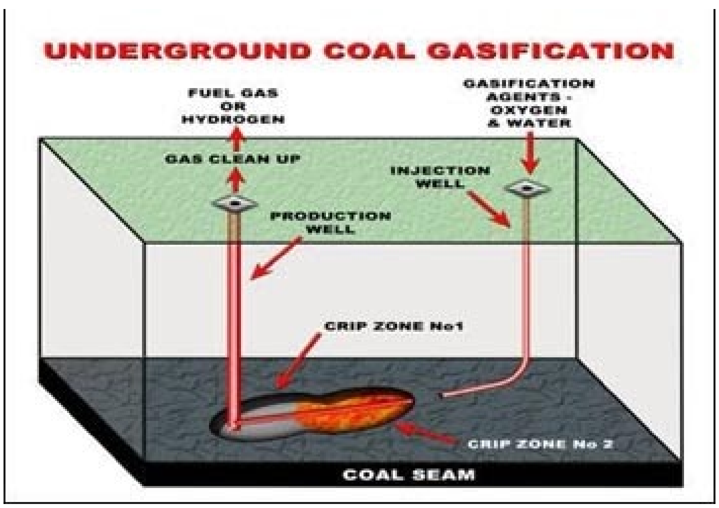
> The plant is located at the Gonggou Coal Mine in Wulanchabu City and by 2010 will produce 1.5 million cu. m/d of syngas, 100,000 mty of methanol and methane and generate 32.4 million kwh/y of power. The city is developing a coal-chemical industry with its more than 15 billion tons in coal reserves. Methane isolated from the syngas will be used to produce town gas and generate electricity.

In Australia Carbon Energy having run a successful 100 day study has started to install a 5 megawatt generator at Bloodwood Creek.

Let me, briefly, concentrate on two problems.

In the initial concept, it was proposed that two wells could be drilled from the surface to the coal seam. In one early US test of this idea, in Hannah WY, the seam was relatively close to the surface, and for the first test the wells were set 75 ft apart. After reaching the seam, it was intended that the connecting passage between the injection well and the extraction well would be created by starting a small fire at the bottom of the seam, at the first producing well, and then by blowing air down the injection well have the fire work back to that well along the cleats through which the air was passing. By restricting the flow it was intended that the passage would be small, and run along the bottom of the seam. Then, once a passage existed, more air and steam could be fed into the injection well, increasing the size of the fire, and creating the producer gas that could be extracted from the production well.

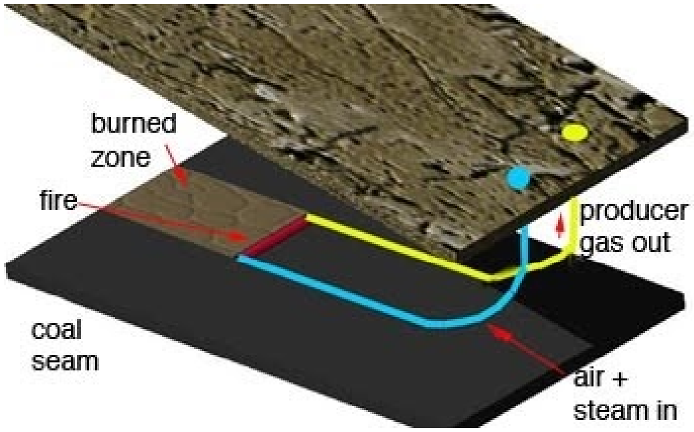
Unfortunately the fire would not "behave" and over-burned the coal, rather than burning in the lower section, and did not otherwise go as planned. The conclusion was that this passage had to be artificially created first. The need for a long hole in the coal requires a directional drilling tool, and in the 1970s when the earlier trials were made, those were not available, particularly ones that could turn ninety degrees within the 140 ft from the surface to the seam. One had to be invented (and was). Thus in recent experiments the UK planners have looked at directional drilling from the surface to the coal, as a way of creating the initial passage, and providing paths for the air and steam to the fire and for the producer gas to come out.



Source UK Coal

Two different approaches are being looked at in China, one of which works by creating panels in existing mines from adjacent cross-cuts, while the second uses a pair of directionally drilled holes with the fire to be initiated between them. Although as I mentioned from the work done in the

US, getting that initial connection may be rather difficult, and long-term control of fire location gets to be rather tricky.



Chinese method of UCG Derived from the BERR report.

The use of the two bounding holes confines (in thinner seams) the burn to the geometry desired and gives a method of control that is more difficult to achieve in larger seams, or without those bounds.