The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Coal in an Engine does not need Fischer Tropsch

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There has been a fair amount of discussion about the need to form liquid fuels from coal. As the more conventional liquid fuels get more expensive, and less easy to find and produce, an alternative source of fuel has been suggested in the Fischer Tropsch conversion of coal into diesel and gasoline. Can I ask why?

No, not in the sense of do we need the fuel, but rather why go through this long, complex and relatively inefficient process of making the liquid, when, for just the price of grinding it down to micron size, you can mix the coal with water and happily drive your vehicle away. "Preposterous !" I can almost hear the splutters from here, but no, actually it is not, and I thought I would revisit a program that General Electric and others carried out in collaboration with the Department of Energy, between 1982 and 1993, which explains what some of the problems were and how they were resolved.

My initial reference can be downloaded as a pdf from ref. 4 here . The pre-cursor work comes from Jerald Caton's overall review, which can be downloaded as ref. 7 from the same source.

The idea itself is not new. Rudolph Diesel ran one of his engines with a powdered coal fuel back in 1896, though the test only ran 7 minutes, before being stopped to see what the dry coal dust had done to the engine. Dr Caton considers it likely that the coal was at around 100 microns in size, and left the engine gummed with a considerable amount of sludge (the coal had perhaps 10% ash). There were later tests of differing engine designs in Germany, all using coal dust, from different sources, but mainly using the German lignite, which has about 20% ash and particle sizes in the 75 – 100 micron range. The coal was introduced in a compressed air stream (about 90 psi), but the engines still underwent high wear rates, sludge accumulation and a lack of reliability and control. These issues had not been solved by the time that the Second World War came to an end and development stopped.

After the war the research largely moved to the United States, with the coal being mixed with various liquids, including diesel itself, in part as a way of getting around the problems of feeding coal particles in compressed air, since this can be an explosive mix, and is difficult to control and provide a constant feed. Some of the problems can be seen from this reported result

> The slurry was used in a commercial Caterpillar diesel engine with an unmodified mechanical fuel injection system. During the testing the fuel injection system repeatedly failed due to pump plunger and injector nozzle pin seizures. A wear rate 35 times the normal level was recorded for the piston rings and cylinder liner. Performance of the

> engine remained similar regardless of the type of coal mixed with the diesel oil. Scope limitations and budget constraints ended the research. The final conclusions were that fuel-injection problems were severe, energy-release characteristics of coal fuels in engines were poor, and that significant wear problems were caused by ash and incompletely combusted particles.

To understand part of the problem with the ignition of the coal, with the higher rpm engines consider that the fuel is injected into the cylinder as a fan mist, and that the fuel must then atomize, ignite, and be totally consumed all within about 10 milliseconds. This becomes more of a problem as the coal particles get larger, and conversely it meant that by making the particles smaller, it became easier to get the coal to completely combust.

By using 2 micron coal, though only at 15% concentration in diesel oil, it became possible to get a diesel to run reliably, although the coal was specially prepared to have negligible ash content and nozzle blockage problems still persisted. Gradually the concentration of coal was increased, to the point that, with a slower cycling engine, it proved possible to run 31% coal in the diesel, with the coal in the 2 – 10 micron size, and the potential economics of making the transition also began to become evident, as oil prices began to rise in the 1970's. It was about this time that the switch was also made to running the coal particles in water, rather than diesel oil, and with mixes up to 34% coal in water. Some cited advantages to making the switch (apart from improving the economics) were that the combustion temperatures would be lower, reducing disassociation reactions and the oxides of nitrogen.

By the beginning of the 1980's the potentials of the change in fuels were becoming more evident, as well as a clarification of some of the technical problems that would have to be overcome for the technology to reach the market. And so the Department of Energy began a program where they worked with major diesel manufacturers (Caterpillar, Cooper-Bessemer, Detroit Diesel, General Electric and General Motors) and a program at Sandia looked at ways to improve the injector systems. The Caterpillar program was directed more at an intermediate stage conversion of the coal to gas, but the other four focused on the coal:water combination.

Cooper-Bessemer developed a technique that led to an engine being tested for more than 750 hours, using a coal:water mixture in which the 12-micron sized coal mixed 50:50 with the water, to give a consistency similar to paint. They concluded that, in 1993, the technology would only be economic with power plants above 8 MW, and were planning at that point, to launch a product line. At the time it was anticipated that the engines would come on market in the 2005 to 2010 time frame with an installed cost of $1300/kW (1992 dollars); an efficiency of 48.2%; NO_2 emissions of 0.11 lb/MMbtu; SO_2 emissions of 0.37 lb/MMbtu (equivalent to 0.3% sulfur diesel oil); and particulate emissions of 0.01 lb/MMbtu.

To reach this point it had been necessary for the manufacturers to solve the problems of the injectors (while CB used ceramic, GE had moved to the use of diamond nozzles – a product increasingly now available); hardening the piston rings, cylinder liners and valves; and improving the emissions controls. The increase in coal concentrations not only increased the economics, but since around 1% of the coal is required to evaporate a 10% water fraction in the mix, obviously the greater the mix, the better the engine performed. For stationary engines it is more cost competitive to ship the coal dry, and then do the final preparation and water mixing at the engine site, saving the cost of the freight. The paper was written in 1993, and projected that the use of such an engine, today, would produce electricity at a cost of $0.0611/kWh, against the cost of an oil/gas plant which was estimated to cost $0.0625/kWh. The oil/gas price was assumed to be $4.50 per MMbtu, coal price was anticipated to be $1.63 - $1.74 per MMbtu. The entire economics, with those input prices, however was based on the assumption that the preparation costs for the coal slurry fuel would not bring the overall price above $3.00 per MMbtu. The engine would require a higher maintenance cost $0.0036/kWh as opposed to $0.0016 for conventional. (More detailed costs are given in the paper).

Detroit Diesel focused more on large off highway haulage trucks and marine applications and had, by 1993 reached the point that they could achieve auto-ignition and get a combustion efficiency of around 99.2%, the application required a higher rpm engine, and this, in turn, mandated a smaller droplet size (20 microns).

General Motors were oriented more toward locomotive manufacture, and looked at a variety of liquid fuel bases for the coal combination, however, it was the GE team, through their Transportation Systems division, that had the greatest success, with the program reaching the point that a fully modified 2500 hp locomotive was run, during November and December 1991, around the GE test track, with equivalent power outputs to those of the conventional diesel oil powered plant.

> Among the major accomplishments of this program were the development of specialized fuel injection equipment, for coal-water slurries, diamond compact inserts for the nozzle tips for wear resistance, and an integrated emissions control system. Over 500 hours of engine operation was accumulated using coal fuel during the duration of this program A major milestone was attained when, during November and December 1991, a coal-fueled diesel engine powered a locomotive on the General Electric test track. . . .They estimated that the coal-water slurry would be about half the cost of diesel fuel, on an energy basis.

In 1993 the further drop in the price of oil, and the discontinuation of the programs at the Department of Energy brought all these programs to a conclusion, and interest faded.

However as the GE Review concluded

> GE has developed the critical technologies in the completion of the second phase, electronically controlled fuel injection engine with all durable parts and a complete emissions clean-up system. When the market environment again becomes favorable in the future, the technologies can be further improved and packaged into a commercial system very quickly.

.Well it would appear that we are now entering into those times, so it will be interesting to see how long it takes for this technology to be resurrected.

Some years ago I seem to remember seeing either on TV or on a news show at the cinema (for this was in the UK) the then Chairman of the National Coal Board driving around London in a car powered by this coal:water fuel. Unfortunately my memory is not good enough to remember the source, and though the folks that now have custody of the NCB films have searched diligently they cannot find any reference, so if anyone else can remember I would like (among other things for my own peace of mind) to hear about it.

Thanks!