CLEAN ENERGY FROM CARBON RICH REAL ESTATE

Introduction

In May of this year the Natal Branch of the National Association for clean air held a meeting in Durban and Mr. W. Meihack of the Chemical Engineering Department of the University of Natal gave an address on the above subject.

We publish notes on his address and on some of the question and answer which followed it.

Various people have used the "Energy Crisis" as a justification for various schemes of alternative means of energy release. However, there are other reasons for such investigations, – among them, energy independence for a country or quite simply, their engineering elegance.

Whether fluidised combustion and gasification measure up to the second reason, is for you, the audience to decide.

SOUTH AFRICA'S COAL RESERVES

To put the subject matter into perspective it is useful to sketch the coal reserves of our country. Two factors must be taken into account

1. *Accessibility:-*

   is it technologically and economically possible to bring the coal to the surface?

2. *Quality:-*

   can the coal be used when it has been extracted?

The "mineable" coal reserves fall into three classes

We have no coal with ash less than 5%
We have 12 billion tons with less than 20% ash.
We have 50 billion tons with less than 28% and
90 billion tons with less than 35% ash.

Sep van der Linden of Curtis Wright in the USA where 10% ash is considered high, remarked, on seeing a sample of 37% ash coal, "That's not coal, that's carbon rich real estate". Hence the title of the address.

High ash content makes coal difficult to burn because:

There is a great mass of material that absorbs energy as it is heated. Carbon that is enclosed by ash does not readily come into contact with Oxygen.

De-ashing coal is an expensive process and yields large quantities of discard material. Don't forget that coal crushing also gives large quantities of discards.

Normally 6–25 mm coal is what the market requires. All material < 6 mm is dumped. The coal dumps smoulder and foul the air.

If you drive past Newcastle at night you can see the glowing smokey eyesores. In the day, of course the glow can't be seen!.

Sulphur is another contaminant in coal which makes it unpleasant to burn rather than difficult, so only a coal with a Sulphur level below that which can be economically removed from the flue can be used. Corrosion of tubes, if these are below the dewpoint as is often the case in economizer tubes, is also a problem.

Fluidised coal conversion ie. combustion and gasification offers significant improvement in ash and Sulphur levels that can be tolerated over conventional firing, allowing poor quality coal and discards to be used.

3. *What is fluidisation?*

   It is possible by passing air through a bed of fine particles to create a fluid-like state with good mixing.

4. *Why consider fluidised combustion?*

   1) Good mixing and therefore good contact efficiency

   2) Attrition of particles breaks down ash and exposes more carbon.

Other Advantages

Good Heat transfer
Low NO_x – low temperature
Ash fusion is not a problem because of low temperature
Low temperature makes for less stringent material selection criteria
Higher carbon utilisation

Sulphur capture in situ with limestone or dolomite regenerates sulphated limestone to give Sulphur production of which 90% of Sulphur can be recovered.

Some Problems

A feed with a wide size distribution causes defluidisation and elutriation.
Turn down of combustion rate is limited because the range of velocities which will support fluidisation is limited.
It is not possible to remove ash without removing coal at the same time and this affects combustion adversely.
There is an urgent need to clean up particles in the hot gas.

TYPES OF FLUIDISED BED COMBUSTORS

There are already a large number of designs, all different compromises to minimise problem areas, as all engineering designs must be:

Basically there are 2 types: Air Fluidised Beds and Pressure Fluidised Beds

AFB's – have a low capital cost

PFB's – are more expensive but have a higher percentage of carbon utilization and Sulphur capture.

Also hot pressurised gas can be expanded through a turbine.

I will now try and describe some of the individual designs commercially available at present. Contractors mentioned offer to sell you PFB systems!

1. *Foster Wheeler*

Steam generator Air Fluidised Bed Combustor
Split Bed for turndown
Overbed coal feeder – not suitable for fines
Fines re-injected to give good Carbon Combustion
Tubes in bed and in freeboard
45,4 tons per hour at 275–625 psi

2. *Babcock and Wilcox – Renfrew AFBC*

Old boiler – retrofit
Horizontal tubes
18 tons per hour at 406 psi
Designed for a 25 – 35% ash, high Sulphur coal

3. *Curtis Wright – 500 Mw*

3 beds PFBC
Air cooled tubes in bed (65%)) Mix their way to reduce
Fluidised air (35%)) dust loading to turbo
Expand through turbines to give electricity (60%)
Waste Heat Boiler gives additional heat prior to the gases passing to a scrubber
Coal pile to busbar efficiency of about 42%.

4. *Stone Platt*

Package boiler
Sized to fit railway truck and pass through tunnels on route
Turndown – reduce main air and coal) Constant
– reduce control air to) Temperature
uncover tubes)
Also can reduce coal only – but temperature drops
16,3 tons per hour at 150 psi 85% efficiency
Emissions all meet EPA standards

FLUIDISED BED COMBUSTORS IN SOUTH AFRICA

Ngwelezane Hospital 3,6 tons per hour at 150 psi AFBC
Vertical shell boiler – 3 sections with individual plenums to give turndown.
Mondi – no details available.

FLUIDISED BED GASIFIERS

Again there are various designs
The most successful is Westinghouse
Gasification has advantages in that wet scrubbing can be used with relatively small drop in overall efficiency since energy is stored chemically rather than thermally.
Fluidised Bed Combustor and gasification is still in its infancy.
Originally thought of about 1960
Taken seriously since about 1972
Much research is going on at 13 locations around the world. Mostly USA Companies.
National Coal Board in Britain and the University of Natal in South Africa.

RESEARCH AT UND

1. *Multistage Combustion*

1 Mw at 900°C has been used to burn up to 75% ash coal.

Later modified for gasification. Produced only low BTU gas on approximately 40% ash discards – efficiency about 80%.

2. *Small scale – observation rig.*

3. *PFBC in a deep bed.*

Emphasis on the use of fines now being used for gasification.

To sum up obviously I have run over a large area

FBC offers
- low grade coal utilisation
- low NO_x and SO_x emissions
- high efficiency
- competitive capital cost

I think it has a big future.

QUESTIONS AND ANSWERS

Q: Had any problems been experienced with tar oils and phenols?

A. Fluidised bed combustion has most of the problems associated with the burning of fuel, but much depends upon the fuel feed.

Q. In practice, what happens to the ash generated?

A. The ash has sufficiently low carbon content and can therefore be utilised in building materials and with the minerals present results in a very refractory material during normal burning processes but the fluidised bed technique produces a product dealt with more easily.

Q. Two fluidised bed boilers have been operated in Natal (Empangeni en Tongaat). The reported carbon loss is of the order of 15% whereas spreader stokers have achieved 3,5% loss with 6% being considered very poor. (using 15/20% ash content fuel)?

A. 40% ash coal gives 99% carbon utilisation. Westinghouse 10 – 15% carbon loss, Empangeni 2 – 3% loss. These figures were produced by UND over 48 hours with 12 hours of steady operation.

Q. If the ash is fed back twice, does this not increase efficiency and reduce carbon loss?

A. Use of additional equipment is costly and "fines" are difficult to re-use.

Q. Best quality coal is said to be exported and the major proportion of coal in RSA use is for electricity generation?

A. Prospects seem good for the use of low-grade fuels. The fluidised bed boiler is better under constant load conditions and is not, at this stage, satisfactory where turn-down is necessary.

Q. Are problems not very real in the case of very large (sealed up) units?

A. Tendency is to provide one feeder per 10 m^2 surface – however many feeders do result in high capital cost.

Q. Pilot scale or micro industrial scale seems promising but what was the situation with larger units? Larger problems?

A. This is certainly true to some extent. The great advantage was in the use of lowgrade fuels which would otherwise be unusable. Large scale fluidised bed combustors do not behave in the same way aerodynamically as small units.

Q. What possibilities exist for automation of operation with minimum supervision?

A. The process should not require more skilled operators than for standard boilers.

Q. What percentage of ash can be re-introduced?

A. Designs vary – but up to 70% can be returned.

Q. Is ash build up a problem?

A. An overflow pipe is fitted for oversize material. Dust load 0,01 to 0,1 g/m^3.

Q. Was material used up to 40% ash?

A. Yes in UND trials.

Q. Is high ash content fine material used on large or small units?

A. Experimental units to 500 mm diameter, but Curtis Wright (USA) claim 600 Mw units are practicable.

In answer to questions Mr. Meihack produced some further information concerning chemical reactions, and findings concerning useable air pressures and efficiencies found at the University laboratory.

Heat transfer in Fluidised Bed 3 to 4 times that expected between gas and tubes.

Sulphur can be captured in the bed using calcined limestone:-

$$CaCO_3 \rightarrow CaO + CO_2$$
$$CaO + S \rightarrow CaS + \tfrac{1}{2}O_2$$
$$CaS + ZO_2 \rightarrow CaSO$$

Then

$$CaSO_4 + CO \rightarrow CaO + CO_2 + SO_2$$
$$3CaSO_4 + CaS \rightarrow 4CaO + 4SO_2$$
$$CaS + SO_2 \rightarrow CaSo_4$$
$$CaS + \tfrac{3}{2}O_2 \rightarrow CaO + SO_2$$

Some American coals have Sulphur contents 3 to 4 times that of South African coal.

Turn down ratios of ± 3:1 are reasonable. Cyclones have been used with limited success – fluidised bed sand filters (2 or 3 in series) and then a final scrubber. The system is difficult to clean efficiently.

Atmospheric pressure units of low cost with limited bed thickness and lower efficiency – deeper beds have small bubbles at the bottom but bigger ones on top so particulate emissions become high. Low bed units result in difficult ash removal.

Pressurised fluid bed combustion (8 – 10 bar). Can use low pressurised gas with turbo entry giving greater efficiency.

A mix at UND utilises a pressure bed upto 6 bar with 3 shallow fluidised beds vertically fitted in the hope of producing good combustion conditions upto the cyclone atop of the unit to return oversize material. Efficiency 99% combustion, burning 75% ash coal, at 850°C with 1 to 1,4 Mw thermal output. The unit was modified for thermal gas with 80 – 85% carbon efficiency.

A second unit (10") with a very small screw feed at the bottom and a vibratory feed at the top with a vertical column and cooling coil within has been operated. Current interest is in pressurised fluidised bed combustion with a deep bed and gasification therein.

Bed 4,9 m high pre-heated with LP gas burner at the base to give 450°C then the coal feed is started and combustion proceeds satisfactorily. A pressure vessel (to 10 bar) with conical base is used.

UND have successfully burnt fly ash with efficiencies upto 99% in pressurised fluid beds. 50% fly ash with 50% water feed by diaphragm pump works satisfactorily but efficiency lower than dry feed.

A major problem occurs with very fine ash being carried out of the top of the combustor requiring extremely good filtration if used for gas turbine operation.