Coal preparation research in South Africa

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Synopsis

South Africa is reliant on coal for the generation of almost all the electricity used in the country, and several large industrial concerns such as Sasol are also coal based. Research relating to the mining, beneficiation and utilization of coal is important in order to ensure the optimal exploitation and use of coal within the country. The Fuel Research Institute (FRI) of South Africa was established in 1930 to investigate all aspects of coal beneficiation and utilization in South Africa. The FRI went on to conduct world-class research, and in 1957 a pilot coal preparation plant was constructed in Pretoria to enable large-scale practical experimentation. The pilot plant played a pivotal role in the establishment of South Africa's low ash coal export project.

Political and economic factors contributed to the eventual closure of the FRI and South Africa experienced a period of about 10 years between 1990 and 1999 during which very little public coal preparation research was done. This changed for the better towards the end of 1999 when Coaltech 2020, a collaborative research program was established. Participants included the CSIR, universities, the government and the major coal producers. Coal preparation research conducted under Coaltech thus far include dewatering and drying of fine coal, size classification of ultra-fine coal and dense-medium fine coal beneficiation. Currently, the Coaltech focus is on the beneficiation of low-grade coal reserves and is investigating existing as well as new techniques that can be utilized to provide cost-effective beneficiation of low-grade raw coals and reject coals.

Introduction

South Africa is dependent on coal for the generation of almost all the electricity used in the country. Large industrial concerns such as Sasol and the country's metallurgical industries are also coal based. South Africa is furthermore a major exporter of coal through the port of Richards Bay. Research relating to the mining, beneficiation, and utilization of coal is important in order to ensure the optimal exploitation and use of coal within the country. In the past, this function was fulfilled by the Fuel Research Institute but coal research in the country came to a virtual halt after 1990 when changes in legislation cut off the funding source for coal research. Today, thanks to the formation of Coaltech in 1999, coal research is again being actively conducted.

History

Coal mining in South Africa started in about 1864 when the first colliery opened near the town of Molteno in the Eastern Cape Province[1]. The earliest record of coal washing goes back to 1905 when the first of five jig plants was installed in Natal Province[2]. In 1934, a 90 000 ton per month Rheolaveur plant was commissioned in the Transvaal Province and a year later, the first double-stage Chance plant came into production[2]. This plant was capable of processing some 100 000 tons of raw coal per month. Dense-medium processes using magnetite as the medium came into use after about 1951.

Prior to 1922, the accepted 'standard' for high grade coal produced in South Africa was a calorific value of 12.5 lbs/lb (28.22 MJ/kg). Most producers managed to deliver the required quality of coal by selective mining combined with good hand-sorting. In 1922, the Coal Grading Act was passed which laid down a standard calorific value for A-Grade coal of 12.8 lbs/lb (28.89 MJ/kg). Many producers became pressed to meet this quality and the shortcomings of their particular method of maintaining quality became apparent. Producers began to consider washing their raw coals as a means of delivering the required quality of coal to customers and making their coal reserves go further. By about 1938, the first coal washing plants, built for this purpose, came into service and these plants processed the total output of thermal coal from mines. Coal smaller than 10 mm, termed 'duff coal' was discarded since, at the time, there was no market for coal of this size.

A number of washing plants, especially in Natal, aimed to produce coking coal. The objective was to produce a coke containing 10% ash. Since the coal contained approximately 30% volatile matter, it was required to wash the coal to 7% ash in order to achieve the 10% ash in the resulting coke. This proved to be very difficult indeed, due to the difficult

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washing characteristics of South African coal. In the end, a compromise was adopted with the coal being washed to between 12 and 15% ash. The South African iron and steel industry had to adapt to these levels of ash in the coke feedstock, and the cokes produced in South Africa therefore contained up to 20% ash.

The South African government realized the importance of coal to the development of industry and promulgated the Fuel Research Institute and Coal Act in 1930. This led to the establishment of the Fuel Research Institute of South Africa.

Fuel Research Institute of South Africa (FRI)

The FRI was formally established in 1930 and operated as an autonomous organization under the control of the Fuel Research Board until 1980 when it was incorporated into the Council for Scientific and Industrial Research (CSIR).

The functions of the FRI were:

- To study and investigate the fuel resources of South Africa
- To test, analyse and grade coal and coal products
- To undertake research on all matters relating to fuels and fuel products.

The FRI was funded from two sources. Capital funds were obtained from grants voted by parliament whereas running expenditures were covered by a levy imposed on the sale of coal.

During its 50-year existence, the FRI conducted world-class research. The activities of the institute were divided into the following areas:

- *Surveying and grading*—the Institute did not undertake quality control but did sample all the grades of coal marketed in the country on a regular basis. The results of these analyses were published annually in the form of the 'Coal Bulletin'. Assistance was provided to prospectors and samples from bore-cores were analysed free of charge
- *Coal preparation*—washability and liberation analysis studies were conducted on bulk samples of coal from many collieries in order to assist companies to optimize the recovery of product coal from their reserves. A pilot plant was commissioned in 1957 to facilitate the processing of large coal samples in order to produce bulk samples suited to industrial–scale coking and combustion tests. The pilot plant was furthermore used for research work, much of it aimed at finding an efficient means of producing coking coal from the Witbank and Waterberg coalfields. This required low-gravity separation of coals with high amounts of near-dense material. The research proved successful and contributed significantly towards the establishment of South Africa's coal export business through the port of Richards Bay. The Institute furthermore conducted regular efficiency tests on producing coal preparation plants and assisted greatly in optimization of these plants. A photograph of the dense-medium cyclone in the FRI pilot plant is shown in Figure 1
- *Carbonization and briquetting*—laboratory and pilot-scale tests were carried out at the Institute to determine the suitability of South African coals for blast furnace coke manufacture as well as for the production of char for use as reductants in the ferroalloy industry. Briquetting of coal and the production of formed-coke and char was also investigated and demonstrated on a pilot scale
- *Combustion*—extensive test work was conducted on a full-scale test boiler to assess the thermal performance of coals and the efficient utilization of the heat generated. The viability of fluidized-bed combustion of low-grade coals and discards was also successfully researched and demonstrated in a pilot fluidized bed combustion unit. This unit is shown in Figure 2
- *Chemistry*—low-temperature pyrolysis, hydropyrolysis and solvent extraction of coal were some of the activities conducted by the Chemistry Group
- *Other*—the measurement of emission of methane gas from coal strata, determination of the explosiveness of coal dust, and the detection and control of spontaneous combustion and fires in underground mines and discard dumps were also part of the FRI's activities.

In 1980, the responsibilities and activities of the FRI were transferred to the CSIR. A new CSIR division, 'Energy Technology', was formed as a result.

CSIR—Division of energy technology (Enertek)

Most of the activities of the FRI continued under Enertek until 1990. After 1990, the coal levy, which was the primary funding source for energy research at the CSIR, was discontinued following changes in legislation. This had a severely negative influence on coal research in South Africa. Activities at Enertek were scaled down significantly and the pilot coal preparation plant was one of the many facilities that were shut down. A few select projects survived, namely the coal dust explosion tunnel at Kloppersbos, which obtained alternative funding through the Safety in Mines Research

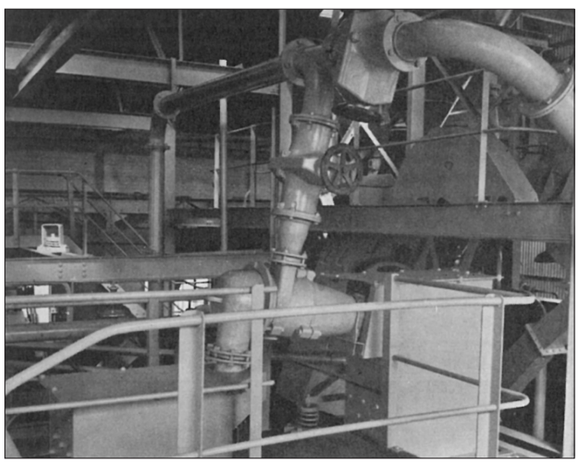

Figure 1—The dense-medium cyclone in the FRI coal preparation pilot plant

Figure 2—Pilot fluidized bed combustion unit

Advisory Committee (SIMRAC) and those activities, such as the coal laboratory, which became self-funding through taking on contract work for outside companies. The latter activities were, however, of a routine nature and for all practical purposes, no coordinated public coal preparation research was conducted in South Africa between 1990 and 1999 when Coaltech was established.

Coaltech

The Coaltech Research Association was established in 1999 as the Coaltech 2020 Research Program. It is a collaborative initiative to develop technology and apply research findings that will enable the South African coal industry to remain competitive, sustainable and safe well into the 21st century.

The Coaltech Research Association is an association incorporated under Section 21 of the Companies Act of 1973. The Coaltech Shareholders are Anglo Coal, Xstrata Coal, Eskom, Exxaro Coal, Sasol Mining, BHP Billiton Energy Coal South Africa, Total Coal, CSIR and the Chamber of Mines. Bon Terra Mining, Kuyasa Mining, Kangra Mining, Leeuw Mining, University of the Witwatersrand, University of Pretoria, National Research Foundation, National Union of Mineworkers, and the Department of Minerals and Energy are partners in the Coaltech work programme.

Coaltech is funded by voluntary contributions from the shareholders. In exchange for their contribution, every shareholder obtains representation on the Coaltech Board as well as on the steering committees. Seven research areas are supported:

- Underground mining
- Surface mining
- Geology and geophysics
- Coal preparation
- Surface environment
- Engineering
- Human and social.

Each research area has a steering committee consisting of representatives of the shareholders and the research providers. The research providers are employees of science councils, universities, and private consulting firms. The chairpersons of the committees are senior representatives from industry. Since industry is represented on the committees, research is kept practical and relevant. The committees meet at least every other month to monitor project progress.

The initial focus of the research was on extending the useful life of coal mining in the Witbank/Highveld coalfields while sustaining job opportunities and utilizing the available infrastructure to the year 2020 and beyond. Although much of this research is still continuing, the rapid depletion of the reserves in the Witbank/Highveld coalfields has necessitated the research focus to also now include the Waterberg coalfield, situated in the northern Limpopo Province. It is expected that most of South Africa's future coal will be mined from this coalfield. The geology of the coalfield is very different from that of the Witbank/Highveld field and presents some formidable challenges to mining and processing engineers.

During the past ten years, more that 100 research projects have been completed or are still ongoing. Some of the projects that have been successfully completed are:

- Categorization, quantification and location of the remaining resources in the Witbank/Highveld coalfields. This project not only identified the remaining coal resources *in situ* and in the pillars left by past bord-and-pillar mining, but it also alerted the various mining houses to the economic possibilities of extracting or combining resources with adjacent companies
- Beneficiation of fine and ultra-fine coal. Spirals are still used extensively in South Africa to process fine (minus 1 mm) coal. Changes in the export market brought about a change in the specification of thermal export coal and most contracts now specify the required coal quality on an 'as-received' basis. This implies that the moisture content of coal has to be brought into consideration when assessing the quality of the coal. Fine coal, due to its high moisture content, negatively influences the quality of the coal railed to Richards Bay. Unless the fine coal can be processed to a high calorific value (approximately 28 MJ/kg) and dewatered to low moisture levels (below 15%), it is not economically viable to include fine coal in the final export product. A better method for processing fine coal was sought and this led to a research project aimed at evaluating dense-medium cyclone processing of fine coal. A 25 ton per hour pilot dense medium cyclone plant that was designed by the Coaltech Coal Processing Steering Committee was built and tested on four collieries. It proved beyond doubt that dense medium processing was more efficient than spirals for many of the coals in the Witbank/Highveld coalfield and that fine coal can be upgraded to a calorific value of 28 MJ/kg. As a result of the tests, Leeuwpan Colliery replaced their spirals with a dense medium cyclone plant. A photograph of the Coaltech test plant is shown in Figure 3
- Binderless briquetting of fine coal. Ultra-fine coals from Tshikondeni and Grootegeluk mines (both mines are situated in the Limpopo Province) contain high percentages of vitrinite. As a result of the high vitrinite content, it was found that very strong and water resistant briquettes can be produced when briquetting these coals without any binder. Binderless briquettes could also be made from the low-vitrinite Witbank/Highveld ultra-fine coals, but these briquettes are not water resistant due to the fact that the binding material in these briquettes is mainly clay. Froth flotation concentrates obtained from Witbank/Highveld coals, however, also produce strong and water resistant briquettes. Figure 4 shows a photograph of the briquetting press used during investigations and some binderless briquettes made from flotation concentrate at a mine in the Witbank area
- Testing and evaluation of various water treatment processes. This work has resulted in one mining company building a full-scale biological treatment plant to process mine water, and also led to a joint venture between two major mining groups who built a plant to deliver potable water from mine water.

Current coal preparation research projects are focusing on dry processing and screening of low-grade raw coals. The supply of coal to the local power generation utility, Eskom, has drastically changed in the last few years. In the past, Eskom was supplied with coal from a few large, dedicated mines. The coal was mined from fairly high-grade reserves, crushed, and sent to the power stations via conveyor belts. Presently, a large number of small suppliers truck coal by road to Eskom stations. Much of this coal is recovered from low-grade reserves, discard dumps, and slurry ponds. In order to meet Eskom's quality specifications, most of the coals require some beneficiation, or at least destoning, but for

Figure 3—Coaltech pilot dense medium cyclone fine coal plant

many small operators, building and operating a dense-medium plant for this purpose is too expensive. Coaltech therefore decided to investigate the viability of inexpensive, dry beneficiation techniques.

Work is presently underway to evaluate dry screening of coal at small apertures (3 to 6 mm) and dry processing of coal using the FGX compound dry separator. Other dry processing techniques, including X-ray sorting and dry-dense medium separation are also considered. Results obtained to date have been encouraging. Water is scarce in South Africa and dry processing is very attractive for this reason. The fact that coal remains dry (which maintains the heat value) and the fact that no slurry is produced make dry processing that much more attractive. Figure 5 shows the Bivitec screen installed at a Witbank colliery. This screen is used to dry-screen coal at 6 mm. Figure 6 shows a photograph of the 10 ton per hour FGX unit in operation at a mine near the town of Belfast in Mphumalanga Province.

Coaltech is now ten years old and is considered to be a successful research programme due to the following factors:

- It is a collaborative partnership between mineral and energy industries, labour unions, the government, universities, and other research organizations
- It is 'industry needs' driven
- It assists in the career development of postgraduate students
- There is formal involvement and partnership with universities
- It is jointly funded by the coal industry, the state and the CSIR.

One of Coaltech's most important successes is the good communication between the different mining companies, which came about as a result of the companies conducting joint research projects. This has benefited all the shareholders and the coal industry at large.

Figure 4—Briquetting press and binderless briquettes produced

Conclusion

Coal preparation research in South Africa has a rich history and the country has been a world player for a long time. Despite temporary setbacks, coal preparation research is on track again—thanks in large to Coaltech.

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Figure 5—Bivitec dry screen

Figure 6—FGX pilot unit