Development and Operation of Coal Preparation Facilities at Thiess Dampier Mitsui Riverside Mine Queensland, Australia

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ABSTRACT
Development of the Riverside Mine in the Queensland Bowen Basin is tied to production and export of medium volatile hard coking coal to Japanese Steel Mills.

This paper outlines the use of exploration samples to generate preparation plant design parameters and process requirements.

The coal preparation process is described, together with the performance of the plant during the first months of operation. Particular reference is made to operation of the flotation circuit.

1. INTRODUCTION
In October, 1983, the first shipment of Riverside coking coal was made to Japan.

Riverside Mine, operated by Thiess Dampier Mitsui Coal Pty. Ltd., is located in the Queensland Bowen Basin, approximately 140 km south west of Mackay and 35 km north of the township of Moranbah. Coking coal is mined from the Goonyella lower seam, cleaned and railed for shipment through the Dalrymple Bay Coal Terminal located south of Mackay.

Exploration drilling at Riverside commenced in 1968 and continued, coupled with laboratory and pilot scale testing, until 1982.

In January, 1981, an agreement was reached with the Japanese Steel Mills allowing development of Riverside Mine. This agreement was for sale of the total coking coal production over the life of the mine only to Japanese Steel Mills. Construction commenced in 1982 and the first clean coal was railed in August, 1983.
The nature of the coal reserve at Riverside and market requirements have resulted in a mine development incorporating several unique features.

2. EXPLORATION

The Riverside Mining Lease contains reserves in excess of 64 million tonne of medium volatile hard coking coal. These reserves are contained in two consecutive seams, the Goonyella middle and the Goonyella lower, varying in thickness from 7 m to 9 m. The majority of the reserves are contained in the lower seam.

Exploration of the Riverside coalfield commenced in 1968 and included extensive cored drilling for the purpose of delineation of geological features and definition of coal quality parameters.

Further detailed information about potential clean coal quality and process design information was generated from twenty 150 mm diameter borecores drilled strategically within the potential mining areas.

In 1973, a 50 tonne shaft mined sample of coal was won from the Goonyella lower seam and tested on both laboratory and pilot plant scales.

Further bulk samples were extracted during 1981 from a box cut located in the proposed mining area. This coal was subjected to extensive pilot plant testing and provided information for definitive process design.

3. PROCESS INVESTIGATIONS

Information gained from laboratory pretreatment and testing of large diameter cores and pilot scale testwork was used to determine the optimum process for Riverside coal.\(^1\)

The pretreatment techniques were designed to simulate breakage of coal during processing in a modern hydraulic preparation plant. Samples generated were subject to standard laboratory testing and analysis.

The Australian Coal Industries Research Laboratories pilot plant facilities were used to process tonnage samples of Riverside coal in near production conditions.

The data showed that the coarse coal beneficiation system would require flexibility of separating gravity in the range 1.40 to 1.50 and that a high proportion of near gravity material would be experienced. These factors clearly indicated a dense medium process.

Further consideration of the coal's run-of-mine size grading, friability and liberation characteristics led to the adoption of a dense medium cyclone circuit, processing minus 45 mm plus 0.50 mm wedgewire feed.

The following factors were taken into account in evaluating the minus 0.50 mm fine coal fraction:

1) Friable coal present producing a high proportion of fines with a concentration of coking properties.

2) Clay material present in raw coal feed.

3) Presence in some mining areas of partly oxidised coal with consequent inferior flotation response.

Testwork showed that ultra fine material was of high ash (60-70% adb) and beneficiation could not be justified. It was concluded that the raw coal minus 0.50 mm fines should be deslimed at approximately 70 micron achieving high ash rejection and improving the flotation response of the remaining fines by removing the clay material.
During the exploration program samples of minus 0.50 mm fine coal, generated from the pre-
treated large diameter borecores, were the subject of laboratory scale batch and continuous flotation
testing. Tests showed single stage flotation on deslimed fine coal produced optimum results.

Distillate was identified as the most effective collector at a dosing rate equivalent to 1000 g/tonne
of flotation feed. MIBC was chosen as the frother as it gave acceptable recovery with good ash
selectivity. Frother addition rates of 100 g/tonne flotation feed was found to be appropriate.

Conclusions drawn from the laboratory scale testwork were confirmed in pilot scale testwork.

As a result of the testwork single stage flotation was proposed using a cell to cell arrangement
with provision for two stage addition of reagents. Design residence time was 5 minutes.

Presence of even minor oxidation in the raw coal was shown to have a significant effect on flota-
tion performance. Investigation of alternative gravity processes were considered and it was shown
that water only cyclones would provide an acceptable clean coal, although at reduced yield.

The net result of poor flotation response of coal containing minor quantities of oxidised material
and lower yield of water only cyclones on unoxidised material would be a lower yield from a plant
having only one of these processes for fine coal treatment. Subsequent evaluation provided
justification for provision of both water washing cyclones and flotation systems.

4. DESIGN PARAMETERS

4.1 Mine Capacity

Annual clean coal production of the mine was defined at 3.3 million tonne/yr. Given an
average process recovery of 60 percent the raw coal capacity was established at 5.5 million tonne/yr.

4.2 Operating Hours and Capacities

Mining, coal haulage, coal handling and preparation plant operations were to be on a 24 h/day,
200 operating day/yr basis and a figure of 85% availability was assigned to preparation plant
operations giving 4080 production h/yr. These figures are typical for mines in the area.

Plant capacity was thus established at 1350 tonne/h.

Due to a requirement for considerable flexibility of coal haulage operations, capacities of the
raw coal receival and stockpiling facilities were established at 2000 tonne/h.

Raw coal stockpile capacity was established at 100,000 tonnes in two 50,000 tonne fully live
stockpiles. An additional 100,000 tonne capacity run-of-mine stockpile is provided for emergency
storage and reclaimed by mobile equipment.

The preparation plant was to be arranged in six independent modules each of which would
therefore have a unit capacity of 225 tonne/h. To affect good distribution of raw coal to each of the
twelve desliming screens, a hydraulic distributor was required for each group of 3 modules (6 screens),
each distributor to be fed by a separate conveyor from a surge bin.

Raw coal sizing was established at 45 mm as this was compatible with the 700 mm dense medium
cyclones used, the clean coal size specification and the size to which the raw coal could be broken in
a rotary breaker. The high Hardgrove grindability index of the Goonyella seam coals gives a friable
coal, easily broken without the need for cruchers.

Dense medium cyclones separate effectively down to a minimum size of 0.50 mm and this size
was adopted for the split between coarse and fine circuits.

High ash clay slimes present in the raw coal were concentrated in the size range below 70 micron.
Figure 1  RIVERSIDE COALFIELD NOMINAL SIZE DISTRIBUTION AND DESIGN RANGE
and hydrocyclones were therefore provided in the fine coal circuit to remove this material.

The size distribution of the coal in the preparation plant was determined from pilot plant trials and borecore pretreatment work.

Figure 1 shows the sizing envelope developed for design purposes. The flotation and water wash cyclone circuits were designed for the finest feed, while the dense medium cyclone circuits were designed on the coarsest feed.

Similarly, the potential yield variations were identified and a similar design envelope developed (ref. figure 2).

Design based on "worst case" conditions for coarse/fine and product/reject loadings, gives an inherent reserve capacity when nominal coal is encountered. Under these conditions the Riverside preparation plant feed rate could be increased to 1500 tonne/h without experiencing any mechanical overloads or reductions in process efficiency.

In order to maximise use of this inherent reserve capacity it is essential plant feed sizing is constant and as close as possible to the nominal sizing. For this reason, and to even out other quality variations in run-of-mine coal, a large raw coal blending system was provided. The system was designed to minimise both fines generation and size variation in plant feed.
5. PLANT DESCRIPTION

Figure 3 is a simplified version of materials handling and preparation plant flowsheet.

5.1 Raw Coal Handling

Run-of-mine coal is dumped from 136 tonne capacity bottom dump coal haulers into two 300 tonne capacity hoppers. Coal is withdrawn by two vibrating feeders and conveyed to the screening and crushing plant where minus 45 mm material is removed by vibrating screens and the plus 45 mm reduced to minus 45 mm in rotary breakers. Minus 45 mm coal is conveyed to the raw coal stockpile area where it is placed in a chevron stockpile by a luffing boom type travelling stacker in one of two available 50,000 tonne capacity stockpile areas.

Stone and tramp material rejected from the breaker is discharged into concrete bunkers at ground level for removal by loader.

A bridge type, double bucket wheel reclaimer withdraws coal from the stockpile and feeds onto a conveying system discharging into a 750 tonne plant feed surge bin.

A bypass chute located at the stacker allows the plant to be fed directly from the road bins when the reclaimer is being maintained.

5.2 Preparation Plant

5.2.1 Feed Preparation

Plant feed is withdrawn from the surge bin by two vibrating feeders, each feeding one of two parallel plant feed conveyors each supplying 3 modules.

Feed from each conveyor is discharged into a hydraulic distributor, distributing coal, mixed with water, to sieve bends followed by vibrating wedgewire screens.

5.2.2 Coarse Coal Circuit

The screens size the material at 0.50 mm. Screen oversize passes directly to the dense medium sump while screen undersize is fed to the desliming cyclone feed sump.

Each dense medium cyclone pump feeds coarse coal (minus 45 mm plus 0.50 mm) and magnetite medium slurry to two dense medium cyclones. Overflow from each cyclone containing clean coal is discharged over individual sieve bends and vibrating screens. The majority of medium is drained from the clean coal on the sieve bend and first half of the vibrating screen. Residual magnetite is washed from the coal as it is carried across the rinsing section of the screen.

Clean coal from each pair of product drain and rinse screens is fed to a vibrating basket centrifuge which in turn discharges dewatered material onto a common clean coal conveyor.

Underflow from each pair of dense medium cyclones, containing reject material, passes to a sieve bend and vibrating screen for removal of magnetite. Coarse reject then discharges onto the refuse disposal conveying system.

Thorough rinsing of washed coal and reject products on drain and rinse screens produces a large volume of dilute medium contaminated with fine non magnetics. This slurry gravitates to a common magnetite thickener.

Magnetite thickener underflow is pumped to two pairs of double drum magnetic separators (one pair per 3 modules).

Magnetite thickener overflow is pumped to the rinsing sprays on all drain and rinse screens.

Concentrate from the magnetic separators gravitates to an overdense medium sump from which it is pumped to a splitter controlling the quantity taken off into the dense medium circuit to maintain
Development and Operation of coal Preparation Facilities

Medium level and density.
Magnetic separator tailing is recirculated to plant feed.
Fresh magnetite is added from a ground level makeup sump into the magnetite thickener as required.

5.2.3 Fine Coal Circuits
Minus 0.50 mm undersize from each pair of desliming screens is pumped through a bank of cyclones where minus 70 micron material containing high ash slimes is removed in the cyclone overflow and sent to the tailing thickener.

Deslimed cyclone underflow sized at minus 0.50 mm plus 70 micron may be treated by flotation, or if the quantity of surface oxidised coal precludes flotation, by water only cyclones.

Deslimed fine coal from the classifying cyclone underflow is fed directly to flotation cells. Collector is added at the classifying cyclone underflow launder and at cell of a five cell flotation bank. Frothing agents are added in the feedbox and intermediate box.

Clean coal is recovered in the froth, discharged into a launder and fed to a drum filter.

Flotation tailing is pumped through thickener protection cyclones (desanding cyclones). Cyclone overflow gravitates to the tailing thickener while cyclone underflow discharges to fines rejects screens. This arrangement protects the thickener from sudden overloads of coarse material resulting from failure of the flotation process. Dewatered fine reject is discharged onto the common coarse refuse conveyor and screen undersize goes to the tailing thickener.

With the plant in water wash cyclone mode, deslimed fine coal is pumped through primary water wash cyclones together with a portion of secondary water wash cyclone overflow.

Primary water wash cyclone overflow containing clean coal and the majority of the feed water is pumped through classifying cyclones. Remaining high ash slime is removed with the overflow and gravitates to the tailing thickener. Clean coal reporting to the classifying cyclone underflow is centrifuged together with the dense media cyclone product and discharged onto the common clean coal conveyor.

Primary water wash cyclone underflow is diluted with water and pumped through secondary water wash cyclones. Secondary water wash cyclone underflow discharges to the fines reject screens and part of the overflow recirculates to the primary water wash cyclone feed, the remainder joins primary cyclone overflow.

5.3 Clean Coal Handling
Clean coal is conveyed from the plant to a clean coal stockpile area and placed onto one of three 70,000 tonne capacity stockpiles.
Vibrating feeders under each stockpile feed clean coal onto a conveying system which feeds a trainloading surge bin. The trainloading control system allows automatic blending of material from the three stockpiles in any combination and ratio. Clean coal is fed from the surge bin into 55 tonne capacity rail wagons.

5.4 Clean Coal Transport
Riverside coal is railed to the Dalrymple Bay Coal Terminal in trains consisting of 120 wagons drawn by 5 locomotives. The railway is owned and operated by Queensland Government Railways.
The Dalrymple Bay Coal Terminal, completed early in 1984, is part owned by TDM together with 3 other users. Riverside coal arriving by train at the terminal is placed in one of 4 stockpile areas. Total stockpile holding capacity for Riverside coal is 330,000 tonne. Coal is reclaimed from
stockpiles by bucket wheel reclaimers and loaded on ships from a 4 kilometre long jetty conveyor at a rate of 6000 tonne/h. The port is able to load ships of 200,000 dwt.

5.5 Refuse Disposal

Coarse refuse is conveyed from the plant to a surge bin. Material discharged from the surge bin by a vibrating feeder is conveyed to the refuse disposal area approximately 1 km from the plant. Refuse is placed by a rail mounted travelling boom type stacker mounted on a movable conveyor structure. The system allows the conveyor to be moved progressively over the refuse area as it fills. Coarse refuse is placed so as not to preclude future reclamation for recovery of energy coal.

Fine tailing is thickened and pumped through a 1.5 km long pipeline to a tailing dam. Clear water is returned to the plant from both the thickener and tailing dam.

6. OPERATIONS

The plant is scheduled to operate 24 h/day on three 8 hour shifts, 5 day/week.

Control of the entire plant operation from raw coal dump station to clean coal stockpiling is by a single operator from a central control room. Except during stockpile changing operations, the entire raw coal handling complex is unmanned.

In addition to the control room operator, two other operators and two labourers are employed on each shift for field adjustment of flotation and filtration equipment, equipment inspection, trainloading operations and cleanup. Two heavy mobile equipment for refuse pushing, trainloading and cleanup. Two tradesmen—one mechanical, one electrical—are employed on each shift to cover breakdown maintenance.

Additional labourers and tradesmen are employed each day shift for cleanup, inspection and routine maintenance.

One analyst on each shift processes routine quality control samples with additional laboratory staff employed each day shift to handle train and process control samples.

One shift supervisor is employed on each shift with additional supervisory and technical staff working on day shift.

A computer based control system allows a single operator to control and monitor the operation of the plant and equipment from road receiveal bins to clean stockpiles. A separate but similar system is provided for trainloading operations.

7. PLANT PERFORMANCE

Commissioning of the materials handling and preparation plant commenced during July, 1983, and the first coal was presented to the plant on 8th August, 1983. TDM co-ordinated the commissioning, utilising its own operations staff, the project managers and their process design consultants on a 24 h/day basis. The main objective of the commissioning program was to place the plant on a production footing using the water only cyclone circuit.

The first shipment of 55,561 tonne was exported from the Hay Point Coal Terminal on 5th October, 1983. This shipment met all quality specifications.

By the latter part of October, 1983, the plant was operating in excess of its nominal rated capacity.

Development work on the flotation circuit was carried out in parallel with commissioning and was initially directed to identification of raw coal feed which would be amenable to flotation. Having
done this, efforts were directed to operation of the flotation circuit.

As discussed in section 5.2.3, each module contains 5 flotation cells with a primary feed box and a secondary feed box (junction box) between the second and third cells. Feed to the primary feed box as designed, was direct from the desliming cyclone underflow. Mass flow measuring equipment was installed on the feed pipe to the primary feed box.

Reagent feeding was by gravity through manual and solenoid valves and controlled by a rotameter. Collector was fed directly into cyclone underflow at the underpan and into the secondary feed box. Frother was fed into both primary and secondary feed boxes.

During early commissioning the frother addition system was found to be unreliable due to varying feed rates and frequent blockages. Valves and rotameters have been replaced with Clarkson feeders.

Initially, difficulty was experienced in obtaining satisfactory flotation response and modifications were made to reagent addition circuits and to the reagents.

Because of the short time between collector addition and entry to the cells, it was believed poor contact was being made between collector and coal. Collector was subsequently added to the air inlets of the first and third cells. On one particular module a deaeration chamber was added ahead of the primary feed box to remove air from flotation feed in an attempt to allow density and flow meters to operate satisfactorily.

Improved flotation response was noticed in that module as a result of the increased conditioning time and collector addition on this module is now back into the cyclone underpan as designed. Conditioning tanks are to be installed on the remaining modules.

The frother addition points were also changed to the air inlets of the first and third cells.

MIBC as frother and distillate as collector were first used as flotation reagents. Laboratory testwork led to the addition of an emulsifier to the distillate. Testwork also indicated frothers, other than MIBC, might give better results, however, no conclusive plant trials have yet been conducted. Dow 400 appears to give a better yield at the expense of higher ash.

Presently, distillate is added at a rate of 500 g/tonne feed solids, 300 g/tonne to the cyclone.

### TABLE 1 TYPICAL SIZE DISTRIBUTIONS OF RIVERSIDE FLOTATION FEED AND FILTER CAKE

<table>
<thead>
<tr>
<th>MILLIMETRE</th>
<th>FEED</th>
<th>WT. %</th>
<th>CUM. WT. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.5w</td>
<td>5.3</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>-0.5w +0.5</td>
<td>17.2</td>
<td>22.5</td>
<td></td>
</tr>
<tr>
<td>-0.5 +0.250</td>
<td>41.1</td>
<td>63.6</td>
<td></td>
</tr>
<tr>
<td>-0.250 +0.125</td>
<td>24.4</td>
<td>88.0</td>
<td></td>
</tr>
<tr>
<td>-0.125 +0.075</td>
<td>7.8</td>
<td>95.8</td>
<td></td>
</tr>
<tr>
<td>-0.075</td>
<td>4.2</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MILLIMETRE</th>
<th>FILTER CAKE</th>
<th>WT. %</th>
<th>CUM. WT. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.5w</td>
<td>1.8</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>-0.5w +0.5</td>
<td>13.7</td>
<td>15.5</td>
<td></td>
</tr>
<tr>
<td>-0.5 +0.250</td>
<td>41.5</td>
<td>57.0</td>
<td></td>
</tr>
<tr>
<td>-0.250 +0.125</td>
<td>29.3</td>
<td>86.3</td>
<td></td>
</tr>
<tr>
<td>-0.125 +0.075</td>
<td>6.3</td>
<td>92.6</td>
<td></td>
</tr>
<tr>
<td>-0.075</td>
<td>7.4</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
underflow and 200 g/tonne at the third cell. Frother is added at the rate of 100 g/tonne of feed solids, most of it going to the first cell.

Flotation response at present is good with little coal reporting to tailing. Ash in the filter cake has ranged from 8.2% to 10.9%, the higher figure resulting when Dow 400 was used as frother.

Typical size distributions for flotation feed and filter cake are shown in Table 1 below.

Computer control of the preparation plant has been operational from the commencement of the commissioning program and has performed to expectations.

The Riverside preparation plant and associated materials handling systems have met production expectations without significant process, mechanical or electrical redesign or failure.

8. COAL QUALITY

During the exploration phase, laboratory testing of borecores and bulk samples indicated the following field average floats at 1.45 S.G. quality—

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inherent Moisture %</td>
<td>1.5</td>
</tr>
<tr>
<td>Ash (adb)%</td>
<td>9.4</td>
</tr>
<tr>
<td>Volatile Matter (adb) %</td>
<td>23.6</td>
</tr>
<tr>
<td>Fixed Carbon (adb) %</td>
<td>65.5</td>
</tr>
<tr>
<td>Sulphur (adb) %</td>
<td>0.58</td>
</tr>
<tr>
<td>CSN</td>
<td>7</td>
</tr>
<tr>
<td>Giesler Fluidity</td>
<td>200–1200 ddpm</td>
</tr>
</tbody>
</table>

Anticipated average mean maximum reflectance of vitrinite was 1.18.

Taking into account the relative uniformity of the deposit and the cleaning processes to be used, Riverside coal was marketed at the following specifications—

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Moisture (as received) %</td>
<td>10.0</td>
</tr>
<tr>
<td>Ash (adb) %</td>
<td>9.8 (with +0.5 tolerance)</td>
</tr>
<tr>
<td>Volatile Matter (adb) %</td>
<td>23.5±1.0%</td>
</tr>
<tr>
<td>Sulphur (adb) %</td>
<td>0.65 max.</td>
</tr>
<tr>
<td>CSN</td>
<td>6–8</td>
</tr>
<tr>
<td>Sizing</td>
<td>minus 50 mm</td>
</tr>
</tbody>
</table>

The first 20 shipments to February, 1984, (828,081 tonnes) have all been well within this specification. Average quality was as follows—

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Moisture (as received) %</td>
<td>7.9</td>
</tr>
<tr>
<td>Ash (adb) %</td>
<td>9.6</td>
</tr>
<tr>
<td>Volatile Matter (adb) %</td>
<td>23.9</td>
</tr>
<tr>
<td>Sulphur (adb) %</td>
<td>0.56</td>
</tr>
<tr>
<td>CSN</td>
<td>7 1/2</td>
</tr>
<tr>
<td>Sizing</td>
<td>100%–50 mm</td>
</tr>
</tbody>
</table>

Average Automatic Giesler Fluidity and mean maximum reflectance of vitrinite have been 612 ddpm and 1.19 respectively.

At Riverside quality control begins with mining operations. The mining plan ensures all raw coal delivered to the plant will produce clean coal within specification.

Particular attention is paid to coking properties as there are significant variations within the deposit. After removal of overburden, areas of coal with poor coking qualities are defined by drilling
and subsequent sample testing and removed by selective mining.

Hand samples are taken before further mining operations to check coking properties of coal to be mined for transport to the preparation plant.

At the preparation plant an automatic sampler continually samples the clean coal product. A bulk sample is collected every 90 minutes and analysed for CSN, ash and moisture. Results are used to monitor quality of clean coal stockpiles and make minor adjustments to plant operation.

During trainloading operations material is automatically sampled and results used to monitor clean coal stockpiles at the port.

REFERENCES