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Coal Beneficiation

1. Introduction

The use of Western Canadian coals for power generation depends on meeting evolving economic and environmental constraints. The ability to reduce the ash content is of importance both for upgrading the fuel and to meet current and future operating and environmental specifications. The derived benefits of beneficiation relate both to the mine (increasing the quantity of coal reserves meeting ash specifications) and to the power plant through thermal efficiency of power generation and reduced fly ash production/handling. Beneficiation, in some cases, also offers the potential to preferentially reject impurities such as mercury and sulphur, which will correspond to an economic benefit or environmental requirement.

The costs of beneficiation are considerable and require a detailed economic analysis to determine the financial benefits and to whom they accrue (mine or power producer). Sound technical data is required to design the optimum coal processing plant and to allow economic modeling to be performed. The coal behavior and optimum coal beneficiation plant design will depend on the properties of the coal from the individual mines.

2. Testing Overview

Conducting a thorough investigation of the physical and chemical characteristics of the coal from the individual seams is the first step towards providing the data from which the performance of individual beneficiation technologies can be estimated.

As one part of a comprehensive earlier CCPC sponsored research project (Project 413 “Coal Beneficiation Technology Review for Western Canadian Coals – Final Report, Rev.2”, July 2011, CCPC Project 413), carried out by Sherritt Technologies, potential dry beneficiation technologies were evaluated.

Of the commercially proven technologies for as received coals, Allmineral and FGX Septech were identified as potential technologies to be used to beneficiate Western Canadian thermal coals. While a technological and economic evaluation of the processes was performed in the earlier project, the data available for the different Western Canadian coals was limited.

Western Canadian thermal coals are broadly split into Saskatchewan lignites (e.g. Boundary Dam and Poplar River) and Alberta subbituminous coals (e.g. Highvale and Genesee), which have different chemical and physical properties that influence the performance of beneficiation processes. It is important that current data on the physical, chemical and thermal properties of the different coals be available to improve our understanding of the performance of the different dry beneficiation processes.

Sherritt Technologies was commissioned to test several Canadian coals to derive data that was used to assess how commercially available coal beneficiation technologies would perform. CanmetENERGY completed further physical tests of the coals.

Washability studies are a useful standardized method of determining the suitability of coal for upgrading based on coal particle size and density. While washability studies were developed to determine the suitability of the coal for wet beneficiation processes, they are also useful for assessing the suitability of coal for dry beneficiation. It is, however, intrinsically more difficult to achieve a clean separation of material using dry separation techniques and the ability to separate diminishes as the particles and density differences get smaller.

Evaluation of dry beneficiation processes based on improved understanding of the physical and chemical properties of the different coals allows a more detailed evaluation of the technology and economic evaluation to be made. From this study it was intended that recommendations be made about whether further testing of the technologies is warranted for any of the coals investigated and possible flowsheets.

Each coal was tested to determine the variation in the following parameters with particle size and density:
- HHV (Higher Heating Value)
- Ash Content
- Ash Composition
- Impurities
- Quartz
- Sulphur
- Mercury
- Ash Fusion Temperature

Moisture reduction was not specifically studied. However, moisture reduction may occur to some extent as the coal is beneficiated.
2.1. Sampling
Samples of coal were collected from four mines and tested to determine their suitability for ash and impurity rejection by dry beneficiation. Two Saskatchewan lignites (Boundary Dam and Poplar River) and two Alberta sub-bituminous coals (Highvale and Genesee) were tested.

The coal samples were collected by a number of different techniques due to mine operation considerations. The sample techniques used to collect the different samples are summarized below. All samples were considered representative, with the exception of the first Boundary Dam sample where a second sample was deemed necessary.

2.2. Coal Composition
The composition of the five raw coal samples tested is summarized below in Table 1.

<table>
<thead>
<tr>
<th>Coal</th>
<th>Moisture % (arb)</th>
<th>Ash % (db)</th>
<th>S % (db)</th>
<th>Hg ppb (db)</th>
<th>HHV (db) kJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary Dam 1(^1)</td>
<td>31.0</td>
<td>9.8</td>
<td>n.d.</td>
<td>n.d.</td>
<td>25.4</td>
</tr>
<tr>
<td>Boundary Dam 2(^1)</td>
<td>28.0</td>
<td>13.1</td>
<td>0.62</td>
<td>53</td>
<td>24.6</td>
</tr>
<tr>
<td>Poplar River(^1)</td>
<td>25.6</td>
<td>20.2</td>
<td>1.0</td>
<td>168</td>
<td>20.6</td>
</tr>
<tr>
<td>Highvale (Seam 1)</td>
<td>19.3</td>
<td>28.1</td>
<td>0.29</td>
<td>134</td>
<td>20.4</td>
</tr>
<tr>
<td>Genesee</td>
<td>22.2</td>
<td>23.3</td>
<td>0.21</td>
<td>25</td>
<td>22.7</td>
</tr>
</tbody>
</table>

\(^1\) The moisture content measured for the Saskatchewan lignites were lower than expected.

3. Washability Data Analysis
Coals are typically tested to determine the variation in properties, such as ash, moisture calorific value and chemical composition, with size and density. These analyses are typically referred to as washability studies and are carried out conforming to specific ASTM standards.

3.1. Float Sink Testing
Washability studies are normally performed by screening a representative sample of the air dried coal and then performing a series of float-sink tests in solutions of different densities (normally between specific gravity 1.2 and 2.2) on the different screen fraction. Test procedure ASTM – Float Sink Analyses: ASTM D4371 – 06(2012) – “Standard Test Method for Determining the Washability Characteristics of Coal”. This is shown schematically in the Figure 1 below.

Each screen fraction-density sub-sample is then quantified by weighing and drying and conducting the required analyses or determinations. A large amount of data is measured or derived in a systematic washability study, especially if extensive chemical and physical analyses are performed on each of the individual size-density sub-samples collected.

Figure 1: Schematic Representation of a Float-sink Test, Reference – Encyclopedia of Physical Science – Coal Preparation R.A. Meyer et al.
3.2. Washability Data
A washability study was conducted on each coal with screening and float sink tests performed on the different size fractions to produce subsamples encompassing the range of size and density. The ash content and other coal properties of samples were measured to quantify their distribution with size and density. Chemical analyses of the coal (S and Hg) and ash were performed as well as fusion temperature measurements on select samples.

The washability study data indicated that the ash and impurity concentrations varied with both density and size. Typically the density was a function of ash content varying from a relative density of about 1.3 for relatively pure coal (carbonaceous fuel) to greater than 2.0 for rock particles with little coal associated with them.

Variations in sulphur, mercury, sodium and other impurities with particle size and density were found in the washability study data.

Variations in sulphur, mercury, sodium and other impurities with particle size and density were found in the washability study data.

Specific impurities such as pyrite (iron sulphide) and clays were found in specific size-density fractions as discrete particles in some of the coals (Poplar River and Genesee, respectively).

The washability study data identified which phases or species (ash and impurities) have significant concentration variations based on size and density that would allow rejection of ash and impurities in the different coals by dry beneficiation.

3.3. Analysis of Washability Data
The washability data was evaluated using 'Henry Reinhard' style washability curves to determine ash rejection, product yields and ash content as well as fuel recoveries. The calculated beneficiation possible for the four test coals, using the washability curves and assuming perfect separation is made at a specific gravity of 1.9, is summarized in Table 2 below.

<table>
<thead>
<tr>
<th>Feed Ash, wt% (db)</th>
<th>Product Yield, %</th>
<th>Fuel Recovery, %</th>
<th>Product Ash wt% (db)</th>
<th>Ash Reject, wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary Dam</td>
<td>13.1</td>
<td>94</td>
<td>99</td>
<td>8.4</td>
</tr>
<tr>
<td>Poplar River</td>
<td>20.5</td>
<td>94</td>
<td>97</td>
<td>16.8</td>
</tr>
<tr>
<td>Highvale Seam 1</td>
<td>28.1</td>
<td>84</td>
<td>94</td>
<td>20.0</td>
</tr>
<tr>
<td>Genesee</td>
<td>23.3</td>
<td>87</td>
<td>98</td>
<td>12.8</td>
</tr>
</tbody>
</table>

The washability curves indicated that, for the Saskatchewan lignites, good separation of a small amount of ash material based on density should be possible while still obtaining high product yields and fuel recoveries. The curves also suggested that it should be possible to cleanly reject a significant amount of ash from the Genesee sub-bituminous coal while still recovering most of the fuel value. In contrast, the shape of the curves for Highvale sub-bituminous coal indicates appreciable amounts of fuel would be rejected with the ash, and suggests the Highvale coal (Seam 1) coal sample tested is not well suited to beneficiation by density.

The data obtained for this 2012 sample of Highvale coal (Seam 1) are different from that of a 2008 TAU study on the same coal (and seam). There is considerably more ash (28.1 vs 23.8 wt%) in the sample tested in the current study, and there is a more gradual gradient in fuel and ash with density resulting in poorer predicted separation for the current sample.

While the washability curve data suggests significant ash rejection can (theoretically) be achieved, by beneficiation using density, for all the coals except for the 2012 Highvale sample, the above analysis is too simplistic. Specifically, it does not consider imperfect separation or the significant influence of particle size on density separation, the effects of which are important for commercial dry beneficiation processes. For commercial dry beneficiation processes the cleanness of separation worsens with decreasing particle size. Particles below 0.5 to 3 mm in size cannot be effectively upgraded by dry beneficiation.
4. Comparison of Allmineral and FGX Air Jigs

The operation and performance of two commercially proven dry beneficiation technologies, Allmineral and FGX Septech air jigs, were evaluated. The technologies were identified in a previous CCPC study “Coal Beneficiation Technology Review for Western Canadian Coals – Final Report, Rev.2”, July 2011, CCPC Project 413. Both air jigs are in commercial operation and use air flow and oscillating forces to affect segregation based on size and density differences. There are several differences in design between the two jigs, which are summarized in the following table.

Table 3: Comparison Expected Coal Beneficiation Technologies

<table>
<thead>
<tr>
<th></th>
<th>Allmineral</th>
<th>FGX Septech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Limitations</td>
<td>&lt;50 mm</td>
<td>&lt;80 mm</td>
</tr>
<tr>
<td></td>
<td>Not sticky (clays?)</td>
<td>Not sticky (clays?)</td>
</tr>
<tr>
<td></td>
<td>&lt;7% surface moisture</td>
<td>&lt;7% surface moisture</td>
</tr>
<tr>
<td></td>
<td>&lt;14% - 0.6mm</td>
<td></td>
</tr>
<tr>
<td>Minimum Size for Cleaning</td>
<td>0.8 mm (fines to vent)</td>
<td>3 mm</td>
</tr>
<tr>
<td>Output Streams</td>
<td>Clean coal</td>
<td>Product coal</td>
</tr>
<tr>
<td></td>
<td>Refuse</td>
<td>Middlings</td>
</tr>
<tr>
<td></td>
<td>Fines (dust)</td>
<td>Rejects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dust</td>
</tr>
<tr>
<td>Cut Point Specific Gravity</td>
<td>&gt; 1.7</td>
<td>&gt; 1.9</td>
</tr>
<tr>
<td>Cut Point Specific Gravity Adjustabe</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Air plus amplitude</td>
<td>Air plus amplitude</td>
</tr>
<tr>
<td></td>
<td>Nuclear density gauge</td>
<td>Table slope and discharge divider position</td>
</tr>
<tr>
<td>Separation Characteristics</td>
<td>Likely better separation of mid-size material</td>
<td>Better at de-shaling</td>
</tr>
<tr>
<td>Unit Size (Max.)</td>
<td>50 t/h</td>
<td>480 t/h</td>
</tr>
<tr>
<td>Largest Plant t/h</td>
<td>700</td>
<td>1,400</td>
</tr>
</tbody>
</table>

The actual performance of the two technologies will depend both on the flowsheet design and coal characteristics. The flowsheet for the FGX air jig is more complex in that a semi-cleaned middlings stream is produced and incorporated in the flowsheet (typically by recycling).

It is not possible to identify one of the two technologies as clearly superior for all applications. The Allmineral is a more complex jig relying on nuclear level gauge to control discharge ash content and is better suited to processing finer coal fractions. The FGX air jig appears to be a simpler device of large size; density separation appears less effective and does not remove ash effectively from feeds below about 1/4” (6.3 mm). A middling stream is therefore typically recycled to improve yield and ash rejection.

In practice, piloting of the two air jigs, on representative coal samples, will be required to determine their operating characteristics. The range of density and coal particle size when the ash or impurities are concentrated may determine which of the two jigs provide superior performance.

5. Suitability of Test Coals for Dry Beneficiation

The suitability of the four coals studied for ash and impurity rejection using commercial dry beneficiation technology was evaluated based on information available in the literature on commercial dry beneficiation technologies and washability data generated in this study.

From data provided by Allmineral LLC and FGX Septech, separation efficiency parameters were extracted that allowed estimates of ash rejection, product yields, ash content and fuel recoveries for the different technologies and coals to be made. It must, however, be emphasized that the performance of the air jigs can be adjusted using the control parameters (air and mechanical oscillations). The estimates are therefore an indicator of air jig performance, which can be compared with the theoretical maximum predicted by the washability curves (this ratio being the confusingly named ‘organic efficiency’).
Selected results for the four test coals are summarized in the table below and can be compared with the similar data estimated using the washability curves. Results for both the Allmineral yields calculated from the Allmineral and FGX parameters are significantly lower than those predicted by the washability data. This reflects a combination of the poor separation coefficient for particles below 1mm and the varying fraction of the mass of coal and ash present as smaller particles in the different coal samples.

Table 4: Allmineral Air Jig (fines reporting to product coal)

<table>
<thead>
<tr>
<th>Feed Ash Content, wt% (db)</th>
<th>Product Yield, wt%</th>
<th>Product Ash Content, wt% (db)</th>
<th>Ash Rejected, % of total ash</th>
<th>Fuel Recovered, % of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary Dam #2</td>
<td>13.3</td>
<td>90.4</td>
<td>9.6</td>
<td>35</td>
</tr>
<tr>
<td>Poplar River</td>
<td>20.5</td>
<td>89.0</td>
<td>17.9</td>
<td>19</td>
</tr>
<tr>
<td>Highvale</td>
<td>28.1</td>
<td>74.3</td>
<td>20.4</td>
<td>46</td>
</tr>
<tr>
<td>Genesee</td>
<td>23.3</td>
<td>80.1</td>
<td>13.0</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 5: FGX Septech Air Jig (fines reporting to product coal, middlings rejected – no recycle)

<table>
<thead>
<tr>
<th>Feed Ash Content, wt% (db)</th>
<th>Product Yield, wt%</th>
<th>Product Ash Content, wt% (db)</th>
<th>Ash Rejected, % of total ash</th>
<th>Fuel Recovered, % of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary Dam #2</td>
<td>13.3</td>
<td>90.6</td>
<td>10.5</td>
<td>28.1</td>
</tr>
<tr>
<td>Poplar River</td>
<td>20.5</td>
<td>92.9</td>
<td>18.9</td>
<td>11.4</td>
</tr>
<tr>
<td>Highvale</td>
<td>28.1</td>
<td>80.3</td>
<td>22.4</td>
<td>35.1</td>
</tr>
<tr>
<td>Genesee</td>
<td>23.3</td>
<td>81.8</td>
<td>15.7</td>
<td>42.5</td>
</tr>
</tbody>
</table>

For both technologies, the trends in the predicted (un-optimized) performance were similar. For ash rejection from lignites, Boundary Dam coal show greater potential for rejecting significant amounts of ash than Poplar River coal, while still obtaining (relatively) high fuel recoveries. For subbituminous coal, while actual fuel recoveries were lower, the Genesee coal showed greater potential for ash rejection and fuel recovery than the Highvale coal tested. Poplar River does not appear well suited to dry beneficiation for ash rejection, as fuel recoveries were low, at 91 per cent (94 per cent FGX), despite only rejecting 19 per cent (11 per cent FGX) of the ash. For Highvale coal, while significant ash rejection is predicted, fuel recoveries are also very low.

In practice it is possible to adjust the separation density to higher (not lower) effective densities and therefore it might be possible to improve the beneficiation for the Poplar River (or Highvale) coal to increase fuel recovery with the trade-off of rejecting less ash.

It is not possible to directly compare the performance of the Allmineral and FGX air jig from the calculated data, as the operation of both can be tuned for optimization. From this preliminary analysis, it could be concluded that the Allmineral Air jig provides superior ash rejection while obtaining a similar fuel recovery to the FGX Septech air jig. This is primarily due to its reported superior separation at smaller particle sizes. FGX partially addresses its inferior separation characteristics by typically splitting out a middling stream and recycling it.

Comparison of the operating characteristics of the two air jigs suggest that FGX air jigs perform better with coarser material, as the top size is 80 mm as compared with 50 mm for Allmineral. Allmineral air jigs likely perform better for separating intermediate size material (0.5 to 5 mm). While FGX partially addresses this by producing a middling stream for recycle, only feeds greater than 3 mm are reported suitable for beneficiation.

The uncertainties associated with the predicted performance of the different air jigs indicates the importance of experimental test work (both vendors have demonstration or mobile pilot units) to determine both the product yield and composition capabilities as well as the operational and performance issues.
6. Impurity Rejection – Air Jig Performance

The study indicates that sulphur and mercury in some coals could be preferentially rejected based on density-size differences. Pyrite rejection from Polar River could result in preferential rejection of sulphur and mercury (as well as iron). Mercury in the Highvale coal ( Seam 1) is associated with denser material, despite not appearing associated with sulphur. It is also possible quartz (silica) present in Poplar River coal could also be rejected, provided it is 1mm or larger; however, this was not proven in this study.

The sodium in Boundary Dam coal is primarily associated with the less dense organic material and would not be preferentially rejected by dry beneficiation.

When sulphur is present as pyrite, such as for Poplar River, sulphur rejection appears feasible by dry beneficiation. Estimates based on the Allmineral jig separation parameters suggested that for Poplar River rejecting about 11 per cent of the mass, 44 per cent of the sulphur would report to the reject stream and the sulphur content of the Poplar River coal could be reduced by 20 per cent from 1 to 0.8 wt%. As the pyrite represents much of the coarse dense material, it is calculated the reject stream would contain over 5.3 per cent sulphur.

It has been reported (Honeker 2007) that FGX air jigs have been installed in a Texas lignite mine for sulphur and mercury rejection. It is reported that sulphur and mercury rejections of 35 and 55 per cent respectively were reported obtained in piloting tests.

It is therefore expected that both the Allmineral and FGX air jigs would reject pyrite, however, the individual performance of the two jigs could vary significantly depending on the size-density distribution of the sulphur and experimental tests are required to quantify differences in performance.

As the composition of ash in the coal samples is not uniform, preferential rejection of denser material will change the composition of the fly ash produced by combusting the coal.

Comparison of the ash fusion temperature measurements indicates that the Saskatchewan lignites tend to have lower fusion temperature than the Alberta subbituminous coals. The results for the Genesee sub-bituminous coal suggests the intrinsic ash associated with the coal has a lower melting temperature, often associated with slagging. As the clays and denser coarser particles appear to have higher melting characteristics, it is possible overall melting temperatures will be reduced if this higher melting temperature material is preferentially removed by dry beneficiation. Selected removal of elements (iron, sulphur as pyrite) will also influence ash fusion temperatures.

While it is possible to calculate the change in ash composition resulting from calculated ash deportments from dry beneficiation, and how this influences ash fusion temperatures, it is beyond the scope of this study to perform this analysis.

7. Economic Analysis

For the implementation of dry beneficiation technologies to make economic sense, the overall performance and cost benefits realized in the power plant must be greater than the increase in the cost of the beneficiated coal feed. For this study, EPRI utilized their proprietary PCCost program to assess the potential performance, capital and operating cost benefits of using beneficiated coal in a new, grassroots conventional pulverized coal-fired power plant. EPRI assumed the same design and cost parameters for each of four reference coals: Genesee subbituminous coal, Highvale subbituminous coal, Boundary Dam lignite and Poplar River lignite. These key design and cost assumptions included the following:

- Plant size: 450 MW net
- Supercritical steam conditions: 3600 psi/1050F/1050F
- Includes FGD, SCR, and Hg control
- Delivered Coal Price = $25/tonne for all four coals
- For consistency with the 2011 study, all costs are in 2010 dollars

For the beneficiated coal cases, EPRI used a simplified levelized cost of electricity (LCOE) model to calculate the delivered price of the beneficiated coal that would result in exactly the same LCOE as the reference PC plant with raw, as-received coal. This economic assessment indicated the highest price that an owner can pay for a beneficiated coal in order for the plant to produce electricity at the same levelized cost. Inputs to the LCOE model were taken from the PCCost model runs, and included:

- Net plant heat rate
- Plant availability (or capacity factor)
- Total plant cost
- Fixed and variable O&M cost
Two dry beneficiated cases were evaluated for each of the four reference coals. These cases are referred to as the “Air Jig” and “Ideal” cases. Sherritt provided a proximate analysis, ultimate analysis and ash analysis for each of the reference coals, as well as for the dry beneficiated coals. For the subbituminous coals, the ash content was reduced by 19 to 20 per cent. For the lignite coals, the Boundary Dam ash content was reduced by 28 to 34 per cent, while the Poplar river ash content was only reduced by 10 to 14 per cent. Note that the Sherritt analyses did not indicate any significant sulfur or mercury reduction for any of the beneficiated coals. The beneficiation processes under consideration did not result in any reduction of moisture, and in some cases there was actually a slight increase in the percentage of moisture.

Some of the key findings:

- There was very little reduction in capital cost for a new power plant firing dry beneficiated coals. The capital cost reduction for subbituminous coals was 2.0 to 2.5 per cent, while the reduction for lignite coals was only 0.2 to 0.5 per cent.

- Boiler tube erosion should be reduced as the coal ash content decreases. The PCCost availability correlation predicted a 0.80 to 0.85 percentage point increase in availability for the subbituminous coals, and only a 0.30 to 0.50 percentage point availability increase for the lignites. This small increase in availability had very little impact on the overall economic benefit.

- In several cases the moisture content of the dry beneficiated coals actually increased, thus leading to a slight reduction in boiler efficiency, and a slight increase in net plant heat rate, especially for lignite.

- As expected, the operating and maintenance (O&M) costs were slightly reduced due to handling less ash, and slightly less coal.

- To produce electricity at the reference plant cost, the delivered cost of the dry beneficiated coals could increase from $25 to $30-31/tonne for subbituminous coals, and from $25 to $27-29/tonne for lignite coals.

8. Conclusions

The current study indicates that significant ash reductions and selective impurity rejection are predicted for several of the coals tested, especially Genesee for ash reductions and Poplar River coal for impurity rejection.

The different sampling methods used to obtain the bulk sample for washability studies were considered (mostly) satisfactory, however, the first Boundary Dam sample was considered non-representative.

Review of two commercially proven dry beneficiation technologies (Allmineral and FGX Sepech air jigs) indicated both are best suited to the rejection of larger, denser material. While the Allmineral air jig appears to have superior separation characteristics, it is a more complex technology. Although effective separation is achieved over a smaller range of densities and particle size with the FGX air jig, a middling stream is produced and recycled to improve yields and recoveries. The actual performance of both technologies will depend on the beneficiation flowsheet, which is beyond the scope of this project. It was not evident that one technology was significantly superior and piloting of both technologies would be recommended for coals identified as suitable for testing.

In general higher yields and fuel recoveries were obtained with the lignites than subbituminous coals. However, the higher moisture contents of the lignites may be less suited to dry beneficiation.

The results of the calculations using separation efficiency parameters for the Allmineral and FGX air jigs suggest:

- **Boundary Dam Coal** – Relatively clean separation of a fraction of the ash is possible but sodium, which is located in the lighter carbonaceous material, is not rejected.

- **Poplar River Coal** – Not well suited for ash rejection by dry beneficiation, with a significant reduction in fuel recovery for modest ash rejection; significant sulphur, mercury and iron rejection is, however, possible due to the presence of larger pyrite particles.
• **Highvale Coal (Seam 1)** – Clean ash separation was not possible by dry beneficiation due to a gradient of ash concentrations with density; some preferential rejection of mercury may be possible (this differs from a 2008 study where better ash separation was predicted).

• **Genesee Coal** – Significant rejection of ash is predicted while recovering much of the fuel, rejection of clay present in the coal appears possible but would need to test whether the presence of clay is detrimental to air jig operation.

For the Genesee coal, the variations in ash melting temperatures with size and density fractions suggests dry beneficiation could influence ash melting properties.

While some coals seem suitable for dry beneficiation to reject ash (e.g. Genesee [include clays] and Boundary Dam) or to reject impurities (i.e. Poplar River to reject S and Hg, or Hg from Highvale), testing is required to verify performance.

Testing of the individual dry beneficiation technologies (Allmineral and FGX Septech air jigs) is necessary to determine precise operating performance and characteristics of the different technologies.

Some fuel will inevitably be rejected by dry beneficiation, so it is important that the economics of dry beneficiation be determined for each specific coal (or seam) and flow sheet chosen, prior to piloting studies. It is important that the flow sheet incorporating the dry beneficiation technology, for either ash or impurity rejection, can be shown to be economically justified prior to testing. The operating characteristics of the different air jigs, identified in this study, provide estimates of operating parameters for these calculations.

### 9. Future Work

As a preliminary step, it is recommended that economic optimization modeling studies be conducted, using the washability data determined in this study and the estimates of operating performance of the different air jigs, to identify the optimum flowsheets or coals seams to process. The analysis would also determine where predicted capital and operating cost could justify further evaluation and piloting.

Of the coals tested, it is recommended that further economic evaluation of flowsheets for sulphur and mercury removal from Polar River and ash removal from Genesee coal be carried out to determine if piloting of the two dry beneficiation technologies is warranted. It is also recommended that discussions are held with mine operators/personnel to determine whether specific material from the mine, best suited to dry beneficiation, can be identified, which could improve process economics.

The current study suggests both the FGX and Allmineral air jig should be tested if the economic evaluation indicates piloting of dry beneficiation processes is warranted.