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Producing Clean Coal from Western Canadian Coal Fields using the Water-based Roben Jig

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Executive Summary

The Canadian Carbonization Research Association (CCRA) in close collaboration with federal and provincial partners including Geoscience BC, Natural Resources Canada/CanmetENERGY, University of British Columbia, Gwil/Birtley Coal & Minerals Testing and Teck Coal, has tested the Roben Jig for washing metallurgical coal from various mine sites in British Columbia. Due to higher inherent ash, coal in British Columbia is almost always washed prior to coal and coke quality characterization. The coking characteristics for metallurgical coal deposit drill core exploration samples are both imperative and critical in properly evaluating project economics, which are intimately linked to the expected market price for the clean coal.

The main objective of the project has been to verify that the water-based Roben Jig cleaning equipment can be commercially used to wash a broad range of coal types found in British Columbia coking coal basins to ultimately produce representative clean coal composites leading to qualities of coal (Thermal

rheology properties) and coke (Coke Strength after Reaction, CSR) that are either superior or at least equivalent to those achievable via conventional organic liquids treatment. This would benefit the coal industry in British Columbia, and globally by eliminating the potential negative effects of perchloroethylene and other organic liquids on coal and coke quality parameters and reduce the exposure of lab technicians/operators to these carcinogenic organic liquids.

This research has found that the Roben Jig can produce a clean coal sample that is very similar to that produced using the traditional float/sink method. It was found that perchloroethylene had negative impacts on coal rheology, however coke strength and size was not affected. It was found that higher ash particles did contaminate lower density slices in the jig, but it is unknown if this misplaced material impacted coke quality. More research need to be undertaken to understand the characteristics of the misplaced material and the effects on coke quality. New jigging methods also need to be tested to develop a procedure to mitigate misplaced material in the lower density fractions.

Introduction

In British Columbia, the occurrence of coal is well known and relatively predictable. Several known thermal coalfields exist as well as two major metallurgical coalfields, the Kootenay and Peace River coalfields (BC Geological Survey, 1992). The challenge isn't in 'finding' the coal, it is in evaluating the coal as a resource for various applications during the exploration stage.

During the exploration phase of coal mine development, the evaluation of metallurgical coal for resulting coke quality is often determined using smaller mass samples collected from drill cores. Drilling is the least expensive method of obtaining representative coal seam samples when compared to developing test pits or adits. If a larger bulk sample is required, it is sometimes possible to use several 6-inch drill program cores. However, depending on the thickness of the seam, even this may be cost prohibitive as many drill holes would need to be used to collect the required large coal mass – i.e. several tonnes. The latter amount would need to be collected to conduct pilot-scale carbonization test work for evaluating its coking potential.

Coal samples from the exploration phase are prepared by screening and washing the coal for further quality testing. The Sink and Float procedure used in coal washability studies, is the process where ash/mineral matter is removed from the coal. The coarser coal is processed using mixtures of organic liquids (i.e. white spirit, perchloroethylene (PCE) and methylene bromide) in this procedure while the finest fraction is cleaned by a process called froth flotation. During the float-and-sink process, the coal sample is separated at relative densities (specific gravity, s.g.) – i.e. white spirit/PCE for 1.4 s.g., PCE for

1.6 s.g. and PCE/methylene bromide for 1.8 s.g. - that produce clean coal samples at different ash contents typical of what would be produced in a commercial coal washing plant.

Project economics are based on the results of the float-sink testing – including information on the yield of clean coal as well as the quality of the cleaned coal and resulting coke quality. The coking characteristics for a metallurgical coal deposit are imperative in evaluating project economics (i.e. expected price for the clean coal). It is critical to ensure that coal/coking properties are correctly assessed from drill core samples to properly evaluate project economics.

Background

For years, the primary concern in the handling and use of organic liquids such as perchloroethylene (PCE) and other organic liquids was the safety risks associated with human exposure. PCE is a known carcinogen and poses a safety hazard for laboratory operators, and therefore must be handled carefully. (Figure 1) shows a laboratory technician working in a specially designed fume hood wearing personal protective equipment including a respirator mask. A number of investigations and ensuing observations about how PCE may impact coal sample coking quality have also been identified and noted.

Figure 1. Operator working with organic liquids in a specially designed fume hood.

In 2010 Michael Campbell at ALS Coal Technology, Australia found that organic liquids could interfere with the properties of interest for a coal producer or end user (Campbell, 2010). That same year, Iveson and Galvin (year) completed an ACARP study (C17051) which comprehensively examined the effects of organic liquids on coking properties of coal (Iveson & Galvin, 2010 and 2012). They concluded that PCE had, on one hand, a negative effect on the coking properties of lower rank and lower fluidity coking coals but on the other hand, a negligible or possibly even a small positive effect on the coke reactivity index (CRI) and coke strength after reaction (CSR) of cokes resulting from coals with relatively good initial coking properties. The latter observation pertaining to a positive impact of PCE on coke quality was reported earlier by DuBroff et al. at Inland Steel, USA (DuBroff et al., 1985). Their 1985 patent outlined a process for improving the quality of some metallurgical coke resulting from coals with high inert content, which had produced coke of lower than expected stability when compared to the coal rank. They studied several medium-volatile bituminous coal samples which had been soaked and agitated in a PCE bath prior to carbonization. For some of the coals, the resultant coke showed improved Stability Index, increased Hardness Index, decreased reactivity and increased tumble strength. It was also found that the carbonization time was decreased. The hypothesis was that the PCE reacted with certain macerals in the coal, producing a "solvent induced reaction product" residue on the coal particles that was highly reactive. In some cases, this reaction product could be thought to 'increase' the reactive-to-inerts ratio at the coal particle surfaces (DuBroff et al., 1985).

Contrary to what the Inland Steel patent outlines, Iveson and Galvin found that the negative effect of PCE treatment/exposure was shown to be more significant when coal had high inertinite content (>40%). These coals produced lower strength coke as a result of being exposed to PCE. In fact, for coals with high inertinite content, CRI was increased (an adverse effect) by an average of 15% and CSR values decreased by an average of 25% (also an adverse effect) when the coal had been exposed to PCE prior to coking. This effect was more pronounced after the coal had aged for more than 16 weeks (oxidized). The explanation proposed by Iveson and Galvin was the high porosity of inertinite, namely semi-fusinite and fusinite, enabled greater access of PCE to the interior of the coal particles (Iveson & Galvin, 2012).

The evidence that organic liquids, as discussed previously, affect the coking properties of low fluidity Australian coals implies that Western Canadian coals, known to have moderate fluidity levels, could be affected in a similar way. Many Canadian geologists have also found that cleaned drill core coal samples often had lower caking/coking properties than bulk or production coal samples. Based on these observations, the Canadian Carbonization Research Association (CCRA) undertook a program to investigate the impact of organic solvents used in float-sink procedures on the coal and coke properties of a higher-inert Western Canadian coal sample.

This study looked at the effects of perchloroethylene on coal rheology and coke quality. It was found that an 80% decrease in Maximum Fluidity occurred in the perchloroethylene treated coal immediately following treatment when compared to the control sample. The coke resulting from the treated sample showed a 16-point decrease in CSR when compared to the control sample. These two coal and coke quality parameters, i.e., Maximum Fluidity and CSR, are key when evaluating coal resources and reserves. The ramifications of using the wrong numbers for the above-mentioned parameters when determining product characteristics for sale are severe and could result in project abandonment or false overvaluing of the property. The CCRA paper resulting from this study has been published in Fuel Processing Technology journal (Effects of Organic Liquids on Coking Properties of a Higher-Inert Western Canadian Coal) (Holuszko et al., 2017).

After the initial study outlined above, the CCRA also completed an exploratory study that examined an alternative to organic liquids when processing coal. A jig (Roben Jig – previously name 'Boner Jig') was used to clean coal using only water and the resulting coal and coke quality characteristics were compared to coal that was processed using the traditional organic chemical washing process. It was found that it was possible to produce a clean coal product that was similar to that generated using the organic liquids. It is believed that due to the coal type used in this phase study, the perchloroethylene had no negative effect on the coal rheology and coke strength parameters. Although this study has not yet been published, its findings are important because it demonstrates that the Roben Jig can be used to produce clean coal composites similar in all aspects as clean composites arising from traditional float/sink methods. The coal used in this work was a relatively "easy to clean" coal in that the particles high in mineral matter could be easily separated from coal. However, as not all coals wash as easily, it is important to test the Roben Jig on a wide variety of coal types.

Objectives

The objective of this project was to verify that the Roben Jig can be commercially used to wash a broad range of coal types to ultimately produce representative clean coal composites for coal and coke analysis. This is beneficial to the coal industry for the following reasons:

1) It eliminates the potential negative effects of perchloroethylene and other organic liquids on coal and coke quality parameters.
2) It would reduce the exposure of lab technicians/operators to carcinogenic organic liquids.

Experimental Methodology

Four coal types (Coals A, B, C, D) from British Columbia were tested in this project. One sample originated from Northeast BC coalfields. The other three coal samples originated from Southeast BC coalfields. All samples were collected in an undiluted, raw state, from active mining faces. Figure 2 shows the location of the coal fields where project coal samples originated.

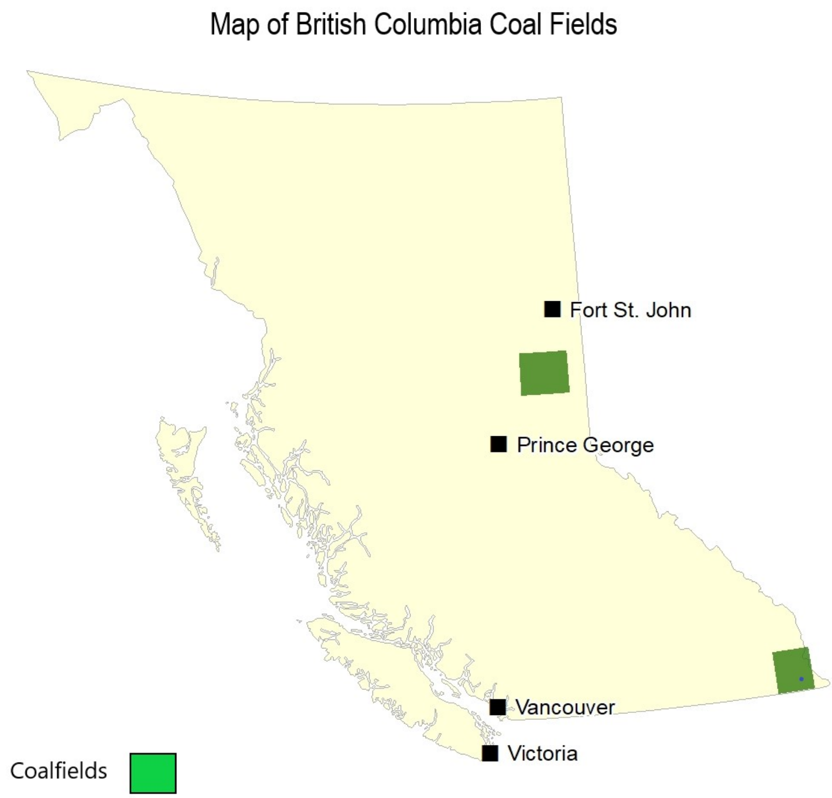

Figure 2. Map of British Columbia showing the Northeast and Southeast BC coalfields.

Upon receipt of the coal samples at Gwil/Birtley Coal Testing Laboratory, Calgary, laboratory staff removed the coal from the sealed drums and left to air dry overnight. As-received and air-dried weights were reported. The coal was then screened through a 12.5mm sieve and the oversize coal was hand-knapped to pass. All coal was sized at -12.5mm. The entire sample was then split into two size fractions: -12.5mm x 0.25mm and -0.25mm. The coarse size fraction (-12.5mm x 0.25mm) will then be split into two samples. One half will undergo washability in organic liquids and the other half will be washed using the Roben jig. The -0.25mm coal was treated in the same way and was cleaned using ASTM D5114-90(2010) froth flotation of coal method (ASTM D5114-90, 2010).

Float/Sink & Jigging Methods

This project evaluated clean coal products resulting from two methods of washing coal: traditional organic liquids float/sink and Roben (previously referred to as Boner) Jig separation. The specific gravity of a coal particle is dependent on the mineral matter content and maceral composition. Coal particles containing the lowest mineral matter content will float when separated at 1.30 Specific Gravity (s.g.) liquid, whereas those with the highest mineral matter content are separated at 1.80 s.g.

The float-sink method ASTM D4371, ‘Standard Test Method for Determining the Washability Characteristics of Coal’ was used in this project (ASTM D4371-06, 2012). This technique fractionates coal and mineral matter particles based on particle density by allowing particles to settle in organic liquid mixtures with a known specific gravity. Mixtures of white spirits, perchloroethylene and methylene bromide are used to produce different media densities from 1.30 s.g. to 1.80 s.g. (Figure 3).

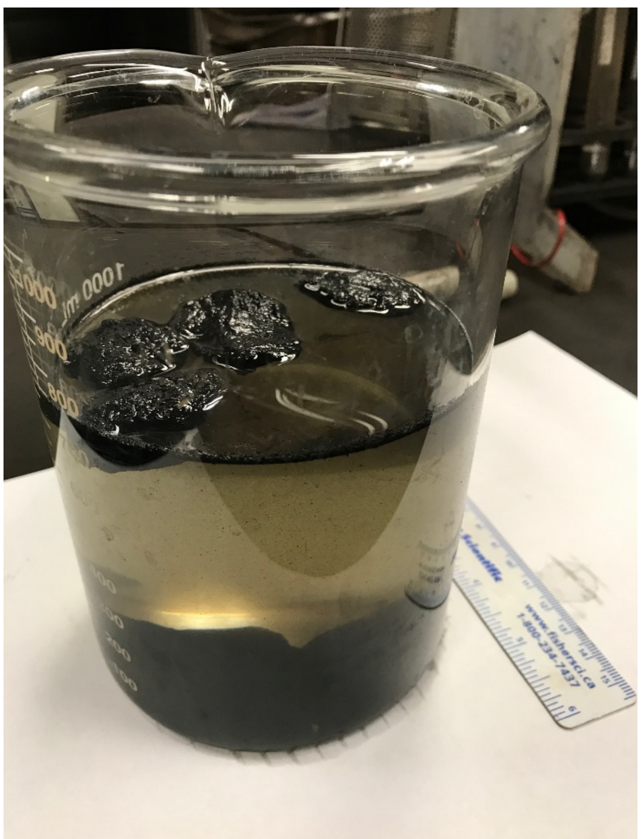

Figure 3. Coal particles floating in perchloroethylene.

The Roben Jig is a device that allows the sorting of coal particles based on density to occur as the coal is jigged up and down in a column of water (Figure 4). Although a published standard (ASTM, ISO, Australian Standards) does not exist for the use of the Roben Jig, the following procedure was developed by the inventor. Approximately 15 Kg of 12.5 mm x 0.25 mm coal and tracers (glass marbles) of a known specific gravity (2.70) were added to the jig tube with a 0.25 mm screen at the bottom. This mesh base allowed water to enter during the jig down stroke as well as allowing particle sorting during the jig upstroke. This tube, with coal added, was gently lowered into the jig vessel. Water level was adjusted so that it was approximately 100 mm above the level of the coal. The Jig tube was attached to the pneumatic jigging mechanism. Once turned on, this mechanism moved the jig tube up and down. The down stroke was rapid to suspend particles individually, the upstroke was slower to allow the particles to sort according to density. The jigging time was 15 minutes. When the jig cycle was complete, the coal sample was presumed to have been sorted into a density continuum column, heaviest material (discard) at bottom, grading to lightest (best) coal at top.

Figure 4. The Roben Jig equipment used in this study.

After jigging was completed, the jigging tube was lifted from the jig vessel allowing the water to drain from the coal. A sample pusher was inserted in the jig tube and pressed to allow more water to drain. The entire tube was then inverted to allow for the coal to be pushed upwards. Once the jig tube was inverted, and the screen removed, the marbles were visible, as they had the heaviest specific gravity. This was evidence that the jigging was successful. A tray was attached to the top of the tube and the sample pusher was rotated, causing the coal to be pushed above the jig tube and allowing the operator to scrape off the layer (Figure 5). The layer was then carefully scraped into the Apparent Relative Density (ARD) basket. Note that, because the jig tube was inverted after jigging, the first fraction collected was the highest density (heaviest or highest ash content). The thickness of the layers was dictated by the size consist of the coal and by how many fractions one expected to remove from the sorted column. As the wet ARD's were calculated immediately, the depth of the layers could be increased or decreased to obtain a range of ARD's and subsequent range of ash contents.

Figure 5. Inverted Roben Jig with coal slice ready to be removed.

Each wet coal layer was weighed and air dried and a dry ARD was calculated for each layer. Samples were then prepped for laboratory testing. Similar ARD's were added together before prepping or tested first to confirm ash results. The calculated ARD is an average of that layer.

Each coal sample was washed using both the jig method and the organic liquids method yielding two clean coal composites per coal type. Each of these samples was analysed at GWIL/Birtley Coal Testing for Yield%, Proximate analysis, Free Swelling Index (FSI), Specific Gravity (SG), Total Sulfur, Hardgrove Grindability Index (HGI), Calorific Value (kcal/kg), Mercury, Ultimate analysis, Mineral Analyses of Ash, % Phosphorous in coal (calculated), Gieseler Fluidity, Ruhr Dilatation, Ash fusion (oxidizing and reducing), Chlorine, Fluorine, Alkali Extraction-Light Transmittance test, Sapozhnikov

X,Y indices and Caking Index G. Petrographic analysis of the coal was completed both at CanmetENERGY and David E. Pearson & Associates. The analytical flow sheets (J1 and OL1), outlining all testing procedures completed, can be viewed in Appendix 1.

Carbonization

Coals A-D Clean Coal Composites (~20 kg each) issued from Float/Sink washing with organic liquids and Roben Jig washing with water were received at CanmetENERGY in Ottawa between May 12 and June 29, 2017. Upon reception, coals were air-dried in open air in the laboratory for 12 hours, homogenized and screened through a nest of sieves covering range +6.35 mm down to -0.5 mm for measuring size consist and for making up sole-heated oven charges for coking in CanmetENERGY's 12 kg capacity carbonization sole-heated oven as per ASTM D2014-97(2010) to measure level of expansion/contraction.

The following provides a description of the features and operation conditions for carbonization of coal in sole-heated oven at CanmetENERGY including the preparation of coke sample from Coals A-D for CSR evaluation following a procedure developed at CanmetENERGY (MacPhee et al., 2013).

Sole-Heated oven (ASTM D 2014-97(2010)

A total of 12 kg of coal (75-100% -3.35 mm or -6 mesh) was divided equally and each half-charged into chambers approximately 280 mm in width, length and depth of a double-chambered oven. A weighted piston applied a constant force corresponding to a pressure of 15.2 kPa (2.2 psi) to the top of the coal bed (thickness in 76-90 mm range), which was heated from below according to a prescribed temperature program. The sole temperature was raised from 554°C to 950°C at a heating rate of 0.9-1°C/min during the test. The movement of the load was continuously monitored during the test, which was complete when the temperature at the top of the coal bed reached 500°C (normally reached after a period of 6-7 hours). The measured expansion or contraction of the sample was converted to a reference base of 833 kg/m^3 (52 lbs/ft^3) and 2% moisture.

After carbonization, semi-coke was removed from the sole-heated oven and re-heated. This treatment heats the semi-coke to 1100 ^oC in nitrogen gas to complete the annealing of the coke.

A schematic of a sole-heated oven is presented in Figure 6 and a picture of sole-heated oven used in this project is shown in Figure 7.

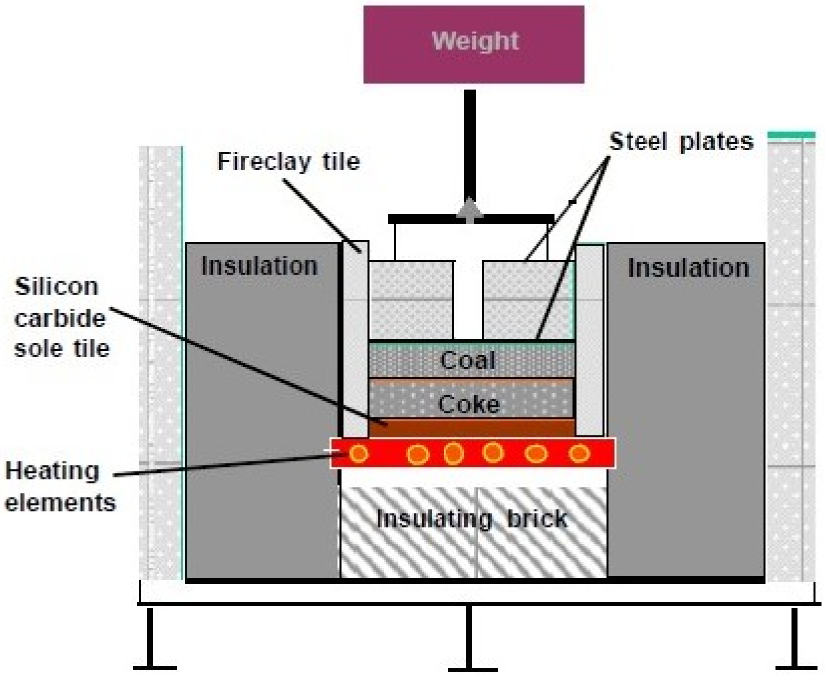

Figure 6 – Schematic diagram of the Sole-Heated Oven.

Figure 7 – Photo of the CanmetENERGY sole-heated oven (12 kg capacity) used in this study.

Cokes from the sole-heated oven were assessed for Apparent Specific Gravity (ASG), hot strength properties, including CSR and CRI following the ASTM D5341-14 standard and analysed for Proximate (Moisture, Ash, Volatile Matter, Fixed Carbon), Sulfur and carbon forms/textures using an optical microscope.

The ASG of coke is defined as the ratio of the mass of a volume of dry coke to the mass of an equal volume of water. Coke ASG varies with the rank and ash content of the coal carbonized, the bulk density of the coal charge in the oven, the carbonization temperature and the coking time (Price & Gransden, 1987). In this project, the ASG of cokes were determined following a method developed at CanmetENERGY and related to the ASTM D167-93 (2004) and ISO 1014:1985 Standards.

According to ASTM D5341-14, the CRI is the percent weight loss of the coke sample after reaction in CO2 at 1100 ºC for 2 hours. The cooled, reacted coke is then tumbled in an I-drum for 600 revolutions at 20 rpm. The cumulative percent of +9.5 mm coke after tumbling is denoted as the CSR.

Microscopical analysis of the textures was also performed on the sole-heated cokes to measure the carbon forms. This technique is extremely useful for understanding the behavior of coal during coking and for interpreting pressure generation and coke quality results.

Carbon form analysis in this project was carried out as per a combination of the US Steel method (Gray & DeVanney, 1986) and the CanmetENERGY method, which is based on work completed by Marsh at the University of Newcastle, UK, in 1978-1981. A single point count is made for each measured field of view. For each field, the stage is rotated in order to determine the possible highest rank carbon form. Normally 500-point counts are performed on a sample. Each carbon form is derived from an assumed parent coal V-type. From the coke texture analysis, one can determine the effective coal reflectance, %Ro.

Accreditation & Standards

All coal and coke testing laboratories were chosen based on years of experience, suitable equipment, willingness to contribute in-kind funds to research and participation in QA/QC programs. Birtley Coal & Minerals testing is a wholly owned subsidiary of GWIL Industries. Birtley Coal & Minerals Testing has been serving the Canadian coal industry for over 45 years and is located in Calgary, Alberta. Heather Dexter has been managing the laboratory for 13 years and has developed an expertise in the preparation of Western Canadian coals. She has seen the lab and employees through the transition into a newly built, state of the art lab 4 years ago. Birtley Coal participates in the CANSPEX round-robin proficiency testing program. CANSPEX is a proficiency testing service that assists laboratories in becoming more competent in ensuring that instrumentation and methods are operating satisfactorily.

CanmetENERGY has been working in partnership with the Canadian Carbonization Research Association for over 40 years and is located in Ottawa, Ontario. This partnership has been working on demonstrating the suitability of Canadian coals for producing good quality metallurgical coke. CanmetENERGY also undertakes round robin QA/QC testing.

David E. Pearson and Associates is a coal petrography company with locations all over the world. The company was founded in 1981 and is well known and respected in the coal industry. The laboratory specializes in petrographic analysis of coking coals, coke petrography and carbon forms. This laboratory did not contribute in-kind funds to the project, but was chosen due to time constraints and the need to complete the petrographic analysis in a timely manner.

All coal and coke analyses were completed according to laboratory standards. Most test work following ASTM International standards. A list of all standards used in this research project can be found in Appendix 2.

Results

Coal and coke analytical results were analysed to determine the following:

1) Was the Roben Jig capable of producing a clean coal composite similar to that of organic liquids for use in coal and coke evaluation?
2) Did perchloroethylene have any impacts on coal rheology, coke strength and coke size?
3) Was there misplaced material (higher ash particles contaminating lower ash/specific gravity slices) in the jig produced sample, and at what specific gravity fraction did the misplaced material occur?
4) Did the misplaced material affect coal and coke quality?

All official laboratory certificates can be found in Appendix 3.

Roben Jig vs Float/Sink Clean Coal Quality

For all samples tested, the Roben Jig was successful in creating a clean coal sample similar to that of the float/sink method, but with better rheology.

Table 1. shows the comparison of some basic coal quality parameters between the Jig and Float/Sink (FS) produced clean coal. Most of the clean coal quality characteristics of the samples produced from both methods compared very closely. Values for ash, volatile matter, fixed carbon, sulfur, (FSI), sulfur, calorific value, fluorine, mercury, specific gravity and most Hardgrove Grindability index values were matched well and thus proved that the Jig was useful in creating comparable clean coal samples. One

unexpected result was the increase in Hardgrove Grindability Index in the float/sink coal samples compared to the Jig washed sample. Potential causes for this result will be researched at a later date.

Clean Coal Quality (air-dried basis)	Coal A		Coal B		Coal C		Coal D	
	FS	JIG	FS	JIG	FS	JIG	FS	JIG
Moisture (%)	0.99	0.97	2.15	0.56	0.50	0.26	1.05	0.90
Ash (%)	5.74	5.88	8.54	9.70	8.42	8.35	10.95	10.85
Volatile matter (%)	31.76	31.95	23.19	23.52	24.41	24.96	22.14	22.35
Fixed carbon (%)	61.51	61.20	66.12	66.22	66.67	66.43	65.86	65.90
Sulfur (%)	0.46	0.51	0.41	0.42	0.55	0.56	0.30	0.31
Free swelling index	8.5	8.5	7.75	7.5	8.5	8.5	3.5	4.5
Calorific value (kcal/kg)	7955	7971	7750	7763	7874	7864	7496	7487
Chlorine (ppm)	3906	271	21450	949	733	472	4600	962
Flourine (ppm)	224	225	118	115	92	134	93	93
Mercury (ppb)	32	24	38	31	86	85	53	55
Hardgrove grindability index	87	82	147	118	81	80	79	78
Specific gravity	1.30	1.31	1.37	1.36	1.35	1.34	1.39	1.37
Gieseler fluidity (ddpm)	1647	1972	57	257	405	488	2	4
Ruhr dilatation								
% contraction	24	27	24	21	23	25	20	16
% dilatation	111	139	3	33	93	103	-	-
% total dilatation	135	166	27	54	116	128	-	-
% SD 2.5	120	154	2	29	86	96	-	-
Caking index (G)	96	98	78	82	93	92	35	46
Sapozhnikov (Y)	17.0	17.5	14.5	15.0	18.5	18.0	6.5	7.0
Petrography								
Vitrinite reflectance (mean max)	0.94	0.94	1.22	1.23	1.20	1.21	1.17	1.17
Maceral Analysis (%)								
Vitrinite	68.7	64	38	46.3	60.6	62.9	41.3	43.4
Semifusinite	9.7	12	24.1	18	13.9	12.8	21.6	20.9
Total reactives	84.4	82.8	62.9	65.1	75.3	76.1	63.5	65.1
Inerts								
Semifusinite	9.7	12	24.1	18	13.9	12.8	21.6	20.9
Total inerts	15.6	17.2	37.1	34.9	24.7	23.9	36.5	34.9

Table 1. Clean Coal Quality

For all Coals, the dilatation and fluidity were lower in the float/sink washed coal when compared to the Jig washed sample. This was expected and was due to the perchloroethylene supressing the rheology of the coal. The Jig was successful in providing a more accurate measurement of the dilatation and fluidity of these coal samples. Only small differences were seen in the Caking Index G and Sapozhnikov values.

Fluidity refers to coal's plasticity during carbonization, where coal changes from a solid material to a fluid (plastic) state, and then to a fused porous solid (coke) during cooling. High fluidity is beneficial in the coke making process. Dilatation determines the swelling properties of coal when heated under standard conditions. Caking Index G is determined through a laboratory test measuring the caking capacity of a sample of coal to ascertain how well the coal binds or fuses together. Higher G index indicates greater caking capacity. Sapozhnikov Y is a measure of the maximum thickness of the plastic mass when the coal is heated to the peak temperature and before it resolidifies. This measure is similar to the Crucible Swelling Number and the level of Gieseler Maximum Fluidity. As expected, chlorine levels were highly elevated in all float/sink coal samples. This was due to residual perchloroethylene remaining on the coal surface and within pore spaces.

Coal petrography is a microscopic technique used to determine a coal's degree of coalification and amount and category of macerals. These macerals can be categorized as reactives or inerts. Reactive macerals are those which burn readily during combustion and those which become plastic during carbonisation in the coke oven. Inert macerals are those macerals which are not reactive. The mean max vitrinite reflectance as well as the amounts of vitrinite, semifusinite, total reactives and total inerts were very comparable between the samples prepared using the Jig and the float/sink method.

When comparing the clean coal quality characteristics, it is apparent that the Roben Jig was able to provide a representative clean coal sample that was able to offer more realistic values of chlorine, fluidity and dilatation when compared to the float/sink based sample. It is also evident that exposure to perchloroethylene caused a decrease in fluidity and dilatation in all four coal samples.

Coal B

When Coal B was tested there were several characteristics about the coal that were interesting and different from the other coals. When Coal B was floated in perchloroethylene baths, during the float/sink procedure, the operators noticed that particles were falling apart. Heavier density particles would sink to the bottom of the bath and lower specific gravity coal pieces were breaking off and floating to the surface. Once all coal was separated, the weights were reconciled with the raw weight and it was found that this coal gained mass. The moisture was also higher even though the coal was left to dry longer than the others. When comparing the fluorine content of the organic liquid washed Coal B with that washed in the Roben Jig, it was 22 times the water based method. Gieseler fluidity was decreased by 78% and the Hardgrove Grindability index was increased from 118 to 147.

What we assumed was happening at the time was what Iveson and Galvin proposed. The explanation proposed by Iveson and Galvin was the high porosity of inertinite, namely semi-fusinite and fusinite, enabling greater access of PCE to the interior of the coal particles (Iveson & Galvin, 2012). Sample B (along with Sample D) did have the highest concentration of fusinite. Upon viewing Sample B using the Scanning Electron Microscope (SEM), and using EDX analysis to detect elements, we found that most of the fusinite pores were filled with kaolinite (Figure 4). There actually wasn't a lot of empty port space. This finding therefore does not support the claim made by Iveson and Galvin. More SEM photos can be found in Appendix 3.

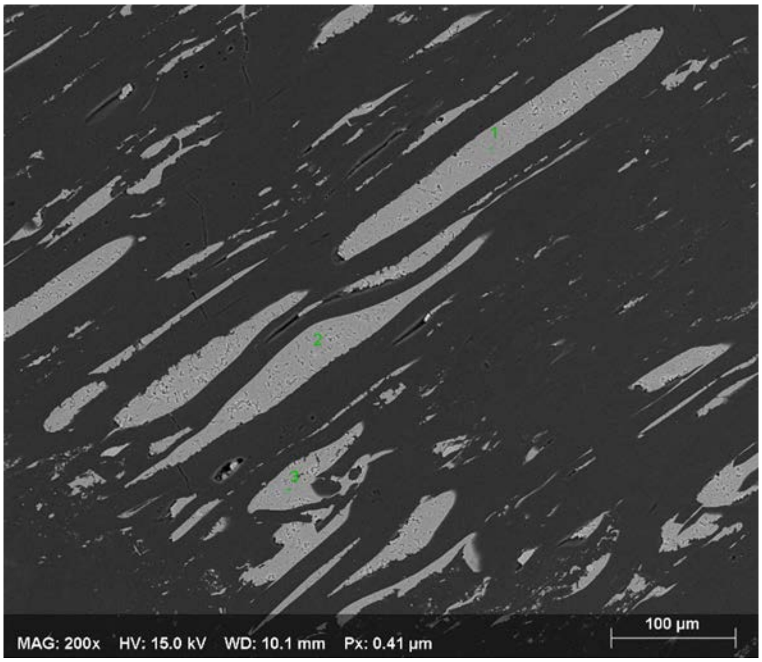

Figure 4. Fusinite pores filled with possible Kaolinite $(Al_2(Si_2O_5)(OH)_4$. Numbers represent EDX analysis locations where elements Si, O, and Al were detected.

It is thought that there may be a chemical reaction occurring between perchloroethylene and the coal macerals and kaolinite within the pore spaces leading to an increase in mass, chlorine content and a reduction in rheology. It is unknown how these reactions are affecting the Hardgrove Grindability Index. More research is needed to determine how perchloroethylene is interacting and affecting the coal chemistry and associated minerals.

Clean Coal Carbonization

For Coals A-D, the percent coal <3.35 mm ranged between 77%, Coal C and 88%, Coal B (Table 2). This indicates that Coal B and Coal C are respectively the finest and coarsest coal among the four coals tested.

Description		COAL A Float/sink	COAL A Jig	COAL B Float/sink	COAL B Jig	COAL C Float/sink	COAL C Jig	COAL D Float/sink	COAL D Jig
Index		26152	26153	26164	26165	26209	26210	26240	26241
Coal Pulverization, Sole-Heated Oven Charge									
Sieve Analysis, cumulative									
6.30 mm	%	4.62	4.15	3.77	4.02	12.74	8.40	8.26	8.54
3.35 mm	%	19.41	17.93	10.77	12.26	25.24	20.90	22.90	20.24
1.70 mm	%	36.12	34.85	20.96	24.37	42.24	38.09	39.05	36.71
0.85 mm	%	52.39	52.87	32.45	39.02	58.72	56.65	53.20	54.07
0.50 mm	%	63.49	65.07	41.39	50.20	69.20	68.76	62.64	66.07
passing 3.35 mm	%	80.59	82.07	89.23	87.74	74.76	79.10	77.10	79.76
Sole Heated Oven									
Test Date		MAY/25/17	MAY/26/17	JUNE/1/17	JUNE/2/17	JUNE/28/17	JUNE/29/17	JULY/20/17	JULY/19/17
Expansion/contraction value		-20.8	-20.5	-22.3	-17.9	-6.6	-9.4	-19.8	-17.2

Table 2. Coals A-D size distribution for sole-heated oven charges as well as reference contraction values obtained from sole-heated oven coke tests.

Contraction levels ranged from -21 for Coal A to approximately -8 for Coal C. In actuality, Coals A, B and D exhibited very similar contraction, in range -18 to -21. The type of washing media, namely using Float/sink and Roben jig washing, did not influence the level of contraction for the individual coals as it remained essentially unchanged.

The low volatile matter content remaining in the cokes, 0.65-1.08%, provides clear evidence that the coals were essentially fully carbonised by a combination of coking in sole-heated oven and heat-treatment of the resulting semi-coke to 1100 ^{o}C under N2 to complete the annealing of coke. Figure 8 shows coke made from carbonising Coal C washed via float-sink in sole-heated oven and after annealing to 1100 ^{o}C. The coke reveals a number of cracks/fissures, which develop due to contraction of the coke due to loss of volatile matter as the semi-coke is heated above re-solidification (Viala et al., 1994). In a sole-heated oven, fissures propagate from the bottom of the oven towards the top as coking progresses.

Figure 8 – Sole-heated oven coke from Coal Sample C cleaned using the Float-sink method.

The Apparent Specific Gravity (ASG) of coke ranged between 1.01 (Coal A and Coal C) and 1.15 (Coal D). As stated earlier, the rank and ash content of the carbonised coal dictates the coke ASG. The low ash content in Coal A, 5.8%, leads to lowest ASG coke whereas the high ash content in Coal D, 10.9%, leads to highest ASG coke.

As shown in Figure 9, CSR result for Coals A, C and D washed using the traditional float and sink method was higher than CSR for these same coals washed using the H_2O-based Roben jig. Coal B, on the other hand, reveals slightly higher CSR result for Roben jig compared to float and sink method. CSR for the four coals examined is in order B > A > C > D. The high CSR and low CRI result for Coal B appears to be dictated by its low Ash Basicity Index of 0.049.

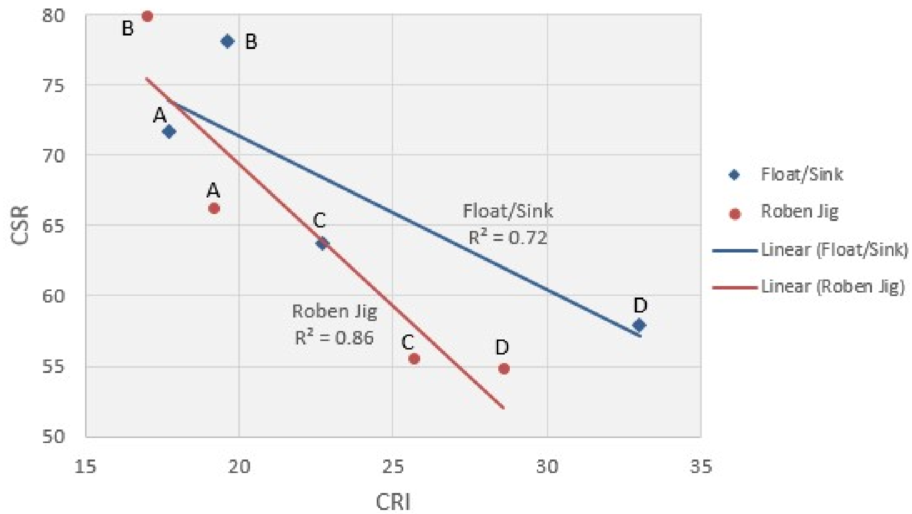

Figure 9. Plot showing CSR and CRI data for all four coal types.

Coke textures/carbon forms (C forms) data are listed in Table 3. A close examination of the data indicates that the washing media does not influence the development of textures during coal to coke transformation for Coals A-D. In actuality, the fractions of reactive and inert textures in the cokes are found to be similar for washing coals via traditional float and sink method with organic liquids and by the Roben jig using water. This is also supported by the fact that the 'effective' coking rank (Roeff) for the individual coals washed in the different media are very similar, except perhaps for Coal C, which shows slightly stronger C forms, (Roeff) value of 1.37 for Jig washing compared to an Roeff of 1.32 for Float-sink washing. The most common classification of coal is based on rank, referring to the degree of coalification that has occurred. The rank of a coal is determined primarily by the depth of burial and temperature to which the coal was subjected over time. Examination of carbon forms in coke, after a coal is transformed into a coke, provide a true measure of the degree of coalification or rank of coal, which is its effective coking rank or Roeff. It is quite revealing and interesting to point out that coking rank based on carbon forms measured in the cokes are, for the four coals coked in this project, appreciably higher than the rank determined from coal petrography. In fact, Coal A: Roeff 1.14 vs Ro 0.94; Coal B: Roeff 1.42 vs Ro 1.20; Coal C: Roeff 1.32 vs Ro 1.21; Coal D: Roeff 1.27 vs Ro 1.17. This indicates that Coals A-D actually produce stronger C forms than expected based on coal petrography v-type measurements.

Description		COAL A Float/sink	COAL A Jig	COAL B Float/sink	COAL B Jig	COAL C Float/sink	COAL C Jig	COAL D Float/sink	COAL D Jig
Index		26152	26153	26164	26165	26209	26210	26240	26241
Coke Analyses									
Proximate Analysis (db)									
Ash	%	7.88	8.10	10.89	10.90	10.55	10.40	13.81	13.55
Volatile Matter	%	0.71	1.08	0.70	0.86	0.65	0.69	1.07	0.81
Fixed Carbon	%	91.41	90.82	88.40	88.24	88.80	88.90	85.12	85.64
Sulphur	%	0.38	0.41	0.30	0.31	0.46	0.45	0.24	0.26
Coke Properties									
Apparent Specific Gravity		1.051	1.009	1.085	1.096	1.018	1.005	1.157	1.145
CSR		71.7	66.2	78.1	79.9	63.7	55.5	57.9	54.8
CRI		17.7	19.2	19.6	17.0	22.7	25.7	33.0	28.6
Coke Textural Analysis									
Reactive Textures									
isotropic	%	0.8	1.4	1.6	0.7	1.3	1.2	1.9	1.4
very fine mosaic	%	1.2	2.4	0.0	0.0	0.6	0.2	0.5	1.3
fine mosaic	%	13.3	12.2	0.0	0.3	1.0	0.8	1.3	1.4
medium mosaic	%	58.8	57.7	2.5	3.1	23.4	13.1	20.5	21.7
coarse mosaic	%	2.8	1.3	2.6	3.1	8.2	4.1	10.0	6.0
elongated fine flow	%	6.9	12.8	6.6	4.5	29.3	24.7	8.4	7.2
elongated medium flow	%	0.4	0.4	50.3	52.1	14.9	30.0	8.0	13.3
elongated coarse flow	%	0.0	0.0	5.1	3.5	0.7	1.9	2.2	2.6
domain flat flow	%	0.0	0.0	0.2	0.0	0.1	0.3	0.3	0.6
domain undulating	%	0.0	0.0	0.8	0.3	0.9	0.1	0.7	1.2
domain ribbon	%	0.0	0.0	0.0	0.0	0.3	0.0	0.5	0.0
Inert Textures									
fusinite	%	0.2	0.5	1.7	0.8	1.1	1.2	1.3	1.9
semifusinite	%	15.4	11.1	26.7	31.2	17.5	21.3	43.4	39.8
unidentifed inerts	%	0.2	0.1	1.9	0.4	0.5	0.9	0.9	1.0
altered vitrinite	%	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.6
Total mosaic	%	76.9	75.0	6.7	7.2	34.5	19.4	34.2	31.8
Total flows	%	7.3	13.2	62.0	60.1	44.9	56.6	18.6	23.1
Total domains	%	0.0	0.0	1.0	0.3	1.3	0.4	1.5	1.8
Total coke inerts	%	15.8	11.7	30.3	32.4	19.3	23.5	45.7	43.3
Coke Mosaic Size Index		2.11	2.14	3.07	3.01	2.72	2.85	2.66	2.65
Estimated Ro of coal	%	1.13	1.14	1.42	1.42	1.32	1.37	1.27	1.27

Table 3. Coke analysis data including chemistry (Proximate and Sulfur), CSR and CRI, and textures/carbon forms.

The Coke Mosaic Size Index (CMSI) for the coals washed in the different media is also very similar. CMSI is a mathematical method to summarize the carbon form analysis Coin, 1982). The higher the CMSI, the higher the rank based on carbon forms measured. In the present study, the CMSI order is B > C > D > A.

Three of the four coals evaluated for their CSR after washing in the two types of media revealed that the float/sink gives a slightly better result than water-based method. It was also found that the washing media (organic/non-organic) does not influence the development of textures during the coal to coke transformation for Coals A-D. Also, for Coals A-D, coking rank based on carbon forms measured in the cokes are appreciably higher than rank determined from coal petrography indicating that these coals produce stronger C forms than expected based on coal petrography v-type measurements.

Washability

Sample A

Clean coal curves produced from sink and float and jig tests for sample A are compared in Figure 10a. Figure 10b and 10c provide correlations between the density of separation and ash and cumulative yield of clean coal from tests using sink and float and jig procedure.

The Jig was able to produce a low ash clean coal sample (below 5% ash), but at a much lower yield when compared to the float/sink method. While it was easy to obtain a coal concentrate at 2% ash with a 47% yield using the float and sink procedure, the jig was only able to provide a concentrate with double the ash content (3.87% ash) at a 37% yield. The Roben Jig always provided higher ash products compared to a similar density of separation to the float/sink method. The greatest disparities were observed in clean coal products below 10% ash (Figure 10a). This coal seems to be somewhat easy to wash.

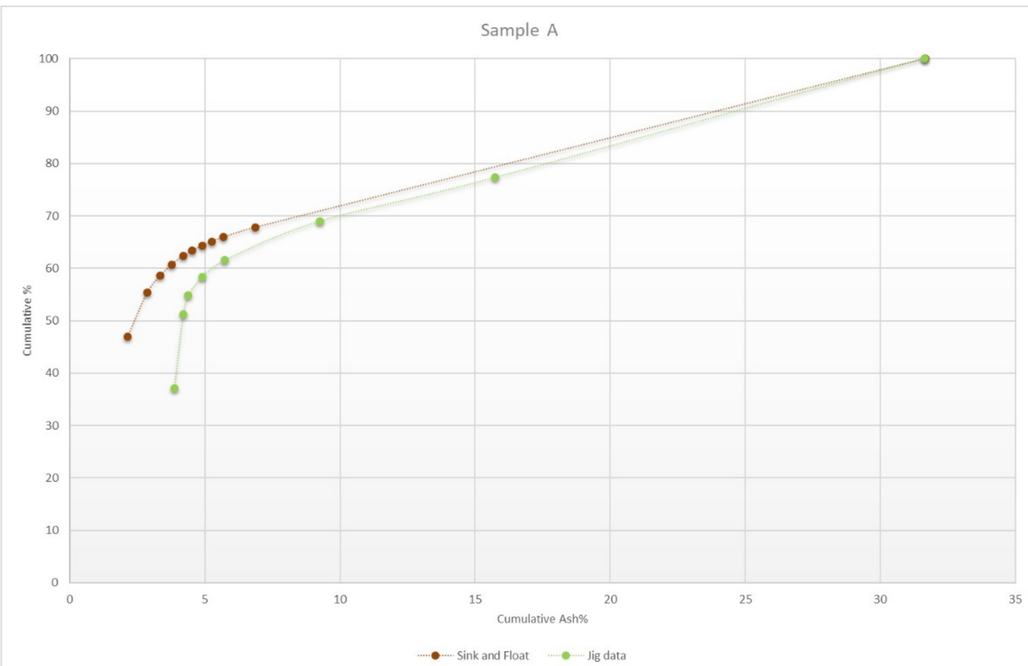

Figure 10a. Clean coal curve for sample A.

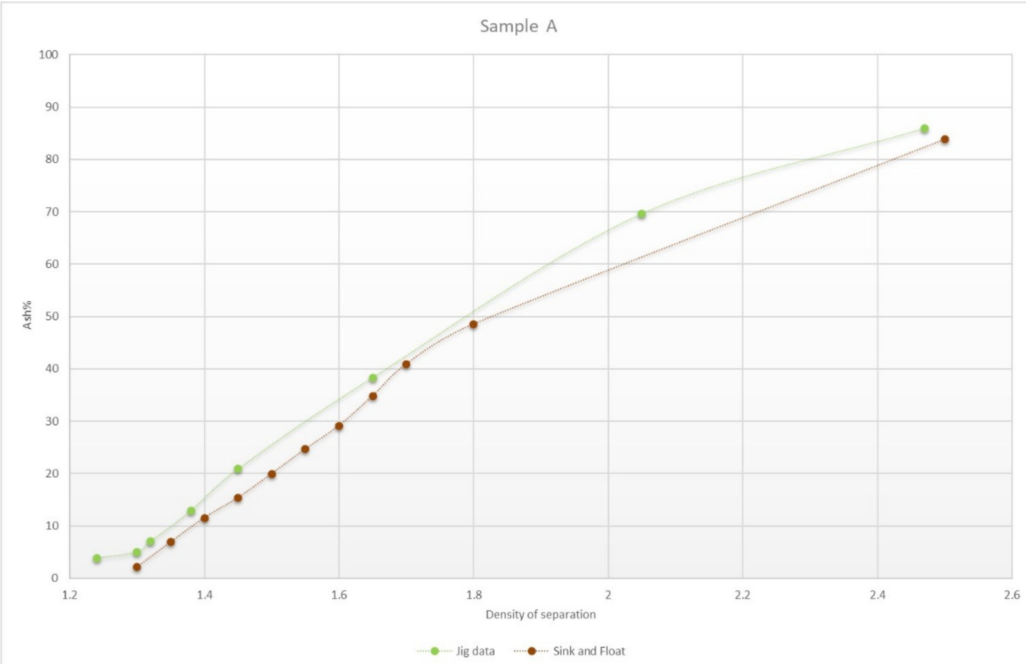

Figure 10b. Density of separation (S.G. and ARD) vs. ash in density fractions for sample A.

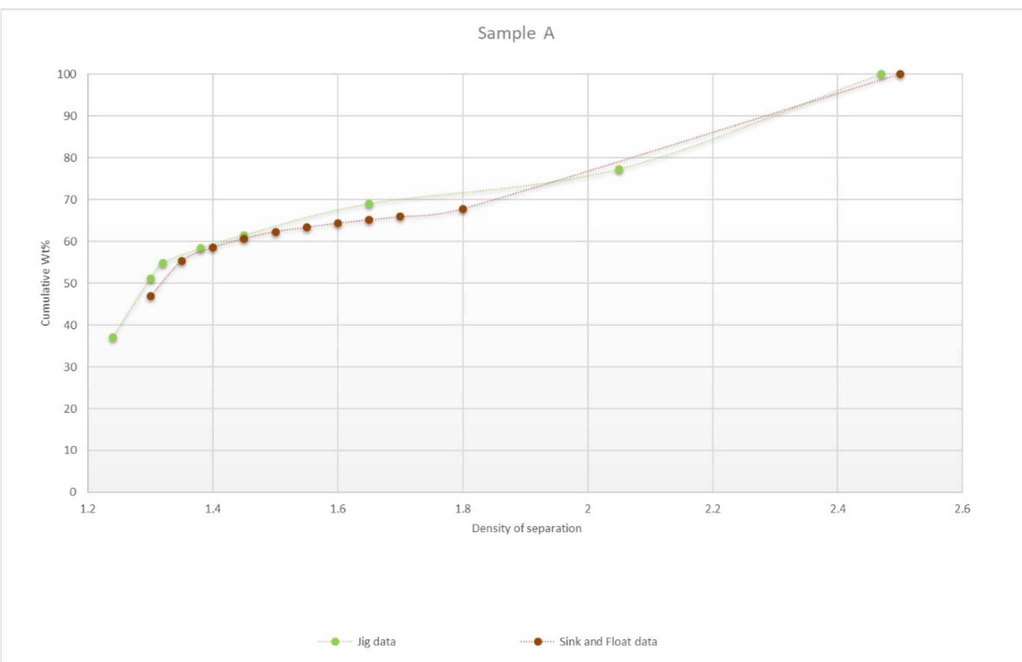

Figure 10c. Density of separation vs. cumulative yield of clean coal for sink and float and jig procedures.

Sample B

It was difficult to obtain lower than 10% ash product using the jig procedure, even though eventually it was possible to obtain a high yield product comparable to that one from sink and float procedure at low density cut (Figure 11a and 11b). Higher yields with higher ash were obtained at the same density cuts (Figure 11b and 11c). Similar as in the sample A greater disparity at below 10% ash. At each density of separation yield higher ash products. This coal seems to be easy to wash (by sink and float), however by comparison to sample A, it provides lower yields at 5 and 10% ash.

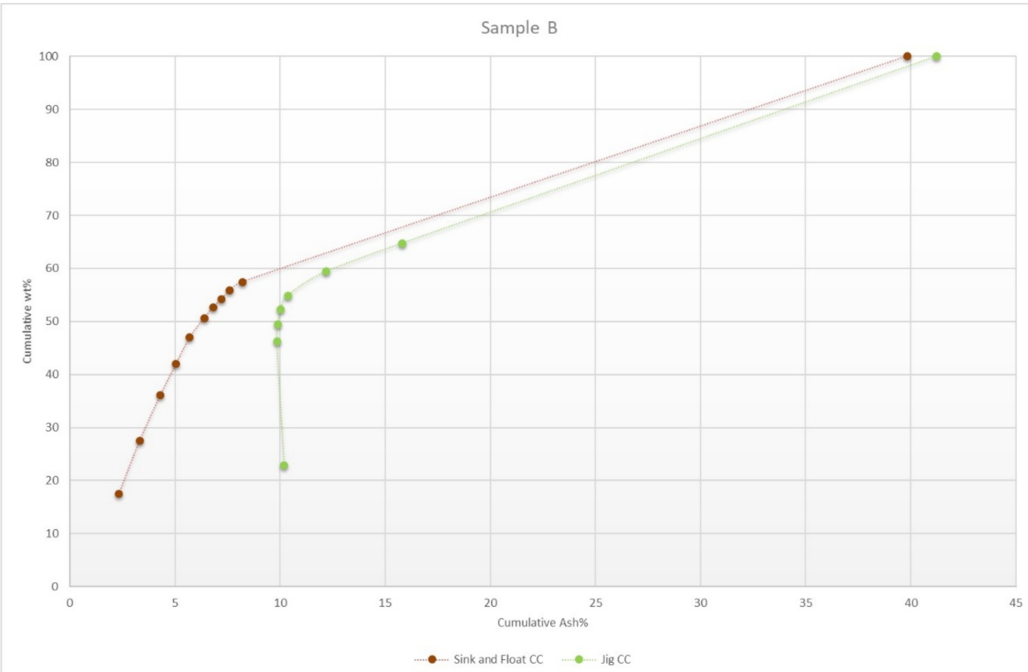

Figure 11a. Clean coal curve for sample B.

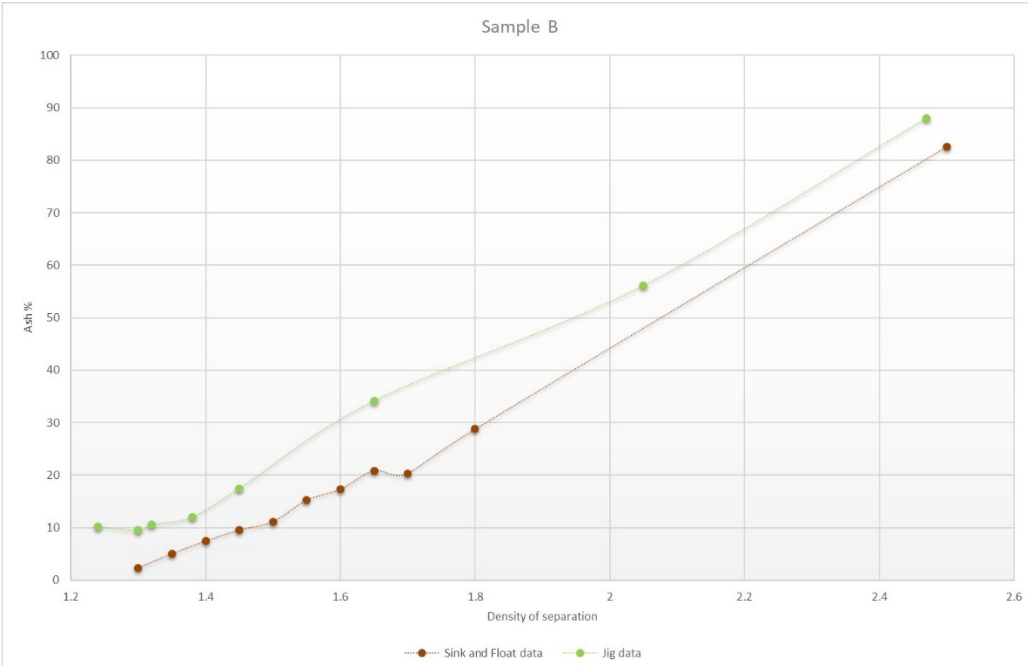

Figure 11b. Density of separation (S.G. and ARD) vs. ash in density fractions for sample B.

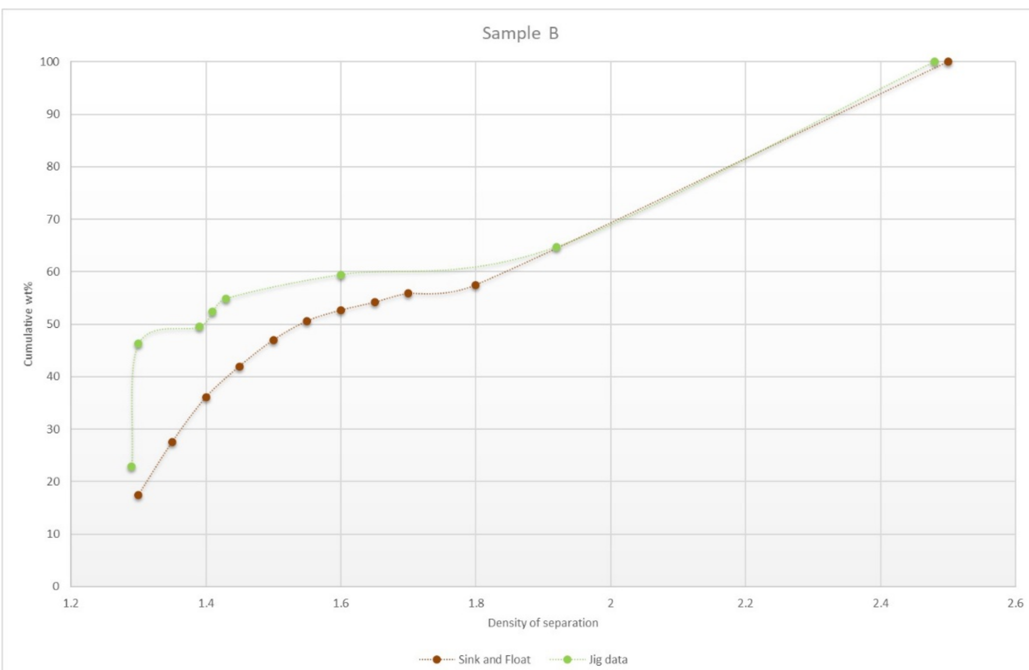

Figure 11c. Density of separation vs. cumulative yield of clean coal for sink and float and jig procedures.

Sample C

Clean coal curves produced from sink and float and jig tests for sample C are compared in Figure 12a. Figure 12b and 12c provide correlations between the density of separation and ash and cumulative yield of clean coal from tests using sink and float and jig procedure.

For this coal while using jig procedure it was not possible to obtain lower that 5% ash content at the same yield of clean coal product as from sink and float. However, similar to A and B, yield of product with 10% ash was comparable to the product obtained from sink and float procedure. Yield of clean coal was higher with higher ash at every density cut. This sample is not easy to wash according to the washability assessment, much lower yields at 5 and 10% ash content, more difficult to wash than A and B samples.

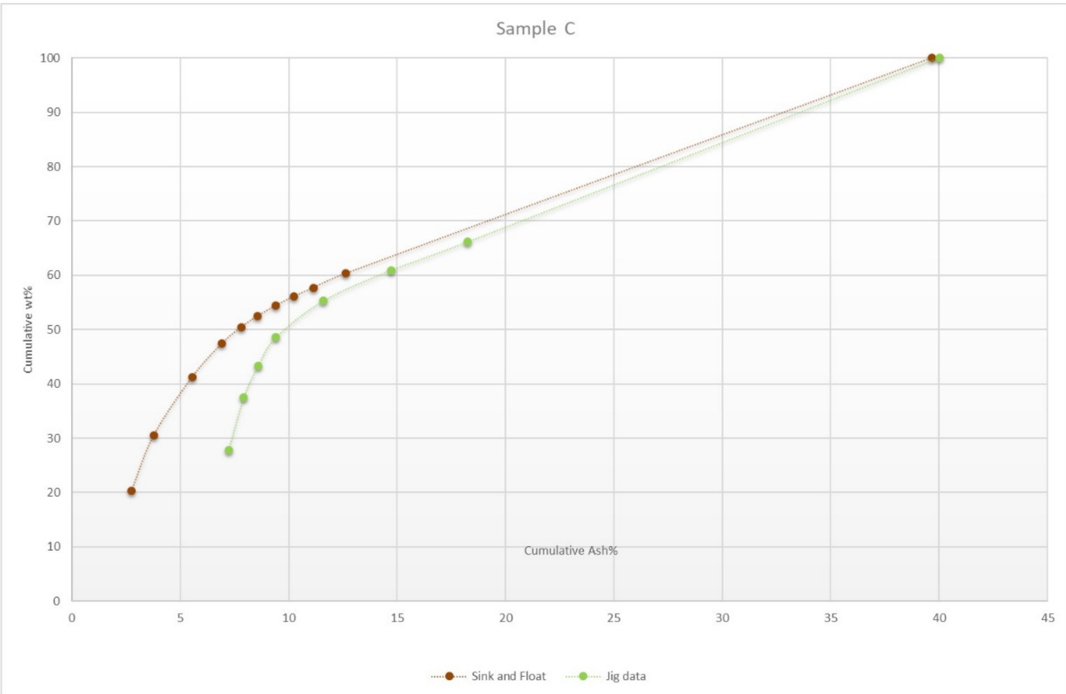

Figure 12a. Clean coal curve for sample C.

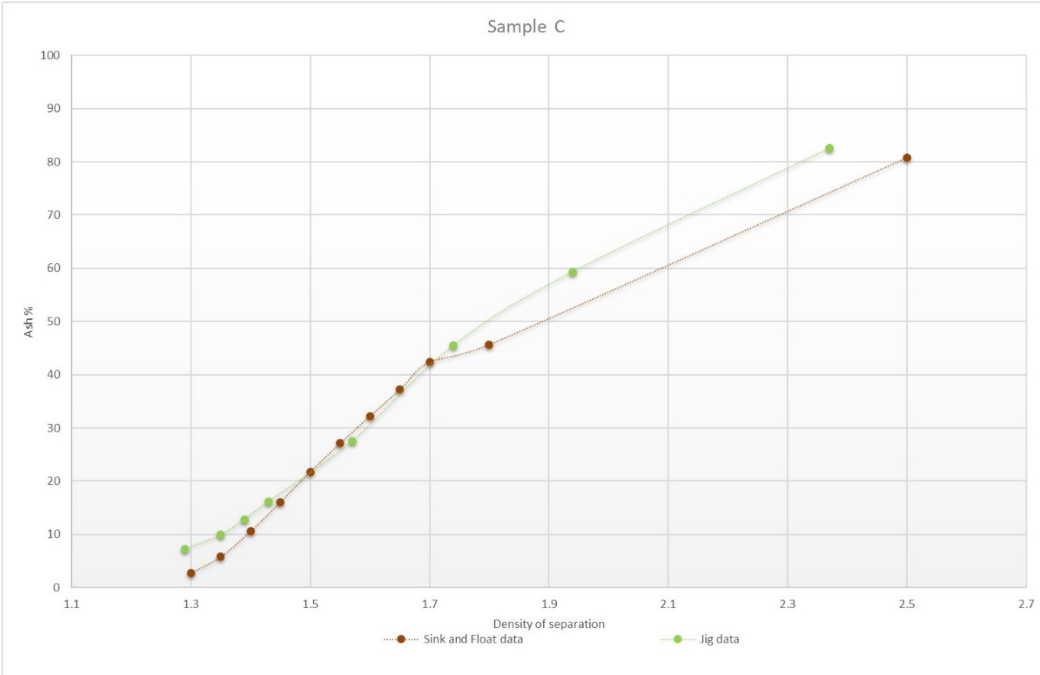

Figure 12b. Density of separation (S.G. and ARD) vs. ash in density fractions for sample C.

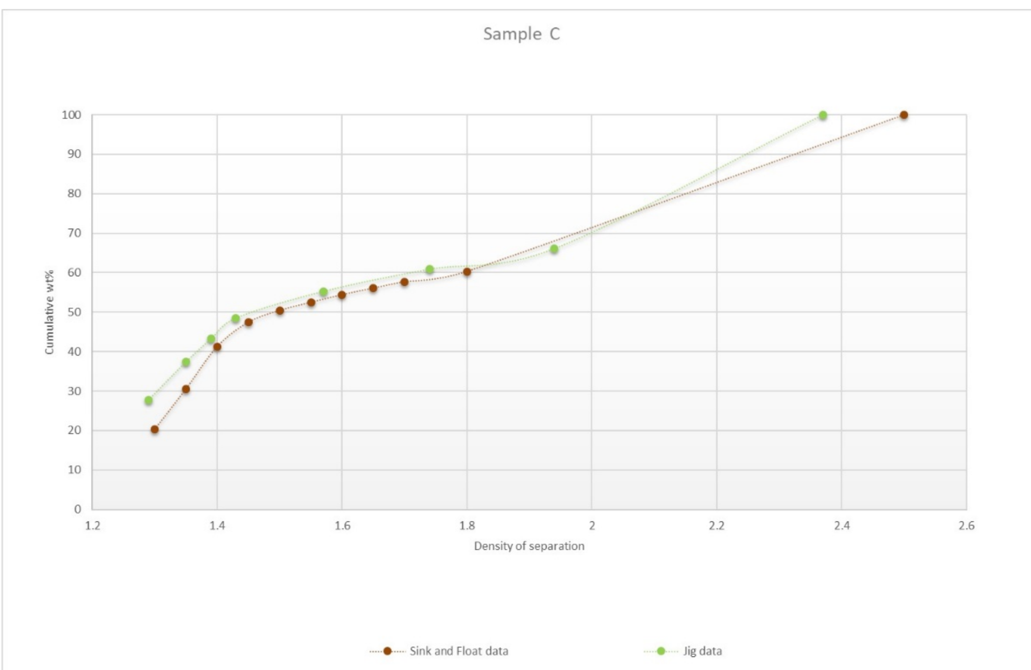

Figure 12c. Density of separation vs. cumulative yield of clean coal for sink and float and jig procedures.

Sample D

Clean coal curves produced from sink and float and jig tests for sample D are compared in Figure 13a. Figure 13b and 13c provide correlations between the density of separation and ash and cumulative yield of clean coal from tests using sink and float and jig procedure.

Sample D exhibited the greatest differences between coal products produced from jig and sink and float procedures even in the range with higher than 10% ash products. It seems that it was not possible to obtain low ash coal with lower than 8.87% ash. This sample seems to be difficult to wash since even sink and float procedure failed to produce high yield of low ash coal.

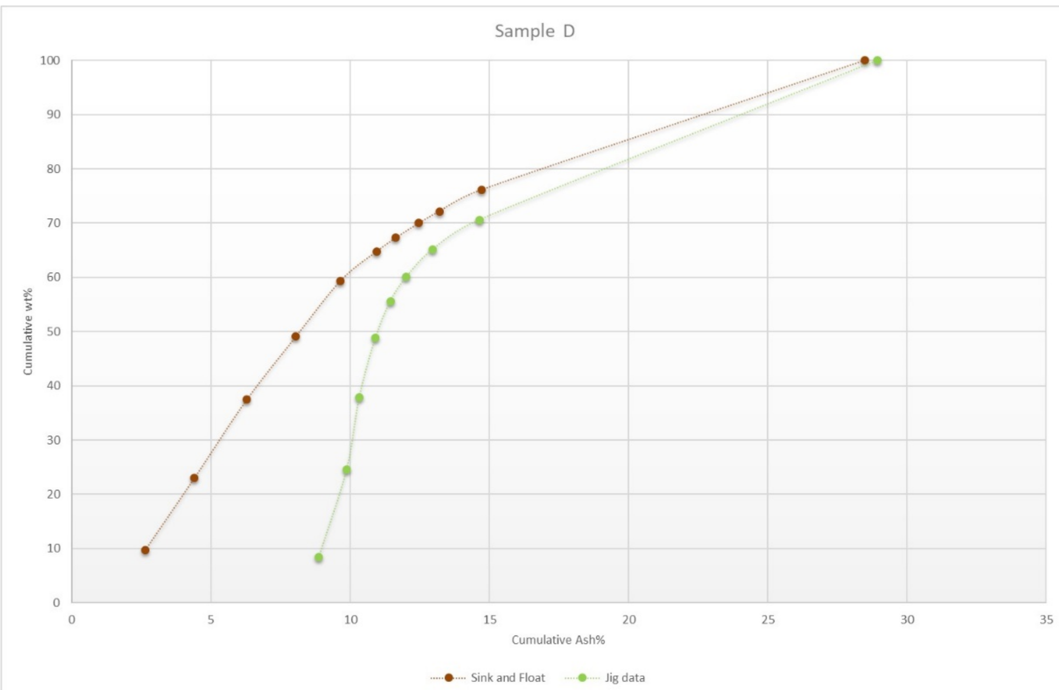

Figure 13a. Clean coal curve for sample D.

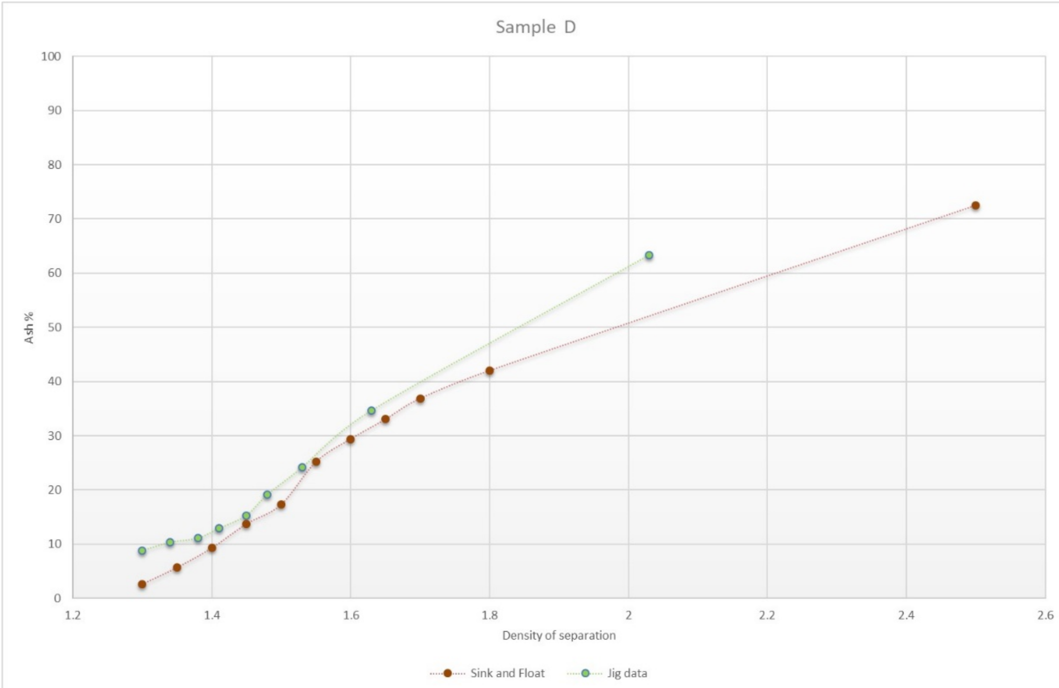

Figure 13b. Density of separation (S.G. and ARD) vs. ash in density fractions for sample D.

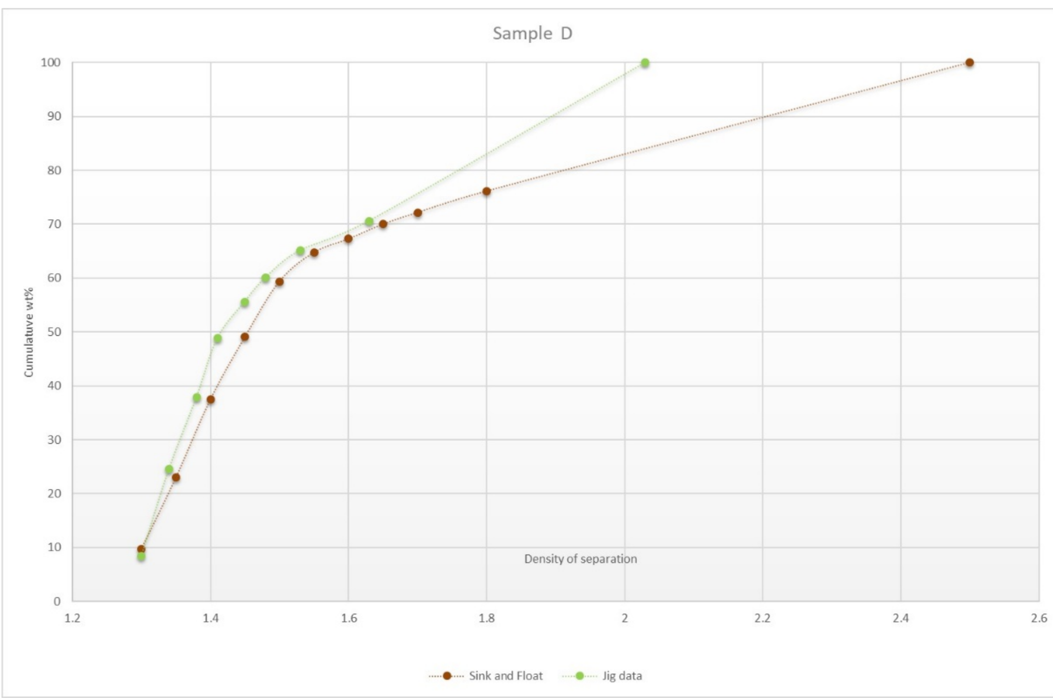

Figure 13c. Density of separation vs. cumulative yield of clean coal for sink and float and jig procedures.

Each of the coal samples tested exhibited different washability characteristics when assessed using standard sink and float procedure. Sample A was the easiest to wash, followed by B and C and sample D was the most difficult to wash.

The float/sink procedure reflects ideal conditions for gravity separation and sample D could be deemed as the most difficult to wash by gravity methods.

The Roben Jig was used in this study to produce a clean coal concentrate comparable in quality to the clean coal concentrate produced during sink and float procedure. While in general it was possible to obtain a clean coal product with 10% ash from A, B and C samples using both methods (sink and float and jig) at similar yields, it was not easy to obtain lower ash products (less than 5% ash) with the jig procedure either not at all or at the comparable yields. Sample D was deemed to be difficult to wash by the classical sink and float procedure and this sample showed the greatest variability between results obtained from the two washing procedures.

Since the jig operation segregates particles by size and density, the stratification of feed containing middling material would pose the greatest challenge for the preparation of a clean coal sample of similar quality by this method. Also, liberated mineral matter could be entrained within the layers of segregated clean coal and increase the ash and yield within each density cut. Even though samples A, B and C had similar patterns for washability as determined by both sink and float, they showed different trends when tested by jig which could indicate that mineral matter characteristics in terms of liberation, clays content and content of fine coal could contribute to these outcomes. This aspect needs to be researched further to delineate the effects of possible clay entrainment and/or misplacement of middlings during the jigging process.

Conclusion

The Canadian Coal Industry needs a reliable method of washing small scale metallurgical coal samples where the exposure of both the coal sample and laboratory technicians to perchloroethylene and other toxic organic liquids can be eliminated. This study evaluated the use of the Roben Jig in satisfying these requirements.

When comparing the clean coal quality characteristics, it is apparent that the Roben Jig was able to clean the coal to create a clean coal sample that was able to offer more realistic values of chlorine, fluidity and dilatation when compared to the float/sink based sample. It is also evident that the exposure of the coal to perchloroethylene (in the float/sink process) caused a decrease in fluidity and dilatation in all four coal samples.

Coke resulting from three of the four coals was evaluated for Coke Strength after Reaction, revealed that the float/sink clean coal gave a slightly better result than the water-based method. It was also found that the washing media (perchloroethylene or water-based) did not influence the development of textures during the coal to coke transformation for Coals A-D. Also, for Coals A-D, coking rank based on carbon forms measured in the cokes are appreciably higher than rank determined from coal petrography indicating that these coals produce stronger carbon forms than expected based on coal petrography v-type measurements.

Because of the jigging action and subsequent known movement of particles there was a possibility that coal particles would be misplaced – fall within a layer of differing specific gravity. Previous work, using "easy to wash" coal showed that the Roben Jig worked well to produce representative clean coal samples. Even though samples A, B and C had similar patterns for washability as determined by both sink and float, they showed different trends when tested by jig which could indicate that mineral matter characteristics in terms of liberation, clays content and content of fine coal could contribute to these outcomes. Since the clean coal quality characteristics were very similar between the samples produced by the two washing methods, it could be suggested that if there is misplaced material, it is not affecting the coal quality significantly. This phase of research involving the Roben Jig is nearing the end, and will be wrapped up by November 2017. More test work needs to be completed in another phase of study in order to identify and characterize any misplaced material that may occur and well as 'fine-tune' the Jig operation methodology.

Acknowledgements

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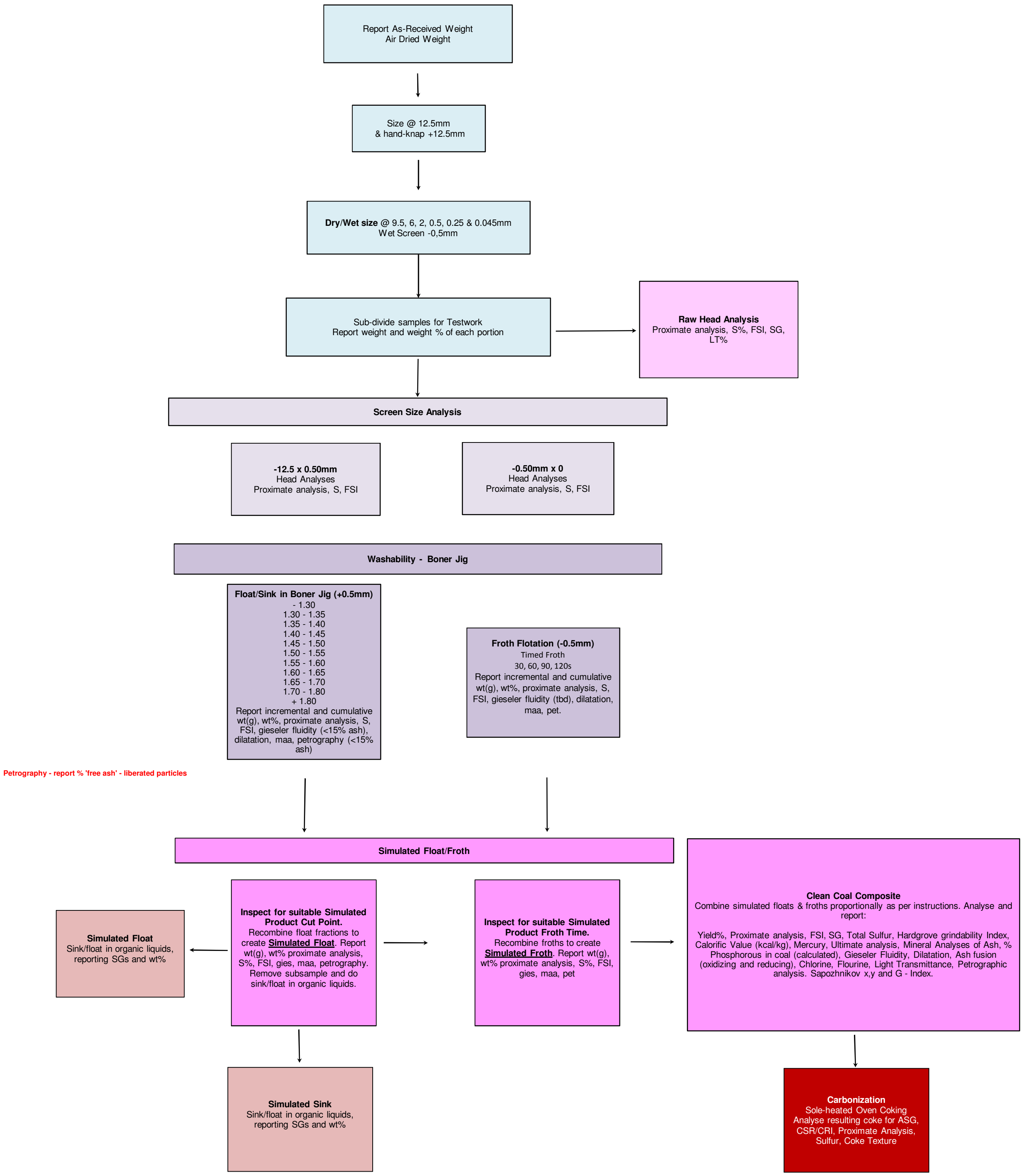
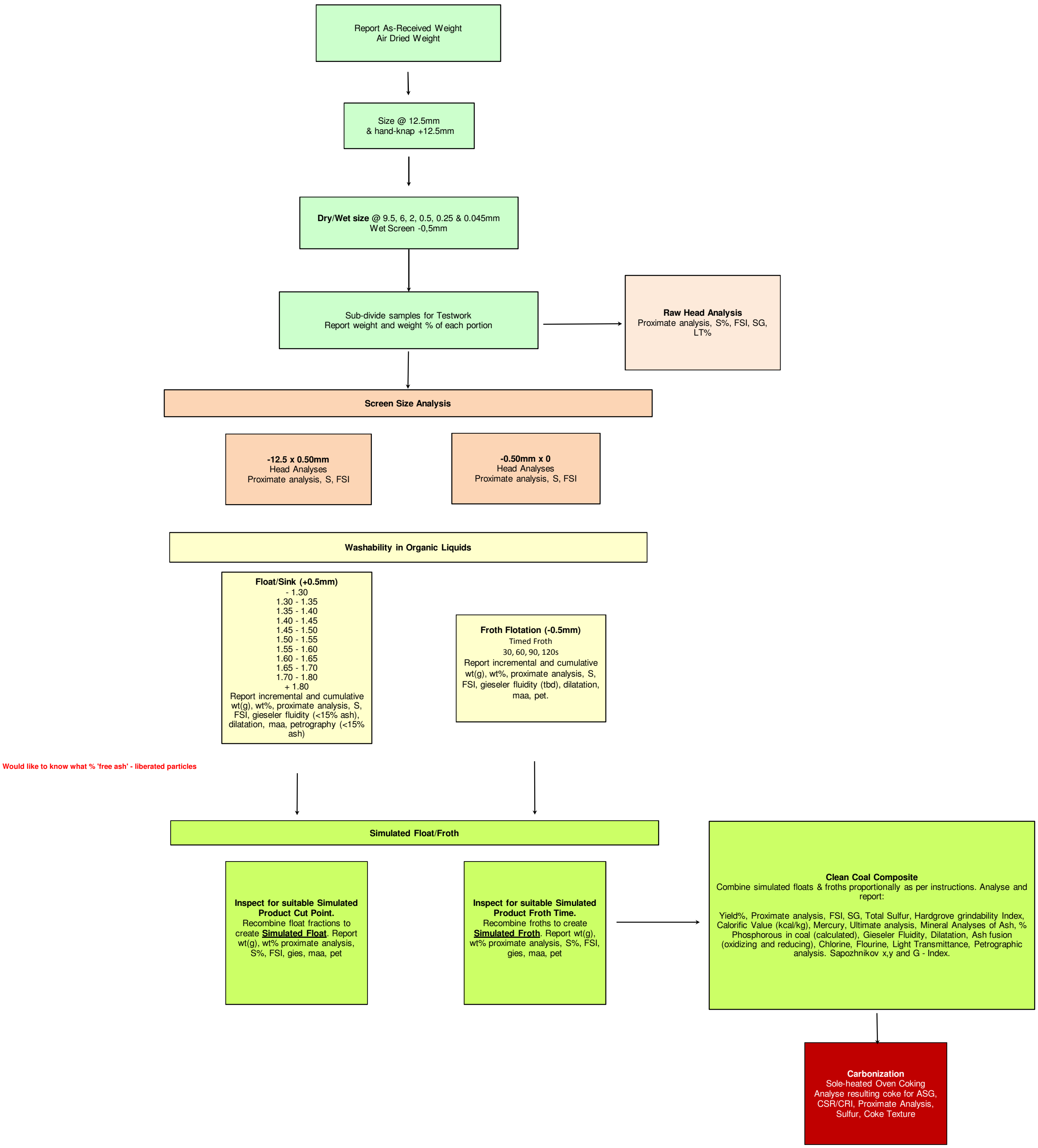
Appendix 1

CCRA Organic Liquids Project Phase 3
Boner Jig Washability Analytical Flowsheet
Flowsheet J1



CCRA Organic Liquids Project Phase 3
Organic Liquids Washability Analytical Flowsheet
Flowsheet OL1



Appendix 2

LABORATORY STANDARDS USED IN ROBEN JIG PROJECT

LABORATORY ANALYSIS	Procedure
APPARENT RELATIVE DENSITY (+2mm)	AS 1038 part 21.2
ASH	ASTM D3174
ASH FUSION ANALYSIS (Ox. and Red.)	ASTM D1857
CALORIFIC VALUE	ASTM D5865
CARBON or HYDROGEN or NITROGEN - COAL	ASTM 5373
CARBON and HYDROGEN and NITROGEN - COAL	ASTM 5373
CHLORINE	ASTM D4208
DILATATION TEST (RUHR-ISO 8264)	ASTM D5515
FLOAT-SINK ANALYSIS (dependent on size fraction and bulk of sample)*	ASTM D4371
FLUORINE	ASTM D3761
FREE SWELLING INDEX	ASTM D720
FROTH FLOTATION (2-Stage Standard Bench Scale Test)	ASTM D5114
GIESELER PLASTOMETER TEST	ASTM D2639
HARDGROVE GRINDABILITY TEST	ASTM D409
LIGHT TRANSMITTANCE FOR OXIDIZED COAL	ASTM D5263
MERCURY	ASTM D6722
MINERAL ANALYSIS OF ASH	ASTM D3682
MINERAL ANALYSIS OF PHOSPHOROUS	ASTM D2795
MOISTURE	
AIR DRIED - ASTM	ASTM D3302
RESIDUAL - ASTM	ASTM D3173
EQUILIBRIUM (INHERENT)	ASTM D1412
PROXIMATE ANALYSIS (Residual Moisture, Ash, Volatile, Fixed Carbon)	ASTM D3172
SCREEN ANALYSIS (dependent on size separation and bulk for sample)	ASTM D4749
SPECIFIC GRAVITY (bottle method)	ISO 1014 (MODIFIED)
SULFUR (Eschka Method)	ASTM D3177
SULFUR (LECO S-632)	ASTM D4239
SULFUR FORMS (includes total, pyritic, sulfate and organic)	ASTM D2492
ULTIMATE ANALYSIS (H2O, C, H, N, S, Ash, O)	ASTM D5373
VOLATILE MATTER	ASTM D3175
MACERAL ANALYSIS	ASTM D2799
VITRINITE REFLECTANCE	ASTM 2798, ISO7404
COKE ASG	CanmetENERGY standard based on ISO1014:1985
CSR/CRI	ASTM D5341-14
PROXIMATE ANALYSIS COKE	ASTMD7582 and ISO562
COKE TEXTURE	CanmetENERGY procedure based on Marsh, Harry; U. Newcastle, UK 1978-1981

Appendix 3

GWIL INDUSTRIES Birtley Coal & Minerals Testing Division

Gwil Industries Inc.
7784 - 62nd St SE
Calgary, AB
T2C 5K2
Tel: (403) 253-8273
Email: info@birtley.ca
www.birtley.ca

SAMPLE A

CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171184

RECEIVED DATE: April 21, 2017

REPORT DATE: May 15, 2017 Final

As Received weight = 148.5 Kg   Coal screened @12.5mm and oversize crushed to pass 12.5mm and homogenized with natural 12.5mmx0

Head Raw Analysis, air dried basis									
ADM%	**MOIST%**	**ASH%**	**VOL%**	**F.C.%**	**S%**	**FSI**	**SG**	**LT%**	BASIS
ASTM D3302	ASTM D3173	ASTM D3174	ASTM D3175		ASTM D4239	ASTM D720	ISO 1014	@ 17mm path ASTM D5263	
5.39	1.19	27.71	26.48	44.62	0.40	7.0	1.51	93.5	adb
	6.52	26.22	25.05	42.21	0.38				arb
		28.04	26.80	45.16	0.40				db

WET SCREEN SIZE ANALYSIS, air dried basis (ASTM D4749)		
SIZE	WT (KG)	WT%
12.5mm X 9.5mm	18.3	13.95
9.5mm X 6.3mm	15.6	11.89
6.3mm X 2mm	29.2	22.26
2mm X 0.6mm	29.8	22.71
0.6mm X 0.25mm	13.7	10.44
0.25mm X 0.45mm	19.4	14.82
0.045mm X 0	5.2	3.93

SCREEN SIZE ANALYSIS, air dried basis								
SIZE	WT%	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	BASIS
12.5mm X 0.25mm	81.25	0.98	31.13	25.18	42.71	0.39	7.0	adb
0.25mm X 0	18.75	0.97	18.77	27.85	52.41	0.49	8.0	adb
CUMULATIVE	100.00	0.98	28.81	25.68	44.53	0.41	7.2	adb

FLOAT SINK ANALYSIS (12.5mmx0.25mm), air dried basis (ASTM D4371)																	
										CUMUALATIVE							
S.G.	WT(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
1.30 FLT	24964	46.91	1.10	2.13	33.77	63.00	0.51	8.5	0.019	46.91	1.10	2.13	33.77	63.00	0.51	8.5	0.019
1.30 - 1.35	4484	8.43	1.24	6.91	29.71	62.14	0.50	7.5	0.135	55.33	1.12	2.86	33.15	62.87	0.51	8.3	0.037
1.35 - 1.40	1732	3.25	1.74	11.56	27.77	58.93	0.50	7.0	0.232	58.58	1.16	3.34	32.85	62.65	0.51	8.3	0.048
1.40 - 1.45	1125	2.11	2.07	15.39	26.36	56.18	0.45	4.0	0.330	60.70	1.19	3.76	32.63	62.42	0.51	8.1	0.058
1.45 - 1.50	881	1.66	2.17	19.98	25.63	52.22	0.46	4.0	0.390	62.35	1.21	4.19	32.44	62.15	0.50	8.0	0.067
1.50 - 1.55	546	1.03	2.54	24.70	24.71	48.05	0.45	4.0	0.442	63.38	1.24	4.52	32.32	61.93	0.50	7.9	0.073
1.55 - 1.60	521	0.98	2.71	29.15	23.22	44.92	0.41	3.5	0.571	64.36	1.26	**4.90**	32.18	61.67	0.50	7.9	0.080
1.60 - 1.65	420	0.79	2.37	34.85	22.10	40.68	0.40	2.0	0.511	65.15	1.27	5.26	32.06	61.41	0.50	7.8	0.085
1.65 - 1.70	419	0.79	1.88	40.93	20.93	36.26	0.41	1.5	0.441	65.94	1.28	5.69	31.92	61.11	0.50	7.7	0.090
1.70 - 1.80	982	1.85	1.66	48.58	20.08	29.68	0.34	1.0	0.401	67.78	1.29	6.85	31.60	60.26	0.50	7.6	0.098
1.80 SINK	17148	32.22	0.94	83.85	10.64	4.57	0.13	0.0	0.102	100.00	1.18	31.66	24.85	42.31	0.38	5.1	0.100

Float Sink mass loss ~100 grams

JIG ANALYSIS (12.5mmx0.25mm), air dried basis																	
										CUMUALATIVE							
ARD *	WT(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
1.24	17082	37.17	1.14	3.87	33.04	61.95	0.53	9.0	0.049	37.17	1.14	3.87	33.04	61.95	0.53	9.0	0.049
1.30	6451	14.04	1.18	5.06	32.57	61.19	0.49	8.0	0.066	51.20	1.15	4.20	32.91	61.74	0.52	8.7	0.053
1.32	1671	3.64	1.00	7.06	31.04	60.90	0.50	8.0	0.106	54.84	1.14	4.39	32.79	61.69	0.52	8.7	0.057
1.38	1625	3.54	0.78	12.92	29.19	57.11	0.48	7.0	0.185	58.38	1.12	**4.90**	32.57	61.41	0.52	8.6	0.065
1.45	1451	3.16	0.84	20.91	26.99	51.26	0.45	7.0	0.199	61.53	1.10	5.72	32.28	60.89	0.51	8.5	0.071
1.65	3439	7.48	0.83	38.33	22.09	38.75	0.38	2.5	0.258	69.02	1.07	9.26	31.18	58.49	0.50	7.8	0.092
2.05	3823	8.32	0.93	69.60	13.40	16.07	0.22	1.0	0.125	77.33	1.06	15.75	29.27	53.93	0.47	7.1	0.095
2.47	10417	22.67	0.96	85.91	9.00	4.13	0.14	0.0	0.120	100.00	1.04	31.65	24.67	42.64	0.39	5.5	0.101

* Apparent Relative Density - this is considered an average of the "slice"

FROTH FLOTATION (0.25mm X 0) (ASTM D5114)																	
										CUMUALATIVE							
TIME	Wt(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
45 SEC	14500	63.40	3.14	9.53	28.60	58.73	0.55	8.5	0.072	63.40	3.14	9.53	28.60	58.73	0.55	8.5	0.072
90 SEC	3160	13.82	1.84	11.19	29.01	57.96	0.56	8.5	0.073	77.21	2.91	**9.83**	28.67	58.59	0.55	8.5	0.072
COMPLETE	872	3.81	1.85	15.43	27.68	55.04	0.54	8.0	0.082	81.02	2.86	10.09	28.63	58.43	0.55	8.5	0.073
TAILS	4340	18.98	1.24	55.54	16.90	26.32	0.33	1.0	0.099	100.00	2.55	18.71	26.40	52.33	0.51	7.1	0.078
PARAMETERS:	10% PULP DENSITY, COND. TIME 1 MINUTE																
	0.667 Kg/T 10:1 Kero:MIBC, DENVER 9L CELL, 1500 RPM																

Yield @1.60 Float & 90 sec froth = 66.77% @5.97% Ash (same ash% if Jig @1.38 ARD used with same proportions)

Heather Dexter
Operations Manager
GWIL Industries

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SAMPLE A

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CLIENT: **Canadian Carbonization Research Association**

LAB#: 171184

RECEIVED DATE: April 21, 2017

REPORT DATE: May 15, 2017 Final

GIESELER FLUIDITY TEST (ASTM D2639)							
	TEMPERATURES °C						Date Tested
SAMPLE ID	INITIAL SOFT (1 DDPM)	MAX. FLUIDITY	SOLIDIFI- CATION	RANGE	MAX. DDPM		
1.30 FLT	398	439	484	86	**7262**		May 1
1.30 - 1.35	410	451	485	75	**619**		May 1
1.35 - 1.40	412	451	481	69	**579**		May 1
1.40 - 1.45	417	452	478	61	**96**		May 1
1.24 ARD	405	454	488	83	**4061**		May 2
1.30 ARD	403	439	476	73	**2873**		May 2
1.32 ARD	415	452	489	74	**1775**		May 2
1.38 ARD	409	448	484	75	**1243**		May 3
45 sec	412	453	489	77	**921**	*	May 4
90 sec	417	455	491	74	**794**	*	May 4
comp	418	450	482	64	**468**	*	May 4

***finer size consist than the ASTM 2639 procedure requires**

RHUR DILATATION (ASTM D5515)								
SAMPLE ID	SOFT TEMP	TMCONT	TMDIL.	%CONT.	%DIL	% TOTAL DIL	**%SD 2.5**	Date Tested
1.30 FLT	370	425	466	25	170	195	**182**	May 1
1.30 - 1.35	376	442	469	21	28	49	**35**	May 1
1.35 - 1.40	375	436	463	22	12	34	**12**	May 1
1.40 - 1.45	379	451	466	21	-18	3	**-2**	May 1
1.24 ARD	379	432	472	22	160	182	**181**	May 2
1.30 ARD	372	430	469	24	141	165	**158**	May 2
1.32 ARD	377	432	466	23	102	125	**105**	May 2
1.38 ARD	377	434	468	24	67	91	**71**	May 2
45 sec	376	430	466	25	135	160	**140**	May 4
90 sec	376	430	464	25	112	137	**111**	May 4
comp	376	436	468	21	64	85	**60**	May 4

MINERAL ANALYSIS OF ASH (ASTM D3682)													
SAMPLE ID	SiO_2	Al_2O_3	TiO_2	CaO	BaO	SrO	Fe_2O_3	MgO	Na_2O	K_20	P_20_5	SO_3	Undet.
1.30 FLT	49.33	29.67	2.22	3.27	0.59	0.32	9.77	0.65	0.12	0.43	2.09	1.32	0.22
1.30 - 1.35	46.97	31.95	1.24	3.69	1.12	0.66	7.74	0.58	0.08	0.40	4.49	0.95	0.13
1.35 - 1.40	46.76	31.61	1.08	3.93	0.92	0.62	7.35	0.58	0.08	0.54	4.60	0.92	1.01
1.40 - 1.45	48.68	29.61	0.99	4.74	0.87	0.51	6.08	0.58	0.08	0.66	4.92	0.95	1.33
1.45 - 1.50	52.64	26.70	0.97	4.45	0.71	0.38	5.66	0.60	0.08	0.81	4.47	0.82	1.71
1.50 - 1.55	55.02	24.58	0.93	4.42	0.61	0.36	5.98	0.63	0.07	0.95	4.10	0.82	1.53
1.55 - 1.60	56.71	23.17	0.96	4.87	0.59	0.30	4.73	0.61	0.08	1.11	4.49	0.80	1.58
1.60 - 1.65	59.59	22.47	1.00	4.11	0.51	0.25	4.53	0.68	0.08	1.41	3.36	0.70	1.31
1.65 - 1.70	62.67	22.03	0.96	3.39	0.48	0.15	3.35	0.66	0.18	1.69	2.47	0.27	1.70
1.70 - 1.80	63.96	20.11	0.97	2.83	0.42	0.10	5.79	0.83	0.09	1.83	1.89	0.50	0.68
1.80 SNK	69.86	17.93	0.78	1.67	0.29	0.05	3.43	1.09	0.11	2.88	0.28	0.40	1.23
1.24 ARD	55.08	24.53	1.64	3.06	0.63	0.42	6.79	0.68	0.09	0.87	2.88	1.12	2.21
1.30 ARD	54.33	26.61	1.20	3.30	0.67	0.40	6.96	0.60	0.08	0.64	2.97	1.40	0.84
1.32 ARD	57.28	25.57	1.04	3.53	0.68	0.38	5.86	0.61	0.04	0.88	3.44	0.97	-0.28
1.38 ARD	57.82	23.11	0.95	3.76	0.54	0.32	5.45	0.70	0.08	1.41	3.28	0.75	1.83
1.45 ARD	60.90	22.09	0.89	2.64	0.46	0.20	5.18	0.80	0.05	1.78	2.18	0.77	2.06
1.65 ARD	65.39	20.48	0.80	2.48	0.38	0.15	4.46	0.88	0.07	2.39	1.54	0.60	0.38
2.05 ARD	68.92	18.95	0.78	1.01	0.31	0.04	3.29	0.96	0.05	2.78	0.41	0.50	2.00
2.47 ARD	70.50	16.57	0.68	2.66	0.26	0.03	4.12	1.19	0.15	2.89	0.32	0.32	0.31
45 sec	61.09	22.83	1.66	1.83	0.54	0.27	4.45	0.80	0.11	2.23	1.74	0.72	1.73
90 sec	63.53	22.66	1.65	1.37	0.52	0.24	2.90	0.75	0.12	2.37	1.49	0.75	1.65
comp	66.12	22.26	1.55	1.33	0.51	0.18	2.40	0.83	0.11	2.43	1.22	0.87	0.19
Tails	70.03	19.23	1.09	0.98	0.28	0.05	2.20	0.91	0.11	2.66	0.41	0.70	1.35

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Operations Manager
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SAMPLE A

CERTIFICATE OF ANALYSIS

CLIENT: Canadian Carbonization Research Association

LAB#: 171184

RECEIVED DATE: April 21, 2017

REPORT DATE: May 15, 2017 Final

Roben JIG REPORT

Lab Ref No: CCRA 171184 - JIG

Description: crushed 12.5mm x 0.25mm

RAW ash = 27.71% (adb)

12.5x0.25mm = 31.13% Ash (adb)

Roben Jig 3 batches of 15.5 Kg	ARD mesh vessel DRY tare	ARD mesh vessel WET tare	Assumed Damp Moisture %					
	0	306	5					
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %
		May 1/17						
		FSI						
1	lid +5 x 3	0.0	10417	2.47	85.91	22.67	100.00	31.64
2	4 x 3	1.0	3823	2.05	69.60	8.32	77.33	15.73
3	3,5,4	2.5	3439	1.65	38.33	7.48	69.02	9.24
4	2,2,2	7.0	1451	1.45	20.91	3.16	61.53	5.71
5	2,3,2	7.0	1625	1.38	12.92	3.54	58.38	4.88
6	2,3,3	8.0	1671	1.32	7.06	3.64	54.84	4.37
7	2,2,3	8.0	1499	1.31	5.45	3.26	51.20	4.17
8	3,3,3	8.0	1909	1.30	5.00	4.15	47.94	4.09
9	5,5,5	8.0	3043	1.29	4.56	6.62	43.79	4.00
10	7,7,7	8.0	4174	1.27	3.90	9.08	37.17	3.90
11	12,12,10	9.0	6534	1.25	3.57	14.22	28.09	3.90
12	8,8,10	8.5	6374	1.22	4.24	13.87	13.87	4.24
			45959.0					

Tube #	1	Ash%
starting weight =	46562	
fraction weight =	45959	
Jig Slurry wt =	247.7	50.96
ARD slurry wt =	234.0	14.49
Total End Weight =	46441	

Fine Losses = 121
(Jig Slurry likely)

cumulative Ash% = 31.66

*Apparent Relative Density - this is considered an average of the "slice" taken

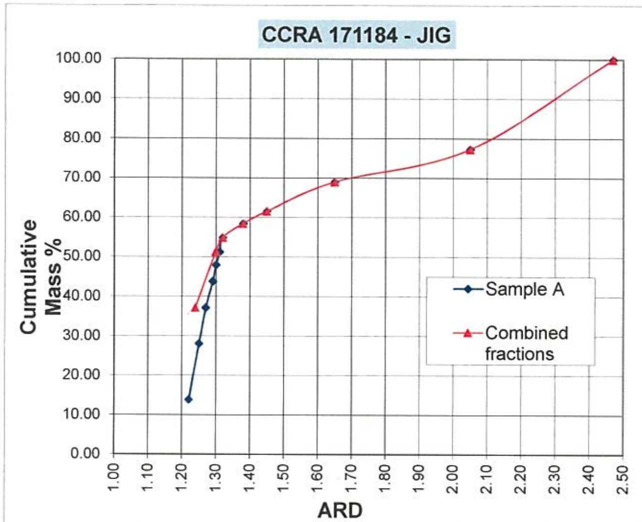
Combining some jig fractions according to ARD & Ash%

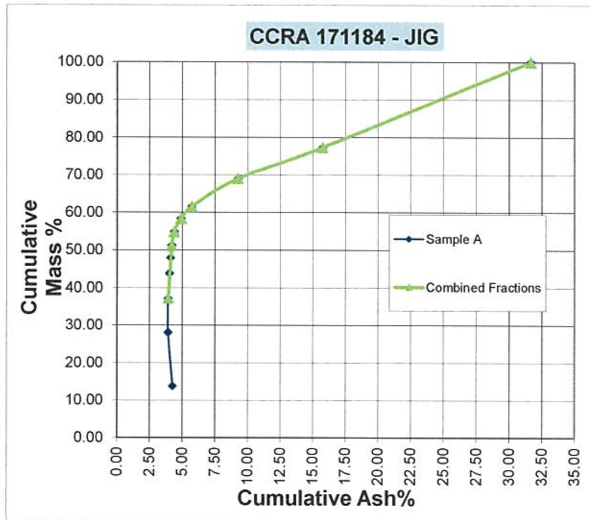
Roben Jig 3 batches of 15.5 Kg	ARD mesh vessel DRY tare	ARD mesh vessel WET tare	Assumed Damp Moisture %						
	0	306	5						
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %	
1		8	10417	2.47	85.91	22.67	100.00	31.64	
2		7	3823	2.05	69.60	8.32	77.33	15.74	
3		6	3439	1.65	38.33	7.48	69.02	9.24	
4		5	1451	1.45	20.91	3.16	61.53	5.71	
5		4	1625	1.38	12.92	3.54	58.38	4.88	cutpoint
6		3	1671	1.32	7.06	3.64	54.84	4.37	
7-9		2	6451	1.30	4.90	14.04	51.20	4.17	
10-12		1	17082	1.24	3.90	37.17	37.17	3.90	
			45959.0						

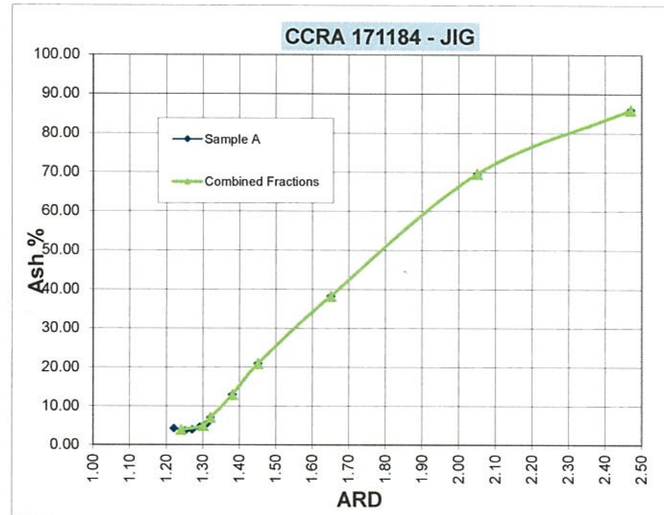
Heather Dexter
Operations Manager
GWIL Industries

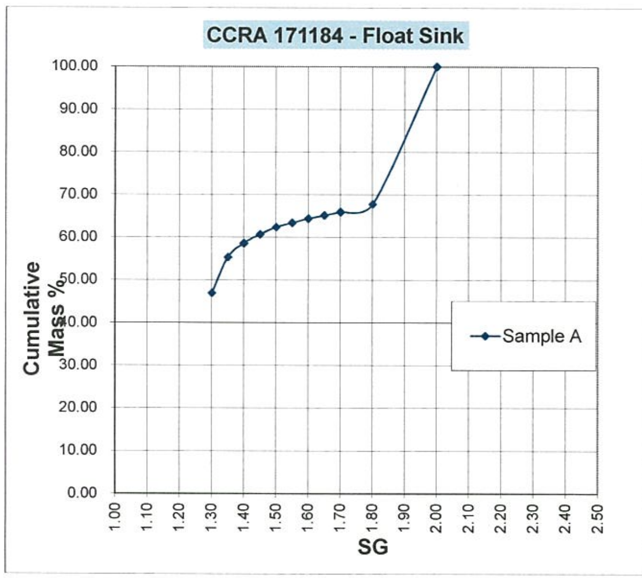
Canadian Carbonization Research Association

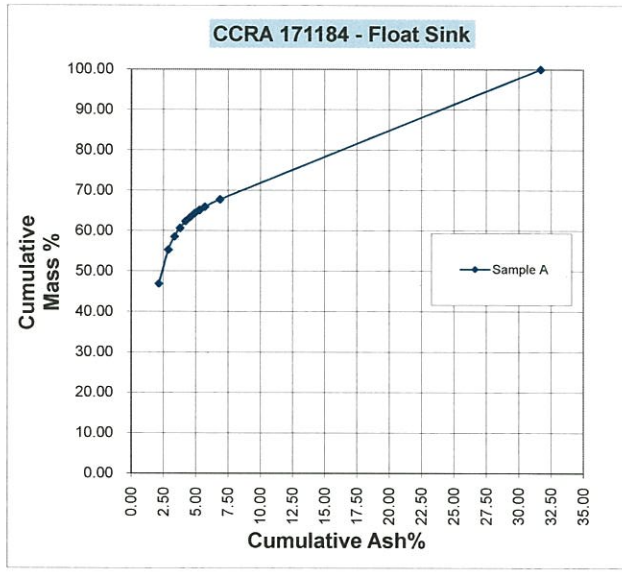
SAMPLE A

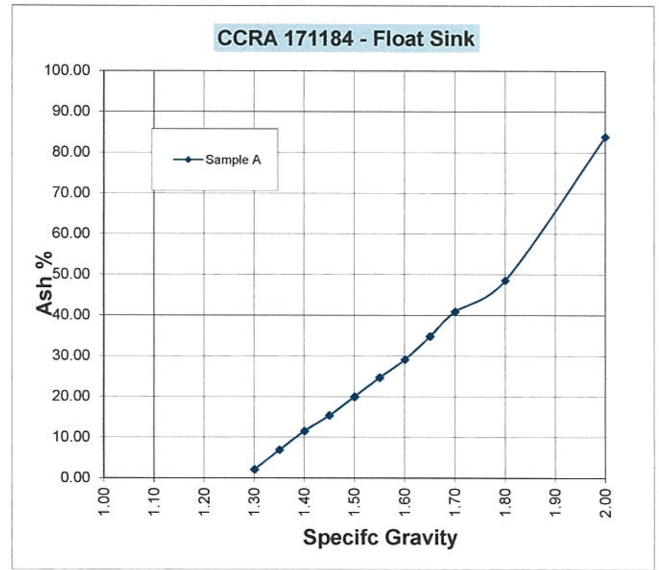












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Simulated Clean Analysis, air dried basis														
ID	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	Cal/g	Cl ppm	F ppm	Hg ppb	HGI	SG	%LT	BASIS
ASTM #	ASTM D3173	ASTM D3174	ASTM D3175		ASTM D4239	ASTM D720	ASTM D5865	ASTM D4208	ASTM D3761	ASTM D6722	ASTM D409	ISO 1014	@ 17mm path ASTM D5263	
SIM FS @1.60 SG	1.07	4.91	32.03	61.99	0.53	8.5	-	-	-	-	-	-	-	adb
		4.96	32.38	62.66	0.54									db
SIM JIG @1.38 ARD	0.94	4.91	32.21	61.94	0.49	8.5	-	-	-	-	-	-	-	adb
		4.96	32.52	62.53	0.49									db
SIM Froth @90 sec	1.22	9.43	30.29	59.06	0.49	8.0	-	-	-	-	-	-	-	adb
		9.55	30.66	59.79	0.50									db
FS CCC	0.99	5.74	31.76	61.51	0.46	8.5	7955	3906	224	32	87	1.30	92.5	adb
		5.80	32.08	62.13	0.46		8035	3945	226	32				db
JIG CCC	0.97	5.88	31.95	61.20	0.51	8.5	7971	271	225	24	82	1.31	91.7	adb
		5.94	32.26	61.80	0.51		8049	274	227	24				db

ULTIMATE ANALYSIS, as received basis (ASTM D5373)									
ID	%MOIST.	%C	%H	%N	%S	%ASH	%O b/d	%P in coal db	BASIS
FS CCC	0.99	79.74	5.03	1.59	0.46	5.74	6.45	0.075	arb
		80.54	5.08	1.61	0.46	5.80	6.51		db
JIG CCC	0.97	79.87	5.04	1.61	0.51	5.88	6.12	0.065	arb
		80.65	5.09	1.63	0.51	5.94	6.18		db

GIESELER FLUIDITY TEST (ASTM D2639)						
	TEMPERATURES °C					
SAMPLE ID	INITIAL SOFT (1 DDPM)	MAX. FLUIDITY	SOLIDIFI- CATION	RANGE	MAX. DDPM	Date Tested
Sim FS	396	436	472	76	**1998**	May 8
Sim Jig	400	438	474	74	**3132**	May 9
Sim Froth	400	443	479	79	**826**	May 9
FS CCC	405	441	473	68	**1647**	May 10
Jig CCC	404	442	479	75	**1972**	May 10

RHUR DILATATION (ASTM D5515)								
SAMPLE ID	SOFT TEMP	TMCONT	TMDIL.	%CONT.	%DIL	% TOTAL DIL	%SD 2.5	Date Tested
FS CCC	376	435	465	24	111	135	**120**	May 10
Jig CCC	373	428	466	27	139	166	**154**	May 10

MINERAL ANALYSIS OF ASH (ASTM D3682)												
SAMPLE ID	SiO_2	Al_2O_3	TiO_2	CaO	BaO	SrO	Fe_2O_3	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
Sim FS	51.89	26.21	1.39	4.18	0.35	0.51	7.85	0.60	0.13	0.58	4.09	0.95	1.27
Sim Jig	57.05	25.26	1.45	2.97	0.26	0.42	7.41	0.68	0.07	0.87	2.93	0.97	-0.34
Sim Froth	62.67	23.30	1.45	1.57	0.39	0.28	4.13	0.83	0.08	2.17	1.73	0.67	0.73
FS CCC	56.34	25.19	1.46	2.95	0.49	0.41	6.41	0.70	0.12	1.26	2.96	0.97	0.74
Jig CCC	56.56	24.55	1.44	2.45	0.57	0.37	5.98	0.73	0.09	1.30	2.52	1.15	2.29

	ASH FUSION TEMPERATURES (°C) (ASTM D1857)							
	REDUCING				OXIDIZING			
SAMPLE ID	IDT	ST	HT	FT	IDT	ST	HT	FT
FS CCC	1269	1373	1411	1457	1320	1421	1439	1473
Jig CCC	1301	1375	1420	1467	1316	1423	1452	1479

FS CCC & Jig CCC sent to SGS-Tianjin May 12, 2017 & CANMET May 10, 2017

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SAMPLE B

CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171316

RECEIVED DATE: May 8, 2017

REPORT DATE: May 26, 2017 Final

As Received weight = 209.2 Kg   Coal screened @12.5mm and oversize crushed to pass 12.5mm and homogenized with natural 12.5mmx0

Head Raw Analysis, air dried basis

ADM%	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	SG	LT%	BASIS
ASTM D3302	ASTM D3173	ASTM D3174	ASTM D3175		ASTM D4239	ASTM D720	ISO 1014	@ 17mm path ASTM D5263	
5.26	0.81	34.33	18.39	46.47	0.30	5.5	1.58	93.8	adb
	6.03	32.52	17.42	44.03	0.28				arb
		34.61	18.54	46.85	0.30				db

WET SCREEN SIZE ANALYSIS, air dried basis (ASTM D4749)

SIZE	WT (KG)	WT%
12.5mm X 9.5mm	14.1	7.11
9.5mm X 6.3mm	15.5	7.82
6.3mm X 2mm	46.5	23.46
2mm X 0.6mm	43.6	22.00
0.6mm X 0.25mm	22.1	11.15
0.25mm X 0.45mm	40.9	20.62
0.045mm X 0	15.5	7.84

SCREEN SIZE ANALYSIS, air dried basis

SIZE	WT%	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	BASIS
12.5mm X 0.25mm	71.54	0.81	39.59	16.98	42.62	0.28	4.0	adb
0.25mm X 0	28.46	0.73	17.02	22.27	59.98	0.37	6.0	adb
CUMULATIVE	100.00	0.79	33.17	18.49	47.56	0.31	4.6	adb

FLOAT SINK ANALYSIS (12.5mmx0.25mm), air dried basis (ASTM D4371)

										CUMUALATIVE							
S.G.	WT(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
1.30 FLT	12606	17.43	1.75	2.33	26.09	69.83	0.48	+9	0.021	17.43	1.75	2.33	26.09	69.83	0.48	+9	0.021
1.30 - 1.35	7304	10.10	2.84	5.06	23.85	68.25	0.41	7.8	0.046	27.53	2.15	3.33	25.27	69.25	0.45	8.5	0.030
1.35 - 1.40	6162	8.52	2.24	7.46	22.42	67.88	0.37	3.0	0.049	36.05	2.17	4.31	24.60	68.93	0.43	7.2	0.035
1.40 - 1.45	4290	5.93	2.69	9.59	21.34	66.38	0.35	1.5	0.049	41.98	2.24	5.05	24.14	68.57	0.42	6.4	0.037
1.45 - 1.50	3605	4.98	3.84	11.17	20.33	64.66	0.32	1.0	0.050	46.97	2.41	5.70	23.73	68.15	0.41	5.8	0.038
1.50 - 1.55	2622	3.63	3.98	15.25	20.24	60.53	0.31	1.0	0.083	50.59	2.53	6.39	23.48	67.61	0.40	5.5	0.041
1.55 - 1.60	1494	2.07	3.73	17.33	20.33	58.61	0.30	1.0	0.109	52.66	2.57	6.82	23.36	67.25	0.40	5.3	0.044
1.60 - 1.65	1083	1.50	3.59	20.88	19.53	56.00	0.30	1.0	0.142	54.15	2.60	**7.21**	23.25	66.94	0.40	5.2	0.047
1.65 - 1.70	1229	1.70	4.25	20.34	19.70	55.71	0.31	1.0	0.130	55.85	2.65	7.60	23.14	66.60	0.39	5.1	0.049
1.70 - 1.80	1168	1.61	3.73	28.80	18.24	49.23	0.29	1.0	0.200	57.47	2.68	8.20	23.01	66.11	0.39	5.0	0.054
1.80 SNK	30761	42.53	1.46	82.62	7.51	8.41	0.11	0.0	0.155	100.00	2.16	39.85	16.42	41.57	0.27	2.9	0.097
	72324	**70900**	**1424**	**gained mass (fractions were twice dried) - took 3 times as long to float sink as normal (excessive fines)**													

JIG ANALYSIS (12.5mmx0.25mm), air dried basis

										CUMUALATIVE							
ARD *	WT(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
1.29	10484	22.92	0.49	10.20	23.78	65.53	0.43	8.0	0.040	22.92	0.49	10.20	23.78	65.53	0.43	8.0	0.040
1.30	10680	23.35	0.66	9.53	24.04	65.77	0.41	7.5	0.049	46.27	0.58	9.86	23.91	65.65	0.42	7.7	0.044
1.39	1476	3.23	0.50	10.56	23.09	65.85	0.40	8.0	0.066	49.50	0.57	9.91	23.86	65.66	0.42	7.8	0.046
1.41	1301	2.84	0.53	12.04	23.11	64.32	0.39	8.0	0.077	52.34	0.57	**10.02**	23.82	65.59	0.42	7.8	0.048
1.43	1176	2.57	0.42	17.49	21.37	60.72	0.39	6.0	0.094	54.91	0.56	10.37	23.70	65.36	0.42	7.7	0.050
1.60	2077	4.54	0.54	34.19	17.62	47.65	0.32	2.0	0.158	59.45	0.56	12.19	23.24	64.01	0.41	7.3	0.058
1.92	2427	5.31	0.68	56.17	12.99	30.16	0.25	1.0	0.167	64.76	0.57	15.80	22.40	61.24	0.40	6.7	0.067
2.48	16120	35.24	0.89	88.00	6.85	4.26	0.11	0.0	0.127	100.00	0.68	41.24	16.92	41.16	0.29	4.4	0.088

* Apparent Relative Density - this is considered an average of the "slice"

FROTH FLOTATION (0.25mm X 0) (ASTM D5114)

										CUMUALATIVE							
TIME	Wt(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
30 SEC	12182	51.13	0.42	10.64	23.71	65.23	0.40	7.0	0.033	51.13	0.42	10.64	23.71	65.23	0.40	7.0	0.033
90 SEC	7551	31.69	0.36	11.65	23.38	64.61	0.40	6.5	0.032	82.82	0.40	**11.03**	23.58	64.99	0.40	6.8	0.032
COMPLETE	1293	5.43	0.34	13.67	22.22	63.77	0.40	5.5	0.035	88.25	0.39	11.19	23.50	64.92	0.40	6.7	0.032
TAILS	2800	11.75	0.53	57.82	14.14	27.51	0.25	1.0	0.126	100.00	0.41	16.67	22.40	60.52	0.38	6.1	0.043
PARAMETERS:	10% PULP DENSITY, COND. TIME 1 MINUTE 0.667 Kg/T 10:1 Kero:MIBC, DENVER 9L CELL, 1500 RPM																

Yield @1.65 Float & 90 sec froth = 62.31% @8.65% Ash (@1.41 ARD used with same proportions = 10.45% Ash)

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CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171316

RECEIVED DATE: May 8, 2017

REPORT DATE: May 26, 2017 Final

GIESELER FLUIDITY TEST (ASTM D2639)

SAMPLE ID	INITIAL SOFT (1 DDPM)	MAX. FLUIDITY	SOLIDIFI-CATION	RANGE	MAX. DDPM		Date Tested
	TEMPERATURES °C						
1.30 FLT	411	456	483	72	**1161**		May 16
1.30 - 1.35	420	454	485	65	**54**		May 17
1.35 - 1.40	442	454	481	39	**1.2**		May 17
1.40 - 1.45	not applicable as 1.35-1.40 very low						N/A
1.29 ARD	426	463	497	71	**296**		May 17
1.30 ARD	425	462	499	74	**427**		May 16
1.39 ARD	430	470	492	62	**322**		May 17
1.41 ARD	430	464	493	63	**153**		May 17
30 sec	430	468	502	72	**197**	*	May 18
90 sec	426	463	494	68	**110**	*	May 18
comp	434	461	492	58	**25**	*	May 17

***finer size consist than the ASTM 2639 procedure requires**

RHUR DILATATION (ASTM D5515)

SAMPLE ID	SOFT TEMP	TMCONT	TMDIL.	%CONT.	%DIL	% TOTAL DIL	%SD 2.5	Date Tested
1.30 FLT	385	423	464	22	178	200	**186**	May 16
1.30 - 1.35	394	450	472	20	0	20	**2**	May 17
1.35 - 1.40	403	490	-	23	-	-	**-**	May 17
1.40 - 1.45	not applicable as 1.35-1.40 very low							N/A
1.29 ARD	376	444	473	25	28	53	**31**	May 17
1.30 ARD	397	451	481	29	39	68	**36**	May 16
1.39 ARD	385	453	476	23	20	43	**19**	May 17
1.41 ARD	385	456	476	23	-3	20	**-1**	May 17
30 sec	372	418	448	18	28	46	**29**	May 18
90 sec	390	436	448	17	15	32	**12**	May 18
comp	395	462	476	15	-10	5	**-16**	May 17

MINERAL ANALYSIS OF ASH (ASTM D3682)

SAMPLE ID	SiO_2	Al_2O_3	TiO_2	CaO	BaO	SrO	Fe_2O_3	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
1.30 FLT	59.40	26.34	3.71	3.51	0.16	0.05	1.49	0.23	0.08	0.39	2.07	0.22	2.35
1.30 - 1.35	61.43	28.19	1.98	3.01	0.16	0.04	1.27	0.18	0.04	0.23	2.10	0.17	1.20
1.35 - 1.40	63.29	29.08	1.47	2.43	0.20	0.04	1.40	0.22	0.04	0.19	1.51	0.35	-0.22
1.40 - 1.45	63.10	29.67	1.36	1.96	0.17	0.03	1.39	0.23	0.13	0.03	1.18	0.22	0.53
1.45 - 1.50	63.42	30.65	1.29	1.41	0.13	0.03	1.50	0.23	0.07	0.20	1.02	0.17	-0.12
1.50 - 1.55	61.63	30.23	1.49	1.96	0.20	0.02	1.52	0.27	0.03	0.30	1.25	0.17	0.93
1.55 - 1.60	60.04	30.20	1.51	2.14	0.16	0.02	1.67	0.32	0.07	0.36	1.44	0.25	1.82
1.60 - 1.65	62.27	28.91	1.55	2.34	0.11	0.02	1.90	0.36	0.07	0.47	1.56	0.30	0.14
1.65 - 1.70	63.12	27.02	1.54	2.21	0.15	0.03	2.50	0.50	0.07	0.57	1.46	0.40	0.43
1.70 - 1.80	63.25	26.32	1.53	2.46	0.10	0.03	1.87	0.50	0.07	0.77	1.59	0.40	1.11
1.80 SNK	73.90	16.74	0.78	0.90	0.17	0.03	2.05	0.83	0.13	2.60	0.43	0.25	1.19
1.29 ARD	65.80	25.45	1.60	1.40	0.17	0.03	1.60	0.50	0.09	0.90	0.89	0.20	1.37
1.30 ARD	64.02	27.19	1.60	1.89	0.18	0.03	1.43	0.40	0.08	0.63	1.18	0.15	1.22
1.39 ARD	63.72	26.36	1.51	2.11	0.20	0.03	1.83	0.46	0.07	0.77	1.44	0.17	1.33
1.41 ARD	64.51	26.68	1.43	2.25	0.25	0.03	1.62	0.46	0.05	0.71	1.47	0.20	0.34
1.43 ARD	64.90	24.83	1.24	2.49	0.22	0.03	2.55	0.81	0.09	1.04	1.23	0.80	-0.23
1.60 ARD	67.51	21.77	1.04	1.82	0.22	0.02	2.49	0.80	0.09	1.67	1.06	0.22	1.29
1.92 ARD	71.06	19.84	0.87	1.43	0.22	0.03	2.03	0.88	0.09	2.19	0.68	0.35	0.33
2.48 ARD	74.55	17.25	0.80	0.74	0.20	0.02	1.86	0.91	0.11	2.57	0.33	0.17	0.49
30 sec	61.69	29.89	1.79	1.13	0.20	0.03	2.00	0.53	0.11	0.94	0.70	0.25	0.74
90 sec	61.63	29.52	1.81	0.98	0.19	0.03	1.76	0.51	0.07	0.94	0.63	0.26	1.67
comp	63.74	27.65	1.67	1.15	0.20	0.03	1.27	0.53	0.07	1.12	0.58	0.27	1.72
Tails	69.28	22.03	0.92	0.85	0.20	0.03	1.27	0.73	0.07	1.92	0.50	0.40	1.80

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SAMPLE B

CERTIFICATE OF ANALYSIS

CLIENT:	**Canadian Carbonization Research Association**
LAB#:	171316
RECEIVED DATE:	May 8, 2017
REPORT DATE:	May 26, 2017 Final

Roben JIG REPORT

Lab Ref No: **CCRA 171316 - JIG**

Description: **crushed 12.5mm x 0.25mm**

RAW ash = 34.33% (adb)

12.5x0.25mm = 39.59% Ash (adb)

Roben Jig 3 batches of 15.5 Kg	**ARD mesh vessel DRY tare**	**ARD mesh vessel WET tare**	**Assumed Damp Moisture %**					
	0	**306**	**5**					
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %
		May 11/17						
		FSI						
1	lid +5,+5,+6	0.0	10308	2.53	90.24	22.54	100.00	41.30
2	4,3,3	0.0	3539	2.45	87.00	7.74	77.46	27.06
3	2,2,2	0.5	2273	2.32	79.79	4.97	69.73	20.41
4	3,2,2	1.0	2427	1.92	56.17	5.31	64.76	15.86
5	2,2,3	2.0	2077	1.60	34.19	4.54	59.45	12.26
6	1,1,3	6.0	1176	1.43	17.49	2.57	54.91	10.44
7	2,2,2	8.0	1301	1.41	12.04	2.84	52.34	10.10
8	2,2,3	8.0	1476	1.39	10.56	3.23	49.50	9.99
9	5,5,7	7.5	3998	1.31	9.93	8.74	46.27	9.95
10	10,12,10	8.0	6682	1.30	9.56	14.61	37.53	9.95
11	17,17,14	8.0	10484	1.29	10.20	22.92	22.92	10.20
			45741.0					

Tube #	**1**	
		Ash%
starting weight =	**46557**	
fraction weight =	45741	
Jig Slurry wt =	288	58.28
ARD slurry wt =	311	17.04
Total End Weight =	**46340**	
Fine Losses = (Jig Slurry likely)	**217**	
cumulative Ash% =	**41.24**	

*Apparent Relative Density - this is considered an average of the "slice" taken

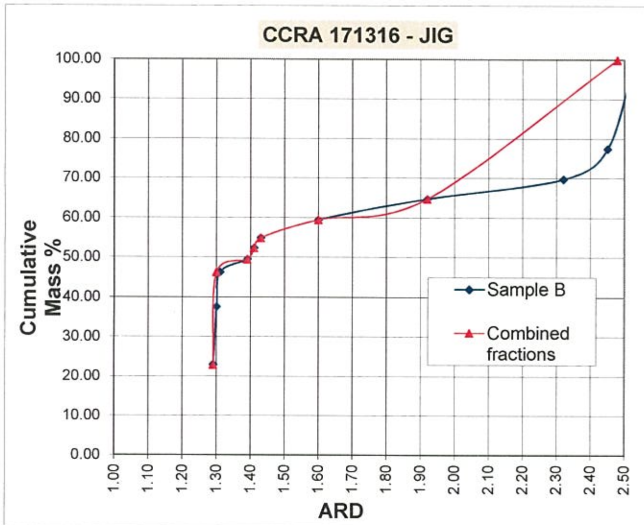
Combining some jig fractions according to ARD & Ash%

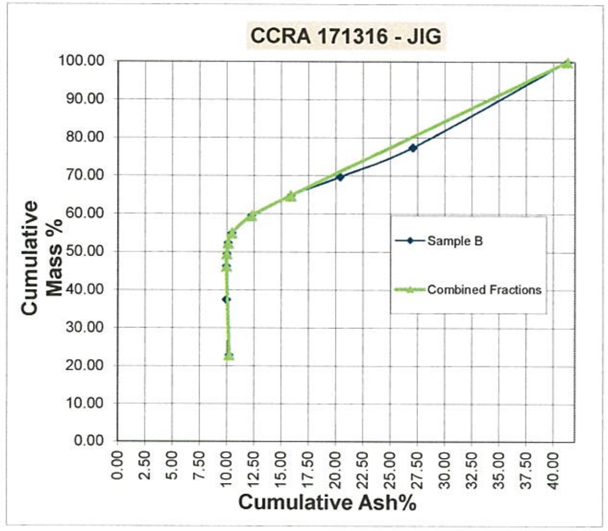
Roben Jig 3 batches of 15.5 Kg	**ARD mesh vessel DRY tare**	**ARD mesh vessel WET tare**	**Assumed Damp Moisture %**						
	0	**306**	**5**						
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %	
#1,2,3			16120	2.48	88.06	35.24	100.00	41.30	
4			2427	1.92	56.17	5.31	64.76	15.86	
5			2077	1.60	34.19	4.54	59.45	12.26	
6			1176	1.43	17.49	2.57	54.91	10.45	
7			1301	1.41	12.04	2.84	52.34	10.10	cutpoint
8			1476	1.39	10.56	3.23	49.50	9.99	
#9-10			10680	1.30	9.70	23.35	46.27	9.95	
#11			10484	1.29	10.20	22.92	22.92	10.20	
			45741.0						

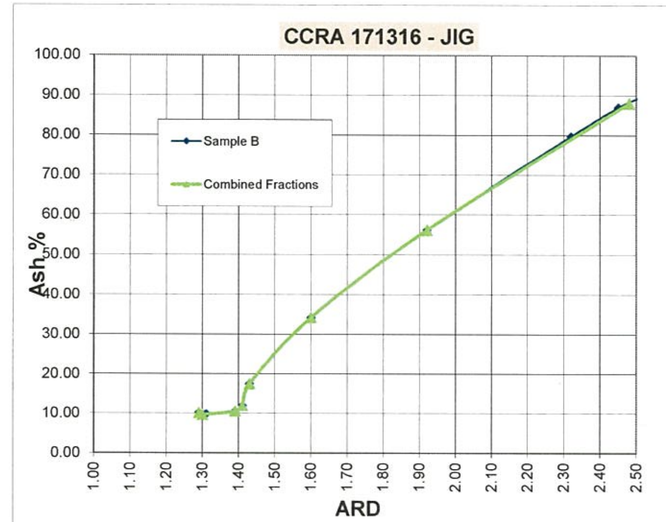
Heather Dexter
Operations Manager
GWIL Industries

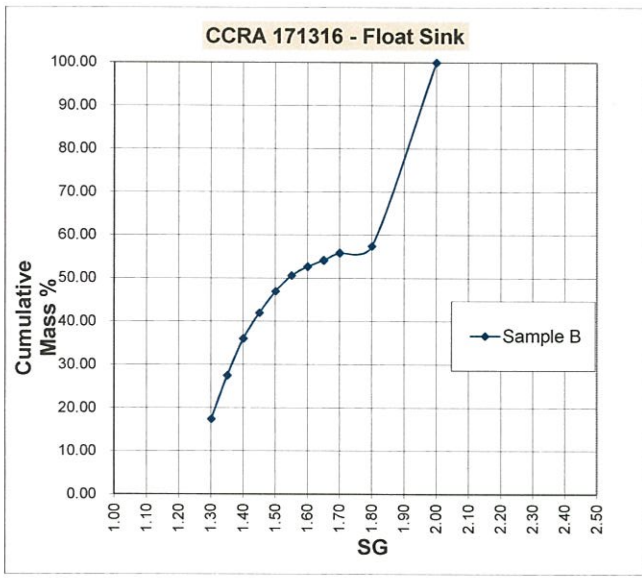
Canadian Carbonization Research Association

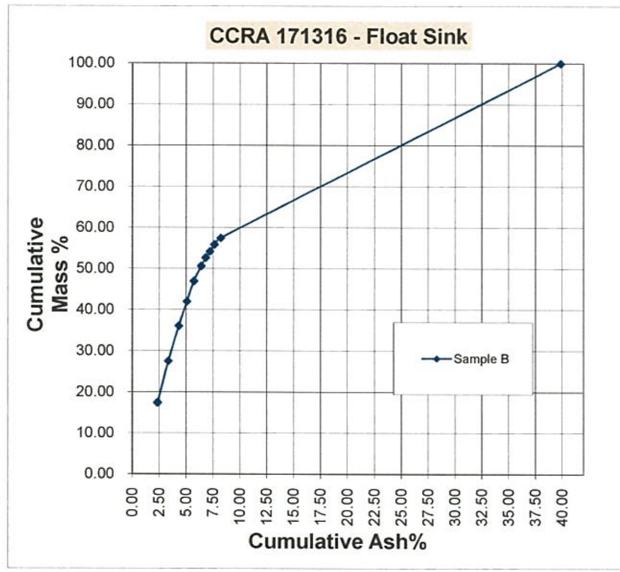
SAMPLE B

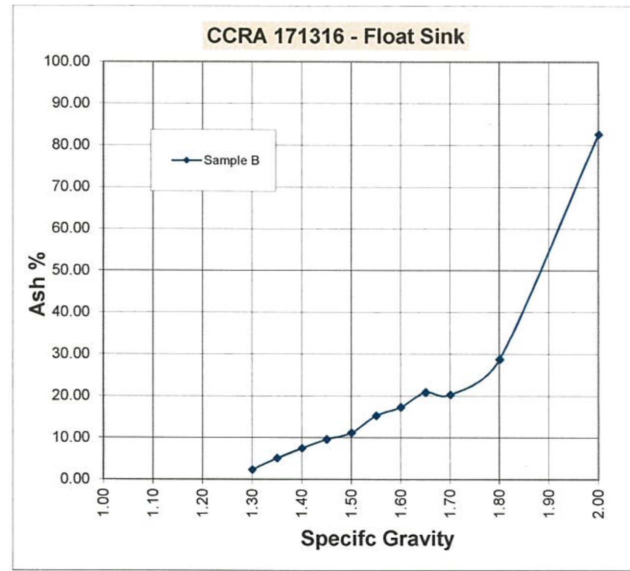












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SAMPLE B

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CERTIFICATE OF ANALYSIS

CLIENT:	**Canadian Carbonization Research Association**
LAB#:	171316
RECEIVED DATE:	May 8, 2017
REPORT DATE:	June 14, 2017

Roben JIG REPORT

Lab Ref No: **CCRA 171316 - JIG**

Description: **crushed 12.5mm x 0.25mm**

RE-JIG OF FRACTION #11 FROM ORIGINAL JIGGING

Roben Jig 1 batch of 1 Kg	**ARD mesh vessel DRY tare 0**	**ARD mesh vessel WET tare 306**	**Assumed Damp Moisture % 5**					
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %
1	lid +1		158	1.39	22.77	15.49	100.00	9.41
2	2.0		56	1.27	7.99	5.49	84.51	6.96
3	3.0		79	1.34	7.03	7.75	79.02	6.89
4	4.0		129	1.28	6.95	12.65	71.27	6.87
5	5.0		129	1.28	6.54	12.65	58.63	6.86
6	5.0		100	1.32	6.73	9.80	45.98	6.94
7	10.0		369	1.27	7.00	36.18	36.18	7.00
			1020.0					

Tube #	**4**	**Ash%**
starting weight =	**1095**	
fraction weight =	1020	
Jig Slurry wt =	52	17.68
ARD slurry wt =	10	8.71
Total End Weight =	**1082**	
Fine Losses = (Jig Slurry likely)	**13**	
cumulative Ash% =	**9.80**	

*Apparent Relative Density - this is considered an average of the "slice" taken

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SAMPLE B

CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171316

RECEIVED DATE: May 8, 2017

REPORT DATE: May 26, 2017 Final check analysis June 20, 2017

Simulated Clean Analysis, air dried basis

ID	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	Cal/g	Cl ppm	F ppm	Hg ppb	HGI	SG	%LT	BASIS
ASTM #	ASTM D3173	ASTM D3174	ASTM D3175		ASTM D4239	ASTM D720	ASTM D5865	ASTM D4208	ASTM D3761	ASTM D6722	ASTM D409	ISO 1014	@ 17mm path ASTM D5263	
SIM FS @ 1.65 SG	3.24	7.02	23.21	66.53	0.40	7.5	-	-	-	-	-	-	-	adb
		7.26	23.99	68.76	0.41									db
SIM JIG @ 1.41 ARD	0.72	9.83	23.38	66.07	0.41	8.0	-	-	-	-	-	-	-	adb
		9.90	23.55	66.55	0.41									db
SIM Froth @ 90 sec	0.55	10.80	23.29	65.36	0.40	7.5	-	-	-	-	-	-	-	adb
		10.86	23.42	65.72	0.40									db
FS CCC	2.15	8.54	23.19	66.12	0.41	7.75	7750	21450	118	38	147	1.37	96.4	adb
		8.73	23.70	67.57	0.42		7920	21921	121	39	144 ck			db
JIG CCC	0.56	9.70	23.52	66.22	0.42	7.5	7763	949	115	31	118	1.36	96.9	adb
		9.75	23.65	66.59	0.42		7807	954	116	31	117 ck			db

ULTIMATE ANALYSIS, as received basis (ASTM D5373)

ID	%MOIST.	%C	%H	%N	%S	%ASH	%O b/d	%P in coal db	BASIS
FS CCC	2.15	78.96	4.31	1.23	0.41	8.54	4.40	0.041	arb
		80.69	4.41	1.26	0.42	8.73	4.50		db
JIG CCC	0.56	79.07	4.49	1.21	0.42	9.70	4.55	0.033	arb
		79.52	4.51	1.22	0.42	9.75	4.58		db

GIESELER FLUIDITY TEST (ASTM D2639)

SAMPLE ID	TEMPERATURES °C INITIAL SOFT (1 DDPM)	MAX. FLUIDITY	SOLIDIFI-CATION	RANGE	MAX. DDPM	Date Tested
Sim FS	417	452	484	67	**39**	May 19
Sim Jig	426	464	498	72	**339**	May 19
Sim Froth	425	464	498	73	**153**	May 19
FS CCC	415	447	477	62	**57**	May 23
Jig CCC	421	459	493	72	**257**	May 23

RHUR DILATATION (ASTM D5515)

SAMPLE ID	SOFT TEMP	TMCONT	TMDIL.	%CONT.	%DIL	% TOTAL DIL	%SD 2.5	
FS CCC	397	448	475	24	3	27	**2**	May 23
Jig CCC	394	452	478	21	33	54	**29**	May 23

MINERAL ANALYSIS OF ASH (ASTM D3682)

SAMPLE ID	SiO_2	Al_2O_3	TiO_2	CaO	BaO	SrO	Fe_2O_3	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
Sim FS	62.31	29.91	1.91	2.04	0.21	0.03	1.29	0.28	0.08	0.33	1.30	0.07	0.24
Sim Jig	63.81	27.63	1.75	1.64	0.19	0.03	1.62	0.46	0.07	0.88	0.99	0.10	0.83
Sim Froth	62.67	28.72	1.86	1.02	0.22	0.03	1.90	0.55	0.13	1.00	0.48	0.25	1.17
FS CCC	61.07	29.20	1.94	1.74	0.18	0.03	1.53	0.40	0.09	0.63	1.07	0.07	2.05
Jig CCC	63.47	27.68	1.78	1.34	0.19	0.03	1.67	0.46	0.07	0.92	0.77	0.12	1.50

ASH FUSION TEMPERATURES (°C) (ASTM D1857)

	REDUCING				OXIDIZING			
SAMPLE ID	IDT	ST	HT	FT	IDT	ST	HT	FT
FS CCC	+1500	+1500	+1500	+1500	+1500	+1500	+1500	+1500
Jig CCC	+1500	+1500	+1500	+1500	+1500	+1500	+1500	+1500

FS CCC & Jig CCC sent to SGS-Tianjin May 24, 2017 & CANMET May 24, 2017

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SAMPLE C

CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171455

RECEIVED DATE: May 15, 2017

REPORT DATE: June 9, 2017 final

As Received weight = 207.0 Kg   Coal screened @12.5mm and oversize crushed to pass 12.5mm and homogenized with natural 12.5mmx0

Head Raw Analysis, air dried basis									
ADM%	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	SG	LT%	BASIS
ASTM D3302	ASTM D3173	ASTM D3174	ASTM D3175		ASTM D4239	ASTM D720	ISO 1014	@ 17mm path ASTM D5263	
4.15	0.61	36.66	18.24	44.49	0.44	5.5	1.62	96.9	adb
	4.73	35.14	17.48	42.64	0.42				arb
		36.88	18.35	44.76	0.44				db

WET SCREEN SIZE ANALYSIS, air dried basis (ASTM D4749)		
SIZE	WT (KG)	WT%
12.5mm X 9.5mm	29.11	14.68
9.5mm X 6.3mm	26.01	13.12
6.3mm X 2mm	49.80	25.11
2mm X 0.6mm	36.09	18.20
0.6mm X 0.25mm	18.17	9.16
0.25mm X 0.45mm	30.27	15.26
0.045mm X 0	8.87	4.47

SCREEN SIZE ANALYSIS, air dried basis								
SIZE	WT%	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	BASIS
12.5mm X 0.25mm	80.26	0.62	39.20	18.01	42.17	0.40	5.0	adb
0.25mm X 0	19.74	0.79	21.73	21.93	55.55	0.71	7.0	adb
CUMULATIVE	100.00	0.65	35.75	18.78	44.81	0.46	5.4	adb

FLOAT SINK ANALYSIS (12.5mmx0.25mm), air dried basis (ASTM D4371)																	
										CUMUALATIVE							
S.G.	WT(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
1.30 FLT	12080	20.28	0.49	2.75	26.98	69.78	0.56	+9	0.003	20.28	0.49	2.75	26.98	69.78	0.56	+9	0.003
1.30 - 1.35	6087	10.22	0.51	5.80	24.30	69.39	0.50	8.0	0.006	30.49	0.50	3.77	26.08	69.65	0.54	8.7	0.004
1.35 - 1.40	6398	10.74	0.49	10.59	23.28	65.64	0.45	5.0	0.022	41.23	0.49	5.55	25.35	68.61	0.52	7.7	0.008
1.40 - 1.45	3696	6.20	0.50	16.09	19.56	63.85	0.44	4.0	0.027	47.43	0.50	6.93	24.59	67.98	0.51	7.2	0.011
1.45 - 1.50	1775	2.98	0.44	21.80	18.76	59.00	0.49	2.5	0.032	50.41	0.49	7.81	24.25	67.45	0.51	6.9	0.012
1.50 - 1.55	1228	2.06	0.49	27.12	17.88	54.51	0.54	2.0	0.024	52.47	0.49	**8.56**	24.00	66.94	0.51	6.8	0.013
1.55 - 1.60	1165	1.96	0.48	32.24	16.72	50.56	0.50	1.0	0.023	54.43	0.49	9.41	23.74	66.36	0.51	6.5	0.013
1.60 - 1.65	983	1.65	0.57	37.19	16.18	46.06	0.50	1.0	0.018	56.08	0.49	10.23	23.52	65.76	0.51	6.4	0.013
1.65 - 1.70	964	1.62	0.65	42.47	15.12	41.76	0.47	1.0	0.009	57.70	0.50	11.14	23.28	65.09	0.51	6.2	0.013
1.70 - 1.80	1555	2.61	0.66	45.66	14.51	39.17	0.43	1.0	0.016	60.31	0.51	12.63	22.90	63.96	0.50	6.0	0.013
1.80 SNK	23649	39.69	0.76	80.79	9.64	8.81	0.21	0.0	0.021	100.00	0.61	39.68	17.64	42.07	0.39	3.6	0.016
	59580	**59687**	**107**	**grams loss**													

JIG ANALYSIS (12.5mmx0.25mm), air dried basis																	
										CUMUALATIVE							
ARD *	WT(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
1.29	13230	27.83	0.61	7.22	25.25	66.92	0.55	8.0	0.007	27.83	0.61	7.22	25.25	66.92	0.55	8.0	0.007
1.35	4577	9.63	0.80	9.92	23.69	65.59	0.51	7.0	0.009	37.45	0.66	7.91	24.85	66.58	0.54	7.7	0.008
1.39	2771	5.83	0.65	12.86	21.97	64.52	0.48	5.5	0.016	43.28	0.66	**8.58**	24.46	66.30	0.53	7.4	0.009
1.43	2509	5.28	0.75	16.13	20.38	62.74	0.47	5.0	0.018	48.56	0.67	9.40	24.02	65.91	0.52	7.2	0.010
1.57	3209	6.75	0.70	27.51	18.07	53.72	0.46	3.0	0.016	55.31	0.67	11.61	23.29	64.43	0.52	6.7	0.010
1.74	2665	5.61	0.65	45.52	15.08	38.75	0.43	1.0	0.002	60.91	0.67	14.73	22.54	62.06	0.51	6.1	0.010
1.94	2488	5.23	0.71	59.34	12.54	27.41	0.31	1.0	0.005	66.15	0.67	18.26	21.75	59.32	0.49	5.7	0.009
2.37	16096	33.85	0.75	82.57	9.34	7.34	0.18	0.0	0.032	100.00	0.70	40.03	17.55	41.72	0.39	3.8	0.017

* Apparent Relative Density - this is considered an average of the "slice"

FROTH FLOTATION (0.25mm X 0) (ASTM D5114)																	
										CUMUALATIVE							
TIME	Wt(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
45 SEC	8826	45.22	0.65	8.26	24.65	66.44	0.66	9.0	0.003	45.22	0.65	8.26	24.65	66.44	0.66	9.0	0.003
90 SEC	2400	12.30	0.70	9.89	24.17	65.24	0.67	8.5	0.004	57.52	0.66	**8.61**	24.55	66.18	0.66	8.9	0.003
COMPLETE	1559	7.99	0.73	13.22	23.13	62.92	0.69	8.0	0.005	65.50	0.67	9.17	24.37	65.79	0.67	8.8	0.003
TAILS	6733	34.50	0.65	51.00	16.16	32.19	0.68	1.0	0.007	100.00	0.66	23.60	21.54	54.20	0.67	6.1	0.004
PARAMETERS:	10% PULP DENSITY, COND. TIME 1 MINUTE 0.667 Kg/T 10:1 Kero:MIBC, DENVER 9L CELL, 1500 RPM																

Yield @1.55 Float & 90 sec froth = 53.46% @8.57% Ash (@1.39 ARD used with same proportions = 8.59% Ash)

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SAMPLE C

CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171455

RECEIVED DATE: May 15, 2017

REPORT DATE: June 9, 2017 final

GIESELER FLUIDITY TEST (ASTM D2639)

SAMPLE ID	INITIAL SOFT (1 DDPM)	MAX. FLUIDITY	SOLIDIFI-CATION	RANGE	MAX. DDPM		Date Tested
	TEMPERATURES °C						
1.30 FLT	405	448	490	85	**1420**		May 29
1.30 - 1.35	418	461	496	78	**429**		May 29
1.35 - 1.40	432	463	489	57	**19**		May 29
1.29 ARD	417	461	497	80	**827**		May 29
1.35 ARD	416	454	490	74	**514**		May 30
1.39 ARD	424	461	493	69	**299**		May 29
45 sec	413	457	487	74	**303**	*	June 1
90 sec	418	455	489	71	**110**	*	June 1
comp	430	463	491	61	**35**	*	June 1

***finer size consist than the ASTM 2639 procedure requires**

RHUR DILATATION (ASTM D5515)

SAMPLE ID	SOFT TEMP	TMCONT	TMDIL.	%CONT.	%DIL	% TOTAL DIL	%SD 2.5	Date Tested
1.30 FLT	382	428	477	20	243	263	**253**	May 29
1.30 - 1.35	388	445	478	21	66	87	**66**	May 29
1.35 - 1.40	391	457	484	20	-10	10	**-10**	May 29
1.29 ARD	370	430	474	26	137	163	**135**	May 30
1.35 ARD	391	445	476	21	69	90	**64**	May 30
1.39 ARD	387	450	474	22	24	46	**21**	May 30
45 sec	389	444	477	26	107	133	**105**	June 1
90 sec	383	445	477	21	67	88	**66**	June 1
comp	391	451	484	17	25	42	**19**	June 1

MINERAL ANALYSIS OF ASH (ASTM D3682)

SAMPLE ID	SiO_2	Al_2O_3	TiO_2	CaO	BaO	SrO	Fe_2O_3	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
1.30 FLT	53.13	25.57	2.34	4.80	1.65	0.23	4.15	0.99	0.31	0.60	0.21	5.84	0.18
1.30 - 1.35	68.36	22.17	2.11	1.50	0.56	0.07	2.15	0.55	0.23	0.55	0.23	1.20	0.32
1.35 - 1.40	70.57	21.66	1.73	1.15	0.50	0.05	1.60	0.41	0.13	0.63	0.48	0.77	0.32
1.40 - 1.45	70.85	21.01	1.66	0.91	0.39	0.04	1.46	0.41	0.24	0.55	0.39	0.55	1.54
1.45 - 1.50	70.50	20.73	1.64	0.80	0.30	0.04	1.63	0.53	0.12	0.89	0.34	0.65	1.83
1.50 - 1.55	72.68	19.14	1.65	0.60	0.28	0.03	1.87	0.58	0.11	1.04	0.20	0.57	1.25
1.55 - 1.60	72.66	18.76	1.59	0.49	0.25	0.03	1.52	0.58	0.11	1.17	0.16	0.45	2.23
1.60 - 1.65	73.45	18.61	1.58	0.45	0.21	0.03	1.47	0.63	0.13	1.29	0.11	0.45	1.59
1.65 - 1.70	75.27	18.35	1.50	0.41	0.12	0.03	1.52	0.68	0.15	1.47	0.05	0.40	0.05
1.70 - 1.80	74.37	19.10	1.41	0.32	0.13	0.02	1.37	0.63	0.18	1.47	0.08	0.27	0.65
1.80 SNK	70.44	19.99	0.97	1.06	0.15	0.02	2.33	1.29	0.12	1.95	0.06	0.50	1.12
1.29 ARD	65.75	23.19	1.59	1.76	0.57	0.07	2.62	0.78	0.18	0.98	0.23	1.95	0.33
1.35 ARD	68.47	21.33	1.46	1.19	0.49	0.05	2.26	0.61	0.12	0.78	0.20	1.27	1.77
1.39 ARD	69.86	20.46	1.41	1.12	0.38	0.04	2.22	0.60	0.12	0.77	0.28	1.07	1.67
1.43 ARD	71.06	20.60	1.36	0.85	0.29	0.04	1.82	0.58	0.12	0.89	0.25	0.72	1.42
1.57 ARD	71.64	20.56	1.34	0.64	0.28	0.03	1.72	0.71	0.12	1.33	0.13	0.62	0.88
1.74 ARD	72.53	20.16	1.16	0.42	0.30	0.02	1.93	0.85	0.12	1.65	0.01	0.45	0.40
1.94 ARD	70.50	21.20	1.07	0.52	0.27	0.02	1.82	0.95	0.13	1.71	0.02	0.40	1.39
2.37 ARD	69.73	20.86	0.79	1.11	0.17	0.02	2.70	1.33	0.15	2.01	0.09	0.37	0.67
45 sec	63.66	21.88	1.98	1.86	0.50	0.06	4.59	1.08	0.22	1.53	0.08	1.72	0.84
90 sec	62.29	22.12	1.75	1.88	0.45	0.06	4.83	1.21	0.19	1.65	0.09	1.70	1.78
comp	62.37	21.81	1.44	1.96	0.48	0.05	5.06	1.48	0.19	1.81	0.08	2.17	1.10
Tails	68.02	19.52	0.75	1.65	0.38	0.03	4.62	1.58	0.13	1.86	0.03	1.92	-0.49

Heather Dexter
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SAMPLE C

CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171455

RECEIVED DATE: May 15, 2017

REPORT DATE: June 9, 2017 final

Roben JIG REPORT

Lab Ref No: **CCRA 171455 - JIG**

Description: **crushed 12.5mm x 0.25mm**

RAW ash = 36.66% (adb)

12.5x0.25mm = 39.20% Ash (adb)

Roben Jig 3 batches of 15.5 Kg	ARD mesh vessel DRY tare	ARD mesh vessel WET tare	Assumed Damp Moisture %					
	0	306	5					
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %
1	lid +5 x 3		8614	2.46	87.65	18.12	100.00	40.25
2	4 x 3		4204	2.36	81.94	8.84	81.88	29.76
3	3 x 3		3278	2.15	72.01	6.89	73.04	23.44
4	3,3,2		2488	1.94	59.34	5.23	66.15	18.38
5	3,4,2		2665	1.74	45.52	5.61	60.91	14.86
6	2,4,2		2264	1.58	29.66	4.76	55.31	11.76
7	1,2,1		945	1.55	21.46	1.99	50.55	10.07
8	1,3,1		1158	1.45	17.39	2.44	48.56	9.60
9	2,2,2		1351	1.41	16.60	2.84	46.12	9.19
10	2,2,2		1482	1.40	13.80	3.12	43.28	8.71
11	2,2,2		1289	1.38	12.39	2.71	40.16	8.31
12	3,2,2		1624	1.36	10.53	3.42	37.45	8.02
13	3,2,2		1474	1.35	9.69	3.10	34.04	7.76
14	3,2,2		1479	1.34	8.54	3.11	30.94	7.57
15	3,3,3		1852	1.32	7.42	3.90	27.83	7.46
16	3,3,3		1823	1.31	6.94	3.83	23.93	7.47
17	5,5,5		3151	1.29	6.78	6.63	20.10	7.57
18	7,7,8		6404	1.28	7.96	13.47	13.47	7.96
			47545.0					

Tube #	1	Ash%
starting weight =	**47905**	
fraction weight =	47545	
Jig Slurry wt =	155	25.79
ARD slurry wt =	182	17.22
Total End Weight =	**47882**	

Fine Losses = 23 (Jig Slurry likely)

cumulative Ash% = **40.11**

*Apparent Relative Density - this is considered an average of the "slice" taken

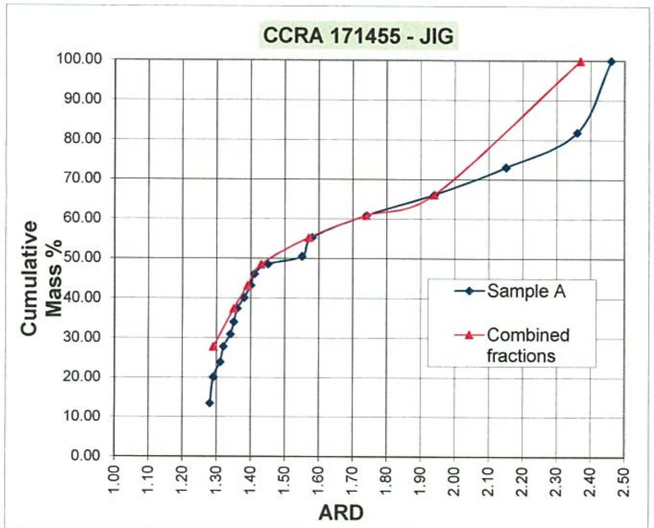
Combining some jig fractions according to ARD & Ash%

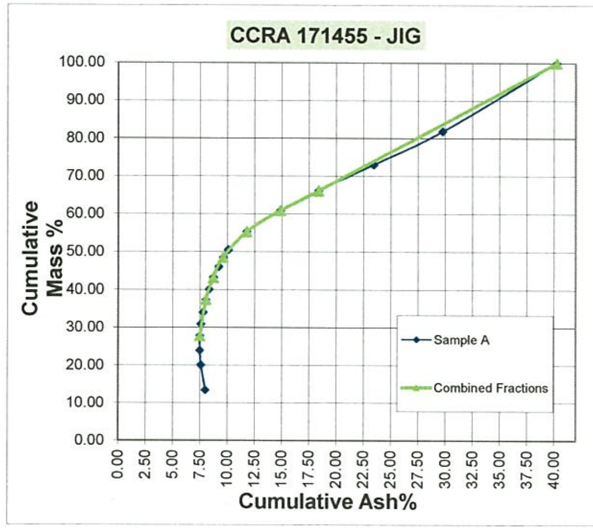
Roben Jig 3 batches of 15.5 Kg	ARD mesh vessel DRY tare	ARD mesh vessel WET tare	Assumed Damp Moisture %					
	0	306	5					
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %
#1,2,3			16096	2.37	82.97	33.85	100.00	40.25
4			2488	1.94	59.34	5.23	66.15	18.38
5			2665	1.74	45.52	5.61	60.91	14.86
#6-#7			3209	1.57	27.25	6.75	55.31	11.76
#8-#9			2509	1.43	16.96	5.28	48.56	9.60
#10-#11			2771	1.39	13.14	5.83	43.28	8.71
#12-#14			4577	1.35	9.62	9.63	37.45	8.02
#15-#18			13230	1.29	7.46	27.83	27.83	7.46
			47545.0					

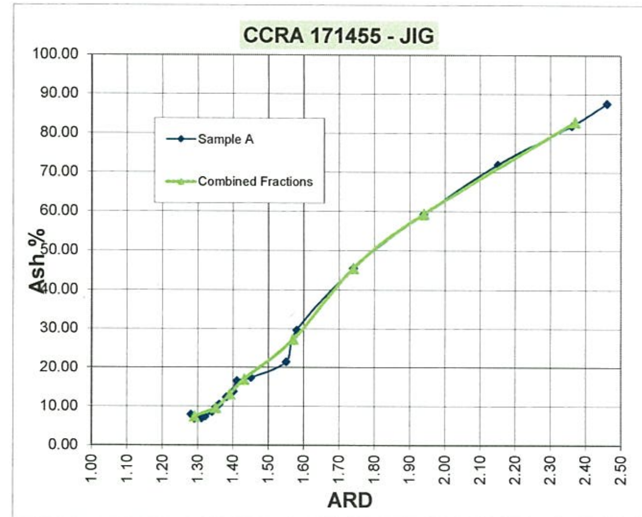
Heather Dexter
Operations Manager
GWIL Industries

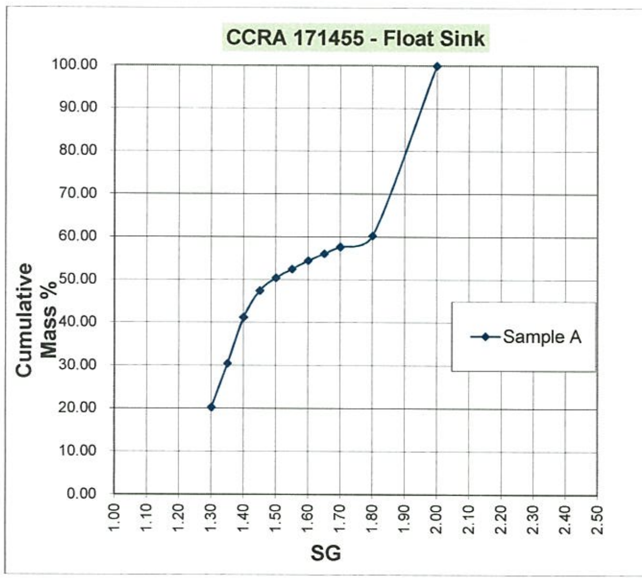
Canadian Carbonization Research Association

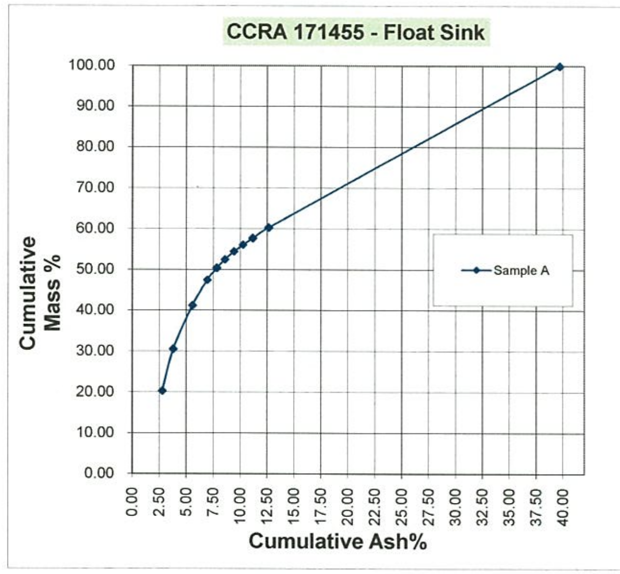
SAMPLE C

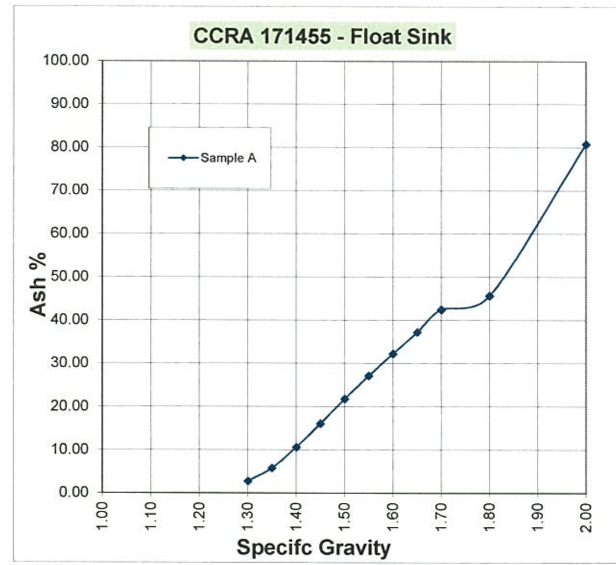












GWIL INDUSTRIES Birtley Coal & Minerals Testing Division

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SAMPLE C

CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171455

RECEIVED DATE: May 15, 2017

REPORT DATE: June 9, 2017 final

Simulated Clean Analysis, air dried basis														
ID	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	Cal/g	Cl ppm	F ppm	Hg ppb	HGI	SG	%LT	BASIS
ASTM #	ASTM D3173	ASTM D3174	ASTM D3175		ASTM D4239	ASTM D720	ASTM D5865	ASTM D4208	ASTM D3761	ASTM D6722	ASTM D409	ISO 1014	@ 17mm path ASTM D5263	
SIM FS	0.48	8.70	24.22	66.60	0.52	7.0	-	-	-	-	-	-	-	adb
@ 1.55 SG		8.74	24.34	66.92	0.52									db
SIM JIG	0.55	8.50	24.51	66.44	0.54	7.5	-	-	-	-	-	-	-	adb
@ 1.39 ARD		8.55	24.65	66.81	0.54									db
SIM Froth	0.44	8.77	24.90	65.89	0.68	8.0	-	-	-	-	-	-	-	adb
@ 90 sec		8.81	25.01	66.18	0.68									db
FS CCC	0.50	8.42	24.41	66.67	0.55	8.5	7874	733	92	86	81	1.35	98.4	adb
		8.46	24.53	67.01	0.55		7914	737	92	86				db
JIG CCC	0.26	8.35	24.96	66.43	0.56	8.5	7864	472	134	85	80	1.34	95.3	adb
		8.37	25.03	66.60	0.56		7884	473	134	85				db

ULTIMATE ANALYSIS, as received basis (ASTM D5373)								
ID	%MOIST.	%C	%H	%N	%S	%ASH	%O b/d	%P in coal db	BASIS
FS CCC	0.50	80.58	4.53	1.05	0.55	8.42	4.37	0.009	arb
		80.98	4.56	1.06	0.55	8.46	4.39		db
JIG CCC	0.26	80.70	4.61	1.04	0.56	8.35	4.48	0.008	arb
		80.91	4.62	1.04	0.56	8.37	4.49		db

GIESELER FLUIDITY TEST (ASTM D2639)						
	TEMPERATURES °C					
SAMPLE ID	INITIAL SOFT (1 DDPM)	MAX. FLUIDITY	SOLIDIFI-CATION	RANGE	MAX. DDPM	Date Tested
Sim FS	420	459	495	75	**529**	June 2
Sim Jig	421	460	500	79	**701**	June 2
Sim Froth	422	462	497	75	**263**	June 2
FS CCC	417	461	494	77	**405**	June 5
Jig CCC	419	461	496	77	**488**	June 5

RHUR DILATATION (ASTM D5515)								
SAMPLE ID	SOFT TEMP	TMCONT	TMDIL.	%CONT.	%DIL	% TOTAL DIL	**%SD 2.5**	Date Tested
FS CCC	385	442	475	23	93	116	**86**	June 5
Jig CCC	379	442	475	25	103	128	**96**	June 5

MINERAL ANALYSIS OF ASH (ASTM D3682)													
SAMPLE ID	SiO_2	Al_2O_3	TiO_2	CaO	BaO	SrO	Fe_2O_3	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
Sim FS	69.07	21.09	1.58	1.37	0.47	0.07	1.90	0.53	0.13	0.63	0.33	1.32	1.51
Sim Jig	67.83	22.07	1.53	1.57	0.60	0.07	2.26	0.71	0.18	0.87	0.28	1.47	0.56
Sim Froth	62.78	22.58	1.85	1.90	0.60	0.06	4.35	1.16	0.22	1.49	0.14	1.92	0.95
FS CCC	68.11	21.64	1.65	1.53	0.57	0.06	2.57	0.73	0.16	0.82	0.24	1.22	0.70
Jig CCC	67.49	22.13	1.54	1.55	0.57	0.06	2.65	0.76	0.15	0.95	0.23	1.27	0.65

	ASH FUSION TEMPERATURES (°C) (ASTM D1857)							
	REDUCING				OXIDIZING			
SAMPLE ID	IDT	ST	HT	FT	IDT	ST	HT	FT
FS CCC	1501	+1510	+1510	+1510	1510	+1510	+1510	+1510
Jig CCC	1502	+1510	+1510	+1510	1510	+1510	+1510	+1510

FS CCC & Jig CCC sent to SGS-Tianjin June 6, 2017 & CANMET June 6, 2017

Heather Dexter
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CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**

LAB#: 171785

RECEIVED DATE: June 13, 2017

REPORT DATE: July 5, 2017 Final

As Received weight = 139.9 Kg   Coal screened @12.5mm and oversize crushed to pass 12.5mm and homogenized with natural 12.5mmx0

Head Raw Analysis, air dried basis									
ADM%	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	SG	LT%	BASIS
ASTM D3302	ASTM D3173	ASTM D3174	ASTM D3175		ASTM D4239	ASTM D720	ISO 1014	@ 17mm path ASTM D5263	
2.36	1.05	26.70	20.18	52.07	0.27	1.5	1.54	99.0	adb
	3.39	26.07	19.70	50.84	0.26				arb
		26.98	20.39	52.62	0.27				db

WET SCREEN SIZE ANALYSIS, air dried basis (ASTM D4749)		
SIZE	WT (KG)	WT%
12.5mm X 9.5mm	17.05	14.38
9.5mm X 6.3mm	14.23	12.00
6.3mm X 2mm	28.69	24.20
2mm X 0.6mm	23.18	19.55
0.6mm X 0.25mm	10.32	8.70
0.25mm X 0.45mm	17.26	14.56
0.045mm X 0	7.84	6.61

SCREEN SIZE ANALYSIS, air dried basis								
SIZE	WT%	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	BASIS
12.5mm X 0.25mm	78.83	0.60	28.02	20.24	51.14	0.25	1.5	adb
0.25mm X 0	21.17	0.79	19.96	21.01	58.24	0.30	2.0	adb
CUMULATIVE	100.00	0.64	26.31	20.40	52.64	0.26	1.6	adb

FLOAT SINK ANALYSIS (12.5mmx0.25mm), air dried basis (ASTM D4371)										CUMUALATIVE							
S.G.	WT(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
1.30 FLT	4556	9.78	1.21	2.64	26.91	69.24	0.41	9.0	0.005	9.78	1.21	2.64	26.91	69.24	0.41	9.0	0.005
1.30 - 1.35	6153	13.21	0.95	5.70	23.43	69.92	0.32	5.5	0.017	23.00	1.06	4.40	24.91	69.63	0.36	7.0	0.012
1.35 - 1.40	6747	14.49	0.96	9.29	21.58	68.17	0.27	1.0	0.019	37.49	1.02	6.29	23.62	69.07	0.32	4.7	0.015
1.40 - 1.45	5396	11.59	0.95	13.74	20.87	64.44	0.26	1.0	0.014	49.08	1.00	8.05	22.97	67.97	0.31	3.8	0.014
1.45 - 1.50	4801	10.31	1.05	17.31	20.81	60.83	0.26	1.0	0.012	59.39	1.01	9.66	22.60	66.73	0.30	3.3	0.014
1.50 - 1.55	2507	5.38	0.89	25.20	21.00	52.91	0.26	1.0	0.007	64.77	1.00	**10.95**	22.46	65.58	0.30	3.1	0.013
1.55 - 1.60	1171	2.51	0.76	29.42	20.48	49.34	0.25	1.0	0.003	67.29	0.99	11.64	22.39	64.98	0.30	3.0	0.013
1.60 - 1.65	1271	2.73	1.10	33.05	20.34	45.51	0.24	1.0	0.003	70.02	1.00	12.47	22.31	64.22	0.29	3.0	0.013
1.65 - 1.70	1009	2.17	1.09	36.90	20.67	41.34	0.24	1.0	0.002	72.18	1.00	13.21	22.26	63.53	0.29	2.9	0.012
1.70 - 1.80	1849	3.97	1.33	42.05	20.36	36.26	0.23	1.0	0.002	76.15	1.02	14.71	22.16	62.11	0.29	2.8	0.012
1.80 SNK	11104	23.85	1.00	72.54	13.57	12.89	0.15	0.0	0.003	100.00	1.01	28.50	20.11	50.37	0.26	2.1	0.010
	46564	**46724**	**160**	**grams loss**													

JIG ANALYSIS (12.5mmx0.25mm), air dried basis										CUMUALATIVE							
ARD *	WT(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
1.30	3360	8.38	0.81	8.87	23.47	66.85	0.33	7.0	0.012	8.38	0.81	8.87	23.47	66.85	0.33	7.0	0.012
1.34	6483	16.16	0.75	10.39	22.89	65.97	0.32	5.5	0.014	24.54	0.77	9.87	23.09	66.27	0.32	6.0	0.013
1.38	5361	13.37	0.77	11.16	21.93	66.14	0.30	5.0	0.016	37.90	0.77	10.33	22.68	66.22	0.32	5.7	0.014
1.41	4377	10.91	0.80	12.92	21.52	64.76	0.29	3.0	0.015	48.82	0.78	**10.91**	22.42	65.90	0.31	5.1	0.014
1.45	2740	6.83	0.59	15.34	21.19	62.88	0.27	1.5	0.013	55.65	0.75	11.45	22.27	65.53	0.30	4.6	0.014
1.48	1786	4.45	0.77	19.15	20.56	59.52	0.26	1.0	0.017	60.10	0.76	12.02	22.14	65.08	0.30	4.4	0.014
1.53	2030	5.06	0.66	24.15	20.09	55.10	0.24	1.0	0.004	65.16	0.75	12.96	21.98	64.31	0.30	4.1	0.014
1.63	2185	5.45	0.66	34.66	19.50	45.18	0.23	1.0	0.002	70.61	0.74	14.64	21.79	62.83	0.29	3.9	0.013
2.03	11789	29.39	0.68	63.32	15.31	20.69	0.18	0.0	0.006	100.00	0.72	28.94	19.89	50.45	0.26	2.7	0.011

* Apparent Relative Density - this is considered an average of the "slice"

FROTH FLOTATION (0.25mm X 0) (ASTM D5114)										CUMUALATIVE							
TIME	Wt(g)	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P	WT%	MOIST%	ASH %	VM %	FC %	%S	FSI	%P
45 SEC	10809	58.15	1.06	11.18	22.20	65.56	0.31	4.0	0.006	58.15	1.06	11.18	22.20	65.56	0.31	4.0	0.006
90 SEC	2579	13.87	1.08	12.09	21.47	65.36	0.32	2.5	0.011	72.02	1.06	**11.36**	22.06	65.52	0.31	3.7	0.007
COMPLETE	1156	6.22	0.93	14.10	21.49	63.48	0.32	1.0	0.010	78.24	1.05	11.57	22.01	65.36	0.31	3.5	0.007
TAILS	4044	21.76	0.92	46.21	17.53	35.34	0.23	0.5	0.004	100.00	1.02	19.11	21.04	58.83	0.29	2.8	0.006

PARAMETERS: 10% PULP DENSITY, COND. TIME 1 MINUTE
0.667 Kg/T 10:1 Kero:MIBC, DENVER 9L CELL, 1500 RPM

Yield @1.55 Float & 90 sec froth = 53.46% @8.57% Ash (@1.39 ARD used with same proportions = 8.59% Ash)

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SAMPLE D

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CLIENT: **Canadian Carbonization Research Association**

LAB#: 171785

RECEIVED DATE: June 13, 2017

REPORT DATE: July 5, 2017 Final

GIESELER FLUIDITY TEST (ASTM D2639)							Date Tested
	TEMPERATURES °C						
SAMPLE ID	INITIAL SOFT (1 DDPM)	MAX. FLUIDITY	SOLIDIFICATION	RANGE	MAX. DDPM		
1.30 FLT	419	454	479	60	**166**		Jun 20
1.30 - 1.35	433	452	473	40	**3.6**		Jun 20
1.35 - 1.40	not applicable as 1.30-1.35 very low						-
1.30 ARD	439	463	490	51	**11**		Jun 20
1.34 ARD	443	465	489	46	**5.7**		Jun 20
1.38 ARD	not applicable as 1.34 ARD very low						
45 sec	442	462	486	44	**2.5**	*	Jun 21
90 sec	454	460	485	31	**1.0**	*	Jun 21
comp	not applicable as 90 sec very low					*	

***finer size consist than the ASTM 2639 procedure requires**

RHUR DILATATION (ASTM D5515)								Date Tested
SAMPLE ID	SOFT TEMP	TMCONT	TMDIL.	%CONT.	%DIL	TOTAL DIL	**%SD 2.5**	
1.30 FLT	397	448	475	27	76	103	**82**	Jun 20
1.30 - 1.35	421	484	-	19	-	-	**-**	Jun 20
1.35 - 1.40	not applicable as 1.30-1.35 very low							-
1.30 ARD	415	473	493	16	-14	2	**-15**	Jun 20
1.34 ARD	409	480	-	17	-	-	**-**	Jun 20
1.38 ARD	not applicable as 1.34 ARD very low							
45 sec	415	487	-	15	-	-	**-**	Jun 21
90 sec	424	500	-	12	-	-	**-**	Jun 21
comp	not applicable as 90 sec very low							

MINERAL ANALYSIS OF ASH (ASTM D3682)

SAMPLE ID	SiO_2	Al_2O_3	TiO_2	CaO	BaO	SrO	Fe_2O_3	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
1.30 FLT	57.37	23.51	5.28	3.09	0.87	0.28	3.02	0.76	1.13	0.58	0.41	2.52	1.18
1.30 - 1.35	58.80	24.64	2.86	2.74	0.85	0.22	3.80	0.90	1.29	0.40	0.68	2.47	0.35
1.35 - 1.40	58.57	25.38	1.82	2.76	0.73	0.14	4.07	1.03	1.21	0.31	0.48	2.57	0.93
1.40 - 1.45	58.18	26.11	1.52	3.02	0.39	0.09	3.65	1.13	0.86	0.28	0.23	2.82	1.72
1.45 - 1.50	60.41	25.60	1.56	3.34	0.32	0.07	3.45	1.13	0.62	0.24	0.16	2.65	0.45
1.50 - 1.55	59.40	24.89	1.57	4.72	0.36	0.06	2.87	1.23	0.40	0.33	0.06	2.35	1.76
1.55 - 1.60	59.06	25.40	1.60	4.87	0.45	0.03	2.73	1.28	0.31	0.37	0.02	1.97	1.91
1.60 - 1.65	57.54	25.68	1.48	7.11	0.42	0.06	2.52	1.46	0.28	0.46	0.02	1.70	1.27
1.65 - 1.70	56.83	24.75	1.44	9.15	0.39	0.08	2.46	1.61	0.27	0.55	0.01	1.55	0.91
1.70 - 1.80	56.14	24.26	1.37	9.70	0.29	0.08	2.05	1.36	0.24	0.72	0.01	1.32	2.46
1.80 SNK	65.69	25.72	1.18	2.18	0.32	0.04	1.26	0.68	0.20	1.43	0.01	0.40	0.89
1.30 ARD	59.34	25.09	2.75	2.59	0.68	0.10	3.05	0.81	0.81	0.49	0.32	2.40	1.57
1.34 ARD	58.80	25.08	2.37	2.78	0.65	0.10	2.95	1.04	0.77	0.48	0.31	2.52	2.15
1.38 ARD	58.72	25.53	2.16	2.70	0.57	0.10	3.12	0.93	0.80	0.45	0.32	2.47	2.13
1.41 ARD	58.87	24.94	1.91	3.32	0.63	0.09	2.92	1.01	0.77	0.43	0.27	2.97	1.87
1.45 ARD	59.32	24.70	1.65	4.02	0.50	0.09	3.03	1.19	0.70	0.42	0.20	3.00	1.18
1.48 ARD	61.30	25.13	1.66	3.37	0.36	0.08	3.02	1.19	0.59	0.53	0.20	2.25	0.32
1.53 ARD	59.89	25.64	1.65	4.27	0.36	0.07	2.77	1.23	0.49	0.59	0.04	2.07	0.93
1.63 ARD	57.71	26.98	1.50	4.84	0.21	0.06	2.36	1.21	0.36	0.96	0.01	1.50	2.30
2.03 ARD	62.55	27.21	1.40	3.27	0.19	0.05	1.64	0.91	0.20	1.31	0.02	0.60	0.65
45 sec	58.31	28.10	2.46	2.88	0.45	0.10	2.72	0.91	0.69	0.70	0.23	2.40	0.05
90 sec	57.11	27.65	2.32	2.98	0.50	0.10	2.57	0.88	0.74	0.71	0.21	2.25	1.98
comp	57.97	27.55	2.14	3.19	0.58	0.09	2.19	0.90	0.71	0.92	0.17	2.40	1.19
Tails	59.87	26.08	0.95	5.86	0.58	0.08	1.80	0.99	0.65	1.20	0.02	1.02	0.90

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SAMPLE D

CERTIFICATE OF ANALYSIS

CLIENT:	**Canadian Carbonization Research Association**
LAB#:	171785
RECEIVED DATE:	June 13, 2017
REPORT DATE:	July 5, 2017 Final

Roben JIG REPORT

Lab Ref No: **CCRA 171785 - JIG**

Description: **crushed 12.5mm x 0.25mm**

RAW ash = 26.70% (adb)

12.5x0.25mm = 28.02% Ash (adb)

Roben Jig 3 batches of 13.6 Kg	ARD mesh vessel DRY tare	ARD mesh vessel WET tare	Assumed Damp Moisture %					
	0	306	5					
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %
		June 19/17						
		FSI						
1	10,9,9	0.0	11789	2.03	63.32	29.39	100.00	28.93
2	2,3,3	1.0	2185	1.63	34.66	5.45	70.61	14.61
3	2,3,3	1.0	2032	1.53	24.15	5.07	65.16	12.94
4	2,2,3	1.0	1786	1.48	19.15	4.45	60.10	11.99
5	2,2,2	1.0	1384	1.45	15.78	3.45	55.65	11.42
6	2,2,2	1.5	1356	1.44	15.18	3.38	52.20	11.13
7	3,3,4	2.5	2220	1.42	13.89	5.53	48.81	10.85
8	3,3,3	3.0	2157	1.40	12.29	5.38	43.28	10.46
9	4,4,5	3.5	2902	1.39	11.88	7.23	37.90	10.20
10	4,4,4	5.0	2459	1.36	10.87	6.13	30.67	9.81
11	5,5,5	5.0	3308	1.35	9.65	8.25	24.54	9.54
12	5,5,5	6.0	3175	1.33	10.14	7.92	16.29	9.49
13	5,5,3	7.0	3360	1.30	8.87	8.38	8.38	8.87
			40113.0					

Tube #	**1**	
		Ash%
starting weight =	**40741**	
fraction weight =	40113	
Jig Slurry wt =	197	48.89
ARD slurry wt =	299	14.86
Total End Weight =	**40609**	
Fine Losses =	**132**	
(Jig Slurry likely)		
cumulative Ash% =	**28.92**	

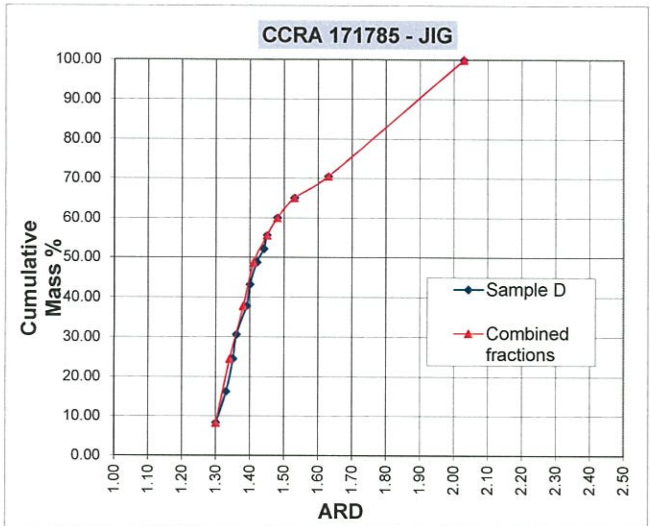
*Apparent Relative Density - this is considered an average of the "slice" taken

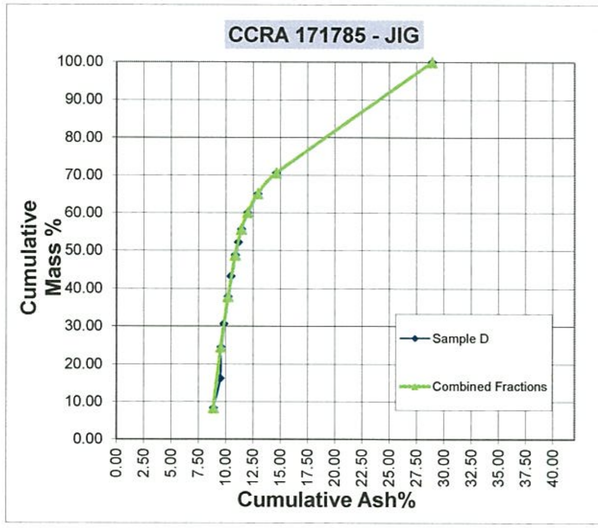
Combining some jig fractions according to ARD & Ash%

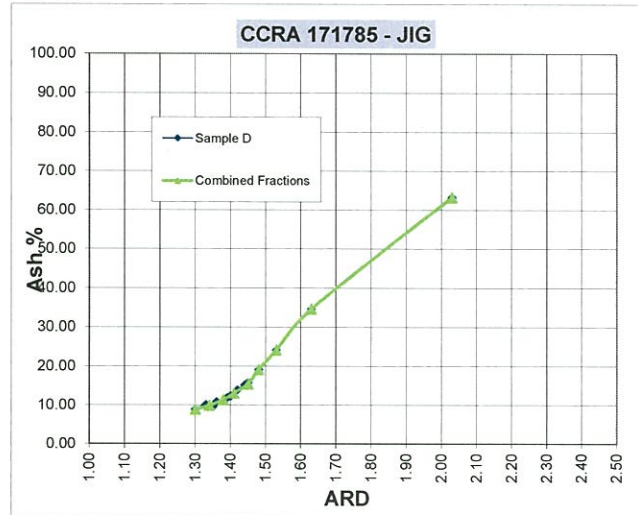
Roben Jig 3 batches of 15.5 Kg	ARD mesh vessel DRY tare	ARD mesh vessel WET tare	Assumed Damp Moisture %					
	0	306	5					
Tray Number	Rotations		Dry Coal mass (g)	Relative Density	ASH %	Mass%	Cum mass %	Cum ASH %
1			11789	2.03	63.32	29.39	100.00	28.93
2			2185	1.63	34.66	5.45	70.61	14.61
3			2032	1.53	24.15	5.07	65.16	12.94
4			1786	1.48	19.15	4.45	60.10	11.99
5,6			2740	1.45	15.48	6.83	55.65	11.42
7,8			4377	1.41	13.10	10.91	48.81	10.85
9,10			5361	1.38	11.42	13.36	37.90	10.20
11,12			6483	1.34	9.89	16.16	24.54	9.54
13			3360	1.30	8.87	8.38	8.38	8.87
			40113.0					

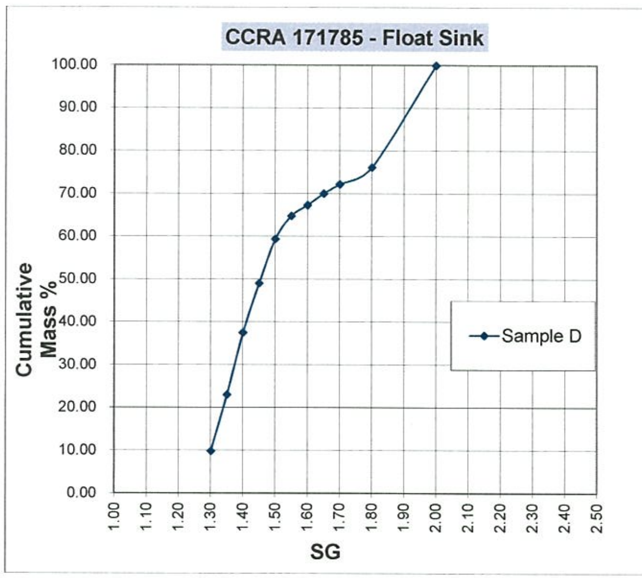
Heather Dexter
Operations Manager
GWIL Industries

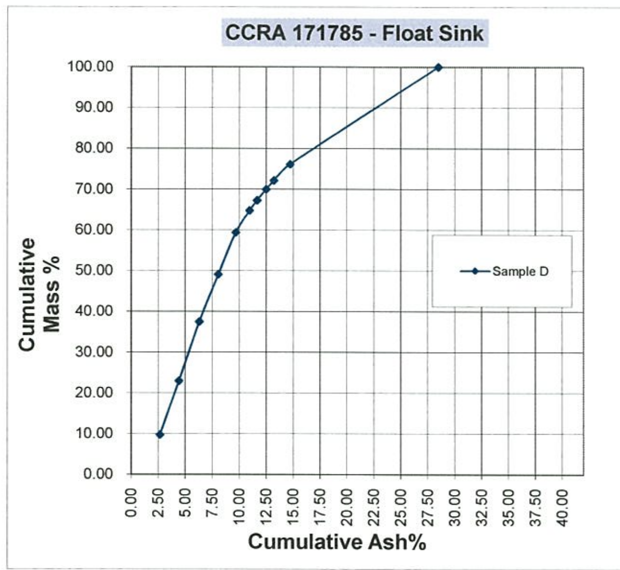
SAMPLE D

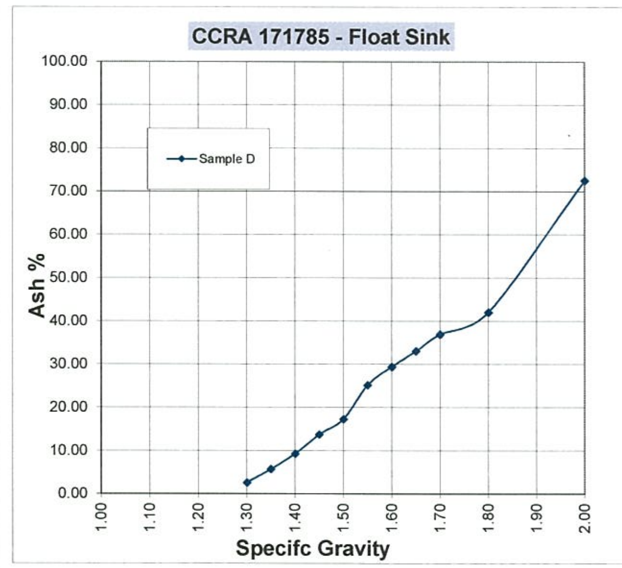

CCRA 171785 - JIG
Cumulative Mass %
ARD
Sample D
Combined fractions


CCRA 171785 - JIG
Cumulative Mass %
Cumulative Ash%
Sample D
Combined Fractions


CCRA 171785 - JIG
Ash %
ARD
Sample D
Combined Fractions


CCRA 171785 - Float Sink
Cumulative Mass %
SG
Sample D


CCRA 171785 - Float Sink
Cumulative Mass %
Cumulative Ash%
Sample D


CCRA 171785 - Float Sink
Ash %
Specifc Gravity
Sample D

GWIL INDUSTRIES Birtley Coal & Minerals Testing Division

Gwil Industries Inc.
7784 - 62nd St SE
Calgary, AB
T2C 5K2
Tel: (403) 253-8273
Email: info@birtley.ca
www.birtley.ca

SAMPLE D

CERTIFICATE OF ANALYSIS

CLIENT: **Canadian Carbonization Research Association**
LAB#: 171785
RECEIVED DATE: June 13, 2017
REPORT DATE: July 5, 2017 Final

Simulated Clean Analysis, air dried basis

ID	MOIST%	ASH%	VOL%	F.C.%	S%	FSI	Cal/g	Cl ppm	F ppm	Hg ppb	HGI	SG	%LT	BASIS
ASTM #	ASTM D3173	ASTM D3174	ASTM D3175		ASTM D4239	ASTM D720	ASTM D5865	ASTM D4208	ASTM D3761	ASTM D6722	ASTM D409	ISO 1014	@ 17mm path ASTM D5263	
SIM FS	1.08	11.04	22.13	65.75	0.30	3.5	-	-	-	-	-	-	-	adb
@ 1.55 SG		11.16	22.37	66.47	0.30									db
SIM JIG	0.89	10.45	22.33	66.33	0.31	4.5	-	-	-	-	-	-	-	adb
@ 1.41 ARD		10.54	22.53	66.93	0.31									db
SIM Froth	1.13	11.48	21.95	65.44	0.32	4.5	-	-	-	-	-	-	-	adb
@ 90 sec		11.61	22.20	66.19	0.32									db
FS CCC	1.05	10.95	22.14	65.86	0.30	3.5	7496	4600	93	53	79	1.39	96.4	adb
		11.07	22.37	66.56	0.30		7576	4649	94	54				db
JIG CCC	0.90	10.85	22.35	65.90	0.31	4.5	7487	962	93	55	78	1.37	96.4	adb
		10.95	22.55	66.50	0.31		7555	971	94	55				db

ULTIMATE ANALYSIS, as received basis (ASTM D5373)

ID	%MOIST.	%C	%H	%N	%S	%ASH	%O b/d	%P in coal db	BASIS
FS CCC	1.05	77.04	4.20	1.18	0.30	10.95	5.28	0.013	arb
		77.86	4.25	1.19	0.30	11.07	5.33		db
JIG CCC	0.90	77.45	4.25	1.21	0.31	10.85	5.03	0.012	arb
		78.15	4.29	1.22	0.31	10.95	5.08		db

GIESELER FLUIDITY TEST (ASTM D2639)

SAMPLE ID	TEMPERATURES °C INITIAL SOFT (1 DDPM)	MAX. FLUIDITY	SOLIDIFI-CATION	RANGE	MAX. DDPM	Date Tested
Sim FS	448	461	488	40	**1.9**	Jun 23
Sim Jig	440	466	490	50	**4.9**	Jun 23
Sim Froth	446	466	489	43	**2.6**	Jun 23
FS CCC	446	462	486	40	**2.0**	Jun 23
Jig CCC	442	465	489	47	**4.3**	Jun 23

RHUR DILATATION (ASTM D5515)

SAMPLE ID	SOFT TEMP	TMCONT.	TMDIL.	%CONT.	%DIL	% TOTAL DIL	%SD 2.5	Date Tested
FS CCC	412	484	-	20	-	-	-	Jun 23
Jig CCC	425	481	-	16	-	-	-	Jun 23

MINERAL ANALYSIS OF ASH (ASTM D3682)

SAMPLE ID	SiO_2	Al_2O_3	TiO_2	CaO	BaO	SrO	Fe_2O_3	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
Sim FS	58.03	25.94	2.11	3.27	0.60	0.10	3.37	1.13	0.77	0.30	0.30	3.00	1.08
Sim Jig	57.63	26.72	2.27	3.05	0.64	0.11	3.07	0.99	0.78	0.45	0.32	2.77	1.20
Sim Froth	57.39	28.53	2.61	2.91	0.59	0.09	2.73	0.93	0.67	0.70	0.20	2.40	0.25
FS CCC	57.24	27.04	2.28	3.05	0.59	0.10	3.30	1.05	0.78	0.39	0.27	2.62	1.29
Jig CCC	57.90	26.68	2.25	3.06	0.59	0.10	3.03	1.03	0.70	0.49	0.26	2.65	1.26

ASH FUSION TEMPERATURES (°C) (ASTM D1857)

SAMPLE ID	REDUCING IDT	ST	HT	FT	OXIDIZING IDT	ST	HT	FT
FS CCC	1446	1487	1503	+1510	1488	1499	1508	+1510
Jig CCC	1456	1496	1510	+1510	1499	+1510	+1510	+1510

FS CCC & Jig CCC sent to SGS-Tianjin June 28, 2017 & Pearson/CANMET June 27, 2017

Heather Dexter
Operations Manager
GWIL Industries

Coal B
Scanning Electron Microscope Visual
Aluminosilicate clay infilling pores of fusinite