

## **A PRELIMINARY COMPARISON OF COAL CLASSIFICATION AND PROCESSING BETWEEN CANADA AND CHINA**

\*Ting Lu, P. Eng. and Gerard Laman

*Tetra Tech, WEI  
555 West Hastings Street  
Vancouver, Canada V6B 1M1  
(\*Corresponding author: [ting.lu@wardrop.com](mailto:ting.lu@wardrop.com))*

### **ABSTRACT**

This document compares the systems of coal classification described under American Society for Testing and Materials (ASTM) standards used in Canada to GB standards used in China. A preliminary connection of metallurgical coal classes was set up between the two classifications. In GB classification system, there are nine metallurgical coal groups, namely PS, SM, JM, FM, ½ ZN, RN, 1/3 JM, and QM used in coal blending for coke production. PS coal is almost equivalent to the Low Volatile Bituminous coal; SM, JM, and FM coal groups fall into Low to Medium Volatile Bituminous range; ½ ZN, RN, 1/3 JM, and QM are equivalent to bituminous coal with medium to high volatile matters; QF contains higher volatile bituminous coal compared with High Volatile Bituminous coal.

The caking properties commonly used in respective country are also compared in this document. These properties include free swelling index (FSI) and maximum fluidity used in Canada, as well as caking index ( $G_{R.L.}$ ), and the maximum plastic layer thickness (Y) mainly employed in China. It has been observed that the log of the maximum fluidity has a stronger correlation with the caking index than the Y values.

Metallurgical coal processing strategy and typical coking coal product qualities are briefly discussed in the last section of this paper. Currently there is a trend to use heavy medium cyclone in both countries. In Canada the conventional two-product cyclone technology is the preferred practice; whereas in China the three-product heavy medium cyclone arrangement is widely used.

### **KEYWORDS**

Coal ranking system comparison, ASTM, GB, caking properties, coal washing strategy

## NOMENCLATURE

ASTM.....	American Society for Testing and Materials
b.....	maximum dilatation
CSN.....	Crucible swelling index number
CSR.....	Coke strength, after reaction
ddpm.....	dial division per minute
dmmf.....	dry mineral matter free basis
FSI.....	free swelling index
f.a.s.....	free alongside ship
GB.....	standard GB/T5751-1986
G. I.....	Roga Index
G <sub>R.I.</sub> .....	caking index
maf.....	moist ash free
Mmf.....	mineral matter free
P.....	phosphorus
Pm.....	transmittance
Qgr.....	gross calorific value
ROM.....	run of mine
S.....	sulphur
Y.....	plastic layer thickness

## **INTRODUCTION**

Coal can be simply classified by applications into two categories: i) thermal coal used to provide heat energy in combustion, and ii) metallurgical coal which is converted to coke, in a carbonization process, and used mainly in the iron and steel industry. Metallurgical coal contains even higher heating values than thermal coal. In addition, it presents unique plastic properties during carbonization which in turn produces a porous solid, high in carbon referred to as coke. Coke is one of the most important raw materials in the iron and steel industry.

About 1.4 tonnes of clean coking coal is required to produce 1 tonne of coke. Each tonne of crude steel production normally requires about 0.5 to 0.6 tonnes of coke as the reducing agent, the heating source, and material support in blast furnace. It was estimated that about 70% of steel is produced by using blast furnace technology. The remaining steel is produced by recycling steel in electric arc furnaces (World Coal Association, 2011).

The metallurgical coal selling price has been increasing significantly since 1996. The data from Energy Information Administration of the US Department of Energy shows that the average price was US\$46/ton (short) in the first quarter of 1996, which reached a peak value of US\$156/ton (short) at the end of 2008. The price dropped to US\$ 111/ton (short) in the 3<sup>rd</sup> quarter of 2009 due to the economy slowing down. Currently, the price was about US\$170/ton (short) in the 1<sup>st</sup> quarter of 2011. All the prices mentioned above are on the f.a.s. basis (free alongside ship).

Recently, metallurgical coal property acquisitions have been active, driven by the attractive selling price and the positive prediction on steel market. Some differences in coal classification systems and major metallurgical properties are noticed in our work. This paper tries to present the differences and equivalences in the two systems, as well as the major metallurgical coal quality parameters. A typical coking coal blending requirement in China is also presented. The last section in this paper compares varied coal washing strategies used in Canada and in China.

## **COAL CLASSIFICATION BY RANK COMPARISON**

The coal classification employed in Canada is the ASTM ranking system that is based on the fixed carbon, and calorific value on the dry mineral matter free basis (dmmf). This system was adopted in 1938 and is a general guideline to classify different coal ranks. Table 1 lists coal rank classification under ASTM standard. Bituminous class is the only coal group used for the metallurgical coal purpose. It is primarily classified into three types by the varied volatile matter, including Low Volatile Bituminous, Medium Volatile Bituminous, and High Volatile Bituminous coal. The High Volatile Bituminous coal is further classified into A, B, and C levels, with a descending heating value on a moisture mineral matter free basis (mmf).

Table 1 - Classification of coal by rank (ASTM D-388)

Coal Rank	Volatile Content	Gross Calorific Value Limits		Agglomerating Characteristics
	%	Btu/ lb	MJ/kg	
	dmmf	moisture mmf	moisture mmf	
I. Anthracites Class				Non-agglomerating
Meta-Anthracit	< 2%			
Anthracite	2 to 8%			
Semi-Anthracite (Lean Coal)	8 to 14%			
II Bituminous				Commonly agglomerating
Low Volatile Bituminous	14 to 22%			
Medium Volatile Bituminous	22 to 31%			
High Volatile A Bituminous	> 31%	≥ 14,000	≥ 32.6	
High Volatile B Bituminous	>31%	13,000 to 14,000	30.2 to 32.6	
High Volatile C Bituminous	>31%	10,500 to 13,000	24.4 to 30.2	
III Subbituminous				Non-agglomerating
Subbituminous A Coal		10,500 to 11,500	24.4 to 26.7	
Subbituminous B Coal		9,500 to 10,500	22.1 to 24.4	
Subbituminous C Coal		8,300 to 9,500	19.3 to 22.1	
IV Lignite				Non-agglomerating
Lignite A		6,300 to 8,300	14.7 to 19.3	
Lignite B		< 6,300	< 14.7	

The classification of Chinese coal is defined by national standard GB/T5751-1986 (GB) which is shown in Table 2. There are nine bituminous coal types presenting caking properties, including PS, SM, JM, 1/3JM, FM, QF, QM, 1/2ZN and RN. In addition to the volatile matter values, GB employs three caking properties to distinguish the different bituminous coal types. These caking properties include caking index ( $G_{R,L}$ ) which is modified from Roga Index (ISO335-1974), maximum thickness of plastic layers (Y, mm), and maximum dilatation (b, %). The gross moist ash free (maf) basis calorific value (Qgr, maf) and transmittance (Pm) are only used to classify lignite coal types.

Table 2 - Classification of Chinese coals (GB/T5751-1986)

Class	Group	Vdaf %	G <sub>R,I</sub>	Y mm	b %	Pm %	Qgr, maf MJ/kg
Anthracites	WY-01	≤3.5					
	WY-02	3.5 to 6.5					
	WY-03	6.5 to 10					
Bituminous	PM	10 to 20	≤5				
	PS	10 to 20	5 to 20				
	SM	10 to 28	20 to 65				
	JM	10 to 28	50 to 65	≤25	≤150		
	1/3 JM	28 to 37	>65	≤25	≤220		
	FM	10 to 37	>85	>25	>150		
	QF	>37	>85	>25	>220		
	QM	28 to 37	35 to 65	≤25	≤220		
	1/2ZN	20 to 37	30 to 50				
	RN	20 to 37	5 to 30				
	BN	20 to 37	≤5				
	CY	>37	≤5			>50	
Lignite	HM1	>37				≤30	
	HM2	>37				30 to 50	≤23.9

The dry volatile matter content of metallurgical coal types in the two classification systems are compared in Figure 1. A general connection between GB and ASTM coal classification can be made, that is PS coal is equivalent to the Low Volatile Bituminous coal; SM, JM, and FM coal seem belong to Low and Medium Volatile Bituminous coal; 1/2 ZN, RN, 1/3 JM, and QM are equivalent to the Medium to High Volatile Bituminous coal; QF contains higher volatile matter than High Volatile Bituminous coal.

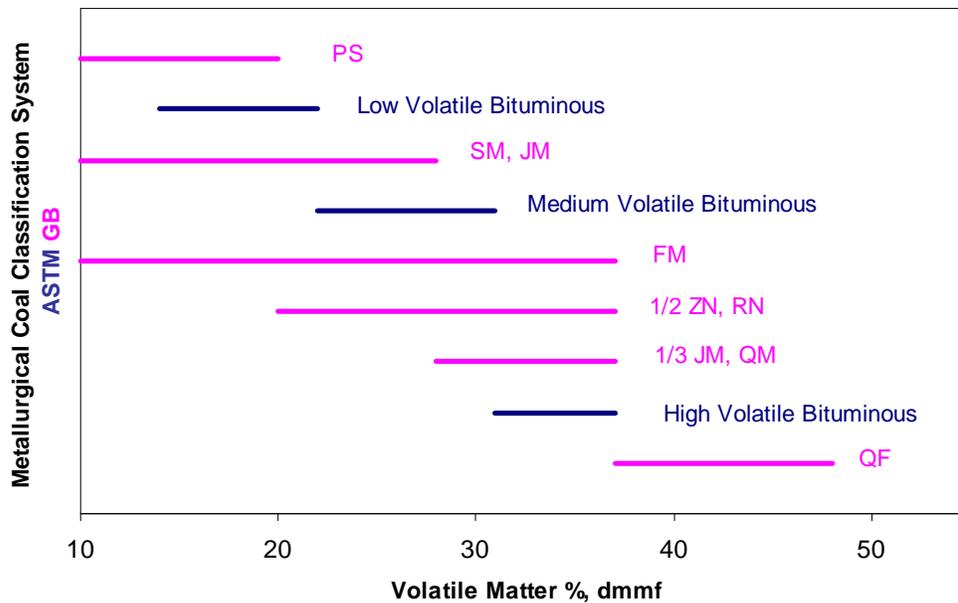


Figure 1 – Comparison of ASTM and GB bituminous coal classification

GB metallurgical coal presents a wider range of volatile matter than ASTM metallurgical coal. For example, FM has a volatile matter from 10 to 37%, dmmf; both SM and JM contain about 10 to 28% volatile matter, dmmf. This high variation range of the volatile matter indicates a potentially high fluctuation of the metallurgical coal quality in the respective group. This also indicates the other caking parameters should be employed to further classify the GB metallurgical coal groups. This will be discussed in the next section.

## METALLURGICAL COAL QUALITY REQUIREMENTS

The modern blast furnace requires high quality coke to be generated from high quality metallurgical coal in terms of chemical elements, ash content, moisture, caking properties, and strength.

### Chemical Elements, Ash and Moisture

The most important chemical elements of the coking coal consist of sulphur (S) and phosphorus (P), and alkalis (Na, K). These properties, as well as ash and moisture, should be controlled due to the significant impact on the steel making process. Most sulphur in coal will transfer to coke and will affect the iron/steel quality. Although it can be removed in the iron making process but the cost is much higher. Ash content will be transferred from coal to coke and affect the slag production and steel quality. The impact of alkali elements will reduce the coke strength and attack the refractory bricks in blast furnace. Most blast furnace operations desire 7 to 9% ash, and 0.65 to 0.85% sulphur, and 0.03 to 0.06% phosphorous, and 0.2 to 0.4% alkali contents (Wozek & Ricketts, 1994).

### Caking Properties

Parameters used to evaluate caking properties can be classified in three major aspects: i) parameters describe quantity and quality of liquid matter in coking process, including maximum plastic layer thickness, maximum fluidity, and maximum dilatation; ii) parameters focus on coke profiles and geometry, such as FSI, Grey-King index, Crucible swelling index number (CSN); iii) parameters regarding the coal caking ability to combine inertinite matter, including Roga Index (G. I.).

Regarding parameter FSI, maximum fluidity, maximum dilatation are preferred in North America, while caking index, maximum plastic layer thickness, and maximum dilatation are normally used in the Chinese system. FSI, caking index, maximum fluidity, and maximum plastic layer thickness will be discussed in the following descriptions.

### FSI

FSI is the simplest method that preliminarily evaluates a coal caking property. The produced coke button after combustion will be visually compared with the standard profiles. A number between 0 and 9 is assigned (ASTM D-720) to describe the different profiles. Some typical FSI values are shown in Table 3. Clean coking coal produced at northeast and southeast mines in BC have FSI values typically between 6 and 8 (Griev, Holuszko, & Goodani, 1996).

Table 3 - Typical FSI values

Coal Type	FSI
Non-caking	0
Weakly -Caking	1 to 2
Medium-Caking	2 to 4
Strong-Caking	4 to 9

### Caking Index ( $G_{R.I.}$ )

Caking index is one of the most widely used parameters to evaluate the coal caking ability in China (GB5447-85). The caking index is modified from Roga index by changing the particle size of standard anthracites sample from 0.1 to 0.2 mm, and reducing the tumbling test numbers from 3 times to twice (Zhong et al, 1988). In addition, the coal blending ration between the tested sample and standard sample has been modified for weakly caking coal which has a  $G_{R.I.}$  lower than 18. The application of caking index can facilitate in the classification of high rank caking coal with a Roga Index (R. I.) over 80. Table 4 compares typical  $G_{R.I.}$  and R. I. values.

Table 4 - Typical  $G_{R.I.}$  and R. I. of Chinese metallurgical coal (Gong, 2004 & Zhong 1988)

Coal Type	PS	SM	JM	1/3 JM	FM	QF	QM	½ ZN	RN
R. I.	-	10 to 60	60 to 85	-	80 to 92	-	15 to 90	-	10 to 40
$G_{R.I.}$	5 to 20	20 to 65	>50	>65	>85	>85	35 to 65	30 to 50	5 to 30

### Maximum Fluidity and Maximum Plastic Layer Thickness

Both the maximum fluidity and maximum plastic layer thickness are parameters related with the plastic phase in coking process. These are used to predict the caking ability of the tested coal samples. The maximum fluidity is widely accepted in North American and Australia; while the maximum plastic layer thickness is more familiar in China.

#### Maximum Fluidity

By ASTM standard, the maximum fluidity is measured on the heated fine coal sample (< 0.5 mm) at a controlled heating rate, in which a paddle under a constant torque is inserted. The paddle starts to rotate as the coal sample softens. The speed of paddle rotation is recorded in the unit of dial division per minute (ddpm), together with the temperatures (ASTM D2639).

The log values of measured maximum fluidity are found in a linear correlation with vitrinite reflectance by researchers. Grieve et al in 1996 reported a linear relationship with  $r^2 = 0.6$  on the run of mine (ROM) coal samples (Grieve, Holuszko, & Goodani, 1996). Typical mean fluidity values of BC coking coal are abstracted from the report and listed in Table 5. The Northeast BC coalfield is the Peace River coalfield, consisting of three major economic coal formations, Mines Group, Gething Formation, and Gates Formation. The east Kootenay coalfield in the Southeast BC is composed of three coalfields, including Elk Valley, Crowsnest and Flathead coalfields.

Table 5 - Typical fluidity of BC ROM coking coal

Coalfield /Formation	Initial Softening Temperature °C	Fluidity Max, Temperature °C	Resolidification Temperature °C	Fluidity Temperature Range °C	Max Fluidity ddpm
Northeast BC/Gates	421.5	461	493	71	440.4
Southeast BC	437.5	467	493	55.5	192.8

#### Maximum Plastic Layer Thickness

The maximum plastic layer thickness is measured from Sapozhnikov test procedure proposed in 1932 (GB/T429). In addition to the maximum thickness, the final drop of the expansion-pressure curve X value and the volume curve are also produced from the test (Zhong et al, 1988). In the test, the coal sample is heated at a controlled rate to simulate the coking process. As the temperature gradually increases,

different iso-temperature surfaces will form in the container. The maximum plastic layer thickness is measured manually via a probe inserted into the sample. At the end of the test, when the plastic material becomes “semi-coke”, the sample will contract and the reduced vertical distance of the coal sample is recorded as an X value. In the presence of a liquid phase, the coal sample volume is also recorded in the test which is referred to as a volume curve.

The plastic layer thickness of some typical prime coking coal (JM, 1/3 JM, and FM) are shown in Figure 2, based on the data published by major coking producers in China (Gong, 2004).

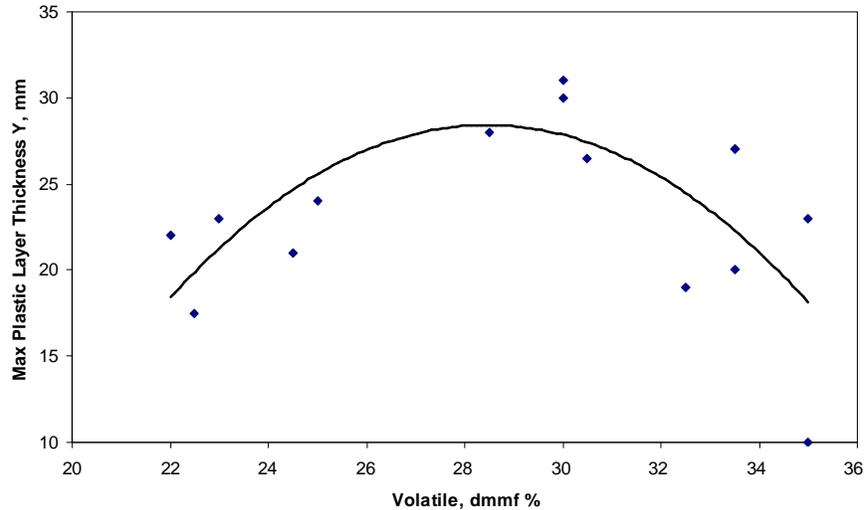


Figure 2 - Volatile and maximum plastic layer thickness of typical prime coking coal in China

#### Correlation between Fluidity and Plastic Layer Thickness

The plastic layer thickness describes the quantity of the plastic matter, while fluidity is focused on the flow-ability of the liquid. There are some connections between the two parameters, as the vitrinite contents in coal samples are the major contributor of the liquid production.

Chen tested caking properties of more than 400 bituminous coal samples from China and made statistical analysis on the results (Chen, 1985). Table 6 is adapted from the reference paper. It is found that a correlation factor of 0.66 between the maximum plastic layer thickness and the log of maximum fluidity. The caking indices ( $G_{R.I.}$  and R. I.) present a stronger correlation with log of the maximum fluidity with a correlation coefficient of 0.86 for  $G_{R.I.}$  and 0.87 for R. I. value. It seems the maximum fluidity is more related with caking index rather than the maximum plastic layer thickness.

Table 6 - Correlation coefficient between indices of cohesiveness of coal

	$G_{R.I.}$	R. I.	C.S.N.	G.K.	Y	b	Log $\alpha_{max}$
$G_{R.I.}$	1.00	0.98	0.78	0.94	0.83	0.73	0.86
R. I.	0.98	1.00	0.77	0.91	0.80	0.69	0.87
C.S.N.	0.78	0.77	1.00	0.80	0.63	0.58	0.37
G.K.	0.94	0.91	0.80	1.00	0.86	0.83	0.88
Y	0.83	0.80	0.63	0.86	1.00	0.92	0.66
b	0.73	0.70	0.58	0.83	0.92	1.00	0.76
Log $\alpha_{max}$	0.86	0.87	0.37	0.88	0.66	0.76	1.00

### Maximum Dilation (b. %)

This parameter is both widely used in North America (ASTM D-5515) and in China (GB/T5450). The coal sample is prepared by fine grinding to minus 0.25 mm (60 mesh), and then pressed to form a 60 mm thick cylinder. The coal sample is then placed in a calibrated tube with a graduated piston on top. The tube is heated in a furnace at a controlled rate of 3 °C/minute from 330 to 600 °C. The movement of the piston is recorded as the percentage of the total of original coal cylinder length, as well as the correlated temperature.

### Coking Coal Strength

The strength of the cake produced from metallurgical coal is used to evaluate the coking coal quality and also to measure the coke performance in the blast furnace. Coke strength, after reaction with CO<sub>2</sub> (CSR), and tumbler tests are normal means in the evaluation. Considering the major purpose of this paper, coke strength will not be discussed. Further reading is recommended for readers who are interested in this topic.

## **COKING COAL BLENDING IN CHINA**

Coking coal blending is made by blending the premium coking coal with the inferior quality coking coal. Depending on the required coke specification in the subsequent application, different cokes can be produced of varied strength and porosity. The prime coking coal used, as the blending basis, in China includes JM, FM, and 1/3 JM. These coal types are normally blended at a ratio between 20 and 30% by weight. The ratio of the base coking coal in China is not high with an estimated value of 35%, and the contained sulphur can be high which in some cases is difficult to be removed effectively using conventional coal washing technologies. These factors determine that high quality coking coal will be in a high demand from the iron and steel industry in China. Typical requirements for blended coking coal in China are listed in Table 7.

Table 7 - Typical blended coal property requirements

Description	Ash %	Total S %	Volatile Matter %	Y mm
Coking Coal Property	<10	<1	25 to 30	15 to 20

Proximate analysis, petrographic analysis, determination of the total sulphur, and the caking property related measurements are four major aspects in determining the blending ratios. Coke producers will determine the specific blending ratios based on the coking coal quality and respective cost, the employed coking technology, and the required coke properties by different markets.

## **METALLURGICAL COAL PROCESSING COMPARISON**

### **Canada**

Canada is a metallurgical coal exporting country. The current major market is in the Pacific-Asia area where Japan, South Korea, China, and Taiwan are the top four clients. Except for year 2009, Canada exported about 27 million tonnes of metallurgical coal every year since 2007 to 2010. The exportation rate in 2009 was 21 million tonnes. The metallurgical coal resource in Canada is mainly in Western Canada. Most metallurgical coal resources are located in the Rocky Mountains and foothills of British Columbia and Alberta. Quality parameters of some typical clean coal products of Fording River Coal Mine (2006) and of Coal Mountain Mine (2006) are shown in Table 8.

Table 8 - Clean coal product quality in Rocky Mountain area

Coal Quality	Fording River Coal Mine (2006)		Coal Mountain Mine (2006)	
	Soft Coking Coal	Hard Coking Coal	Soft Coking Coal	Thermal Coal
Ash, %	9.0 to 11.0	6.0	10.0 to 11.5	15.0 to 17.0
Calorific Value, MJ/kg	29.3 to 33.5	32.4	29.3 to 31.0	26.0 to 28.0
Volatile Matter, %	22.0 to 24.0	26.7 to 29.4	21.0 to 23.0	21.0 to 23.0
Sulphur, %	0.6 to 0.7	0.6 to 0.65	0.3 to 0.4	0.3 to 0.5

It has been widely recognized that the metallurgical coal fines should be recovered as long as the economic benefit can cover the extra flotation circuit and subsequent dewatering process. The typical coal washing separation in Canada is shown in Table 9. Heavy medium separation is common in coal washing plants as it is easy to adjust the separation density for the different qualities of raw coal material.

Table 9 - Typical metallurgical coal separation in Canada

	Coarse Coal Separation	Small Coal Separation	Fine Coal Separation
Typical Size Distribution			30 to 35%
Particle Size Range	100 mm x 1.0 mm	1.0 mm x 0.2 mm	0.2 mm x 0
Equipment	Heavy Medium Vessels/ Heavy Medium Cyclone	Spiral Concentrators	Flotation
Mechanical Dewatering	Dewatering Screen/Centrifuge	Centrifuge/Screenbowl	Screenbowl
Thermal Drying	Required for clean coal product		

Recently, large diameter heavy medium cyclone with over 1 m diameter applications have gradually replaced the heavy medium vessel/bath, and become a dominant practice thanks to large cyclones over 1 m in diameter. However, there are still some debates regarding the high capacity, heavy medium cyclone versus the traditional heavy medium vessel/bath technology. One of the concerns with the large cyclone is the reduced separation efficiency due to the large size distribution of the raw coal material (Meenan, 2010). This issue can be solved for example by taking a two-stage heavy medium cyclone circuit that will produce three products: clean coal, middlings, and refuse. However, due to the market limits in Canada, the middlings are rarely produced. In this case, a practical solution is to reduce the raw coal top particle size to 50 mm which is a normal practice in Canada.

The high portion of fine coal (minus 0.5 mm) over 30% by weight in Western Canada and the cold weather require the application of further drying of the mechanical dewatered clean coal product.

## China

China has 15% of the metallurgical coal resource (including anthracite) in the world (World Energy Council, 2010). The metallurgical coal distribution in China is in Shanxi province which contains over 50% metallurgical coal. Although metallurgical coal production in China was more than 1.1 billion tonnes in 2009 and 2010, respectively, China is an importing country of metallurgical coal. Australia, Mongolia, Canada, Russia, and Indonesia are the top five countries which exported about 42.8 million tonnes of coking coal in 2010. Some clean coal qualities of prime coking coal in China are listed in Table 10. As a comparison with that in Canada, the sulphur content is higher.

Table 10 - Clean coal product quality in Shanxi Province area (Gong, 2004)

Coal Quality	Huozhou Coal Electricity Group (2004)		
	JM	FM	1/3 JM
Ash %, dry	9.51 to 11.0	9.01 to 11	8.51 to 10.5
Calorific Value, Q <sub>net, ar</sub> , MJ/kg	27.7 to 28.1	27.6 to 28	27.8 to 28.2
Volatile Matter %, daf	25 to 28	30 to 37	30 to 37
Water %, total	<9	<9	<9
Sulphur %, total, dry	≤0.8	≤1.0	≤1.0

Heavy media separation is also the major operation of choice in China which has been employed in most newly built coal preparation plants (Wang et al, 2011), jigging is still found in places in coarse raw coal circuit (from 100 x 25 mm, or 50 x 13 mm) but is generally used for thermal coal processing. Table 11 summarizes the typical metallurgical coal washing practice in China.

Table 11 - Typical metallurgical coal separation in China (Wang et al, 2011)

	Coarse Coal Separation	Small Coal Separation	Fine Coal Separation
Typical Size Distribution			30 to 35%
Particle Size Range	100 mm x 25 mm or 50 mm x 13 mm	25 mm x 0.5 mm or 13 mm x 0.5 mm	0.5 x 0 mm
Equipment	Jigging or Heavy Medium Vessel	Heavy Medium Cyclone	Flotation Column
Mechanical Dewatering	Dewatering Screen plus Centrifuge	Dewatering Screen plus Centrifuge	Pressure Filters
Thermal Drying	Required for clean coal product in area with coal climate		

The heavy medium cyclone technology in Table 11 is the traditional 2-product cyclone arrangement. Recently, the three-product heavy medium cyclone technology has been used widely from easy to difficult coal washability situations. The middling product will be generated by using this strategy. Although having ash content higher than the clean coal product, in some cases middlings can be used to blend with the final clean coal product based on the final product requirement. The feed particle size for a 3-product heavy medium cyclone arrangement can be as coarse as 100 mm for both gravity-fed and pumping-fed conditions.

The arrangements of pressure-fed and gravity-fed systems of a typical three-product heavy medium cyclone are shown in Figure 3. When the feed material of the coal washing plant is low in coal fines and so no desliming is required, the gravity-fed three-product cyclone circuit is preferred due to the benefits of reducing coal slime generation in the pumping process and reduced processing stages. As reported by Zhao in 2007, about 215 coal washing plants in design considered the gravity-fed three-product cyclone strategy, which reduced the processing stages to 20 to 24 while the conventional circuit will have over 30 operation stages.

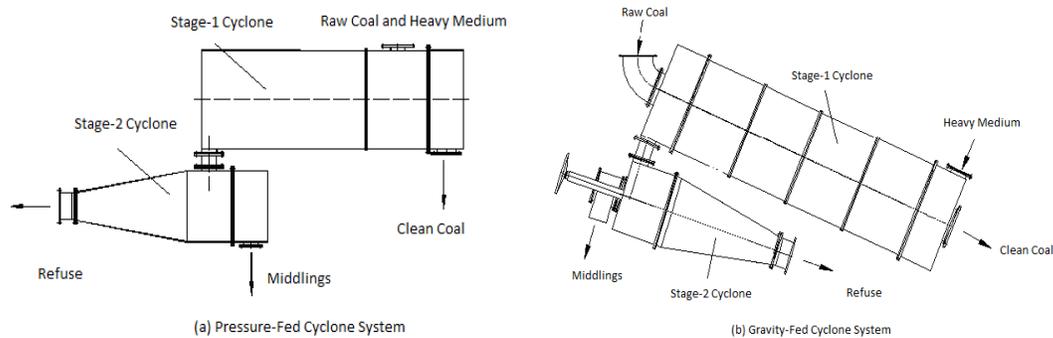


Figure 3 - Three-Product heavy medium cyclone (a) pressure-fed cyclone system (b) gravity-fed cyclone system (Zhao, 2007)

## CONCLUSIONS

This paper compares the coal classification systems employed in North America and in China. A preliminary connection was set up between the coking coal classifications in both systems. PS coal is almost equivalent to the Low Volatile Bituminous coal; SM, JM, and FM coal seems to belong to Low and Medium Volatile Bituminous coal;  $\frac{1}{2}$  ZN, RN,  $\frac{1}{3}$  JM, and QM is similar to the Medium to High Volatile Bituminous coal; QF has higher volatile bituminous coal than High Volatile Bituminous coal.

The Chinese GB system employs other caking properties in metallurgical coal ranking in addition to the volatile matter, and heating values which are the basis of ASTM classification. These caking properties consist of caking index, maximum plastic layer thickness, and maximum dilation. As a comparison, parameters used in Canada are presented including free swelling index, maximum fluidity, and maximum dilation as well. It was observed that caking index under the GB system, is more related to the maximum fluidity.

The metallurgical coal washing strategy is compared in Canada and in China. Heavy medium separations, especially the heavy medium cyclones have been widely used in both countries. However, due to the coal washability properties, and the active coal middling market in China, three-product-cyclone technology is used in many plants. In Canada, the process is realized by using traditional two-product cyclones.

## REFERENCES

- Chen Peng (1985). The Prediction of The Quality of Coke by the Use of Vr - G Diagrams. Industrial & engineering chemistry product research and development , Volume 24, pp. 207-212.
- Coal Mountain Mine, product information (2006)
- Fording River Coal Mine, product information (2006)
- Gong Xuegang (2004). Coal Trading Manual. Beijing, P. R. China: Coal Industry Press.
- Grieve. G. A., Holuszko M.E. , & Goodani F.(1996). British Columbia Coal Quality Survey. Victoria, BC: Ministry of Employment and Investment, Energy and Minerals Division, Geological survey branch.
- Meenan Gary (2010). Current Coal Processing at Consol Energy. International Coal Preparation Congress (pp. 18-23). Littleton, Colorado, USA: SME.

Wang Guangde, Rick Honaker, & Maoming Fa (2011). Coal Preparation Practices and Trends in China. CPSA Journal, Volume 10, No.1 pp. 12-15.

World Coal Association, Coal and Steel Statistics (2011).

World Energy Council, Survey of Energy Resources (2010).

Wozek J.S. & Ricketts J.A. (1994). Metallurgical coal quality - a customer's perspective. SME annual meeting presentation reprint (pp. 1-25), Albuquerque, New Mexico.

Zhao Shuyan (2007). Coal Washing Technology Development in China and Three-Product Heavy Medium Cyclone Concentrators. Tangshan Dehua Science & Technology Inc.

Zhong Yunying, Guan Mengbin, Cui Kairen, & Wang Huizhong (1988). Coal Chemistry. Jiangsu Province, P. R. China: China University of Mining and Technology Press.