



Low Volatile

JELLINBAH SEMI SOFT COKING COAL

- An alternative coal for coke blending

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1 INTRODUCTION

The task of selecting coals for coke making has become increasingly more technical worldwide. The Brazilian Steel Mills (BSM) have followed this trend since the 1980's and have well established procedures for selecting and evaluating coals. Indicative of such a technical trend is the permanent improvement of the blend selection models which currently account for pressure development during carbonisation and the more recent utilisation of soft/semi soft coking coals under conventional coke making. They also emphasise the relevant parameters that influence blast furnace performance such as Coke Strength after Reaction (CSR).

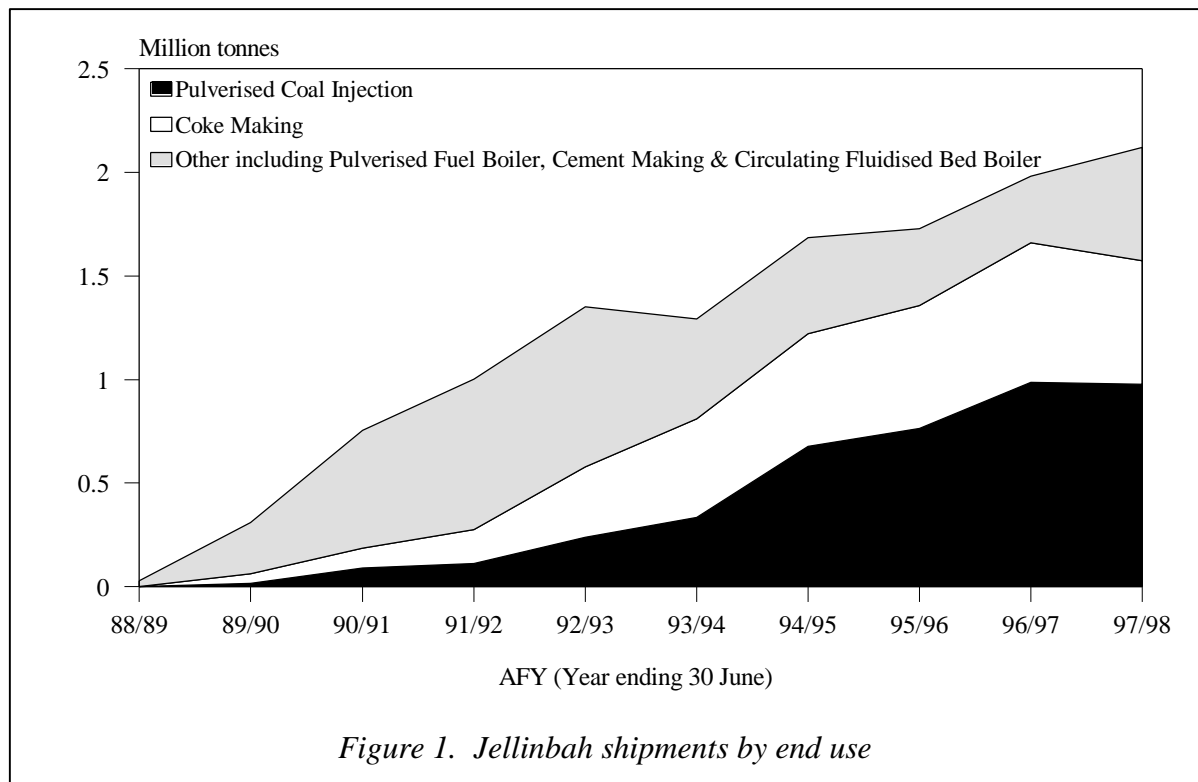
Due to this more stringent approach, traditional concepts were challenged such as the well-known Schapiro & Gray model developed in the early seventies which proved to underestimate the contribution of Australian and Canadian coals to coke quality. This model was based on Appalachian "well-behaved" coals and, for this reason, coals of the type of Jellinbah East (JE) were considered unsuitable for blending and were left aside for many years by the coke makers.

As globalisation forced the steel mills to minimise the cost of their products to compete in world markets, coke makers started to look for weaker coals to be added to their blends.

Since the late 1980's, Jellinbah Resources Pty Ltd (*formerly Advance Queensland Resources & Mining Pty Ltd) have realised the potential of low volatile Australian coals of minimum caking properties as feasible components of blends for coke making. The Jellinbah East (JE) project was started in early 1989, and faced the challenge of proving its ability to replace part of the US Low Volatile coals in conventional blends with no major technical effect on coke quality, but bringing about significant cost advantage. Figure 1 illustrates the increasing sales of JE and its end-use distribution.

Brazilian Steel Mills are very successful in using JE in coke oven blends, up to 16%, as will be later shown in this report which is aimed at sharing this Brazilian experience.

* Advance Queensland Resources & Mining Pty Ltd changed its name to Jellinbah Resources Pty Ltd effective 2 December 1998.



2 THE AUTHOR

Jorge G Caldeira, metallurgical engineer, M.S. in Coal Science from Pennsylvania State University, USA, 12 years of research and laboratory work at the Brazilian National Steel Company - CSN, 4 years as General Manager of Coke Making Operations at CSN and recently 5 years as independent Consultant.

3 THE LABORATORY

Both the bench scale and the pilot oven testing were carried out during the first half of 1998 at the R&D Centre of USIMINAS - Usinas Siderúrgicas de Minas Gerais, the second largest of the BSM.

Jellinbah Resources acknowledges the efforts of Mr Murilo Botelho Ulhoa and Mr Gilson Correa, USIMINAS researchers, for their efforts in the accomplishment of the tests.

4 INDUSTRIAL DATA

The data reported on the utilisation of Jellinbah in actual industrial blends was obtained as feedback information from various visits to the BSM. At their request, the names of the individual coals used and the specific mills where the blends were indeed utilised are not disclosed.

5 EXPERIMENTAL

JELLINBAH RESOURCES and USIMINAS selected the individual coals to be tested in mutual agreement based on the shipping schedule for the first quarter of 1998. As is usual practice the coals were received at Praia Mole Port, Vitoria, Brazil and railed some 350 km to Ipatinga, Minas Gerais State, where the mill is located. They were stored at the yard under normal conditions. The selection comprised:

- 2 High Volatile¹ American hard coking coals (HV US 1 & 2);
- 2 Medium Volatile American hard coking coals (MV US 1 & 2);
- 1 Medium Volatile Australian hard coking coals (MV AU);
- 1 Low Volatile American hard coking coals (LV US1), and
- **Jellinbah** (JE) as a second Low Volatile coal.

These coals were sampled, riffled, prepared and carefully stored in separate drums under water to prevent oxidation through the whole process. Representative samples were then taken and split as shown in Figure 2 for full characterisation testing. Standard methods employed at USIMINAS as indicated in Appendix 1 were used for testing.

¹ For the purposes of this report the coal is classified as follows: High Volatile > 31% VM (dry), Medium Volatile 22-31% VM and Low Volatile 14-22% VM.

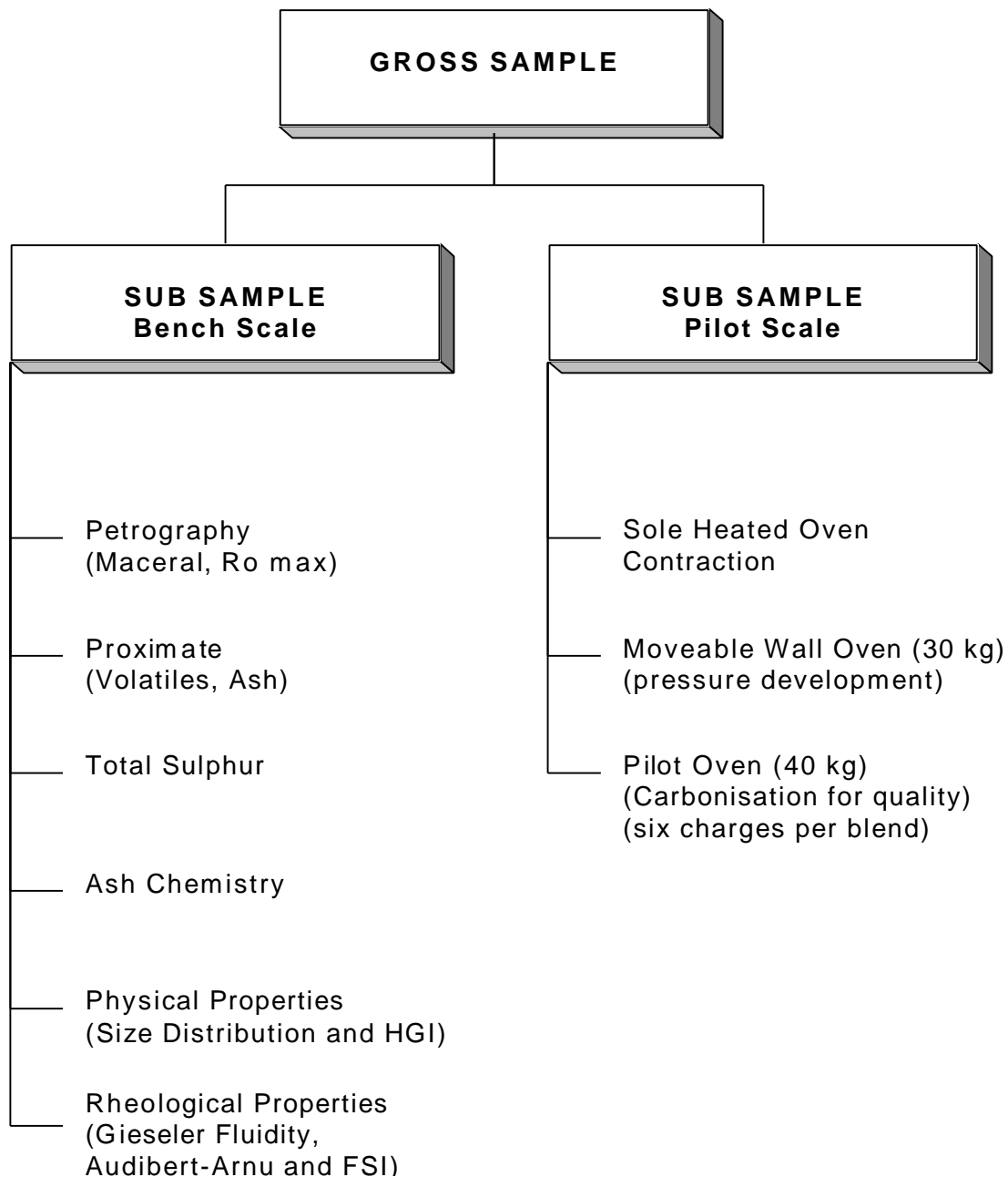


Figure 2. Splitting of gross coal sample

Procedures for measuring pressure development by the movable wall oven and for carbonisation testing for quality are described in Tables 1 and 2. Table 3 describes the procedure for coke microscopy whereas Figure 3 shows the procedure for splitting the coke sample.

Considering that carbonisation of Jellinbah by itself (100% JE) did not yield a coherent coke mass, a procedure of successive blending was developed to assess its Coke Reactivity Index (CRI) and Strength after Reaction (CSR), as described in Appendix II.

As this report is also aimed at customers outside of Brazil, coke strength is also reported as Micum, according to the method for progressive tumbling in the Extended ½ Micum Test in use at Teesside Laboratories of British Steel PLC, whose procedure is described in Appendix IV.

Movable Wall Oven (Pressure Development)	Electrically heated oven built by USIMINAS <ul style="list-style-type: none"> - Capacity: 30 kg - Inner Volume: 0.036 m³ - Max. pressure: 6 psi (40 kPa approx)
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Table 1. Standard procedure for carbonisation pressure determination

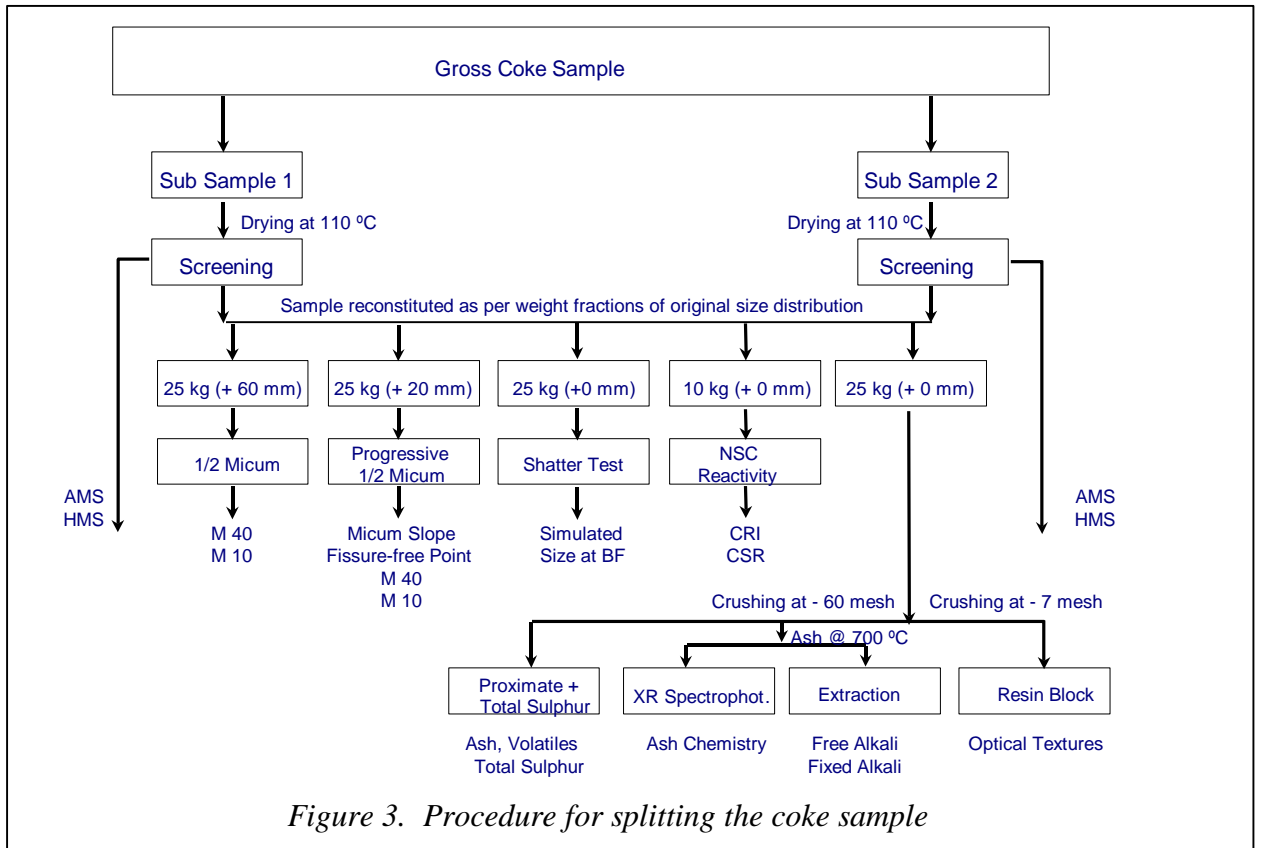
Pilot Oven (Quality Determination)	Electrically heated oven built by USIMINAS <ul style="list-style-type: none"> - Capacity: 40 kg - Inner Volume: 0.054 m³ - Heating Wall Temperature: 1,050°C - Charging Moisture: 6% - Bulk Density: 740 kg/m³. Charge is prepacked into a steel box to the required density. - Coking time: Until centre temperature reached 950°C plus 2 hours soaking at same temperature - Wet quenching - Sole and top portions were discarded. - 6 charges were carbonised under same conditions and numbered from 1 to 6 to produce a total 240 kg of coke. - Standard procedure simulates average conditions of a 4m high, 400 mm wide industrial oven. - Coke pretreatment was carried out to stabilise it before further testing by allowing for 3 drops from standard height (Shatter Test apparatus).
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Table 2. Standard procedure for pilot oven (quality purposes)

Type	Maceral Precursor		Description
Non-Fused Isotropic	Ro >0.80% (Vitrinites)	Inf	Parent Vitrinite does not fuse and keep original sharp edges.
Fused Isotropic	0.80<Ro<0.90% (Vitrinites)	If	Parent Vitrinite does fuse. Edges suggest some softening. Porous matrix.
Fine-Size Mosaic	0.90<Ro<1.10% (Vitrinites)	Mf	Fused vitrinite; grain $\phi < 2.0 \mu\text{m}$. Mesophase formation process.
Coarse-Size Mosaic	1.10<Ro<1.55% (Vitrinites)	Mc	Fused vitrinite; grain $\phi > 2.0 \mu\text{m}$. Oriented mosaic included. Mesophase formation process.
Flow-Type	1.55<Ro<1.85% (Vitrinites)	F	Fibers (width < 10 μm); Bands (width > 10 μm). Looks like a flowing fluid; strong anisotropy. Mesophase formation process.
Basic Anisotropy	Ro > 1.75% (Vitrinites)	BA	Non-fused. Anisotropy is peculiar to the original vitrinite.
Isotropic Inert	Fusinites (inertodetrinites), Non-fused semi - fusinite	I	Isotropic upon rotation of microscope stage.
Anisotropic Inert	Fused semi-fusinites, micrinites.	AI	Strong anisotropy upon rotation of microscope stage.
Pyrolytic Carbon	Pure carbon ex cracking of volatiles	C	Very anisotropic and colourful appearance. Typical of over heating in industrial ovens.
Inorganic Inclusion	Ex mineral matter	II	
Additives		Ad	Charcoal, pet coke, coke breeze or any other material added to the blend.

Zeiss Polarised Light Microscope - 400 times Magnification.

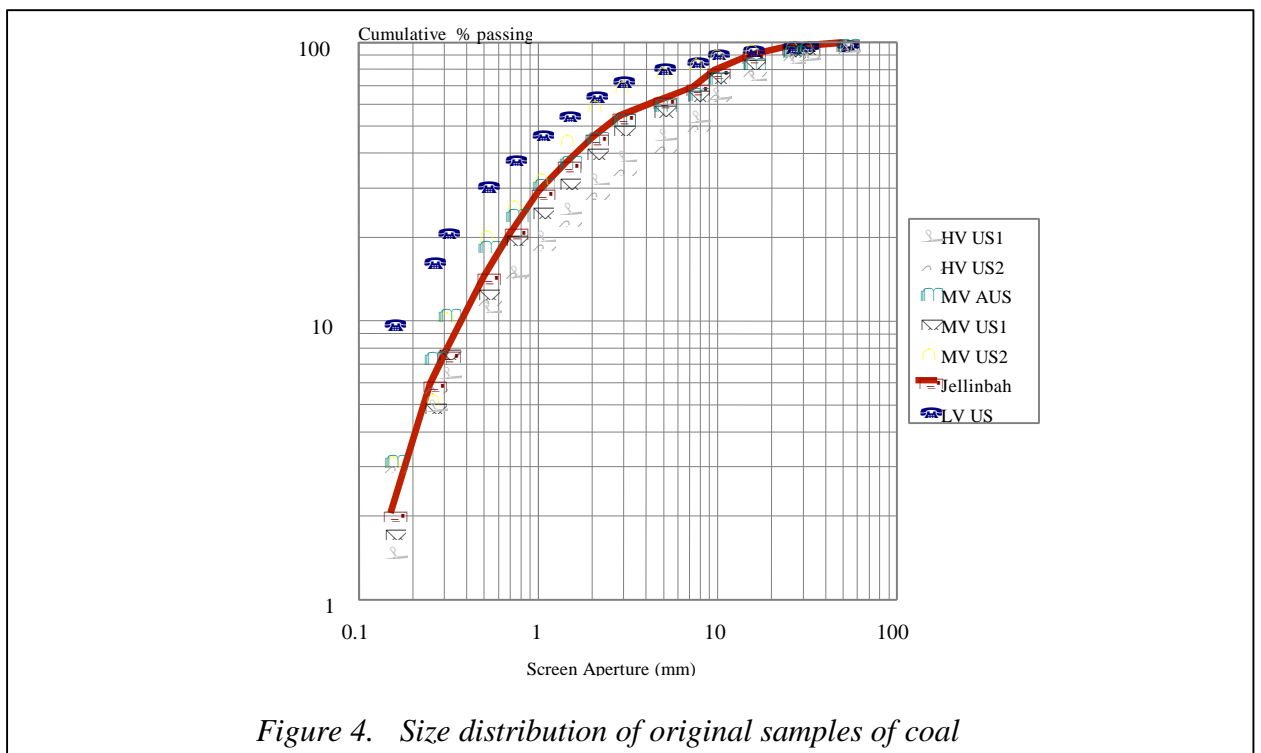
Table 3. Standard procedure for coke microscop



6 RESULTS

6.1 Coals

The size distribution of original samples taken is shown in Figure 4 whereas Tables 4 and 5 show the full characterisation of the selected individual coals and respective carbonisation results.



	ORIGINAL COAL SAMPLES						
DESCRIPTION	HV US1	HV US2	MV AU	MV US1	MV US2	JE	LV US
Ash (% db)	6.2	5.5	9.3	7.3	8.2	9.7	4.6
VM (% db)	34.2	35.2	21.1	30.0	25.9	16.4	19.3
Sulphur (% db)	0.88	0.97	0.59	0.71	0.92	0.73	0.83
Ash Analysis							
SiO ₂	54.6	51.8	62.0	54.4	47.7	50.2	41.5
Al ₂ O ₃	28.6	29.7	29.1	28.2	30.7	29.9	26.8
Fe ₂ O ₃	9.81	11.40	3.03	8.68	12.00	9.92	16.90
CaO	1.42	2.02	1.59	2.50	2.71	3.97	7.19
MgO	0.93	0.88	0.46	1.24	1.37	1.02	1.88
TiO ₂	1.56	1.63	1.55	1.69	1.52	1.38	1.38
MnO	0.018	0.023	0.029	0.27	0.038	0.053	0.042
P ₂ O ₅	0.17	0.32	1.17	0.28	1.34	1.90	0.14
SO ₃	0.13	0.23	0.097	0.89	0.74	0.97	3.29
K ₂ O	1.70	1.42	0.91	1.79	2.07	1.00	1.79
Na ₂ O	0.46	0.47	0.55	0.56	0.66	0.55	0.80
ZnO	0.013	0.043	0.017	0.011	0.051	0.007	0.056
HGI	50	49	92	73	101	90	96
Fluidity (ddpm)	8594	15835	84	4025	3952	-	2
Audibert-Arnu Expansion (total dilatation) %	172	201	79	199	269	7	46
FSI (CSN)	7.5	8	9	7	9	2	4.5
R _{o max} (%)	0.97	1.03	1.48	1.17	1.30	1.71	1.70
Standard Deviation (σ)	0.07	0.07	0.11	0.09	0.12	0.10	0.13
Maceral Analysis							
Vitrinite (%)	59.4	67.6	65.2	66.1	78.7	47.8	79.3
Sporinite (%)	3.7	3.9	0	2.7	0.4	0	0
Cutinite + Resinite (%)	5.0	5.6	0	1.7	1.5	0	0
Semi Fusinite (%)	18.9	14.5	23.3	18.2	9.3	43.6	13.4
Sclerotinite (%)	0	0.2	0	0	0	0	0
Micrinite (%)	5.6	3.9	1.9	4.4	2.5	0.6	2.5
Fusinite (%)	3.9	1.2	4.2	2.7	2.9	2.5	2.1
Mineral Matter (%)	3.6	3.1	5.5	4.2	4.8	5.7	2.6

Table 4. Individual characterisation of the selected coals

DESCRIPTION	HV US1	HV US2	MV AU	MV US1	MV US2	JE	LV US
Wall Pressure (psi)	0.2	0.4	1.0	0.3	0.5	Nil	>6.0
Sole-Heated Oven Contraction (%)	-19.3	-10.2	-8.2	-22.0	-8.2	-8.6	+23.2
DI ¹⁵⁰ ₁₅ (%)	72.7	72.7	80.2	77.0	82.0	*	79.9
CRI (%)	31.7	36.0	15.2	24.3	27.6	Est 34.5*	43.4
CSR (%)	43.8	34.0	70.2	59.1	57.1	Est 45.8*	42.3

* Jellinbah carbonised by itself did not yield a coherent coke mass. Therefore, CRI and CSR were estimated via successive blending and extrapolation as described in Appendix II.

Table 5. Carbonisation of the individual coals

Although the carbonisation of Jellinbah did not produce enough coherent volume to allow for the determination of all the required tests on cokes, the volume that was available was prepared for further analyses. Table 6 shows the results of Coke Texture Analysis of Jellinbah.

TEXTURES	CODE	BLOCK 1 %	BLOCK 2 %	MEAN %
Non-Fused Isotropic	I _{nf}			
Fused Isotropic	I _f	1.2	1.6	1.4
Fine Size Mosaic	M _f			
Coarse Size Mosaic	M _c			
Flow-type	B	24.8	26.0	25.4
Basic Anisotropy	BA	4.0	3.2	3.6
Isotropic Inert	I _n	10.4	12.8	11.6
Anisotropic Inert	AI	59.2	56.0	57.6
Pyrolitic carbon	PC			
Inorganic Inclusion	II	0.4	0.4	0.4
Additives	A			
TOTAL		100.0	100.0	100.0

Table 6. Microscopic textures of Jellinbah's coke

6.2 Blends and Cokes

The models currently utilised by the BSM to select blends for coke making essentially consider restrictions of:

- Volatile matter content that answers the needs for the equilibrium between the production of by-products and coke yield;
- Maximum ash and sulphur contents as specified;
- Ash chemistry analysis to permit calculation of ash basicity index;

- Adequate reflectance and fluidity according to the MOF² diagram (Miyazu et al₍₆₎) from which these parameters should range respectively between 1.20 and 1.30% and 200 and 1,000 ddpm;
- Parameters related to the development of coking pressures (inert content) and coke high temperature properties (CSR/Reactivity).

The blends selected for characterisation and study of the effect of Jellinbah's utilisation essentially followed the same criteria (Table 7).

Coal	Blend % by Weight			
	I	II	III	IV
HV US 1	15	15	15	15
HV US 2	15	15	15	15
MV AU	20	20	20	25
MV US 1	15	15	15	12.5
MV US 2	15	15	15	12.5
JELLINBAH	Nil	10	20	20
LV US	20	10	Nil	Nil
TOTAL	100	100	100	100

Table 7. Blends selected for testing

Based on the target bulk density of carbonisation charges (740 kg/m³) as described in Table 2, the size consist of the various coals was adjusted accordingly. Table 8 shows both target and actual pulverisation obtained for the various coals to be blended. Minor adjustments of bulk density were achieved by moisture control.

COAL	Target % < 2.83 mm	Actual % < 2.83 mm
HV US 1	80.0	81.2
HV US 2	80.0	80.8
MV AU	85.0	84.3
MV US 1	85.0	84.3
MV US 2	85.0	84.4
JELLINBAH	90.0	91.6
LV US	80.0	81.0

Table 8. Pulverisation of coals to be blended

² Miyazu Okuama Fukuyama

As explained before, 6 tests were conducted at standard conditions for each of the blend to produce enough volume for all coke tests. Average pulverisation of the blends was around 85% under 2.83 mm as shown in Appendix III. Full characterisation of blends and resultant cokes is given in Table 9.

ITEM		Blend I 0% JE	Blend II 10% JE	Blend III 20% JE	Blend IV 20% JE	
C O A L B L E N D	Moisture (%)	6.0	6.0	6.0	6.0	
	Ash (% db)	7.3	7.3	7.8	7.8	
	VM (% db)	26.3	26.1	25.6	25.5	
	Sulphur (% db)	0.82	0.84	0.80	0.79	
	Fluidity (ddpm)	875	929	720	577	
	$R_{o\max}$ (%)	1.29	1.29	1.26	1.29	
	Standard Deviation (σ)	0.27	0.26	0.24	0.24	
	Vitrinite (%)	66.4	65.0	60.9	62.8	
	Sporinite (%)	1.8	2.0	1.9	1.8	
	Cutinite (%)	2.0	2.0	1.5	2.0	
	Resinite (%)	0	0	0	0	
	Semi Fusinite (%)	18.3	20.9	26.0	24.7	
	Scleroritinite (%)	0	0	0	0	
	Micrinite (%)	4.2	2.8	2.6	1.6	
	Fusinite (%)	3.1	3.1	2.6	2.5	
	Min. Matter (%)	4.2	4.2	4.5	4.5	
	Movable wall pressure (psi)	<0.6	<0.6	<0.6	<0.6	
	<hr/>					
	C O K E	Ash (% db)	9.7	10.1	10.5	10.7
VM (% db)		1.3	1.4	1.4	1.4	
Sulphur (%)		0.73	0.72	0.70	0.69	
DI ¹⁵⁰ ₁₅ (%)		80.5	80.2	80.1	79.6	
CRI (%)		30.2	30.7	30.7	29.6	
CSR (%)		51.6	52.0	51.2	52.1	
Micum Slope (%)		1.31	1.29	1.32	1.37	
M 40 (+ 10mm)		45.2	35.8	34.5	41.5	
M 10 (+10 mm)		7.1	7.1	8.3	8.2	
FFS (D_{ff})		41.1	37.6	36.9	39.2	
Coke Stability – S (%)	82.2	82.3	76.3	82.0		

Table 9. Characterisation of blends and resultant cokes

The details for the determination of the Fissure-free Size of Coke (D_{ff} or FFS) and for Micum slope are given in Appendix IV whereas size distribution and sample composition for determination of JIS Drum Index are given in Appendix V.

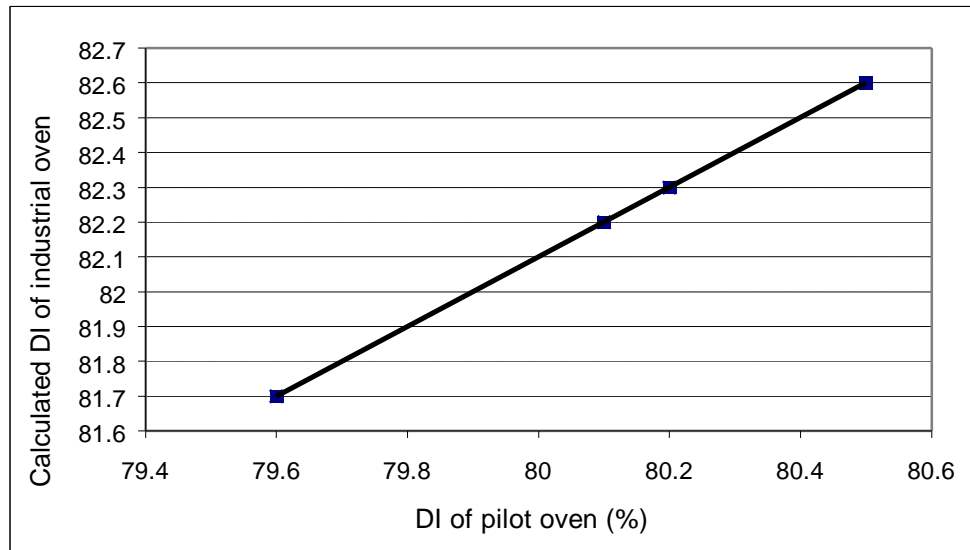


Figure 5. Relationship between results of DI^{150}_{15} derived from pilot and calculated industrial ovens

There is extensive literature to confirm that results of pilot oven testing correlate well with those of industrial scale ovens_{REF(1)} even for mini-oven design (25 – 40 kg) as encouraged by Hoogovens' research group⁽²⁾. Drum Index data obtained in pilot oven testing for Blends I - IV correspond respectively to 82.5, 82.3, 82.2 and 81.7% as derived from correlation used by USIMINAS for 4.5 m high conventional ovens as shown below in Figure 5.

A comparison among the various tests used in Europe to assess the physical strength of cokes is given in Table 10⁽³⁾.

TEST	COKE		DRUM		TEST		STRENGTH INDICES
	Wt. kg	Size mm	Width m	f m	RPM	Total Revolutions	
Micum	50	> 60	1	1	25	100	$M_{40} = \% > 40 \text{ mm}$ $M_{10} = \% < 10 \text{ mm}$
Half Micum	25	> 60	0.5	1	25	100	$M_{40} = \% > 40 \text{ mm}$ $M_{10} = \% < 10 \text{ mm}$
IRSID	50	> 20	1	1	25	500	$I_{20} = \% > 20 \text{ mm}$ $I_{10} = \% < 10 \text{ mm}$
Extended Micum	50 or 25	> 20 or > 60	1 or 0.5	1	25	100, 200, 300, 500 & 800 *	M_{40} , M_{10} , FFS, Micum Slope ($1/AMS^2/\text{rev.}$)

* The Arithmetic Mean Size (AMS) is determined at each stage.

Table 10. Comparison of tests to assess the physical strength of coke in Europe

7 DISCUSSION

7.1 Characterisation of Individual Coals

All the coals were classified according to ASTM Standard for Classification of Coals by Rank (ASTM D 388-95) which takes mineral matter-free volatile matter as the driving parameter. Hence, Jellinbah is classified as a Low Volatile Bituminous Coal.

According to the International Classification of Coals by Type prevailing in Europe, Jellinbah is assigned to 311-type of moderate caking/coking properties whereas it is classified as a High Rank Low Fluidity Coal by the Japan Iron and Steel Institute.

Although Jellinbah does not present noticeable fluidity under normal testing conditions in the Gieseler Plastometer, it does produce a coherent “pencil” in the Audibert-Arnau dilatation test as well as a Free Swelling Index in the range of approximately 2.

Most interesting are the results derived from coke microscopy shown in Table 6 and further illustrated by the set of microtextures shown in Appendix VI. Analysis of Jellinbah’s coke textures resulted in 25% of bands which are quite typical of the fusible precursors existing in low volatile bituminous coking coals.

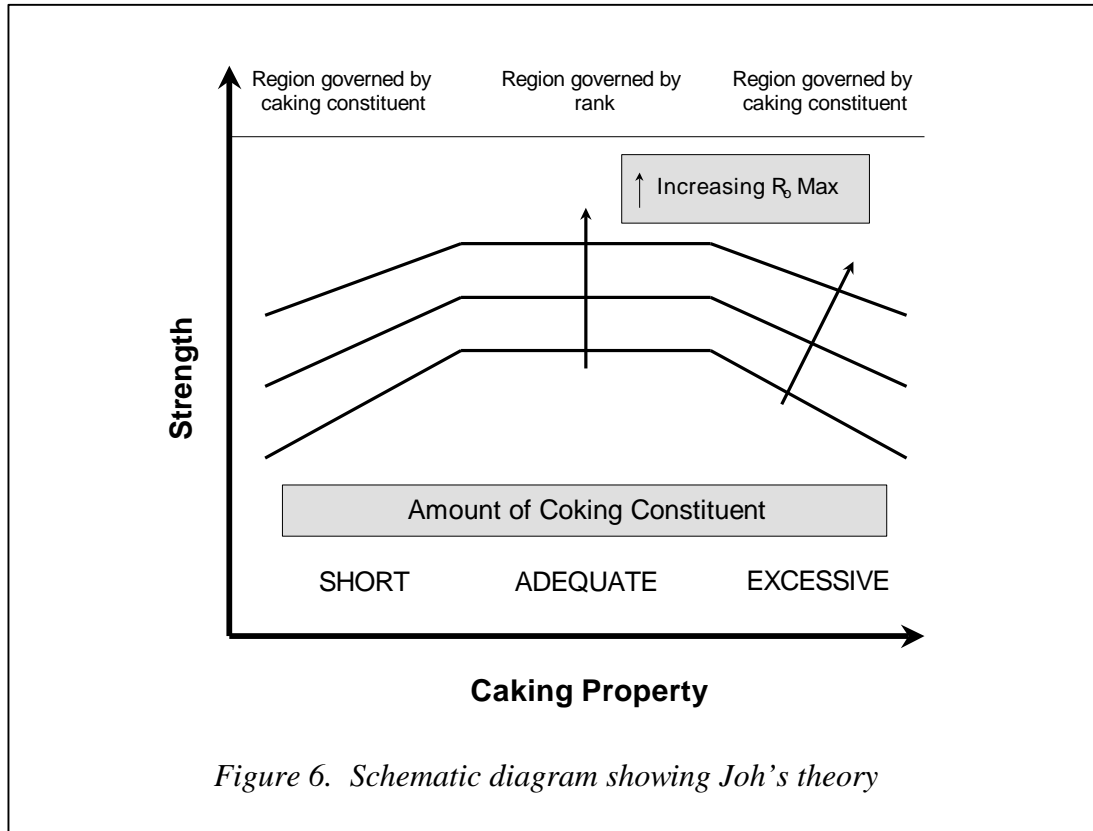
This can be explained not only by its unique coalification pattern but also for its high content of non-vitrinite fusible material. Comparing the two LV coals selected, LV US and Jellinbah of about the same reflectance, the former contains 13% of semi-fusinite versus about 44% in Jellinbah. **A greater part of this semi-fusinite may add to the so-called “reactive” macerals.**

7.2 Characterisation of Blends Selected

In the manufacture of metallurgical coke by blending different coals a proper combination of characteristics is aimed at. Several methods for evaluation have been devised but apparently most of them coincide in that a good coke strength depends on the equilibrium between fusible and non-fusible components as indicated by Joh back in late 1940’s; it is necessary to increase the strength of fibrous portion and also to properly balance the caking component therewith.

For the purpose of this report, the former refers to reflectance as the rank parameter which is the major contribution of low volatile coals whereas the latter can be represented by fluidity which is mainly supplied by the high volatile coals. Medium volatile coals in blends have an intermediate behaviour and make up the blend.

As shown in Figure 6₅, Joh defines a “Low Fluidity Control Region” in which increase in fluidity (as well as in rank) drives the increase in strength; inside the region controlled by rank, any further contribution to the blend fluidity is useless: only increase in rank leads to increased strength. Inside the High Fluidity Control Region, excessive fluidity is detrimental to quality but rank can still contribute to strength.



Miyazu's contribution to blending theory is also appreciated⁽⁶⁾. The blends selected for this work followed essentially this approach ie. $R_b \text{ max}$ between 1.2 and 1.3% and Maximum Fluidity in the range of 200 and 1,000ddpm which is in accordance with the BSM's criteria. These findings were recently confirmed in Europe⁽⁷⁾.

The addition of Jellinbah to 20% in replacement of the other LV coal in the base blend brought about the following benefits:

- **no detrimental carbonisation pressure despite keeping the same rank contribution;**
- **about 1% improved coke yield due to Jellinbah's lower volatility which is important for mills which are coke-deficient;**
- **essentially no changes in Drum Index (test reproducibility is 1 point %);**
- **about 5.5% lower sulphur in the coke produce for 20% JE in the blend.**

All the blends showed similar pressure development upon carbonisation (<0.6%). Results of Jellinbah in both movable wall and sole-heated oven carbonised by itself (Table 5, summarised below) emphasise the different behaviour of the two LV coals in the blends:

	LV U.S.	JELLINBAH
Movable wall pressure (psi)	> 6.0	Nil
Sole-Heated contraction (%)	+ 23.2	- 8.6
Audibert Arnu total dilatation (%)	46	7 (contraction only)

It suggests that JE can be used in the blend as a pressure moderator despite its high rank.

7.3 Characterisation of Resultant Cokes

Typical coke size and strength values sought by the European Steel Mills (ESM) are detailed in Table 11.

Coke Parameter	Range
Mean Size (mm)	40 - 60
M ₄₀ (%)	> 78 - > 88
M ₁₀ (%)	< 5 - < 8
I ₄₀ (%)	53 - 55
I ₂₀ (%)	> 77.5
Micum Slope	0.5 - 1.0
Fissure Free Size (mm)	50 - 55
Stabilisation Index	90 - 95

Table 11. Typical characteristics of European cokes

The extended Micum Slope is a surface abrasion index where the higher the number the more abradable the coke can be. The volumetric index is the Fissure Free Size which represents the arithmetic mean size (AMS) of a completely stabilised coke which for the European mills makes more sense than the traditional mean size calculation. The higher the “Coke Stability” (S) defined as the ratio FFS/AMS, the lower the level of size reduction en-route to the stockline.

Absolute values for coke quality given in Table 9 are within expected ranges for pilot oven testing which can lead to results 3-4 points lower than industrial wharf coke. Also M40 results derived from +20mm as in this case do not make much sense since a greater proportion of particles below 40mm already exist in the test sample. Therefore, it is suggested that Micum Slope and Stability should be considered instead.

The key here is to compare the cokes produced from the 4 blends one with the other. Hence, one can conclude that the inclusion of Jellinbah up to 20% did not significantly alter those parameters (Figures 7 and 8).

Reproducibility of CRI and CSR tests are respectively 2.0 and 2.7 units.

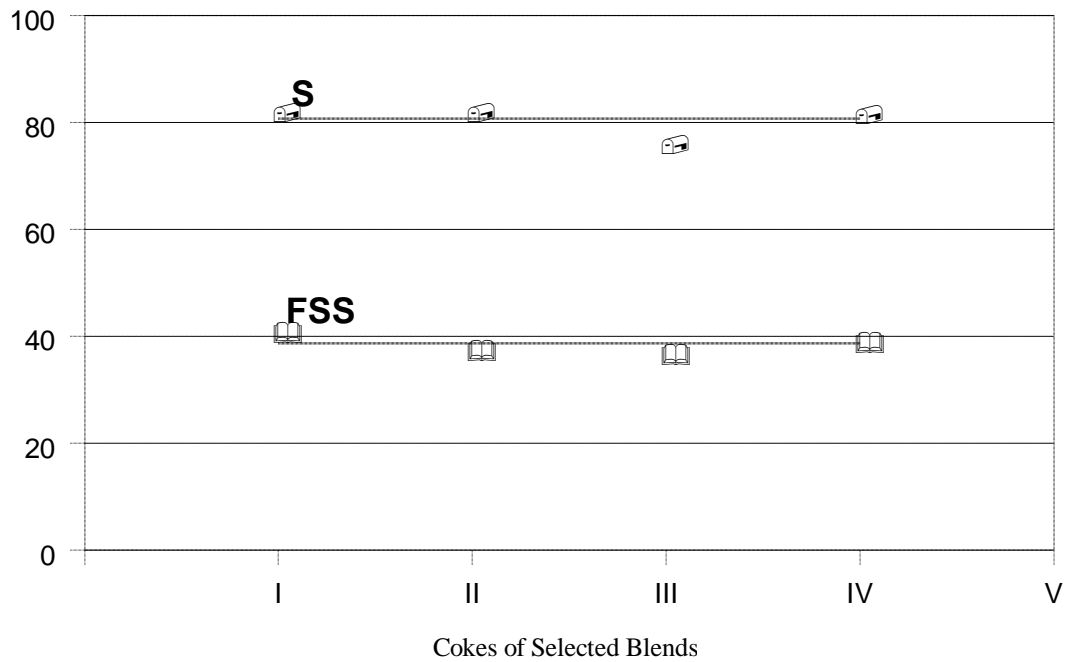


Figure 7. Effect of the addition of JE on fissure-free size and stability

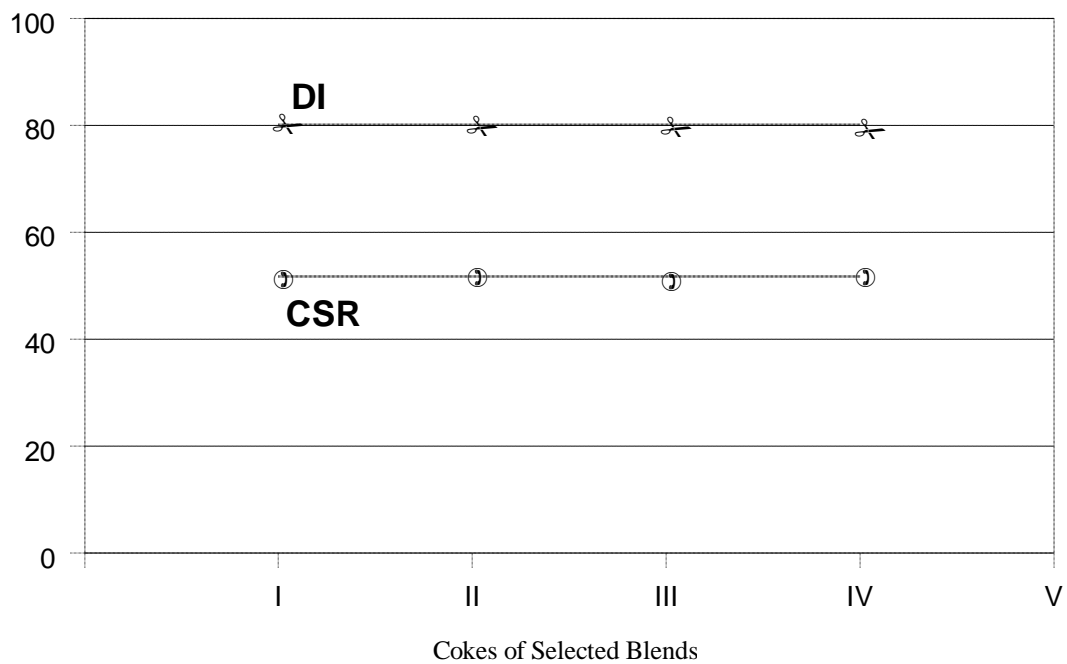


Figure 8. Effect of the addition of JE on drum index and CSR

A set of photo micrographs for the cokes of blends I (reference blend) and III (20% Jellinbah) is given in Appendix VII.

It is very difficult to assign individual coke textures to the parent coals, with the exception of the flow-type that is only derived from low volatile coking coals.

Considering that blends I and III had only one low volatile coal each in their composition, respectively US LV and Jellinbah, it is reasonable to state that the existing flow-type textures identified in cokes of blends I and III come from those LV coking coals.

Therefore, it is clearly seen in photo micrographs of coke III that Jellinbah's maceral components were well mixed within the coke matrix. Observed flow textures derived from Jellinbah were reasonably similar to those derived from US LV in coke I despite the higher coking potential of the latter compared with the former.

It has been observed that the presence of Anisotropic Inert textures in cokes derived from Australian coals have lower reactivity to CO₂ and adequate interparticle resistance as suggested by a higher CSR of Australian coals.

There is also evidence that Flow-type textures are the least reactive amongst the coke textures₍₈₎. **Jellinbah's contribution to the overall coke matrix is mainly made of Anisotropic Inert (about 54%) and Flow (about 25%) which may explain the positive behaviour of Jellinbah in blends.**

V I T R I N I T E	R _{o max} (%)	TEXTURE	CO ₂ REACTIVITY SEQUENCE
	< 0.8	Isotropic	1 (higher CRI)
	0.9 - 1.1	Fine Mosaic	3
	1.2 - 1.4	Coarse Mosaic	4 (lower CRI)
	1.5 - 1.8	Flow-Type	4 (lower CRI)
	> 1.9	Isotropic	2
INERTINITE	Inert (altered fusinite)	2	

Also, industrial ovens are known to have a higher coking rate than pilot ovens thus allowing for a better agglomeration of its particles within semi-coke reactive matrix. In other words, it is suggested that a **greater number of Jellinbah particles than expected go through some softening under industrial operating conditions which end up promoting accommodation of its particle within the coke matrix.**

7.4 Industrial Results of Jellinbah's Utilisation

The BSM have been using Jellinbah in blends for cokemaking since 1991 in replacement of traditional coals from the US and Canada. It is common practice in Brazil to blend Jellinbah coal at around 10-15% of the coke blend. Maximum blend ratios of 16% have been achieved over sustained periods. Over 1.5 million tonnes have so far been purchased and will have been utilised in Brazil by the end of Fiscal Year 1998, all of it under long Term contracts.

A sample of actual utilisation of JE in Brazilian Blends is given in Table 12 below, which confirms the results of the laboratory and **pilot scale work just reported**.

BLENDS		Week number											
		1	2	4	5	6	7	8	9	10	11	12	
COALS		% in blend											
C O A L S	HV US 3												
	HV US 4												
	HV US 5	23											
	HV US 6		18	20	20	20	20	19	19	5	5	5	
	HV Canada							10	10	17	17	15	
	HV Sth Africa soft									10	10	12	
	MV Poland	10	34		33	35	29	18	16				
	MV US 3			35						27	25	27	
	MV AU	32	6	7	7	8	12	14	14	14	15	14	
	MV AU soft	10	10	10	12	10	13	13	15				
	LV AU	8	13	11	11	11	11	11	11				
	LV US 2	17											
	LV Jellinbah		13	15	15	15	15	15	15	15	15	16	15
	LV Canada									12	12	12	
	Clean up (*)		6	2	2	1							
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	
B	VM (% db)	23.2	24.1	24.2	24.2	24.2	23.6	24.0	24.0	24.9	24.9	24.9	
L	Ash (% db)	7.3	8.1	8.0	8.0	8.0	8.1	7.8	7.8	7.2	7.2	7.2	
E	Sulphur (% db)	0.72	0.67	0.68	0.68	0.68	0.70	0.75	0.75	0.78	0.78	0.78	
N	R _{o max} (%)	1.33	1.28	1.27	1.27	1.27	1.29	1.27	1.27	1.27	1.27	1.27	
D	Fluidity DDPM	389	263	316	316	316	323	417	417	295	295	295	
C	Ash (% db)	9.1	10.3	10.1	10.1	10.1	10.2	9.8	9.8	9.2	9.2	9.2	
O	Sulphur (% db)	0.64	0.61	0.62	0.62	0.62	0.63	0.66	0.66	0.67	0.67	0.67	
K	DI ¹⁵⁰ ₁₅ (BF Stockhouse)	84	83	83	83	83	83	84	84	84	84	84	
E													

* Recovery of stock piles

Table 12. Example of actual industrial blends with Jellinbah and respective cokes

8 CONCLUSIONS

The following conclusions can be drawn from the test work:

- Low Volatile **Jellinbah** has proven to be a **feasible replacement** of traditional LV coking coals for coke-making, despite its minor caking properties.
- Detailed laboratory work done at USIMINAS R&D Centre showed that Jellinbah indeed **fused** and was **perfectly bound** to the other coals in the blend, as illustrated by microscopic textures.
- For its high inert content, it does behave as a **pressure moderator** when compared with the high pressure developing US coals.
- Pilot oven testing of blends in which the US LV coking coal was replaced by up to 20% of Jellinbah showed **essentially no changes in coke quality parameters** such as Drum Index, Micum, Micum Slope, Fissure-Free Size and CSR.

This was possible because of the unique characteristics of Jellinbah's macerals and because the Brazilian blends already contain adequate fluidity to compensate for Jellinbah's minimum caking properties.

- Brazilian Steel Mills have purchased and used over 1.5 million tonnes (including balance to be shipped until end of Fiscal Year 1998) at percentages varying from 5 to 16% in blends for extended periods of time.

The use of Jellinbah at those levels brought no changes to the expected coke which was aimed at loading into large blast furnaces as in the case of CST (4,405 m³ inner volume and 14.0 m hearth diameter) and CSN (3,815 m³ inner volume and 13.0 m hearth diameter).

- **The significance of the utilisation of Jellinbah as a blend component is its price differential when compared with traditional LV coals for the same rank contribution.**

9 REFERENCES

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