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by

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INTRODUCTION

The interpretation of the many variables influencing the strength of a coking coal is of great importance to the coal petrographer. Yet quite often predictions cannot adjust for factors such as the effects of oxidation, the role of high concentrations of semi-inert macerals, or operation variables in the coking process. This report examines the effects of the semi-fusinite maceral in the prediction of the ASTM stability factor and suggests that for western Canadian coals, approximately 50 percent of the semi-fusinite constituent is reacting in the coking process.

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Coke Stability Factor Prediction by Petrography

Stability factor prediction using the Shapiro-Gray Method(1) for most Appalachian coals is quite accurate, but unfortunately the same is not true for western Canadian coals. Previous work(2) has indicated that some predictions are close to the coke oven results, but also that a large percentage are not. The problems associated with predicting stability factors have been:

1. The proper identification of semi-inert macerals.
2. The proportion of semi-fusinite which is reactive.
3. The recognition of oxidation.

An oxidized coal becomes apparent from a low coke oven stability factor and sometimes from a low Free Swelling Index. Petrographic analysis suggests a high stability factor reflecting the potential of the coal if not oxidized. A recent Safranin-O stain test for oxidation may also detect oxidation, but not a quantitative estimate of the degree(3).

The reactive to inert ratio of the semi-fusinite macerals becomes critical in coals with high percentages of semi-fusinite. For these samples, petrographic analysis predicts a low stability factor due to the excessive inert proportion, resulting in a poor reactive-inert balance. When charged in the coke oven however, they often yield a coke with a high stability.

Fundamental to the stability factor calculation is the separation of the reactive and inert constituents of the coal based on earlier research of the coking process. However, one maceral, semi-fusinite, straddles the reactive-inert boundary. For the Appalachian coals, Shapiro and Gray, based on earlier work by the Russians, concluded that 1/3 of the semi-fusinite macerals are reactive and 2/3 are inert. It has since been suggested that more than 1/3 of the semi-fusinite is reacting in the coking process for western Canadian coals. To investigate this possibility, four samples from the Canadian Coal Petrographers Group round robin test series were studied. Maceral analysis indicated that a high percentage of semi-fusinite was present in the three western Canadian coals, unlike the relatively samll proportion for the single eastern Canadian coal (Table 1).

TABLE 1

MACERAL ANALYSIS OF FOUR SAMPLES FROM THE CANADIAN COAL PETROGRAPHERS GROUP ROUND ROBIN

Description	Vitrinite	Exinite	Semi-Fusinite	Fusinite	Micrinite	Mineral Matter
KRL	50.5	0.2	31.6	9.0	2.7	6.0
McIntyre	61.8	0.0	22.3	8.0	3.5	4.4
Luscar	53.4	0.3	29.3	7.1	5.5	4.4
Devco 26	77.8	5.3	5.0	3.5	5.8	2.6

It has been assumed but not proven that particles of semi-fusinite with reflectance less than 2.0% are reactive, while those greater than 2.0% are inert. Perhaps this 2.0% division is too high, but it should be safe to assume that macerals with reflectance in excess of 2.0% are indeed inert. Assuming this 2.0% boundary, reflectance analysis of the semi-fusinite macerals was taken on the four samples to determine the reactive/inert proportions (Table 2).

TABLE 2

DISTRIBUTION OF REACTIVE AND INERT SEMI-FUSINITE

Description	Semi-Fusinite Ro:	
	0 - 2.0%	2.0% <
KRL	53%	47%
McIntyre	47%	53%
Luscar	45%	55%
Devco 26	30%	70%

Thus from Table 2:

1. For the eastern Canadian coal, 30% of the semi-fusinite macerals were reactive; 70% inert. This agrees with the 1/3 reactive, 2/3 inert proportions from the Shapiro-Gray Method.
2. For the western Canadian coals, approximately 50% of the semi-fusinite macerals were reactive and 50% were inert.

Reflectance analysis of the semi-fusinite macerals may present a problem in identification. The border between semi-fusinite and fusinite in western Canadian coals is often difficult to determine. During analysis, only the macerals that were clearly semi-fusinite were chosen, and therefore, distribution into Ro types may not represent the entire semi-fusinite component, as the higher reflectances may be absent. Analyzing more samples, will not necessarily eliminate this sampling bias.

Perhaps then, somewhere between 1/2 and 1/3 of the semi-fusinite macerals are reactive. It is also probable that the reactivity of semi-fusinite varies from coal to coal. In view of the analysis of these western Canadian coals, and also for the simplicity of calculations, 50% reactive and 50% inert were chosen.

The following methods of prorating the reactive portion of semi-fusinite were examined:

Method 1.	Prorate against vitrinite Ro types :	1/3 Reactive 2/3 Inert
Method 2.	Prorate against semi-fusinite Ro types:	1/3 Reactive 2/3 Inert
Method 3.	Prorate against vitrinite Ro types :	1/2 Reactive 1/2 Inert
Method 4.	Prorate against semi-fusinite Ro types:	1/2 Reactive 1/2 Inert

The results appear in Table 3.

TABLE 3

STABILITY FACTOR PREDICTIONS OF THREE SAMPLES FROM THE CANADIAN COAL PETROGRAPHERS GROUP ROUND ROBIN TEST SERIES

Description	Semi-fusinite %	Stability MW Oven	Predicted Stability From Method:							
			1	Diff.	2	Diff.	3	Diff.	4	Diff.
KRL	26.3	52.5	48.0	4.5	48.0	4.5	52.5	0.0	52.8	-0.3
McIntyre	20.7	54.0	50.5	3.5	45.5	9.5	55.0	-1.0	53.5	0.4
Luscar	25.7	55.0	51.0	4.0	52.0	3.0	55.4	-0.4	56.0	1.0
Average				4.0		5.7		0.5		0.6

Both methods 3 and 4, of prorating 50% of the semi-fusinite according to vitrinite reflectance types and against measured semi-fusinite reflectance types, resulted in predicted stability factors closer to the coke oven results.

Since reflectance analysis of semi-fusinite involves a lot of time for almost identical results as the prorating method, it is recommended that Method 3, the method of prorating according to vitrinite types using 1/2 reactive and 1/2 inert semi-fusinite, be used.

This method was used to re-calculate the stability factors of 60 samples where semi-fusinite comprised more than 20% of the sample. Table 4 shows that at this level, the change in total reactives and total inerts becomes appreciable.

TABLE 4

COMPARISON OF REACTIVE SEMI-FUSINITE
BASED ON 1/3:2/3 RATIO AND 1/2:1/2 RATIO

Semi-fusinite in sample (%)	5	10	15	20	30	40	50
1/3 Reactive (%)	1.7	3.3	5.0	6.7	10.0	13.3	16.7
1/2 Reactive (%)	2.5	5.0	7.5	10.0	15.0	20.0	25.0
Difference (increase in reactives) (%)	0.8	1.7	2.5	3.3	5.0	6.7	8.3

This method may, of course, be used for samples where semi-fusinite comprises less than 20% of the sample, but will only slightly alter the predicted stability factors from the original Shapiro-Gray calculation.

OBSERVATIONS AND DISCUSSION

The results of these re-calculations appear in Tables 5-8 at the end of the report.

The effects of the change in the reactive/inert proportions of semi-fusinite, tends, in most cases, to decrease the balance index and increase the strength index. The result is an increase in the Stability Factor. With some samples, however, the re-calculation lowers the stability factor. In general, it is impossible to determine the change in stability factor, as the increase or decrease varies with the rank of the coal (due to different optimum inert and strength indices) as well as the percentage of the other inerts.

Specifically, the following observations may be made. Oxidized coals comprised 15% of the total sample, with an average stability factor of 27.7. Excluding the oxidized coals, 71% of the samples had re-calculated stability factors closer to the coke oven results than previous calculations. The re-calculations placed the stability factors an average of 4.2 points away from the coke oven stability, while the original calculation placed them an average of 10.2 points away. The remaining 29% of the samples had re-calculated stability factors an average of 6.2 points away from the oven stability, as compared to an average of 3.4 points for the original calculation. In these samples, however, the predicted stability was greater than the coke oven stability suggesting that either these coals were slightly oxidized or that they did not achieve their potential. It is important to remember that the actual coke strength is affected by such operational variables as:

1. bulk density which is altered by changes in moisture and size consist
2. flue temperature and coking time
3. coal blending
4. coke quenching techniques
5. coke sampling and tumbler test procedures.

Figures 1 and 2 illustrate the distribution of differences between the predicted stability factors and the coke oven stability factors. The original calculations using the 1/3 reactive, 2/3 inert ratio, have predicted stabilities which tend to be lower than coke oven stabilities by an average of 6.8 points. The distribution is also not uniform or bell-shaped. The distribution for the re-calculated samples (1/2 reactive, 1/2 inert) is basically symmetrical about the mean and closer to a bell-shaped curve. In addition, badly oxidized coals become much more noticeable.

Table 9 illustrates the percentage of samples within certain variances from the coke oven results, again excluding the badly oxidized samples.

TABLE 9

SUMMARY OF DIFFERENCES FROM THE COKE OVEN RESULTS

Variance	Original Calculation	Re-Calculation
	Percentage of Samples within limits	Percentage of Samples within limits
±3	16	31
±6	50	60
±9	61	87
±12	83	98
±all	100	100

If the accepted variance is assumed to be ±3, then almost twice as many samples now fall within that range. In addition, 50% of the samples lie within ±5.0 for the re-calculations as compared with ±7.4 for the original calculations.

In conclusion, the estimate of 1/2 reactive, 1/2 inert for semi-fusinite when semi-fusinite exceeds 20% by volume, results in a predicted stability factor which is closer to the coke oven result. If a quantitative test for oxidation were available, capable of altering the stability factor for oxidized coals, predicted stabilities would probably be very close to actual stabilities.

REFERENCES

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3. Gray, R.J., Rhoades, A.H., and King, D.T., "Detection of Oxidized Coal and the Effect of Oxidation on the Technological Properties", paper presented at AIME Annual Meeting, Dallas, Texas, February, 1974.

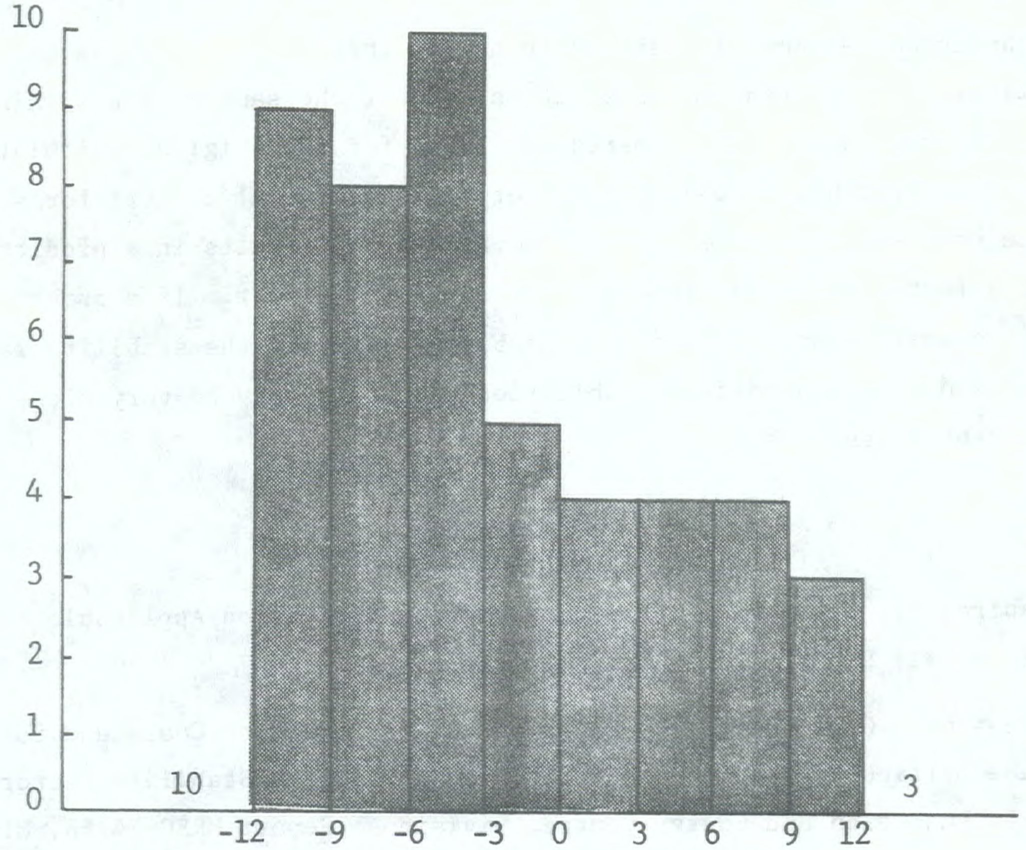

FIGURE 1 DIFFERENCES BETWEEN PREDICTED AND COKE OVEN STABILITY FACTORS FOR SEMI-FUSINITE 1/3 REACTIVE, 2/3 INERT

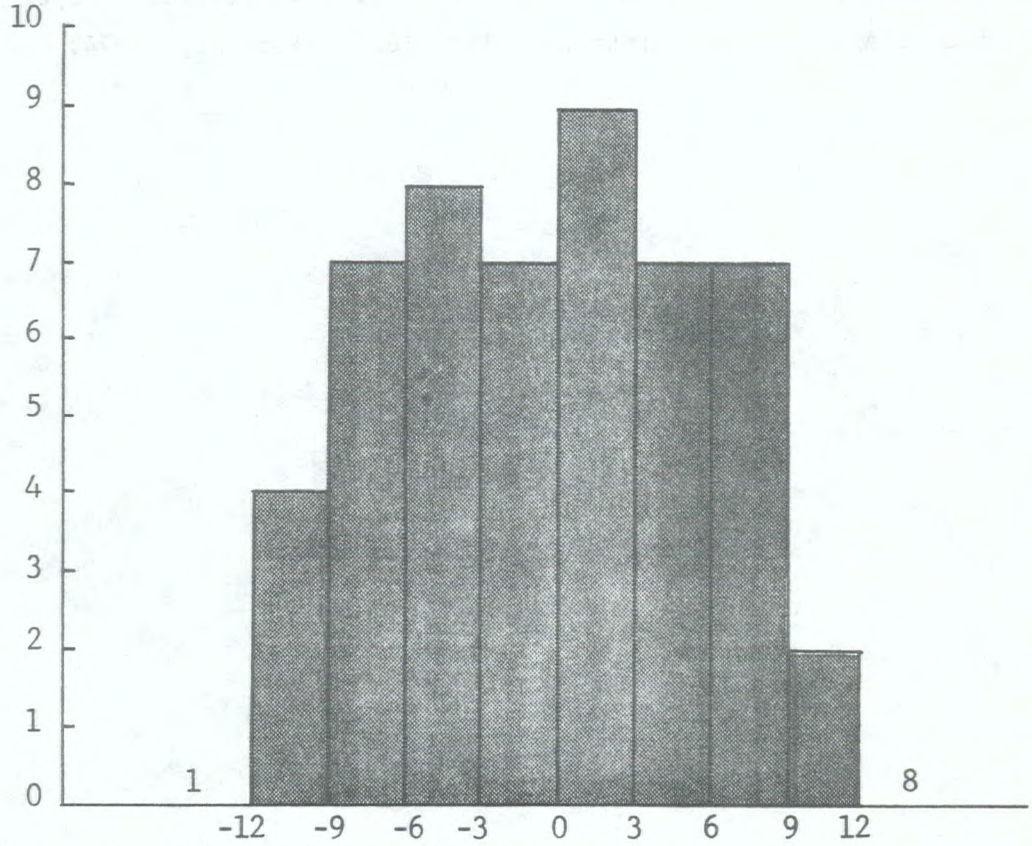

FIGURE 2 DIFFERENCES BETWEEN PREDICTED AND COKE OVEN STABILITY FACTORS FOR SEMI-FUSINITE ½ REACTIVE, ½ INERT

TABLE 5

Prediction Factor Prediction Improved (Prediction Lower than Coke Oven Results)

Sample Number	Semi-fusinite %	MW Coke Oven Stability	SF - 1/3 Reactive		SF - 1/2 Reactive	
			Predicted	Difference	Predicted	Difference
2748	53.2	56.7	24.0	32.7	44.0	12.7
2665	38.9	57.6	46.0	11.6	53.5	4.1
2672	35.6	53.2	51.0	2.2	51.1	2.1
2714	42.1	52.5	43.0	9.5	52.2	0.3
2722	33.2	48.2	40.0	8.2	46.4	1.8
2724	50.8	44.5	23.0	21.5	42.2	2.3
2788	28.8	53.7	37.0	16.7	44.8	8.9
2803	23.9	49.0	38.0	11.0	42.8	6.2
2804	22.6	48.2	38.2	10.0	44.1	4.1
4118	20.0	36.4	20.0	16.4	30.0	6.4
4193	24.3	67.9	54.0	13.9	58.5	9.4
4121	20.2	47.5	40.4	7.1	44.5	3.0
4002	22.7	49.8	40.0	9.8	46.0	3.8
3130	29.5	56.5	43.0	13.5	49.8	6.7
3062	33.4	58.3	41.0	17.3	50.4	7.9
2674	48.6	52.4	30.0	22.4	44.0	8.4
2701	33.1	58.2	49.0	9.2	54.5	3.7
2743	26.8	62.2	53.0	9.2	61.1	1.1
4425	28.8	55.5	44.0	11.5	50.4	5.1
4545	23.2	64.4	55.0	9.4	59.8	4.6
4604	32.0	51.1	32.0	19.1	41.2	9.9
4719	21.1	43.7	36.6	7.1	37.5	6.2
4609	25.3	54.7	49.4	5.3	54.0	0.7
5164	35.7	47.8	31.2	16.6	41.6	6.2

TABLE 6

Stability Factor Prediction Improved (Prediction Higher than Coke Oven Results)

Sample Number	Semi-fusinite %	MW Coke Oven Stability	SF - 1/3 Reactive		SF - 1/2 Reactive	
			Predicted	Difference	Predicted	Difference
2838	50.5	45.1	39.0	6.1	50.6	-5.5
2721	39.0	50.6	57.0	-6.4	55.2	-4.6
2801	21.6	51.8	49.5	2.3	52.0	-0.2
3212	38.5	43.5	36.9	6.6	46.0	-2.5
3077	33.6	54.8	50.2	4.6	56.0	-1.2
4606	20.7	48.6	44.0	4.6	50.0	-1.4
4120	45.0	46.8	40.5	6.3	51.2	-4.4
3396	23.5	54.3	51.3	3.0	55.0	-0.7
3391	24.4	52.1	48.0	4.1	53.0	-0.9
4608	23.3	48.5	43.7	4.8	51.0	-2.5
5207	37.5	38.5	33.0	5.5	43.1	-4.6
5137	40.7	49.9	44.3	5.6	52.5	-2.6
3017	27.1	52.2	46.2	6.0	52.2	0.0

TABLE 7

Stability Factor Prediction Not Improved

Sample Number	Semi-fusinite %	MW Coke Oven Stability	SF - 1/3 Reactive		SF - 1/2 Reactive	
			Predicted	Difference	Predicted	Difference
2874	41.7	50.3	47.0	3.3	44.4	5.9
2898	39.6	57.8	49.0	8.8	48.0	9.8
4406	25.1	44.4	46.0	-1.6	51.5	-7.1
3213	26.7	47.2	50.5	-3.3	54.6	-7.4
2664	36.5	48.4	50.0	-1.6	56.5	-8.1
2725	30.2	48.5	55.0	-6.5	55.6	-7.1
4119	22.6	49.3	52.8	-3.5	56.2	-6.9
2865	41.8	51.6	50.0	1.6	56.5	-4.9
2901	42.9	36.2	40.0	-3.8	43.0	-6.8
2878	32.8	53.8	54.0	-0.2	58.0	-4.2
2873	40.6	53.0	52.0	1.0	54.2	-1.2
2870	45.0	45.6	48.0	-2.4	50.7	-5.1
2893	28.7	52.1	61.0	-8.9	61.5	-9.4
3095	23.1	56.2	55.5	0.7	60.2	-4.0
3222	36.7	45.7	42.6	3.1	51.8	-6.1

TABLE 8

Oxidized Coals

Sample Number	Semi-fusinite %	MW Coke Oven Stability	SF - 1/3 Reactive		SF - 1/2 Reactive	
			Predicted	Difference	Predicted	Difference
2720	44.7	34.4	42.0	-7.6	52.4	-18.0
2713	51.7	26.1	36.0	-9.9	50.7	-24.6
4208	23.7	23.7	45.0	-21.3	48.0	-24.3
2807	21.0	18.5	23.3	-4.8	31.0	-12.5
3215	30.4	39.8	52.2	-12.4	57.7	-17.9
3267	24.6	40.5	51.4	-10.9	54.5	-14.0
5209	37.6	23.2	33.0	-9.8	42.8	-19.6
4277	20.0	15.5	30.2	-14.7	33.5	-18.0