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CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY
(Former Mines Branch)

MINUTES OF THE THIRD MEETING OF THE CANADIAN COAL PETROGRAPHERS GROUP

HELD AT THE BOARD ROOM, INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY
GEOLOGICAL SURVEY OF CANADA, N.W. CALGARY, ALBERTA

DR. B.N. NANDI
ENERGY RESEARCH LABORATORIES
OTTAWA
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ENERGY RESEARCH PROGRAM

Report ERP/ERL/75/148 (C)

Members and Delegates Present:

C.J. Aizenman	Geol. Surv. of Canada	3303, 3rd St. N.W. Calgary
J.C. Botham	CANMET	555 Booth Street, Ottawa
T.F. Birmingham	Geol. Surv. of Canada	3303, 3rd St. N.W. Calgary
A.R. Cameron	Geol. Surv. of Canada	3303, 3rd St. N.W. Calgary
W. Dowhaniuk	Algoma Steel Corp. Ltd.	Sault Ste. Marie, Ontario
B. Dutt	Luscar Coal Ltd.	Edmonton, Alberta
C. Gange-Harris	Geol. Surv. of Canada	3303, 3rd St., Calgary
P.R. Gunther	Geol. Surv. of Canada	3303, 3rd St., Calgary
J. Hachkowski (Mrs.)	Algoma Steel Corp. Ltd.	Sault Ste. Marie, Ontario
A. Hampson	Dominion Foundries & Steel Ltd.	Hamilton, Ontario
J. Kasperczyk	Elco Mining Ltd.	239, 9th Ave. Calgary, Alberta
B. Morris	Kaiser Resources Ltd.	Fernie, B.C.
F. Martonhegyi	Can-Pac Minerals Ltd.	205, 9th Ave. S.E., Calgary
B.N. Nandi	CANMET	555 Booth Street, Ottawa
R. Nolan	Robertson Research	Calgary, Alberta
E.J. Patterson	Steel Company of Canada Ltd.	Hamilton, Ontario
J.L. Pittion	INRS Univ. du Quebec	Quebec City, Quebec
P.J. Readyhough	Steel Company of Canada Ltd.	Hamilton, Ontario
W.S. Wilson	Fording/Can-Pac Minerals Ltd.	239, 9th Ave., Calgary, Alberta
J. Wright	Can-Pac Minerals Ltd.	205, 9th Ave., Calgary, Alberta

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JUNE 12-13, 1975

After welcoming members and delegates, Dr. A.R. Cameron, Chairman, invited Dr. D.F. Stott, Director, Institute of Sedimentary and Petroleum Geology to open the meeting and to address the delegates on the activities of his Institute.

Dr. Stott briefly summarized the following activities of the Institute:-

1. Coal Petrography - a major project in the field of coal, oil, and gas exploration - national responsibilities of the evaluation of coal of different ranks.
2. Programme on the energy resources in the next 20 years.
3. Development of energy from coal.

He also added that Canadian coal petrographers will eventually play a major role in these projects.

Introduction of Coal Petrography

Dr. A.R. Cameron spoke on the Introduction of Coal Petrography to the participants who are not familiar with the terminology. He discussed briefly: a) the types of macerals present in coal and their nature, b) reflectance of macerals and especially vitrinite and its usefulness in the rank determination of coal seams, c) application of coal petrography in the exploration of oil and gas, d) coke making - prediction of stability index from the petrographic analysis and reflectance measurements, e) reactivity of coal and coke.

The Growing Importance of Petrography of Canadian Coals in Coke Making

Mr. J.C. Botham stated that Canadian industries are becoming more cognizant of the necessity to be self-sufficient in the energy requirements including coking coals. The Canadian steel industry has recently indicated real interest in the use of eastern Canadian coking coals as well as those of western Canada. Until quite recently the marriage of eastern and western Canadian coal was considered to be beyond the realm of possibility but at the present moment, coke from blends of eastern and western Canadian coal are being manufactured at the (Sysco) coke plant, Sydney, N.S. There are proposals for new integrated steel plants, and industry will be looking for technical advice concerning the use of coals from both parts of Canada. With regard to production for export, Japan has dominated the market for western Canadian coking coal. Other foreign outlets are now becoming more prominent. Studies on western Canadian coals indicate low coking propensity of some of these coals in relation to the long established coals of traditional sources. In certain blends they have demonstrated blending properties equal to or on occasion superior to those of coals with the traditionally higher thermal rheological properties.

Relevant facts associated with the eastern and western Canadian coals are:- a) Different in geological ages and conditions of coalification b) Widely different in their extraneous material c) In general on the opposite ends of the coking coal scale d) Widely different in caking propensity. Hence, the coals have different maceral analysis and different reflectance. There is a necessity to determine accurate reflectance and maceral analysis which should agree with results amongst the different petrographers. Of extreme importance, is the identification of the extent of oxidation and to what extent oxidized coal can be tolerated in a blend for the production of coke for steel making. Other matters for consideration are the correlation of coal petrography with coking pressures and coke shrinkage properties. The steel people insist on the reduction of the ash content to the levels which they presently demand.

Preparation or processing of the coal to achieve this end will alter the distribution of the coal macerals as well as remove mineral matter with accrueing significant changes in the caking and coking properties.

At CANMET recent studies of the petrographic and rheological properties of coal at different depths of the new Lingan Mines are very interesting and Dr. Nandi will present up-to-date results of these studies later. He concluded that coal and coke microscopy in the previously mentioned area would be an important factor in Canadian coal evaluation.

Panel Discussion on the Quality in Relation to Application on Iron Making

Mr. W.T. Dowhaniuk introduced his paper on coke for blast furnaces. He first described the blast furnace and its operation and the properties of coke in relation to the blast furnace. He mentioned the use of coke and oil in the blast furnace and the use of western Canadian coal for coke making. He also stated some progress was made to use formed coke in the blast furnace.

Mr. F. Martonhegyi of Can-Pac Minerals opened the discussion. He asked about the forms of sulphur and the effect of sulphur and phosporous in coke in iron making and the maximum allowable percentage of sulphur in coke.

Mr. Dowhaniuk said that sulphur was present in coal in 3 forms: organic sulphur, sulphate sulphur and sulphides, (mostly sulphate sulphur and very little sulphides). Organic sulphur in coal produces gas during coke making. Maximum sulphur allowable in coke is 1%. Sulphur from coke enters either into the slag or in the iron which requires an expensive process to remove it from the pig iron. He briefly described the process of removing sulphur by the Bessemer Converter and open hearth furnace. Phosphorous is also detrimental and the content of phosphorous in coke should be less than 0.1%.

Most of the phosphorous is removed during the Benefication Process.

Mr. A. Hampson said that the cost of removing sulphur is less than that of ash.

Mr. Nolan asked what is the suitable stability index of blast furnace coke. Mr. Dowhaniuk replied, an index of 55-56 was quite satisfactory. His opinion is that coke of higher stability does not necessarily give better performance in the blast furnace. Longer coking times produce greater variations in the stability index. Uniformity in the stability index is more important than higher stability indices. He mentioned that during the past year, Algoma Steel used a batch of coke of stability index of 60 in their blast furnace and a very poor performance was observed, (the coking time was 25-28 hrs). Another batch of coke was produced from the same coal blend at a lower temperature with reduced coking time. The stability index was decreased to 52-53 and this lower stability showed better performances in the blast furnace.

Mr. Nolan inquired about formed coke and its use in the blast furnace. Mr. Dowhaniuk said, that formed coke would probably be ideal from the point of uniformity but insufficient data is available to draw a conclusion as to its suitability in the blast furnace.

Mr. J.C. Botham briefly described the formed coke process, mentioning the two basic principles, namely hot and cold briquetting methods. The former method requires coking coal as one of the constituents and utilizes the caking properties of the coal as the binder. Cold briquetting usually requires pitch as the binder, but has the advantage of using non-coking coals, chars and other sources of carbon. Although briquetting of the coal is normally the method of agglomeration, pelletizing and extrusion techniques have been applied for some methods.

Dr. Kasperzyk mentioned that any kind of coal could be used for the production of formed coke.

Mr. P.J. Readyhough presented the next paper on "interpreting coal properties for utilization in commercial coke making." He described the methods of evaluating a coking coal as an interpretation of the results at Stelco. Coke ash has a substantial effect on blast furnace operation. Each percent increase in coke ash requires an additional 30 lbs. of dry coke per net ton of hot metal produced. The results indicate a decrease in blast furnace productivity of approximately 3 per cent. Sulphur in coal also requires more consumption of coke to maintain acceptably low sulphur levels in the hot metal. Each 0.1 per cent increase in coke sulphur requires an additional 8 lbs. of dry coke per net ton of hot metal and results in a decrease in production of 0.8 per cent. Both phosphorous and alkali oxides have detrimental effect on the blast furnace operation.

The ASTM stability index remains the only parameter of coke strength routinely measured at steel plants and has been shown significantly related to blast furnace performance. For each increase of 1 stability index unit, the dry coke rate dropped by approximately 15 lb/NTHM. According to Stelco, no significant gain in blast furnace productivity is realized above a wharf stability index of 55. He mentioned that the analyses namely, chemical rheological, fluidity by Gieseler Plestometer and dilatation tests were carried out for coal evaluation. The expansion and contraction results in the ASTM Sole-Heated ovens determined the blending properties of coals of different ash content.

Petrographic analysis is carried out on a routine basis for the prediction of commercial coke stability. Reflectance distribution of the vitrinite of coal is useful for quality control. He gave a specification for a good blast furnace coke.

Ash	%	8.0
Volatile Matter	%	1.0
Sulphur	%	0.70
Alkali oxide in Coke	%	0.20
Phosphorous Pentoxide in Coke	%	0.27
ASTM Stability		55.0

He discussed the variation of stability with different types of ovens and different bulk densities. The coking rate has also different effects on coke quality.

oven length	18"	12"	30"	Commercial
Bulk density dry charge				
lb/cu ft	46.5	51.0	51.0	46.5
coking rate in/hr	1.0	1.3	2.3	1.0

He also showed several graphs and formula to predict actual stability factor. He also mentioned that a higher percentage of Canadian coals in blends gave better results.

Mr. Readyhough concluded that much work was done on the petrographic evaluation and also in the coal pilot plants for Appalachian coals. Further work is undoubtedly necessary on western Canadian coals and the recently formed Canadian Coal Petrographers' group shows some progress in this area.

Dr. A. Cameron opened the discussion, and his first question was whether Shapiro and Gray's method of 2/3 inert semifusinite and 1/3 reactive. semifusinite was used in the prediction; pseudo-vitrinite or pitted vitrinite was considered in maceral counting. Second question was: How much variation in the stability index between predicted and experimental?

Mr. Readyhough replied that Shapiro and Gray's method was generally followed and pseudo-vitrinites were not considered in the counting. In commercial practice the coke strength can vary by six stability indexes from pusher to the coke side of an oven. Whereas the coke obtained from the center part of the oven, 0.5 to 1 unit would be tolerated.

Discussion of the Results of Round Robin Reflectance on Single Coal Pellet & Predicted Stability Index of Two Coals from Nova Scotia

The secretary presented the results of the reflectance measurement of a single coal pellet from six laboratories. The reflectance in oil varies from 1.01 to 1.16. This variation is probably due to the use of diversified instruments and methods used by different laboratories.

The secretary then presented the results of the predicted stability index from six laboratories. The average predicted stability indexes for sample 182 and 183 are 38.8 and 30.5 respectively. The variations in the predicted stability index among laboratories are comparatively lower than the previous round robin. It appears that the distribution of V-types varies considerably and this V-type distribution rather than maceral distribution plays a dominant role in correct prediction of stability index. The results of this exercise appear to be very satisfactory.

Dr. B.N. Nandi discussed "The Microhardness test in connection with the oxidation of western Canadian coals and its relation to reflectance." He mentioned that the following correlations were obtained from these tests:

1. Microhardness index and the rank of western Canadian coal.
2. Microhardness index and degree of oxidation.
3. Microhardness index and the reflectance of oxidized and fresh coals.

He said oxidation proceeds from the outer edge to the center of the coal particles and the reflectance increased with the oxidation but the microhardness index or the indentation mark decreased with oxidation. He showed several micrographs to substantiate these statements. He concluded that from the preliminary studies, the microhardness impression indicated the degree of oxidation in high volatile coals. The elastic property of the vitrinite of high volatile coals rapidly increased with the rate of oxidation and the changes in impression were readily observed.

Indications are that in the high volatile coals the plastic and brittle state of fresh vitrinite is transformed into an elastic state with oxidation. In the case of low volatile coals, oxidation does not rapidly alter the impression by the microhardness test although the coal has completely lost its dilatation and contraction. Only in the case of severe oxidation does the vitrinite of low volatile coals produce some noticeable change from the brittle state to the elastic state.

Coke Microscopy

Mr. A. Hampson said that coke microscopy can be an important parameter to examine the structure of coke from different coal and its blending in the future. At present Dofasco is not actively engaged in the microscopic examination of coke but he said it would be desirable to get more information on the subject. He referred to the work done by German and American coal petrographers and its usefulness.

Dr. Nandi presented a paper on the microscopic examination of coke in relation to other physical and chemical properties. He mentioned preliminary evaluation prior to the 500 lb movable wall oven test can be made from a maceral analysis, dilatation tests and the microscopic examination of semicoke from the Ruhr dilatometer. The microscopic examination of semicoke generally indicates whether vitrinite in the coal is oxidized and also indicates to some degree, a) the bonding characteristics of different macerals and b) fluidity of the vitrinite on pyrolysis. Macropores, cracks and fissures can be judged in a more satisfactory manner from the microscopic examination of high temperature coke. There is very little difference in the microscopic examination of semicoke produced at 550°C and high temperature coke except that the latter coke will show more mosaic structure, anisotropy and micropores.

At the first International Conference on Coal Science in Heerlen (1955), Dr. Prof. M.T. Mackowsky illustrated the value of the microscopic investigation in the studies of coke structure and strength. The area of macropores in coke can be quickly determined by the modern IMANCO QUANTIMET or ZEISS MICRO VIDEOMAT. Macropores and fissures in coke can be easily identified by the optical microscope, but to determine the total area of macropores and fissures in coke with an integrating stage in the optical microscope is a very laborious and time consuming process. The area of micropores in our opinion is another useful property for evaluating the strength of coke.

The experimental ASTM stability index is at present the most important parameter to evaluate coke for the blast furnace. Several North American scientists expressed doubts about this test because it is generally done at room temperature. It was observed that by tumbling some coke of high stability index at 1000^{o}C in CO_2 atmosphere, very fine particles below 1.6 mm was obtained though reactivity in CO_2 was very low. Again there is no correlation between ASTM stability index and the coke CO_2 reactivity value. The pattern of mosaic structure and anistropy depends on the quality and the rank of the coal initially charged in coke-making.

Dr. Nandi presented a short report on 'The effect of Depth on the Coking Properties of Coal from the New Lingan Mine, Harbour Seam, Nova Scotia: 5 samples were taken at a depth of 96', 375', 608, 848' and 996' from the surface. The petrographic analyses show more or less the same composition except the sample from depth of 96' which showed about 6% higher inertinite. The reflectance progressively increased from 0.80 to 0.91 with the increase of depth. The proximate analysis and F.S.I. value practically remained the same in all five samples. The dilatation also increases progressively from 6% to 181% with the increase of depth. The most interesting feature is the maximum fluidity which was increased from 160 ddm (at 96' ft.) to 20,250 ddm (at 996 ft.).

He concluded that (1) the rank of the coal increased slightly from the reflectance measurement but from proximate analysis this variation of rank increase could not be detected. (2) The coking properties and fluidity increased with the depth.

Discussions on Reflectance Measuring Conditions & Results on New British Standards

Dr. L.M. Jukes of British Steel Corporation sent Dr. Nandi 3 synthetic standards, namely YAG, 3G and Spinel to compare with the existing standard used by the North American Coal Petrographers. The determination of the reflectance of these synthetic standards against the glass standards were carried out by Mr. P.R. Gunther of Geological Survey of Canada and Mr. B.H. Moffatt of CANMET. There was a very slight variation in the results of the reflectance measurement between the two laboratories.

Mr. P.R. Gunther spoke on three main topics, two of them being minor and subsequent to the original main topic which concerned the New British Standards:

(a) The New British Standards were cross-checked in three ways:

1. Each standard was used to calibrate the equipment then each of the existing glass standards were read for random, minimum and maximum value.
2. The YAG was used as the calibration standard and then the maximum values of the Spinel and 3G were determined.
3. The 3G was used for calibration and 4 other positions on its surface were read.

It was concluded that the new standards had only an accuracy equivalent to that of the old standards and therefore were only an asset because of hardness.

(b) One of the consequences of the above study involved calibration at a random stage position versus calibration at the stage position of maximum reflectance.

Here it was concluded that the maximum reflectance position method of calibration became more critical the higher the rank

(c) The final consequent study involved green light (546 MM) versus white light.

Here again it was concluded that as the rank increases, so does the difference in the reflectance values using the two types of light.

Dr. Nandi mentioned that from the results of his laboratories the indications were that the high reflectance glass standard (Ro-1.81) was not very stable and the reflectance (Ro) varied from one place to another. The equipment was calibrated with 3 synthetic standards. All the low reflectance standards gave the same accuracy to those of synthetic standards. These synthetic standards are more stable, better polished and give a more consistent reflectance from the center to the edges.

Dr. Cameron expressed that because of the high cost price of the synthetic standards the members would be hesitant to replace the glass standards.

<u>Discussion on the problems related to western and eastern Canadian coal from the invited guests and attending members</u>

Dr. B. Dutt opened the discussion by asking, why the western Canadian coal is not used by Steel Producers of Canada. Mr. Hampson said that it was not economical to use western Canadian coal because of its high ash content, material handling problems and insufficient technological data. However, Stelco, Dofasco and Algoma used significant amounts of Canadian coal. Again it had limited use. Paul Readyhough mentioned that there was lack of railway cooperation and also handling difficulties during the winter months due to moisture. Major problems - ash and alkali matters in coal.

Ash content in western Canadian coal is about 2% higher than the coal used by steel producers. For the flowability of coal, size and moisture content are important factors during transportation.

Dr. Dutt asked what was the suitable ash content for coke-making in the blast furnace. Mr. Hampson said 5.2% - 7% ash content would be ideal. But 5-8% ash content during beneficiation of coal would be economical. He also mentioned 10-12 million tons of western Canadian coals were used in steel making.

Business Meeting

Mr. Readyhough proposed that a series of micrograph of different macerals would be circulated to different laboratories for identification. The results of identification would be sent directly to him and the results of this Round-Robin will be discussed in the next meeting. This proposal was accepted and Dr. Nandi will prepare a pellet which will be forwarded to Mr. Readyhough for this exercise.

Owing to the great variation in the last Round-Robin results on the reflectance determination, Dr. Cameron suggested that a single pellet from eastern Canadian coal would be circulated to different laboratories stipulating the conditions of determining the reflectance. Dr. Nandi will circulate this pellet.

Mr. Readyhough moved a motion that the admission of new members to this group should be the subject of approval from the CCRA as this group is engaged in some confidential work related to steel companies. The chairman, Dr. Cameron, pointed out that there was no constitution or charter of this group and this group was simply affiliated to the CCRA. Dr. Cameron requested Mr. W. Dowhaniuk (Chairman of the Technical Committee and also representative of CCRA) to express his views on this matter.

Mr. Dowhaniuk replied that he was unable to comment without discussing this matter with CCRA committee members. He requested postponement of this motion till the next meeting.

Next Mr. Readyhough suggested a CCRA proposal on the characterization and utilization of western Canadian coking coals through petrography. He has circulated the proposals of Mr. Paulencu and requested the Chairman to submit a report of the comments and suggestions of the attending members to Mr. Paulencu.

Mr. Dowhaniuk mentioned that CCRA Technical Committee was not aware of this proposal, however, the CCRA Technical Committee would discuss Mr. Paulencu's proposal at their next meeting.

The Chairman invited the comments and proposals from the members on Mr. Paulencu's proposal and he would send a summary of the comments and proposals directly to Mr. Paulencu.

Dr. Nandi circulated the letter from Mr. N. Kaye of the British Carbonization Research Association, England, and the minutes of the third meeting of the British Coal Petrographer's Group. It was decided that Dr. Nandi would continue liaison with Mr. Kaye and British Coal Petrographer's group. On the issue of inviting Coal Petrographers from the U.S.A., this proposal will be discussed at the next meeting. Probably later, an invitation would be extended to U.S.A. Coal Petrographers to attend our meeting.

Dr. Cameron said that he would be away for 1 year and under these circumstances, it would be difficult for him to continue as Chairman of this group. Dr. Nandi proposed the name of Dr. P.A. Hacquebard for Chairmanship and his proposal was unanimously accepted by the members. Dr. Cameron was requested to write a letter to Dr. Hacquebard to be the next Chairman of this group.

Mr. Readyhough proposed that the next meeting would be held at Hamilton, Ontario in early January, 1976. He informed that the Steel Company of Canada would be very pleased to be the host of this meeting. His proposal was unanimously accepted. He also suggested a panel discussion on the Geology of eastern and western Canadian coal fields. The secretary said that he would include these topics in the agenda for the January Meeting.

There will be arrangements made to tour the Stelco Research Laboratories at Burlington after the Meeting.

The Meeting was adjourned at 3:30 PM.