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A LABORATORY METHOD FOR DETERMINING COAL FLY-ASH RESISTIVITIES FOR COMPARISON WITH PILOT-SCALE DATA

H. Whaley, J.K. Wong, G.N. Banks, K.V. Thambimuthu and D.G. Savignac

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A LABORATORY METHOD FOR DETERMINING COAL FLY-ASH RESISTIVITIES FOR COMPARISON WITH PILOT-SCALE DATA

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H. Whaley*, J.K. Wong**, G.N. Banks***, K.V. Thambimuthu***
and
D.G. Savignac****

ABSTRACT

The Combustion and Carbonization Research Laboratory (CCRL) of the Canada Centre for Mineral and Energy Technology (CANMET) has been involved for many years in pilot-scale research on coal combustion. One of the essential objectives has been to assess the environmental impact of coal combustion and to develop methods for reducing or containing the ensuing pollutant emissions.

The in situ measurement of fly ash resistivity is useful in determining the efficiency with which it can be collected in an electrostatic precipitator. Such measurements are few in number because they are expensive and are often difficult to obtain during pilot-scale combustion experminents.

CCRL has developed an isothermal laboratory method for producing representative ash samples and determining their resistivity variation with combustible content. The technique employs the same point-plane probe as that used in the pilot-scale tests.

The technique is described and data from several Canadian coals are given which compare favourably with in situ measurements.

*Section Head, **Physical Scientist, ***Research Scientist and **** Research Technologist, Industrial Combustion Processes, Combustion and Carbonization Research Laboratory, Energy Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, K1A 0G1.

UNE MÉTHODE DE LABORATOIRE POUR DÉTERMINER LA RÉSISTIVITÉ DES CENDRES DE CHARBON EN VUE D'UNE COMPARAISON AVEC DES DONNÉES À L'ÉCHELLE PILOTE

par

H. Whaley*, J.K. Wong**, G.N. Banks, K.V. Thambimuthu***
et D.G. Savignac****

RÉSUMÉ

Depuis de nombreuses années, le Laboratoire de recherche sur la combustion et la carbonisation (LRCC) du Centre canadien de la technologie des minéraux et de l'énergie (CANMET) participe à des travaux de recherche sur la combustion du charbon, dont l'un des buts principaux est d'évaluer les effets de la combustion du charbon sur l'environnement et d'élaborer des méthodes pour réduire ou contenir les émissions polluantes qui en résultent.

Il est utile de mesurer in situ la résistivité des cendres pour déterminer l'efficacité avec laquelle elles peuvent être recueillies dans un dépoussiéreur électrostatique. Ces mesures sont effectuées en petit nombre en raison de leurs coûts élevés et de la difficulté que l'on éprouve souvent à les obtenir durant les essais de combustion à l'échelle pilote.

Le LRCC a mis au point une méthode isothermique de laboratoire en vue produire des échantillons de cendres représentatifs et de déterminer la variation de leur résistivité par rapport au contenu du combustible. Selon cette méthode, on utilise la même sonde ponctuelle avec plaque que celle employée lors des essais à l'échelle pilote.

Dans le présent rapport, les auteurs décrivent cette technique et présentent des données sur plusieurs charbons canadiens qui se comparent favorablement aux mesures in situ.

* Chef de section, ** Chercheur en sciences physiques, *** Chercheur scientifique et **** Technologiste chercheur, Procédés de combustion industriels, Laboratoire de recherche sur la combustion et la carbonisation, Laboratoires de recherche sur l'énergie, CANMET, Énergie, Mines et Ressources Canada, Ottawa, K1A 0G1.

INTRODUCTION

Control of particulate emissions from industrial combustion processes has long been a major pollution problem in industrialized countries. The enactment of more stringent air pollution control legislation demands that micron and submicron size particles must be removed at high efficiency (>99%). They account for most of the visible stack emissions and are injurious to health. Electrostatic precipitation is one of the basic processes used for effectively removing such particles in the flue gas stream. First the particles are electrically charged at high voltage to form a corona of ionized particles, which are then discharged on grounded collector electrodes. Then the electrode plates are rapped at intervals in order to discharge the ash into hoppers for removal.

The resistivity of the pulverized fuel ash is an important factor in determining the efficiency of capture and re-entrainment in electrostatic precipitators. Ash particle resistivity is used to determine the suitability of a precipitator for particulate emissions control and ultimately to assist in determining the size of a full-scale precipitator.

Particle resistivity measurements are made with high voltage conductivity cells, designed for use at high temperature and for the rugged conditions encountered in the field. Several types of cells have been developed, but all are based on the concept of measuring the leakage current through a particle layer to which a high voltage field is applied.

Although the measurement of the resistivity of bulk layers of particles involves only simple concepts, the actual measurements in particles are influenced by a number of other factors. The resistance depends on ash composition, size, compaction, the electric field applied to the layer and the temperature, humidity and chemical composition of the surrounding gases. Thus, the value obtained for the resistivity depends essentially on the conditions of measurement. The most logical approach, when determining resistivity for electrostatic precipitator design and operation purposes, is to duplicate, insofar as possible, the conditions that exist in the collected particle layer in precipitators (1).

EXPERIMENTAL TECHNIQUES

Several methods are used to determine particle resistivity, but the point-plane apparatus used directly in a plant flue gas stream reasonably simulates conditions found in a precipitator. This point-plane concept involves the use of a probe that consists of point-plane cells, a high voltage DC power supply and a current measuring circuit. These are shown schematically in Figures 1 and 2. The point-plane cell is inserted into the flue gas stream and the particle resistivity is determined in situ. In this way the resistivity is determined exactly where the gas properties including moisture content, temperature, trace concentrations of contaminant gases would be in the full-scale electrostatic precipitator.

IN SITU FLY ASH RESISTIVITY DETERMINATIONS

In situ fly ash resistivity measurements are obtained during pilot-scale combustion experiments. The pilot-scale research boiler used in the combustion trials was described elsewhere (2) and the location of the resistivity measurement device is illustrated in Figure 3.

The in situ fly ash resistivity was measured by inserting a point-plane measuring probe into the flue gases (3). Before taking measurments, the probe is allowed to reach thermal equilibrium (~175 ^{o}C) with the gas stream; then a voltage sufficient to generate a corona is applied to the point at one end of a measuring cell. Fly ash deposits electrostatically on the plane at the opposite end of the cell. When an adequate dust layer has been collected (in approximately 1 h), the high voltage corona is removed and the voltage/current characteristics of the dust layer and its thickness are measured (4). The resistivity is calculated using:

$$R = \frac{V}{I}\frac{A}{L}$$

where
R = resistivity, ohm-cm
V = applied voltage, volts
I = measured current at voltage applied, amps
A = area of plane, 5 cm^2
L = thickness of the dust layer, cm

FLY ASH BENCH-TOP ISOTHERMAL RESISTIVITY DETERMINATIONS

CCRL has developed a simple bench-top isothermal procedure to corroborate resistivity measurements obtained in situ as follows:

1. A 10 g fly ash sample (S), collected during combustion experiments, is ashed at 500 ^{o}C for 6 h in an oxidizing atmosphere to produce a combustible-free ash sample (Sa).
2. Blends of sample (S) and ashed sample (Sa) are then prepared to obtain mixtures with a range of combustible contents.
3. The actual combustible content of each mixture is determined by ashing a portion of the samples at 500 ^{o}C for 6 h.
4. Resistivity measurements of the fly ash blends are then obtained using the same point-plane resistivity apparatus as that used for the in situ measurements. In order to perform these tests, the resistivity probe is mounted in an electrically heated oven, thermostatically controlled at 175 ^{o}C. The probe is preheated to the set temperature; then a thin layer of prepared ash sample is placed on the point-plane cell. When the probe reaches thermal equilibrium, the voltage/current characteristics of the sample and its thickness are measured and the resistivity determined.

When the fly ash collected contained an extremely low combustible content, an attempt was made to blend the fly ash sample with the original coal sample in order to produce a sample with a higher combustible content. Resistivity measurements of these ashed fly ash/coal blends were obtained using the same method as that for the fly ash blends.

RESULTS

Figures 4 to 8 show the relationship between ash resistivity and combustible content for several Western Canadian bituminous coals having different volatile matter contents. The isothermal resistivities showed good agreement with the in situ measurements, following an "S" type relationship in which the coal ash dominates at low combustible content and carbon dominates at higher levels. Consequently, in each case the initial value was about 13 log ohm-cm and decreased to about 5. The abrupt change in resistivity occurred between 2 and 6% combustible content and must be considered to be influenced by the many factors discussed earlier.

The laboratory blended ash/coal samples did not show the decrease in resistivity with increasing combustible content. This was probably due to constituents in the coal which are normally volatilized during combustion.

It must be noted that most coals examined at CCRL (5) showed the "S" type relationship, but the initial values and the location of the abrupt decrease to the carbon resistivity varied according to the coal type. Some coal ashes had lower initial resistivities than 13 log ohm-cm.

CONCLUSIONS

Isothermal resistivity values obtained with laboratory blended fly ash samples correlated well with in situ resistivity measurements obtained in pilot-scale combustion tests.

This laboratory technique can be used to determine accurately the expected electrical resistivity of fly ash containing a specified combustible content and thus aid in predicting the ease of collection in a electrostatic precipitator.

The laboratory blended ash/coal samples failed to provide representative results. This was probably due to constituents in the coal portion which are normally volatilized during combustion.

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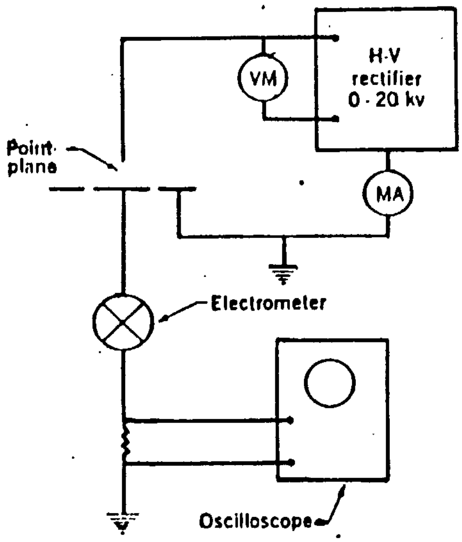


Fig. 1 - Schematic circuit diagram of resistivity apparatus

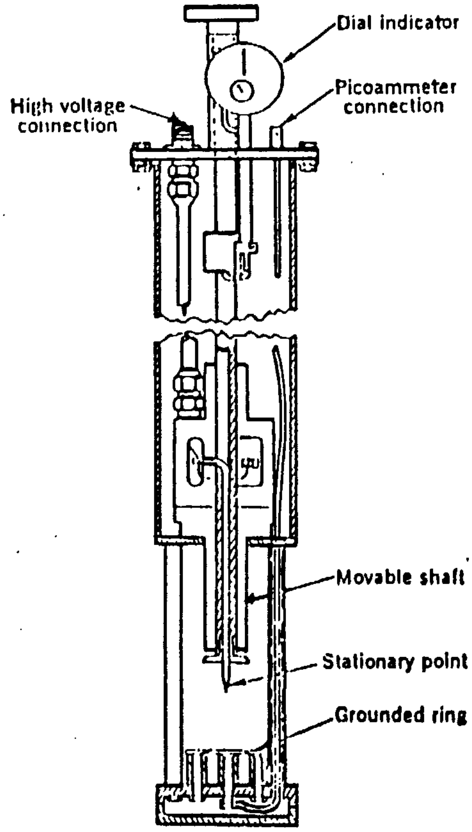


Fig. 2 - Point-plane resistivity device, with built-in layer thickness measuring gauge

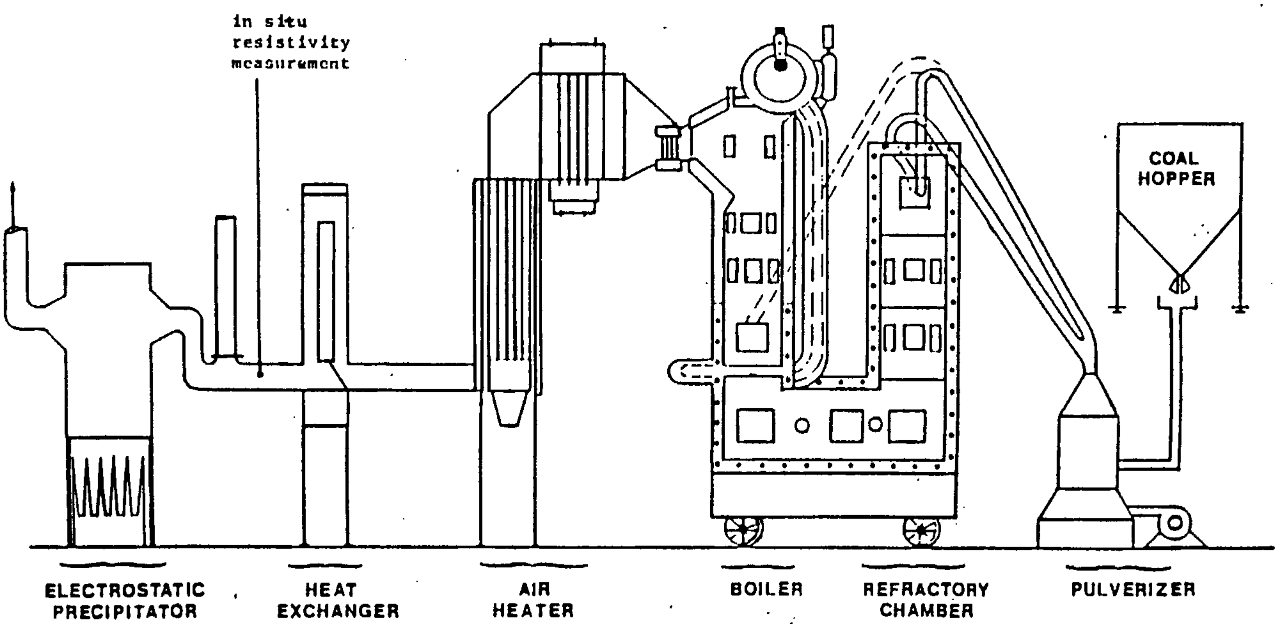


Fig. 3 - Schematic illustration of the CCRL pilot-scale research boiler

Fig. 4 - Raw H.V. Bituminous Coal (Seam 1N)

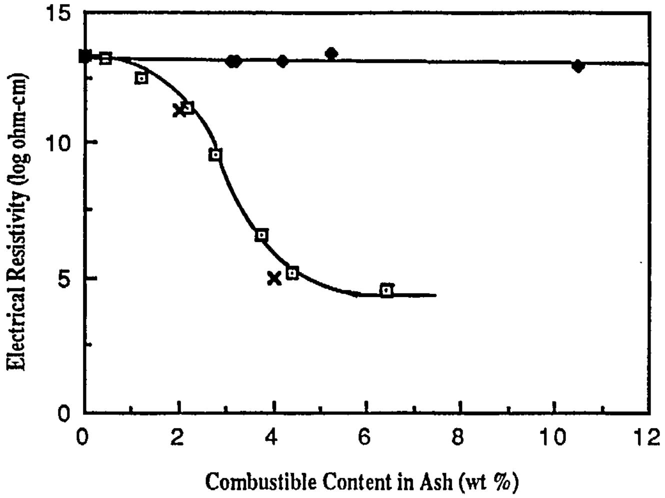


Fig. 5 - Washed H.V. Bituminous Coal (Seam 1S)

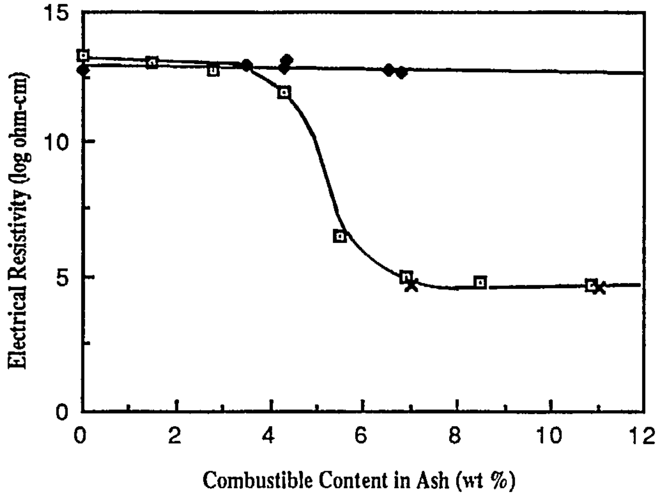


Fig. 6 - Reference H.V. Bituminous Coal

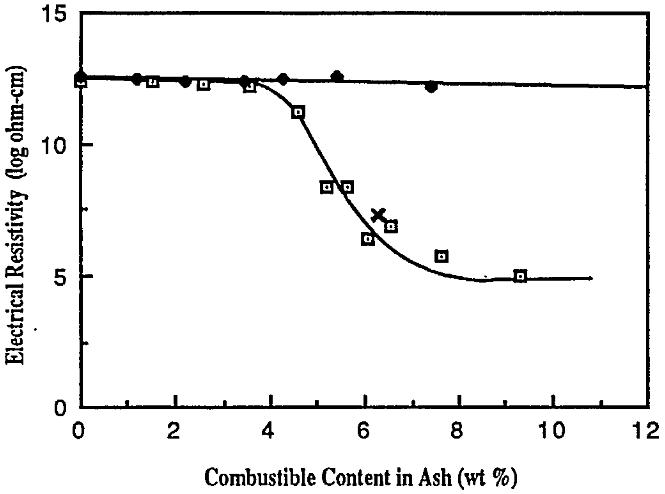


Fig. 7 - M.V. Bituminous Coal

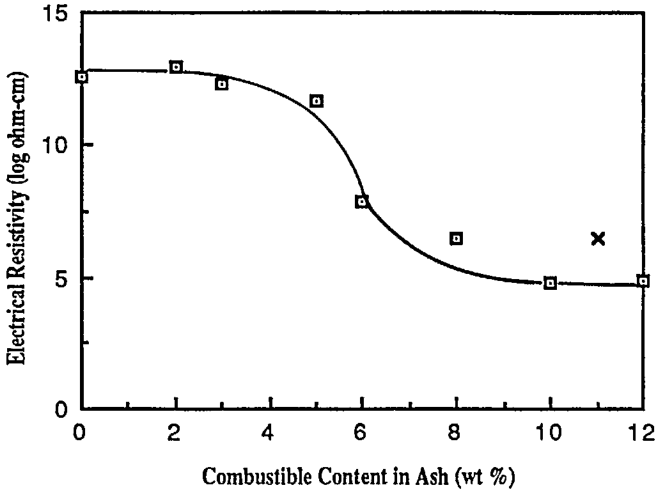
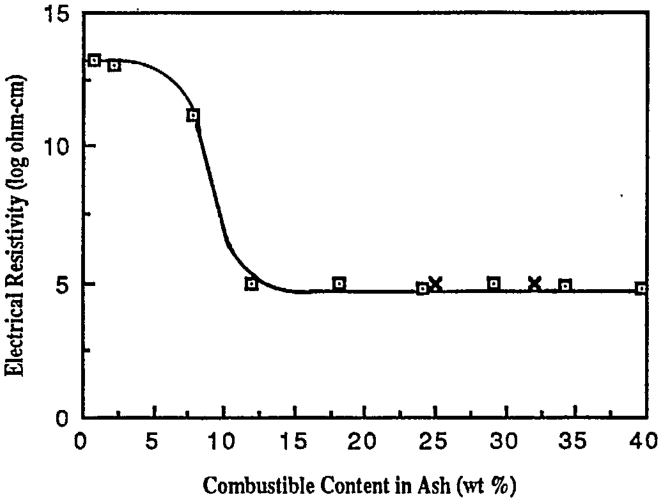


Fig. 8 - L.V. Bituminous Coal



◆ Isothermal resistivity of coal blended ash

▫ Isothermal resistivity of ash blended ash

✕ In situ resistivity

Figs. 4-8 - The effect of combustible content on fly ash electrical resistivity