Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

A LABORATORY ISOTHERMAL TECHNIQUE USED TO ASSESS THE FACILITY OF COLLECTING FLY ASH IN ELECTROSTATIC PRECIPITATORS

H. Whaley, J.K. Wong, K.V, Thambimuthu and G.N. Banks
Combustion and Carbonization Research Laboratory

May 1988

For presentation at the 1988 Joint Power Generation Conference, Sept. 25-29, 1988, Philadelphia, U.S.A. and for publication in proceedings.

ENERGY RESEARCH LABORATORIES
DIVISION REPORT ERL 88-53 (OPJ)

A LABORATORY ISOTHERMAL TECHNIQUE USED TO ASSESS THE FACILITY OF COLLECTING FLY ASH IN ELECTROSTATIC PRECIPITATORS

by

H Whaley*, JK Wong**, KV Thambimuthu*** and GN Banks***

ABSTRACT

The in situ measurement of resistivity is a useful parameter in determining the efficiency with which coal fly ash can be collected in an electrostatic precipitator (ESP). Such measurements are few because they are expensive and they are often difficult to obtain during pilot-scale combustion experiments and even more so on operational boilers.

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 major objectives has been to assess the environmental impact of coal combustion and to develop methods for reducing or containing the ensuing pollutant emissions.

This research program has resulted in the development of 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 and can be used in the field.

Data from several coals and coal blends are given which show the relationship between the screening method, in situ resistivity measurements and fly-ash precipitability.

This laboratory procedure is inexpensive and can be extremely valuable in providing ESP manufacturers with reliable design data without recourse to expensive and often unreliable field measurements.

---

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

DÉVELOPPEMENT EN LABORATOIRE D'UNE TECHNIQUE ISOTHERMIQUE POUR ÉVALUER L'EFFIICACITÉ D'UN DÉPOUSSIÉREUR ÉLECTROSTATIQUE EN CE QUI Ã TRAIT Ã LA COLLECTE DES CENDRES VOLANTES

par

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

RÉSUMÉ

La mesure in situ de la résistivité s'est avéré un paramètre utile pour déterminer l'efficacité d'un dépoussiéreur électrostatique pour la collecte des cendres volantes. Ce genre de mesure est rarement effectué en raison de son coût élevé et du fait qu'il est difficile à réaliser pendant les essais de combustion à l'échelle-pilote et plus onéreux encore quand les chaudiéres de service sont utilisées.

Le Laboratoire de recherche sur la combustion et la carbonisation (LRCC) du Centre canadien de la technologie des minéraux et de l'énergie (CANMET) s'intéresse depuis plusieurs années à la recherche expérimentale sur la combustion du charbon. Un de ses objectifs principaux a consisté dans l'évaluation des effets de la combustion du charbon sur l'environnement et le développement de méthodes en vue de réduire ou de contrôler les émissions de contaminants.

Le programme de recherche a donné lieu au développement en laboratoire d'une méthode isothermique en vue de produire des échantillons de cendre représentatifs et de déterminer la variation de leur résistivité quand ils ont un contenu combustible. Pour les besoins de la technique, on utilise la même sonde à surface ponctuelle que celle dont on se sert pour les essais à l'échelle-pilote et qui est utilisable sur le terrain.

Le rapport comprend des données sur plusieurs charbons et mélanges de charbon. Elles indiquent les rapports entre la méthode de criblage, la mesure in situ de la résistifité et la précipitation électrostatique des cendres volantes.

La technique developpée en laboratoire est peu coûteuse et peut s'avérer extrémement utile pour fournir des données d'études fiables aux fabricants de dépoussiéreurs électrostatiques sans avoir recours aux techniques de mesure sur le terrain qui sont coûteuses et douvent incertaines.

*Chef de section, **Chercheur, spécialiste des sciences physiques, *** Scientifique de la recherche, Procédés de combustion industrielle, 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

Most of the particulate emissions that are injurious to human health are in the micrometer and sub-micrometer size range. The more stringent emissions control regulations that are being enacted by industrialized nations mean that ash particles must be collected at efficiencies greater than 99%. One of the most effective processes for collecting fly ash particles from coal combustion is electrostatic precipitation. In the operation of an electrostatic precipitator (ESP), the fly ash particles are electrically charged at high voltage to form a corona of ionized particles, which then migrate towards grounded collector plates.

Many properties of the coal and its ash composition as well as the design of the ESP, influence the collection efficiency, and one such parameter is the ash resistivity. Several types of cells have been developed for measuring particle resistivity, but all are based on the concept of measuring the leakage current through a particle layer to which a high voltage field is applied.

The measurement of the resistivity of particles also depends on ash composition, size, compaction, the electric field applied and the temperature, humidity and chemical composition of the surrounding gases. The value obtained for the resistivity will depend on the actual conditions of measurement and thus the most logical approach, when determining the resistivity for electrostatic precipitator design and operational purposes, is to duplicate the conditions, so far as possible, that will exist in the collected particle layers in the precipitators (1, 2).

This paper describes a laboratory method that can be used to determine the resistivity variation with ash carbon content. It also gives some data relating to the in situ determination of resistivity and electrostatic precipitator performance obtained during pilot-scale combustion evaluations of a three coal blend of varying properties.

EXPERIMENTAL TECHNIQUES

Several methods can be used to determine ash 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 Figure 1. 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 and trace concentrations of contaminant gases would be in the full-scale ESP.

PILOT-SCALE COMBUSTION EQUIPMENT

Figure 2 shows the pilot-scale research boiler used in the combustion trials which has been described in detail elsewhere (3). The location of the sampling ports and the ESP are also indicated.

IN SITU FLY ASH RESISTIVITY DETERMINATIONS

The in situ fly-ash resistivity was measured by inserting a point-plane measuring probe into the flue gases (4). Before taking measurments, the probe is allowed to reach thermal equilibrium (~175°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 (5). 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°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°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°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 is determined.

When the fly ash 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 fly ash/coal blends were obtained using the same method as that for the fly ash blends.

RESULTS

Figures 3 to 5 show the relationship between ash resistivity and combustible content for three Western Canadian bituminous coals (low, medium and high volatility). 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 (6) 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.

In the pilot-scale combustion tests of a nominal 50% eastern US high-volatile bituminous coal and 50% of a mixture of medium- and high-volatile Western Canadian coals, the same decrease in resistivity is found at about 12% combustible in fly ash as shown in Fig. 6. This also coincides with peak precipitator performance.

CONCLUSIONS

In situ measurements of fly-ash resistivity have been shown to have a strong influence on the performance of a small ESP unit in pilot-scale combustion experiments on coal blends.

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 an ESP.

The laboratory blended ash/coal samples failed to provide representative results, probably due to constituents in the coal which are normally volatilized during combustion and have an influence on the value.

REFERENCES

1. White, H. J. "Resistivity problems in electrostatic precipitation", Journal of the Air Pollution Control Association, April 1974, Volume 24, No.4, pp. 314-338.

2. Smith, W.B., Cushing, K.M. and McCain J.D. "Procedures manual for ESP evaluation EPA 600/7-77-059 US EPA RTP NC NTIS PB269698 June 1977.

3. Lee, G.K., Friedrich, F.D., Steindl, S.I. and Whaley, H. "A pilot-scale combustion research facility for low-quality fuels", Division Report ERP/ERL 81-52 (OP)(TR), 1981, CANMET, EMR Canada, Ottawa.

4. Southern Research Institute, Birmingham, Ala., "A manual of electrostatic precipitator technology. Part 1 - Fundamentals"; prepared under Contract CPA 22-69-77 for the National Air Pollution Control Association, Division of Process Control Engineering, 1970.

5. Western Research and Development Ltd., "In situ point-plane resistivity apparatus manual", Calgary, Alberta, Canada, 1976.

6. Lee, G.K., Whaley, H. "Modification of combustion and fly ash characteristics by coal blending", Journal of the Institute of Energy, Volume LVI, Dec. 1983, pp. 190-197.

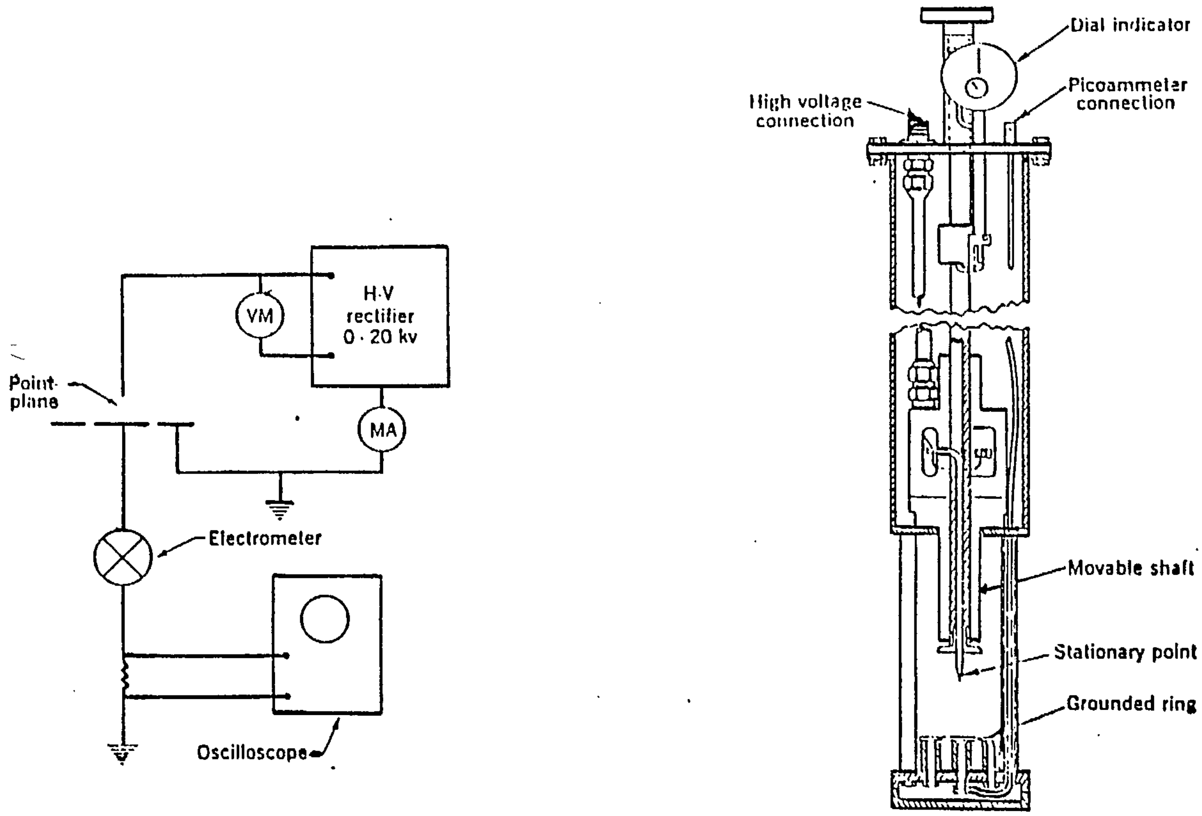

Fig. 1 - Schematic illustration and circuit diagram of point-plane resistivity apparatus

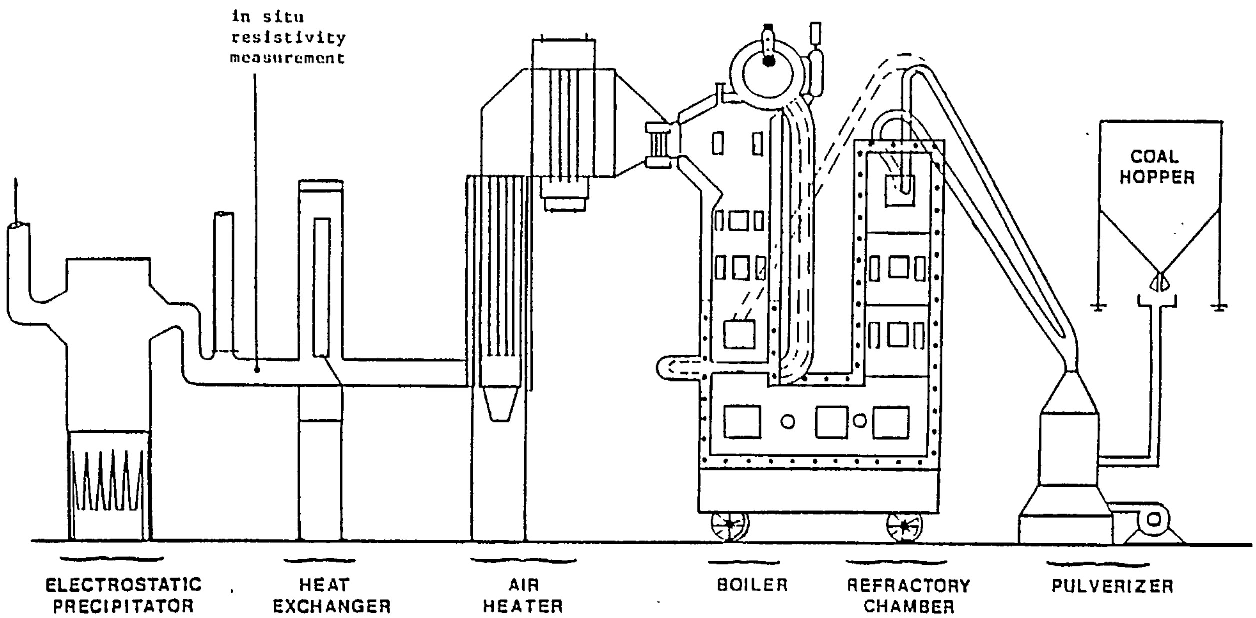

Fig. 2 - Schematic illustration of the CCRL pilot-scale research boiler

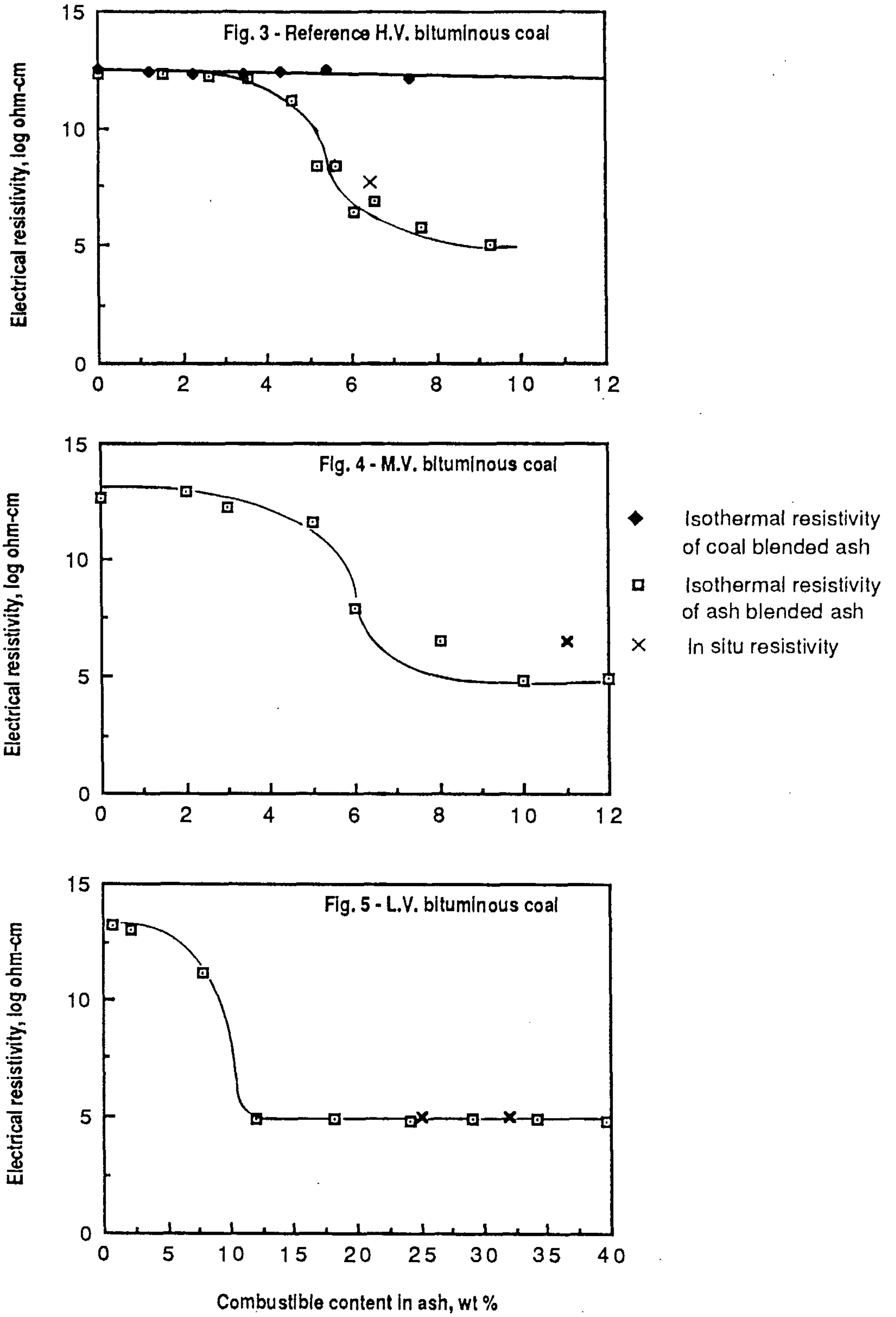

Fig. 3-5 - Effect of combustible content on fly ash electrical resistivity

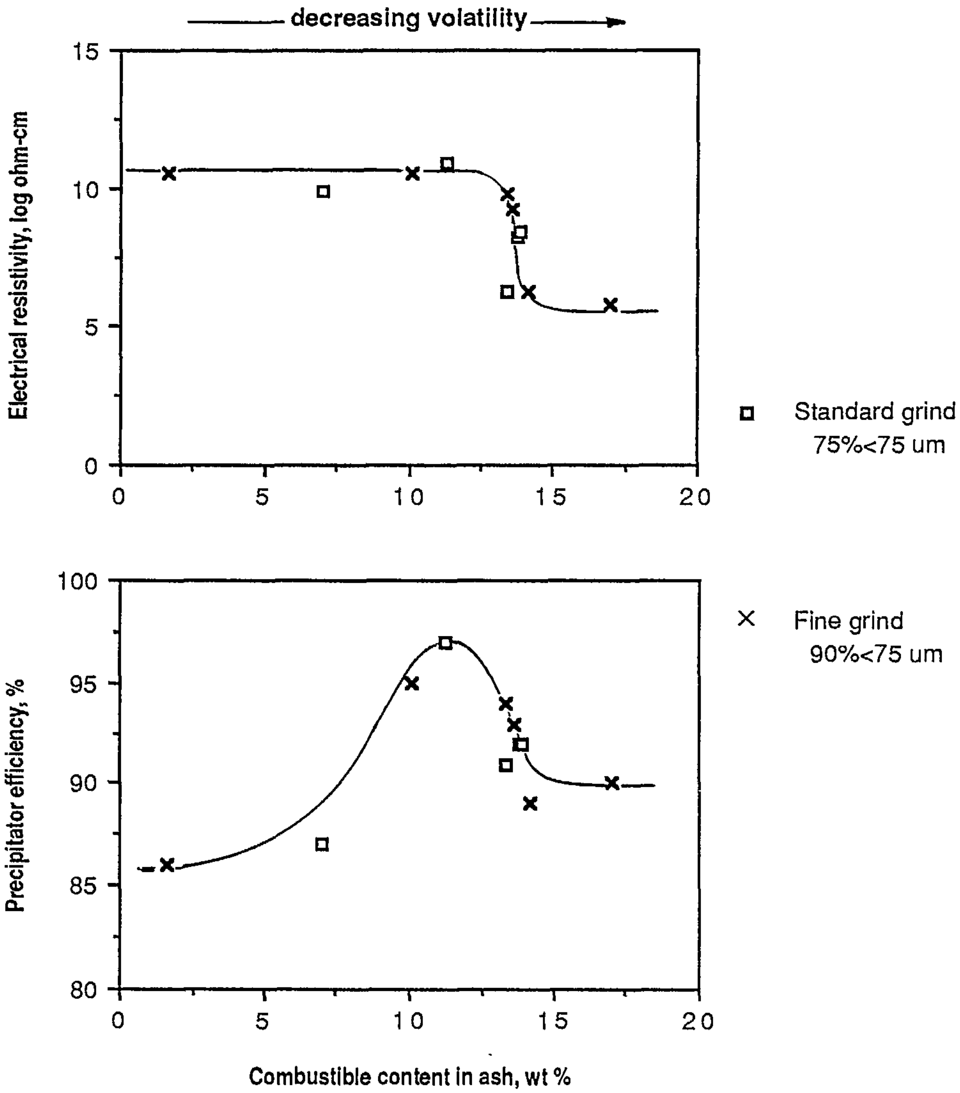

Fig. 6 - Effect of combustible content on fly ash resistivity and precipitator efficiency