INVESTIGATIONS ON FLY ASH RESISTIVITY OF VARIETIES OF COALS USED IN INDIAN POWER PLANTS

A. Chandra[1], S. Kumar and Sanjeev Kumar
Centre for Energy Studies
Indian Institute of Technology Delhi,
Hauz Khas, New Delhi –110 016 (India)

ABSTRACT

Fly ash resistivity measurements facility has been set up at Centre for Energy studies, Indian Institute of Technology Delhi (India) to develop a data base for India and to monitor the impacts of any technique use to modify ash resistivity, like U.S. laboratories we also follow the IEEE Standards Criteria (IEEE Std. 548-1984) and guidelines for the laboratory measurements and reporting of fly ash resistivity. The test procedures captures the changes in ash resistivity with respect to temperature and composition changes of ash. The required instruments needed are Kiethly electrometre, Fluke power supply, Blue M oven, lattice frame, digital temperature readers, variacs, vacuum equipments, relay rack and sensitive thermocouples.

In the present study we have measured the fly ash resistivity and its variation in ascending and descending temperature modes (90-460 ^{0}C) for the fly ash samples of different thermal power plants. The study also reports the results on the effect of sodium conditioning in coal on fly ash resistivity and it is observed that the resistivity decreases significantly due to change in the chemical composition of the coal.

Key Words: coal properties, fly ash resistivity and sodium conditioning

INTRODUCTION

Coal is the main source of generating power in India, at present and likely to remain so in future as well. The total installed capacity in India has reached 1,09,868 MW with thermal capacity of 77868 MW as on 1st November 2003 [1]. In India, 59% of the power generation is from coal-fired thermal power plants and 70% of the coal produced has been used for thermal generation [2]. This is expected to be doubled in the next 10-12 years to meet the situation of "power on demand''. Almost all the thermal power plants at present and in future as well are likely to be based on the coal available in India.

In coal –fired power plant, the design and operation of electrostatic precipitators (ESP) depends largely on the properties of the coal burned and fly ash generated. The average characteristics of Indian coal is given in table 1 [3]. Most of the times Indian coal is characterized by high ash (34– 45%) and low sulfur contents. Because of the low sulfur contents in Indian coals (<0.5%), the resistivity is 100 to 1000 times higher than that generated, say, in U.S. and other Europeans countries. As a result the ESPs in India, despite being much larger, have lower collection efficiencies, than the ESPs in the U.S. Thus a knowledge of ash resistivity is essential for the design improvements of ESPs.

The electrical resistivity of fly ash strongly depends on the chemical composition of the fly ash., Table 2 indicates the typical fly ash chemical compositions data for some of the Indian thermal power stations with major constituents e.g. silica (SiO_2), alumina (Al_2O_3) and iron oxides (Fe_2O_3).

In the paper, we have determined the fly ash resistivity and its variation with temperatures in ascending and descending modes for different fly ash samples (two samples from U.S. thermal power station (E1035-143-12 & Miller steam) and ten samples from Indian thermal power station, Korba). The effect of sodium conditioning/dosing in the coal being burnt in the boilers on the fly ash resistivity for the temperature range 90-460 ^{0}C in ascending and descending modes has also been studied.

[1] Corresponding author, E mail: Chandra@ces.iitd.ernet.in

EXPERIMENTAL SET UP AND TEST PROCEDURE

An experimental test arrangement was set up as per IEEE standard criteria and guidelines (IEEE Std. 548-1984) [4] for the fly ash resistivity measurements as shown in Fig.1. The test apparatus includes four electric resistivity test cells enclosed in the test chamber in such a manner that the fly ash under test is maintained in intimate contact with the specified gaseous environment. The test cells are housed in a thermally controlled chamber so that resistivity can be determined at temperature range of 90–460 degree C. The resistivity test cell has parallel plate construction made from SS 304 steel. The test facility also includes an arrangement to obtain the fly ash resistivity at the desired value of the moisture content by adjusting the water bath temperature.

Fly ash sample was prepared in accordance with the IEEE standard and placed in the test cell in a grounded environmental chamber. The upper electrode is gently placed on the top of ash with a defined pressure. The oven is started and once the desired temperatures are reached the readings are taken for the temperature, voltage and current using the instrumentation provided in the test facility. The tests were performed in ascending and descending temperature modes. The current across the fly ash layer under test is limited to 2×10^{-5} A/cm^2 to avoid the ohmic heating of the fly ash sample. In ascending mode a direct current high voltage power supply was used to impress the required magnitude of electric field strength. The environment was maintained as per the standard. The environmental water concentration was introduced by bubbling a portion of dry gas through distilled water maintained at a selected temperature in a thermostatically controlled water bath. In the present study, the water content of 9 % at the specified temperature was used for resistivity measurement. The oven is capable of operating in the desired temperature range, within 0.01 degree C accuracy. In descending temperature mode, natural convective cooling of the test apparatus was allowed and it took 6 hours to cool from 460 to 90 degree C. The resistivity cell current was measured using a sensitive electrometer capable of reading current in the range of 10^{-3} to 10^{-11} A with an accuracy of ± 2% of the full scale reading.

The resistivity of fly ash is calculated from the following standard relation:

$$\rho = \left[\frac{V}{I}\right] \left(\frac{A}{l}\right)$$

Where ρ is the resistivity (ohm–cm), V is the applied d.c. potential (volts), I is the measured current (amperes), l is the ash layer thickness (cm) and A is the electrode phase area (cm^2).

RESULTS AND DISCUSSIONS

The figures 2(a)–2(c) represent the experimental results for fly ash resistivity variation with temperature in ascending and descending modes. The Fig. 2(a) represent the variation of fly ash resistivity for different temperatures in ascending mode for two samples from U.S. power station (E1035-143-12 & Miller steam) and two samples from Indian power station (KORBA 3A1L 06/10/03 & KORBA 3A3L 07/10/03). It can be observed that the resistivity obtained in Indian samples is higher than U.S. samples. The peak resistivity of Indian samples ranges from 6.09×10^{11} to1.41×10^{12} whereas it varies from 1.29×10^{10} to 5.75×10^{10} for U.S. samples at temperature 158 ^{o}C. Fig 2(b) shows the variation of resistivity vs temperature in descending mode for same ash samples. It can be seen that the similar trend of curves is obtained as found in the ascending mode. Fig. 2(c) indicates the comparison in the variation of resistivity vs temperature in ascending and descending mode for Indian and U.S. fly ash samples.

Figs 3(a)-3(c) show the effect of sodium conditioning in the coal on the resistivity of Indian fly ash for different temperatures (90-460 ^{o}C) in both ascending and descending modes. Fig 3(a) indicates the variation of resistivity with temperature in ascending mode for four different ash samples with and without sodium conditioning. It is observed from the figure that with the sodium conditioning the peak values of resistivity drops from 9.13×10^{12} to 8.62×10^{11}. Fig 3(b) indicates the similar trend of the resistivity variation with temperature is obtained in descending mode as found in the ascending mode. It is further observed that the values of the fly ash resistivity are lower in this mode due to the burning of unburnt carbon. Fig 3(c) indicates the comparison of the resistivity variation with temperature in ascending and descending modes with and without sodium conditioning. It is seen from the figures 3(a)-3(c) that the ash resistivity is significantly decrease with sodium conditioning due to change in the chemical composition of the coal.

CONCLUSIONS

The experimental investigations were carried out to determine the fly ash resistivity of different ash samples for different temperatures in ascending and descending modes. The following main conclusions have been obtained:

- The resistivity of Indian fly ash is higher by 40-80% than U.S. fly ash.
- With sodium conditioning the resistivity of Indian fly ash is decreases significantly.

ACKNOWLEDGEMENTS

The work has been partially supported by the U.S. agency for International Development (USAID-India) and the U.S. Department of Energy's National Energy Technology Laboratory (NETL) for providing the funding for obtaining the equipment for the ash resistivity laboratory. The authors would like to acknowledge the fly ash sample contributions provided by National Thermal Power Corporation Limited (NTPC) India.

The authors also would like to express their sincere appreciation to Mr. G.H. Wim Marchant and Mr. John G.Hester of Southern Reasearch Institute, Birmingham (U.S.A.) for their contribution in setting up the experimental facility at CES, IIT Delhi (India).

REFERENCES

[1] Annual Report - 2003, Ministry of Power, Government of India, New Delhi.

[2] Shahi, R. V., Conference on "Coal and Electricity in India", Ministry of Power, Government of India, New Delhi.(India), (2003)

[3] Report on design and operating parameters of electrostatic precipitators, Programme Objective Series: Probes/45/1992, Central Pollution Control Board, Delhi (India), (1994).

[4] IEEE Standared Criteria and Guidelines for the Laboratory Measurement and Reporting of Fly ash Resistivity, IEEE Std. 548-1984.

Table 1. Average characteristics of Indian coal

Coal Mines / Characteristics	**Singareni**	**Kushm-anda**	**Singrauli**	**Jharia**	**Neyveli**	**Total average value**
Proximate Analysis (%)						
Moisture	9.6	10.0	12.0	13.0	42.52	17.42
Volatile matter	23.3	23.0	20.1	17.51	24.5	21.68
Fixed Carbon	32.9	25.0	27.9	28.22	19.5	26.70
Ash	34.0	40.5	40.0	36.08	7.5	31.61
Sulphur	0.363	0.28	0.31	0.41	0.63	0.39
HHV(kJ/kg)	4133.3	5590.0	3641.6	3300.0	2850.0	3902.98
Ultimate (Ash) Analysis (%)						
SiO_2	59.35	61.3	60.73	57.64	65.2	60.84
Al_2O_3	22.04	27.42	25.7	26.39	13.27	22.96
Fe_2O_3	8.05	5.28	6.4	10.19	3.6	6.70
TiO_2	-	1.70	1.76	1.43	-	1.63
P2O5	-	0.54	0.7	0.82	-	0.68
Cao	5.57	1.42	1.2	1.78	11.2	4.23
MgO	2.26	0.97	0.93	0.60	5.0	1.95
SO_3	-	0.23	0.26	0.59	1.37	0.61
Na_2O	-	1.07	0.26	0.20	0.32	0.46
K_2O	-	-	1.73	-	0.04	0.88
Mn O	-	0.055	-	-	-	0.05

Table 2. Chemical composition of Indian fly ash

S. No.	Power stations	Fly Ash Compounds (weight %)									
		SiO_2	Al_2O_3	TiO_2	Fe_2O_3	Mn O	MgO	Cao	K_2O	Na_2O	LOI
1.	Badarpur	57.36	31.78	1.65	4.62	0.21	0.23	0.62	0.59	0.23	2.66
2.	Dadri	52.74	37.80	0.90	3.41	b.d.	0.24	1.00	0.66	0.14	3.01
3.	Rihand	59.75	34.1	0.5	6.1	0.4	0.35	0.2	0.45	0.3	0.45
4.	Unchahar	59.60	30.60	1.50	4.20	0.10	0.40	0.90	0.70	0.20	-
5.	Korba	62.09	31.30	1.82	3.33	b.d.	0.01	0.03	0.04	0.09	1.21
6.	Vindhyanchal	62.89	27.08	1.10	6.12	b.d.	0.10	0.80	0.27	0.10	1.50
7.	Ramagundam	60.83	26.63	1.13	4.19	0.080	0.80	3.03	0.90	0.40	1.81
8.	Vijayawada	61.63	30.92	1.72	3.33	b.d.	0.05	1.11	0.61	0.13	0.40
9.	Neyveli	38.03	43.38	1.82	4.05	0.12	0.02	7.67	0.05	0.43	3.40
10.	Kahalgoan	60.35	30.12	1.81	5.62	b.d.	0.40	0.80	0.56	0.12	0.20
11.	Farakka	60.30	30.90	1.30	5.02	b.d.	0.60	0.90	0.50	0.15	0.30

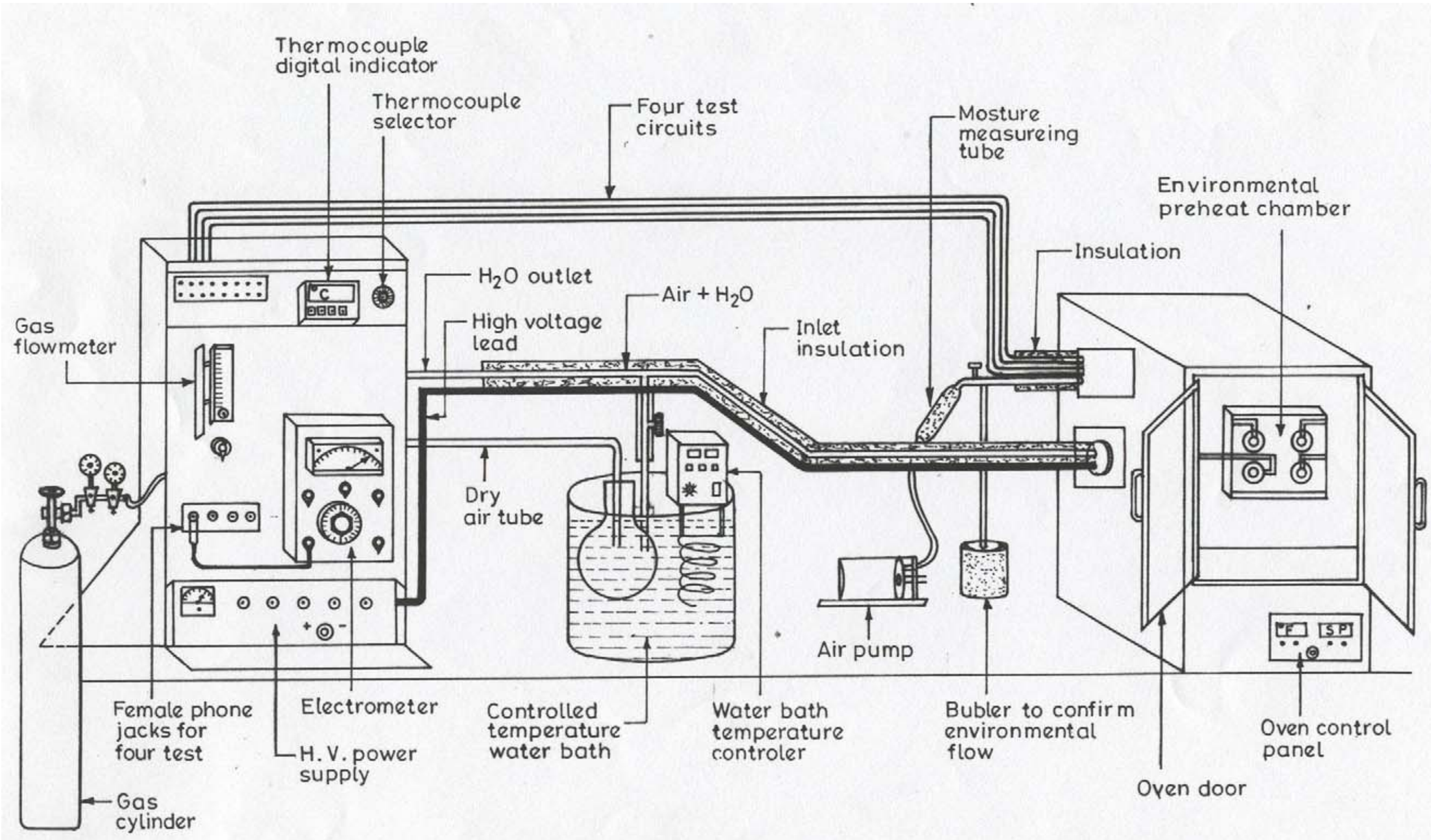

Fig 1. Schematic diagram of fly ash resistivity measurement set up apparatus.

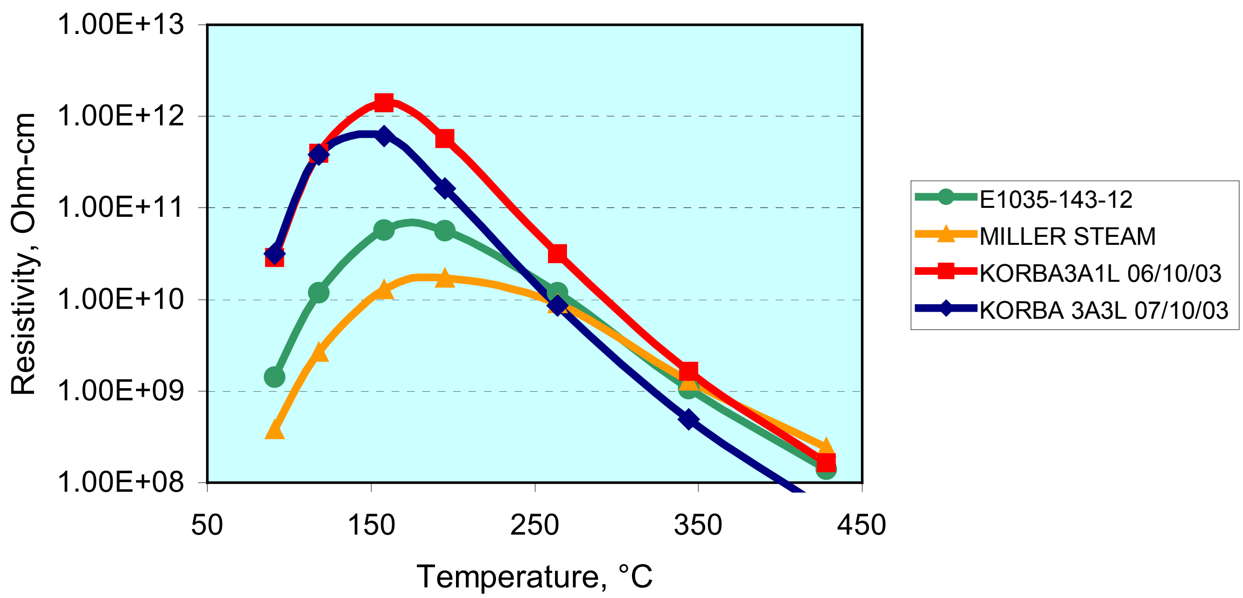

Fig 2(a) Variation of resistivity vs temperature in ascending mode for four fly ash samples [two U.S. power station samples (E1035-143-12 & Miller steam) and Two Indian power station samples (KORBA 3A1L 06/10/03) & KORBA 3A3L 07/10/03)]

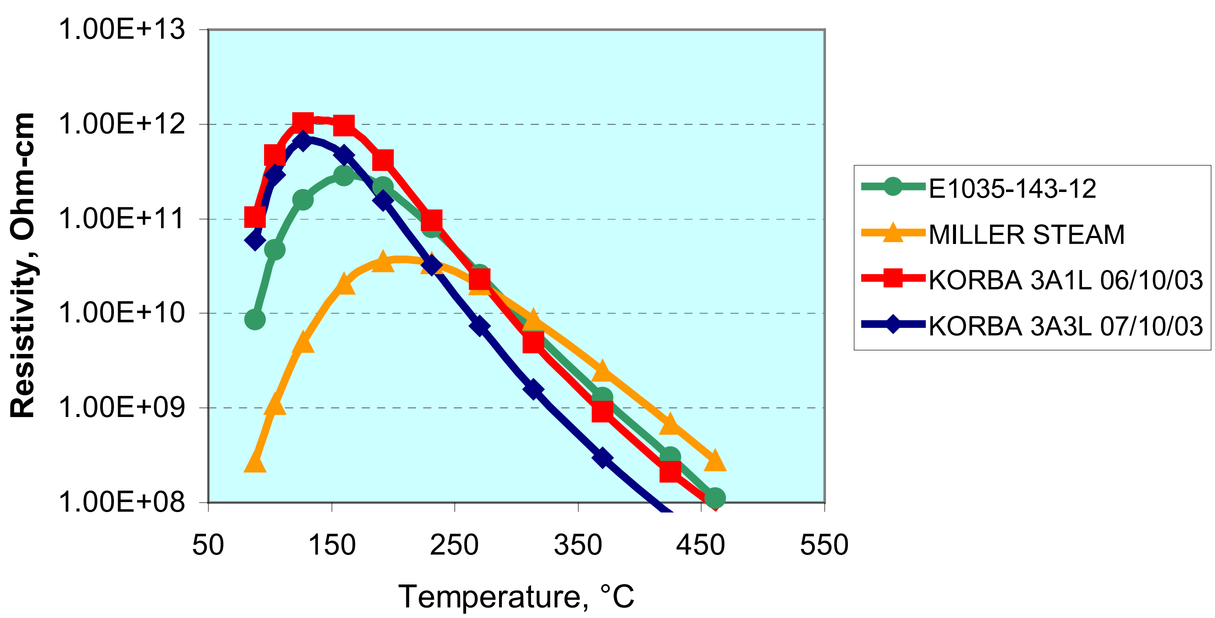

Fig 2(b) Variation of resistivity vs temperature in descending mode for four ash samples [two U.S. power station samples (E1035-143-12 & Miller steam) and Two Indian power station samples (KORBA 3A1L 06/10/03) & KORBA 3A3L 07/10/03)]

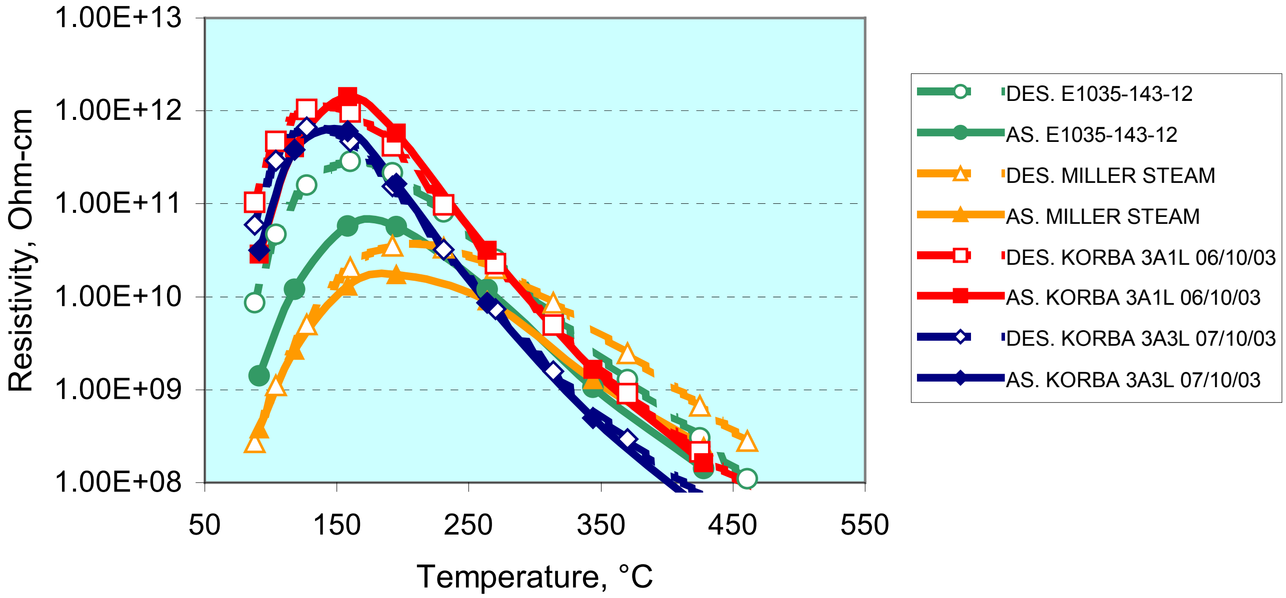

Fig 2(c) Variation of resistivity vs temperature in ascending and descending mode for four fly ash samples [two U.S. power station samples (E1035-143-12 & Miller steam) and two Indian power station samples (KORBA 3A1L 06/10/03) & KORBA 3A3L 07/10/03)]

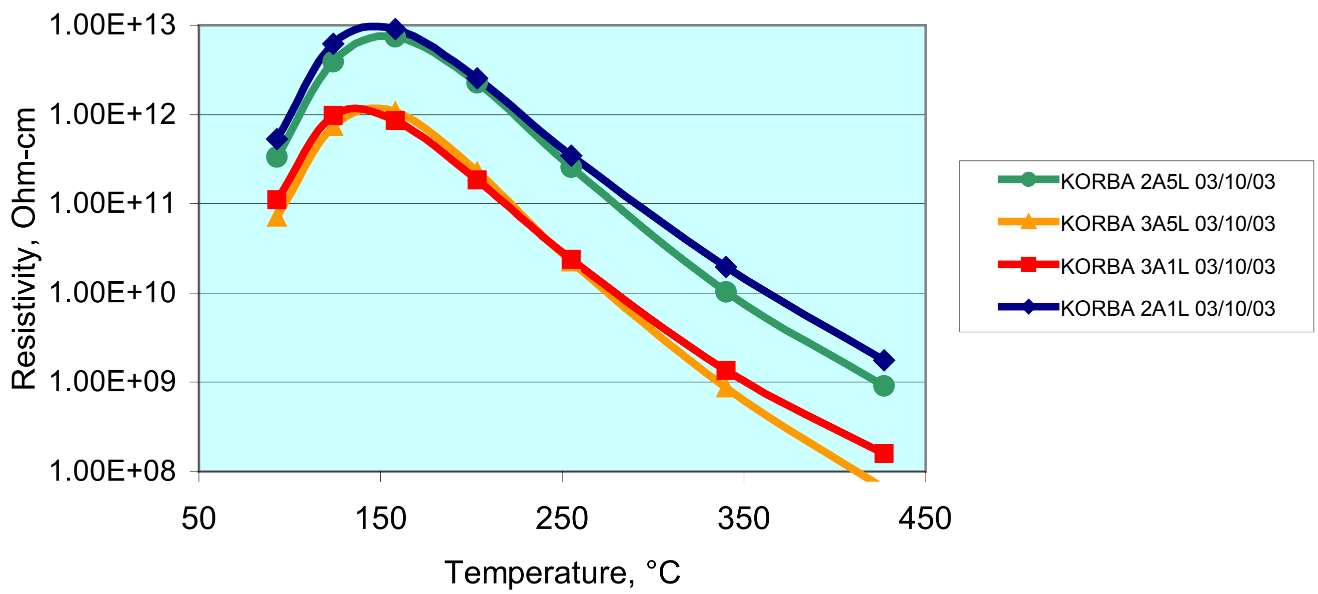

Fig 3(a) Variation of resistivity vs temperature in ascending mode for four fly ash samples with and without sodium conditioning.

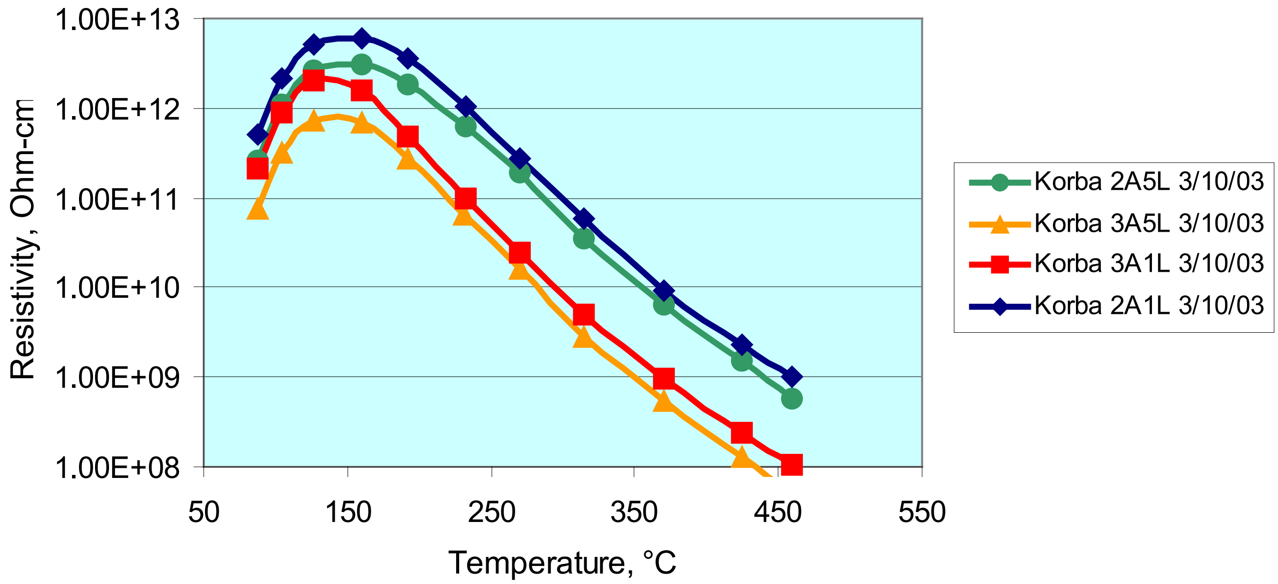

Fig 3(b) Variation of resistivity vs temperature in descending mode for four fly ash samples with and without sodium conditioning.

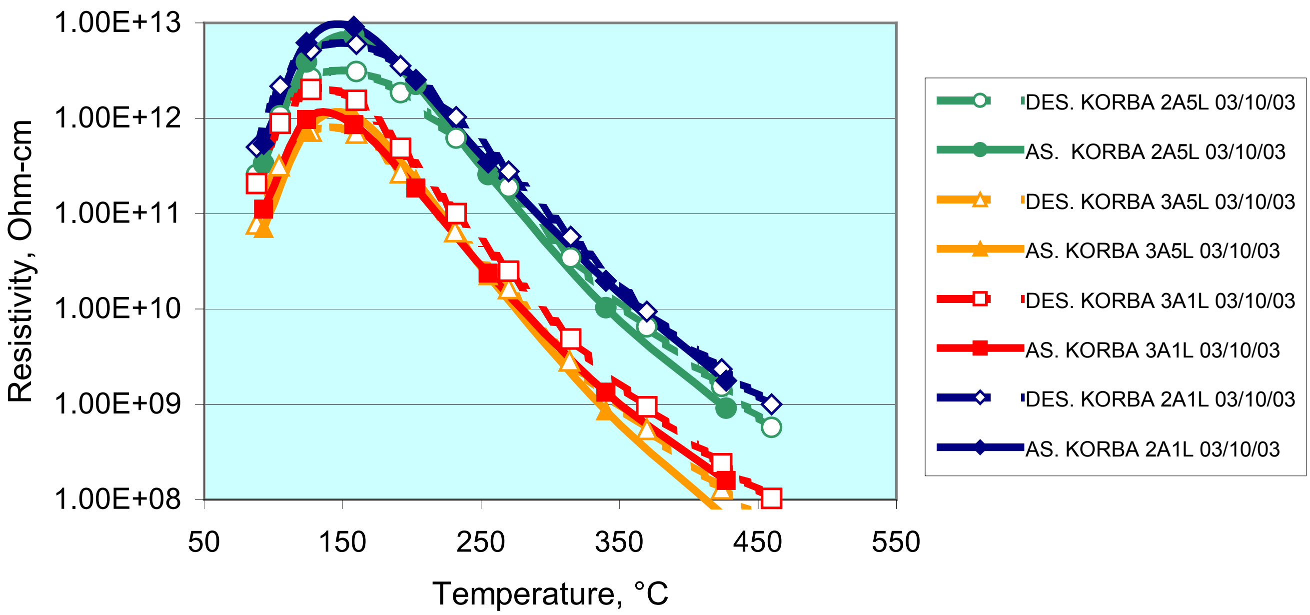

Fig 3(c) Variation of resistivity vs temperature in ascending and descending modes for four fly ash samples with and without sodium conditioning.