ELECTRICAL PROPERTIES OF COAL-PEATS FOUND IN FARIDPUR AND KHULNA DISTRICTS OF BANGLADESH

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A THESIS ON

"ELECTRICAL PROPERTIES OF COAL PEATS FOUND IN FARIDPUR AND KHULNA DISTRICTS OF BANGLADESH"

by

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has been accepted as satisfactory in partial fulfilment for the degree of Master of Philosophy in physics and certify that the student demonstrated a satisfactory knowledges of the field covered by this thesis in an oral examination held on 31ist December 1989.

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This is to certify that the project entitled "Electrical properties of coal-peats found in Faridpur and Khulna Districts of Bangladesh" has been done by me and it has not been submitted elsewhere for award of any degree or diploma.

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ABSTRACT

Fuel and electrical characteristics of coal-peats found in Faridpur and Khulna districts of Bangladesh have been studied. The suitability of the coal-peats for use as fuel and for other technical purposes has been assessed on the basis of its fuel value along with its proximate analyses and electrical response of the samples . The results indicate that the peat is technically feasible for domestic and industrial uses. The electrical study involving the change of resistivity with temperature ascertains that the peat available in this region like other peats in the world have the semi-conducting properties.

The high insulating character in the temperature region (239.82- 279.47)$^{\circ}$C has been found in Chanda Beel peats and in the temperature regions (191.04 - 346.2)$^{\circ}$C; (293.57-318.72)$^{\circ}$C for two samples of Baghia Beel peats respectively and (247.83 -346.20)$^{\circ}$C for Kola Mouza peats, that is, the resistivity increases with increasing temperature in each case. Above the ranges of temperature, i.e. for temperature range (438.75 - 624)$^{\circ}$C of Chanda Beel peats (399.75 - 536.72)$^{\circ}$C ; (402.10 - 570.70)$^{\circ}$C of Baghia Beel peats and (366 - 550)$^{\circ}$C of Kola Mouza peat, the hydrocarbons and other oxides of different materials are found to decompose and the molecules of parent materials are structurally ordered. Here a liquid mesophase is formed in each case of

and hence a sharp fall of resistivity is observed. This sharp fall of resistivity ascertains the semiconducting characters of the samples. It has also been found that peat under investigation are structurally different in different areas as indicated by resistivity vs inverse of temperature curves.

CONTENT

CHAPTER - I
INTRODUCTION

Bangladesh is one of the most densely populated countries of the world with the added disadvantage having continuing high growth rate of population. Although determined efforts are now being made to control this growth, we are soon going to hit the 100 million mark. The population has to be fed, clothed, housed and cared for medically. All these need production and the production needs energy.

The very concept of energy is fundamental to physics .Long before energy became a global concern, physicists discovered the conservation of energy principle. They developed thermodynamics and the concept of the efficiency of energy conversion. The science and technology of the most conveniently transportation and convertible form of energy, electric current came out of the physicists' brain and hands. The equivalence of mass and energy discovered by a physicist has opened up vast possibilities which have so far only been partly realized. Recent developments in semiconductor physics, material research, plasma physics and other branches of physical science reinforce the conviction that physicists with their deep insight and logical approach will play the key role in the solution of the energy problem(1).

The different aspects of the energy problem are inherently complex involving many disciplines and technologies. The multifarous energy problem requires multidisciplinary approach involving Physicists, Engineers, Geo-physicists, Geologists, Bio-scientists, Economists and even social scientists.

Though the problem of augmenting existing energy supplies is a universal phenomenon, the exact approach to a solution is specific to every country. Priorities would vary according to financial and fuel resources, state of economic and industrial growth, availability and adaptibility of alternative energy sources and even on the internal and external political philosophy of the national government.

The energy is perhaps the single most important factor in economic development. A proper approach to energy technologies development and application can make the difference between success and failure in meeting economic growth targets and increased standard of living .The type and quality of energy available in an economy will determine the effective level of technology and the productivity of work force.

Industry as we know it today is based primarily on heat radiation, the most diffuse and efficient form of energy. It is accessed for the most part on the basis of elementary 19th century physics. What we must be aiming toward over the next thirty years is to move away from the mechanical thermodynamic basis for industry and move into looking at the entire spectrum of radiation as becoming the physical base both in terms of physical principles and in terms of applications for our technologies. This is the promise held out by the emerging plasma technologies(2).

Energy sources fall into two broad categories, commercial and noncommercial. With the advent of technological advancement, the quantity of commercial energy consumption is being widely recognized as an index of overall development of any country .In developed countries, almost the entire energy consumption is supplied by commercial sources, while in developing countries predominent portion of total energy consumption (50 - 80)% are met by non-commercial sources. It is believed that the share of non-commercial sources in developing countries will gradually decrease to a level of((10 - 20%) mainly through increase in use of electricity within the next thirty to forty years(3).

In the international energy scene,position of Bangladesh is not only at the bottom, but the consumption is well below the average for even developing countries. In 1981, for instance, the per capita commercial energy consumption was 46 kg coal equivalent compared to a world average of 1983 kg and an Asian average of 597 kg. The per capita electricity production in Bangladesh at the same time was only 33 kwh, compared to the world average of 1862 kwh and Asian average of 519 kwh(4).

Energy consumption in Bangladesh is characterized by heavy reliance on non-commercial sources. In 1973-74 these sources supplied 200 trillion BTU which is about 7.8 million ton coal equivalent (TCH). This was 72% of our total energy consumption. This situation had not improved much in 1981-82, when traditional fuel still constituted 61% (232 trillion BTU), i.e, about 8.4 million TCE of our total energy use. Out of this 19% came from cowdung,51% from different agricultural wastes (Jute stick, straw, rice husts, bagasse), and the rest from the fire wood (51%), twigs and leaves (14%) and other unidentified wastes (11%). It is evident that in rural areas, the use of traditional fuel is approaching a saturation level and the increment in future is expected to be normal, if at all.

There are some trillion cubic-ft. gas stored in various region of Bangladesh. According to scientific view point this gas will be exhausted by 20th century. So alternate fuel is required as the substitute for gas. Within the last decade a huge tons of peat is discovered in different districts such as Khulna, Faridpur, Tangail, and Bogra districts. This huge quantity of peat may satisfy the requirement of fuel. Nevertheless this raw material may be artificially graphitized by suitable process, such as mechanical, heat-treatment process, etc.

The main objective of the present investigation is to study the fuel value and chemical character of Bangladeshi coal-peats to see their use as fuel and for chemical processing and also to study the electrical character to test whether the material may be artificially changed into the valuable product-graphite or not by thermal treatment. The measurement of fuel value along with proximate analyses of peats available in the different areas of Faridpur and Khulna districts ascertains whether they are suitable for domestic and industrial uses and also for chemical processing. The electrical study may indicate the semiconducting nature of the peat thereby signifying ultimately whether it is graphitic or not. Thus as a a precursor to graphitization, the study of coal-peat in this area is worthwhile.

For the measurements following parameters are selected for study.

A. For fuel and proximate analyses-

A.1 Mass of wet and dry samples.

A.2 Applied pressure, temperature and time of burning.

A.3 Water equivalent of the apparatus.

A.4 Mass and length of fuse wire.

A.5 Amount of heat produced.

B. For electrical study.

B.1 Area of cross-section of the samples.

B.2 Lengths of the samples.

B.3 Voltage across the sample (V_s) and voltage accross the fixed resistance (V_F).

B.4 Thermo. e.m.f and hence the heat-treatment temperature.

B.5 Resistance of the samples (R_s); and hence the resistivity (ρ).

B.6 In ρ and $10^3/T^oK$.

CHAPTER - II

GEOLOGY OF PEAT FORMATION

2.1 INTRODUCTION

Peat is a fossile fuel like other fuels, such as, coal, oil, gas, tar, petroleum etc. and it is a brown fibrous mass of partially decayed plant material that has accumulated in bulk under water logged conditions. The agencies causing decay are mainly acrobic bacteria, near the surface and increasingly inacrobic with increasing depth(5).

In other sense peat is the initial stage of coal in its formation from plant materials. It is formed in swamps. Of various types of peat the one that are formed in swamp of wood is the most common and recognized. In a wooded swamp the growth of trees is often so thick that under its shade no plant can live. Moss and Lichens cover the ground around the trees between pools of water. Soon after a tree dies, it falls and decomposition sets in. The decomposition or rotting of the tree is mainly due to the disintegrating action of micro-organism, bactoria and fungi on the vagetal matters and this action is aided by the presence of moisture and the air. The micro-organisms break down many of the plant structures and the tree and its fragments gradually disintegrate. More trees and the organism sprout from the layer of debris grow for a period and in their turn die. Their decomposition products add to the accumulation of organic matter. The newer layers gradually press the preceding ones down into and below the surface of the swamp water. Cut-off from air by stagnant water and the subsequent layers of debris, the organisms die and further decomposition of the plant matter proceeds extremely slowly. Unless subjected to other action, the submerged vegetal fragments may retain their existing shapes and structures almost indefinitely. Such actions, leading to the growth of plants and their subsequent decay, have continued year after year so that deposits of plant debris grow in thickness$^{(6)}$.

Forest peats are different in character as coming mainly from the decay of tree growth under high-temperature conditions. It is considered that it is this material which formed the basis of the main deposits of carboniferrous coals. Other influences, such as, the organic matter present, the acidity of the mass and the presence of bacteria and fungi, have produced various type of peat having characteristic differences:

(a) Fern peat has been formed in a basic environment from material containing alkaline mossess.

(b) Moor bog and moss peats have been formed in an acid environment due to the development of organic acids. These may again be devided into: Valley peat, collected in water, blanket moss is formed on high moorland with an abundant rainfall and hill peat similar to blanket moss but formed under condition of better drainage.

2.2 Properties of Peat:

The composition of peat substance, when it is freed from water and ash eliminated, varies over only a moderate range The following data enlisted in tables are mainly from analyses by British coal research Laboratory:

Table 2.a

	Element	Limit (%)	Average (%)
Bohemian peat	Carbon	56-63	57.5
	Hydrogen	5.7-6.3	6.1
	Sulfur	0.6-1.00	-
	Nitrogen	1.3-2.7	-
	Oxygen	31-38	34.9
Irish peat	Carbon	-	60.1
	Hydrogen	-	5.8
	Sulfur	-	0.6
	Nitrogen	-	1.4
	Oxygen	-	32.1

In peat mineral matter is uniformly distributed. Dirt bands are not present as in coal seams. The amount is variable. It is exceptional to find less than 3%, but not uncommon for over 10% to be present, most of which is undoubtly due to unfiltration. The lower layers will contain usually high ash as compared with the upper filtered peat(6).

The volatile matter in peat varies with its position in bog. The following table of Irish peat furnished by Purcell illustrates the above statement.

Table 2.b

Name of peat	Volatile matter (%)	Ash (%)
Brown peat(Ticknevin)	67.20	1.00
Black peat(Ticknevin)	65.00	7.80
Dense Black	65.50	7.10
Light fibrous peat (Denbigh Moor)	70.40	0.70
Dense black peat	61.80	15.20

In the formation of peat all the plant ingradients are not degraded at the same rate. Protoplasm and oils decay relatively rapidly. Carbohydrates, such as cellulose and lignin disintegrate more slowly. But spores and pollens, waxes and resins are highly resistant and remain unchanged long after other parts of the plant have completely disintegrated.

The character of the original plant material, the extent of the decay of its constituents, the amount of derivatives which remain and the remnants of micro-organisms all contribute to the deposit of peat and affect its properties(8).

2.3 Formation of coal from peat:

The quality of peat may be changed by pressure, temperature and some other chemical reactions and hence converted to coal. The period in the formation of coal deposit during which a layer of partly decomposed organic matter has been accumulated by the independent actions of plant growth and biological decomposition is known as the "Biochemical period".

The conversion of peat into coal is believed to be largely due to the pressure exerted by the overlying strata laid down upon the layer of peat and by mountain building and earth disturbances. Heat has contributed to the changes and the mineral matter accumulated in the vegetal deposits also has probably influenced the results. Slow changes in the elevation are constantly proceeding throughout the crust of the earth and as a result some portions of the surface are being depressed, other portions being elevated. If as a result of such crust movement, the area of peat bog slowly sank at a rate faster than the deposit accumulated. A time might have come when the entire surface was covered with water and transformed into a lake. As water covered the bog further growth of vegetation ceased. In time clay, sand and silt were washed in from higher ground around the lake and the deposit of peat was covered by a layer of earth. Accumulation of overburden gradually compacted the peat. In the Great Dismal Swamp in the North Carolina and

Virginia a subsidence of the bog is going on. The entire area is gradually changing from a swamp into a lake. If the sinking continues, the deposit of decayed vegetation will be submerged and eventually covered by a layer of soil washed in from the surrounding land.

In course of time subsidence of the surface may have been reversed and the former swamp raised upto the form of dry land, and even hills and mountains. In such elevating movement, great thrust were generated, some of which were also exerted on the deposit. The movement and the exertion of the pressures probably added from subterranean sources or by chemical ractions. The combination of pressure and heat applied over long periods of time could cause far reaching changes in deposit of peat. At the same time the water gradually drained away as the area was raised.

The chemical changes which occured probably consisted not only of a further loss of moisture, but also of carbon-dioxide and methane to leave increased proportions of carbon in the residual deposit. The changes from wood to peat and hence to anthracite is shown in table (2.c).

The distinct decrease in oxygen content between wood and bituminous-coal, with a relatively constant hydrogen content, indicates elimination of oxygen as carbon-dioxide. During the transition bituminous coal to anthracite, both hydrogen and oxygen decreased. The hydrogen, however, decreased more rapidly than can be accounted for by evaluation as water vapour. Apparently during that stage a large proportion of hydrogen disappears in the form of hydrocarbons. The compositions suggest that, in the earlier stage of coalification, the gases were high in carbon-dioxide, but in the later stages the proportions of moisture and hydrocarbons increased. Such changes which may have taken hundreds of millions of years, are believed to have converted peat to lignite and progressively, through successively higher ranks of coal, to anthracites. The duration and severity of conditions to which the former layer of peat was exposed during this period, as well as the nature of organic deposit, probably determined the rank of coal which was finally produced. The temperature ranges from below 100°C upto 600°C for coal formation from peat. Earth pressure may also accelerate the process of transformation, The long period during which pressure, accompanied by the action of heat, was probably exerted, is termed the "hydro-dynamical period" of transformation(7). The conversion of peat to coal istermed "methanorphin or coalification". The rate of formation of coal from the peat is difficult to estimate, but it is possible to say that about three ft. of old peat might have been required for the formation of one(1) ft. of bituminous coal. Thus roughly saying, 20- 25 ft. of accumulated vegetal matter might produce one ft. of coal.

Table 2.c(3) Chemical changes in composition of wood to anthracites during coalification process .

Genus	Moisture in raw state (%)	Percent on dry, ash-free basis			
		Carbon	Hydrogen	Oxygen	Volatile matter at 900°C (1652°F)
1. Wood (typical composition)	20	50	5	42.5	75
2. Peat (")	90	60	5.5	32.3	65
3. Brown Coal	60-40	60-70	5 (about)	25	50
4. Lignites	40-20	65-75	5 (about)	16-25	40-50
5. Sub-bituminous	20-10	75-80	4.5-5.5	12-21	45 (about)
6. Bituminous	10	75-90	4.5-5.5	5-20	18-40
7. Semibituminous	under 5	90-92	4.0-4.5	4-5	5-20
8. Anthracite	under 5	92-94	3.0-4.0	3.4	15

2.4 Peat deposits in different areas of Bangladesh.

In Bangladesh huge tonage of coal-peat reserve have been discovered in seam of Khulna, Faridpur, Comilla and Sylhet. According to the second rough report of National Physical Planning Project the coal peat deposits are illustrated in table 2.d(9).

Table 2.d.

District	Amount of peat (tons)
Gopalgonj (Faridpur)	12,50,00,000
Kola Mouza (Khulna)	80,00,000
Moulabi Bazar (Sylhet)	29,00,000
Chorkhy (Sylhet)	12,00,000
Shala (Sylhet)	5,00,000
Khatiainga, Mokundapur (Comilla)	7,50,000
Total	= 13,83,50,000

2.5 Peat utilization in different countries of the world.

The quantity of coal-peat reserve and their use in different countries of the world are shown in table 2.e.

Table 2.e

Country	Fuel peat $\times 10^{-3}$ tons/yr.	Fertilizer peat $\times 10^{-3}$ tons/yr.	Total $\times 10^{-3}$ tons/yr.	Peat area (sq mile)
USSR	80,000	120,000	20,0000	1,500,000
Ireland	5,590	380	5,950	11,800
Finland	3,100	500	3,600	108,000
West-Germany	250	2,000	2,250	11,000
China	800	1,300	2,100	34,800
Canada	0	490	490	1,70,000
Poland	0	280	280	13,500
Sweden	0	270	270	70,000
East Germany	0	170	170	-
U.K.	-	170	170	15,000
France	50	100	150	-
Denmark	0	110	110	-
Norway	01	83	84	-
Newzeland	0	10	10	-
Indonesia	-	-	-	260,000
Malayasia	-	-	-	23,600
Cuba	-	-	-	4,500
Nethrland	-	-	-	2,500
Japan	-	-	-	2,500
Bangladesh	-	-	-	13,800

CHAPTER - III

ELECTRICAL PROPERTIES OF ORGANIC COMPOUNDS

3.1 Historical Survey:

A great number of the organic materials have been found to be electrical insulators and little attention has been given by the physicists to study the semiconducting properties of organic solids. In recent years, a number of organic compounds having conspicuous electronic conductivity in solid state have been found(10,11). The semiconducting properties of organic compounds are remarkably important firstly because they are molecular crystals and secondly, as because they are synthetic compounds, we can expect a variety of electronic properties in association with the possible molecular structures. Lastly, the semiconducting properties of organic compounds have become important for the aspect of energy transfer during chemical reactions .

It is well known that solids are classified into four ideal types: metals, ionic crystals, valence crystals and molecular crystals(12). Metals are formed by the combination of the atoms of electro-positive elements and they are distinguished by their good electrical and thermal conductivities.

Ionic crystals are formed by a combination of highly electropositive and electronegative elements and they possess good ionic conductivity at only high temperatures. Valence crystals, possessing homopolar bonds throughout the crystal structures, are very hard and they have high melting points but poor electronic and ionic conductivities. Molecular crystals are formed by inactive atoms or saturated molecules, held together by a weak force of the vander waals' type. There are good reason to believe that organic materials with substantial electrical conductivity are difficult to find, because they are mostly molecular crystals and the interaction between molecules is usually too small to give good electron transfer from one molecule to another.

Quite a good number of solids, however, have properties which correspond to a border line between two or more of these ideal types. The semiconductive materials are usually found in such a border line solids. Silicon and Germanium are remarkable examples of border line solids between covalent crystals and metals. Their crystal structures are nearly similar to that of diamond, which is a covalent crystal.

In molecular crystals, one can also find compounds which are border line to the other crystal types. Graphite consists of layer lattices of carbon atoms which are seperated by a distance so large (3.35Å) that there can be no covalent bonds between layers. Each of the layers is a giant aromatic molecule. The superimposed molecules are held together only be weak Vander Waals' forces. The electrical conduction along the layers is metallic with a resistivity of 10^{-5} Ω-cm. at room temperature. The corresponding resistivity is 10^{-1} Ω-cm in the direction perpendicular to the layers.

The semiconducting nature of organic compounds can be known by measuring its conductivity with the rise of temperatures. Photo conductivity, photo-voltaic activity and other related optical properties have also been studied in the case of some aromatic compounds which consists of planer molecules(10). The prime examples are polycyclic aromatic compounds and phthalocyanines. A remarkable point common to those compounds is that they have valence electrons (π- electrons) which can move throughout the molecular plane. Little is known about the molecular interaction in those solids. However, it may be presumed that the molecular orbitals of π- electrons are diffused and that those on neighbouring molecules overlap slightly. This would be expected to be the case especially for large-size molecules. In such cases one should expect of shift of properties towards those of a border-line solid.

From the view point of organic semiconductors, structures such as $(- CH = CH -)_n$ or $(=c=c)_n$ in linear form should be expected, because they would form π-bonds. The former structure is found in diphenylpolyenes and in carotinoids. However, polyenes which have conjusted double bonds long enough to give a measurable conductivity are not known(12). The later structue is more probable, however, a compound with this structure apparently has not yet been developed. Another family of interesting compounds are those which have free radicals and they would shift their properties towards those of a border-line solid. Few surveys concerning the electronic properties of the free radicals are found presumbly because of their unstability. Stable free radicals are found in carbonized materials, such as chars and coals, and also in solid polymers which have been treated with high energy irradiations (13). α, α′- Diphenyl - β- picrylhydrazyl is the only simple compound which is relatively stable in the solid form; it has a fairly low resistivity (14).

Some organic compounds can form solid molecular complexes with halogens or alkali metals. Recently, Mulliken has proposed a charge transfer mechanism to explain the interaction in the molecular addition compounds (15). Thus aromatic hydrocarbons, for instance, can react as electron donors or acceptors in such solid complexes. They can be seen as the border line compounds between molecular and ionic crystals. The electronic properties of the solid complexes are quite attractive from the view point of organic semiconductors.

3.2 Classes of Organic Semiconductors:

From chemical view point organic semiconductors are classified in three groups.

1 . Compounds which have a number of delocalized electrons (π - electrons) in the molecules;

2. The organic free radicals; and
3. The intermolecular addition compounds.

Substantial investigations have been conducted on the semiconducting properties of the first group, viz, the condensed polycyclic aromatic compounds, the phthalocyanines and some dyestuffs .On the contrary ,few surveys have been made on the simple free radicals.

An investigation into the electronic properties of the third group has been carried out with success. The molecular complexes formed between aromatic hydrocarbons and alkali metals, and also between aromatics and halogens are prime examples of this group.

3.3 Structural Aspects of Organic Compounds.

Most of the organic semiconductors, which have so long been investigated, have been found to consist of the conjugated and aromatic molecules. For examples, in benzene the carbon atoms lie at the vertices of a plane hexagon and the six hydrogen atoms lie in the same plane directed radially outward from the carbons in such a manner that all the valence angles are 120°. This implies that of the four valence electrons ($2s$ $2p^3$) of the carbon atoms; three (sp^2) are hybridized in the trigonal state so that they give rise to localized C-C and C-H bonds. Both the bonds σ- type molecular orbitals which are symmetrical around the bond axis. The fourth valence electron (p_z-electron) is unhybridized. Those six electrons, one for each carbon atom, are π - electrons as their atomic orbitals are all directed parallel to each other and extend perpendicularly to the molecular plane having the ± 1 component of angular momentum around the bond direction . The pairing of these neighboring electrons leads to the molecular orbital of π- type which is a symmetrical around the bond axis. However, any one of these atomic orbitals overlaps both of its neighbors equally, so that the π - electrons have to occupy the molecular orbital which extends over all six carbon atoms.

The mobility of the π - electrons contributes to the important physical and chemical properties of aromatic compounds . For instance, aromatic molecules show a remarkable diamagnetic anisotropy . The tiny electron currents give rise to a large diamagnetism when the magnetic field is perpendicular to the plane of the molecule (16.17) . This anisotropy becomes larger as the molecular size increases, (18,19) .

In the case of graphite, a gaint aromatic molecule, its magnetic anisotropy has been interpreted with substantial success even with a simple model based on a two dimensional free electron gas (20,21) . The electron conduction in the planer lattice of graphite is presumbly associated with the motion of π - electrons drifted under the electrical field (22,23) .

Another important character of π- electrons arising from their mobility is that the electronic transition takes place much easier than that for π- electrons. Thus most strong absorption spectra which are observable in the visible region are the result of electronic transition from the π- bonding orbitals to the π^* antibonding orbitals (so called, N-V transitions). The dyestuffs which are colored compounds necessarily consists of the conjugated molecules including aromatic rings. They have the mobile electrons.

It is well known that a number of lower condensed aromatic hydrocarbons, such as, napthalene, anthracene, pyrene and chrysene are produced by extraction from a coal-tar pitch. Recently, through the hydrogenation of a coal tar pitch, a fairly large quantity of coronene, the seven membered aromatics has been produced (24). Similar to coal-tar pitch aromatic hydrocarbons, such as, napthalene, anthracene, pyrene, picene , chrysene and also coronene, the seven membered aromatics have been also found to be present in the peat complexes.

During carbonization these organic compounds give rise to ordered molecular arrangement in the temperature range (350 - 650°C: approx.) and hence they show the semiconducting properties. For instance, the resistivity of some typical polycyclic aromatic compounds, such as, vialanthrone and isoviolanthrone has been measured. Fig. (3.a) shows the electrical character of the matrix.

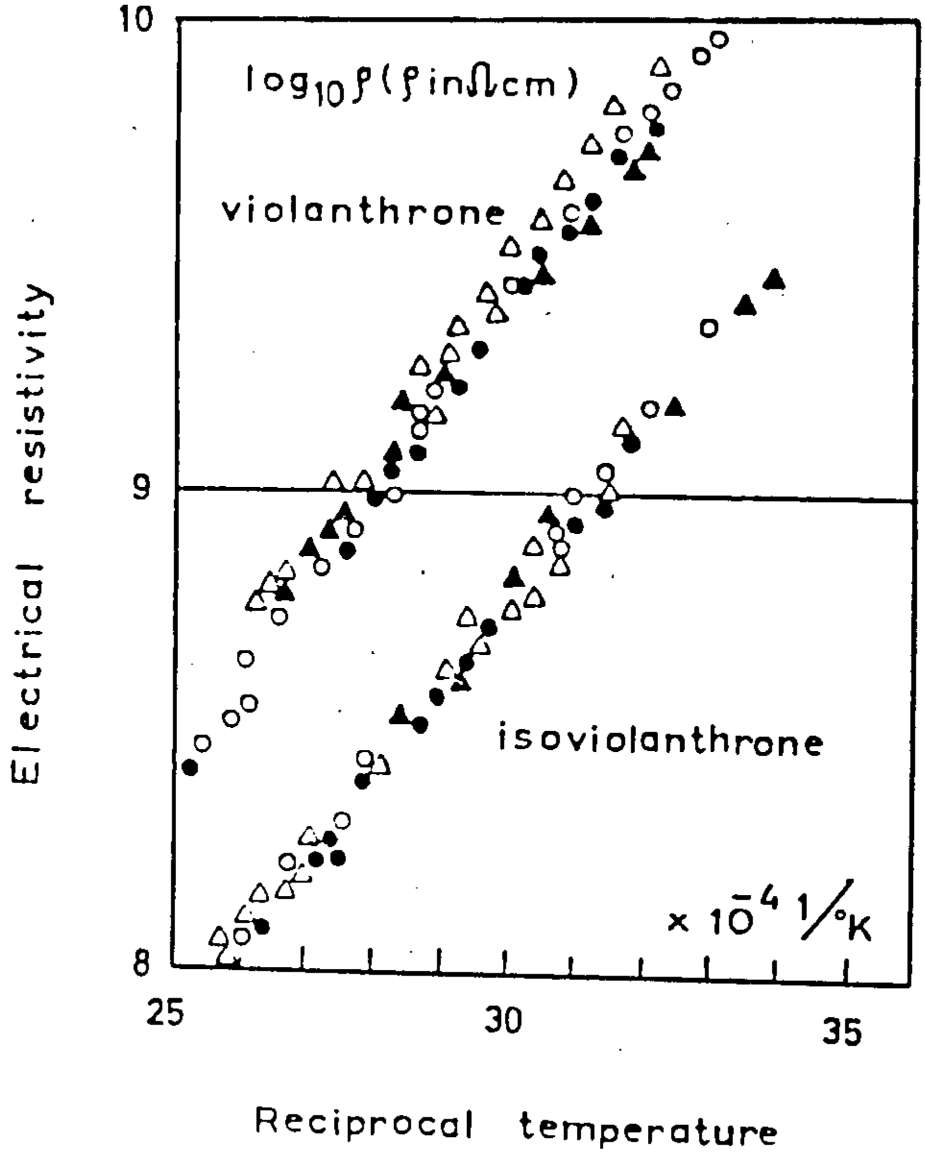

Fig. 3.c Log $_{10}\rho$ vs $\frac{1}{T}$ curves for violanthrone and and isoviolanthrone.

Phyrolysis of benzene, napthalene, phenanthrene and chrysene have been carried out and it has been established that these polycyclic aromatic compounds produce planer sheets of aromatic molecules ultimately to form graphite (25).

3.4 The General Properties of Semiconducting Material:

The mechanical properties of semiconductors vary greatly. However, in respect of hardness, brittleness, and fracture strength, semiconducting crystals resemble insulating crystals more than the metal do. Most semiconductors lack in high density in electrons which may help them becoming ductile and plastic in character like some metals.

Photoconductivity is a property of many semiconductors . They have a resistance changeable by light, the wave length of which may range from ultraviolet to the infrared, depending on the substance.

One of the most important properties of the semiconducting materials is the temperature dependence of the electrical resistivity. Magnetically, they may be diamagnetic, paramemetric, or even ferormagnetic.

Their thermal properties, such as, specific heat and thermal conductivity are also more or less independent of their semiconducting properties(26).

CHAPTER - IV

REVIEW OF THE PRESENT INVESTIGATION

4.1 FUEL CHARACTERISTICS:

The exploitation of the peat deposits would enable Bangladesh to reduce its fuel imports and to stop the depletion of its forests. It would also improve the economy of the country by replacing coal imports from outside and providing jobs for hundreds and hundreds of the inhabitants of Bangladesh.

Some national and international organizations have undertaken the study of the peat deposits found in the different regions of Bangladesh.So long the fuel and chemical characteristics of the peats have been studied.

Begum. D.A. and Hossain , T. [27] have studied the properties of 84 peat samples collected from Kola Mouza of Khulna and Baghia Beels of Faridpur districts of Bangladesh. The suitability of the peats for fuel and other purposes has been assessed on the basis of the proximate analyses. The results show that Bangladeshi peats are poor raw materials for chemical processing, but can be used as fuel because of their high calorific value.

In their opinion the result of proximate analyses of the peats differ widely, but the average calorific values of the Chanda and Baghia Beel peats are very similar despite the different ash contents. The calorific values of the upper peat layer of Kola Mouza are much lower than those from Chanda and Baghia Beel peats.

They also pointed out that on the average, the peat from the upper layers of Kola Mouza was inferior in quality to that sampled from higher depths in the same area. The results of their study, in average , are shown in table 4.a .

Table 4.a.

Field	Moisture content (%) by wt.	Ash content (%) by wt.	Volatile matter (%) by wt.	Fixed carbon (%) by wt .	Cal.Value KJ/kj
Kola Mouza	38.25	51.19	31.28	17.53	9946
Chanda Beel	66.84	42.56	45.15	12.29	13013
Baghia Beel	42.66	30.58	51.41	18.01	13811

According to Canadian International Development Agency Mission report on Bangladehi peat(9) it is noticed that as the peat deposits are flooded for atleast six months a year the peat has relatively high ash content. In Madaripur peat the oven dried proximate analyses indicates that the average ash content is 31(%) by weight. In Kola Mouza peat the ash content even reaches as high as 45%.

Another feature of the Kola Mouza peat is that almost the entire area is below the sea level. While the dam is opened at once the peat field is flooded with water coming from the river. According to the same report the water of the river has comparatively ~~high~~ high salinity and for these reasons they possibly concluded that the peat of the area is also saline.

They finally mentioned that the peat has relatively high sulfur content. In Kola Mouza peat the sulfur content ranges from (1.7-2.6) (%) by weight. The Madaripur peat has a sulfur content going as high as 3.94(%). They suggested that Bangladeshi peat is technically feasible for demestic use. The peat could solve the purpose of coal for use as fuel. It could be a means to reduce its fuel imports and to stop the deforestration.

4.2 ELECTRICAL CHARACTERISTICS:

Peat is a bulk material composed of complex organic and inorganic compounds. It is usually insulating in character. Although there is no sufficient work worth-mentioning in this field some relevant work is described below. Because the electrical character is studied mostly by thermal treatment so some works on thermal process is presented below. The mechanism of carbonisation process of coke has been studied by Hoffmann as follows. In the initial stages of pyrolysis of an organic compound, highly condensed aromatic molecules are formed which arrange themselves in a graphite like layered structure. As the temperature rises graphite nuclei are formed surrounded by chemically bound complex hydrocarbon rings and chains. These can neither be extracted by solvent process nor be removed in high vacuum at 500°C and it is, therefore, inferred that they are chemically bound round the borders/corners of hexagon planes of graphite nuclei. As the coking proceeds they decompose and consequently some of the carbon atoms are lost in the form of volatile compounds. The remainder fixes themselves to the edges of the hexagon planes, thereby causing the lateral growth of graphite crystallites. In the 400°C coke there are sufficient number of disordered carbon-hydrogen and oxygen atoms available to satisfy fully the valency requirement of the border carbon atoms and to bring about rapid lateral growth of the plane by a condensation process with increasing temperature(10).

Riley presented an explanation of the sudden development in the electrical conductivity of coke during carbonization at 700°C by a theory which involves the bonding of disordered hydrogen atoms between the hexagon layer planes of the graphite crystallites. Riley pointed out that the nature of the volatile matter evolved during carbonization changes abruptly at about 700°C and above this temperature the above gas is principally hydrogen. He suggested that the rapid increase of electrical conductivity with increasing carbonization temperature in the region of 700°C indicates that the electrons which are employed in bonding the disordered hydrogen atoms at the borders of the hexagon planes become free and contributes to the metallic conductivity of the specimen.

Riley also points out that the yield of mellitic acid, obtained from various carbons by controlled oxidation with nitric acid followed by alkaline permanganate enhances the carbonization temperature upto 700°C at which the aromatization is almost complete. The penetration of the reagent between the hexagon layer planes is retarded by the presence of hydrogen associated with the graphite crystallites of the samples and thus the electrical conductivity is found to increase (30).

Manchuk, R.V. et al, (1986) studied the electrical conductivity of carbonized peat. The addition of $Alcl_3$ to the peat decreases the elctrical conductivity of the composites with silicates. The electrical conductivity of peat increases as the composite volume fraction increases and the percentage of $Alcl_3$ decreases. The use of this material in electrical switches is discussed (31).

Belkevich, P.E. et al (32) investigated the interrelation between electrophysical, optical and paramagnetic properties of heat-treated peat. They found that the electrical conductivity of peat semicokes decreased exponentially as coking temperature increased from 200°C to 400°C. There is no corelation between peat semicoke electrical conductivity and paramagnetic center concentration, but there is a corelation with the relaxation characteristics of these centers.

CHAPTER - V
EXPERIMENTAL

5.1 THEORY FOR PROXIMATE ANALYSES AND THEORY FOR THE DETERMINATION OF FUEL VALUE

5.1. 1 Proximate Analyses:

Proximate analyses comprises of the determination of moisture content, volatile matter, Ash and Fixed carbon. This is the most widely used method for analysing coal-peats. It is relatively quicker, easy to carryout in most of the physical laboratories and the method furnishes a satisfactory indication about the quality of coal-peats$^{(7)}$.

5.1.2 Moisture Content:

Moisture content of any solid fuel is determined by drying a properly weighed sample of coal-peat at a temperature between (105 ± 5)°C. Mathematically-

The total moisture content in peat,

W = moisture content of wet sample in air, Wa + moisture content from air dry to oven dry at (105 ±5)°C in inert atmosphere, W_o.

$$W = W_a + W_o \qquad (1)$$

This moisture content is expressed in weight percentage.

5.1.3 Ash Content:

Coal-peat ash is derived from clay, iron pyrites, limestone, sand and other mineral matter, all of the fractions in more or less finely divided form being distributed throughout the coal-peat seam. Besides some inherent inorganic matters are chemically combined with the organic matter of the coal peat.

The ash is determined by complete combustion of a weighed sample of coal-peat in excess of air. From the weight of noncombustible residue the percentage of ash is determined(7).

5.1.4. Volatile Matter:

The volatile matter represents that portion of coal-peat which is converted into volatile products when the material is heated in absence of air. Because the portion thus vaporized varies with temperature and time of heating, for comparative results the conditions of the test are standardized according to ASTM standard(7).

5.1.5. Fixed Carbon:

Wet peat comprises of moisture, ash, volatile matter and fixed carbon. When it is oven dried (105 ± 5) °C moisture is driven out and so it contains volatile matter, ash and fixed carbon. So if the quantity of volatile matter and ash is known the fixed carbon can be easily found out.

5.1.6. Sulfur:

Sulfur usually occurs in coal-peats in the form of inorganic and organic compounds. The inorganic forms are

Iron pyrites, FeS_2, calcium sulphate, $CaSO_4$, and Feric sulfate $Fe_2(SO_4)_3$. Organic sulfur is combined in complex coal-peat molecules and is almost uniformly distributed throughout the pure coal-peat substance.

Sulfur is determined by oxidation to sulfur dioxide and sulfur trioxide, absorption of of the oxides with an alkali to form the corresponding sulfate and sulfate, further oxidation to the sulfite to sulfate and finally conversion of all the sulfate to insoluble barium sulfate by the action of $Bacl_2$. From the weight of barium sulfate produced, the percentage of sulfur in coal-peat is calculated(7).

5.1.7 Fuel Value:

The fuel value of any fuel refers to the amount of heat evolved due to complete combustion of unit quantity of it, It is determined by the carefully measured quantity of fuel according to ASTM standard[33]. The fuel value is thus:

$$Q == \frac{\text{Heat absorbed by the apparatus}}{\text{mass of the fuel}} \quad (kJ/kg) \qquad (2)$$

More specifically, it is ,

$$Q = \frac{\text{(Water equivalent of the apparatus) x corrected rise of temperature - (Heat from the fuse wire + cotton thread)}}{\text{mass of the fuel}} \qquad \text{.... (3)}$$

5.2 THEORY FOR ELECTRICAL STUDY:

The electrical conductivity of any bulk semiconducting material is a measure of inverse of resistivity and is expressed in $\Omega^{-1}- cm^{-1}$ (26).

That is,

$$\sigma = \frac{1}{\rho} \quad (\Omega^{-1}-cm^{-1}) \qquad (4)$$

$$\text{or} \quad \rho = \frac{1}{\sigma} \quad (\Omega-cm) \qquad (5)$$

where ρ = the electrical resistivity .

σ = the electrical conductivity.

If R_s is the resistance of a sample in tablet form having uniform area of cross section A, and of length L, its resistivity is expressed by

$$= \frac{R_s A}{L} \quad (\Omega- cm) \qquad (6)$$

In our present investigation the increase of resistivity during thermal agitation in the temperature range (190-400)°C is owing to the random distribution of the impurity contents and the rearrangement of the bonding of molecules . This is the unavoidable character of the sample.

5.3 EXPERIMENTAL PROCEDURES OF PROXIMATE ANALYSES:

5.3.1 Moisture Content:

5.3.2 Moisture content on air dry basis: W_a:

100g - 150g of wet coal peat is kept in a plastic tray and the system is put in a free atmosphere for a week or more. The air dried peat is then weighed very acurately and hence the moisture content is determined by weight percentage. In determining the moisture content special care is taken to stop undesirable loss of the peat.

5.3.3 Moisture content on oven dry basis: (W_o).

The air dried peat is powdered in a mortor and pestle and is passed through No. 72 sieve, to make the powder of 72 mesh size. One gram peat is carefully weighed by a sensitive electronic balance reading to 0.0005 g. The sample is then kept in a previously weighed clean and dry glass bottle fitted with a cap. The covered bottle with a sample is put in appropriate position on the moisture free oven in which there is provision for renewing the air at a definite rate. Before placing the sample bottle the furnace is preheated to a temperature between $(100-110)^{\circ}C$ and some inert gass is allowed to blow simultaneously. The sample is then heated upto $(105 \pm 5)^{\circ}C$ for two hours. While the bottle was inside the oven it remains uncovered to keep the peat in nitrogen atmosphere to prevent the oxidation.

After two hours the bottle is covered,removed and cooled in a desicator over sulfuric acid and weighed. The difference in weight gives the moisture content expressed in percent (W_o). The total moisture is then found out.

5.3.4 Ash Content:

One grams of the oven dried peat $(105 \pm 5)^oC$ of 72 mesh is taken in porcelain crucible and is placed in an electric muffle furnace, with good air circulation and capable of having its temperature regulated between $(800 \pm 10)^oC$. The sample is continously heated for 2 hours at the specified temperature. To avoid the mechanical loss by the rapid expulsion of volatile matter, the sample is heated in such a manner so that the temperature reaches 600^oC in one hour and 810^oC in two hours. The ignition is completed at $(800 \pm 10)^oC$ with occasional stirring until all the carbon particles have disappeared. The product along with crucible is cooled in a desicator and is weighed as soon as it is cold. Then alternate heating and weighing is continued until the weight becomes constant. Ash contains sulfates, pyrites and calcites. To ensure whether the ash contains carbon particles or not, a little amount of ash is moistened with alcohol. The colour of the ash would be blackened if there remains unburnt carbon particles along with ash.

5.3.5 Volatile Matter:

One gram of oven dried sample (105 ± 5)°C is put in a porcelain crucible and is spread uniformly in an even layer over its bottom. The crucible is rapidly and carefully placed inside a muffle furnace previously heated to (950 ± 25)°C The heating is continued for exactly 7 minutes in an inert atmosphere. The crucible is then removed and is placed on a cold iron plate to provide rapid cooling thereby preventing oxidation of the residue. While still warm the crucible is transfered to a desicator and is allowed to cool to room temperature and reweighed. The percentage loss in weight is assigned to the volatile matter expelled from peat(34).

5.3.6. Fixed Carbon:

Fixed carbon is obtained by substracting from 100 the sum of the percentages of volatile matter and ash in the dry peat(7).

5.3.7. Sulfur (Bomb Method).

The sample is oxidized by combustion in a bomb containing oxygen under pressure. The sulfur as sulfate in the bomb washings is determined gravimetrically as barium sulfate (35).

5.3.8. Description of the bomb calorimeter:

The bomb calorimeter, shown in fig. 5.1 consists of a stout gun metal cylinder C, fitted with a strong cover L which is

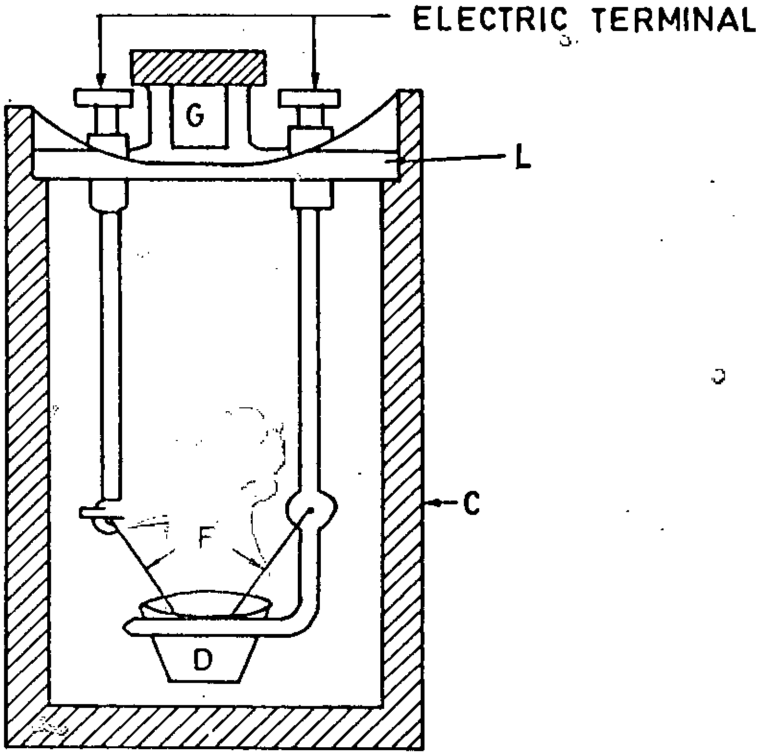

FIG. 5.1. OXYGEN BOMB CALORIMETER.

firmly screwed down and is so designed to withstand a high pressure without leaks. It is made up of an acid resistant stainless steel. The calorimeter is lined with platinum to prevent its walls from the corrosive action by the products of combustion.

A measured quantity of the fuel under investigation is taken in a platium crucible and fuse wire made of platinum is immersed in it. Oxygen under a very high pressure (~25 atm) is introducedthrough the passage G, into the calorimeter. The calorimeter is kept immersed in a measured quantity of water held in a calorimeter. To prevent the loss of heat by convection and radiation, the container is surrounded by a double walled vessel containing water in annular space(33).

A precesion Beckman's thermometer is used to measure the change of temperature and this thermometer permits reading as small as 0.005°C.

5.3.9. Working Process:

Platinum wire of 7 cm is used as fuse wire. The ignition circuit is capable of supplying sufficient current to ignite the cotton wire of 22 cm length. The two terminals of fuse wire is attached to the two electrical terminals. The cotton thread is adjusted in such a way that it would touch the sample. About 5 mL of sodium carbonate (Na_2CO_3) solution is taken in the bomb and the bomb is rotated so that its interior surface is moistened by the solution. The sample cup with the sample is placed in position. The bomb is then assembled and the cover is tightened securely. Then oxygen is allowed to enter into the bomb. The bomb is then immersed in distilled water-bath as usual. The circuit is then closed to ignite the sample. After 10 minutes of ignition the bomb is removed from the bath. The pressure in the bomb is released slowly at the uniform rate, such that the operation requires 1(one) min. The bomb is then opened and no sample is found unburnt.

The interior of the bomb is rinsed and the inner surface of the bomb cover is also washed with a fine jet of distilled water. The washed liquid is then collected in a 600 mL beaker and filled upto the mark indicating 75 mL. Any precipitate in the bomb is removed by means of a rubber policeman. The base of the terminals is also washed. 10 (ten) mL of saturated Bromine water is added to the washings in the beaker. The sample cup is then put in a 50 mL beaker. 5(five) mL saturated bromine water, 2(two) mL of Hydro-chloric acid (Hcl) and enough distilled water is added just to fill the cup. The contents of the beaker is heated to just below its boiling point for 3(three) or 4(four) minutes. The overall contents are then added to 600 mL beaker containing bomb washings. The sample cup and 50 mL beaker is washed throughly with distilled water. Any precipitate in the cup is removed by means of a rubber policeman.

The combined washings is then slowly evaporated to 200 mL, the slow boiling being regulated by a temperature controller. While still boiling 10 mL of saturated Barium chloride ($Bacl_2$) solution is added in the fine stream. During $Ba\ Cl_2$ addition the entire solution is being kept stirred and 2 (two) minutes thereafter the beaker is then covered with a glass cover. Boiling is continued slowly until the solution has evaporated to a volume of approximately 75 mL. Heating is then discontinued and the beaker is allowed it to cool for 1(one) hour after which it is filtered.

The precipitate is washed with water until free from chloride. The filtered paper along with the precipitate is transferred to a previously weighed curcible and is dried at low heat until the moisture has evaporated. The paper is charred completely without igniting it and finally ignited at a bright red heat until residue is white in color. After ignition is complete the crucible is allowed to cool to room temperature and weighed (35). A blank determination is made whenever a new reagent , white oil or other low sulfur combustible material are used.

Calculation

$$\text{Sulfur (\% by weight)} = \frac{(P-B)\ 13.73}{W} \qquad (7)$$

where P = weight of Ba SO_4 obtained from sample.

B = weight of Ba SO_4 obtained from blank

and W = weight of the sample used.

5.4 FUEL VALUE

A small accurately weighed peat sample is burnt in a oxygen atmosphere within a heavy metal receptacle (bomb) immersed in an agitated water bath. A temperature rise of water and bomb results from the absorption of energy released by combustion of the fuel. The amount of this energy is determined from a knowledge of the temperature rise and the thermal capacity of the bomb, water bath, and the water bath container The energy released by combustion is equal to the product of the water equivalent of the apparatus, specific heat of water and the rise of temperature.

Heat loss from the calorimeter is reduced by highly polished metal parts and by using an insulated enclosure for water container.

5.4.1 Working Process:

A weighed sample of the peat in briqutte form is placed in the sample cup. The mass of the sample ranges from 0.5 to 1 gram. A previously weighed short platinum wire about 6 to 7 cm in length is attached to two electrodes in such a manner that it is not in contact with the fuel. A cotton thread, 22 cm in length, of known fuel value is used to ignite the briqutted sample from lower surface. About 20 mL water is kept in the bottom of the bomb to saturate the oxygen with moisture. The oxygen passing valve on the bomb is opened and connection is made with the oxygen tank. The regulating valve is closed and the valve on the tank is opened. Oxygen is then allowed to flow slowly into the bomb, until the pressure gauge reads about 25 atm. The valve on the bomb is then closed tightly and the line is disconnected. The sealed bomb is then tested for leaks by immersing it in a pail of water. Any leaks causing more then occasional bubble is stopped by further tightening. 2,000 mL of distilled water is taken into the calorimeter container and the bomb is placed in proper position and then electrical connections are made.

After all other components of the set-up are in place, the thermometer is carefully suspended in the opening provided for it in the cover, so that the bulb of the thermometer is about 10-12 cm below the surface of water. The stirring is started and its speed is adjusted so that the distribution of temperature remains uniform throughout the water.

As soon as the thermometer reading has become steady, not less than 2 mins. After the stirrer is started, accurate temperature reading is recorded together with the time of observation at one minute interval for 5 (five) minutes. As soon as the reading is recorded at a tem~~perature~~ time "a" the switch is on thus igniting the oxygen. After the signal indicates fusing of the wire, the switch is off. Thermometer readings are recorded at 12-sec. intervals until a rise of about 5°C has attained. Thermometer readings are closely observed until the temperature rise ceases and momentarily constant-maximum temperature is observed at a time "c". Readings are then recorded at 12-sec intervals until the drop for successive minutes is practically uniform. In the investigation Dickinson method is used for radiation correction. Because a portion of the fuse wire is found to have burnt to oxide, a correction is also made. The correction for cotton thread is also considered.

5.5 ELECTRICAL STUDY:

5.5.1 Preparation of Samples.

5.5.2 Cleaning

Coal-peat is cleaned in order to reduce the concentrations of mineral matter and sulfur which it contains, and to remove foreign objects, such as pieces of iron and wood. Pieces of iron and wood sometimes get into the coal-peat during mining and handling. In order to remove injury to the peat-handling equipment, removal of such foreign bodies is necessary(7).

The cleanability of the coal-peat depends on the forms in which the impurities, the mineral matter and sulfur are present, their distribution, the friability of coal, and the relative specific gravities of coal-peat and refuse.

Impurities in coal may be classified as (i) the finely divided material which is structurally a part of the coal substance and inseperably mixed with it and (ii) coarse, segregated particles which may be seperated from the coal-peat by mechanical means. The segregated impurities are seperate , distinct masses, such as shale, clay, slate, pyrites, gypsum and other mineral compounds. They occur in layers deposited in the coal seam, as infiltrations. Since the size of the segregations decreases from these clearly perciptible down to very fine particles intimately distributed through the coal-peat, the efficiency of the cleaning is affected by the size of the coal peat washed.

Mineral matter and sulfur which are intimately and structurally mixed with the coal-peat cannot be seperated from it by cleaning. The portions of the combined mineral matter and sulfur consequently represent limits below which it is impossible to reduce the ash and sulfur contents. These limits are designated by several names, such as the fixed or inherent ash and sulfur respectively. Although, the total ash in a seam may vary, the fixed ash usually remains fairly constant. Because differentiation between finely divided, segregated impurities and the structurally combined impurities is difficult and depends on the fineness of the coal-peat in practice, the fixed ash content as determined tends to vary. There are many process for reducing the ash content of coal-peat. But the fixed ash content cannot be removed.

Now it is of interest to know the specific gravity of coal-peat for seperating it from ash and other impurities. The pieces which make up the coal-peat from a mine range in density from the lightest forms of bright coal-peat to the heaviest forms of shale and pyrite. The specific gravities of the particles depend on the kind of coal and the moisture and mineral matter contents. Specific gravities of several kinds of coal and mineral matter are as follows:

Name of coal/Mineral matter	Specific gravities
i. Pure bituminus coal	1.28 – 1.37
ii. Bone coal	1.40 – 1.60
iii. Shale, clay, and sandstone	2.00 – 2.64

iv.	Pyrites	2.40 - 4.95
v.	Calcite	2.7
vi.	Gypsum	2.3

A cleaning process affects a seperation between coal and impurities by utilizing the differences in their specific gravities.

5.5.3 Process of Cleaning:

The process for cleaning coal may be classified as follows:

A. Gravity separation:

  1. Wet process
  2. Dry process

B. Float-and-sink methods:

(C) Froth floatation)

Wet and dry process are further classified as

1. Wet process:
   - a. Launder washers
   - b. Jigs
   - c. Rising current classifiers
   - d. Tables

and

2. Dry process:
   - a. Jigs
   - b. Tables

A. Gravity Seperation Process

1. Wet process.

1.a. Launder washers:

Launders or trough washers are one of the oldest devices used for washing coal-peat and the Pheolaveur washer is the principal example of this type. Where a stream consisting of coal-peat, or other material of non uniform density and water is directed down a trough, stratification occurs according to the hindered settling rates of the particles. The heavier particles settle rapidly and reach the bottom quickly. The lighter particles settle more slowly and are carried further down the stream before they can reach the bottom. In the Launder washer, the efficiency of seperation is accentuated because the main body of the stream is flowing rapidly, while the layer of heavier material is retarded by friction with the bottom and moves more slowly. Consequently, the heavy portions of the coal accumulate as a relatively slow moving layer, above which the coal is carried rapidly. The speed of movement of the particles is also influenced by their shape and size. But the process is applicable for coarse particle size.

1.b Jig washers.

In a hydraulic jig, coal, is stratified by alternating upward and downward pulsation of water. Jig washers are usually manufactured in standard sizes, and multiplicity of units is installed to handle the plant load. They are handling in practice a wide range of coal sizes, from 8" down to zero size.

1.c Classifiers

In classifiers, the coal-peat and mineral matter are seperated by regulating the speed of an ascending current of water,in which the raw coal-peat is suspended, so that the larger and heavier particles fall downward against the current while the smaller and lighter particles are carried upward. A classifier is limited in the range of sizes which it will handle and should be fed with fairly closely sized coal-peat. Fine particles suspended in water cannot be seperated but assist in the seperation of wider size range of particles. The fine particles have the effect of increasing the specific gravity of the seperating fluid. In water with a density of 1 gm/c.c, the ratio of the sizes of coal particles with a specific gravity of 1.35 that can be seperated from ash particles of 2.5 specific gravity of 4.3:1. In case the suspended particles serve to increase the effective specific gravity of the water to 1.1, the ratio of sizes becomes 5.6:1.

1.d. Tables:

Tables are adopted for cleaning the finer sizes of coal-peat with a maximum size of about 1 inch. The capacity of a table depends on the size and washability of the coal-peat. One type is able to clean efficiently 6 to 7 tons of 5/6" coal-peat per hour, in the case of coal-peat of ½" to 1" maximum size, 6 to 10 tons were washed per hour.

2. Dry process

Much of the water is seperated from the slurry of coal-peat and water produced in a wet-cleaning process by discharging the slurry over a dewatering screen. Another method for seperating water is the use of drain pits or bins. The pit is fitted with coal-peat, and most of the water drains out through grids in the bottom. After several hours the coal-peat can be dug out of the pit with grab buckets. The water content of coal-peat dewatered in screens or in pits will run from 10 to 20% being higher the finer the coal-peat.

Air cleaning of coal-peat has an advantage over wet cleaning in that the cleaned coal-peat is dry .On the other hand, precautions must be taken to prevent the escape of dust into the atmosphere, dust catchers are required on the outlet air from the cleaners and the apparatus is tightly enclosed.

2.a .Tables

Air tables are operated much as are wet tables. The coal-peat is fed to one corner of a pervious deck which is transversely inclined. The table is suspended so that it may be shaken back and forth in a horizontal direction and is provided with riffles which extend at an angle along the deck. The deck is connected to an air chest located below it,so that the air may be blown through the deck. The coal-peat to be treated spread out over the table surface where, under the combined action of the air currents, motion of the table deck, the light particles stratify above the refuse particles and flow down over the side of the table. The heavy refuse is trapped in the riffles and moves to the end of the table.

2.b. Jigs

Jig-type cleaners are stationary devices utilizing pulsating air currents for stratification of the coal-peat.

B. Float-and-sink Process.

The cleaning quality of a coal-peat is now being extensively studied by what is known as a float-and-sink process. A coal-peat can be seperated into two fractions by immersing it in a liquid having a specific gravity intermediate between that of the coal-peat and that of the principal impurities. The materials lighter than the liquid will float, and those heavier will sink. By using a series of solutions having different specific gravities, the coal is seperated into a number of fractions. Although the sizes and shapes of the coal-peat particles do not affect the proportions of these fractions, they are important in a actual washing process and because they influence the rate of settling and stratification, the float-and-sink process of sepreation is consequently an ideal process which can be applied with success in the washery.

Table 5.a. shows float and sink fractions of two coals, one a coal fairly easy to wash, the other a bone coal difficult to wash.

Table 5.a

Specific gravity range	Easily washable coal (%)	Bony coal, Difficult to wash (%)
1.80 and greater	8.00	8.00
1.60-1.80	1.50	18.50
1.50-1.60	1.00	16.00
1.40-1.50	3.00	22.00
1.30-1.40	26.50	23.50
Below 1.30	60.00	12.00

The fractions below 1.40 specific gravity consist of good coal-with minimum ash. The 1.40 - 1.60 fractions are middlings and may contain 25 to 30 percent ash. Material within this range is not appreciably affected by ordinary washing process. The fractions above 1.60 are high in ash and are discarded as refuse. An ideal coal would have no fractions between the first and the last. Such float-and-sink test are conducted on new coals to determine their cleanability or washability and are regularly run in coal washeries to determine the washing efficiencies.

The liquids used in the float-and-sink processes are solutions of inorganic salts and organic liquid solvents like benzene, toluene etc. Calcium chloride solution with specific gravity as high as 1.40 can be prepared; with zinc chloride specific gravity of the solution may rise as high as 1.90. These solutions are cheap and satisfactory for use with coals of ordinary size. Because the viscosity of the salt solutions are relatively high and their wetting characteristics for fine particles are poor, organic liquids are preferable for testing fine coals . In the float-and-sink process choloroform having a specific gravity of 1.5; carbon tetrachloride, 1.6; and bromoform; 2.9, are some of the organic liquids which are widely used. The later is diluted to lower specific gravity by the addition of toluence or benzene. In such solution coal-peat is suspended. The clean coal-peat remains in the top of the bath and is skimed off, but the ash content settles in the bottom.

In our present investigation the sample materials have specific gravity ranging from 0.80 to 1.15 and hence we adopted float-and-sink process. The air dried coal-peat is put into an appreciable quantity of distilled water and stirred at intervals. After a sufficient length of time when the slurry settles the muddy water is changed carefully from the top and this process is continued repeatedly for three to four weeks. In the decantation process it has been observed that there are two to three layers of material in the glass container. The components of the sample materials having high specific gravity settles down to the bottom of the tube.

The upper layer containing wood and fibrous material is of relatively low specific gravity. This is easily freed while pouring the water from the top when it is settled in the container. If the decantation process is repeated the upper layer will be mostly peat containing slurry, the heavier impurities falling down the container. The upper layer of the sample is finally decanted in a pastry disk. The sample is then air dried under sun for two to three days or sometimes for a week and becomes hard thick sheet. This is transferred in sample bottle. The sample bottle along with the peat sheet is then kept in dessicator to keep the sample free from moisture.

Washing and sun dried samples of various thickness are selected for electrical resistivity measurement. The sample is then given a definite shape and size as required for experimental set up. The diameter of the samples ranges from 4.50 to 5.25 mm and the thickness lies between 2 3 mm. To make the samples of the above mentioned sizes first of all a number of pieces were taken from the preserved samples of different fields respectively. By breaking each of the sheets pieces of rough diameters and thickness are chosen and then by a mechanical polisher the rough surfaces of each sample are removed using emery papers of various grain sizes and finally the finest grit paper is used. The samples are then found to be well polished and more or less of uniform diameter and thickness. This uniformity of surfaces is necessary for the well electrical contact of the specimen.

5.6 Description of Experimental Set-up and Mode of Action.

The sample was put into a cylinder made of borasilicate glass of 5.30 mm internal diameter and 7.20 mm outer diameter (Fig.5.2). A nikel-plated iron piston is inverted vertically into the glass cylinder from both ends In order to achieve a good electrical contact, the sample is pressed at 250 PSI upon the piston. The complete assembly is again placed vertically inside a tabular furnace, the temperature of which may be raised upto 700°C. The furnance temperature is raised slowly at the rate of $(2-3)^{\circ}$ k/min, to facilitate attaining uniform temperature throughout the process. The furnace was insulated carefully by wrapping with adbestos thread upto a thickness of 2 cm. It is further surrounded by adbestos sheet 1 cm thick, keeping an annular air space of 1 cm in between. Similar arrangements are made in the side and at the top of the furnace. These precuations are made to prevent the loss of heat from the sample during temperature rise. The temperature stability thus achieved is of the order of $\pm 0.5^{\circ}$k. The resistance of the properly sintered and polished samples are measured by D.C. method with the help of a precision multimeter accurately reading to 10^{-3} mv at intervals of 1°k/20 sec. in the range 105°C to 700°C.

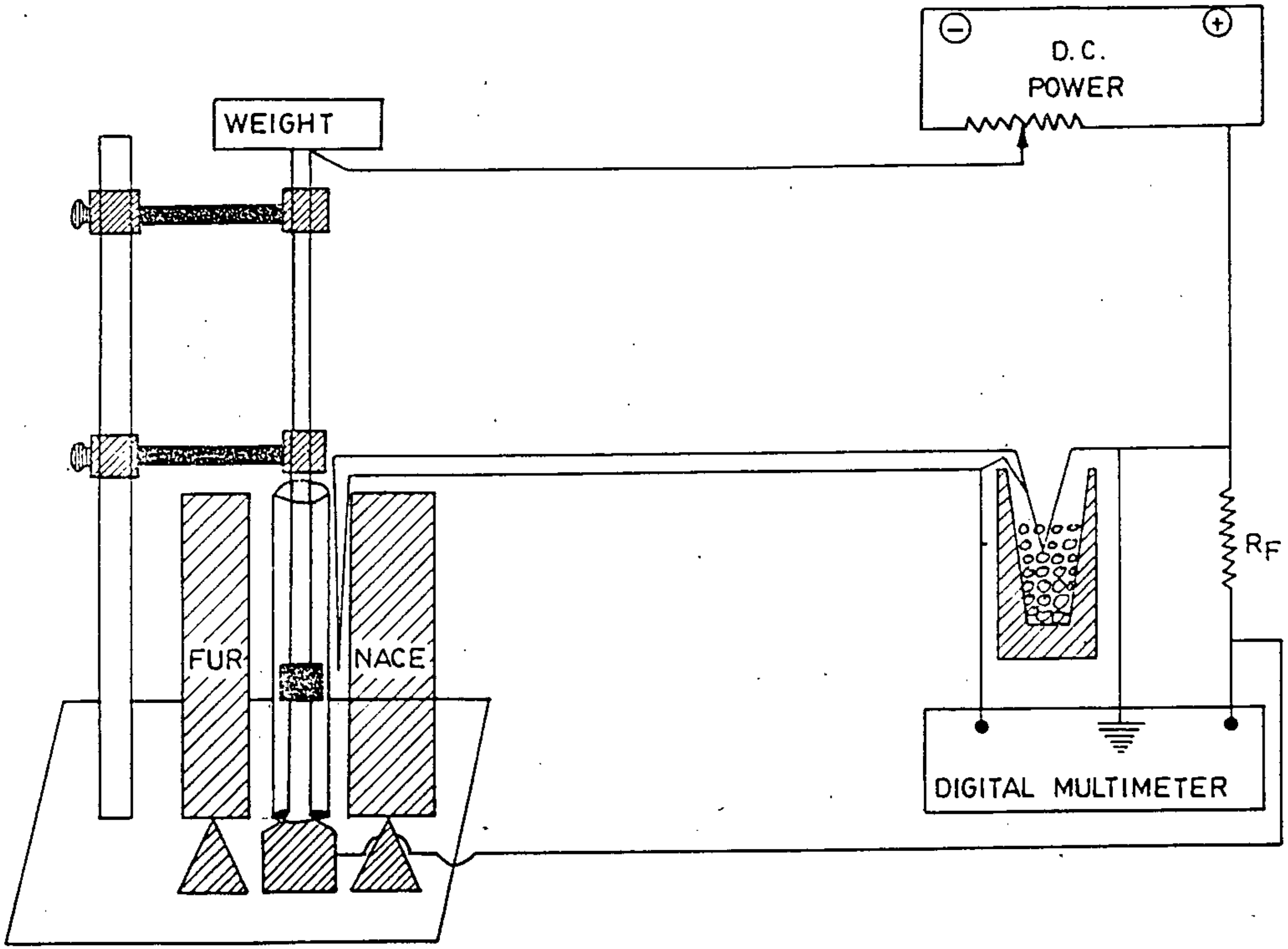

FIG.5.2 EXPERIMENTAL SET-UP FOR ELECTRICAL STUDY.

The temperature is measured by a calibrated iron-constantan thermo-couple. Two to four readings are taken for each temperature, the mean readings are then recorded for analyses(36). The standard deviation for the readings:

$$\sigma_r = 0.004 - 0.006.$$

and the standard deviation for two successive readings for two successive temperatures is

$$\sigma_s = 0.005.$$

CHAPTER - VI

RESULTS, DISCUSSIONS AND CONCLUSION

The fuel characteristics along with proximate analyses of peats collected from Chanda Beel , Baghia Beel of Faridpur and also of Kola Mouza of Khulna Districts are presented in Tables (No. 6.1; No. 6.2; No. 6.3) respectively. The results of proximate analyses show that the ash content ranges from (28-50)% ; (24-44)%; and (26-50)% by weight in the case of Chanda Beel, Baghia Beel and Kola Mouza peats respectively. The volatile matter contained in the peats of the three fields ranges from (38-53)%; (30-55.50)% and (26-47)% by weight respectively. The fixed carbon content ranges from (8-24)%; (11-26)% and (12-31)% respectively and sulfur content (1-3.20)% ; (1.50-3.50)% and (1.50-2.50)% respectively. The proximate analyses show a characteristic difference of peats in the different areas . From the analyses it is observed that the peats of these regions are poor raw materials for chemical processing and unless some intimately mixed undesirable constituents are removed. They cannot be used for chemical processing. From the same table it is noticed that the fuel value of the peats ranges from (10,000 - 22,000) KJ/kg; (9500-21863) KJ/kg and (11000-17,500) KJ/kg respectively. The fuel characteristics of Chanda and Baghia Beel peats are more or less similar. But the fuel value of Kola Mouza peat is comparatively low. Inspite of these draw backs their use in domestic and industrial work is feasible.

For the purpose of electrical study, some preliminary experiments on some samples of the three fields were carried out. Four samples of highest calorific value of the different fields were chosen for study. In our investigation, current and input voltage were kept constant throughout the process. The rise of temperature was controlled by universal temperature controller and was kept at 2 - 3°C/min. The voltage across the fixed resistance and across the sample were measured by Digital multimeter and the thermo. e.m.f. were read by Digital millimultimeter. The thermo. e.m.f.s were then converted to temperature by calibration. The sample resistance at a particular temperature were found out. To see the electrical response of the samples logarithms of resistivity vs 10^3/absolute temp. curves were drawn. It is observed, in the curves No.6.a, No. 6.b; No. 6.c respectively, that the resistivity of all the samples remains unchanged upto a certain range of temperature, i.e. upto 239.82°C for Chanda Beel peats; 191.04°C and 293.57°c for Baghia Beel peats. and 247.83°C for Kola Mouza peats.

The insulating character of the samples under investigation is remarkably observed just above the aforesaid temperatures and continued upto 279.47°C for Chanda and 346.20°C 318.72°C for Baghia and 346.2°C for Kola Mouza peats respectively. The electrical behaviour of the samples of different areas are similar, that is, the resistivity increases during a certain range after which the electrical behaviour of the samples returns to the initial state in character. The above ranges of temperature may be refers to the initial stage of carbonization for the complex compounds. In these stages irregular variation of resistivity with temperature is observed. This may occur due to evolution of various hydrocarbon gases, Co_2 etc. during heat-treatment. This random variation of resistivity in the initial stage of carbonization occurs due to the rearrangements of the molecules of the samples. Because of their rearrangement, the energy gap increases and hence the valence electrons need more energy to be transferred from valence band to unfilled band. As a result the resistivity increases with the rise of temperature at this stage. This is an unavoidable character of the samples. Above this stage, that is, at temperatures 453.27°C for Chanda 399.75°C and 402.13°C for Baghia and 366°C for Kola Mouza peat, the samples start to decompose and hence these temperatures may be called transition temperatures. The points corresponding to these temperatures may be said to be transition points for the respective samples. From the transition points a sharp fall of resistivity is observed. Here the ordering of the molecules in the parent materials begins and hence the energy gap decreases gradually so that intrinsic conduction in the samples takes place. The more the molecules are structurally ordered the more the conduction becomes significant and hence the resistivity decreases continously with increasing temperature. The sharp fall of resistivity continued upto temperatures 623.86°C for Chanda Beel peats; 536.72°C and 570.70°C for Baghia Beel peats and 550°C for Kola Mouza peats. The resistivity falls to 1723.31 Ω-cm for Chanda; 4023.87 Ω-cm and 1274.104 Ω-cm for the two samples of Baghia Beel peats respectively , and 10404.104 Ω-cm for Kola Mouza peats. The fall of resistivity are found from 824833.45 Ω-cm to 1723.30 Ω-cm for Chanda, 488942.41 Ω-cm to 4023. 8724 Ω-cm and 1264263.1 Ω-cm to 1274.106 Ω-cm for the two samples of Baghia Beel peats and 2303637.6 Ω-cm to 10404.56 Ω-cm for Kola Mouza peats. The results indicate the remarkable change of resistivity with temperature although the change is not so large.

The temperature ranges for the four samples, viz (424.27-623.86)°C (399.75-530.72)°C (402.18-570.70°C) and (366-550)°C may be referred to the transition zones and signify the intermediate state of carbonization or otherwise called mesophase formation zones respectively. Although the peats of different areas are structurally different they have similar semiconducting properties and the peat samples have graphitizing characters. In our investigation the sudden change in resistivity with temperature both in heating and cooling of the samples indicate that there is a critical temperature at which the samples undergo a transformation in respect of electronic behabiour. This transition temperature may be attributed to the excitation of the electrons to the conduction band and to overcome the band gap in organic semiconductors.(*) There is some behabiour of the material for its heating and cooling processes indicating some irreversibility, shown in Lnp Vs $10^3/T$ curve (Fig. 6.e), since the samples could not be completely purified and some irreversibile process of vapourization and grain reorientation are expected to be accompained with the heating,the small hysteresis observed is not unusual.

Inspite of the draw-backs of having excessive moisture, ash, sulfur in Bangladeshi peats efforts are being made to utilize peat in a number of ways by carbonizing it, thereby producing, "peat charcoal" and crude oils, paraffin wax, asphalt and power gas, etc. One tons of peat, if treated as gas producer, is capable of giving as much as 90 lbs of amonium sulphate along with as much as 90,000 cuft of gas.

The principal uses of peat in United states are as fertilizer ingradient, soil conditioner, packing material for some vegetable products and insulating material.

Peat briqutte may be utilized as the substitute of coal, wood and gas. It may be used as fuel for producing bricks, molasses and for tobacco curing etc. The peat briqutte may be extensively used in electric power generation centre.

Powder peat is used widely for power stations in Sweden, Russia and Ireland.(5) Briguetting peat, self binding briquttes are made readily from air-dried peat in extrusion type (or ring roll) mechanics.

We may get valueable chemicals both organic and inorganic from peat by different process,thermal and chemical. The coal peats available in Bangladesh may be changed into the valuable materials, such as, graphite, diamond by suitable heat treatment process. But this artificial preparation of graphite, etc.is still found uneconomic.

If the material is used properly in our country we may save the hard earned foreign currency employed for importing coal. And if factories and mills, large or small, are installed for different purposes, the pressure on unemployment problem will be lessened to a large extent.

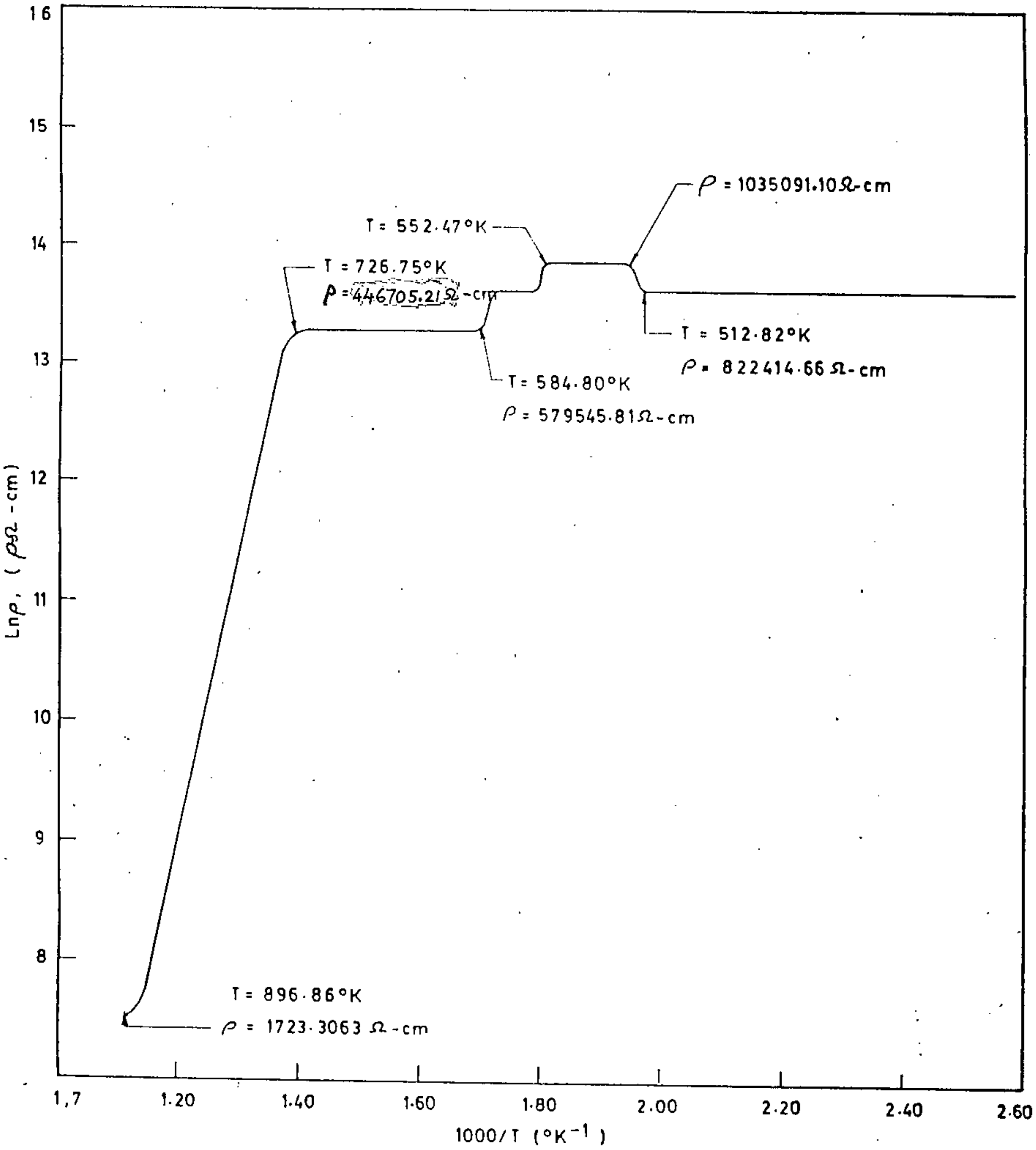

FIG. 6.a : RESISTIVITY – TEMPERATURE CURVE FOR CHANDA BEEL PEAT.

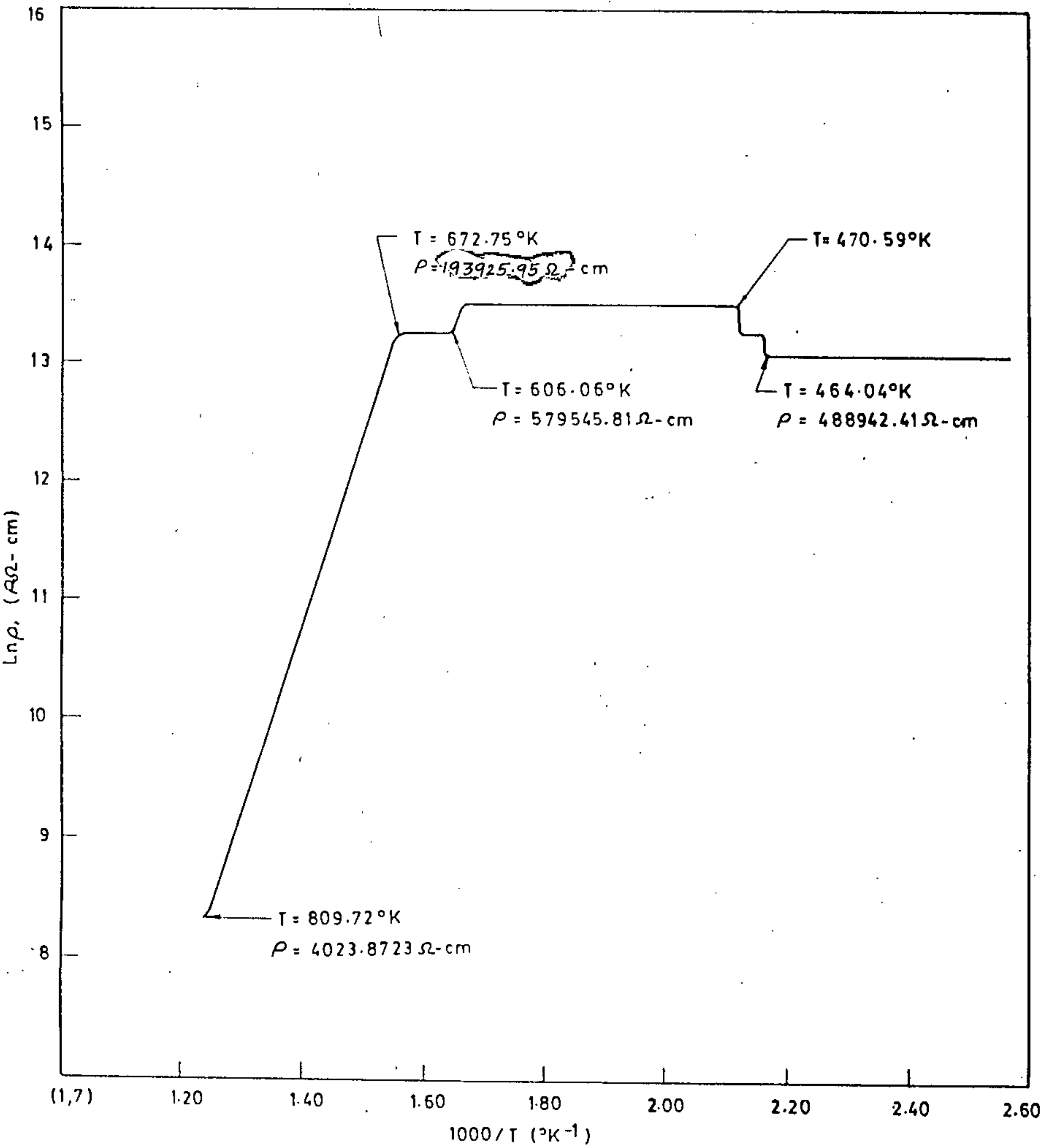

FIG. 6.b : RESISTIVITY - TEMPERATURE CURVE BAGHIA BEEL PEAT (1).

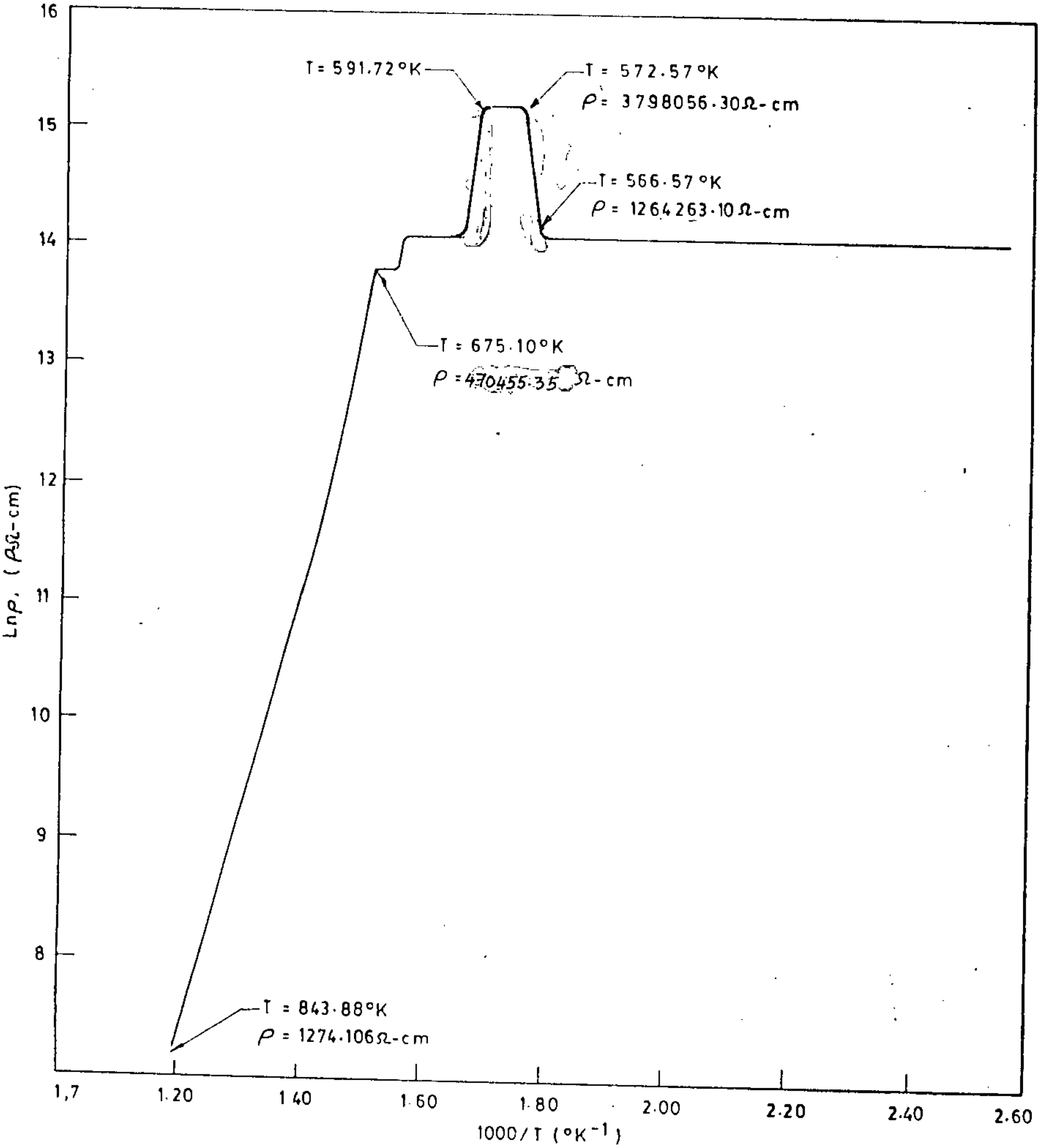

FIG. 6.c : RESISTIVITY – TEMPERATURE CURVE FOR BAGHIA BEEL PEAT (2).

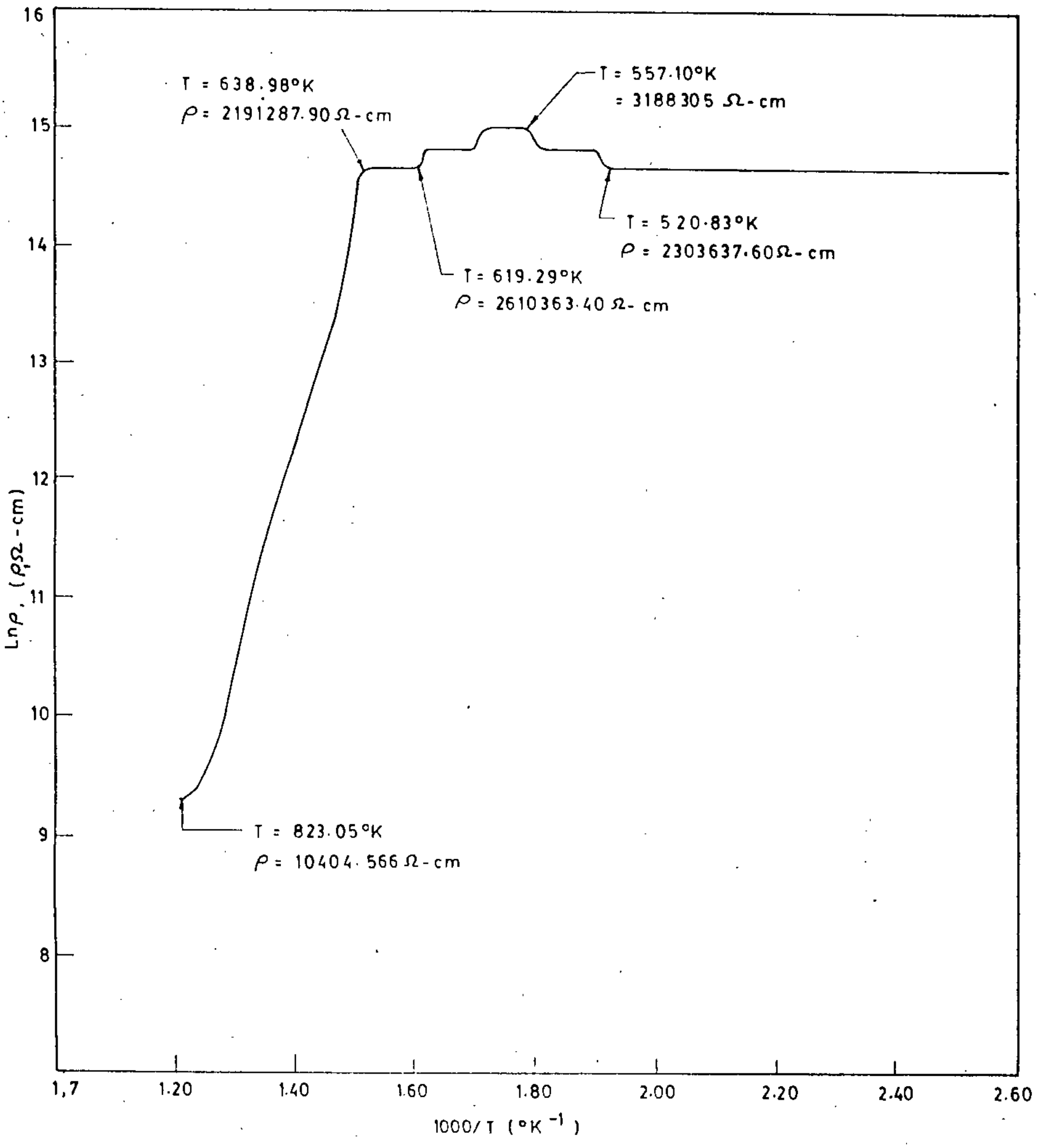

FIG. 6.d : RESISTIVITY – TEMPERATURE CURVE FOR KOLA MOUZA PEAT.

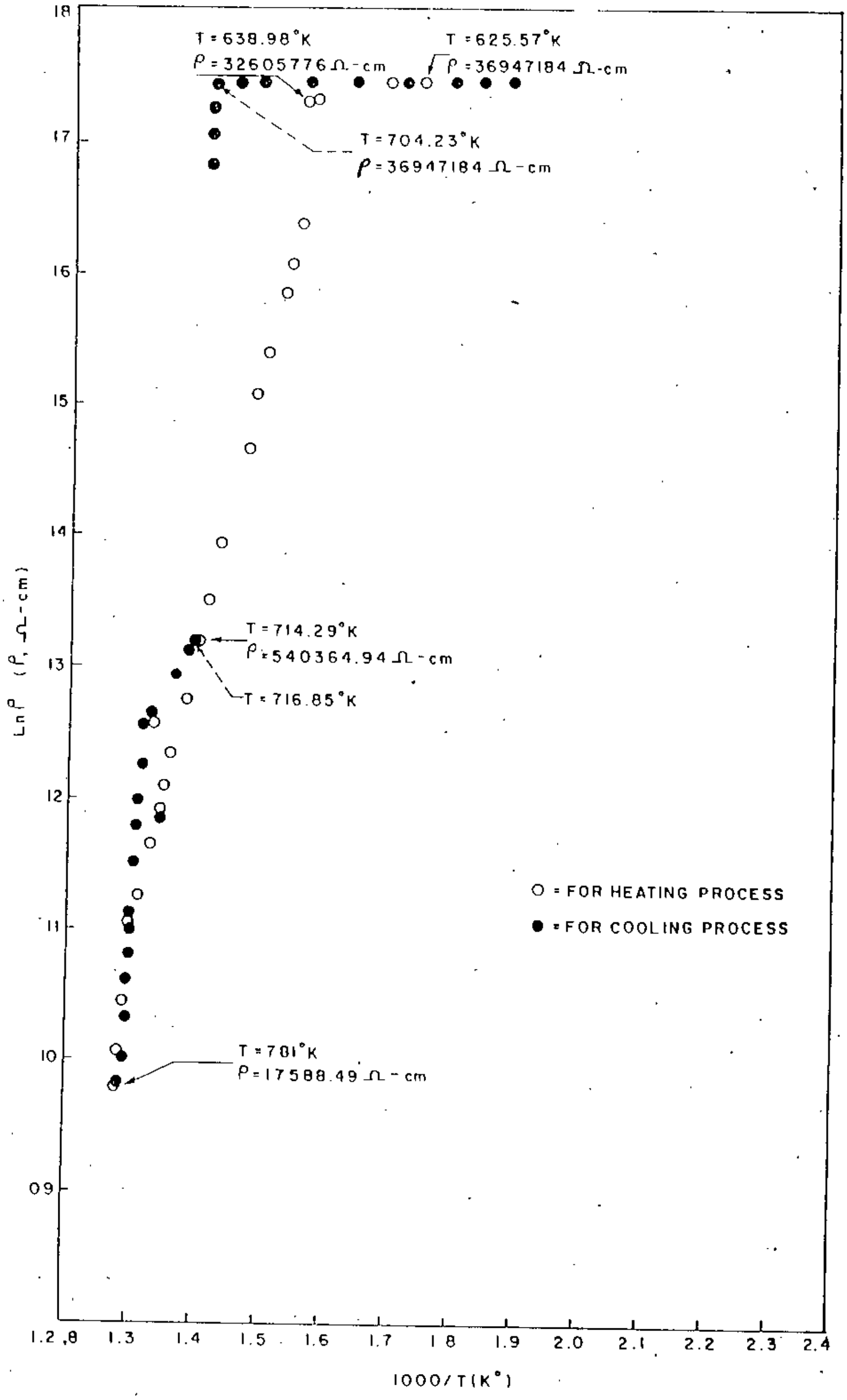

FIG. 6 a Ln ρ VS 1000/T FOR HEATING AND COOLING.

TABLE 6 .1 CHANDA BEEL PEAT

Sample No/ depth	Moisture content % wt. (Total)	Ash content % wt.	Volatile matter % wt.	Fixed carbon % wt.	Sulpur % wt.	Calorific value KJ/kg.
CH-6"-3'	85.15	47.00	38.52	14.48	2.55	12222.28
CH-4'.2"-6'.6"	82.52	28.18	48.16	23.66	1.91	21368.686
CH-7'.0"-9'	78.62	32.15	53.00	14.85	2.85	18257.826
CH-10'.0"-11'-6"	68.75	48.00	43.52	8.48	3.01	11222.167
CH-2.6"-4'	80.52	40.63	42.15	17.22	1.25	12224.296
CH-12'	65.35	49.35	34.65	16.00	2.32	10035.94
CH-8'	79.78	35.42	44.15	20.43	1.27	19255.42
Average	77.24	40.104	43.45	16.45	2.17	14940.944

TABLE 6.2 BAGIA BEEL PEAT

Sample No/ Depth	Moisture content % wt (Total)	Ash content (dry basis) % wt.	Volatile matter % wt.	Fixed carbon (dry basis) % wt.	Sulfur content % wt.	Calorific value KJ/kg
B.B.L (24)8'	80.20	24.52	49.78	25.76	2.52	21862.874
B.B.L(25)9'	74.42	23.90	55.25	20.85	1.72	15164.462
B.B.L(12)11'	72.55	26.50	52.75	20.75	3.12	12792.107
B.B.L(10)12'	68.92	53.00	31.97	15.03	1.90	9582.4513
B.B.L(26)5'	73.46	35.15	52.91	11.94	2.09	12606.04
B.B.L(24)1'	78.32	27.75	49.85	22.40	2.15	21254.67
B.B.L-10 0.6"-1.6"	82.18	43.15	41.85	15.00	3.45	13508.464
Average	75.72	33.42	47.77	18.82	2.42	15253.008

TABLE 6.3 KOLA MOUZA PEAT

Sample No/ depth	Moisture content % wt. (Total)	Ash content % wt. (dry basis)	Volatile matter % wt	Fixed carbon % wt.	Sulfur % wt.	Calorific value KJ/kg
S.H-4 4'-6"-7'	80.00	32.00	44.50	23 50	2.25	16480.600
S.H-12 0-4'	82.89	38.85	42.75	18.40	2.05	13997.52
S H-16 5'-6'6"	72.00	49.00	38.55	12.45	1.90	10103.64
S.H-33 5'-7'	78.00	46.52	40.53	12.95	1, 95	14205.00
S.H-35 1'6"-3'	77.52	37.55	41.23	21.22	2.15	14908.53
S.H-44 5'-7'	73.35	26.85	43.95	29.20	2 20	15101.50
S.H-47 3'-5'	79.25	27.75	42.00	30.25	1.97	15509.00
S.H-52 9"-1'.9"	75.55	28.15	48.95	22 90	1 .75	13042.00
**J H-24 6'-8'6"	72.75	37.25	37.29	25.46	2 22	17450.55
J.H-46 0-6"-2'2"	73.00	46.00	39.58	14.42	1.77	11689.00
Average	76.43	36.99	59.90	21.08	2.02	14248.734

EXPERIMENTAL DATA

BEEL CHANDA : SAMPLE NO.CH-24(4'-6'-6")

FIXED RESISTANCE R_F=20KΩ

TABLE NO. 6.4

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ $(o_k{}^{-1})$
378	1.98	0.05	792000	824833.45	13.6229	2.6456
414	"	"	"	"	"	2.4155
460	"	"	"	"	"	2.1739
470	"	"	"	"	"	2.1277
480	"	"	"	"	"	
490	"	"	"	"	"	2.0408
500	"	"	"	"	"	2.0000
510	"	"	"	"	"	1.9608
513	1.97	0.04	985000	1025940.5	13.8411	1.9493
515	1.97	0.05	788000	820752.43	13.6180	1.9417
517	1.97	0.04	985333	1025940.5	13.8411	1.9342
540	"	"	"	"	"	1.8519

Temperature T ($(^o{}_k)$)	Voltage across sample, V_s (volt)	Voltage across fixed resist V_R (volt)	Sample resist R_s (Ω)	Resistivity of the sample (Ω-cm)	Ln ρ	$10^3/T$ ($(^o{}_k{}^{-1})$)
554	1.97	0.05	788000	820752.43	13.6180	1.8051
580	1.96	0.05	784000	816586.18	13.6129	1.7241
582	1.96	0.06	653333.33	680488.48	13.4306	1.7182
584	1.94	0.07	554285.71	577324.05	13.2662	1.7123
719	"	"	"	"	"	1.3908
721	1.94	0.08	485000	505158.54	13.1326	1.3870
725	1.93	0.09	428888.89	446715.23	13.0097	1.3793
730	1.92	0.10	384000	399960.58	12.8991	1.3699
734	1.91	0.10	382000	397877.45	12.8939	1.36260
735	1.90	0.12	316666.67	329828.6	12.7063	1.3605
736	1.89	0.13	290769.23	302854.76	12.6210	1.3587
737	"	"	"	"	"	1.3567
738	1.88	0.14	268571.43	279734.33	12.5416	1.3550
741	1.87	0.15	249333.33	259696.62	12.4673	1.3495

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
742	1.86	0.16	232500	242163.63	12.3974	1.3477
743	1.85	0.16	231250	240861.68	12.3920	1.3459
745	1.85	0.17	217647.06	226693.34	12.3314	1.3423
746	1.84	0.18	204444.44	212941.97	12.2688	1.3405
747	1.83	0.19	192631.58	200638.12	12.2093	1.3387
749	1.82	0.20	182000	189564.65	12.1525	1.3351
750	1.81	0.21	172380.95	179545.79	12.0982	1.3333
751	1.80	0.22	163636.36	170437.75	12.0461	1.3316
752	1.79	0.23	155652.17	162121.70	11.9961	1.3298
753	1.78	0.24	148333.33	154498.66	11.9479	1.3280
754	1.77	0.25	141600	147485.46	11.9015	1.3263
755	1.76	0.26	135384.62	141012.74	11.8566	1.3245
757	1.74	0.28	124285.71	129451.83	11.7711	1.3210
758	1.72	0.30	114666.67	119420.33	11.6904	1.3193
759	1.71	0.31	110322.58	114896.16	11.6518	1.3175

Temperature T (o$_k$)	Voltage across sample, V$_s$ (volt)	Voltage across fixed resist. V$_R$ (volt)	Sample resist. R$_s$ (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	10^3/T (o$_k$-1)
760	1.70	0.32	106250.00	110654.74	11.6141	1.3158
761	1.68	0.33	101818.18	106039.20	11.5716	1.3141
764	1.63	0.38	85789.474	89345.996	11.4003	1.3089
766	1.61	0.41	78536.585	81792.429	11.3119	1.3055
768	1.60	0.42	76190.476	79349.059	11.2816	1.3021
770	1.57	0.44	71363.636	74322.116	11.2162	1.2987
772	1.55	0.47	65531.915	68248.632	11.1309	1.2953
774	1.52	0.49	620408.016	64612.805	11.0762	1.2920
776	1.49	0.53	56226.415	58557.36	10.9778	1.2887
778	1.46	0.56	52142.857	54304.512	10.9024	1.2853
780	1.37	0.63	43492.063	45295.088	10.7210	1.2821
784	1.34	0.67	40000.00	41658.256	10.6373	1.2755
786	1.30	0.72	36111.111	37608.148	10.5350	1.2723
788	1.26	0.76	33157.895	34532.502	10.4497	1.2690
790	1.23	0.79	31139.241	32430.161	10.3868	1.2658

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
792	1.20	0.82	2926.293	30481.65	10.3245	1.2626
794	1.15	0.85	26744.186	27852.904	10.2347	1.2594
796	1.13	0.89	2539.258	26445.971	10.1829	1.2563
798	1.09	0.92	23695.652	24677.989	10.1137	1.2531
800	1.08	0.94	22978.723	23931.339	10.0829	1.2500
802	1.04	0.98	21224.49	22104.381	10.0035	1.2469
804	1.02	1.00	20400.00	21245.711	9.9639	1.2438
806	0.98	1.03	19029.126	19818.005	9.8943	1.2407
808	0.96	1.06	18113.208	18864.116	9.8450	1.2376
810	0.92	1.10	16727.273	17420.725	9.7654	1.2346
812	0.89	1.12	15892.857	16551.718	9.7142	1.2315
814	0.87	1.14	15263.158	15895.913	9.6738	1.2285
817	0.82	1.19	13781.513	14352.844	9.5710	1.2240
818	0.80	1.21	13223.14	13771.324	9.5303	1.2225

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω -cm)	Lnρ	10^3/T (o_k-1)
820	0.79	1.23	1812845.528	13378.058	9.5014	1.2210
822	0.75	1.26	11904.762	12398.29	9.4253	1.2165
824	0.72	1.29	11162.791	11625.56	9.3610	1.2136
826	0.69	1.33	10375.94	10806.089	9.2879	1.2107
828	0.66	1.36	9705.8824	10108.253	9.2211	1.2077
830	0.63	1.39	9064.74	829440.54	9.1528	1.2048
832	0.60	1.41	8510.6383	8863.4587	9.0897	1.2019
834	0.58	1.45	8000.000	8331.6512	9.0278	1.1990
836	0.54	1.48	7297.2973	7599.817	8.9359	1.1962
838	0.51	1.50	6800.000	7081.9035	8.8653	1.1933
840	0.48	1.54	6233.7662	6492.1957	8.7784	1.1905
842	0.47	1.55	6064.5161	6315.9291	8.7508	1.1876
844	0.03	1.58	5696.2025	5932.3466	8.6882	1.1848
846	0.41	1.60	5125.00	5337.4641	8.5825	1.1820
848	0.39	1.63	4785.2761	4983.6564	8.5139	1.1792
850	0.36	1.66	4337.3494	4517.1603	8.4156	1.1765

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
852	0.35	1.67	41916.6168	4365.3861	8.3815	1.1737
854	0.32	1.69	3786.9822	9343.9769	8.2799	1.1710
856	0.31	1.71	3625.731	3776.0407	8.2364	1.1682
858	0.29	1.73	3352.6012	3491.5879	8.1581	1.1655
860	0.27	1.74	3103.4483	3232.106	8.0809	1.1628
862	0.25	1.77	2824.8588	2941.9672	7.9868	1.1601
865	0.25	1.77	"	"	"	1.1561
868	0.23	1.79	2569.8324	2676.3684	7.8922	1.1521
870	0.21	1.80	2333.3333	2430.6649	7.7957	1.1494
874	0.19	1.82	2087.9121	2174.4694	7.6849	1.1442
876	0.19	1.83	2076.5027	2162.587	7.7691	1.1416
878	0.18	1.83	1967.2131	2048.7667	7.6250	1.1390
880	0.18	1.84	1956.5217	2037.6321	7.6195	1.1364
882	"	"	"	"	"	1.1338

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
883	0.17	1.85	1837.8378	1914.028	7.5570	1.1325
885	0.16	1.85	1729.7297	1801.4381	7.4963	1.1299
887	0.16	1.86	1720.4301	1791.7529	7.4905	1.1274
890	"	"	"	"	"	1.1236
892	"	"	"	"	"	1.1211
894	"	"	"	"	"	1.1186
896	"	"	"	"	"	1.1161
898	"	"	"	"	"	1.1136
899	0.17	1.85	1837.8378	1914.0228	7.5570	1.1123
900	0.18	1.84	1956.5217	2037.6321	7.6195	1.1111
902	0.24	1.77	2711.8644	2824.2885	7.9460	1.1086
903	0.31	1.69	3668.639	3820.7276	8.2482	1.1074
904	0.53	1.55	6838.7097	7122.218	8.8710	1.1062
905	1.95	0.06	650000	676946.66	13.4253	1.1050
907	1.96	0.06	653333	680418.18	13.4305	1.1025
908	1.96	0.06	653333	680418.18	13.4305	1.1013

EXPERIMENTAL DATA

BEEL - BAGHIA SAMPLE NO. B.B.L. 24(8')

FIXED RESISTANCE R_F = 20K Ω

TABLE 6.2

Temperature T ($^o k$)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Ln ρ	$10^3/T$ ($^o k^{-1}$)
378	1.99	0.045	884444.44	651048.40	13.3863	2.6455
380	"	"	"	"	"	2.6316
390	"	"	"	"	"	2.5641
400	"	"	"	"	"	2.5000
407	"	0.05	796000.00	585943.56	13.28098	2.4570
410	"	"	"	"	"	2.4390
420	"	"	"	"	"	2.3810
430	"	"	"	"	"	2.3256
440	"	"	"	"	"	2.2727
450	"	"	"	"	"	2.2222
460	"	"	"	"	"	2.1739
470	2.00	0.05	800000	588888	13.2860	2.1277
474	"	0.04	1000000	736110	13.50913	2.1097

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ ($o_k{}^{-1}$)
482	2.00	0.04	1000000	736110	13.50913	2.0747
490	"	"	"	"	"	2.0408
500	"	"	"	"	"	2.0000
510	"	"	"	"	"	1.9608
520	"	"	"	"	"	1.9231
530	"	"	"	"	"	1.8868
540	"	"	"	"	"	1.8519
550	"	"	"	"	"	1.8182
560	"	"	"	"	"	1.7857
570	"	"	"	"	"	1.7544
580	"	"	"	"	"	1.7241
590	"	"	"	"	"	1.6949
602	2.005	0.04	1002500.0	737950.28	13.51163	1.6611
605	2.005	0.05	802000	950360.22	13.28849	1.6529
622	2.005	0.055	729090.91	536691.11	13.19318	1.6077
629	2.00	0.055	727272.73	535352.73	13.19068	1.5898
637	1.99	0.06	663333.33	488286.30	13.098657	1.5699

Temperature T (^{o}K)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ ($^{o}K^{-1}$)
646	1.98	0.07	565714.29	416427.95	12.939469	1.5480
651	1.97	0.08	492500	362534.72	12.800876	1.5360
659	1.96	0.095	412631.58	303742.69	12.623936	1.5174
660	1.955	0.10	391000	287819.44	12.570089	1.5115
662	1.95	0.11	354545.45	260984.85	12.472218	1.5105
666	1.94	0.12	323333.33	238009.26	12.380065	1.5015
672	1.91	0.145	263448.28	193927.2	12.175238	1.4880
674	1.90	0.15	253333.33	186481.48	12.136087	1.4837
676	1.89	0.16	236250	173906.25	12.066272	1.4793
678	1.88	0.17	221176.47	162810.46	12.000342	1.4749
680	1.88	0.18	208888.89	153765.43	11.943184	1.4706
682	1.86	0.19	195789.47	144122.81	11.87842	1.4663
684	1.84	0.21	175238.1	128994.71	11.767527	1.4620
688	1.82	0.23	158260.87	116497.58	11.665626	1.4534
692	1.795	0.26	138076.92	101639.96	11.529192	1.4459

Temperature T (^{o}k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ $(^{o}k^{-1})$
694	1.77	0.29	122068.97	89856.322	11.405967	1.4410
696	1.75	0.30	116666.67	85879.63	11.360702	1.4368
698	1.75	0.31	112903.23	83109.319	11.327912	1.4327
700	1 73	0.33	104848.48	77180.135	11.253897	1.4286
706	1 65	0.40	82500	60729.075	11 014178	1.4164
708	1.635	0.42	77857.143	57311.421	10.956235	1.4144
710	1.60	0.45	71111.111	52345.6	10.865623	1.4084
712	1.56	0.49	63673.469	46870.678	10 755148	1.4045
714	1.53	0.52	58846.154	43317.242	10.676306	1.4005
718	1.51	055	54909.091	40419.131	10.607058	1.3928
722	1.44	0.61	47213 115	34754.046	10.456051	1.3850
724	1.40	0.65	43076.923	31709.354	10.364367	1.3812
728	1.37	0.68	40294.118	29660.903	10 297585	1.3736

Temperature T (^{o}k)	Voltage across sample, V_s (volt)	Voltagge across fixed resist. V_R (volt)	Sample resist, R_s (Ω)	Resistivity of the sample (Ω-cm)	Ln ρ	$10^3/T$ ($^{o}k^{-1}$)
730	1.35	0.70	38571.429	28392.814	10.253891	1.3699
732	1.29	0.77	33506.494	24664.466	10.113119	1.3661
734	1.26	0.80	31500	23187.465	10.051367	1.3623
736	1.22	0.83	28705.882	21130.687	9.9584816	1 3587
738	1.19	0.87	27356.322	20137.262	9.9103272	1.3550
740	1.16	0.90	25777.778	18975.28	9.8508924	1.3514
742	1.14	0.92	24782.609	18242.72	9.8115217	1.3477
744	1.12	0.93	24086.022	17729.962	9.7830112	1.3441
746	1.09	0 98	22244.898	16374.692	9.7034922	1.3405
748	0.1	1.01	19801.98	14576.436	9.5871615	1.3369
750	1.02	1.03	19805.825	14579.266	9.5873557	1.3333
752	1.00	1.06	18867.925	13888.868	9.5388429	1.3298
754	0.98	1.08	18148.148	13359.033	9.4999481	1.3262
756	0.95	1..11	171117.117	12600 081	9.4414585	1.3228
758	0.92	1.14	16140.351	11881.074	9.382702	1.3193

Temperature T (^{o}K)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ ($^{o}K^{-1}$)
762	0.88	1.18	14915.254	10979.268	9.303764	1.3123
764	0.85	1.21	14049.587	10342.041	9.2439725	1.3089
766	0.84	1.22	13770.492	10136.597	9.2239076	1.3054
768	0.81	1.25	12960	9539.9856	9.1632473	1.3021
770	0.79	1.27	12440.945	9157.9039	9.1223726	1.2987
772	0.77	1.29	11937.984	8787.6698	9.0811049	1.2953
776	0.73	1.33	10977.444	8080.606	8.9972222	1.2887
780	0.69	1.37	10072.993	7414.8307	8.9112374	1.2821
781	0.67	1.39	9640.2878	7096.3122	8.8673305	1.2804
784	0.64	1.42	9014.0845	6635.3577	8.8001679	1.2756
785	0.62	1.45	8551.7244	6293.0097	8.7475125	1.2739
786	0.61	1.46	8219.1781	6050.2192	8.7078498	1.2723
788	0.58	1.48	7837.8378	5769.5108	8.6603426	1.2690
790	0.57	1.49	7651.0067	5631.9825	8.6362168	1.2658
792	0.54	1.52	7105.2632	5230.2553	8.5871652	1.2626

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ ($o_k{}^{-1}$)
794	0.53	1.53	6928.1046	5099.8471	8.5369658	1.2594
796	0.50	1.56	6410.564	4718.6538	8.4592788	1.2563
798	0 49	1.57	6242.0382	4594.8268	8.4326863	1.2531
800	0 47	1.59	5911.9497	4351.8453	8.3783552	1.2500
802	0 46	1.60	5750	4232.6325	8.3505794	1.2469
804	0.45	1.61	5590.0621	4114.9006	8.32237	1.2438
806	0.45	1.61	5590.0621	4114.9006	8.32237	1.2407
807	0.45	1.61	5590.0621	4114.9006	8.32237	1.2392
808	0 45	1.61	5590.0621	4114.9006	8.32237	1.2376
810	0 45	1.60	5590.0621	4114.9006	8.32237	1.2357
812	0.50	1.57	6369.4268	4688.5987	8.452889	1.2315
813	0 52	1.54	6753.2468	4971.1325	8.511403	1.2300
814	0.58	1.48	7837.8378	5769.5108	8.6603426	1.2285
816	0 68	1.39	9784.1727	7202.2273	8.8821456	1.2254

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample $(\Omega\text{-cm})$	Lnρ	$10^3/T$ $(o_k{-1})$
817	0.70	1.35	10370 37	7633.733	8.9403323	1.2246
818	2.01	0.05	804000	591832.44	13.290979	1.2225
820	2.01	0.045	893333.33	657591.6	13.396339	1 2195
822	2.01	0.045	893333.33	657591.6	13.396339	1.2165
824	2.01	0.045	893333.33	657591.6	13.396339	1.2136
825	2.015	0.05	806000	593304.66	13.293463	1.2121
826	2.015	0.045	895555.56	659227.4	13.398824	1.2107
828	2.015	0.045	"	"	"	1.2092
830	2.015	0.04	"	"	"	1.2077
832	"	"	"	"	"	1.20192
834	"	"	"	"	"	1.2005
838	"	"	"	"	"	1.1933
840	"	"	"	"	"	1.1905
842	"	"	"	"	"	1.1876
844	"	"	"	"	"	1.1848

Temperature T (^{o}k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resistance R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	$10^3/T$ $(^{o}k^{-1})$
845	2.01	0.05	804000	591832.44	13.290979	1.1834
848	2.01	0.05	804000	591832.44	13.290979	1.1792
850	"	"	"	"	"	1.1765
852	"	"	"	"	"	1.1737
860	"	"	"	"	"	1.1628
870	"	"	"	"	"	1.1494
880	"	"	"	"	"	1.1364
890	"	"	"	"	"	1.1236

EXPERIMENTAL DATA

BEEL - BAGHIA : SAMPLE NO. B.B.L. 24(1').

FIXED RESISTANCE, R_E = (20 KΩ)

TABLE NO. 6.3

Temperature	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω -cm)	Lnρ	$10^3/T$ ($^\circ K^{-1}$)
378	1.99	0.03	1326666.7	1280145.6	14.062484	2.6456
398	1.99	0.03	"	"	"	2.5126
402	1.99	0.03	"	"	"	2.4876
404	1.99	0.03	"	"	"	2.4752
410	1.99	0.03	"	"	"	2.4390
414	1.99	0.03	"	"	"	2.4096
418	1.99	0.03	"	"	"	2.3923
422	1.99	0.03	"	"	"	2.3697
428	1.99	0.03	"	"	"	2.3364
430	1.99	0.03	"	"	"	2.3256
432	1.99	0.03	"	"	"	2.3202
436	1.99	0.03	"	"	"	2.2936
440	1.99	0.03	"	"	"	2.2727
444	1.99	0.03	"	"	"	2.2523
450	1.99	0.03	"	"	"	2.2222
454	1.99	0.03	"	"	"	2.2023
460	1.99	0.03	"	"	"	2.1740
470	1.99	0.03	"	"	"	2.1277

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	10^3/T (o_k-1)
478	1.99	0.03	1326666.7	1280145.6	14.062484	2.0921
480	1.99	0.03	"	"	"	2.0833
484	1.99	0 03	"	"	"	2.0661
486	1.99	0.03	"	"	"	2.0576
488	1.99	0.03	"	"	"	2.0492
490	1.99	0.03	"	"	"	2.0408
492	1.99	0.03	"	"	"	2.0325
494	1.99	0.03	"	"	"	2.0243
496	1.99	0.03	"	"	"	2.0161
498	1.99	0 03	"	"	"	2 0080
500	1 99	0.03	"	"	"	2.0000
504	1.99	0.03	"	"	"	1.9801
506	1.99	0.03	"	"	"	1.9724
508	1.99	0.03	"	"	"	1.9646
510	1.99	0.03	"	"	"	1.9569
512	1.99	0.03	"	"	"	1.9493
514	1.99	0.03	"	"	"	1 9455

Temperature T (o$_{k}$)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ (o$_k$-1)
567	2.01	0.01	4020000	3879034.3	15.171097	1.7637
568	"	"	"	"	"	1.7606
570	"	"	"	"	"	1.7543
572	"	"	"	"	"	1.7483
574	"	"	"	"	"	1.7422
575	2.02	0.01	4040000	3898333	15.17606	1.7391
576	"	"	"	"	"	1.7361
578	"	"	"	"	"	1.7301
580	"	"	"	"	"	1.7241
583	2.02	0.01	4040000	3898333	15.17606	1.7153
584	"	"	"	"	"	1.7123
586	"	"	"	"	"	1.7065
588	"	"	"	"	"	1.7007
590	2.02	0.01	4040000	3898333	15.17606	1.6949

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Ln ρ	$10^3/T$ (o_k-1)
592	2.02	0.01	4040000	3898333	15.17606	1.6892
594	"	"	"	"	"	1.6834
596	2.00	0.04	1000000	964933.9	13.779815	1.6779
597	2.00	0.035	1142857.1	1102781.6	13.913346	1.6750
598	2.00	0.03	1333333.3	1286578.5	14.067497	1.6722
600	"	"	"	"	"	1.6667
602	"	"	"	"	"	1.6611
604	"	"	"	"	"	1.6557
606	"	"	"	"	"	1.6501
608	"	"	"	"	"	1.6447
610	"	"	"	"	"	1.6393
612	"	"	"	"	"	1.6340
614	"	"	"	"	"	1.6287
616	"	"	"	"	"	1.6234
618	"	"	"	"	"	1.6181

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Ln ρ	$10^3/T$ ($o_k{-1}$)
520	2.00	0.03	1333333.3	1286578.5	14.067497	1.6129
622	"	"	"	"	"	1.6077
624	"	"	"	"	"	1.6026
626	"	"	"	"	"	1.5974
628	"	"	"	"	"	1.5924
630	"	"	"	"	"	1.8873
632	"	"	"	"	"	1.5823
634	"	"	"	"	"	1.5773
636	"	"	"	"	"	1.5723
638	"	"	"	"	"	1.5674
640	"	"	"	"	"	1.5625
642	1.99	0.05	796000	768087.38	13.551657	1.5576
644	"	"	"	"	"	1.5527
646	1.99	0.04	995000	960109.23	13.774802	1.5480

Temperature T (o_k)	Voltage across sample V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ $(o_k{}^{-1})$
648	1.99	0.04	995000	960109.23	13.774802	1.5432
650	"	"	"	"	"	1.5385
652	"	"	"	"	"	1.5337
654	"	"	"	"	"	1.5290
656	"	"	"	"	"	1.5244
658	1.98	0.05	792000	764227.65	13.546621	1.5198
660	"	"	"	"	"	1.5152
662	1.98	0.06	660000	636856.37	13.364299	1.5157
664	"	"	"	"	"	1.5060
665	1.97	0.06	656666.67	633639.93	13.359236	1.5038
666	"	"	"	"	"	1.5015
668	1.96	0.07	560000	540362.98	13.199996	1.4970
670	"	"	"	"	"	1.4925

Temperature T (o_k)	Voltabe across sample V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Ln ρ	10^3/T (o_k-1)
671	1.96	0.08	490000	472817.61	13.066465	1.4903
672	"	"	"	"	"	1.4890
673	1.95	0.08	487500	470405.28	13.06135	1.4859
674	"	"	"	"	"	1.4837
675	1.95	0.09	433333.33	418138.02	12.943567	1.4815
676	"	"	"	"	"	1.4793
677	1.94	0.10	388000	374394.35	12.833065	1.4771
678	"	"	"	"	"	1.4749
679	1.93	0.11	350909.09	338664.08	12.732587	1.4728
680	1.92	0.11	349090.91	336849.65	12 727392	1.4706
682	"	"	"	"	"	1.4663
683	1.91	0.13	293846.15	283542.12	12.55516	1.4641
684	1.91	0.13	"	"	"	1.4620
685	1.90	0.14	271428.57	261910.63	12.475759	1.4599

Temperature T (o_k)	Voltage across sample V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample - resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ $(o_k{-1})$
687	1.89	0.15	252000	243163.34	12.401489	1.4556
688	1.88	0.16	235000	226759.47	12.331645	1.4535
689	1.87	0.16	233750	225553.3	12.326312	1.4514
690	1.87	0.17	220000	212285.46	12.265687	1.4493
691	1.86	0.17	218823.53	211150.24	12.260325	1.4471
692	1.85	0.18	205555.56	198347.52	12.197776	1.4451
693	1.84	0.19	193684.21	186892.46	12.138289	1.4430
694	1.83	0.20	183000	176582.9	12.081546	1.4409
695	1.82	0.21	173333.33	167255.21	12.027276	1.4088
696	1.82	0.21	"	"	"	1.4368
697	1.81	0.22	164545.45	158775.49	11.975246	1.4347
698	1.80	0.24	150000	144740.09	11.882695	1.4327
699	1.78	0.25	142400	137406.59	11.8307	1.4306
700	1.77	0.26	136153.85	131379.46	11.785845	1.4286

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
701	1.77	0.27	131111.11	126513.56	11.748105	1.4265
702	1.76	0.28	125714.29	121305.98	11.706071	1.4245
703	1.75	0.29	120689.66	116457.45	11.665282	1.4225
704	1.73	0.30	115333.33	111289.04	11.619886	1.4205
705	1.72	0.31	110967.74	107076.54	11.581299	1.4184
706	1.71	0.32	106875	103127.31	11.54372	1.4164
707	1.70	0.33	1.03030.3	99417.432	11.507083	1.4144
708	1 67	0.37	90270.27	87104.844	11.374868	1.4124
709	1.60	0.37	89729.73	86583.258	11.368862	1.4104
710	1.65	0.38	86842.105	83796.891	11.336151	1.4085
711	1.64	0.39	84102.564	81153.415	11.304097	1.4065
712	1.62	0.41	79024.39	76253 313	11.241816	1.4045
713	1.60	0.44	72727.273	70177.011	11.158776	1 4025
714	1.59	0.45	70666.667	68188.662	11.130034	1.40006

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
715	1.58	0.47	67234.043	64876.407	11.080239	1.3986
716	1.57	0.48	65416.667	63122.759	11.052837	1.3967
717	1.56	0.48	65000	62720.704	11.046447	1.3947
718	1.51	0.53	56981.132	54983.026	10.91478	1.3928
719	1.50	0.54	55555.556	53607.439	10.889443	1.3908
720	1.47	0.56	52500	50659.03	10.832873	1.3889
721	1.46	0.57	51228.07	49431.702	10.808347	1.3870
722	1.44	0.60	48000	46316.827	10.743261	1.3850
723	1.43	0.61	46885.246	45241.163	10.719763	1.3831
724	1.42	0.62	45806.452	44200.198	10.696485	1.3812
715	1.39	0.65	42769.23	41269.481	10.627879	1.3793
726	1.37	0.67	40895.522	39461.476	10.58308	1.3774
727	1.34	0.70	38285.714	36943.184	10.517136	1.3755
728	1.32	0.72	36666.667	35380.91	10.473928	1.3736
729	1.30	0.74	35135.135	33903.083	10.431261	1.3717

Temperature T (^{o}K)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Ln ρ	$10^3/T$ ($^{o}K^{-1}$)
730	1.29	0.75	34400	33193.726	10.410116	1.3699
731	1.26	0.78	32307.692	31174.788	10.347365	1.3680
732	1.25	0.79	31645.57	30535.383	10.326658	1.3661
733	1.24	0.80	31000	29912.951	10.306047	1.3642
734	1.23	0.81	30370.37	29305.4	10.285527	1.3624
735	1.22	0.82	29756.098	28712.667	10.265094	1.3605
736	1.18	0.86	27441.86	26479.581	10.184129	1.3587
737	1.17	0.87	26896.552	25953.395	10.164058	1.3569
738	1.16	0.88	26363.636	25439.166	10.144045	1.3550
739	1.15	0.89	25842.697	24936.494	10.124088	1.3531
741	1.13	0.91	24835.165	23964.292	10.08432	1.3495
742	1.13	0.92	24565.217	23703.811	10.073391	1.3477
743	1.12	0.93	24086.022	23241.419	10.053691	1.3458
744	1.11	0.94	23617.021	22788.864	10.034027	1.3440
745	1.09	0.96	22708.333	21912.041	9.9947916	1.3423

Temperature T (^{o}K)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ $(^{o}K^{-1})$
746	1.06	0.98	21632.653	20874.08	9.9462635	1.3405
747	1.05	0.99	21212.121	20468.295	9.9266324	1.3386
748	1.04	1.00	20800	20070.625	9.9070126	1.3369
749	1.02	1.01	20198.02	19489.754	9.8776442	1.3351
750	1.02	1.03	19805.825	19111.312	9.8580357	1.3333
751	1.01	1.03	19611.65	18923.946	9.8481834	1.3316
752	0.99	1.08	18333.333	17690.455	9.7807805	1.3298
753	0.98	1.09	17981.651	17351.105	9.7614115	1.3280
754	0.94	1.10	17090.909	16491.598	9.7106063	1.3263
755	0.93	1.11	16756.757	16169.163	9.6908612	1.3245
756	0.92	1.12	16428.571	15852.485	9.6710816	1.3228
757	0.91	1.14	15964.912	15405.085	9.6424529	1.3210
758	0.90	1.14	15789.474	15235.798	9.6314031	1.3193
759	0.87	1.17	14871.795	14350.299	9.5715261	1.3175
760	0.87	1.18	14745.763	14228.687	9.5630154	1.3158

Temperature T (o$_k$)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	10^3/T (o$_k$-1)
761	0.85	1.19	14285.714	13784.77	9.5313196	1.3147
762	0.83	1.21	13719.068	13237.936	9.4908419	1.3123
763	0.82	1.22	13442.623	12971.243	9.4704901	1.3106
764	0.80	1.24	12903.226	12450.76	9.4295369	1.3089
765	0.79	1.25	12640	12196.764	9.408926	1.3072
766	0.78	1.26	12380.952	11946.801	9.3882188	1.3054
767	0.77	1.27	12125.984	11700.773	9.3674102	1.3034
768	0.76	1.28	11875	11458.59	9.346495	1.3020
769	0.75	1.29	11627.907	11220.162	9.3254676	1.3004
770	0.72	1.32	10909.091	10526.552	9.261656	1.2987
772	0.69	1.35	10222.222	9863.7688	9.1966236	1.2953
773	0.69	1.36	10147.659	9791.241	9.1892435	1.2937
774	0.67	1.37	9781.0219	9438.6396	9.1525036	1.2920
775	0.65	1.39	9352.818	9024.5617	9.1077052	1.2903
776	0.64	1.41	9078.0142	8759.6836	9.0779151	1.2887

Temperature T (^{o}K)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ ($^{o}K^{-1}$)
777	0.63	1.42	8873.2394	8562.0895	9.0550995	1.2870
778	0.61	1.43	8531.4685	8232.3039	9.0158211	1.2853
779	0.60	1.45	8275.8621	7985.6599	8.9854027	1.2836
780	0.58	1.47	7891.1565	7614.4444	8.9378023	1.2821
781	0.57	1.47	7755.102	7483.1609	8.9204106	1.2804
782	0.56	1.48	7567.5676	7302.2625	8.8959313	1.2788
783	0.55	1.50	7333.3333	7076.1819	8.8644898	1.2771
784	0.54	1.51	7152.31179	6901.514	8.8394961	1.2755
785	0.52	1.52	6842.1053	6662.1793	8.7951551	1.2739
786	0.51	1.53	6666.6667	6432.8927	8.7691796	1.2723
787	0.50	1.55	6451.6129	6225.38	8.7363898	1.2706
788	0.49	1.55	6322.5806	6106.8724	8.7161871	1.2690
789	0.47	1.57	5987.2611	5777.311	8.6616937	1.2674
790	0.47	1.58	5949.3671	5740.746	8.6553444	1.2658
791	0.46	1.59	5786.1635	5583.2653	8.6275291	1.2642

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Samle resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ $(o_k{-}1)$
792	0.44	1.61	5465.8385	5274.1728	8.5705771	1.2626
793	0.44	1.61	"	"	"	1.2610
794	0.42	1.62	5185.1852	5003.361	8.5178652	1.2594
795	0.41	1.63	5030.6748	4854.2687	8.4876137	1.2579
796	0.40	1.64	4878.0488	4706.9946	8.4568049	1.2563
797	0.39	1.66	4698.7952	4534.0268	8.4193657	1.2547
798	0.38	1.67	4550.8982	4391.316	8.3873842	1.2531
799	0.36	1.68	4285.7143	4135.431	8.3273468	1.2516
800	0.36	1.69	4260.355	4110.961	8.3214121	1.2500
801	0.35	1.70	4117.6471	3973.2572	8.2873415	1.2484
802	0.34	1.71	3976.6082	3837.1964	8.2524888	1.2469
803	0.33	1.71	3859.6491	3724.3063	8.2226359	1.2453
804	0.31	1.73	3583.815	3458.1446	8.1484875	1.2438
805	0.31	"	"	"	"	1.2422
806	0.30	1.74	3448.2759	3327.3583	8.109934	1.2407
807	0.29	1.76	3295.4545	3179.8958	8.0646037	1.2392

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
808	0.28	1.76	3181.8182	3070.2442	8.0295124	1.2376
809	0.27	1.77	3050.8475	2943.8661	7.987479	1.2361
810	0.26	1.78	2921.3483	2818.908	7.9441049	1.2346
811	"	"	"	"	"	1.2330
812	0.25	1.79	2793.2961	2695.3461	7.8992819	1.2315
813	0.24	1.80	2666.6667	2573.1571	7.852888	1.2300
815	0.23	1.81	2541.4365	2452.3182	7.8047891	1.2270
816	"	1.82	2527.4725	2438.8439	7.7992794	1.2255
817	0.22	"	2417.5824	2332.8072	7.7548276	1.2240
818	0.21	1.83	2295.082	2214.6024	7.7028282	1.2225
819	0.20	1.84	2173.913	2097.6824	7.6485884	1.2210
820	"	"	"	"	"	1.2195
821	"	"	"	"	"	1.2180
822	0.19	1.85	2054.0541	1982.0264	7.591875	1.2165

Temperature T (^{o}k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Ln ρ	10^3/T (^{o}k^{-1})
823	0.19	1.86	2043.0108	1971.3703	7.5864842	1.2151
824	0.18	1.87	1925.1337	1857.6268	7.527055	1.2136
826	0.17	1.87	1818.1818	1754.4252	7.4698966	1.2107
827	0.17	1.88	1808.5106	1745.0932	7.4645633	1.2092
830	"	"	"	"	"	1.2048
834	0.16	1.89	1693.1217	1633.7505	7.3986336	1.1990
836	0.15	1.90	1578.9474	1523.5798	7.328818	1.1962
837	0.14	1.91	1465.9686	1414.5628	7.2545758	1.1947
840	0.13	1.92	1354.1667	1306.6813	7.1752459	1.1905
841	0.15	1.89	1587.3016	1531.6411	7.3340951	1.1891
842	0.18	1.84	1956.5217	1887.9142	7.5432279	1.1876
843	0.23	1.80	2555.5556	2465.9422	7.8103292	1.1862
844	0.28	1.74	3218.3908	3105.5344	8.0409411	1.1848
845	0.32	1.70	3764.7059	3632.6923	8.1977293	1.1834
846	0.50	1.55	6451.6129	6225.38	8.7363898	1.1820
847	0.90	1.15	15652.174	15103.313	9.6226694	1.1806

Temperature T (^{o}K)	Voltage across samples, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ $(\Omega\text{-cm})$	$\ln\rho$	$10^3/T$ $(^{o}K^{-1})$
848	1.00	1.05	19047.619	18379.693	9.8190017	1.1792
849	1.10	0.95	23157.895	22345.838	10.014395	1.1779
850	1.15	0.96	23958.333	23118.208	10.048376	1.1764
851	1.81	0.20	181000	174653.04	12.070557	1.1751
852	1.99	0.04	995000	960109.23	13.774802	1.1737
859	1.99	0.03	1326666.70	1280145.60	14.062484	1.1641
868	"	"	"	"	"	1.1521

EXPERIMENTAL DATA

BEEL KOLA MOUZA: SAMPLE NO.JH-24 (6'-8'6")

FIXED RESISTANCE R_F = 10K Ω

TABLE 6.4

Temperature T (^{o}k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Ln ρ	$10^3/T$ (^{o}k^{-1})
378	1.82	0.008	2275000	1972612	14.4949	2.6455
380	"	"	"	"	"	2.6316
384	"	"	"	"	"	2.6042
387	1.82	0.007	2600000	2254413.7	14.62840	2.8540
388	"	"	"	"	"	2.5641
392	"	"	"	"	"	2.5510
394	"	"	"	"	"	2.5381
400	"	"	"	"	"	2.5000
402	"	"	"	"	"	2.4876
410	"	"	"	"	"	2.4390
420	"	"	"	"	"	2.3809
430	"	"	"	"	"	2.3256
440	"	"	"	"	"	2.2727
450	"	"	"	"	"	2.2222

Temperature T (^{o}k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample (Ω-cm)	Lnρ	10^3/T (^{o}k^{-1})
460	1.82	0.007	2600000	2254413.7	14.62840	2.1739
470	"	"	"	"	"	2.1231
480	"	"	"	"	"	2.0833
490	"	"	"	"	"	2.0400
500	"	"	"	"	"	2.0000
510	"	"	"	"	"	1.9608
520	"	"	"	"	"	1.9231
527	1.82	0.006	3033333.3	2630149.3	1478255	1.8975
530	"	"	"	"	"	1.8868
540	"	"	"	"	"	1.8519
550	"	"	"	"	"	1.8182
557	1 .82	0.0055	3640000	3156179.20	14.96487	1.7953
560	"	"	"	"	"	1.7857
570	"	"	"	"	"	1.7544
580	"	"	"	"	"	1.7241

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ $(o_k{-1})$
586	1.82	0.006	3033333.33	2630149.3	14.78255	1.7065
590	"	"	"	"	"	1.6949
600	"	"	"	"	"	1.6667
610	"	"	"	"	"	1.6393
633	1.82	0.007	2600000	2254413.7	14.62840	1.5798
640	"	"	"	"	"	1.5625
650	"	"	"	"	"	1.5385
660	"	"	"	"	"	1.5152
663	1.81	0.01	18100000	1569418.8	14.26623	1.5083
664	1.81	0.015	1206666.7	1046279.2	13.860751	1.5060
666	1.81	0.017	1064705.9	923187.52	13.735588	1.5015
668	1.81	0.021	857142.86	743213.32	13.518738	1.4970
670	1.80	0.020	900000	780373.98	13.567529	1.4925
672	1.80	0.21	857142.86	743213.32	13.518738	1.4890

Temperature T (o$_k$)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ (o$_k$-1)
674	1.81	0.022	822727.27	713372.17	13.477759	1.4837
676	1.80	0.018	1000000	867082.2	13.672889	1.4793
678	1.80	0.024	750000	650311.65	13.385207	1.4749
680	1.81	0.024	754166.66	653924.49	13.390747	1.4706
682	1.81	0.023	786956.52	682355.99	13.385207	1.4663
684	1.80	0.022	818181.82	709430.89	13.472218	1.4620
686	1.80	0.027	666666.67	578054.8	13.26724	1.4577
688	1.80	0.029	620689.66	538188.95	13.195965	1.4535
690	1.80	0.030	600000	5202409.32	13.162063	1.4493
692	1.79	0.032	559375	485024.11	13.091954	1.4451
694	1.80	0.034	529411.76	459043.52	13.0369	1.4409
696	1.79	0.035	511428.57	442480.61	13.002342	1.4368
698	1.79	0.040	447500	388019.28	12.86881	1.4327
700	1.79	0.046	389130.43	337408.07	12.729048	1.4286
702	1.78	0.049	363265.31	314980.88	12.660267	1.4245
704	1.78	0.055	323636.36	280619.33	12.544754	1.4205
706	1.77	0.057	310526.32	269251.84	12.503402	1.4164

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
708	1.77	0.056	316071.43	274059.91	12.521102	1.4124
710	1.76	0.062	283870.97	246139.46	12.413654	1.4082
712	1.76	0.071	247887.32	214938.69	12.278108	1.4045
716	1.75	0.075	233333.33	202319.18	12.217602	1.3966
718	1.74	0.095	183157.89	158812.95	11.975482	1.3928
722	1.73	0.092	188643.48	163049.15	12.001807	1.3850
724	1 73	0.099	174747.47	151520.42	11.928476	1.3812
726	1.73	0.11	157272.73	136368.38	11.823115	1.3774
728	1.71	0.12	142500	123559.21	11.724476	1.3736
730	1.70	0.12	141666.67	122836.61	11.718664	1.3699
732	1.69	0.13	130000.1	112720.69	11.632668	1.3661
734	1.69	0.13	130000.1	112720.69	11.632668	1.3234
736	1.68	0.15	112000	97113.206	11.483633	1.3405
748	1.66	0.16	103750	89959.778	11.407118	1.3369
750	1.66	0.17	97647.059	84668.027	11.346493	1.3333

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample reisst. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	$10^3/T$ (o_k-1)
752	1.64	0.19	86315.789	74842.885	11.223146	1.3298
754	1.63	0.20	81500.00	70667.199	11.165737	1.3263
756	1.61	0.21	76666.667	66476.302	11.10460	1.3228
758	1.60	0.23	69365.217	60318.762	11.007398	1.3193
760	1.58	0.25	63200	54799.595	10.911438	1.3158
762	1.56	0.27	57777.778	50098.083	10.821738	1.3123
764	1.54	0.28	55000.00	47689.521	10.772467	1.3089
766	1.52	0.31	49032.288	42514.998	10.657612	1.3054
768	1.50	0.33	45454.545	39412.827	10.581847	1.3021
770	1.47	0.35	42000.00	36417.452	10.802803	1.2987
772	1.45	0.37	39189.189	339802.248	10.4033535	1.2953
774	1.44	0.39	36923.077	32015.343	10.373971	1.2920
776	1.41	0.41	34390.244	29819.168	10.302907	1.2887
778	1.38	0.44	31363.636	27194.851	10.210783	1.2853
779	1.37	0.45	30444.444	26397.836	10.181037	1.2837

Temperature T (o$_k$)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	10^3/T (o$_k$-1)
780	1.36	0.46	29565.217	25635.474	10.151732	1.2820
782	1.33	0.49	27142.857	23535.088	10.066248	1.2788
784	1.30	0.52	25000	21677.055	9.9840096	1.2755
786	1.26	0.56	23773.585	20613.652	9.9227089	1.2723
788	1.24	0.58	21379.31	18537.619	9.8275574	1.2690
790	1.22	0.60	20333.333	17630.671	9.7773954	1.2658
792	1.20	0.63	19047.619	16515.851	9.7120759	1.2626
794	1.17	0.65	18000	15607.48	9.6555055	1.2594
796	1.15	0.67	17164.179	14882.754	9.6079584	1.2563
798	1.13	0.70	16142.857	13997.184	9.5466115	1.2531
800	1.11	0.71	15633.803	13555.792	9.5145692	1.2500
802	1.10	0.73	15068.493	13065.622	9.4777398	1.2469
804	1.09	0.74	14729.73	12771.886	9.4550017	1.2438
806	1.07	0.76	14078.947	12207.605	9.4098144	1.2407

Temperature T (o$_k$)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	10^3/T (o$_k$-1)
808	1.05	0.77	13636.364	11823.848	9.3778738	1.2376
810	1.05	0.78	13461.538	11672.26	9.3649704	1.2346
812	1.03	0.79	12875	11163.683	9.3204212	1.2315
814	1.03	0.80	12875	11163.683	9.3204212	1.2285
816	1.02	0.81	12592.593	10918.813	9.2982425	1.2255
818	1.01	0.82	12317.073	10679.915	9.2761201	1.2225
820	1.02	0.81	12592.593	10918.813	9.2982425	1.2195
822	1.00	0.82	12195.122	10574.173	9.2661698	1.2165
824	1.00	0.83	12048.193	10446.773	9.2540485	1.2136
826	1.01	0.81	12469.136	10811.766	9.2883902	1.2107
828	1.02	0.81	12592.593	10918.813	9.2982425	1.2077
830	1.05	0.77	13636.364	11823.848	9.3778738	1.2048
832	1.06	0.76	13947.368	12093.515	9.4004246	1.2019
834	1.08	0.74	14594.595	12654.713	9.445785	1.1990
836	1.09	0.74	14729.73	12771.886	9.4550017	1.1962

Temperature T (o_k)	Voltage across sample, V_s (volt)	Voltage across fixed resist. V_R (volt)	Sample resist. R_s (Ω)	Resistivity of the sample ρ (Ω-cm)	Lnρ	10^3/T (o_k-1)
838	1.10	0.72	15277.778	13247.089	9.4915331	1.1933
840	1.15	0.68	16911.765	14663.89	9.5931433	1.1905
842	1.19	0.63	18888.889	16378.219	9.7037076	1.1876
844	1.36	0.47	28936.17	25090.038	10.130226	1.1848
846	1.48	0.36	41111.111	35646.713	10.481412	1.1820
848	1.81	0.008	2262500	1961773.5	14.489359	1.1792
850	"	"	"	"	"	1.1765
854	1.81	0.007	2585714.3	2242026.80	14.622891	1.1701
856	1.81	0.007	"	"	"	1.1682
858	"	"	"	"	"	1.1655
860	"	"	"	"	"	1.1628
862	"	"	"	"	"	1.1601

REFERENCES

1. National Energy Data Report, Australia, Korea, Maxico, Thailand, World Energy Conference (1981).

2. Henke-Parpart, U.; Proc. of Int .Conf. of Phys. and Energy for Development, 195, Dhaka (1985).

3. Round Table Discussion on Energy Problem in Developing Countries .World Energy Conf. (WEC), New Delhi -Sept '1985).

4. Year Book of World Energy Statistics (1981).

5. Skinner, B.J.; Earth Resources, 24-25, 2nd Edn. (1976), published by Prentice-Hall, Inc. New Jersey .

6. Francies, W.; Fuels and Fuel Technology . 1, 12-15, (1965), published by Pergamon Press, London .

7. Bramme, J.S.S.; and King, J.G.; Fuel-Solid, Liquid and Gases, 43-47, 5th Edn. (1961), published by Edward Arnold Ltd.

8. Wilson, P.J . and Wells, J.H.; Coal, Coke and Coal Chemicals, 40-63, 96-130, (1950), published by McGraw-Hill Book Compy. Ltd. Inc.

9. Second Rough Report of Bangladesh Physical Planning Project (B.G. D-81-005) 29.

10. Akamatu, H. and Inokuchi, H.; "Proc. of the Third Conf. on Carbon" 51 (1959), published by pergamon press London.

11. Garett, G.B . in "Semiconductors", 634 (1959), published by Reinhold, New York.

12. Drefahl, G. and Henkel, H.J.; Z. Physik Chem. 206 , 93 (1956).

13. Ingram, D.J.E.; in "Free radicals" 170, 196 (1958), published by Betterworths, London.

14. Eley, D.D. and Inokuchi, H., Z. Elektro Chem. 63, 29 (1959).

15. Mulliken, R.S.; J. Am. Chem. Soc. 74, 811 (1952).

16. London, F.; J. Phys. Radium 8, 397 (1937).

17. Pauling, L.; J. Chem. Phys. 4, 673 (1936).

18. Akamatu, H. and Matzunaga, Y.; Bull. Chem. Soc. Japan 26, 364 (1953).

19. Akamatu, H. and Matzunaga, Y., Bull Chem. Soc. Japan 29 800 (1956).

20. Ganguli, N. and Krishnan, K.S.; Proc. Phys. Soc. A 177 168 (1941).

21. Pacault, A. and Marchand, A.; Compt. Rend. Acad. Sci. 241, 489 (1955).

22. Wallace, P.R.; Phys. Rev. 71, 622 (1947).

23. Coulson, C.A.; Proc. Phys. Soc. A 65, 815 (1952).

24. Boente, L.; Brennstoff-Chem. 36, 210 (1955).

25.a). Hossian, T. and Jahan, T.S.; J. Phy. Teacher, Indian Physical Society, April-June, 101-107, (1987).

25.b) Hossian, T. and Dollimore, J.; Thermochemical Acta, 108 211-220 (1986).

26. Dunlap, Jr. W.C.; An introduction to semiconductors. 1,4,5,179,319 (1960) published by John Wiley & Sons Inc. London.

27. Begum, D A. and Hossian, T.; International Peat Soc. 2, 127-136 (1987).

28. Canadian International Development Agency Mission Report on Bangladeshi Peat (1987).

29. Hoffmann, U.; Chem. Ber. B 65 1821 (1932).

30. Riley, H.L.; Quaterly Rev. Chem. Soc. London 1, 59 (1947).

31. Manchuk, R.V., et al, Chem. Abs. 150 26 Dec. (1986).

32. Bel'Kevich, P.E. et al, Chem. Abs. 110, 12 March 20, (1989).

33. Hossian, T.; A text Book of Heat .160-162, 3rd Edn. (1982), published by Barnamala Press & Publication, Dhaka.

34. Campell, J.R.; Method of Analysis of Fuels and Oils 2-3 (1951), published by Constable & Compy. Ltd. London.

35. 1960 Book of ASTM Standards with Related Material .Part-18, 27-31, (1916), published by the Ame. Soc. for Testing Material.

36. Ahmed, N.A.; et al, Proc. Pakistan Acad. Sci. 24, 4 (1987).