STUDY O ? ELECTR CAL AND THERMAL PROPERTIES OF WOOD UNDER SALINITY AND HUMIDITY

BY

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DEDICATED TO MY PARENTS

CERTIFICATE

This is to certify that the research work embodied in this thesis has been carried out under my supervision . The research work presented here in is original. This thesis has not been submitted for the award of any degree or diploma by any other University.

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Certification of Thesis

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has been accepted as satisfactory in partial fulfilment for the degree of Master of Philosophy in Physics and certifying that the student demonstrated a satisfactory knowledge of the field covered by her thesis in an oral examination held on June 30, 1998.

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ABSTRACT

Thermal conductivity and dielectric constant of two types of wood Gorjan and Segun have been studied for their dependence on salinity and moisture content. The dielectric constant was measured at a constant frequency using a Wein Bridge Oscillator type B 224. A standard voltage derived from a Wein Bridge Oscillator was applied simultaneously to the component under test and the internal standards via the Decade switches. The resulting currents are summed in the current transformer and the difference was fed to the logarithmic detector and hence to the null indicating meter. By adjustment of the voltage applied to the standards, the balance between the standard and unknown channels was made exact, when the detector output fell to a minimum. At this point the standard and unknown bear a numerical ratio as indicated by the significant figures read from the Decade controls, and the Range switch units. The variation of dielectric constant of the Gorjan and Segun wood is explained in terms of the additional contribntions from water molecules and the ions from the salt solutions. The moisture content of the samples in the form of small disc was varied by immersing the samples in water and the moisture content of the wood was determined from the difference of weight of the treated samples and the dry samples. The same procedure was applied to induce salinity in the wood samples where saline solutions of different strengths were used. The thermal conductivity of Gorjan and Segun wood were determined using a technique which is a modification of Lees method in order to avoid the error due to the air gap between the sample and the conducting disc used as heat source and heat sink. The effective temperature of the wood samples at which conductivity was measured was altered by changing the temperature of the heat source (electricaly). Conductivity of both the types of wood increased with increasing salinity. The conductivity was also observed to increase with increasing temperature. Results are explained in terms of the additional contribution from the water molecules and ions and also in terms of the transfer of few electrons from the valence band to the conduction band which act as the thermal energy carrier.

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CHAPTER - I

Chapter - 1

INTRODUCTION

Wood is an extremely heterogeneous material and it is not surprising that its chemical composition, anatomy and physical properties vary within wide limits. Its macrostructure is evident in its grain, its micro structure is of biological origin and its atomic coordination are molecular.

Wood is a composite material consisting of three major polymers namely cellulose, hemicellulose and lignin. Variation in the amounts of cellulose, hemicellulose and lignin in wood, the changes in them and degradation of products formed under different conditions are discussed by W.E. Hills.[1.1] . He also discussed the changes in the nature of hemicelluloses which appear to play an important role in conveying stability.

The properties of wood and cellulose have been investigated in the past by many authors. Wood as a composite insulating material has many interesting physical characteristics. The present research work includes the developments of technique for more accurate measurement of thermal conductivity and dielectric constants of different kind of wood (Segun, Gorjan) in their normal states and under conditions of humidity and salinity.

In explaining the mechanism of electrical conduction, the general assumption that the electrical changes are carried by ions in wood and cellulose rather than by electrons was observed by Barkar W.W. et-al[1.2] Brown J.H.[1.3], Hearle J.W.S [1.4] Murphy E.J.[1.5] Skaar C.[1.6] These ions arise from metallic residues or impurities In addition cellulose and wood exhibit polarization phenomena that are typical characteristics of ionic conduction in direct electric

field as reported by Brown J.H.[13] and O'sullivan J.B.[17] The migration of ions through wood under the influence of an applied field by using radioactive ions was observed by Lin. R.T[18] by metallic ions that posses characteristic colours by Murphy E.J.[1.9] O'sullivan J.B.[1.7] and Skaar C[1.6] and by the PH valne of materials that accnmulatc at the electrodes observed by Ito S.[1 10]. Therefore ions play an important role in electrical conduction. But there have been no quantitative measurements of the extent to which changed transport is electrolytic.

All timbers tend to come to an equilibrium with the relative humidity of the surrounding air. The most important effect of this is that the wood shrinks on swells. The movement in the direction along the grain of the wood is negligible as one would expect from the molecular structure. The cross grain swelling and shrinkage is however, very large. Every one percent change of moistnre content may cause about a half percent shrinkage or swelling over the range of moisture contents likely to be reached in air. The lateral dimensions of wood can thus change between five and ten percent i.e. is up to an inch on a ten inch wide plank.

Even indoors , the relative humidity is changing all the time, especially between night and day. Floor board and furniture tend to follow the humidity change and this is the reason for the ghostly noises one hears in the house at night. If wood is physically restrained from shrinking when it does so it will split, because it has almost no tensile strength across the grain. If it is physically restrained from swelling when it wants to swell very considerable pressures are built up.

The most important effect of moisture on wood is to cause it to swell. A rather less important effect, from the practical point of view, is to change the

mechanical properties . Thoroughly wet wood has something like a third of the strength and stiffness of completely dry wood.

Wood consists of closed tubes which in the living tree are partly full of water or rather sap. In freshly felled wood the moisture content varies but may be over 100 percent of the weight of the dry wood substance. About 25 percent of this water is absorbed on the hydroxyl is of the Sibaria wall, the remainder is liquid water inside the cell. Seasoning consists in removing most of the water in a controlled way; essentially it is a drying operation and nothing more.

Since the cells are closed spindle-shaped tubes, the liquid water inside them is not very easy to get out. It can only be dried out by diffusing it slowly through the tube walls .This would present no great difficulty if one were dealing with a single cell but real lumber contains many thousands and it is necessary to diffuse the water from the inner cells through the wall of most of the other cells which lie between them and the outer world . So, if the moisture gradient is too sharp the outside will be notably drier, in the intermediate stages of seasoning than the inside, and so it will shrink more and will thus split .This is why one cannot season too fast without ruining the timber. At about 25 percent moisture content however these hydroxyls become saturated and the cell walls can absorb no more water this is known as the fibre saturation point. Up to the fibre saturation point the lumen or hollow part of the cell is empty of water. Above the fibre saturation point virtually the whole of the additional moisture exists as loose liquid water within the lumen. All the dimensional and mechanical changes in wood which are due to moisture occur below the fibre saturation point , that is between zero percent and 25 percent moisture content.

Contractions of wet wood during freezing is observed by Kubler[1.11] as well as Schirp[1.12] and Kubler on several wood species . In thermal expansion tests with wood samples Starrier* paid no attention to possible varieties in moisture content. Glatzel[1.13] noticed some drying of his samples but disregarded the corresponding shrinkage and Villari[1.14] used oil - soaked samples apparently assuming that the oil prevented or at least reduced changes in moisture content . Hendershot and Ogarkora (1.20) corrected observed expansions and contractions for measured changes in moisture content, a method that is inaccurate because of swelling and shrinkage .

The bonds between atoms of a molecule are much stronger than bonds between molecules. Consequently, intramolecular bond may be assumed to be more stiff and to permit less thermal vibration than bonds between adjoining molecules. Wood consists mainly of chainlike cellulose molecules most of which are arranged parallel to each other approximately in fiber direction In such a structure exist many' variable' intermolecular joint per unit of specimen length in the transverse direction than longitudinally.

In dry wood, cellulose - cellulose hydrogen bonds represent the variable links between adjoining molecules When wood swells entering water splits cellulose - cellulose hydrogen bonds and forms cellulose - water cellulose hydrogen bonds. With the water molecule intruding, the links in the swollen moist wood become not only longer but also weaker and less stiff than in dry wood

Forsaith[1.16] speculated that the atomic vibrations in the elongated slender cellulose molecule develop sufficient disturbance to cause the chain to vibrate

in a plane perpendicular to its long axis. This leads to transverse thermal expansion which is much larger than thermal expansion of most materials.

The coefficient of thermal conductivity should apply only to homogeneous materials in which the heat transfer is by conduction alone, as in metals. Heat is transferred across an air space, by radiation, conduction on convection . The rate of heat transfer across an air space is affected materially by the orientation of the space. The equipment for the determination of conductance values must be so designed that the air space can be rotated to various positions. Wilkis and Peterson designed an equipment and it has been in almost constant use since that time with some refinements added. If the structure of an insulating material is sufficiently open to permit convection currents, the rate of heat flow is affected by orientation. Air spaces of sufficient width for convection to occur transfer heat at different rates, depending upon whether the direction of heat flow is horizontal, vertically, upward or vertically downward. This transference is much more pronounced in air spaces formed by reflection insulation.

Stamm, A.J. et al[1,17] reported that when wood is heated under temperature time conditions that cause a loss of water of constitution, together with other broken down product, the less in weight is accompanied by dimensional stabilization.

Stam A. J[1 18] shown that the rate of the thermal changes occurs in wood and paper prior to give them dimensional stabilization can be greatly increased by introducing salts into the wood or paper prior to heating. These catalysts do not change the nature of the reactions as indicated by the constancy of the activation energy and they do not affect various strength losses that accompany the attainment of any definite level of dimensional stabilization.

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REVIEW OF THE PAST WORK ON DIELECTRIC PROPERTIES OF WOOD

Scientific developments are the outcome of long active research. In many cases, it becomes very difficult to locate the exact data on when and how the phenonena arc first established. This may also be applied in the case of dielectric materials like wood and study of their properties. The dielectric properties are important not only for understanding the structure of wood and cellulose at the molecular level, but also for practical application in industrial heating and in measuring density and moisture content of cellulosic materials. However, according to many people who worked with the dielectric properties of materials, Faraday was the man who first pointed out the increase of the capacity of condenser with the presence of the dielectric materials by neutralizing charges at the electrode surfaces which otherwise would contribute to the external field. Drude was also one of the pioneer in the systematic study of the dielectric properties. In 1931 Stoops measured the dielectric constant of a few vegetable oils over the wide range of temperature and calculated their polarization and electrical moments. He discussed the results from the stand point of molecular structures. The interpretation of dielectric polarization from the standpoint of molecular structnre depeuds upon a representative molecule of a specimen of the dielectric substance under the influence of a uacroscopic electric field. The dielectric measurement by Cole and Drude gave evidence of anomalous dielectric dispersion i.e the decrease in the dielectric constants at high frequencies.

For wood products the dielectrie properties have already been studied on a large scale at lower frequencies (Skaar)[2 1], Krouer[2 2], Hearmon Burcham[2 3], Vodoz[2.4], Rafaisk[2.5] vermaas[2.6], James[2.7]. In

the microwave range however, alot of work have still to be performed. Interesting studies in this respect were done by James and Hamil and Tinga[28]. In all materials continuons random vibration of molecules are noticed. The temperature of the material is a measure of the energies of these vibrations . In thc case of microwave heating the rise in vibration motion is attributed to the mechanism of ionic (for electrolytic) conduction and mainly dipole rotation.

N.E . Hill[29] showed that the application of Onsagar's theory of dielectric dispersion contained an incorrect assumption abont the behavior of the reaction field when the applied field is varied.

Ionic conduction is practically independent of temperatnre or micro wave frequency but is only effective for wood at high moisture contents . The electric field applied at microwave freqencie causes a dissociation of molecules and a migration of ions by delivering kinetic energy . The ordered Kinetic energy is then converted into disordered K.E. which may be regarded as heat by collision of the migrating ions with an-ionized molecules . This transfer of energy leads to an increase in temperature.

In all materials continuous random vibration of molecnles are noticed . The temperature of the material is a measnre of the energy of these vibrations . In order to increase the energy or magnitude of vibrations of the individual molecules . In the case of microwave heating the rise in vibrational motion is attributed to the mechanisms of ionic conduction and mainly dipole rotation.

Dipole rotation, on the other hand is characterized by both temperature and frequency dependency . However, it also may take place

in wood at low moisture contents, because of the presence of polar groups . The vibrations that are induced in the interior of the dielectric material are based an a rotation of the polar molecules under the influence of the external electric field. When an electric field is applied the randomly oriented dipoles align themselves in a direction opposite to that of the external field.

The cellulose in wood has amorphons regions and contains ionic impurities soluble in water. With ions present the dielectric behavior of moist wood could be similar to that of weak electrolytes.

Brown and Skaar[2.10] suggested that when an external alternating electric field is applied and the frequency is not too high, each time the field is reversed the polar molecules reverse their position too a continuous dipole rotation is the result. The total stored energy consists of the sum of the potential and kinetic energies of the rotating molecules . Although, during each cycle a certain fraction of the total energy is dissipated due to friction, the energy levels of the adjoining molecules are raised owing to collisions and transfer of energy and this results iu a temperature rise.

Professor M. R. Sarker[2.11], S.P Bhattachajeec and Mr. Ekin Uddin studied the dclectric properties of some local varieties of wood at 3 cm. Wavelength in the electronic Research Laboratory Department of Physics, University of Rajshaihi.

W.E Courtny[2.12], presented the theory and experimental result to show possibility of using a resonant post technique for characterizing dielectric and magnetic materials at microwave frequencies.

J. Handling and L. Bottle[2.13] presented technic for accurate determining the dielectric constant of microwave materials. The concept was to resonate a cut off circular wave guide cavity by inserting the dielectric disk sample, Unlike most dielectric measurement technique which rely on perturbation methods that one determined the dielectric constant from the absolute measurement of the resonant frequency. Also the use of a cut off cavity presents false dielectric constant reading by elecminating spurious resonance.

R. Broko[2.14] studied the dielectric properties of composite media in 1979. The electrostatic polarizability of two component composite media was studied theoritically by him using the integral equation method. My sore R.Lakshminaraya, L.D. Paulaing and W.A Cook used the standard perturbation theory analysis to develop a new microwave technique for simultaneously and independently measuring the size and dielectric constant of dielectric samples.

James, Hamil [2.15] and Lin R.T[2.16] observed that, with increasing moisture content, the amount of water within the wood matrix increases, which itself is characterized by high dielectric values. On the other hand, the polar components of the cell wall and the cellulose get more freedom of rotation at higher moisture contents and in this way also contribute to a more pronounced dielectric behavior.

Norimoto et.al[2.17] studied the dielectric behavior of Pinus densiflora Sieb. et zuce the anisotropy in longitudinal and transverse direction is described to a difference in the arrangement of cell wall and lumen.

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REVIEW OF THE PAST WORK ON THERMAL CONDUCTIVITY OF WOOD

Wood is a complex material because of its complex and hygroscopic structure. Wood consists of small crystal - like regions dispersed in a matrix of amorphous material which is hygroscopic. So wood contains moisture in proportion to the humidity of its environment. Condnctivity is a material property that determines the current density resulting from a given voltage gradient in the material. Its reciprocal is resistivity. The conductivity of wood varies enormously with its moisture content.

Chemically wood is a partially oxygenated solid composed of cellulose, the hemicellulose, lignin and extractives.

Cellulosic materials are most hygroscopic substance and its thermal conductivity depends upon its moisture content, temperature and applied voltage. In oven dry wood, resistivity is of the order of 10^{17} to 10^{18} Ohm-centimeters at room temperature observed by Clark J.D and J.W Williams[3.1], kollmann, [3.2] Stamm[3.3] Above fiber saturation, the path for condnction gradually shifts from cell walls to cell cavities of wood or void spaces of paper and fiber board and the conductivity takes place along continuos water columns observed by Ito S.[3.4] and katz. A.R and D. G Miller. [3.5] Moisture content has the predominant effect upon conductivity of wood and Cellulosic materials but conductivity is also affected by temperature, which is observed by, Anderson. R.O[3.6] R. W Davidson and Lin R.T.[3.7] . At moisture contents above fiber saturation. Lin R.T. [3.7] observed a discontinuity in the curve near 0^0C . This may have been related to the change in moisture content of the cell wall due to freezing associated with the phenomenon known as "Coldness Shrinkage" observed by Kubler. H. [3.8] and Lin R.T. [3.7].

In explaning the mechanism of electrical conduction it has been generally assumed that the electrical charges are carried by ions in wood and cellulose rather than by electrons as observed by Barkas. W.W. R.F.S Hearinon and G.H. Pratt, [3.9] Brown J.H. [3.10], Hearle J.W.S [3.11] and Lin R.T. [3.7].

Barkas W.W. R.F.S Hearmon and G.H. Pratt [3.9] and Brown. J.H [3.10] reported that these ions arise from metallic residues or impurities. In addition, cellulose and wood exhibit polarization phenomena that are typical characteristics of ionic conduction in direct current electric fields.

Hearle [3.11] recognized that the conductivity of cellulose may be governed both by the number of free ions and by their mobility. He considered that the nuuber of free ions, on the other hand, is influenced by the presence of water in moist wood that has a large dielectric constant. Therefore, he postulated that the conductivity of hygroscopic nuaterials increases with increasing moisture content because of the increase in its dielectric constant.

Murphy [3.12] applied the theory of electrical conduction for ionic crystals to cellulose and proposed that its conductivity be represented by the sum of the intrinsic conduction and extrinsic conduction. The theory was further extended by Lin [3.7], who considered that the formation of charge carries in wood is statistical and that equilibrium exists with temperature.

Since wood lacks the free electrons which so rapidly transfer heat and electricity in metals, it conducts heat by the relatively inefficient transfer of vibrational energy from one particle to the next. For this reason, and because wood's hollow cells trap air, wood and wood based panel products are low in thermal conductivity. In the longitudinal or fiber direction, which is lengthwise in most pieces wood conducts heat 1.5 to 2.8 time faster than in the transverse direction, perpendicular to the fibres. This is due to the orientation of fibers and

of cellulose - chain molecules. The higher ratios apply more to dry wood and the lower ratios more to - wet wood in which water equalizes the difference between longitudinal and transverse conductivity. In dry wood the ratio averages 2.5.

The thermal conductivity of water is more than 20 times higher than that of air and also exceeds the conductivity of cell-wall substance. Therefore thermal conductivity increases with increasing moisture content. Moisture also contributes to heat conduction by diffusion as vapor from the warm to the cold side.

Ito S.[3.4] and Skaar [3.13] reported that when current passes through conducting media, it is always accompanied by Joule's heating, which will increase the temperature of the conducting body. With cellulose and wood, resistivity is initially reduced. Such initial decrease in resistance is opposed by the effects of electrode reaction and polarization, which increases the resistance.

Temperature has the strongest influence ou thermal conductivity at a given moisture content, which is lower for deuse wood than for light wood. Dense wood, after all, has relatively little cell cavity space for water and for diffusing vapor.

In wood-based panel products, fibres are usually oriented in the plane of the panel, so that heat flows across the panel perpendicular to the fibers, as in its flow across solid wood. In solid wood, however all fibers lie paralled to each other and are grown together, whereas in the panels a number of fibers lie at angles and touch each other only over a part of their length.

Gilbo C.F [3.14], Mélean [3.15] and Wangaard [3.16] reported that the thermal conductivity of wood has been determined by clamping an externally insulated heating plate with a heated edge guard ring to prevent lateral heat losses on one

surface of a board and measuring the electrical energy input per unit of time required to maintain the surface of the board at a fixed temperature above the opposite face, the temperature of which is thermostatically controlled. After a linear steady state temperature gradient is set up across the board, the amount of heat required to maintain the gradient per unit of time becomes constant.

Clarke, L. N and Kingston[3.17] observed a more recent method for measuring heat couductivity makes it possible to measure heat conductivity and specific heat simultaneously as the temperature is raised.

Ward, R.J., and Skaar, c.,[3.18] reported that two indentical specimens to be tested are clamped on opposite faces of a "heat sink' (a copper or aluminum block having an accurately known total heat capacity of the same order as that of the wood) with a guard ring around it that is heated electrically at a rate to keep its temperature equal to that of the heat sink thus avoiding lateral heat losses. Electric hot plates are clamped on the outer faces of the two test specimens and adjusted to give equal heating and a rise in temperature at a rate about equal to the rate of rise in temperature of the heat sink. Part of the heat entering the test specimens is used in raising their temperature and the remainder is conducted across the specimens to raise the temperature of the heat sink. Thus, both the specific heat of the test specimens, C and their thermal conductivity, K an involved through the following relationship,

$$K = {}^{dTc}/_{dt} \{L (PCL + P_1C_1L_1) / 2 (T_h - T_c)\}.$$

Where ${}^{dTc}/_{dt}$ is the rate of temperature rise of the heat sink in 0^0 C/sec, L is the thickness of the identical specimens and L_1 is the thickness of the heat sink in cm, P is the specific gravity of the specimen, P_1 is the specific gravity of the heat sink metal & C_1 its specific heat, T_h is the temp of the hot plate & T_c is the temperature of the heat sink in 0^0C

Mclean, J.D [3 19] observed that the thermal conductivity of oven-dry wood is 2.25 to 2.75 times greater in the fiber direction than in the transverse direction. Variations between the radial and the tangential directions are practically negligible.

The direction of heat flow through most heat insulators has little effect on the thermal conductivity, but there are some important exceptions to this statement. Griffiths [3 20] measured, the thermal conductivity of some light weight woods perpendicularly and in parallel to the grain and found the K values 60 to 80% greater when the heat flow was parallel instead of perpendicular to the grain. Frinck [3 21] made thermal conductivity determinations on various fibrous materials and showed the effect produced on the K value by different arrangement of the fibers.

The rate of heat transfer across an air space is affected materially by the orientation of the space equipment. For the determination of conductance values must be so designed that the air space can be related to various positions. Wilke and Peterson [3 22] designed the equipment and it has been in almost constant use since that time, with some refinements added.

The electrical resistivity of Cellulosic material is also affected by the presence of water soluble electrolytes. This is reflected in the fact that heart wood in general not only shows higher conductivity but also requires less activation energy which observed by Breeze, J.E and J. Vitins. [3.23]. Hearle J.W.S, [3.11] Katz A.R and D.G. Miller [3.5] and skaar. [3.13] are shown that the conductivity of wood and cellulose is increased by the introduction of ionic salts into the structure.

The electrical conductivity of wood and cellulose does not follow Ohm's. law. Apparent resistance of cellulosic materials depend upon the applied voltage, known as the Evershed Effect which was observed by, Brown J H, [3.10] Davidson R.W [3.24]. The direct current resistance decreases rapidly with increase in applied voltage from Zero to approximately 150 volts per cm. though temperature, moisture content and type of material affect the result slightly. Above this range, the decrease in the resistance with increasing voltage is so small that resistance can be considered as essentially constant.

When conductivity is measured with alternating current of 60 cycles frequencies, the Evershed Effect is not observed. Therefore, it appears to be a characteristic of ionic conduction for polar dielectric and may be attributed to the dependence of the degree of polarization of polar substances on field strength.

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AIM OF THE THESIS WORK

Wood is an important material with complex properties which have variety of applications as a construction material . Some physical properties of wood such as thermal conductivity and its dielectric constant have been studied in the past but the existing information is not exhaustive and demands further study specially for wood of local origin . Its composite structure and physical properties vary from one kind of wood to another depending on the plant source, seasoning, moisture content and specially the content of salts as absorbed chemicals.

Moisture and salinity can have far reaching effects on electrical properties of wood and can alter the value of the breakdown voltage. Wood as a construction material therefore, needs to be studied for its physical changes dne to moister and temperature variation . Wood is often used for building cold storage for its thermal insulating property. The study of thermal and electrical properties is important for their variation due to salinity and humidity.

The research findings of the present work will therefore, have usefulness in the application of wood as a construction material and also for understanding of the complex mechanism of thermal conduction and electrical response in wood as dielectric material.

CHAPTER - II

Chapter - II

KIND OF WOODS

Many varieties of wood are available in Bangladesh. But this research work is about two different kinds of wood, whose local names are Segun (Teak) and Gorjan.

Segun : It is a very strong and durable timber with a beautiful golden yellow colour. It is easy to season and easy to work. It is considered to be a very superior timber. It can resisit attack to some extent. It is also not easily attacked by termites. It is very commonly used for all sorts of house hold construction and structural works, for manufacture of high class furniture, ship building , railway sleepers, flooring, veneers and decorative structural works.

Gorjan : It is very stroug and durable timber. It is difficult to work with and does not take good polish. It is widely used for house building, railway sleepers and carriage floors, buildings, general structural works, rough furniture, etc. It is liable to excessive shrinkage. It must be given a preservative treatment as it is easily attacked by fungi.

It is found in the Hills of Chittagong and Sunderbans.

PROPERTIES OF WOOD

Wood is the hard substance under the bark of trees and shrubs. The outer bark (protecting the tree) is the dead corky part that varies in thickness with the kind of tree and its age. The inner bark carries the food made in the leaves down to branches, trunk and roots.

Hardwoods differ greatly from softwoods in some of their uses and properties. In general hardwood species are not only harder but also heavier and tougher thau soltwoods , and have a tendency to shrink more. Hardwoods and softwoods are very similar in stiffness, which means that on a weight for weight basis the soltwoods are stiffer.

Hardness means that the wood is solid or firm and that the surface does not dent, scratch, or cut easily . The main disadvantage of hard woods is the difficulty of cutting them with tools. They are harder to nail and are much more likely to split.

Teak, which is a very fine furniture wood, is extremely hard and abrasive and requires machining by carbide - tipped tools. Hardness is of great value when selecting woods for flooring, fine furniture and tool handles. But the classification of woods by species into hardwoods and softwoods does not mean actual hardness. Many softwoods cut from evergreen trees are actually harder than some hardwoods cut from broad-leaf trees.

The weight of wood is an important consideration in many types of construction. Weight is a good indicator of the relative strength of wood. A heavy piece of dry wood will be stronger than one of the same size that is light in weight like any other plant material. Wood tends to shrink as it dries and

to swell as it take on moisture. Wood shrinks and swells almost twice as much in width if it is flat grained as it does if it is quarter sawed on edge grained.

Bending strength is the ability of lumber to be bent without breaking. . A small increase in the height of the beam aids beuding strength far more than does a siinilar increase in width . For exainple, an increase of one inch in the height of a 10 inch beam will increase its beading strength by 21 percent, whereas a similar increase in width will add only about 10 percent to the bending strength.

Stiffness is the quality that resists bending under loads. This is particularly important in house construction in selecting the correct kind and size of floor joists and standing . Height and length have great effect on stiffness. All wood gain stiffness when properly seasoned. Compression strength means the ability of a piece of lumber to resist being mashed or squeezed together by weight applied against its ends. A supporting post is an example of a structural member that must have good compression strength. The compressive strength of timber along the grain depends upon the structure and the moisture content of the timber.

Wood will last almost indefinitely if it is kept thoroughly dry. It will decay only when there is too much moisture present, particularly when it is in contact with the ground. Wood decays through the growth of certain fungi . A fungus however, requires warmth, oxygen, food and moisture for survival. Unless wood has excess moisture, fungi die for lack of the water necessary for growth. The proper klin drying of lumber kills any fungi that exist in wood. Wood can also be treated with certain preservatives to prevent fungi from developing .

Structural members of wood consist of a nonhomogeneons material with anisotropy properties and a wide degree of variability. Anisotropy means that it should come as no surprise that dimensional changes that accompany variations in temperature , moisture and mechanical loading in wood are anisotropy. The features of wood that bring about its variable nature and its anisotropy properties can be explained by envisioning the cross- section of a tree.

The basic structural element of wood, the fiber generally aligned longitudinally to the tree. In a material of this construction, the longitudinal compressive and tensile strength are expected to be high and the transverse valves to be lower.

Warping is described as any variation from a true or plane surface, A warp may be a bow crook, cup or twist. Warping causes much waste of lumber in construction and manufacturing .

Fasteners, including nails, are the weakest part of any construction. The resistance that wood offers to the withdrawal of a nail is an important quality. Wood should never be nailed if the moisture content is to remain high since nails lose much of their holding power as wood dries. Of course, if wood splits as it is nailed, holding power is greatly reduced, even if the split is only a slight one.

Durability is the property of timber to remain in sound condition for a long time when exposed to the forces of nature in an exposed or under ground condition . All timbers must be durable . For this the timber should be free from natural and artificial defects. The annual rings should be regular and uniform and lustrous The timber should be well-seasoned . Hardness, density, specific gravity and strength seem to have direct influence on the durability of timber.

NATURE OF WOOD

Growth and structural characteristics of wood :

Growth characteristic : Trees grow in all shapes and sizes and their timbers look very different. These variations are however, more or less superficial and the main differences between timbers lie in their density.

All trees are primarily divided into two groups according to their manner of growth. These are :

(i) Exogenous trees or Exogenous.

(ii) Endogenous trees for Endogenous.

Exogenous trees increase in diameter by the annual formation between the old wood & the bark of a layer of new wood which envelops the entire living portion of the tree.

Endogenous tresses grow both diametrically & longitudinally. principally the latter, by the addition of new wood fibre intermingling with the old.

Exogenous Trees : They are mainly two types.

(a) Conifers (needle leaved trees) &

(b) Broad leaved trees.

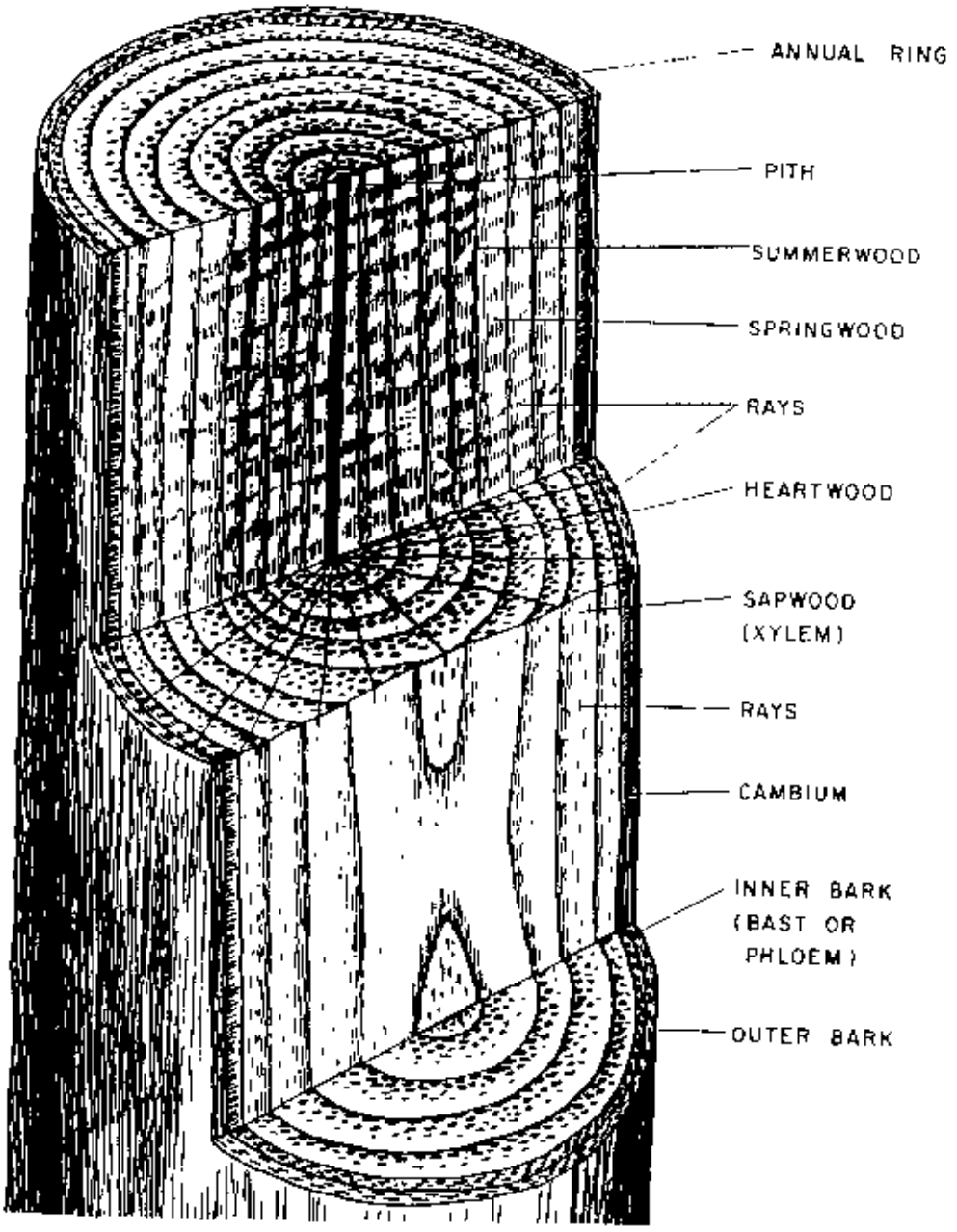
Conifers form a portion of important timber trees, comprising principally the pines, fur, kail, ceder, chir & deodar. They are usually light and soft, and hence, often called "soft woods". Timbers from conifers is used mainly for sport goods, furniture, interior finishing and cabinet works.

Broad leaved trees comprise many varieties of teak (segun), sal, gorjan, shisam, suudari, Jarul, mango, mahogony, and many other species of lesser commercial importance. They are usually heavy and hard, strong, flexible and

capable of resisting tensile, compressive and shear stresses quite well, hence often called "hardwoods". Most of the timber used by engineers in engineering constructions is derived from deciduous trees.

Endogenous Trees :

This group is confined largely to tropical & semitropical regions like Bangladesh, India, Burma, etc. The main endogenons are palms, coconut, betel-nut, bamboo & cane. The palms, coconut, betel-nut & date trees are locally used for making piles, battens, posts etc. and also used as fuel but have practically no other commercial uses.

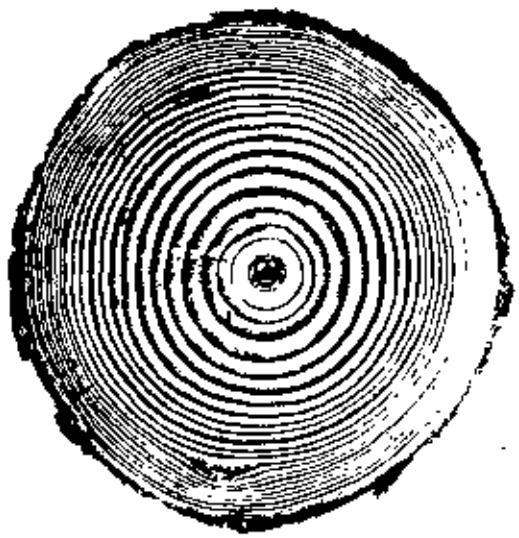


Cross section of a tree

Annual Growth rings :

Growth rings in trees are made up of springwood and summer wood. The portion formed easily in the growing season is called springwood and that which is formed later is called summer wood. Springwood has larger cell cavities and thinner walls. In some woods the change from spring wood to summerwood may be gradual white in others it is abrupt. It depends on the kind of wood and the growing conditions when the wood is formed.

Cross section of a log showing the annual growth rings. Each light ring is springwood each dark ring summerwood



Spring and summer wood :

The growth of all exogenous trees is a process of formation of new wood fibre between the old wood and the inner bark . Owing to the inability of trees to sustain their physiological activities of indefinitely and the effect of the alternation of seasons in all temperate zones, the growth is intermittent, and the zones (rings) of growth in general correspond to the annual rings. The succeeding rings of growth may easily be distinguished from one another in most species because of the different structure of the wood, formed rapidly in the spring and that formed more slowly in the summer. No wood is added during the winter months.

The rate of growth of trees is quite variable, not only in different species, but even for different specimens of the same species . This means that the growth rings are of variable thickness.

Sapwood & Heartwood :

The living element of the tree are called "sapwood" & the dead element of the tree are called heartwood.

All young trees show a higher percentage of sapwood than old trees of the same species. The proportion of sapwood in general varies from 20 to 60 percent of the total contents of wood.

The distinction in colour between sapwood & heartwood, which is the characteristic of most woods, is due to the darkening of the deadwood by the presence of infiltrated pigments, gums, resins, tannins, latex etc. Sapwood is rich in plant food material such as sugars, starch & albumen, which is in a putrescible form & sets up decay in wood by the process of fermentation.

Sapwood contains proportionately higher percentage of moisture than heartwood and this has an effect in reducing its strength & durability.

Generally heartwood is darker in colour, has more compact annual rings, is denser and more close grained in texture than sapwood.

The cells of heartwood have stronger cell walls & contain substances like tannins, resins, gums & latex which are poisonons to fungus & other which are poisonous to fungus and other insects. These materials impart natural immunity and durability of heartwood. Heartwood is heavier and less permeable to moisture than sapwood. In general, the heartwood is more highly valued than the

sapwood of the same variety . This is because the heartwood offers greater resistance to decay than the sapwood.

Living sapwood cells consists of enclosed cell wall and a cavity filled with protoplasm. Protoplasm is a liquid which is the physical basis of life. It is the living substance of all plant and animal cells.

Heartwood cell do not contain protoplasm, therefore they do not contribute to the growth of the tree. Most of the cells are arranged in a vertical fashion, which gives wood its straight grain

Sapwood are to help conduct sap and to store food for trees growth. Heartwood is made up of inactive cells that have already performed their functions for sap conduction and other life processes of the tree. There is no great difference in weight and strength between heartwood and sapwood when both are dry.

Structural Characteristics of wood :

Wood may be considered to be made up of two chief structural elements, cells and vessels. The elemental cells are technically subdivided as tracheids, wood fibres, medullary rays and parenchyma. Although there is considerable difference in form and functions between these various sub-divisions, such distinctions are beyond the scope of this discussion and all these elements will be here referred to simply as cells. In cross-section these cells are roughly polygonal and most commonly appear to be rectangular with rounded corners. The cells are formed of organic tissues with a cavity and a nucleus in it. The nucleus forms the living part of cell and constitutes what is termed as protoplasm.

In most timber, a very large proportion of these cells will be formed with the longitudial axes approximately parallel to the trunk of the tree. These are termed as vertical cells or fibre cells. These vertical cells are crossed in a radial direction by a different class of cells called radial cells or medullary rays, extending from the centre of the trunk to the outside. The medullary rays maintain communication between the interior and the outside in transmission and storage of food and other materials. There are other types of cells also which act as storages for gums and resins. In a combination they act as inter-cellular canals and ducts in which these snbstances are deposited. They run both vertically and radially.

Cell walls consist essentially of cellulose in the form of fibrils which are long spiral strands; some lignin is also present. The walls are anisotropic bnt are cemented together by a layer of isotropic substance, essentially lignin, called the middle lamina.

From the engineering point of view, however all woods may be considered as bundles of parallel tubes, rather like bundles of drinking straws. Since the tubes are made of substantially the same materials the large range of density is caused by the various thickness of the cell walls.

Structural members of wood consist of a non homogeneous material with anisotropic properties and a wide degree of variablity. The features of wood that bring about its variable nature and its anisotropic properties can be explained by envisioning the cross section of a tree. Starting at the center, the tree grows outward, adding a growth-ring each year. The growthring is usually component of two types of cells, spring wood formed in period of fast growth and summer wood formed during the period of slow growth.

The water in the cell wells is known as hygroscopic water. Wood can absorb and retain within itself a certain amount of this type of moisture and can actually pick it up from the surrounding atmosphere. Therefore, the amount of water within the cells, even of seasoned wood, depends on the relative humidity of the area to which the piece is exposed. The amount of water also depends to some extent on whether the wood is sapwood or heartwood. At the same humidity, sapwood usually has a higher moisture content than does heartwood. Since free water dries out first, shrinkage does not begin until the fiber saturation point is reached. This point varies from about 23 to 30 percent moisture content. When a piece of wood is exposed to air, evaporation takes place and continues until there is a balance between the water in the wood and the moisture in the air. After the fiber saturation point has been reached, the cell walls begin to give up their moisture.

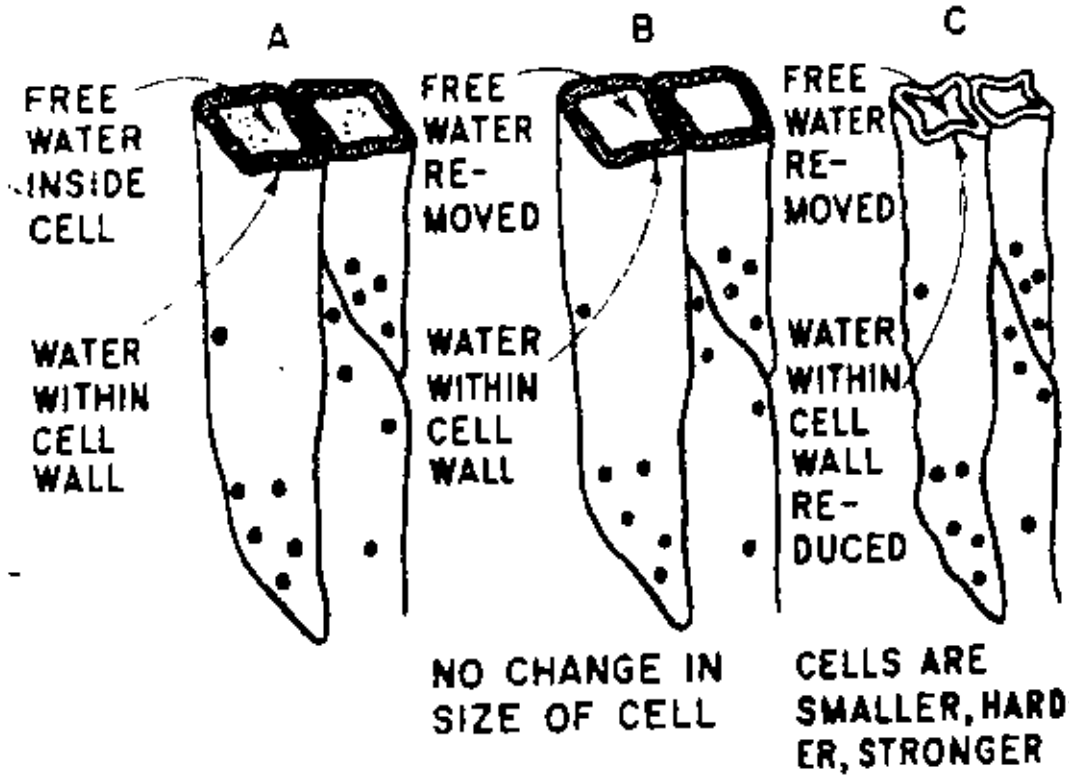


fig (2) How wood cells change as water is removed. (a) Green wood (b) Fiber saturatuion point, (c) Kiln dried

Chemical composition of wood :

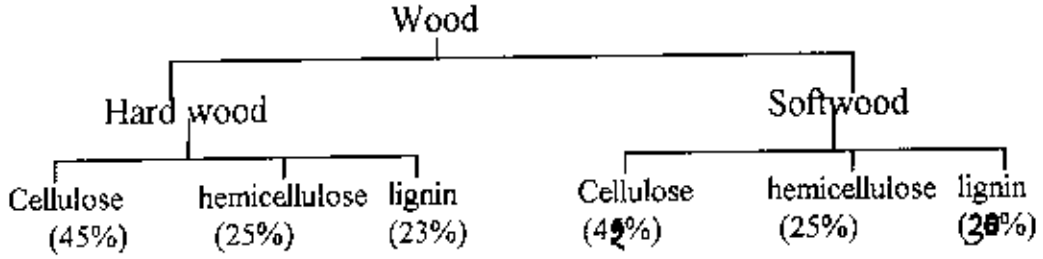
Wood is an extremely heterogeneous material and it is not surprising that its chemical composition anatomy and physical properties vary within wide limits. Within each tree, the roots, stem and branches may differ in chemical composition and in the stemwood there are variations with the height above the ground and with the distance from the pith.

The chemical composition of the wall is not the same for the tracheids and the ray cells in the softwoods and this also applies to the fibers, vessels and ray cells in the hardwoods. The middle lamella, the primary wall and the secondary wall do not have the same composition.

Wood is a composite material consisting of three major polymers namely cellnlosc, hemicellnlose and lignin.

An average hardwood consists of 45 percent cellulose , 25 percent hemicellulose and 23 percent lignin plus some 7 percent of other materials.

On the other hand, the average softwood contains about 42 percent cellulose, 25 percent hemicellulose, 30 percent lignin and about 3 percent other materials



Cellulose :

Cellulose is the most abundant organic chemical on earth It is estimated that about 50 billion tonnes of cellulose are produced every year in nature. Wherever it occurs, cellulose is present in a fibrillar form.

Cellulose is a 1,4-linked glucan consisting of B - D glucopyranose residues in the chair conformation, linked together by glycosidic bonds between C - 1 in one unit & C - 4 in the next to form long, linear chains. Every glucose residue is turned over 180^0 with resepect to ists neighbors.

The cellulose present in the secondary wall of wood cells has a degree of of polymerization of 10,000. There are indications that this cellulose is monodispersed, that is it consists of chair molecules of the same size.

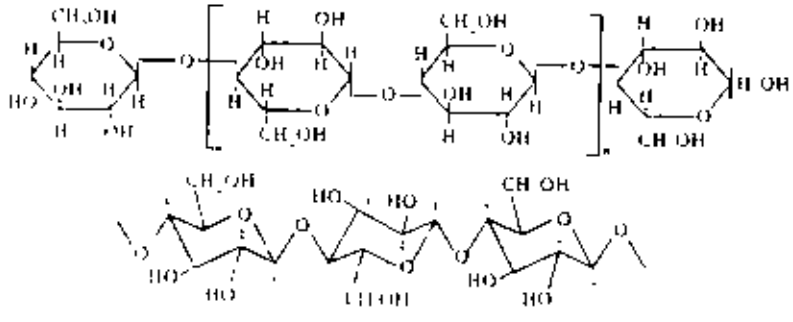


Fig. 1

All cellulose fibers are partly crystalline to the extent of 50 - 60% in wood. Cellulose can occur in two major & two minor crystallographic forms as shown in the figure.1

(1) In cellulose 1, the modification in which cellulose is found throughout nature, the chains are all oriented in the same direction (Parallel). They are bound together by strong hydrogen bonds in one of the two transverse directions but by only weak forces in the second. In addition, there are hydrogen bonds between adjacent glucose residues within each chain.

Crystalline, native cellulose has a rigid structure, which is both a chain lattice & a layer lattice impermeable to water.

(2) Cellulose is formed wheu the lattice of cellulose 1 is destroyed either by swelling with strong alkali or by dissolution . It is thermodynamically more stable of the two modifications. In cellulose the chains are antiparallel & there are hydrogen bonds between the chains not only within each layer but also between the layers.

Hemicelluloses :

The hemicelluloses are linear polysaccharides of moderate size that are invariably associated with cellulose & lignin in plant cell walls. Pectin is a large, acidic & branched polysaccharide with 1,4 - linked α - D galacturonic acid residue as a major constituent. In wood, it is present only in the primary wall.

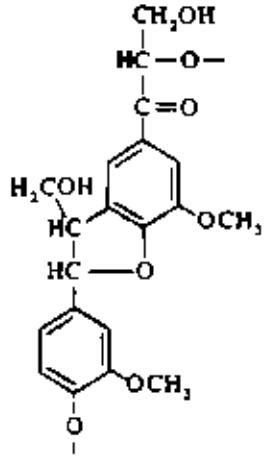
Some of the hemicelluloses can be isolated directly from wood by extraction with aqueous alkali, while others require prior removal of the lignin.

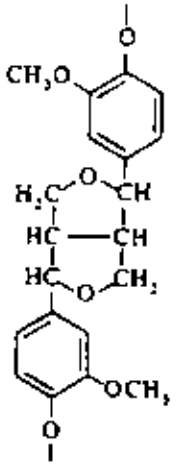
The predominant hemicellulose in hardwood is an acidic xylan. The xylan content can reach 35%, but in most species 25 ± 5 % . Hardwood xylans consist of a main chain 1 - 4 linked β - D xylopyr an residues some of which carry a single terminal O - methyl - α - D - glucuronic acid unit attached to . These side chains are distributed at random also the xylan backbone . Most hardwood species have on average one side chain per ten xylose residues. Hardwood xylans have a DP of 200 and are amorphous in their native state, although they can be induced to crystallize after the acetyl and some of the acid

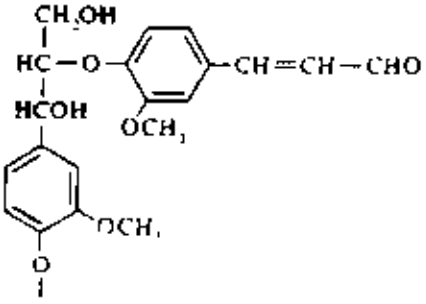
side chains have been removed. There strong evidence that the xylan chains have orientation parallel to the chains of cellulose.

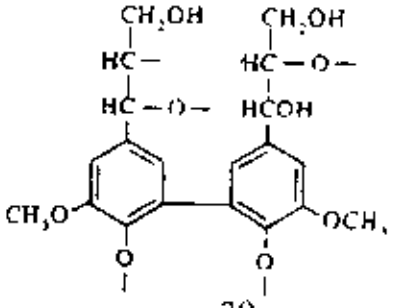
Lignin :

Lignin is a three-dimensional polymer composed of phenylpropane units that encrusts the intercellular space and the cell wall after the polysaccharides have been formed. Its function in wood is to cement the cells together and to impart strength to their wall. Lignin is best isolated by extraction with organic solvents of finely ground wood, preferably after pretreatment with polysaccharide- degrading enzymes. Almost all softwoods contain a guiacyl lignin with only one methoxyl group while hardwoods have a guiacyl lignin with one or two methoxyl groups.









The molecular weight of lignin indeterminate. Lignosulfonates obtained in sulfite pulping process can have a molecular weight of 10^0 or higher. While cellulose imparts tensilstrength to wood, lignin is partly responsible for compressive srtength. It also offers a certain protection against microbial attack.

Lignin, the "wood glue" that holds the other materials together, can be converted into vanilliu or into a chemical material nsed in foundry molds. It can be made into tanning ageuts for leather, or used for many other purposes.

SEASONING

The amount of moisture in lumber is an important factor in its usability. Because of the change is size of wood cells, lumber shrinks as it dries and swells as moisture is added. If lumber holds too much moisture (over 20%) over an exteuded period of time , a fungus may develop which will cause the wood to deteriorate.

Moisture in green wood exists in two conditions , as free water in the cell cavities, and as water absorbed in the cell walls. When all of the free water is removed and the wood contains just enough water to saturate and the cell walls, it is said to be at fiber saturation point. The removal of free water has little effect upon the properties of wood except to reduce its weight . However, as water in the cell walls evaporates, the walls contract and wood begins to shrink. Free water removed first. Therefore, shrinkage does not really begin until the fiber saturation point has been reached. At the fiber saturation point, wood has approximately 23 to 30 percent moisture content.

1. Natural or Air seasoning : This process of seasoning is also known as air drying. The natural seasoning is done by a long outdoor exposure of timber to the action of the air. The timbers are stacked in a dry elevated platform which is covered by a temporary shed to protect timbers from the

action of rain. Sometimes, permanent shed is also erected for the same. Timber is generally turned freqnently to ensure equal drying all round, because irregular drying causes splits and cracks. This is a very slow process and the time required varies from 2 to 3 years to remove the moisture by evaporation to the desired extent. This method is commonly employed all over Bangladesh.

2. Artificial Seasoning : The drying of timber by exposure for a limited period to high temperatures in a closed chamber or by applying chemicals, steam and smoke is termed as artificial seasoning. The following are the various methods of artificial seasoning .

(a) Kiln Seasoning : Two types of kilns are available for artificial seasoning : (i) compartment kiln in which the conditions of temperature and humidity are changed as the drying progress, the timber being stacked in the compartment ; and (ii) progressive kiln in which a low temperature with high humidity condition is maintained at the entering end of the kiln and a high temperature with low humidity condition at exit end, timber being moved periodically through the kiln. Both types of kiln may have either natural or forced air circulation . The advantages of forced circulation of air are accurate control of humidity and faster drying without any danger to the timber.

In kiln seasoning , temperatures 70 to 82^0 C (158 to 180 F^0) are usually employed. Soft woods generally require 4 to 6 days for 1 to 2 inch planks (boards). Hard woods (first air seasoned for 3 to 6 mouths to allow the first shrinkage take place more gradually and are then exposed to above temperatures in the kiln) require 6 to 12 days for 1 to $2^1/_2$ inch boards. This method is used in Bangladesh.

(a) Chemical Seasoning : This is also known as salt seasoning . In this method, timber is first soaked in an aqueous solution of a suitable chemical salt

(usually, solution of urea) before it is passed through the process of kiln seasoning . The vapor pressure of the salt solution is less and therefore, the interior moisture of the timber is drawn out. the drying of interior moisture of the timber is drawn out. The drying of timber from the center to the surface is at a uniform rate. The drying process is also accelerated. The most commonly used chemical is urea. It is a very good dehydrating agent and does not cause any harm to the seasoned timber. This method is not generally used in our country.

(c) Electrical Seasoning : In this process, high frequency alternating currents are passed through timber in a closed chamber and the resistance caused by the passage of the currents produces heat which dries the timber. Electrical seasoning is generally preceded by air drying .

This is a quick process of seasoning but is not used in this country.

(b) Steaming : In this process, steam is passed through the stacked timber in a closed chamber and thereafter timber is dried gradually in natural air. The steam is usually passed for 4 to 6 hours.

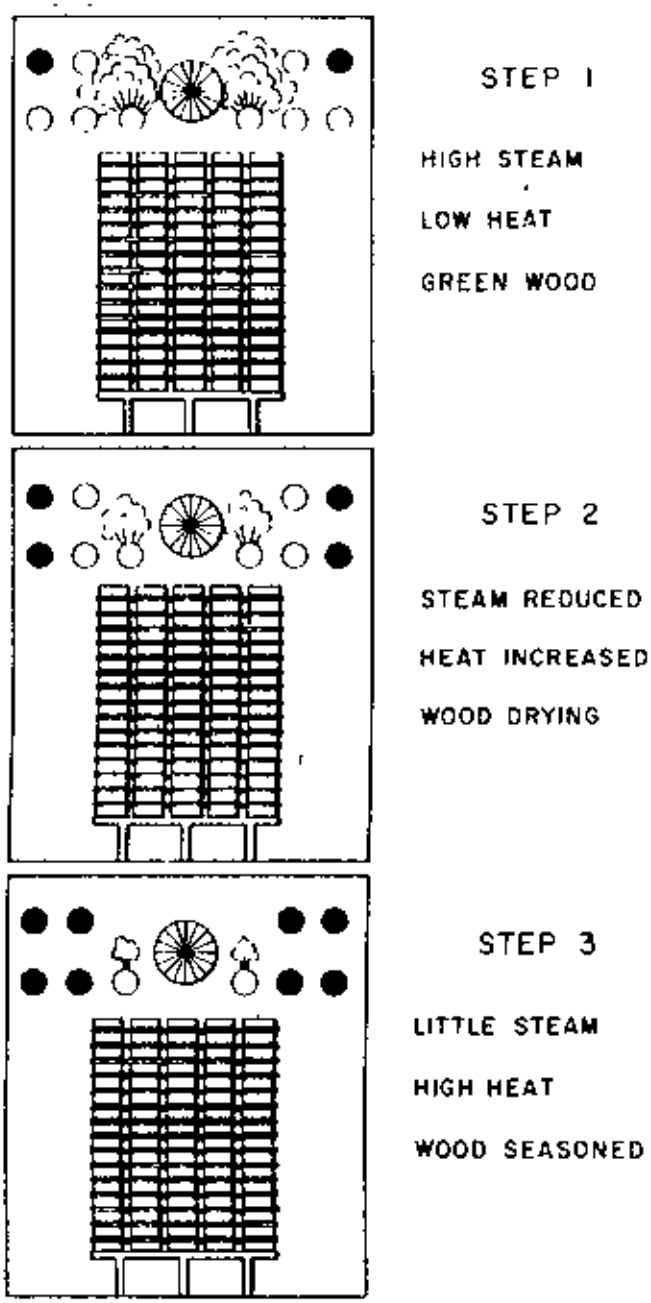
This is a quick method but it reduces the plasticity and strength of timber. This method is used in certain parts of this country.

(e) Boiling : In this process, the timber is immersed in boiling water for a certain period of time. Thereafter, the timber is dried slowly by natural air. This is also a quick process but it also reduces elasticity and strength of timber. This method is very rarely used in Bangladesh.

(f) Smoke Seasoning : This is a very old practice of drying timber in smoke heat over a fire of straw, sawdust and wood savings. This method is claimed to be efficient to make timber more durable and resistant to decaying

agents. Heat is gradually applied to prevent splitting and warping . This method is very frequently used in Bangladesh in boat-making industries.

(3) Water Seasoning : In this process, timber and logs are immersed and allowed to remain in water for a couple of days, wherefore they are dried by in natural air. In this process, the sap is dilated and is partly removed. This reduces the possibilities of decay and increases the durability of timber. Water seasoned timber also dries more quickly. This process of seasoning is good for timber containing a lot of sap, but it reduces the strengthof timber to some extent. This method is commonly used all over Bangladesh.



Kiln drying.

Uses of Timber :

The following are the various uses of timber :

1. Permanent structural works : Timbers used in permanent structural works are mainly of two types : (a) Light structural members and (b) Heavy structural members.

(a) Light structural members : Beams, post, roof trusses, floor boards, door and window frame's, and battens, railway sleepers, bridge floorings, electric poles, fencing poles, poles for transmission lines, gates, ratings, etc.

(b) Heavy structural members : Piles, bridge piers, jetty - foundation and superstructure , wood stoves, stairs, etc.

2. Furniture works : Chair, tables, almirah, sofa-set, dressing tables, cup boards, cots, beds, etc.

3. Transportation works : For making country boats, launches, speed boats, ship, body frames of railway coaches , omnibuses and air crafts, body frames of railway coaches , omnibuses and air crafts. For making jetties and landing platforms. Also used for making cart-wheels.

4. Temporary works during construction : Scaffolding and general centering works of all types in R.C.C construction works. For providing shoring and strutting to support the sides of soft soil excavatiou. Timber is used for making packing boxes and pattern making in foundry castings.

5. Commercial uses : Timber is used for manufacturing sport-goods, toys, and for making veneers which are used in manufacturing plywood, batten boards, laminated boards etc. and reconstructed wooden boards like insulating boards, hardboard, fibre boards, particle boards, linoleum, etc.

6. Industrial uses : Wood is used for the manufacture of matches , paper, newsprint, eard boards, well-papers, artificial synthetic fibber, roofing felt, preservative, etc.

CHAPTER - III

Chapter - III

INTRODUCTION

While wood is a very old material that has been used from the time man has been an this earth, only in recent years has it developed into material with thousands of uses. This is particularly, true of the many man made wood products now utilized in furuiture and building construction. Also wood remains the favorite building material for homes, furniture, boats, musical instruments, sports equipment and thousands of other items. But to select wood wisely, one must know its thermal and electrical property. Some woods which are strong and of good enough quality for the exposed part of furniture lack necessary hardness. Some woods should have minimum tendency toward wharpage, excessive shrinking and swelling. The electrical properties of wood is of particular interest because these properties undergo drastic changes depending on the water content. Since wood consist of small crystaline regions called wood fibers which are dispersed in lignin that serves as amorphous materials. Wood is very much hygroscopic.

The electrical properties of two kinds of wood namely, Gorjan and Segun were measured as affected by moisture and salt eontent. The dielectric constant of a material is a measure of the electric energy it will absorb form an electric field and store internally as polarization. This is of practical iuportance because, while wood are used as electrical switch boards, there are often short circuits due to absorption of saline water from the walls specially, in the rainy season.

The electrical properties of wood are complex because of its complex hygroscope structure. Wood consist of siuall crystal--like regions

dispersed in a matrix of amorphous material. is hygroscopic. So wood contains moisture in proportion to the humidity of its environment. The electrical properties considered here is dielectric constant.

Procedure :-

In preparing the good quantity of research samples wood was cnt into thin pieces. The broad farces of the specimen samples were polished by sand paper. Two types of wood, namely. Garjon and Teak (Segun) were used for the research work. The diameter and thickness of specimen samples of the wood samples were nearly the same as shown below :

Sample	Diameter	Thickness cm
Gorjan	2.6 cm (approx)	0.9 cm(approx)
Segun	2.7 cm (approx)	0.82 cm (approx)

Process I

Six samples of Gorjan and six samples of Segun (the diameter and thickness of the samples were nearly the same) were studied. The weight of each of these samples were measured prior to soaking and then soaked in distilled water for 48 honrs. The soaked samples were again polished by sand paper Later on, those were dried in an oven at a temperatnre of 122^0C. After one hour, one sample of Gorjan and one sample of Segun were taken out. Then, their weight were measured and the moisture content and dielectric constant were determined. After two hours, again the weight of another sample of Gorjan and another sample of Segun were taken, weighed and their moistnre content and dielectric constant were determined. Similar measurements were carried out at the end of every hour upto 6 hours, for the remaining Gorjan and Segun samples.

Process II

For the study of the effects of NaCl treatment on the water absorption and dielectric constants of wood six samples of Gorjan wood and six samples of Segun (nearly of same thickness and diameter) were taken and weighed. These samples were then soaked in 0.1% NaCl solution for 48 hours. After soaking, those samples were polished by sand paper and their actual thickness were measured . Samples were then dried in an oven at a temp of 122^0c. After one hour two samples (one of Gorjan and one of Segun) were weighed and determined the maisutre content (by difference of weight) and dielectric constant of those samples with the help of a Wein-bridge aparatus. Similarly, moisture content and dielectric constant were determined for every hour of drying upto six hours for the remaining Gorjan and Segun samples.

Process III

In order to study the effect of higher concentration of NaCl on the same dimensions the samples were soaked in 0.3%, 0.5%, 0.7%, 0.9%, 1.0% and 1.5% NaCl Solution for 48 hours By similar measurements as before, the moisture content and dielectric properties of those samples (being soaked in NaCl solution of different concentration) were determined.

DESCRIPTION OF THE INSTRUMENT FOR MEASURING DIELECTRIC CONSTANT :

The usual methods of measuring the dielectric constaint are based on a comparism of the capacity c" of a capacitor filled with the substance and the capacity c' of the empty capacitor the ratio $c''/c' = \epsilon'$ the dielectric constant. The determination of the value of the capacitance may in principle be accomplished by using a Wein-Bridge oscillator of type B 224 at room temperature (Fig.1.1)

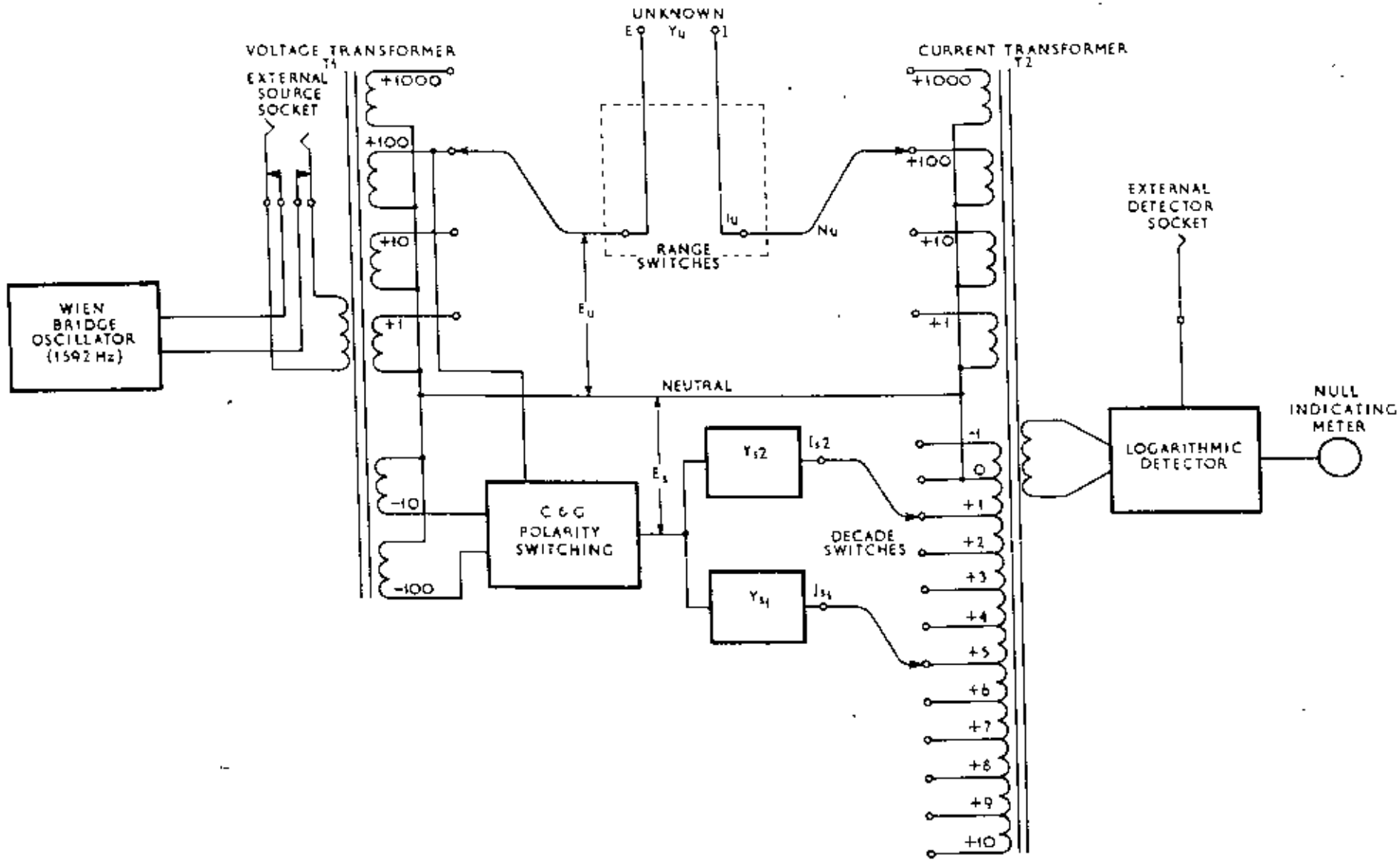


Fig 11 B224 Block Schematic

FUNCTIONAL DESCRIPTION

The Instrument comprises a transformer ratio-arm bridge fed form a 1592Hz oscillator, a logarithmic detector and a null indicating meter.

A standard voltage derived from a Wien Bridge oscillator is applied simultaneously to the component under test and the internal standards via the Decade switches. The resulting current are summed in the current transformer and the difference is fed to the logarithmic detector and hence to the nul iudicating meter. By adjustment of the voltage applied to the standards, the balance betweeu the standard and unkuown channels is made exact, and the detector output falls to a minimum. At this point the standard and unknown bear a numerical ratio as indicated by the significant figures read from the Decade Controls, aud the Range switch units.

THE BRIDGE NUCLEUS (Normal Measurements - Ranges 4-10)

Referring to Fig 1.1, the voltage transformer T1 has windings of 1.10,100 and 1000 turns, the tapping of which are selected to produce an voltage E_u. This voltage, thc value of which is determined by the turns selected, is applied to one side of the unknown, Y_u, and causes a current I_u to flow through Y_u to one of four windings of 1, 10, 1000 and 1000 turns on the current transformer T2. The required winding on each transformer is selected by means of thc Range switch SG.

A voltage E_s is obtained from one of three windings on the voltage transformer T1 and applied to the standards Y_{S1} and Y_{S2}, via the C and G polarity switching. There are in fact eight standards, four for conductance and four for capacitance; for clarity, only two of these, Y_1 and Y_2, are

shown. This causes currents I_{S1} and I_{S2} to flow in the Decade windings on the current transformer T2. Two of these windings are of 100 tuns, but reversed in sense. By slecting the appropriate winding, positive or negative capacitance or conductance can be measured independently. The third winding is of ten turns, and of correct sense for the measurement of positive values only. When this latter winding is selected, the voltage applied to the standards is reduced to one tenth of the normal value. This increases the ration E_u to E_s by a factor of term C or G, as required.

A winding on the current transformer T2 has 11 turns, tapped every turn, this is the decade wiuding to which the currents I_{S1} and I_{S2} are fed. In the iuain circuit diagraiu (Fig. 1.1) thc capacitance standards are C5 and C7 trimmed by C6 for the first decade, C9 trimmed by C8 for the second decade, C11 trimmed by C10 for the third decade, and C4 for the fourth decade or ~~vernire~~ vernier. The conductance standards are R17 trimmed by R18 for the first decade, R15 for the second decade, R13 for the third decade and R9 for the fourth decade or vernier.

Initial eapacitance trimming is effected by the potentiometer R6. This is connected from - 100 turns, to +100 turns, on T1 Current is fed from the wiper of R6, via C1, to + 10 turns on T2. Conductance is trimmed by the potentioineter R4. This is connected in parallel with R6. Current is fed from the wiper of R4 via R5 + 10 turns on T2.

2.3 EXTERNAL STANDARDS.

Connection of external standards is facilitated by the use of two panel mounted BNC sockets, engraved EXTERNAL STANDARDS. One of these, engraved 'E' is wired to the - 100 turn tap ou the standards

winding of the voltage transformer T2. The use of these sockets is described in the Operating Instructions

2.4 EXTERNAL SOURCE AND DETECTOR

Inserting a jack into the EXTERNAL SOURCE socket JKI connects the external source to the primary of the voltage transformer T1, at the same time disconnecting both the output from, and the supply to, the Wien Bridge Oscillator.

A specially prepared dielectric testing Jig was used to hold the samples wood. The resistance of the Jig was in the order of nearly $10^{10}\Omega$.The diameter of the electrode of the Jig was made 1.2cm. The experimental set up is shown in fig. (1.2).

The bridge was first balanced to reduce the capacitance and conductance present in the circuit (without mounting specimen in the dielectric Jig). It was noted that the indicator was moving with any type of movement due to the stray capacitance of the environment. It was overcome by grounding the body of the Jig. The specimen was then inserted in between the electrodes (fig 1.2). The capacitance (C) and the conductance (G) were directly noted as a function of frequency by taking the indicator at the null point.

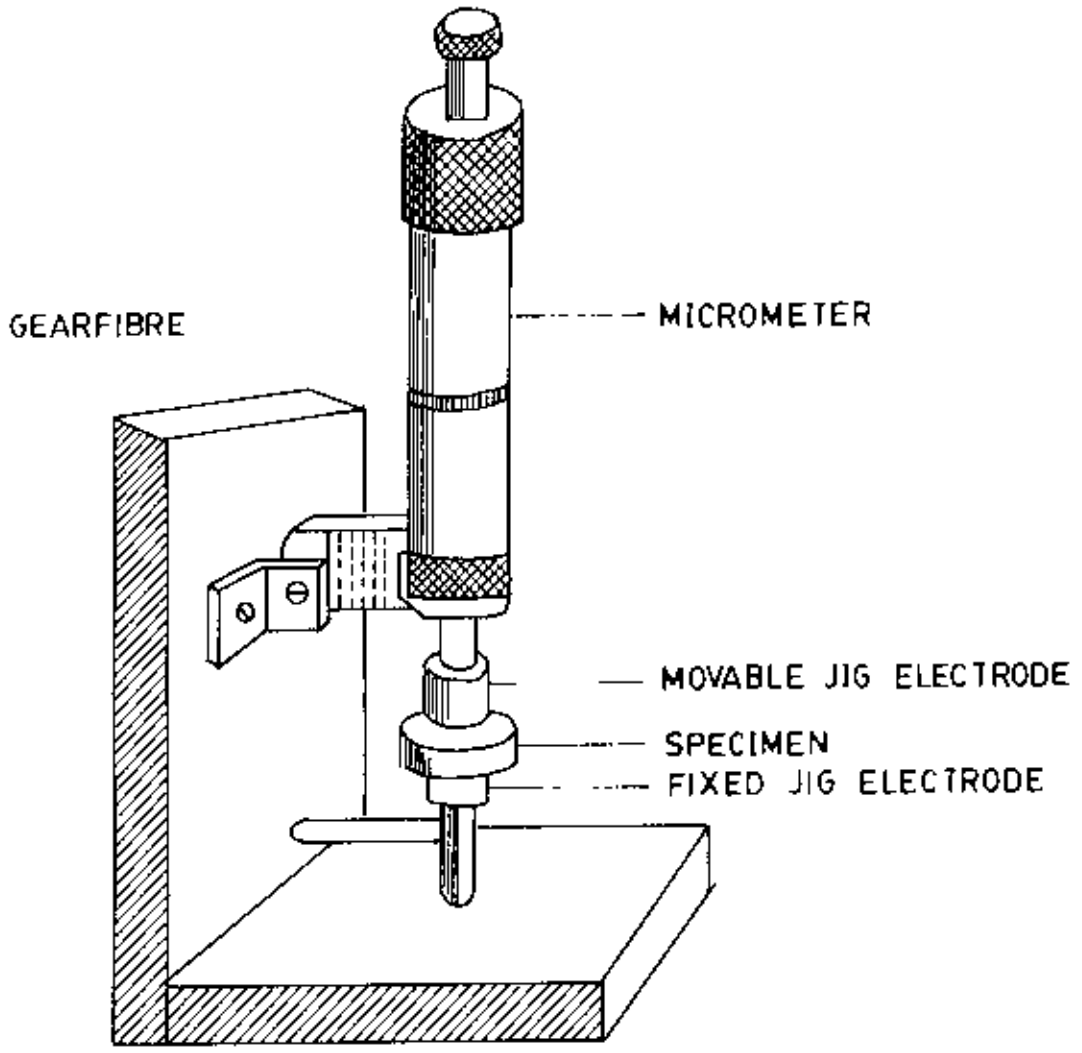


FIGURE 1.2 : DIELECTRIC JIG FOR MEASURING DIELECTRIC PROPERTIES AT ROOM TEMPERATURE

MEASUREMENT TECHNIQUE AND THEORY.

Theory :

If a given electrical voltage is impressed across a condenser in which the electrodes are separated by a vacuum, a certain electrical charge, Q_o, accumulates on the condenser. When the condenser is filled with substance such as wood or cellulose, some alignment of polar molecules in wood or cellulose takes place and more charges are stored in the condenser. If Q_w is the charge held by a similar condenser that is filled with a dielectric substance, Q_w depends upon the properties of the dielectric substance and the ratio ($^{Q_w}/_{Q_o}$) is known as the dielectric constant of the material.

The element, constructed simply of two parallel conducting plates separated by an insulating material is called a capacitor. Expressed as an equation, the capacitance is determined by

$$C = \frac{Q}{V} \quad \text{.....(1)}$$

Where, Q=Charge,

V=Potential Difference.

It a potential difference of **v** volts is applied across the two plates separated by a distance of d, the electric field strength between the plate is determined by,

$$E = \frac{V}{d} \text{ volts / meter} \quad \text{.....(2)}$$

Many values of capacitance can be obtained for the same set of parallel plates by the addition of certain insulating materials between the plates.

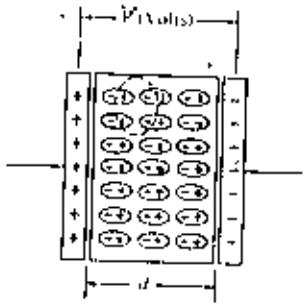


fig (a)

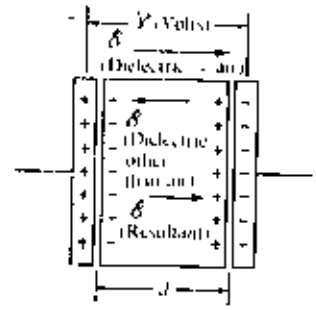


fig (b)

In fig. (a) : an insulating material has been placed between a set of parallel plates having a potential difference of v volts across them.

Since the material is an insulator the electrons within the insulator are unable to leave the parent atom and travel to the positive plate . The positive components (protons) and negative components (electrons) of each atom do shift however (as shown in fig. (a) to form dipoles.

When all the atoms of the insulating material become dipoles and align themselves as shown is fig. (a), the material is polarized. The layer of positive charge on one surface and the negative charge on the other are not neutralized, however, resulting in the establishment of an electric field within the insulator [fig (b)]. The net electric field between the plates [$E_{resultant} = E_{air} - E_{diel}$] would therefore, be reduced due to the insertion of the dielectric.

The purpose of the dielectric, therefore, is to create an electric field to oppose the electric field set up by free charges on the parallel plates.

In either case with or without the dielectric if the potential across the plates is kept constant and the distance between the plates is fixed, the net electric field within the plates must remain the same, as

determined by the equation $E = \frac{V}{d}$.

For different dielectric materials between the same two parallel plates different amounts of charge will be deposited on the plates. But $\psi = Q$, so the dielectric is also determining the number to flux lines ψ, between the two plates and consequently the flux density $D = \psi/A$ ....(3) where A is a fixed.

The ration of the flux density to the electric field intensity in the dielectric is called the permittivity of the dielectric

$\epsilon = D/E$ farads / meter . .....(4)

For a vacuum, the value of ϵ_0 (denoted by to) is 8.85×10^{-12} F/m. The ratio of the permittivity of any dielectric to that of a vacuum is called the relative permittivity or dielectric constant, ϵ',

$$\epsilon' = \frac{\epsilon}{\epsilon_0} \qquad \therefore \epsilon = \epsilon' \epsilon_0 \ldots\ldots\ldots\ldots (5)$$

Now from eqation

$$\epsilon = \frac{D}{E} = \frac{\psi / A}{V / d}$$ [Putting the value of eqn (5) and (2)]

$$\epsilon = \frac{Q / A}{V / d}$$

or $$\epsilon = \frac{Qd}{VA}$$

$$\therefore \quad \epsilon = \frac{Cd}{A} \quad [\because C = \frac{Q}{V}]$$

$$\text{or,} \quad C = \frac{\epsilon A}{d} = \epsilon' \epsilon_0 \frac{A}{d} \ldots\ldots\ldots\ldots (6)$$

Where, A is the area in square meters of the plates,

d " " distance between the plates.

ϵ' " " dielectric constant

Now, $C = \frac{\epsilon A}{d}$ ..... (7)

Now, the ratio,

$$\frac{C}{C_0} = \frac{\epsilon A / d}{\epsilon_0 A / d} = \frac{\epsilon}{\epsilon_0} = \epsilon'$$

$$\therefore \quad \epsilon' = \frac{C}{C_0} \text{ ..... (8)}$$

$$\text{Dielectric constant} = \frac{\text{Capacitance with wood.}}{\text{Capacitance without wood.}}$$

The relationship between ϵ' and the capacitances provides a method for finding the value of dielectric constant for various dielectrics.

RESULTS

The dielectric constant of Gorjan and Segun were determined under six different moisture conditions, covering the range 9% to 16% at room temperature (30^0c). The results of these samples are shown in Table.1. The moisture content of wood was determined by weighing a sample before and after oven drying. The same procedure was applied to indnce salinity in the wood samples, where NaCl solntions of different strengths were used. The resnlts of these samples as shown in table 3. The value of dielectric constant of these samples soaked in Nacl solution were found to be higher than the general value of dielectric constant of wood not soaked in saline solution.

The results are presented in Table (1) to Table (4). In general, the dielectric constant was found to increase with increasing moisture content. The dielectric constant of wood under salinity also increased with increasing the saline concentration.

The results are graphically represented in fig (1) to fig (4)

Fig (1) and fig (2) shows that dielectric constant increases with increasing moisture content above salinity.

fig (3) shows that for two different types of wood, namely, Gorjan and Segun woods dielectric constant varies with moisture content.

Fig (4) shows that the dielectric constant of two types wood Segun & Gorjan increases with increasing salt concentration.

Table -1

A. Gorjan wood

(Sample Soaked in distilled water for 48 hours.)

Time	After 1 hour	After 2 hours	After 3 hours	After 4 hours	After 5 hours	After 6 hours
Percentage of moisture content	14.01	13.15	12.20	11.01	10.20	9.01
Dielectric constant	2.32	2.14	1.94	1.75	1.55	1.3

Table-2

B. Segun wood

(Sample soaked in distilled water for 48 hours)

Time	After 1 hour	After 2 hours	After 3 hours	After 4 hours	After 5 hours	After 6 hours
Percentage of moisture content	15.50	14.10	12.90	12.00	10.50	9.6
Dielectric constant	2.5	2.3	2	1.85	1.5	1.3

Table-3

Gorjan Wood
(Soaked in saline solution)

M.C.= Moisture content
D.C. = Dielectric constant

Saline concentration	Time	After 1 hour	After 2 hours	After 3 hours	After 4 hours	After 5 hours	After 6 honrs
0.1%	M.C.	14.15	13.10	11.90	11.15	10.10	9.1
	D.C.	2.35	2.2	2	1.81	1.6	1.38
0.3%	M.C.	14.01	12.90	11.70	10.85	10.01	9.01
	D.C.	2.42	2.25	2.05	1.86	1.65	1.4
0.5%	M.C.	13.80	12.50	11.50	10.70	9.90	9.02
	D.C.	2.5	2.3	2.1	1.9	1.7	1.5
0.7%	M.C.	13.60	12 25	11.40	10.60	9.85	9.05
	D.C.	2.54	2.35	2.15	1.95	1.75	1.55
0.9%	M.C.	13.50	12.10	11.20	10.50	9.75	9.05
	D.C.	2.6	2.42	2.2	2	1.8	1.6
1.0%	M.C.	13.35	12.10	11.15	10.50	9.80	9.10
	D.C.	2.65	2.45	2.25	2.05	1.85	1.65
1.5%	M.C.	12.90	12.25	11.50	10.90	10.10	9.15
	D.C.	2.8	2.71	2.55	2.4	2.14	1.85

Table-4

Segun Wood
(Soaked in saline solution)

Saline concentration	Time	After 1 hour	After 2 hours	After 3 hours	After 4 hours	After 5 hours	After 6 hours
0.1%	M.C.	15.70	14.01	13.20	12.25	11.01	9.8
	D.C.	2.58	2.36	2.2	2	1.77	1.5
0 3%	M.C.	15.50	14.25	13.25	12.20	11.10	9.7
	D.C.	2.61	2.45	2.25	2.05	1.85	1.52
0.5%	M.C.	15.25	14.25	12.90	11.75	10.80	9.6
	D.C.	2.66	2.52	2.26	2.04	1.85	1.57
0.7%	M.C.	15.01	14.20	12.90	12.00	10.85	9.8
	D.C.	2.7	2.57	2.3	2.15	1.91	1.66
0.9%	M.C.	14.75	13.80	12.80	11.85	10.70	9.6
	D.C.	2.74	2.59	2.4	2.2	1.94	1.71
1.0%	M.C.	14.75	13.50	12.60	11.50	10.50	9.50
	D.C.	2.8	2.6	2.43	2.2	2	1.75
1.5%	M.C.	14.50	13.25	12.60	11.80	10.50	9.5
	D.C.	3	2.82	2.62	2.4	2.17	1.91

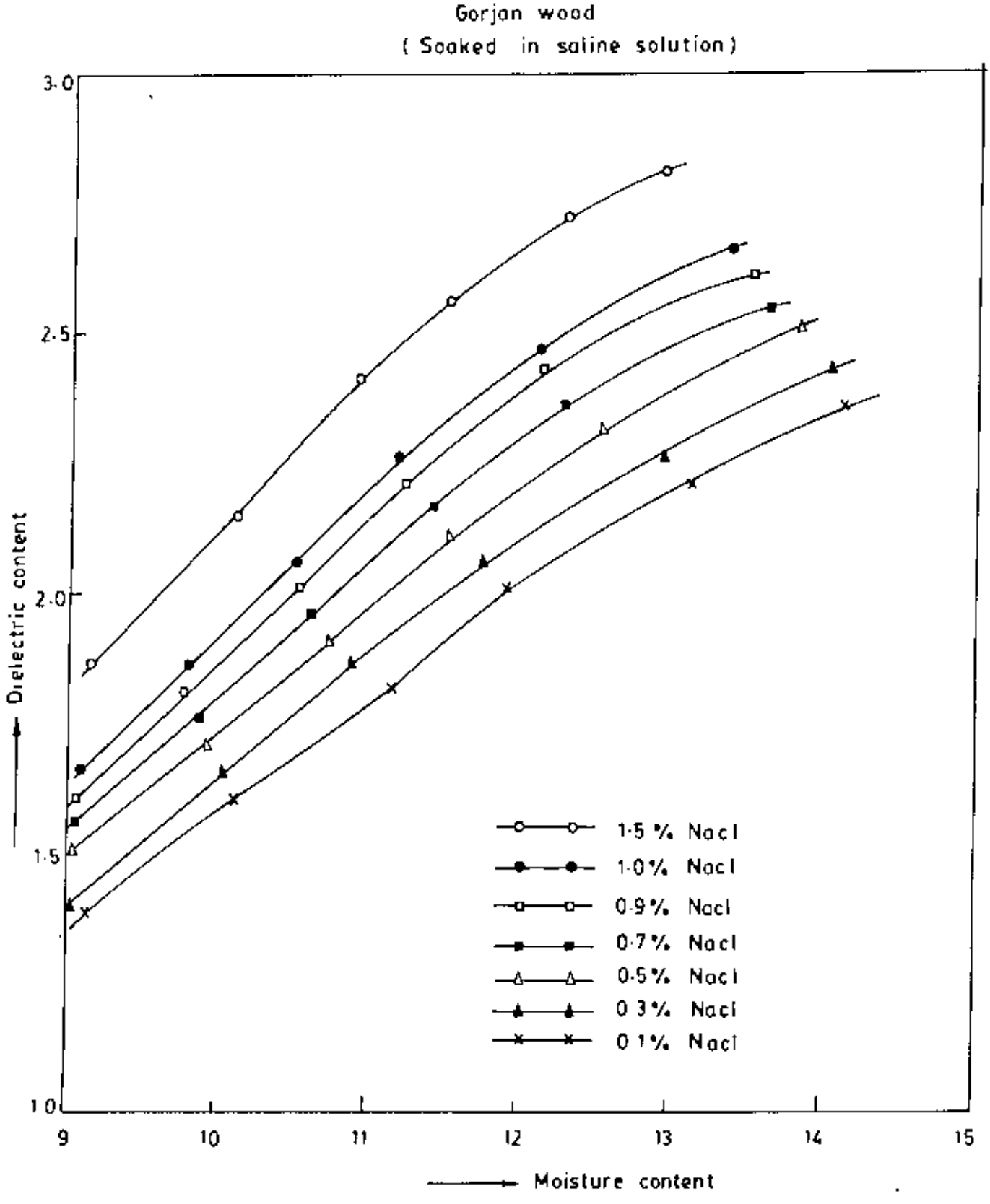

Gorjan wood
(Soaked in saline solution)
3.0
2.5
2.0
1.5
1.0
Dielectric content
9
10
11
12
13
14
15
Moisture content
1·5 % Nacl
1·0 % Nacl
0·9 % Nacl
0·7 % Nacl
0·5 % Nacl
0 3 % Nacl
0 1 % Nacl

Fig 1

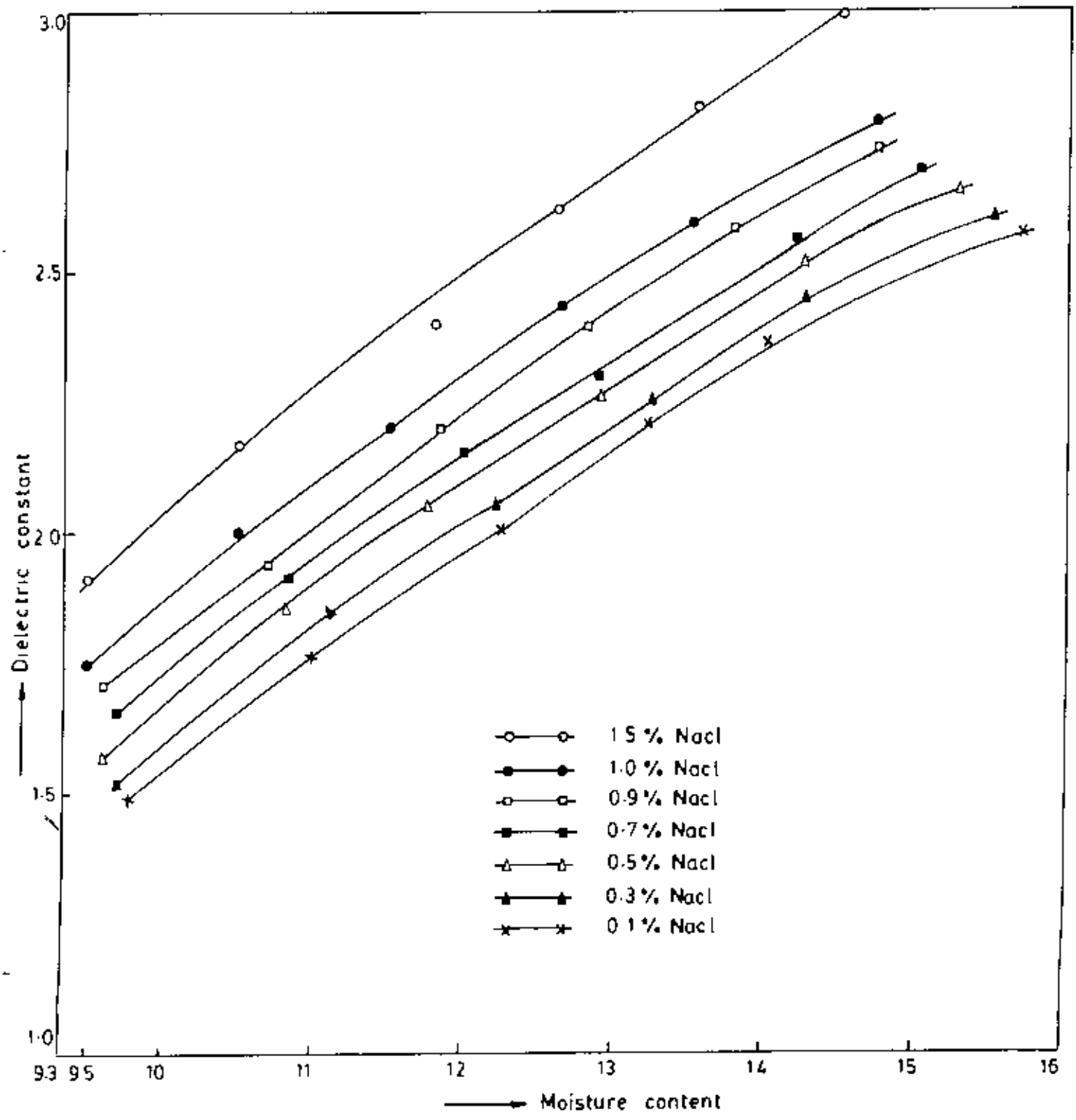

Segun wood
(Soaked in saline solution)
3.0
2.5
2.0
1.5
1.0
Dielectric constant
9.3
9.5
10
11
12
13
14
15
16
Moisture content
1.5 % Nacl
1.0 % Nacl
0.9 % Nacl
0.7 % Nacl
0.5 % Nacl
0.3 % Nacl
0.1 % Nacl

Fig. 2

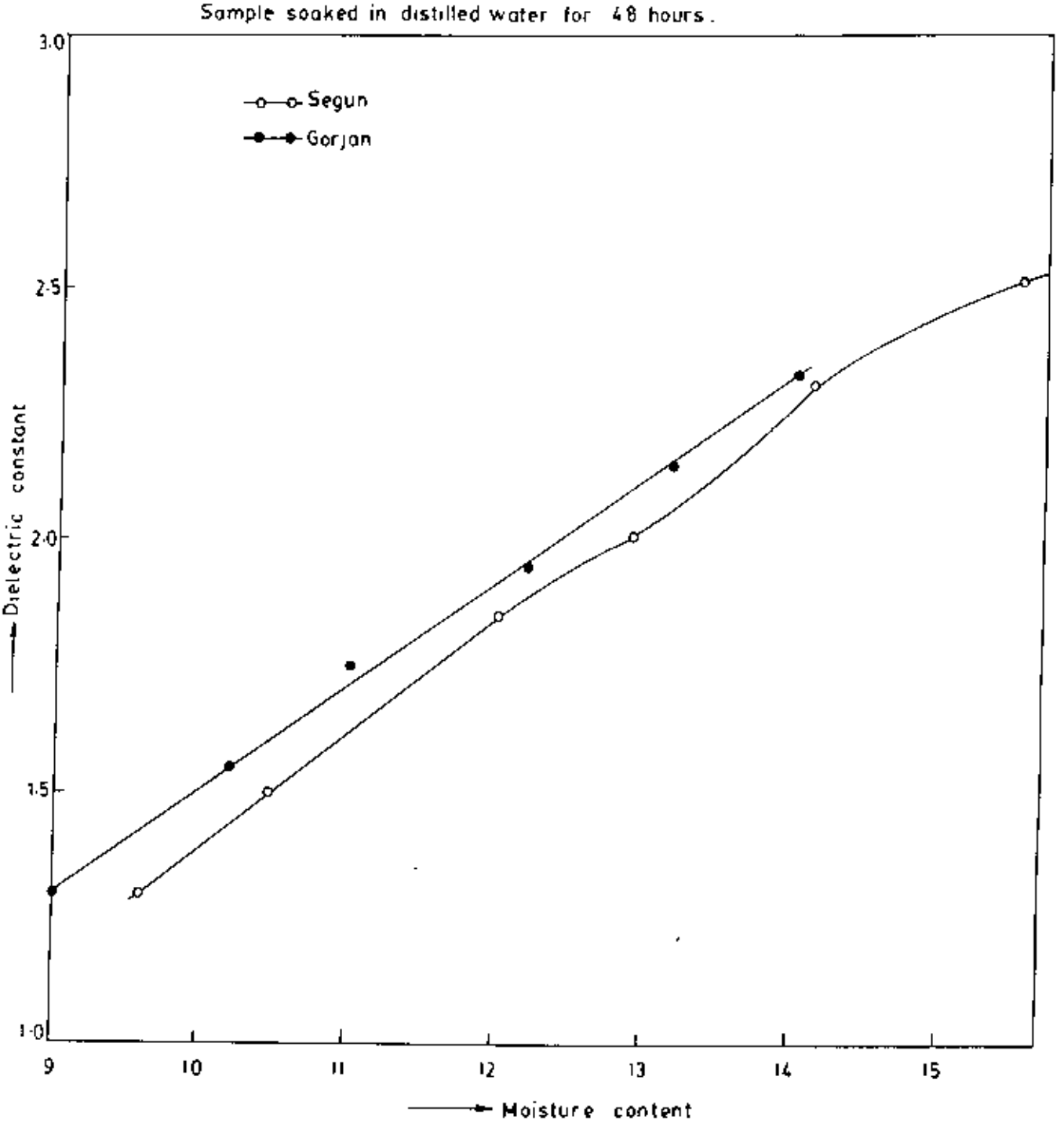
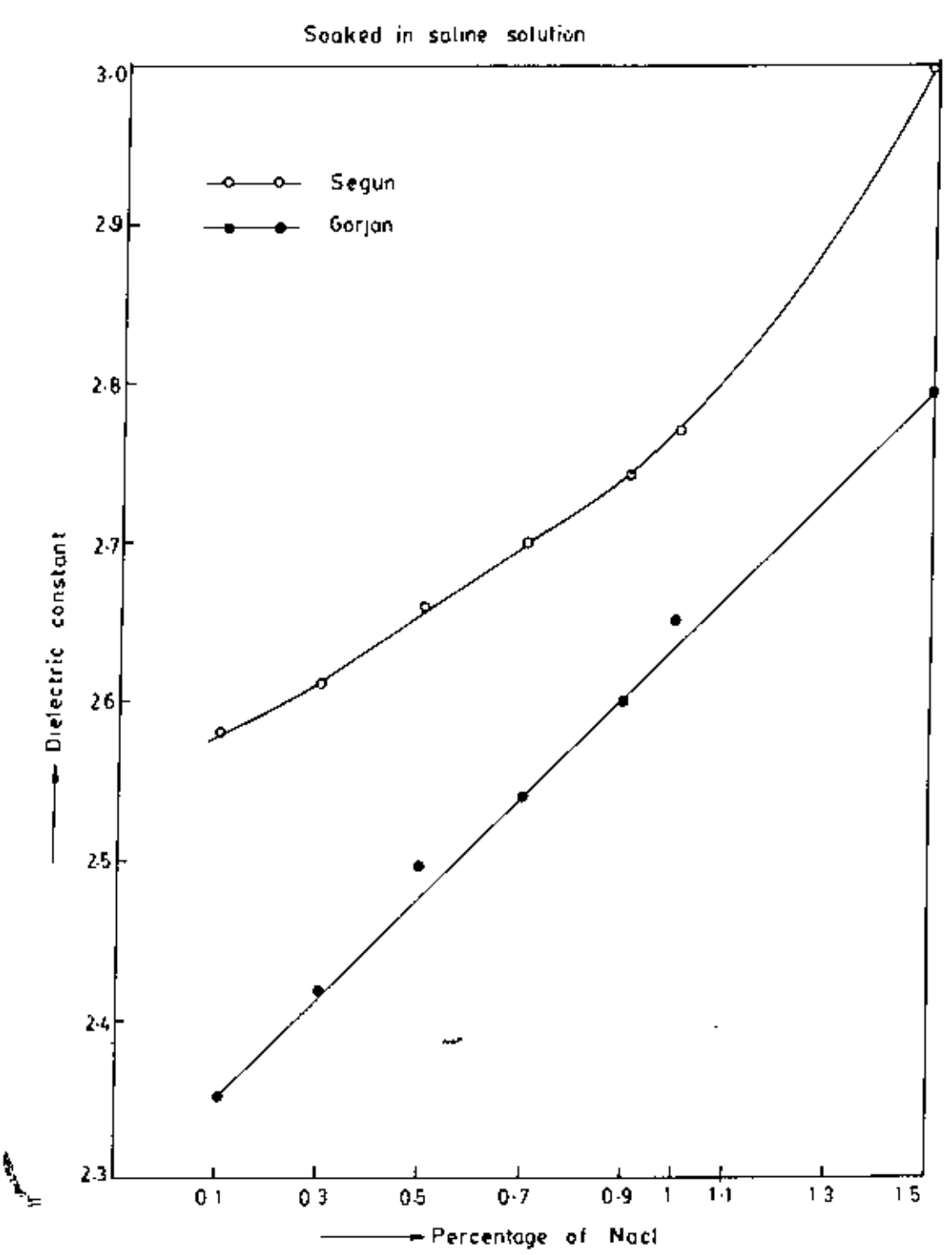

Sample soaked in distilled water for 48 hours.
Segun
Gorjan
Dielectric constant
Moisture content
3.0
2·5
2·0
1·5
1·0
9
10
11
12
13
14
15

Fig. 3


Soaked in saline solution
Segun
Gorjan
Dielectric constant
3·0
2·9
2·8
2·7
2·6
2·5
2·4
2·3
0·1
0·3
0·5
0·7
0·9
1
1·1
1·3
1·5
Percentage of Nacl

Fig·4

DISCUSSION

Wood is affected by the moisture vapour which is always present in the air. Air at any given temperature can hold so much moisture and the relative humidity on a wet day can be as such as 100 percent. All timbers tend to come to an equilibrium with the relative humidity of the surrounding air. Indoor or in dry weather, the relative humidity decreases, although it seldom falls much below 30 percent even in hot dry climate. The moisture threfore, has important effect on the wood

So, wood sample taken from oven is carefully and quickly put into glass jar. Extreme care was taken in measuring the dielectric constants.

With increasing moisture content of air the amount of water within the wood matrix increases, which itself is characterized by high dielectric values. The polar component of the cell wall and the cellulose get more freedom of rotation at higher moisture contents and contribute to a more pronounced dielectric constants. However, as the fiber saturation point approaches, the importance of the polar groups of the wood does not increasc any more because their freedom of rotation gets to a maximum.

Adsorption of salts from solution by wood is very small . A slight negative adsorption of chloride ions may takc from sodium chloride. An ionic bond is formed when one or more electrons form one atom is transferred to the other and the resulting positive and negative ions attract each other. An example is NaCl where the bond exists between Na^+ and and Cl^- ions and not betweon Na and Cl atoms.

When wood is treated with NaCl solution salts enter the cell walls to give a concentration practically as great as the bulk concentration. When

the wood is dried, water is first lost from the coarse capillary structure. The concentration of the solute in the coarse structure thus increases. Hence, solute diffuses into the cell walls in an effort to eqnalize the concentration.

In all materials continuous random vibration of molecules are noticed. The temperatnre of the material is a measure of the energies of these vibrations. The vibrations that are induced in the interior of the dielectric material are based on a rotation of the polar molecules under the influence of the external electric field. When an electric field is applied the randomly oriented dipoles align themselves in a direction opposite to that of the external field. In this ordered configuration the energy snpplied by the field is stored in the molecnles in the form of potential energy. On removal of the field the potential energy is converted into kinetic energy of disordered dipoles. The total stored energy consists of the sum of potential and kinetic energies of the rotating molecules.

The amount of energy that can be stored in the material is related to its dielectric constant. The greater the polarization of the material, the greater will be the dielectric construct.

With increasing moisture content, the amount of water within the wood matrix increases which itself is characterized by high dielectric values. On the Other hand, the polar components of the cell wall and the cellulose get more freedom of rotation at higher moisture contents and in this way also contribute to a more pronounced dielectric behavior.

CHAPTER - IV

Chapter - IV

INTRODUCTION

Properties of wood which has drawn attention for investigation, of those, thermal properties of wood is of particular interest because these properties undergo drastics changes depending on the water content. Wood is very much hygroscopic. Properties of wood again varies from one kind of tree to another that serves as a source of wood The two major kinds of wood that are extensively used as construction material in Bangladesh are Gorjan and Segun. The present work involves the study of the thermal conductivity of these wood as affected by the moisture content and salt content. This study is of practical importance because while wood caps are used as electrical switch boards, there are often short circuits due to absorption of saline water from the attached walls specially in the rainy season.

The basic formula for calculating the rate of heat flow by conduction q_{cd} under steady-state conditions was developed by Fourier in 1822 and may be expressed as follows,

$$q_{cd} = \frac{KA\,(t_2 - t_1)}{l}, \text{where,}$$

A is the area of the slab under investigation and l is its thickness. In other words, the rate of heat flow by conduction through a flat slab is proportional to the area and the temperature difference between the two surfaces. It is inversely proportional to the thickness. K is a factor called the co-efficient of thermal conductivity.

The thermal conductivity of a wood can be determined by Lees and Chorltor's method. In measuring the conductivity of such a poor conductor a thin layer of wood (slab) is used. But difficulty arises in maintaining the slab face at uniform temperature and in measuring that temperature. Lees and Chorton overcome this difficulty by placing a slab of a good conductor of exactly of the same diameter as the experimental slab on each side of the layer of poor conductor.

But the conventional Lees method have three limitations:

(i) The thermal resistance of the air gap between the specimen and the metallic dise : The conductivity of air is much lower, than that of the specimen under investigation, as a result the effect of the air gap is qnite high and cannot be neglected as is usually done.

(ii) The conductivity of the material is measured only on a fixed temperature depending on the steady state attained by the particular experimental set-up.

(iii) The effect of moisture is not taken into account which can be important for material like wood which can absorb quite a good amount of moisture and effect the thermal properties.

In the present work, a techniqne has been developed to account for this air gap by nsing specimens of two different thickness so as to cancel out the effect of air gap from the simultaneous of two equations.

DESCRIPTION OF THE APPARATUS

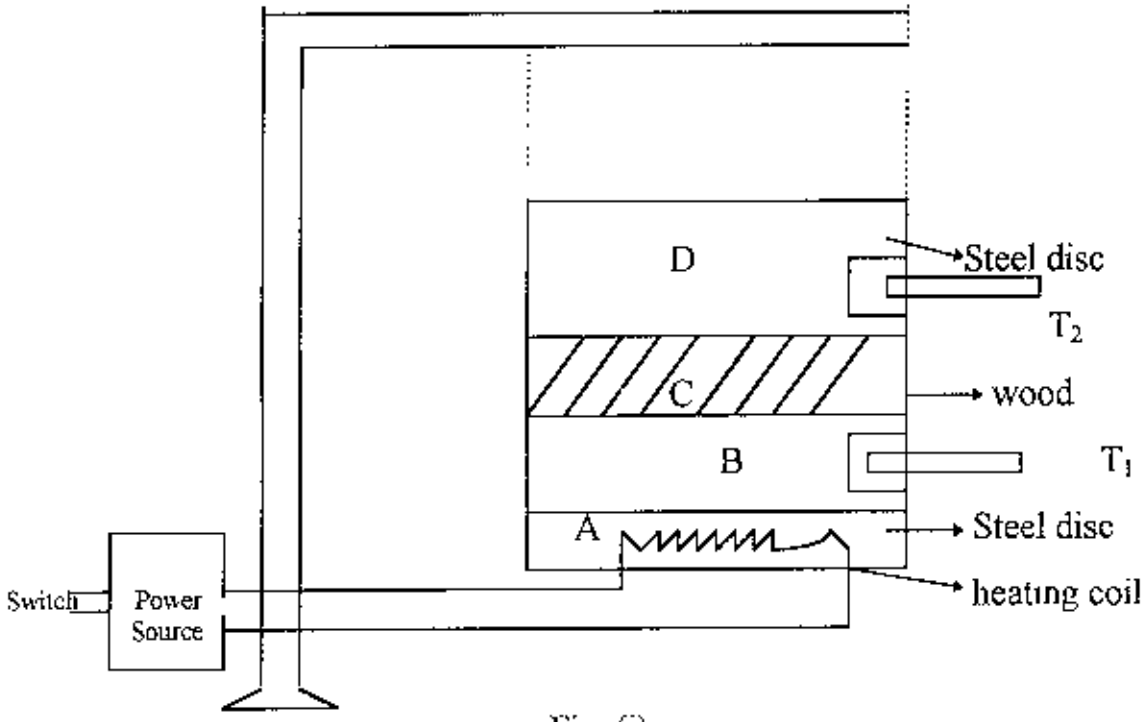


Fig. (i)

The experimental arrangement of the apparatus is shown in fig (i).

The stainless steel disc A of about 10.41 cm in diameter is snpported by means of strings from a large ring on a retort stand. A heating coil is placed on it.

B is a stainless steel disc having the same surface area as of A. A thermometer T_1, is introduced into a holes drilled in the base of B.

C is an experimental specimen (wood) in the form of a thin circular slab. There are two types of wood one is Gorjan and other is Segun. These two types of wood have two different thickness.

D is a stainless steel disc having the same surface area of B. thermometer T_2 is introduced into a holes drilled in the base of D. B and D have same diameter but having different thickness.

The whole system is suspended horizontally from a stand by means of three threads attached is to three small hooks provided symmetrically along the circumference of A.

PROCEDURE

In preparing the good quality of samples wood was cut into thin pieces. The broad faces of the specimen samples were polished by sand paper. Two these of wood, namely Gorjan and Teak (Segun) were used. Samples considered were of two different thickness -- one of thickness 3 cm (approx.) and the other 5 cm (approx.). But the diameter of these samples were same as stated below :

Sample	Thickness	Thickness	Diameter
Gorjan	3 cm (approx.)	5 cm (approx.)	10.4 cm (approx.)
Segun	3 cm (approx.)	5 cm (approx.)	10.4 cm (approx.)

PROCESS I :

Dry samples of two types of wood namely Gorjan and Teak (Segun) were considered. Then the thickness d_1 {3 cm (approx.)} and d_2 {5cm (approx.)} of the two types of samples were accurately determined with the help of a screw-gauge. Weighed the disc D to determine its mass and measured diameter ($D' = 2r$) of the sample specimen C with a scale. The experimental set np is shown in fig. (1).

To start with samples of Gorjan or Segun wood state of thickness 3 cm (approx.) were put in place. When switched on, the heat passed from power source into A. After a linear steady state temperature gradient is set up across the slab the amount of heat required to maintain that gradient per unit of the time becomes constant. When the temperature θ_1, θ_2 became steady, they were noted. Then stopped the supply of current and removed the discs A and D. With the disc

C still on top of D, the disc D was heated by the heating source under it till its temperature was about 10^0 C above the steady temperature θ_2. Then, heating source was removed and allowed C to cool. By keeping C on it, it was ensured that D loses heat in the same surrounding as in the first phase of experiment when it gained heat. The temperature was noted every five minutes until the temperature went down by about 10^0 C from θ_2.

A graph was drawn with the time of cooling as abscissa and the temperature of D as ordinate A, tangent was drawn at a point at which the value of the ordinate is θ_2 . The slope of this tangent gives the rate of cooling $d\theta/dt$ at θ_2.

With these results the value of conductivity at a temperature was calculated.

By changing the applied voltage at the power source i.e the heat source another value of conductivity at difference temperatures were obtained. Three different voltages were considered. Thus, for thickness d_1, three different values of conductivity for Gorjan wood and three different values of conductivity for Segun wood were obtained. Similarly, for samples of 5 cm (approx.) thickness similar measurements were carried out. Thus three different conductivity K values for Gorjan wood and three K values for Segun wood at three different temperatures were obtained.

PROCESS II :

Three samples of Gorjan wood and three samples of Segun (the diameters and thickness of the samples of both types of wood were nearly the same as the process I) were studied. The weight of these samples were separately measured.

These samples were then soaked in 1 % . NaCl Solution for 48 hours. After soaking, those samples were polished by sand paper and weighed. The thermal conductivity of these samples at different temperatures were measured by the same procedure as followed in Process I. In order to study the effects of Nacl solution on wood conductivity use 3 samples of different thickness and these were soaked in 1 % Nacl solution. Using these Nacl solution soaked samples values of three different conductivity for Gorjan wood and three for Segun wood were measured.

PROCESS III :

In order to study the effect of higher concentration of Nacl, the wood samples of same dimensions were soaked in 1.5% and 2% NaCl solution for 48 hours. By similar measurements, three different K values, each for Gorjan and for Segun wood were obtained.

THEORY :

In measuring the conductivity of such a bad conductor (wood) a thin layer (slab) of the wood material is used by placing a slab of good conductor of exactly the same diameter as the experimental slab on each side of the layer of poor or bad conductor. In fig.1, let C be the disc of a poor conductor (wood) and B and D be the stainless steel discs one on either side of C. A is a stainless steel disc, which consist of a heating element from which heat passes through B to C and D.

When heat is passed through A, then B is warmed up by the heat conducted by A. The specimen C is a thin disc and it is warmed by B. After sometime D is warmed by C.

When the rate of flow of heat through C equals the heat lost from D by radiation and convection then a steady state will be reached.

If, θ_1 = temperature of B in the steady state (for d_1 thickness).

θ_2 = temperature of D in the steady state (for d_1 thickness).

A = area of cross-section of the specimen C.

d_1 = thickness of the specimen.

d' = thickness of the air film.

d_2 = Another thickness of the specimen.

k' = thermal conductivity of the air film.

k_1 = thermal conductivity of the specimen.

θ_1' = Temperature of B in the steady state (when thickness = d_2).

θ_2' = Temperature of D in the steady state (for d_2 thickness).

m = Mass of the disc D.

S = sp. heat of the material of D.

Area of cross section, $A = \pi(D/2)^2$ sq. cm.

$$= \frac{\pi D^2}{4} \text{ sq. cm.}$$

D′ = Diameter of the specimen dise, C.

Then the quantity of heat conducted per second, throngh the bad condncting slab C is,

$$Q = \frac{A(\theta_1 - \theta_2)}{\frac{d'}{k'} + \frac{d_1}{k_1}} = \frac{Ak_1(\theta_1 - \theta_2)}{\alpha + d_1} \quad \text{-------- (i)}$$

Where, $\alpha = \left(\frac{d'}{k'}\right)k_1$

In the steady state, this heat Q is radiated per second from the upper disc D.

let, $\frac{d\theta}{dt}$ be its rate of cooling at its temperature θ_2, then the heat lost (radiated) per second from D is,

$$ms\frac{d\theta}{dt} \text{ (for } d_1 \text{ thickness) ..... (2)}$$

from equation (1) and equation (2), we get,

$$ms\frac{d\theta}{dt} = \frac{k_1A(\theta_1 - \theta_2)}{\alpha + d_1} \text{ ..... (3)}$$

for another thickness we get,

$$ms\frac{d\theta'}{dt} = \frac{k_1A(\theta'_1 - \theta'_2)}{\alpha + d_2} \text{ ..... (4)}$$

Let, $x = \theta_1 - \theta_2$ and $y = \theta'_1 - \theta'_2$

Now dividing eqaton (3) by (4), then we get,

$$\frac{\frac{d\theta}{dt}}{\frac{d\theta'}{dt}} = \frac{x}{y} \times \frac{\alpha + d_2}{\alpha + d_1}$$

$$\frac{y}{x}\left\{\left(\frac{d\theta}{dt}\right) / \left(\frac{d\theta'}{dt}\right)\right\} = \frac{\alpha + d_1 + (d_2 - d_1)}{\alpha + d_1}$$

or, $= \frac{\alpha + d_1}{\alpha + d_1} + \frac{d_2 - d_1}{\alpha + d_1}$

$$\text{or, } \frac{y}{x}\left\{\left(\frac{d\theta}{dt}\right)/\left(\frac{d\theta'}{dt}\right)\right\} = 1 + \frac{d_2 - d_1}{\alpha + d_1}$$

$$\text{or, } \frac{d_2 - d_1}{\alpha + d_1} = \frac{y}{x}\{(\frac{d\theta}{dt}) / (\frac{d\theta'}{dt})\} - 1$$

$$\frac{1}{\alpha + d_1} = \frac{1}{d_2 - d_1}\{\frac{y}{x}.\frac{\frac{d\theta}{dt}}{\frac{d\theta'}{dt}} - 1\} \text{ ------ (5)}$$

Now substituting this value in equation (i) it becomes,

$$ms\ \frac{d\theta}{dt} = k_1 Ax.\frac{1}{d_2 - d_1}[\frac{y}{x}\{(\frac{d\theta}{dt}) / \frac{d\theta'}{dt}\} - 1]$$

$$\text{or } k_1 x[\frac{y}{x}\{(\frac{d\theta}{dt}) / \frac{d\theta'}{dt}\} - 1] = (d_2 - d_1).\frac{d\theta}{dt}.\frac{ms}{A}$$

$$\text{or } k_1[y\{\frac{d\theta}{dt} / \frac{d\theta'}{dt}\} - x] = (d_2 - d_1)..\frac{ms}{A}\ \frac{d\theta}{dt}$$

$$\text{or } k_1[y\{\frac{d\theta}{dt} / \frac{d\theta'}{dt}\} - x] = \frac{1225.8 \times 0.116}{85.1775} \times (d_2 - d_1).\frac{d\theta}{dt}$$

$$\text{or } k_1[y\{\frac{d\theta}{dt} / \frac{d\theta'}{dt}\} - x] = 1.6693(d_2 - d_1).\frac{d\theta}{dt}$$

$$\text{or } k_1 = [1.6693(d_2 - d_1)\ \frac{d\theta}{dt}] / [(\theta_1' - \theta_2')\{\frac{d\theta}{dt} / \frac{d\theta'}{dt}\} - (\theta_1 - \theta_2)]$$

$$[\ \therefore\ y = \theta', -\theta_2', x = \theta_1 - \theta_2\ ]$$

Where, k_1 is the thermal Conductivity of the specimen. and its unit is cal cm^{-1} Sec^{-1} $0c^{-1}$

RESULTS

The Value of thermal conductivity of Gorjan and Segun wood were determined under different temperatures. The results are presented in Table 1 and 2 and these value are graphically plotted in fig (1) & (2)

Table - 1 (Gorjan wood)

Sample Gorjan wood	Mean Temperature °c	Thermal Conductivity cal cm^{-I-} sec^{-1} $°c^{-1}$
Dry Sample	82.5	0.000512
	93	.000527
	104.5	.000535
Soaked in 1% Nacl solution	89.5	.000610
	102	.00062
	112.5	0.00063
Soaked in 1.5% Nacl solution	96.5	0.00068
	103	.000693
	115.5	0.000704
Soaked in 2% Nacl solution	103	0.00077
	109.5	0.00078
	118	0.00079

Table - 2 (Segun wood)

Sample Segun	Mean Temperature °c	Thermal Conductivity cal cm^{-1} sec^{-1} $°c^{-1}$
Dry Sample	90.5	0.00056
	101.5	.000574
	113	.00058
Soaked in 1% Nacl solution	96.5	0.000648
	107	0.00066
	117.5	.000676
Soaked in 1.5% Nacl solution	101.5	0.000706
	113	0.000718
	124.5	0.000734
Soaked in 2% Nacl solution	108	0.000795
	117.5	.000805
	126	0.00081

These result shows that thermal conductivity increases with increasing temperature.

The value of thermal conductivity for these samples soaked in Nacl solution were found to be that the thermal conductivity increases with increasing saline concentration .The results are presented in Table (3) and Table (4) and graphically plotted in fig (3) and (4)

Table - 3 (Gorjan Wood)

Saline Concentration	Thermal conductivity at different temperatures cal cm^{-1} sec^{-1} $^{o}c^{-1}$					
1%	.00060	.000606	.00061	.000615	.00062	.00063
1.5%	.00069	.000703	.000705	.00068	.000693	.000704
2%	0.00075	.00076	.00077	.000775	.00078	.00079

Table - 4 (Segun Wood)

Saline Concentration	Thermal conductivity at different temperatures cal cm^{-1} sec^{-1} $^{o}c^{-1}$					
1%	.000628	.000645	.000652	.000648	.00066	.000676
1.5%	.000707	.000716	.00072	.000706	.000718	.000734
2%	.00077	.000786	.000795	.000797	.00085	.00081

Thermal conductivity increases with increasing saline concentration .

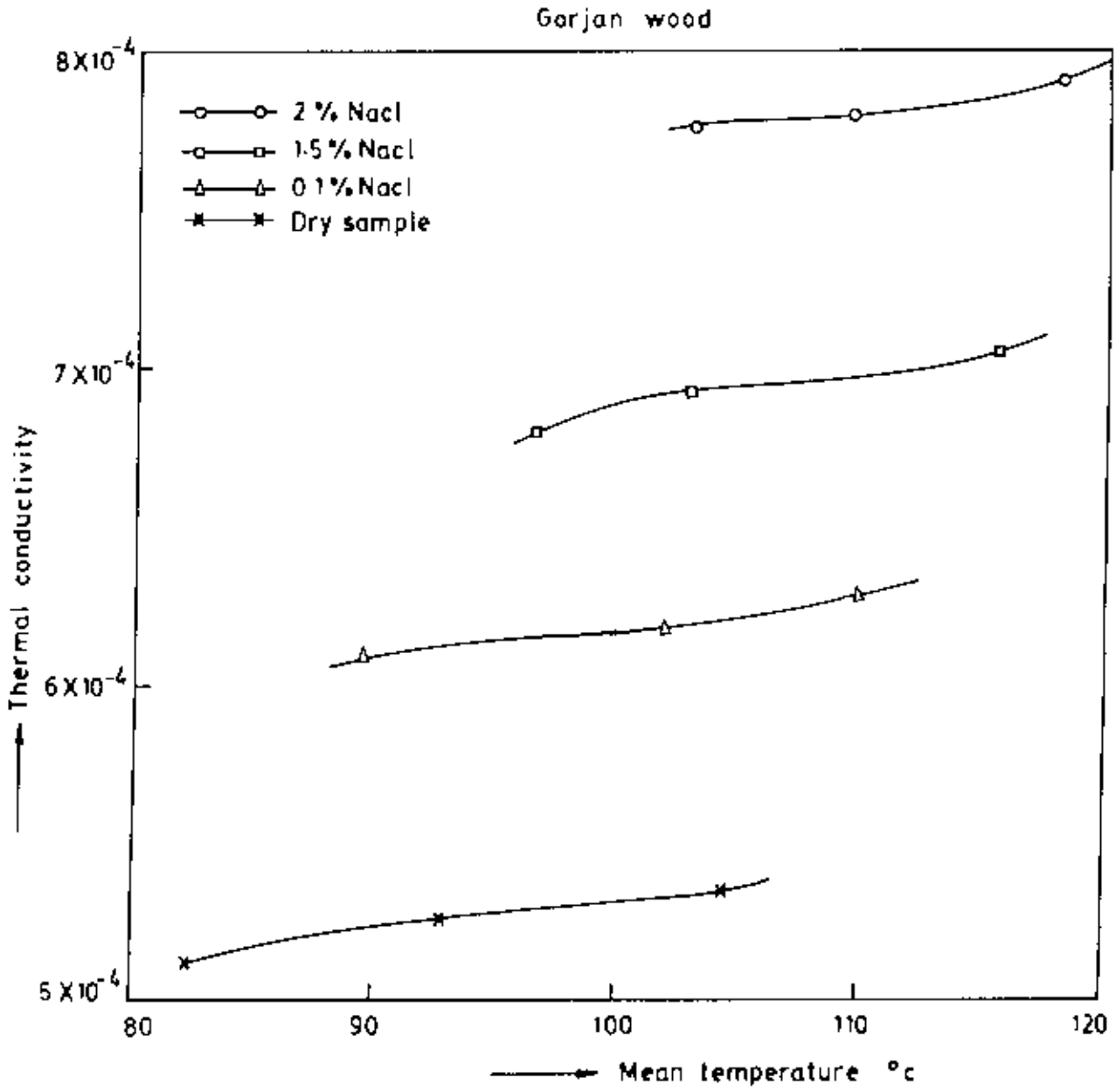

Garjan wood
8X10⁻⁴
7X10⁻⁴
6X10⁻⁴
5X10⁻⁴
2 % Nacl
1·5 % Nacl
0·1 % Nacl
Dry sample
Thermal conductivity
80
90
100
110
120
Mean temperature °c

Fig. 4·1

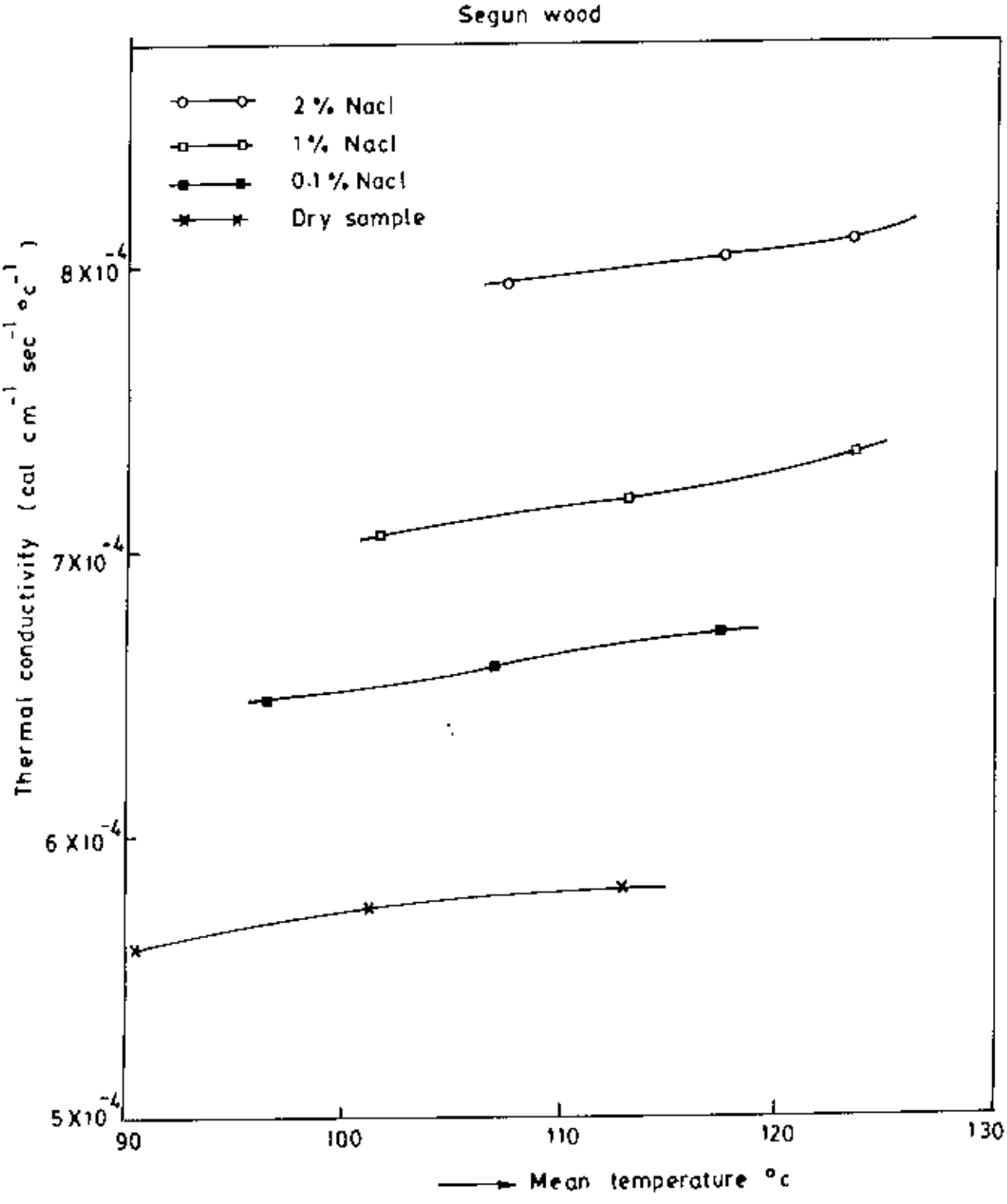

Segun wood
2 % Nacl
1 % Nacl
0.1 % Nacl
Dry sample
Thermal conductivity (cal cm⁻¹ sec⁻¹ °c⁻¹)
8X10⁻⁴
7X10⁻⁴
6X10⁻⁴
5X10⁻⁴
90
100
110
120
130
Mean temperature °c

Fig. 2)

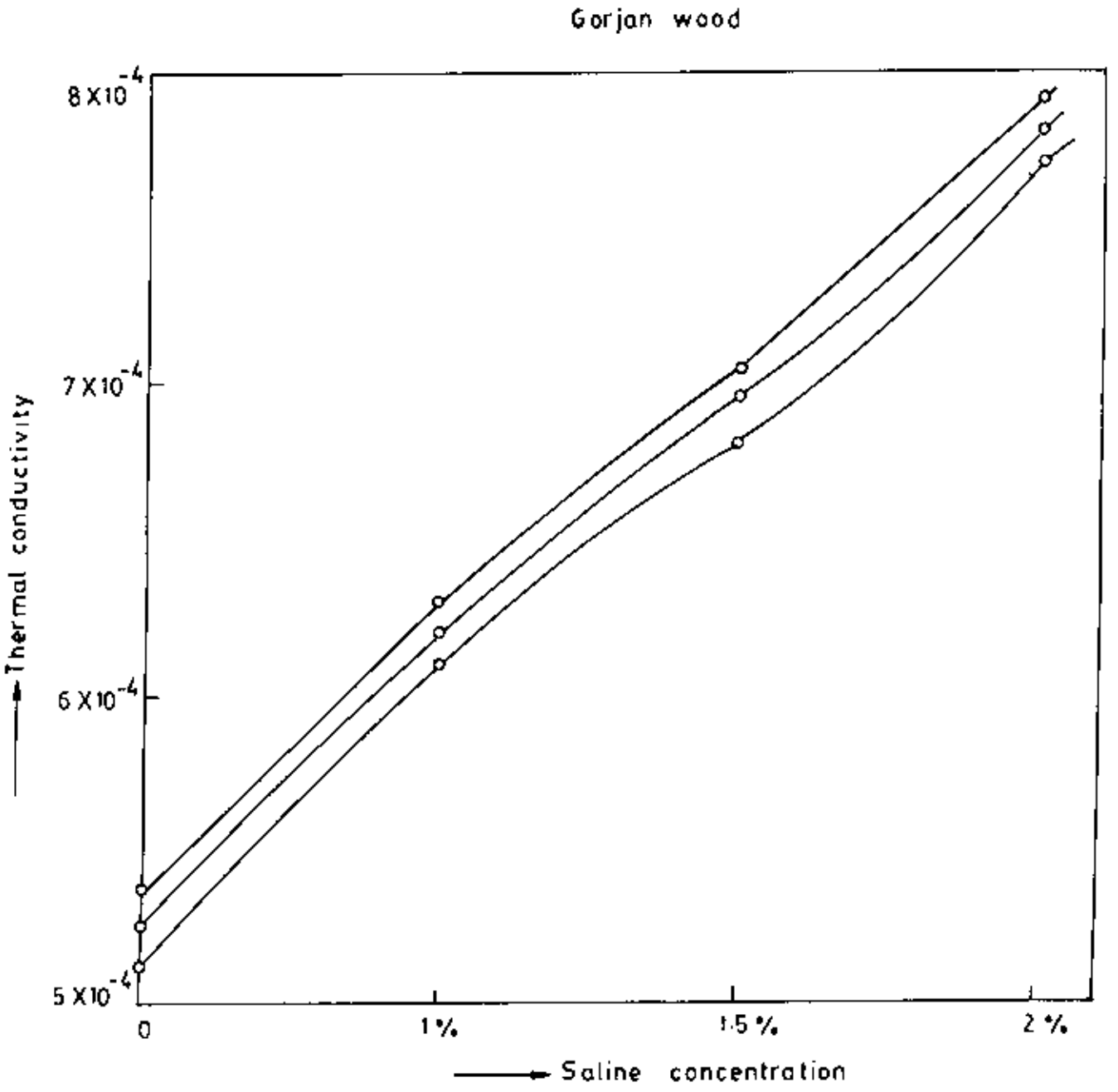

Gorjan wood
8 X10^-4
7 X10^-4
6 X10^-4
5 X10^-4
Thermal conductivity
0
1%
1·5 %
2 %
Saline concentration

Fig. 3 :

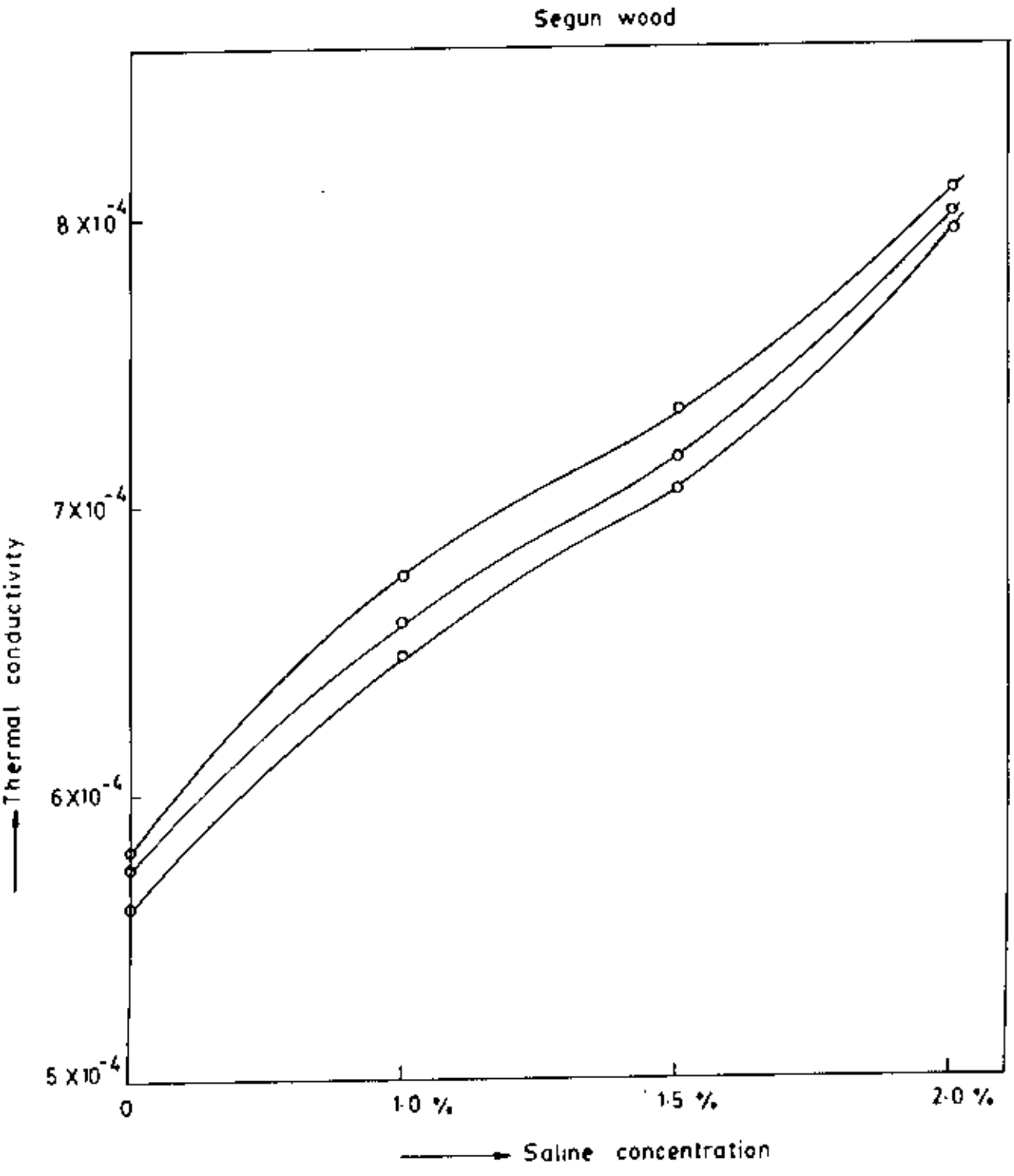

Segun wood
8 X10-4
7X10-4
6X10-4
5 X10-4
Thermal conductivity
0
1·0 %
1·5 %
2·0 %
Saline concentration

Fig 41

DISCUSSION

Wood is a composite material. It is composed of cells. When wood contains just enough water to saturate the cell walls it is said to be at fiber saturation point. The water in the cell walls is known as hygroscopic water. Wood can absorb and retain within itself a certain amount of this type of moisture and can actually pick it up from the surrounding atmosphere. Therefore, the amount of water within the cells, even of seasoned wood, depends on the relative humidity of the area to which the piece is exposed. The amount of water also depends to some extent on whether the wood is sapwood or heartwood. When a piece of wood is exposed to air, evaporation takes place and continues until there is a balance between the water in the wood and the moisture in the air. Cell walls consist essentially of cellulose in the form of fibrils which are long spiral strands. Some lignin is also present. Obviously, the cellulose itself is a good insulator and the conductivity of wood depends on the moisture content.

The thermal conductivity of water is 0 00136 cal cm^{-1} ^{o}c sec^{-1} which is more than ten times the K value of most of the insulating materials for temperature below $100^{0}C$. If moisture is present in insulation one would expect the thermal conductivity, K value to be greater than that of the dry material. Moisture may be added by absorption of water vapour in the insulating material. Then the amount of water present depends upon the relative humidity and the temperature of the ambient air. The effect of moisture content on the K value is very difficult to determine accurately, because in making a thermal conductivity test a temperature difference between the two sides of the sample is maintained and moisture always tends to migrate from the warmer to the colder side. This difficulty leads to uncertain resnlts but sufficient experimental work has been

done to show that an increase in moisture content always means an increase in the K value of insulators. But here, the thermal conductivity of wood was investigated under salinity.

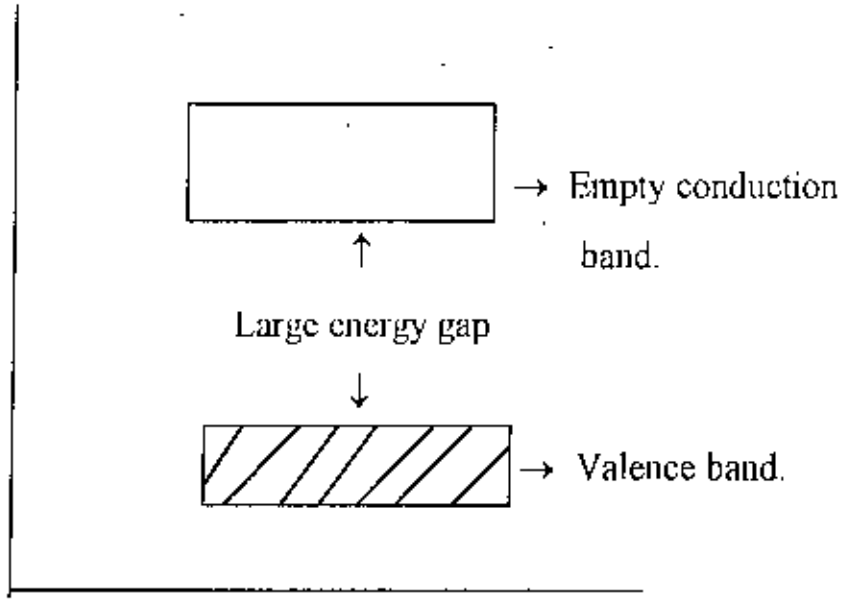
When wood is treated with concentrated salt solutions then the salts enter the cell walls to give a concentration practically as great as the bulk concentration. Some ions are formed in the covalently bound matrix of the wood when one or more electrons from one atom may transfer to the other and the resulting positive and negative ions attract each other. An example, is NaCl, where the bond exists between Na^+ and Cl^- ions. Most of the atoms of different elements do not have their outermost shells completely filled. i.e. they do not have eight electrons in their outermost orbit. The electrons occupying the outermost orbit or shell of an atom are called valence electrons. They determine the chemical and electrical properties of the element. Element deficient in valence electrons are highly active in the sense that they are always ready to chemically combine with other elements. Those elements which have one or two valence electrons are good conductors of electricity. Ionic Bonds occur between two different atoms and are due to permanent transfer of valence electrons from one atom to another. It is a very strong bond. Such bonds are formed between sodium and chlorine atoms during the formation of sodium chloride.

The electrons in the outermost shell of an atom are called valence electrons. They have least binding energy though their orbital energy is maximum. It is these electrons which are most affected when a number of atoms are brought very close together as during the formation of a solid. The energy band occupied by the valence electrons is called the valence band. It may be either completely - filled or partially - filled with electrons but can never be empty.

The electrons which have left the valence band are called conduction electrons. They practically leave the atom or are only weakly held to the nucleus. The band occupied by these electrons is called the conduction band. It may either be empty or partially filled with electrons.

Current flow occurs in a given material when a voltage of suitable magnitude is applied to it which causes the charge carrier within the material to move in a desired direction. This may be due to the process i.e. electron motion and hole transfer. In electron motion, free electrons in the conduction band are moved under the influence of the electric field set up by the applied voltage.

But insulators are those materials in which valence electrons are bound very tightly to their parent atmos thns requiring very large electric field to remove them from the attraction of their nuclei.



When the electron jump from the valence band to the conduction band then degrees of freedom is increased and then the conductivity is also increased.

There are more free molecules in the interstitial space of the solute or of the wood. These relatively free molecules can participate in the conduction of heat due to the increased number of degrees of freedom.

The presence of water molecules or salt molecule most likely alter the strength of the ionic bond that exists in materials like wood. This may effectively change the vibrational modes in the solid. In fact, there is some increase in the modes of vibration, which contribute to the increase of conductivity with increasing moisture content.

CHAPTER - V

Chapter- V

CONCLUSION

Although wood is a very useful construction material, its physical properties are not very well studied. One reason for this is a complexity of wood which has a composite structure and is of different kinds depending on the nature of the plant source, its age, the processing of the wood, its moisture content etc. However, it is important to know the thermal and electrical properties of wood specially for its use as an insulator in electrical boards. In the present work two locally available woods Gorjan and Segun have been selected for the measurements of their dielectric constant and thermal conductivity as affected by moisture content and salt content. A new technique has been developed to improve upon the conventional technique of measuring thermal conductivity of bad conductor by lees method. The thermal conductivity of both types of wood was found to increase with salt content, the result being higher in the case of segun wood. The temperature dependence of wood also shows an increase with increasing temperature.

Dielectric constant of wood measured at 1952 Hz was found to vary from 1.3 to 3. For Gorjan the range between 1.3 to 2.8, for Segun the corresponding range is 1.3 to 3 which depends on the salt content. The introduction of salt ions into the wood matrix increase the dielectric constant by a factor of two. And this increase is quite expected, due to the presence of additional ions. The results are interpreted in the light of existing theories. The explanations of the result in terms of formal quantitative mathematical theories, however, has not been possible, because of the complexity of wood and its composite nature of the wood. Further work is therefore needed to obtaine a more complete understanding of the mechanism involved in thermal and dielectric properties of wood.

APPENDIX

DATA FOR THE MEASUREMENT OF DIELECTRIC CONSTANT OF TWO TYPES OF WOOD.

Soaked in Distilled water for 48 hours
Temperature 122 ^{0}C

Sample	Before Soaking W_1gm	After Soaking w_2 gm	Water absorb	Time for drying	Oven dry weight w_3 gm	Moisture content	C nf	(air) C_0 nf	Dielectric Constant c --- c_0
Gorjan	3 6467	5.5852	53 16	1	4 1576	14.01	0.114	0.049	2.32
	3 6466			2	4 1261	13.15	0.109	0.051	2.13
	3 6463			3	4.0911	12 20	0.107	0 055	1.945
	3 6460			4	4.0474	11 01	0.105	0 060	1 75
	3 6456			5	4.0174	10 20	0.104	0 067	1.55
	3 6450			6	3.9734	9 01	0.102	0 078	1.3
Segun	3 2395	5 0589	56.16	1	3.7410	15.50	0 010	0.004	2.5
	3 2390			2	3 6940	14.10	0 007	0.003	2.3
	3.2388			3	3 6566	12.90	0 006	0.003	2
	3 2385			4	3.6271	12 00	0.003 7	0.002	1.85
	3.2382			5	3.5947	11 01	0.003	0.002	1 5
	3 2379			6	3.5487	9.60	0.004	0 003	1.3

Soaked in 0.1% NaCl Solution for 48 hours

Sample	Before Soaking W_1gm	After Soaking w_2 gm	Water absorb	Time for drying	Oven dry weight w_3 gm	Moisture content	C nf	(air) C_0 nf	Dielectric Constant c --- c_0
Gorjan	3.6568	5 4669	49.50	1	4 1742	14 15	0.127	0 054	2 35
	3.6567			2	4.1357	13 10	0.121	0 055	2 2
	3 6565			3	4.0916	11 90	0 120	0.06	2
	3.6563			4	4.0639	11.15	0 118	0.065	1 81
	3 6560			5	4.0252	10.10	0 117	0 073	1.6
	3.6561			6	3.9888	9 1	0 115	0.083	1.38
Segun	3 2015	4 8662	52%	1	3 7041	15 70	0 031	0.012	2 58
	3 2012			2	3 6491	14 01	0.026	0.011	2.36
	3.2008			3	3 6233	13 20	0.022	0.010	2.2
	3.2005			4	3.5925	12.25	0 018	0.009	2
	3.1998			5	3 5520	11 01	0.016	0.009	1.77
	3 1995			6	3 5130	9.8	0 012	0.008	1 5

Soaked in 0.3% NaCl Solution for 48 hours

Sample	Before Soaking W_1 gm	After Soaking w_2 gm	Water absorb	Time for drying	Oven dry weight w_3 gm	Moisture content	C nf	(air) C_0 nf	Dielectric Constant $\frac{C}{C_0}$
Gorjan	3.6553	5.334%	50 15%	1	4.1674	14.01	0.137	0 056	2 42
	3.6550			2	4.1264	12.90	0.134	0 060	2 25
	3.6549			3	4 0825	11.70	0 131	0 064	2.05
	3 6546			4	4 0511	10 85	0.129	0.069	1.85
	3 6542			5	4.0199	10.01	0.126	0.076	1.65
	3.6540			6	3.9832	9.01	0.123	0.087	1 4
Segun	3 2096	4 8529	51.20%	1	3 7070	15.50	055	0.021	2.61
	3 2091			2	3.6663	14 25	0.054	0.022	2.45
	3.2088			3	3 6339	13.25	0.047	0.021	2.25
	3 2083			4	3 5997	12 20	0.041	0.020	2.05
	3.2081			5	3.5674	11 10	0.037	0.020	1.85
	3.2080			6	3 5191	9.7	0.035	0 023	1 52

Soaked in 0.5% NaCl Solution for 48 hours

Sample	Before Soaking W_1 gm	After Soaking w_2 gm	Water absorb	Time for drying	Oven dry weight w_3 gm	Moisture content	C nf	(air) C_0 nf	Dielectric Constant $\frac{C}{C_0}$
Gorjan	3.6486	5.4375	49.03%	1	4 1521	13 80	0 15	0 060	2 5
	3 6482			2	4 1042	12.50	0 149	0.065	2.3
	3 6476			3	4 0670	11.50	0.147	0.07	2.1
	3.6462			4	4.0363	10 70	0.145	0 076	1.9
	3.6460			5	4.0069	9.90	0.144	0 084	1.7
	3.6455			6	3.9743	9.02	0.142	0 094	1 5
Segun	3.2088	4.8164	50 10%	1	3.6981	15.25	0.064	0 024	2.66
	3 1972			2	3 6528	14 25	0 058	0.023	2 52
	3.1968			3	3 6091	12.90	0.052	0 023	2.26
	3 1967			4	3.5723	11 75	0 045	0 022	2.04
	3.1960			5	3.5411	10 80	0.037	0.020	1.85
	3.1958			6	3.5025	9 6	0.030	0.019	1.57

Soaked in 0.7% NaCl Solution for 48 hours

Sample	Before Soaking W_1 gm	After Soaking w_2 gm	Water absorb	Time for drying	Oven dry weight w_3 gm	Moisture content	C nf	(air) C_0 nf	Dielectric Constant c --- c_0
Gorjan	3.6489	5 3559	46 78%	1	4.1451	13.60	0.140	0.055	2.54
	3 6484			2	4 0953	12.25	0.127	0.054	2 35
	3 6480			3	4 0821	11 90	0 125	0.058	2.15
	3.6472			4	4.0338	10 60	0.123	0 063	1.95
	3 6465			5	4.0056	9 85	0.123	0.070	1 75
	3 6457			6	3 9756	9 05	0.121	0.078	1 55
Segun	3 2096	4.7668	48.52%	1	3 6913	15.01	0.073	0.027	2 7
	3.2092			2	3 6649	14.20	0 072	0 028	2.57
	3.2088			3	3.6227	12 90	0.070	0.030	2.33
	3.2084			4	3.5934	12 00	0.069	0 032	2.15
	3 2082			5	3.5562	10 85	0.067	0.035	1.91
	3 2080			6	3 5207	9 8	0 065	0.039	1.66

Soaked in 0.9 % NaCl Solution for 48 hours

Sample	Befor Soaking W_1 gm	After Soaking w_2 gm	Water absorb	Time for drying	Oven dry weight w_3 gm	Moisture content	C nf	(air) C_0 nf	Dielectric Constant c --- c_0
Gorjan	3.6579	5.2458	43.41%	1	4 1517	13.50	0 172	0.066	2 6
	3.6572			2	4.0997	12 10	0 167	0 069	2.42
	3.6569			3	4.0664	11 20	0.165	0.075	2.2
	3 6561			4	4 0399	1050	0.162	0 081	2
	3 6555			5	4 0119	9 75	0.153	0.085	1.8
	3.6553			6	3.9861	9.05	0 151	0.094	1 6
Segun	3 2129	4 6625	45 12%	1	3.6868	14.75	0.178	0.065	2 74
	3 2125			2	3.6558	13.80	0 174	0.067	2 59
	3.2118			3	3 6237	12.80	0.168	0.070	2.4
	3 2117			4	3 5922	11.85	0 165	0.075	2.2
	3.2110			5	3.5545	10.70	0 155	0 079	1 94
	3.2098			6	3.5179	9 6	0 151	0.088	1.71

Soaked in 1 % NaCl Solution for 48 hours

Sample	Before Soaking W_1 gm	After Soaking w_2 gm	Water absorb	Time for drying	Oven dry weight w_3 gm	Moisture content	C nf	(air) C_0 nf	Dielectric Constant c --- c_0
Gorjan	3 6582	5.1256	40.11%	1	4 1465	13 35	0.190	0.072	2,65
	3 6580			2	4.1006	12 10	0.186	0 076	2,45
	3 6577			3	4 0655	11.15	0 181	0.080	2.25
	3.6575			4	4 0415	10.50	0 175	0 085	2.05
	3.6570			5	4 0154	9 80	0.172	0 092	1.85
	3 6571			6	3.9897	9 10	0 168	0 102	1.65
Segun	3.2248	4 5975	42 57%	1	3 7004	14.75	0.098	0 035	2 8
	3 2240			2	3 6398	12.90	0 097	0 037	2.6
	3.2238			3	3 6299	12 60	0.095	0 039	2.43
	3.2230			4	3 5936	11 50	0.090	0 040	2 2
	3 2219			5	3.5601	10 50	0.092	0 046	2
	3 2210			6	3 5269	9 50	0.091	0 052	1.75

Soaked in 1.5 % NaCl Solution for 48 hours

Sample	Befor Soaking W_1 gm	After Soaking w_2 gm	Water absorb	Time for drying	Oven dry weight w_3 gm	Moisture content	C nf	(air) C_0 nf	Dielectric Constant c --- c_0
Gorjan	3.6582	5 0673	38.52%	1	4 1301	12.90	0 199	0 071	2.8
	3 6580			2	4 1060	12.25	0 198	0 073	2.71
	3.6578			3	4 0784	11 50	0 194	0.076	2.55
	3.6575			4	4.0561	10.90	0.195	0 081	2.4
	3 6572			5	4.0265	10.10	0 193	0 09	2.14
	3 6570			6	3 9916	9.15	0 191	0.103	1 85
Segun	3.2270	4.5210	40.10%	1	3 7013	14.70	0 123	0.041	3
	3 2265			2	3.6540	13.25	0 127	0 045	2.82
	3 2260			3	3.6389	12 80	0 128	0 049	2.62
	3.2258			4	3.6064	11.80	0 132	0.055	2.4
	3 2257			5	3 5643	10.50	0 135	0.062	2 17
	3 2253			6	3 5317	9.5	0 138	0 072	1.91

DATA SHEET

FOR

SEGUN WOOD

Air gap thickness

Calculation

For Segun Wood :

We know, ms $\frac{d\theta}{dt} = \frac{KA(\theta_1 - \theta_2)}{\alpha + d_1}$ ..... (1)

and , ms $\frac{d\theta}{dt} = \frac{KA(\theta'_1 - \theta'_2)}{\alpha + d_2}$ ..... (2)

Where d_1 and d_2 are specimen thickness
and α = air gap thickness.

Now from eq^n (1) and (2) we get,

$$K = \frac{1{\cdot}6693(d_2 - d_1)\frac{d\theta}{dt}}{(\theta'_1 - \theta'_2)\left[\left\{\frac{d\theta}{dt} / \frac{d\theta'}{dt}\right\}\right] - (0_1 - \theta_2)} \quad \ldots\ldots(3)$$

For dry sample,

$V = 10$ volt

$d_2 - d_1 = (5 - 3)$ cm $= 2$ cm

$\frac{d0}{dt} = 0\ 00486$

$\frac{d\theta'}{dt} = 0\ 0042$

$(\theta_1 - 0_2) = 45$

$(0'_1 - \theta'_2) = 64$

Substituting this value in eq^{n} (3) Then we get,

$$K = \frac{1.6693 \times 2 \times 0.00486}{64 \times \frac{0.00486}{0\ 0042} - 45}$$

$$= 0.000558 \text{ cal cm}^{-1} \text{ Sec}^{-1\ O}\text{c}^{-1}$$

Putting this value in eq^{n} (1) then we get,

$$\alpha = \frac{KA(\theta_1 - 0_2)}{ms \frac{d\theta}{dt}} - d_1$$

$$= \frac{0.000558 \times 45 \times 85.1775}{1225.8 \times 0.116 \times 0.00486} - 3$$

$$= 0.0973 \text{ cm}$$

$\therefore$ air gap thickness = 0.0973 cm

SEGUN WOOD

Table - 1
(dry sample)

Specimen thickness d_1 cm	Voltage (volt)	$\frac{d\theta}{dt}$	$(\theta_1-\theta_2)$	$K = \frac{1.6693\,(0.0973 + d_1)}{(\theta_1 - \theta_2)} \frac{d\theta}{dt}$ cal cm^{-1} Sec^{-1} $^{o}c^{-1}$
3 0	10	0.00486	45	0 00055
3.1	11	0.00482	46	0.00056
3.2	12	0.0049	47	0.000574

Table-2
(dry sample)

Specimen thickness d_2 cm	Voltage (volt)	$\frac{d\theta'}{dt'}$	$(\theta'_1-\theta'_2)$	$K = \frac{1.6693\,(0.0973 + d_2)}{(\theta'_1 - \theta'_2)} \frac{d\theta'}{dt'}$ cal cm^{-1} Sec^{-1} $^{o}c^{-1}$
5.0	10	0.0042	64	0 00056
5.1	11	0.0043	65	0.000574
5.2	12	0.0044	66	0.00058

Table-3
(Treatment with 1% Nacl Solution)

Specimen thickness d_1 cm	Voltage (volt)	$\frac{d\theta}{dt}$	$(\theta_1-\theta_2)$	$K = \frac{1.6693\,(0.0973 + d_1)}{(\theta_1 - \theta_2)} \frac{d\theta}{dt}$ cal cm^{-1} sec^{-1} $^{o}c^{-1}$
3.1	10	0.00494	42	0.000628
3.1	11	0.00508	42	0.000645
3.25	12	0.00502	43	0.000652

Table-4
(Treatment with 1% NaCl Solution)

Specimen thickness d_2 cm	Voltage (volt)	$\frac{d\theta'}{dt'}$	$(\theta'_1-\theta'_2)$	$K=\frac{1.6693\,(0\,0973+d_2)}{(\theta'_1-\theta'_2)}\frac{d\theta'}{dt'}$ cal cm^{-1} sec^{-1} $^{o}c^{-1}$
5.1	10	0.00456	61	0.000648
5.1	11	0.00476	62	0.000666
5.2	12	0.00474	63	0.000676

Table-5
(Treatment with 1.5% NaCl Solution)

Specimen thickness d_1 cm	Voltage (volt)	$\frac{d\theta}{dt}$	$(\theta_1-\theta_2)$	$K=\frac{1.6693\,(0.0973+d_1)}{(\theta_1-\theta_2)}\frac{d\theta}{dt}$ cal cm^{-1} sec^{-1} $^{o}c^{-1}$
3.1	10	0.00517	39	0.000707
3.2	11	0.00508	39	0.000716
3 1	12	0.0054	40	0.0007205

Table-6
(Treatment with 1.5% NaCl Solutiou)

Specimen thickness d_2 cm	Voltage (volt)	$\frac{d\theta'}{dt'}$	$(\theta'_1-\theta'_2)$	$K=\frac{1.6693\,(0.0973+d_2)}{(\theta'_1-\theta'_2)}\frac{d\theta'}{dt'}$ cal cm^{-1} sec^{-1} $^{o}c^{-1}$
5.1	10	0.00464	57	0.000706
5.1	11	0.0048	58	0.000718
5.2	12	0.0049	59	0.000734

SEGUN WOOD

Table-7

(Treatment with 2% NaCl Solution)

Specimen thickness d_1 cm	Voltage (volt)	$\frac{d\theta}{dt}$	$(\theta_1-\theta_2)$	$K = \frac{1.6693\,(0.0973 + d_1)}{(\theta_1 - \theta_2)} \frac{d\theta}{dt}$ cal cm^{-1} sec^{-1} $^oc^{-1}$
3.1	10	0.00555	38	0.000779
3.1	11	0.00545	37	0.000786
3 2	12	0.0055	38	0.000797

Table-8

Treatment with 2% NaCl Solution

Specimen thickness d_2 cm	Voltage (volt)	$\frac{d\theta'}{dt'}$	$(\theta'_1-\theta'_2)$	$K = \frac{1.6693\,(0.0973 + d_2)}{(\theta'_1 - 0'_2)} \frac{d\theta'}{dt'}$ cal cm^{-1} sec^{-1} $^oc^{-1}$
5.0	10	0.00526	56	0.000795
5.2	11	0.00522	57	0.000805
5.1	12	0.0054	58	0.00081

Sample Name : Segun Wood
(dry sample)
Thickness = 3 cm (approx.)

Time T (min)	Temperature		Time T (min)	Temperature		Time T (min)	Temperature	
	$\theta_1{}^0c$	$\theta_2{}^0c$		$\theta_1{}^0c$	$\theta_2{}^0c$		$\theta_1{}^0c$	$\theta_2{}^0c$
0	30	29	0	29	30	0	36	29
5	35	29	5	35	30	5	37	29
10	40	31	10	41	32	10	44	32
15	45	33	15	47	34	15	51	35
20	50	35	20	53	36	20	58	38
25	55	37	25	59	38	25	65	41
30	60	39	30	65	40	30	72	44
35	65	41	35	71	42	35	79	47
40	70	43	40	77	44	40	86	50
45	74	45	45	83	46	45	93	53
50	78	47	50	89	48	50	100	56
55	82	49	55	91	50	55	106	59
60	86	51	60	95	52	60	110	62
65	90	53	65	99	54	65	114	65
70	94	55	70	103	56	70	116	68
75	98	57	75	105	58	75	118	70
80	102	59	80	107	61	80	120	73
85	104	61	85	110	64	85	123	76
90	106	63	90	113	67	90	126	79
95	108	64	95	116	70	95	128	81
100	110	65	100	118	72	100	130	83
105	111	66	105	120	74	105	131	84
110	112	67	110	121	75	110	132	85
115	112.5	67.5	115	122	76	115	133	86
120	113	68	120	122.5	76.5	120	133.5	86.5
			125	123	77	125	134	87

Sample Name : Segun Wood
(dry sample)
Thickness = 5 cm (approx.)

Time T (min)	Temperature		Time T (min)	Temperature		Time T (min)	Temperature	
	$\theta'_1{}^0c$	$\theta'_2{}^0c$		$\theta'_1{}^0c$	$\theta'_2{}^0c$		$\theta'_1{}^0c$	$\theta'5^0c$
0	30	29	0	30	29	0	30	30
5	35	29	5	36	29	5	37	30
10	40	31	10	42	31	10	44	31
15	45	33	15	48	33	15	51	34
20	50	35	20	54	35	20	58	38
25	55	37	25	60	37	25	64	42
30	60	39	30	66	39	30	70	45
35	64	41	35	72	41	35	76	48
40	68	43	40	78	43	40	82	51
45	72	44	45	84	45	45	82	53
50	76	45	50	88	47	50	94	55
55	80	46	55	92	49	55	92	57
60	84	47	60	96	51	60	102	59
65	88	48	65	100	53	65	106	61
70	92	49	70	104	55	70	110	63
75	96	50	75	108	57	75	114	65
80	100	51	80	112	59	80	118	67
85	104	52	85	116	61	85	122	69
90	108	53	90	120	62	90	126	71
95	112	54	95	124	63	95	130	73
100	116	55	100	126	64	100	134	75
105	117	55.5	110	128	65	110	138	77
110	118	56	120	130	66	120	142	78
115	119	56.5	130	131	67	125	143	78.5
120	120	57	135	132	68	130	144	79
125	121	57.5	140	133	68.5	135	145	79.5
130	122	58	145	134	69	140	146	80

Sample Name : Segun Wood (Soaked in 1% NaCl Sol^{n} for 48 hours)
Thickness = 3 cm (approx.)

Time T (min)	Temperature		Time T (min)	Temperature		Time T (min)	Temperature	
	$0_1{}^0$c	$\theta_2{}^0$c		$0_1{}^0$c	$\theta_2{}^0$c		$\theta_1{}^0$c	$\theta_2{}^0$c
0	30	29	0	30	29	0	30	30
5	35	29	5	36	29	5	37	30
10	40	31	10	42	31	10	44	33
15	45	33	15	48	33	15	51	36
20	50	35	20	54	35	20	57	39
25	55	37	25	60	37	25	63	42
30	60	39	30	66	39	30	69	45
35	64	41	35	70	41	35	75	48
40	68	43	40	74	43	40	81	51
45	72	45	45	78	45	45	85	54
50	76	48	50	82	47	50	89	57
55	80	51	55	86	49	55	93	60
60	84	54	60	90	51	60	97	63
65	88	57	65	94	53	65	101	66
70	92	60	70	98	56	70	105	69
75	96	63	75	102	59	75	109	72
80	100	66	80	106	62	80	113	75
85	104	68	85	110	65	85	117	78
90	108	70	90	114	68	90	121	81
95	112	71	95	118	71	95	125	83
100	113	72	100	120	74	100	129	85
110	115	73	110	122	77	110	131	87
120	116	74	120	124	80	115	132	89
125	117	75	125	125	82	120	133	90
130	117 5	75.5	130	125.5	83	125	134	91
135	118	76	135	126	84	130	135	92
			140	126.5	84.5	135	135.5	92.5
			145	127	85	140	136	93

Sample Name : **Segun Wood (Soaked in 1% Nacl Solution for 48 hours) Thickness 5 cm (approx.)**

Time T (min)	Temperature		Time T (min)	Temperature		Time T (min)	Temperature	
	$\theta_1{}^0c$	$\theta_2{}^0c$		$\theta_1{}^0c$	$\theta_2{}^0c$		$\theta_1{}^0c$	$\theta_2{}^0c$
0	30	29	0	29	30	0	30	29
5	38	29	5	35	30	5	37	29
10	40	31	10	44	32	10	44	32
15	45	33	15	47	34	15	51	35
20	50	35	20	53	36	20	58	38
25	55	36	25	59	38	25	65	41
30	60	39	30	65	40	30	71	44
35	64	41	35	71	42	35	76	47
40	68	43	40	75	44	40	81	50
45	72	45	45	79	46	45	86	53
50	76	47	50	83	48	50	91	56
55	80	49	55	87	50	55	96	59
60	84	51	60	91	52	60	101	62
65	88	53	65	95	54	65	106	64
70	92	54	70	99	56	70	111	66
75	96	55	75	103	58	75	116	68
80	100	56	80	107	60	80	121	70
85	104	57	85	111	62	85	126	72
90	108	58	90	115	64	90	130	84
95	112	59	95	119	66	95	134	76
100	116	60	100	123	68	100	138	78
105	118	61	110	127	70	110	142	80
110	120	62	120	131	71.5	120	144	82
120	122	63	130	133	72.5	130	146	83
130	124	64	140	135	75	140	147	84
135	125	64.5	145	136	74	145	147.5	84.5
140	126	65	150	137	75	150	148	85
145	126.5	65.5	155	137.5	75.5	155	148.5	85 5
150	127	66	160	138	76	160	149	86

Segun Wood (Soaked in 1.5% NaCl Solution for 48 hours)
Thickness 3 cm (approx.)

Time T (min)	Temperature		Time T (min)	Temperature		Time T (min)	Temperature	
	$\theta_1{}^0$c	$\theta_2{}^0$c		$\theta_1{}^0$c	$\theta_2{}^0$c		$\theta_1{}^0$c	$\theta_2{}^0$c
0	30	29	0	29	30	0	30	30
5	35	29	5	35	30	5	37	30
10	40	31	10	41	33	10	44	33
15	45	33	15	47	36	15	51	36
20	50	35	20	53	39	20	57	39
25	55	37	25	59	42	25	63	42
30	60	39	30	65	45	30	69	45
35	64	41	35	69	47	35	75	48
40	68	43	40	73	50	40	79	51
45	72	45	45	77	53	45	83	54
50	76	47	50	81	56	50	87	57
55	80	49	55	85	59	55	91	60
60	84	51	60	89	62	60	95	63
65	88	53	65	93	65	65	99	67
70	92	55	70	96	68	70	103	71
75	96	57	75	100	71	75	107	75
80	100	60	80	104	74	80	111	79
85	104	63	85	108	76	85	115	82
90	108	69	90	112	78	90	119	85
95	112	72	95	116	80	95	123	88
100	114	74	100	120	82	100	127	90
110	116	78	110	122	84	110	131	92
120	118	80	120	124	86	120	135	96
130	119	82	130	126	88	130	137	98
140	120	82.5	140	128	90	140	139	100
145	121	83	145	129	90.5	145	141	101
150	122	83.5	150	130	91	150	142	102
155	123	84	155	130.5	91.5	155	142.5	102.5
			160	131	92	160	143	103

Segun Wood (Soaked in 1.5% Nacl Solution for 48 hours)
Thickness = 5 cm (approx.)

	Temperature			Temperature			Temperature	
Time T (min)	θ_1^0c	θ_2^0c	Time T (min)	θ_1^0c	θ_2^0c	Time T (min)	θ_1^0c	θ_2^0c
0	30	29	0	30	29	0	30	30
5	35	29	5	36	29	5	37	30
10	40	31	10	42	30	10	44	33
15	45	33	15	48	33	15	51	36
20	50	35	20	54	36	20	58	39
25	55	37	25	60	39	25	64	42
30	60	39	30	66	42	30	70	45
35	64	41	35	70	44	35	76	48
40	68	43	40	74	46	40	82	51
45	72	45	45	78	48	45	86	54
50	76	47	50	82	50	50	90	57
55	80	49	55	86	52	55	94	60
60	84	51	60	90	54	60	98	63
65	88	53	65	94	56	65	102	66
70	92	54	70	98	58	70	106	69
75	96	55	75	102	60	75	110	72
80	100	56	80	106	62	80	114	75
85	104	57	85	110	64	85	118	77
90	108	59	90	118	66	90	122	79
95	112	60	95	122	68	95	126	81
100	116	62	100	126	70	100	130	83
110	120	64	110	130	72	110	134	85
120	124	66	120	134	75	120	138	87
130	126	68	130	137	79	130	142	89
140	128	70	140	139	81	140	146	92
150	129	72	150	141	83	150	150	94
155	129.5	72.5	155	141.5	83.5	155	152	94.5
160	130	73	160	142	84	160	154	95

Sample Name : Segun Wood (Soaked in 2% NaCl Solution for 48 hours)
Thickness = 3 cm (approx.)

	Temperature			Temperature			Temperature	
Time T (min)	θ_1	θ_2	Time T (min)	θ_1	θ_2	Time T (min)	θ_1	θ_2
0	30	29	0	29	30	0	30	30
5	35	29	5	35	30	5	37	30
10	40	32	10	41	33	10	44	33
15	45	36	15	47	36	15	51	36
20	60	39	20	53	39	20	58	39
25	55	42	25	59	42	25	64	42
30	60	45	30	65	45	30	70	45
35	65	48	35	69	48	35	76	48
40	69	51	40	72	51	40	82	51
45	73	54	45	77	54	45	88	54
50	77	57	50	81	57	50	94	57
55	81	60	55	85	60	55	100	60
60	85	63	60	89	63	60	104	63
65	89	66	65	93	66	65	108	66
70	93	69	70	97	69	70	112	69
75	97	72	75	101	72	75	116	72
80	101	74	80	105	75	80	120	77
85	105	76	85	110	78	85	124	81
90	109	78	90	115	81	90	128	85
95	113	79	95	118	84	95	132	90
100	117	80	100	121	87	100	134	95
110	119	82	110	125	90	110	136	100
120	121	84	120	127	93	120	139	102
125	123	86	130	129	95	130	141	104
135	125	88	135	130	96	135	142	104.5
140	125.5	88.5	140	132	96.5	140	143	105
145	126	89	145	133	97	145	143.5	105.5
150	127	89 5	150	134	97.5	150	144	106
155	128	90	155	135	98			

Sample Name : Segun Wood (Soaked in 2% NaCl Solution for 48 hours)
Thickness = 5 cm (approx.)

	Temperature			Temperature			Temperature	
Time t (min)	θ_1	θ_2	Time T (min)	$\theta_1{}^0c$	$\theta_2{}^0c$	Time T (min)	$\theta_1{}^0c$	$\theta_2{}^0c$
0	30	29	0	29	30	0	30	30
5	35	29	5	35	30	5	37	30
10	40	32	10	41	33	10	44	33
15	45	35	15	47	36	15	51	36
20	50	38	20	53	39	20	57	39
25	55	41	25	59	42	25	63	42
30	60	44	30	65	45	30	69	45
35	65	47	35	69	48	35	73	48
40	69	49	40	73	51	40	77	51
45	73	51	45	77	54	45	81	54
50	77	53	50	81	57	50	85	57
55	81	55	55	85	60	55	89	60
60	85	57	60	89	63	60	94	62
65	89	59	65	94	66	65	100	66
70	93	61	70	100	69	70	106	69
75	97	63	75	106	71	75	112	72
80	101	65	80	111	73	80	117	75
85	105	67	85	116	75	85	122	78
90	110	69	90	121	77	90	126	81
95	114	71	95	124	79	95	130	83
105	120	73	105	130	81	105	135	86
115	124	75	115	136	83	115	142	88
125	128	76	125	138	84	125	146	90
135	131	77	135	140	85	135	148	92
140	132	78	140	141	85.5	140	150	93
145	133	78.5	145	142	86	145	151	94
150	134	79	150	143	87	150	152	95
155	135	79.5	155	144	87.5	155	153	95.5
160	136	80	160	145	88	160	154	96

DATA SHEET

FOR

GORJAN WOOD

Air gap thickness calculation :

For Gorjan Wood.

We know, $ms\frac{d\theta}{dt} = \frac{KA\ (\theta_1 - \theta_2)}{\alpha + d_1}$ --------- (i)

$ms\frac{d\theta'}{dt} = \frac{KA\ (\theta'_1 - \theta'_2)}{\alpha + d_2}$ --------- (ii)

Where d_1 and d_2 are specimen thickness,

α = air gap thickness.

Now from eq^n (i) and (2) We get,

$$K = \frac{1.6693\ (d_2 - d_1) \cdot \frac{d\theta}{dt}}{(\theta'_1 - \theta'_2)\ [\{\frac{d\theta}{dt} / \frac{d\theta'}{dt}\}] - (\theta_1 - \theta_2)} \quad \text{---------- (iii)}$$

For dry sample ,

$V = 10$ volt,

$d_2 - d_1 = 4.8 - 3.0 = 1.8$ cm

$\frac{d\theta}{dt} = 0.0044$

$\frac{d\theta'}{dt} = 0.00404$

$\theta_1 - \theta_2 = 45^0c$

$\theta'_1 - \theta'_2 = 65^0c$

Patting this value in equation (3), then we get,

$$K = \frac{1.6693 \times 1.8 \times 0.0044}{65 \times \frac{0.00044}{0\ 00404} - 45}$$

$$= 0.000504 \text{ cal cm}^{-1} \text{ sec}^{-1} {}^{0}\text{c}^{-1}$$

Now from cq^{n} (1), we get,

$$\alpha = \frac{K\Lambda\ (\theta_1 - \theta_2)}{ms \frac{d\theta}{dt}} - d_1$$

$$= \frac{0.000504 \times 45 \times 85.1775}{1225.8 \times 0.116 \times 0.0044} - 3$$

$$= 0.0877 \text{ cm}$$

$\therefore$ Air gap thickness = 0.0877 cm.

Gorjan Wood
(dry sample)

Table-1

Specimen thickness d_1 cm	Voltage Volt	$\frac{d\theta}{dt}$	$(\theta_1 - \theta_2)$	$K = \frac{1.6693\ (0.0877 + d_1)\frac{d\theta}{dt}}{(\theta_1 - \theta_2)}$ cal cm $^{-1}$sec^{-1} ^{0}c^{-1}
3	10	0.0044	45	0.000504
3.05	11	0.0045	46	0.000512
3.0	12	0.0047	47	0.000515

Table-2
(dry sample)

Specimen thickness d_2 cm	Voltage Volt	$\frac{d\theta'}{dt}$	$(\theta'_1 - \theta'_2)$	$K = \frac{1.6693\ (0\ 0877 + d_2)\frac{d\theta'}{dt}}{(\theta'_1 - \theta'_2)}$ cal cm $^{-1}$sec^{-1} ^{0}c^{-1}
4.8	10	0.00404	65	0.000512
5.0	11	0.0041	66	0.000527
5.1	12	0.00415	67	0.000535

Table-3
(Treatment with 1% Nacl Solution)

Specimen thickness d_1 cm	Voltage Volt	$\frac{d\theta}{dt}$	$(\theta_1 - \theta_2)$	$K = \frac{1.6693\ (0.0877 + d_1)\frac{d\theta}{dt}}{(\theta_1 - \theta_2)}$ cal cm $^{-1}$sec^{-1} ^{0}c^{-1}
3.0	10	0.00489	42	0 00060
3 1	11	0.00489	43	0.000606
3.2	12	0.00489	44	0.00061

Table-4
(Treatment with 1.% NaCl Solution)

Specimen thickness d_2 cm	Voltage Volt	$\frac{d\theta'}{dt}$	$(\theta'_1 - \theta'_2)$	$K = \frac{1.6693\ (0.0877 + d_2)\frac{d\theta'}{dt}}{(\theta'_1 - \theta'_2)}$ cal $cm^{-1}sec^{-1}\ ^0c^{-1}$
5.1	10	0.0045	63	0.000610
5.1	11	0.0046	64	0.00062
5.2	12	0.00464	65	0.00063

Table-5
(Treatment with 1.5% NaCl Solution.)

Specimen thickness d_1 cm	Voltage Volt	$\frac{d\theta}{dt}$	$(\theta_1 - \theta_2)$	$K = \frac{1.6693\ (0.0877 + d_1)\frac{d\theta}{dt}}{(\theta_1 - \theta_2)}$ cal $cm^{-1}sec^{-1}\ ^0c^{-1}$
3.0	10	0.00495	37	0.00069
3.1	11	0.00502	38	0.000703
3.2	12	0.00501	39	0.000705

Table-6
(Treatment with 1.5% NaCl Solution)

Specimen thickness d_2 cm	Voltage Volt	$\frac{d\theta'}{dt}$	$(\theta'_1 - \theta'_2)$	$K = \frac{1.6693\ (0.0877 + d_2)\frac{d\theta'}{dt}}{(\theta'_1 - \theta'_2)}$ cal $cm^{-1}sec^{-1}\ ^0c^{-1}$
5.0	10	0.00456	57	0.00068
5.1	11	0.0047	57	0.000693
5.2	12	0.00471	59	0.000704

Table-7
(Treatment with 2% NaCl Solution)

Specimen thickness d_1 cm	Voltage Volt	$\frac{d\theta}{dt}$	$(\theta_1 - \theta_2)$	$K = \frac{1.6693\ (0.0877 + d_1)\frac{d\theta}{dt}}{(\theta_1 - \theta_2)}$ cal cm^{-1}sec^{-1} ^{0}c^{-1}
3.0	10	0.0051	35	0.00075
3.2	11	0.00502	36	0.00076
3.25	12	0.00501	37	0.000775

Table-8
(Treatment with 2% NaCl Solution.)

Specimen thickness d_2 cm	Voltage Volt	$\frac{d\theta'}{dt}$	$(\theta'_1 - \theta'_2)$	$K = \frac{1.6693\ (0.0877 + d_2)\frac{d\theta'}{dt}}{(\theta'_1 - \theta'_2)}$ cal cm^{-1}sec^{-1} ^{0}c^{-1}
4.9	10	0.005	54	0.00077
5.1	11	0.005	55	0.00078
5.2	12	0.005	56	0.00079

GROJAN WOOD

(dry sample)

Thickness = 3 cm (approx.)

10 Volts			11 Volts			12 Volts		
Time T (min)	$\theta_1{}^0c$	$\theta_2{}^0c$	Time T (mm)	$\theta_1{}^0c$	$0_2{}^0c$	Time T (min)	$\theta_1{}^0c$	$0_2{}^0c$
0	30	29	0	29	30	0	29	30
5	34	29	5	29	30	5	33	30
10	38	32	10	34	31	10	37	33
15	42	35	15	38	33	15	41	36
20	46	38	20	42	36	20	45	39
25	50	40	25	46	40	25	44	42
30	54	42	30	50	42	30	53	44
35	58	44	35	54	44	35	57	46
40	62	46	40	58	46	40	61	48
45	66	48	45	62	48	45	65	50
50	72	50	50	66	50	50	71	52
55	78	51	55	70	52	55	77	54
60	83	52	60	34	54	60	82	56
65	88	53	65	80	56	65	87	58
70	92	54	70	86	58	70	91	60
75	96	55	75	92	60	75	95	62
80	99	56	80	98	62	80	99	64
85	100	57	85	102	64	85	103	66
90	101	58	90	106	66	90	107	68
95	102	58.5	95	109	68	95	113	70
100	103	59	100	111	69	100	118	72
105	104	59.5	105	113	70	105	121	74
110	105	60	110	115	70.5	110	123	76
			115	116	71	115	124	77
			120	117	71.5	120	125	78
			125	118	72	125	126	79
						130	126.5	79.5
						135	127	80

Gorjan Wood
(dry sample)
Thickness = 5 cm (approx.)

Time T (min)	$\theta'_1{}^0$c	$\theta'_2{}^0$c	Time T (min)	$\theta'_1{}^0$c	$\theta'_2{}^0$c	Time T (min)	$\theta'_1{}^0$c	$\theta'_2{}^0$c
0	30	29	0	29	30	0	29	29
5	34	29	5	35	30	5	33	29
10	38	31	10	41	32	10	37	30
15	42	32	15	45	34	15	41	32
20	46	34	20	49	36	20	45	36
25	50	36	25	53	38	25	49	40
30	54	37	30	59	40	30	53	43
35	58	38	35	61	42	35	57	45
40	62	39	40	65	44	40	61	47
45	66	40	45	71	45	45	65	49
50	70	41	50	77	46	50	71	51
55	78	42	55	83	47	55	79	53
60	82	43	60	88	48	60	83	55
65	86	44	65	93	49	65	89	57
70	90	45	70	98	50	70	95	59
75	94	46	75	102	51	75	101	61
80	98	46.5	80	106	52	80	107	62
85	102	47	85	109	53	85	113	63
90	106	47.5	90	112	54	90	119	65
95	110	48	95	114	55	95	123	60
100	112	48.5	105	118	56	105	127	67
105	113	49	110	122	57	110	130	68
110	114	49.5	115	124	58	120	133	68.5
125	115	50	125	125	59	125	135	69.5
			130	125.5	59.5	130	136	70
			135	126	60	135	137	70.5
						140	138	71

Gorjan Wood
(Soaked in 1% NaCl solution for 48 hours)
Thickness = 5cm (approx.)

	Temperture			Temperture			Temperture	
Time T (min)	$0'_1{}^0c$	$0'_2{}^0c$	Time T (min)	$\theta'_1{}^0c$	$\theta'_2{}^0c$	Time T (min)	$\theta'_1{}^0c$	$\theta'_2{}^0c$
0	30	29	0	30	29	0	30	30
5	36	29	5	37	29	5	37	30
10	42	30	10	44	30	10	44	31
15	48	32	15	51	32	15	51	33
20	54	34	20	57	34	20	57	35
25	60	36	25	63	36	25	63	37
30	66	38	30	67	38	30	69	39
35	70	40	35	75	40	35	75	41
40	76	42	40	81	42	40	81	43
45	82	44	45	87	44	45	87	45
50	88	45	50	93	46	50	93	47
55	92	46	55	99	48	55	99	49
60	96	47	60	104	50	60	105	51
65	100	48	65	109	52	65	111	53
70	102	49	70	112	54	70	115	55
75	104	50	75	115	56	75	120	57
80	106	51	80	118	58	80	124	54
85	108	52	85	120	60	85	128	61
90	109	53	90	122	62	90	130	63
100	113	54	100	124	63	100	132	67
110	115	55	110	126	65	110	134	70
120	117	56	120	128	66	120	136	72
130	119	57	130	130	67	130	138	74
135	120	57.5	140	132	68	140	140	76
140	121	58	150	133	69	150	142	78
			155	133.5	69.5	155	143	79
			160	134	70	160	144	79.5
						165	145	80

Gorjan Wood
(Soaked in 1.5% NaCl solution for 48 hours)
Thickness = 3cm (approx)

	Temperture			Temperture			Temperture	
Time T (min)	$\theta^0{}_1c$	$\theta^0{}_2c$	Time T (min)	$\theta^0{}_1c$	$\theta^0{}_2c$	Time T (min)	$\theta^0{}_1c$	$\theta^0{}_2c$
0	30	29	0	30	29	0	30	30
5	36	29	5	37	29	5	37	30
10	42	31	10	44	32	10	44	31
15	48	33	15	50	35	15	51	33
20	54	35	20	56	138	20	58	36
35	60	37	25	62	41	25	65	40
30	64	39	30	68	44	30	70	44
35	68	41	35	74	47	35	76	48
40	72	43	40	80	50	40	80	51
45	76	45	45	84	53	45	84	54
50	80	47	50	88	56	50	88	57
55	84	49	55	92	59	55	92	59
60	88	51	60	96	62	60	96	62
65	92	54	65	100	65	65	100	65
70	95	57	70	104	67	70	104	68
75	97	60	75	106	69	75	108	71
80	100	63	80	108	71	80	112	74
85	103	66	85	110	73	85	116	77
90	106	69	90	112	75	90	120	80
100	109	72	100	114	79	100	124	85
110	112	75	110	116	81	110	128	88
115	114	77	120	118	83	120	130	92
120	115	78	125	120	84	125	132	93
125	116	79	130	122	85	130	133	94
130	116.5	79.5	135	123	85.5	135	133.5	94.5
135	117	80	140	124	86	140	134	95

Gorjan Wood
(Soaked 1.5% NaCl solution for 48 hours)
Thickness = 5cm (approx)

	Temperture			Temperture			Temperture	
Time T (min)	$\theta'_1{}^0c$	$\theta'_2{}^0c$	Time T (min)	$\theta'_1{}^0c$	$\theta'_2{}^0c$	Time T (min)	$\theta'_1{}^0c$	$\theta'_2{}^0c$
0	30	29	0	30	29	0	30	30
5	36	29	5	37	29	5	38	30
10	42	31	10	44	31	10	46	33
15	48	33	15	51	33	15	53	36
20	54	35	20	58	35	20	60	39
25	60	37	25	65	37	25	67	42
30	66	39	30	72	39	30	74	45
35	72	41	35	78	41	35	80	48
40	78	43	40	84	43	40	86	51
45	82	45	45	90	45	45	92	54
50	86	47	50	96	47	50	98	57
55	90	49	55	100	49	55	104	60
60	94	51	60	104	57	60	110	62
65	98	53	65	110	53	65	114	64
70	102	55	70	112	55	70	118	66
75	106	57	75	114	57	75	122	68
80	108	58	80	116	59	80	126	71
85	110	59	85	118	61	85	130	73
90	112	60	90	119	63	90	132	75
95	114	61	95	120	65	95	134	77
100	116	62	100	122	67	100	136	79
105	118	63	105	124	68	105	138	80
110	120	64	110	126	69	110	140	81
120	122	66	120	128	71	120	142	83
130	123	67	125.	129	72	130	143	84.5
135	124	67.5	130	130	73	135	144	85
140	125	68	135	130.5	73 5	140	144 5	85.5
			140	131	74	145	145	86

Gorjan Wood
(Soaked 2% NaCl solution for 48 hours)
Thickness = 3cm (approx)

	Temperture			Temperture			Temperture	
Time T (min)	$\theta^0{}_1c$	$\theta^0{}_2c$	Time T (min)	$\theta^0{}_1c$	$\theta^0{}_2c$	Time T (min)	$\theta^0{}_1c$	$\theta^0{}_2c$
0	30	29	0	30	29	0	30	30
5	36	29	5	37	32	5	37	30
10	42	32	10	44	35	10	44	34
15	48	35	20	51	38	15	51	38
20	54	38	25	58	41	20	58	42
25	60	41	30	65	44	25	65	46
30	66	44	35	71	47	30	71	50
35	70	47	40	77	50	35	77	54
40	74	50	45	83	53	40	83	48
45	78	53	50	87	56	45	87	62
50	82	56	55	91	59	50	91	66
55	86	59	60	95	62	55	95	69
60	90	62	65	99	65	60	99	72
65	94	65	70	103	68	65	103	75
70	98	68	75	107	71	70	107	78
75	102	71	80	111	74	75	111	81
80	166	74	85	114	77	80	115	84
85	110	76	90	126	79	85	119	87
90	112	78	100	120	83	90	123	90
100	114	81	110	124	85	100	127	94
110	116	82	120	126	89	110	131	96
120	118	83.5	125	127	91	120	135	98
125	119	84	130	128	92	130	137	100
130	119 5	84.5	135	128.5	92.5	135	138	101
135	120	85	140	129	93	140	138.5	101.5
						145	139	102

Gorjan Wood
(Soaked 2% NaCl solution for 48 hours)

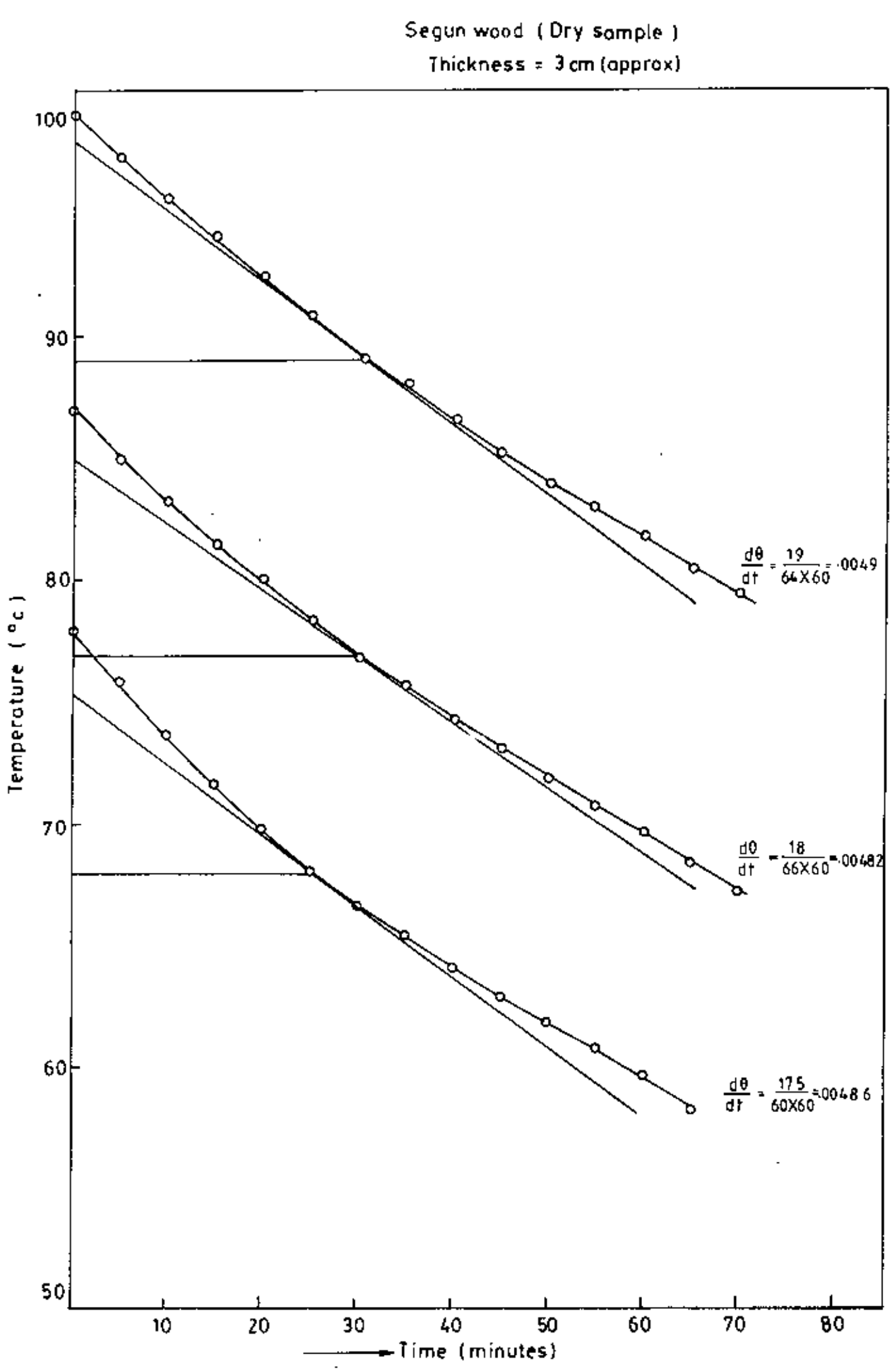
Thickness = 5cm (approx)

	Temperture			Temperture			Temperture	
Time t (min)	$\theta'_1{}^0c$	$\theta'_2{}^0c$	Time T (min)	$\theta'_1{}^0c$	$\theta'_2{}^0c$	Time T (min)	$\theta'_1{}^0c$	$\theta'_2{}^0c$
0	30	29	0	29	30	0	30	30
5	36	29	5	36	30	5	37	30
10	42	31	10	43	32	10	44	33
15	48	33	15	50	34	15	51	36
20	54	35	20	57	36	20	58	39
25	60	37	25	64	38	25	64	42
30	66	39	30	70	40	30	70	45
35	72	41	35	76	42	35	76	48
40	78	43	40	82	44	40	82	51
45	84	45	45	86	46	45	88	54
50	88	47	50	90	48	50	94	57
55	92	49	55	94	50	55	100	60
60	96	51	60	98	52	60	106	62
65	100	53	65	102	54	65	110	64
70	104	55	70	106	56	70	114	66
75	108	57	75	110	58	75	118	68
80	110	59	80	114	60	80	122	70
85	112	61	85	118	63	85	126	72
90	114	63	90	121	66	90	130	74
95	116	64	95	124	69	95	134	76
100	118	65	100	126	72	100	136	78
110	120	67	110	129	74	110	138	82
120	122	69	120	131	76	120	140	85
130	124	71	130	133	78	130	142	86
140	126	73	140	135	80	140	144	88
150	127	74.5	150	136	81	150	145	89
155	128	75	155	136.5	81 5	155	145 5	89.5
160	129	75.5	160	137	82	160	146	90
165	130	76						

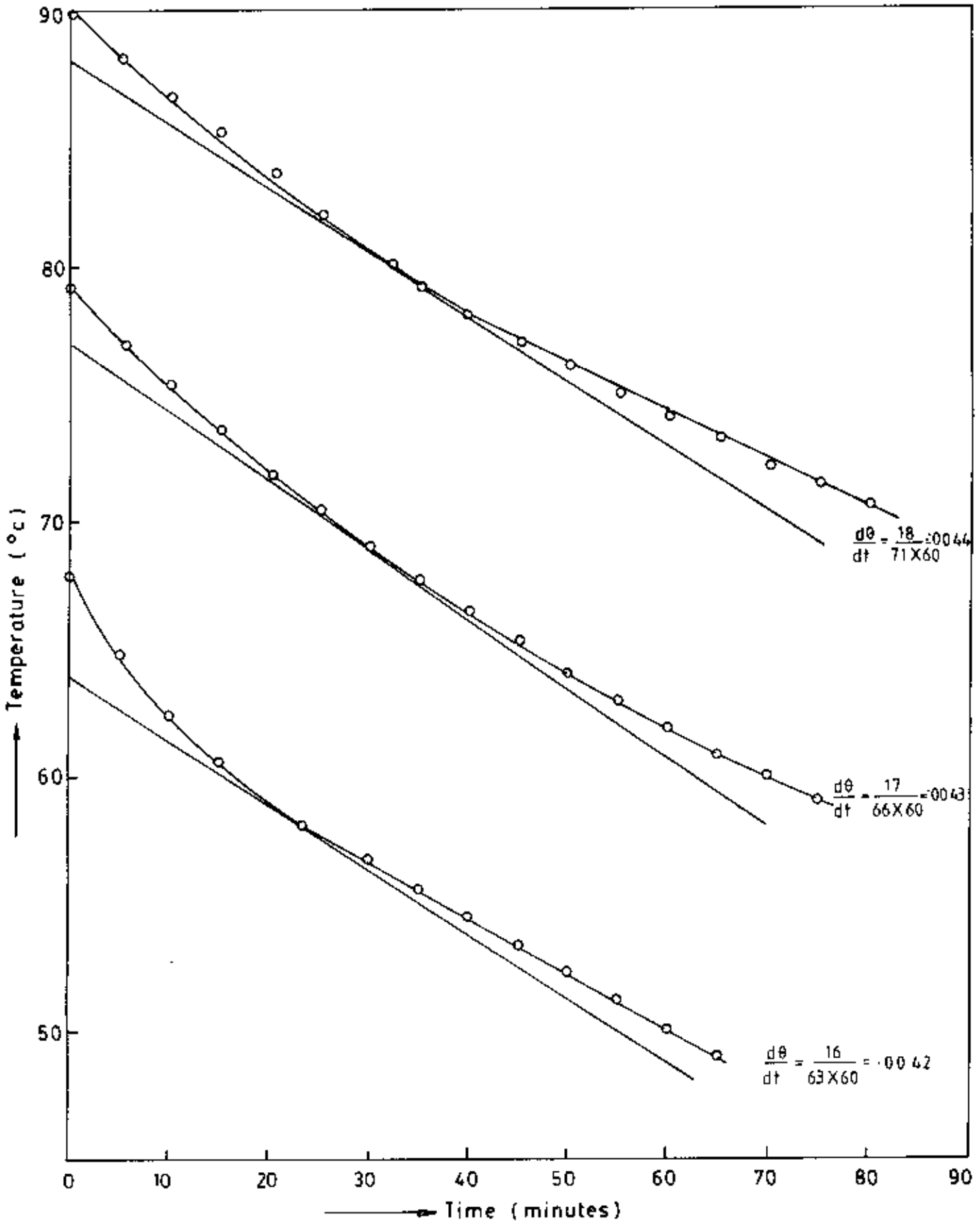
Gorjan Wood
(Soaked 1% NaCl solution for 48 hours)

Thickness = cm (approx)

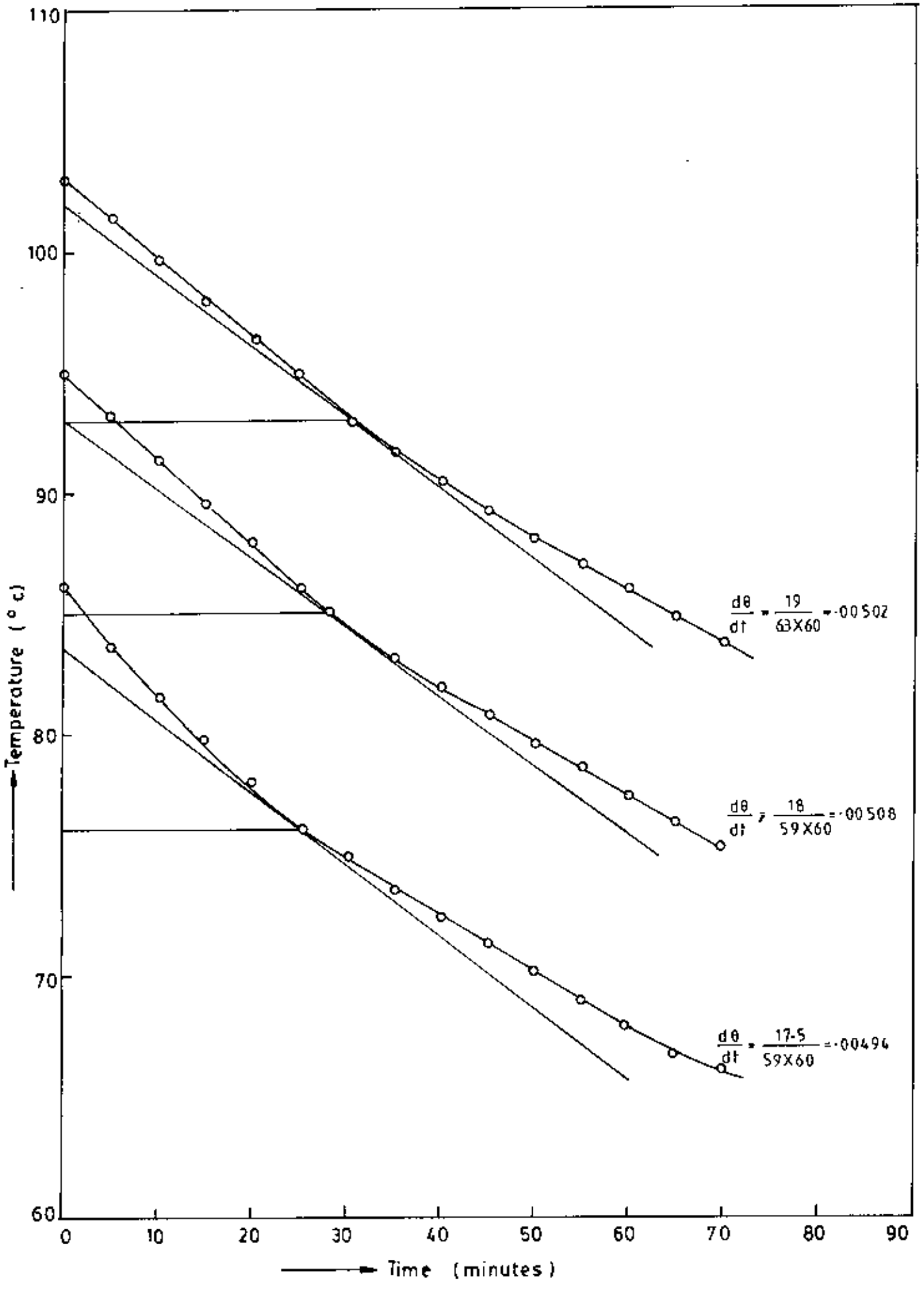
	Temperture			Temperture			Temperture	
Time T (min)	θ_1^0c	θ_2^0c	Time T (min)	θ_1^0c	0_2^0c	Time T (min)	θ_1^0c	θ_2^0c
0	30	30	0	30	30	0	30	30
5	36	30	5	38	30	5	38	30
10	42	30	10	44	32	10	46	32
15	52	32	15	50	34	15	54	34
20	57	34	20	56	387	20	62	36
25	64	36	25	66	42	25	70	40
30	70	38	30	68	46	30	78	45
35	76	40	35	74	50	35	84	48
40	80	42	40	80	544	40	90	51
45	84	44	45	86	57	45	96	54
50	87	46	50	94	80	50	102	57
55	92	48	55	98	62	55	108	60
60	94	50	60	102	64	60	112	63
65	96	52	65	106	66	65	116	66
70	98	54	70	110	68	70	120	69
75	100	56	75	114	70	75	124	72
80	102	58	80	116	72	80	126	75
85	104	60	85	117	74	85	127	79
90	106	62	90	118	75	90	128	82
95	107	64	95	119	76	95	129	85
100	108	65	100	120	77	100	131	87
105	108.5	66	105	121	78	105	132	89
110	109	67	110	121.5	78.5	110	133	90
115	109.5	67.5	115	122	79	115	134	91
120	110	68	120	122.5	79.5	120	135	91.5
			125	123	80	125	136	92


Segun wood (Dry sample)
Thickness = 3 cm (approx)
100
90
80
70
60
50
Temperature (°c)
10
20
30
40
50
60
70
80
Time (minutes)
dθ/dt = 19/64X60 = ·0049
dθ/dt = 18/66X60 = ·00482
dθ/dt = 17.5/60X60 = ·00486

Segun wood
Thickness = 5 cm (approx.)

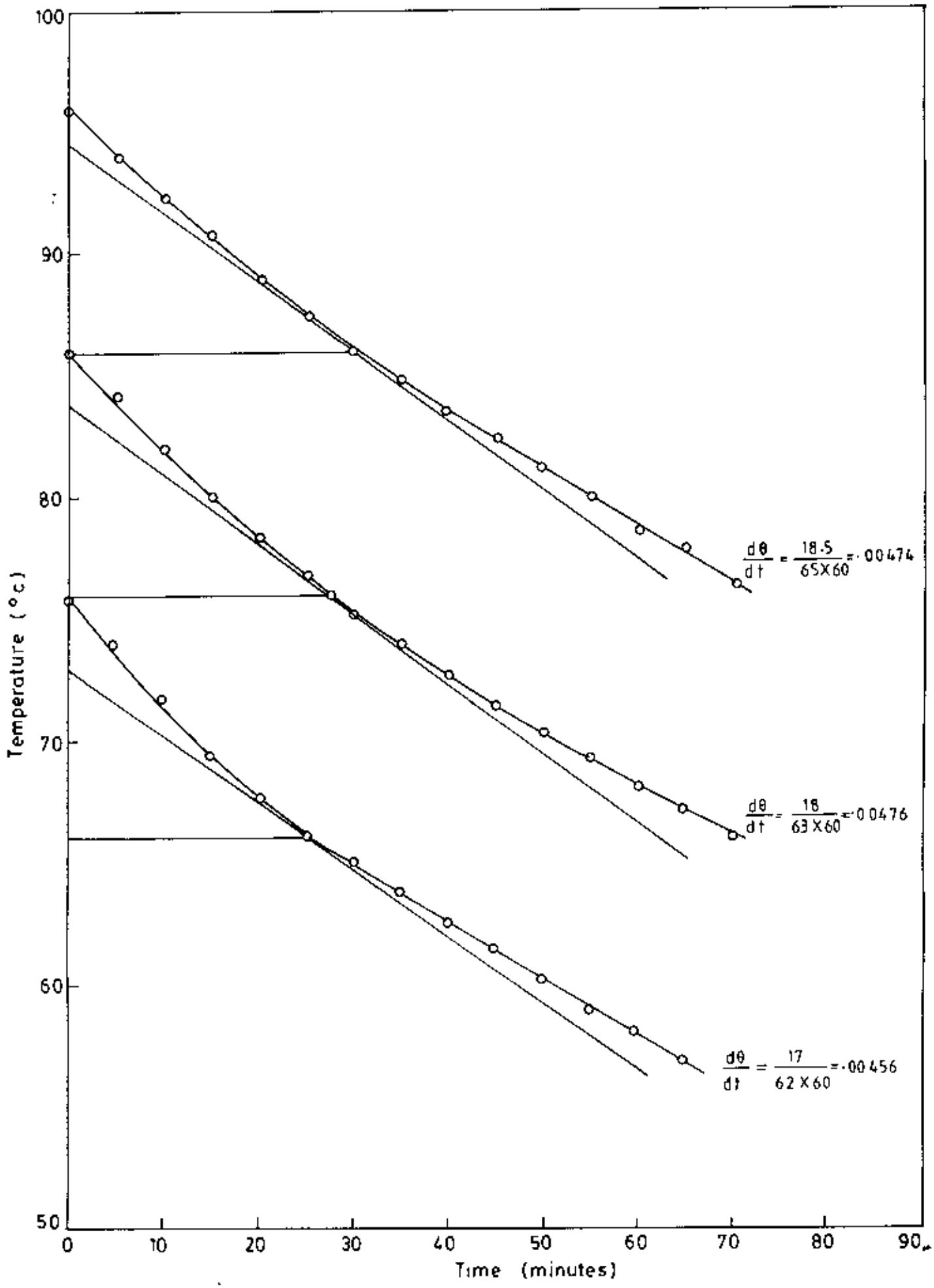


Segun wood
Treatment with 1 % Nacl solution
Thickness = 3cm (approx.)



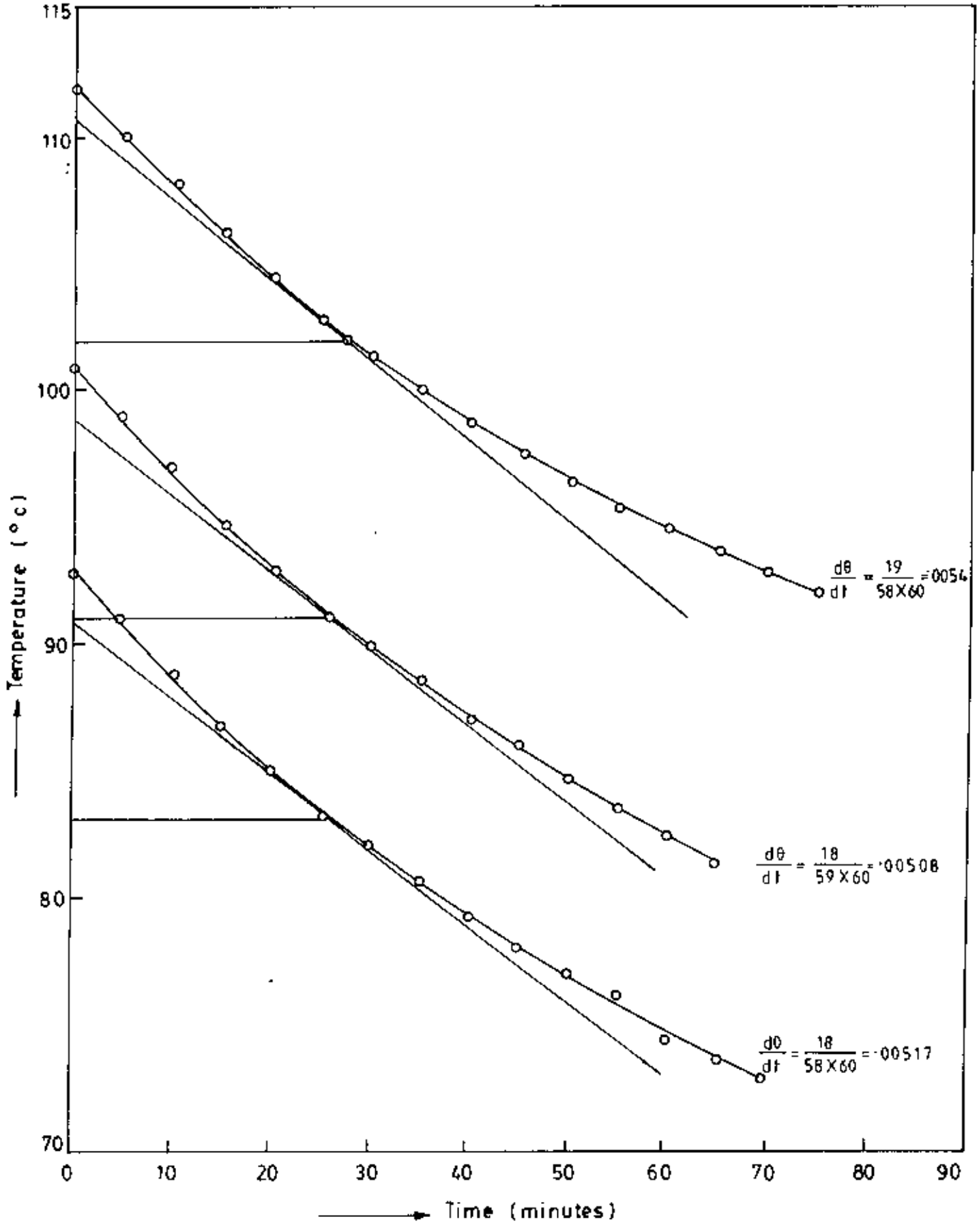
Segun wood 1% Nacl

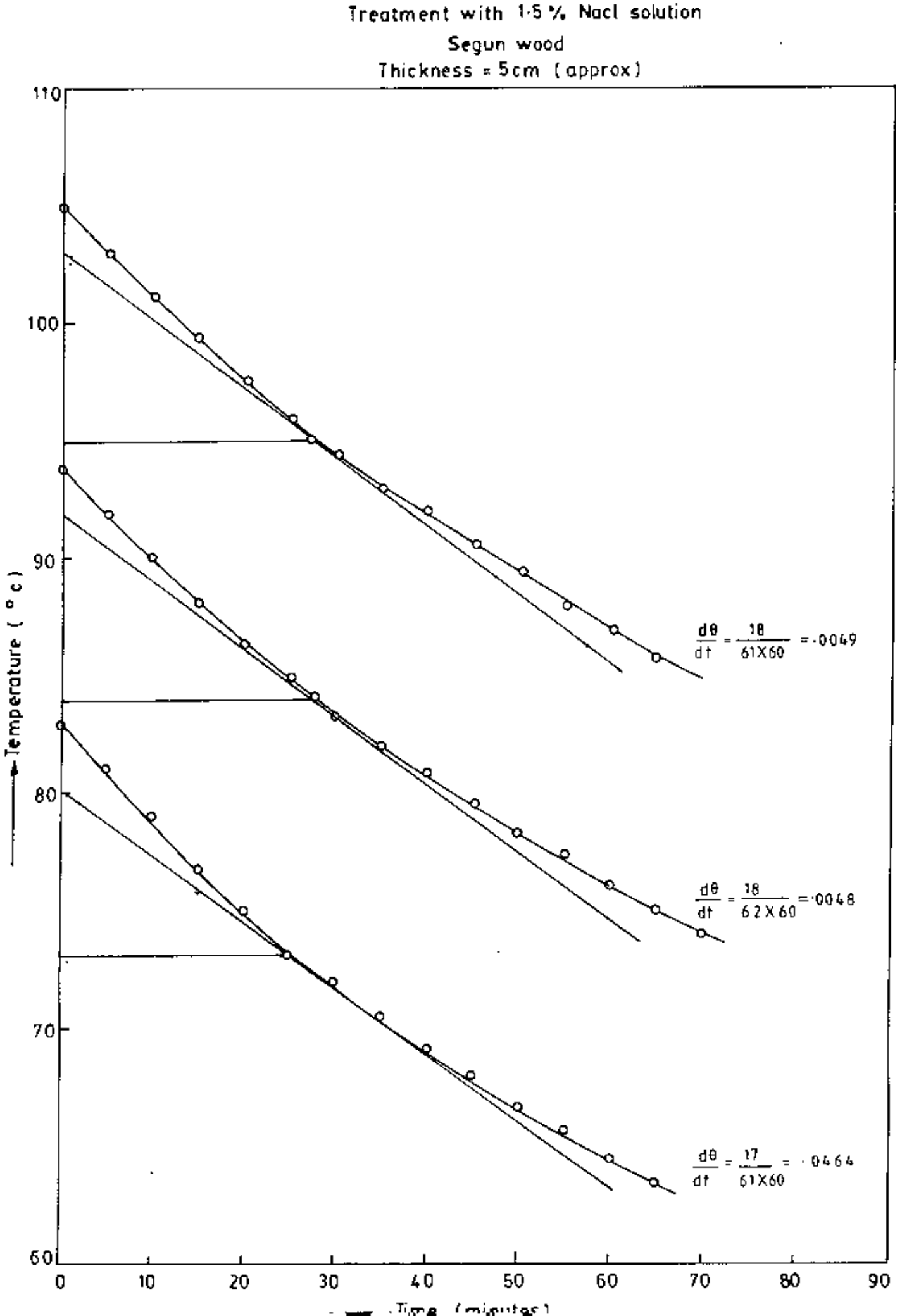
Thickness = 5 cm (approx.)



1·5 % Nacl (Segun wood)

Thickness = 3 cm (approx.)

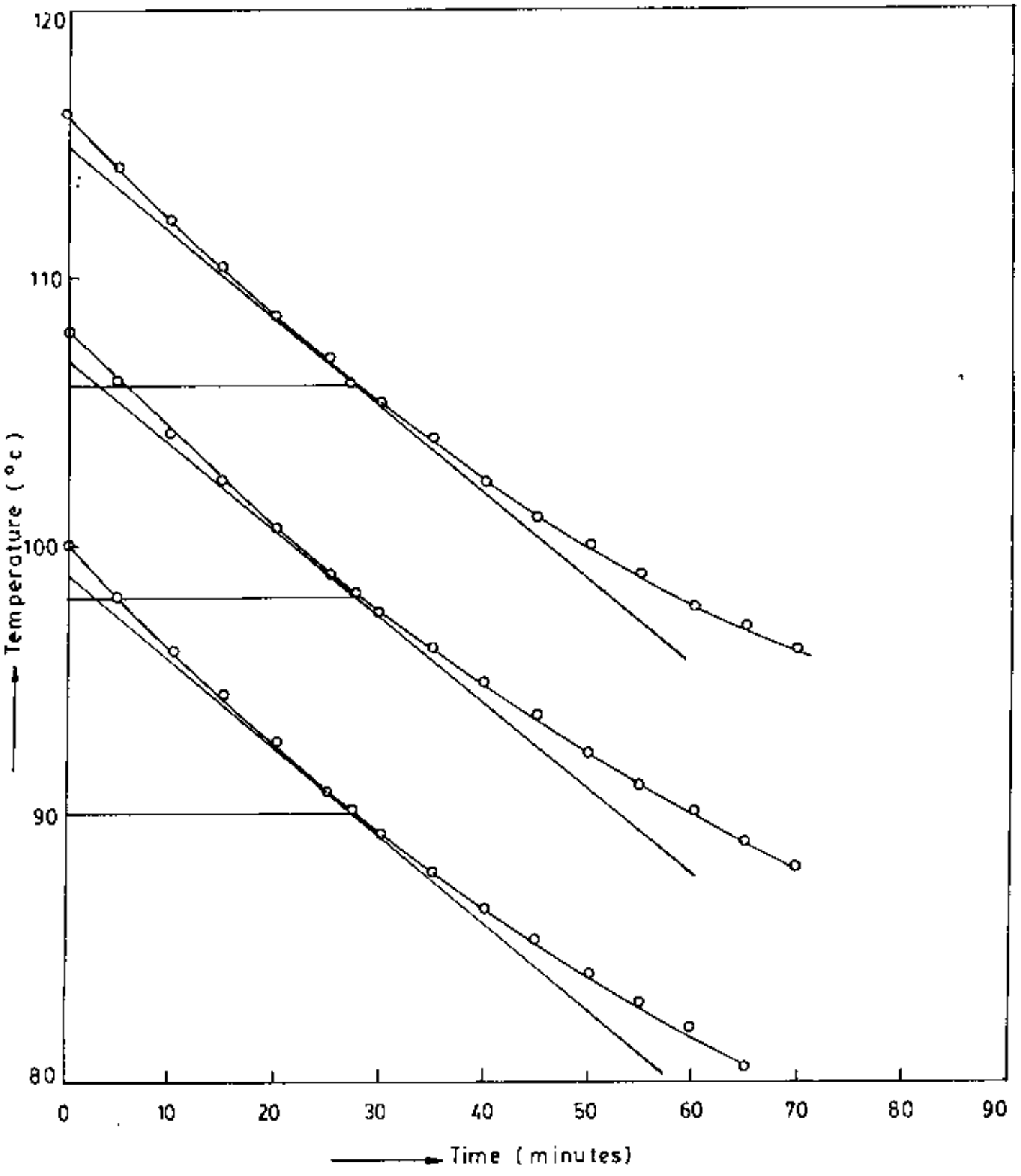



Treatment with 1·5 % Nacl solution
Segun wood
Thickness = 5cm (approx)
110
100
90
80
70
60
Temperature (°c)
0
10
20
30
40
50
60
70
80
90
Time (minutes)
dθ/dt = 18/61X60 = ·0049
dθ/dt = 18/62X60 = ·0048
dθ/dt = 17/61X60 = ·0464

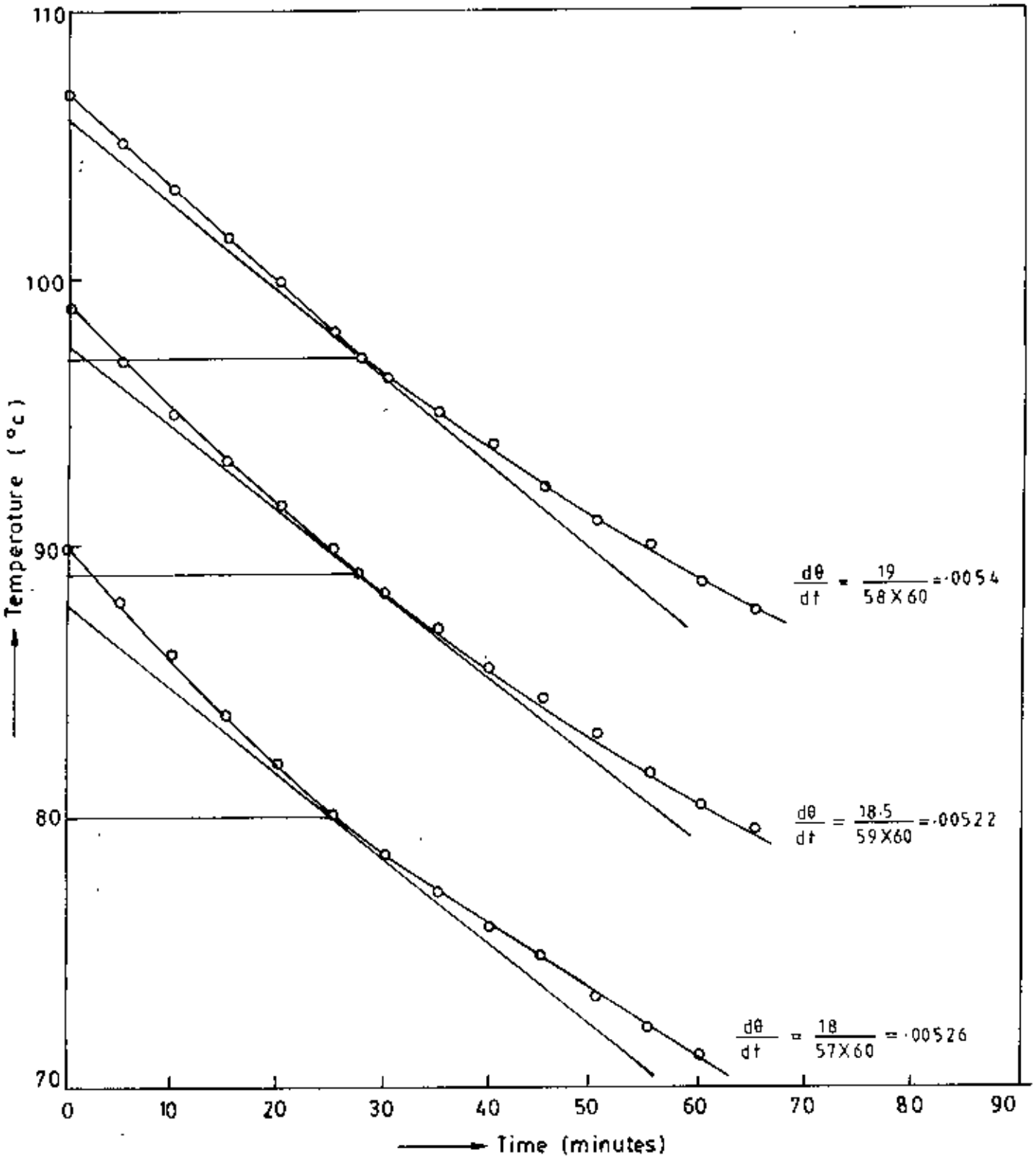
Treatment with 2 % Nacl solution

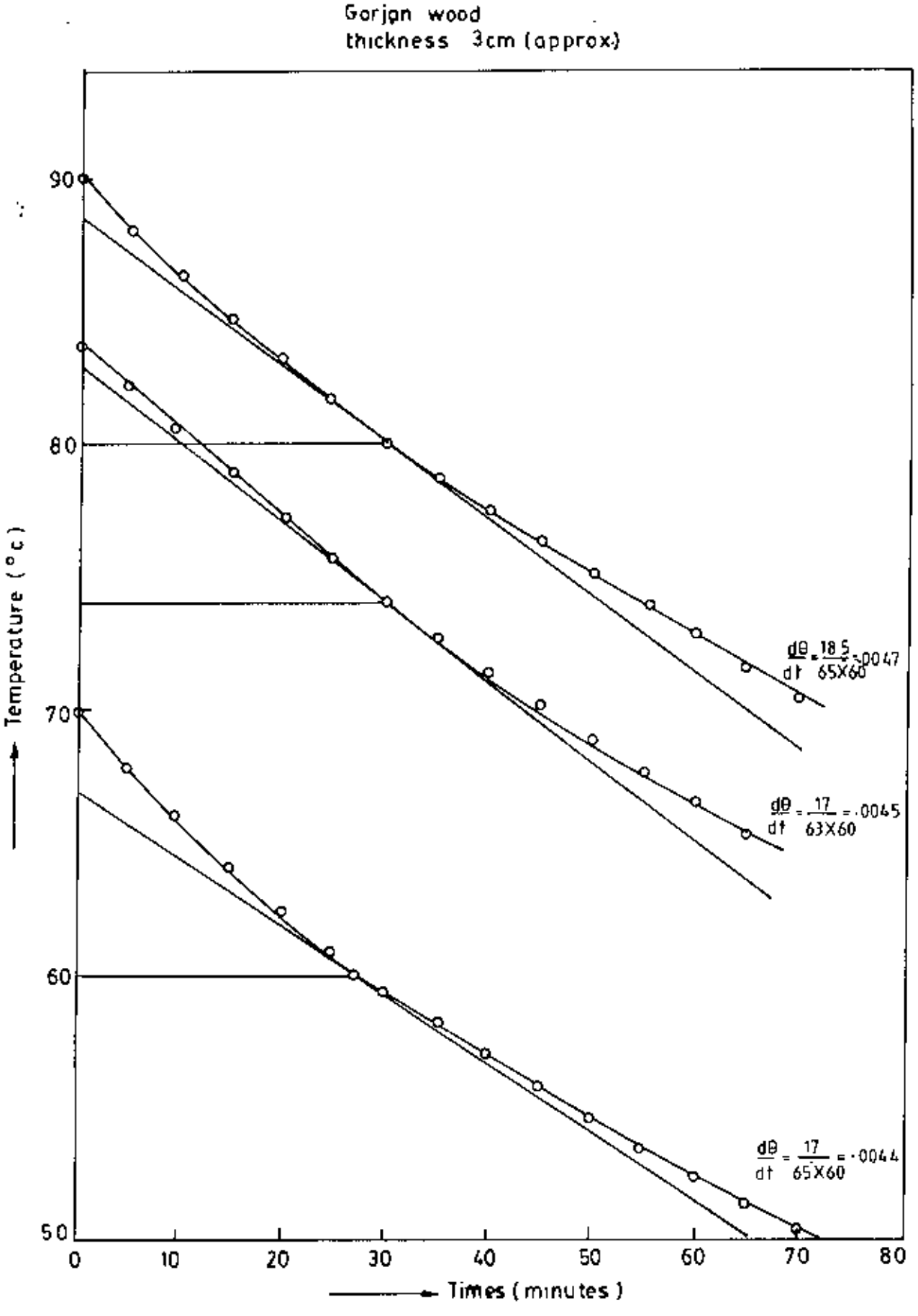
Segun wood

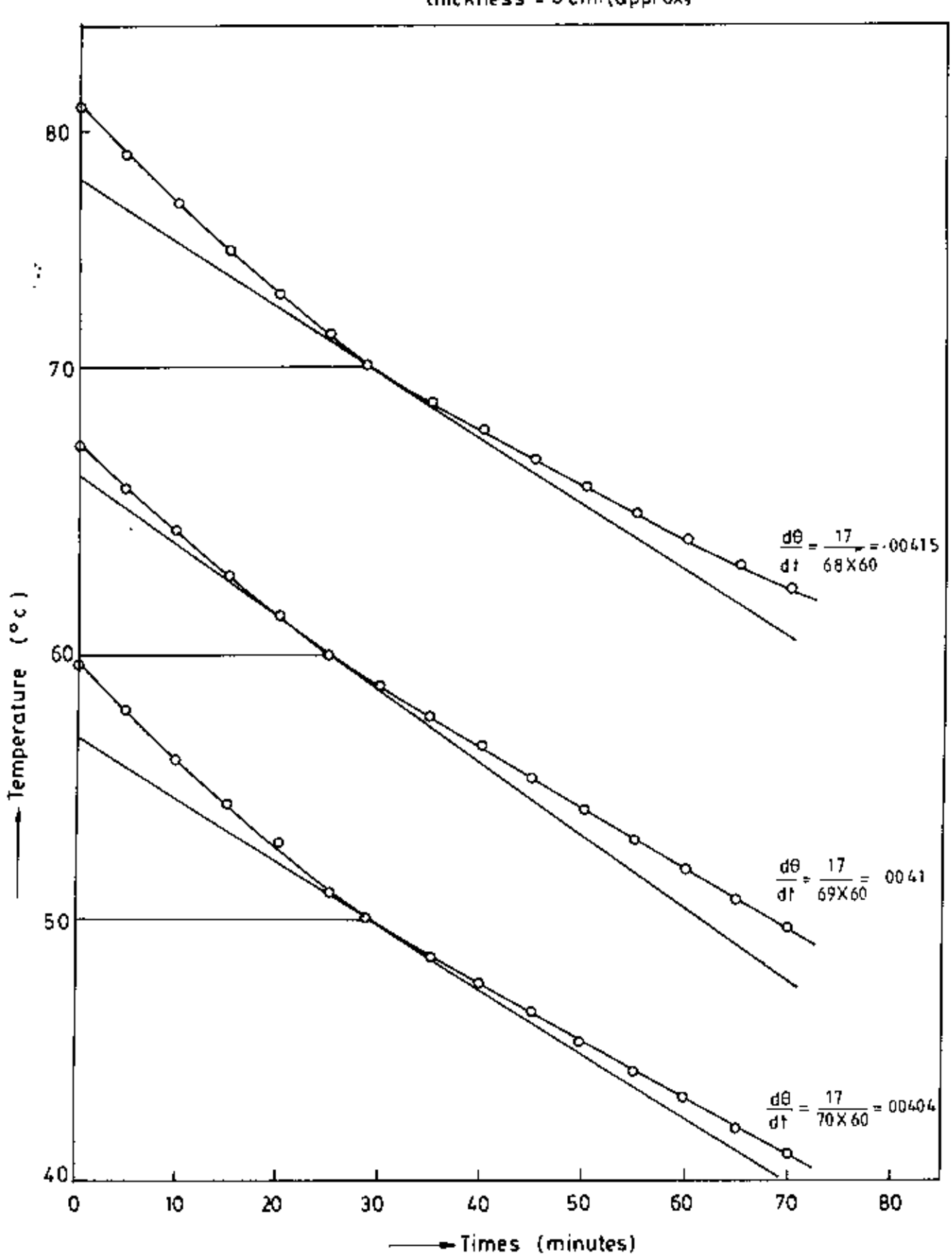
Thickness = 3 cm. (approx.)

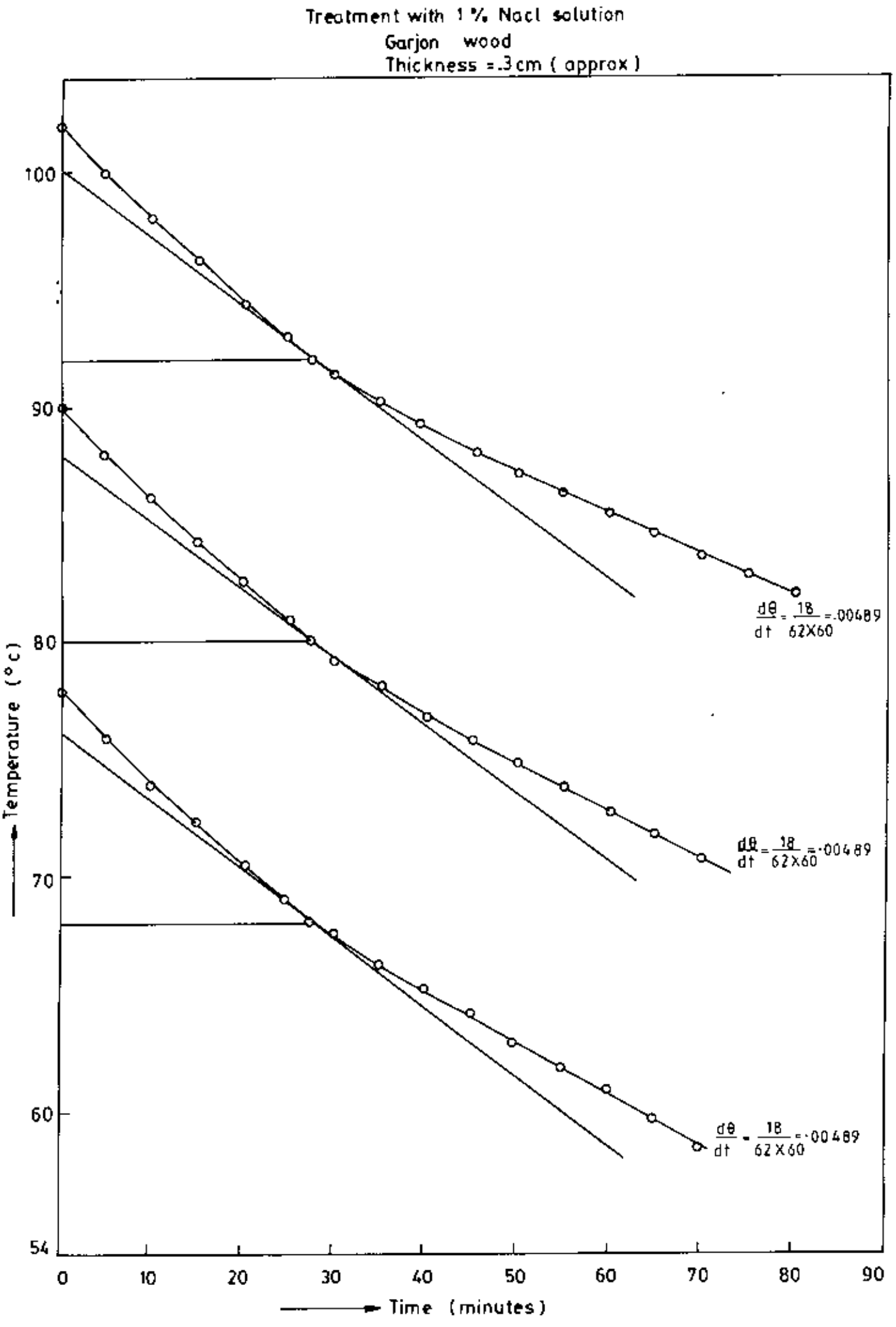


Treatment with 2 % Nacl solution
Segun wood
Thickness = 5 cm (approx.)

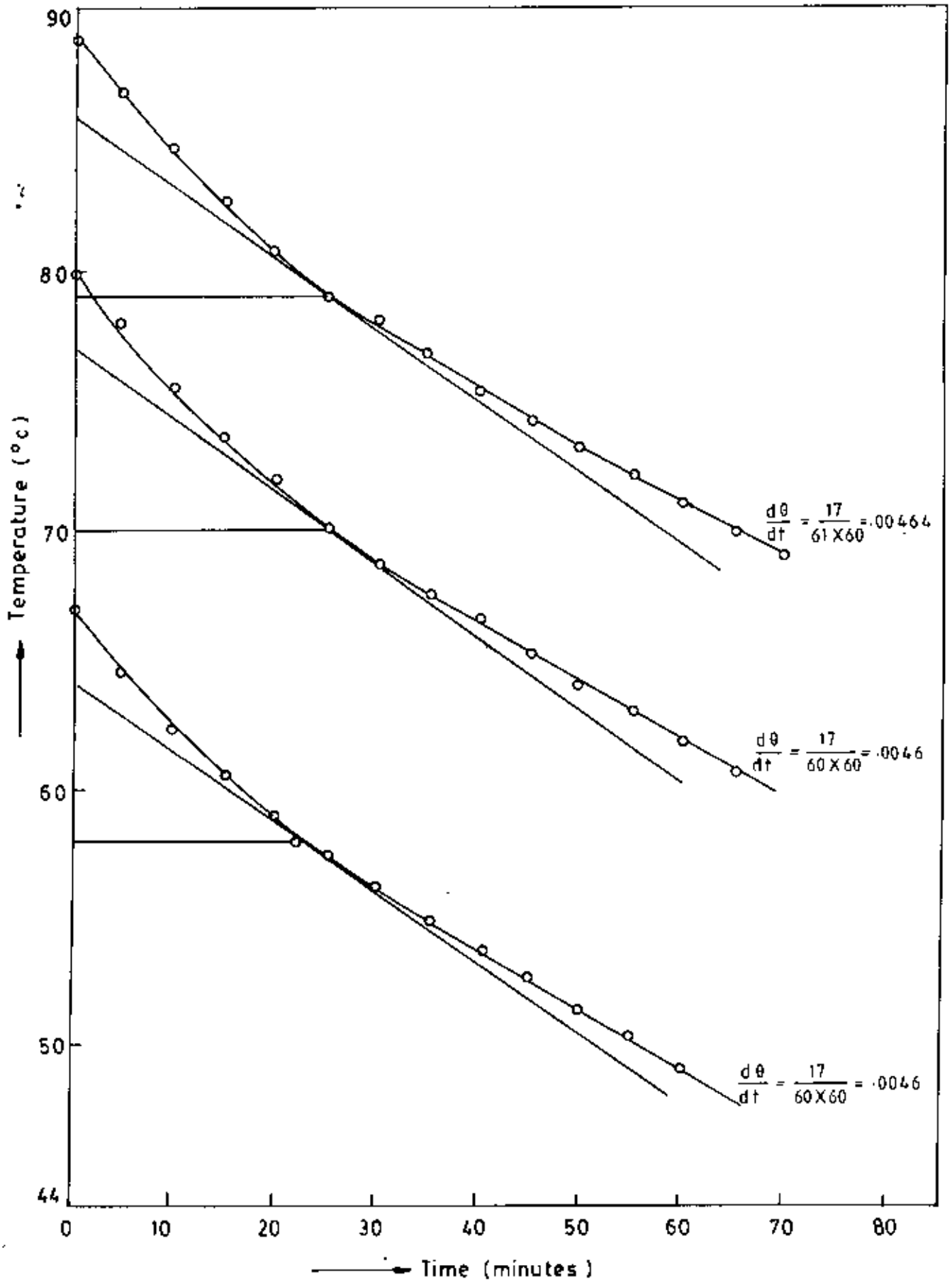



Gorjan wood
thickness 3cm (approx)
90
80
70
60
50
Temperature (°c)
0
10
20
30
40
50
60
70
80
Times (minutes)
dθ/dt = 18.5/65X60 = .0047
dθ/dt = 17/63X60 = .0045
dθ/dt = 17/65X60 = .0044

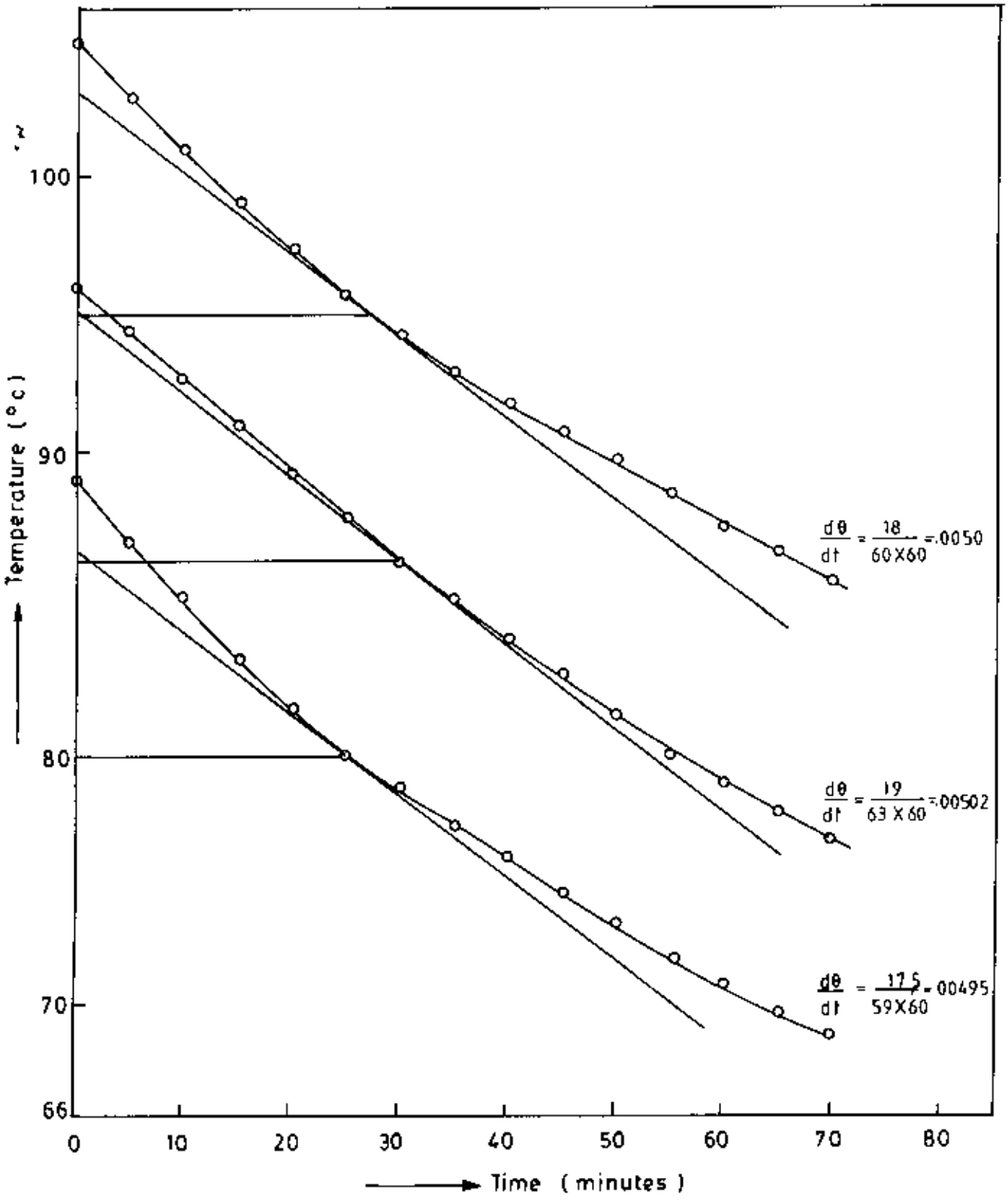

Gorjon wood
thickness = 5 cm. (approx)
80
70
60
50
40
Temperature (°c)
0
10
20
30
40
50
60
70
80
Times (minutes)
dθ/dt = 17/68X60 = ·00415
dθ/dt = 17/69X60 = 0041
dθ/dt = 17/70X60 = 00404


Treatment with 1 % Nacl solution
Garjon wood
Thickness = .3 cm (approx)
100
90
80
70
60
54
Temperature (°c)
0
10
20
30
40
50
60
70
80
90
Time (minutes)
dθ/dt = 18/62X60 = .00489
dθ/dt = 18/62X60 = .00489
dθ/dt = 18/62X60 = .00489

1 % Nacl (Gorjan)
thickness = 5 cm (approx.)

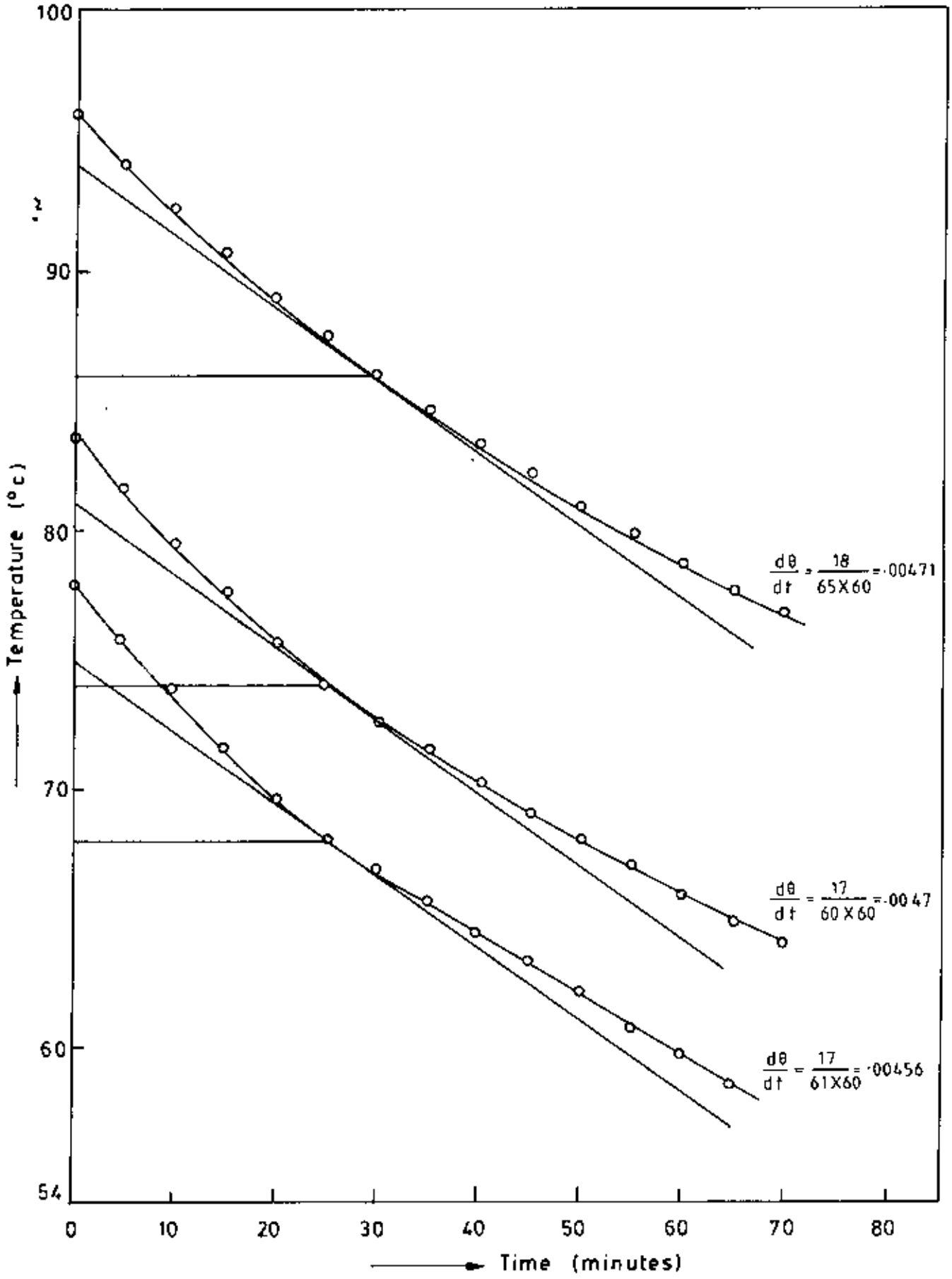


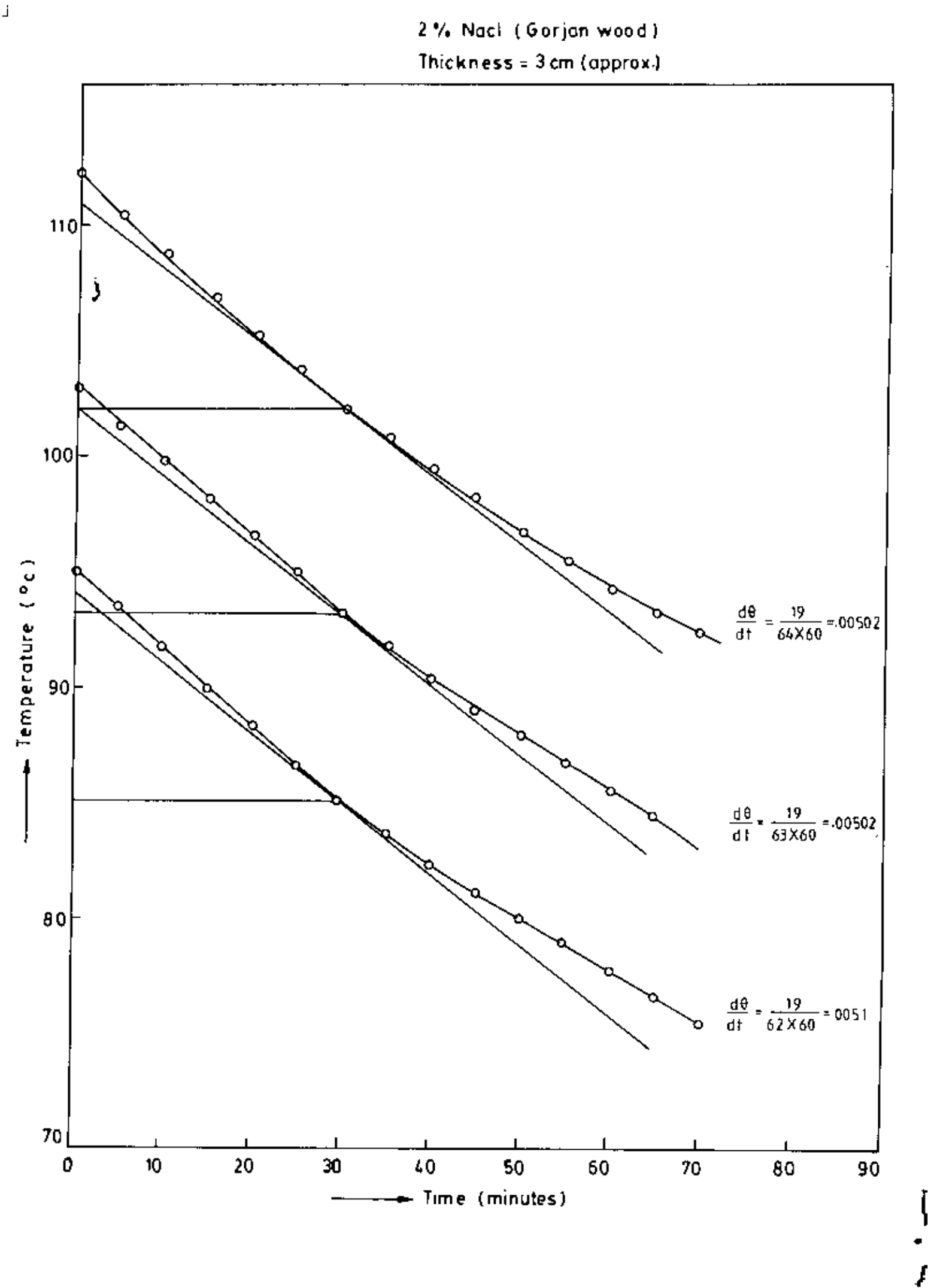
Treatment with 1·5 % Nacl solution
Gorjon wood
Thickness = 3 cm (approx)



1·5 % (Gorjon)

Thickness = 5cm (approx.)




2 % Nacl (Gorjan wood)
Thickness = 3 cm (approx.)
110
100
90
80
70
Temperature (°c)
0
10
20
30
40
50
60
70
80
90
Time (minutes)
dθ/dt = 19/64X60 =.00502
dθ/dt = 19/63X60 =.00502
dθ/dt = 19/62X60 = 0051

Treatment with 2 % Nacl solution
Gorjan wood