INFRARED, MICROSCOPIC AND TENSILE PROPERTIES OF SOME NIGERIAN COTTON VARIETIES.

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BY

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1999

DEDICATION

This thesis is dedicated to my father Mr. J. O. Eze and all those who laid down their lives for the truth.

DECLARATION

This thesis has not previously been presented to another institution for publication or award of a higher degree. It is a record of my own research work and all outside sources of information are indicated and acknowledged accordingly.

SIGN: _____

EZE OSITA JOSEPH

CERTIFICATION

This Thesis entitled "Infra-red, Microscopic and Tensile Properties of Some Nigerian Cotton Varieties" by Eze, Osita Joseph, meets the regulations governing the award of the degree of Masters of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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O. J. EZE

ABSTRACT

The work presented here is a study of the fibre characteristics, infrared spectra, mechanical and absorption/chemical properties of three Nigerian Cotton varieties.

Single fibre and bundle tensile properties of raw, scoured and mercerized (treatments with 17.5% and 24% of Sodium Hydroxide solution) samples were determined. Fibre fineness, maturity, staple length, degree of convolutions, maximum length of convolutions in a fibre test length, unswollen ribbon width and swollen ribbon width were also determined.

An attempt is made to relate infrared spectra, crystallinity and fibre characteristics measurements to mechanical behaviour. Significant differences in specific stress, initial modulus and extension between the three samples were observed and these differences have been attributed to differences in crystallite sizes and orientation. From such relations it is suggested that crystallite size varies for different samples. The results suggest that crystalline size may increase in the order Samcot-8 > Samcot-9 > Samcot-10. Conversely, the Fraction of free hydroxyl groups should decrease in the same order.

It has also been observed that of the three varieties studied Samcot-10 is the most susceptible to alkali treatment and suffer the greatest change especially in specific stress and extension under the processing treatment.

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DEFINITION OF TERMS AND CODES

CODE

R,	Raw cotton samples
S,	Scoured samples with NaoH at 100^{0}C
KB	Kier-boiled samples with NaoH at 100^{0}C industrial scale
S17.5%	Scoured sample and mercerized with 17.5% NaoH
SS24%	Scoured sample and mercerized with 24% NaoH
KB17.5%	Kier-boiled samples mercerized with 17.5% and
KB24%	Kier-boiled samples mercerized with 24% NaoH

TERMS

* Staple length: Longer than average lengths of a fibre; it is a measure of the most frequently occurring length of fibre.
* Fineness: This can be expressed as the fibre perimeter, fibre diameter, Area of Cross Section of fibre, mass per unit length of fibre or specific fibre surface.
* Morphological structure: Features having dimension much larger than those of the chain molecules. It embraces, characteristics such as the length of the fibre, the perimeter and diameter, the shape of the cross section and the thickness and fibrillar pattern in the walls.
* Micro-structure: Structures lower than the size of a crystallite.
* Sub-unit structure: Structure including crystallite and higher than crystallite size.
* Moisture regain: Amount of moisture expressed as a percentage of bone dry weight.
* Moisture content: Amount of moisture expressed as a percentage of the moist weight.
* Maturity Ratio: The percentage occurencce of Normal (N) and dead (D) fibre in a population
* Tex: This is the weight in grammes of kilometer length of fibre
* Length uniformity ratio: Is the proportionate occurence of concentartion of long or short fibres throughout a sample population

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

1.1.1 COTTON FIBRE STRUCTURE

Native cellulose fibre, have in general a spiral arrangement of the component fibrils (Betrabet et al, 1963) in cotton fibres the spiral structures undergo abrupt reversals in directions from left to right or vice-versa, along the fibre length. These are called structural reversals (Betrabet et al, 1963). Another features are the convolutions along the fibre length. Optical studies of cellulosic fibre confirm that the spiral angles are affected by convolutions (Herbert, 1947).

The presence of spirals, reversals, and convolutions is thought to bring about extension in cotton. It has been suggested that higher spirals angles lead to high percentage extension, which could also be related to strength and initial modulus of cotton varieties.

Some workers (Wakeham and Spcier, 1951) have reported that most cotton break at the weak links where the reversals occur. Other workers (Orr et al, 1961; Pillay and Shankaranarayana, 1961; Betrabet et al, 1963) seem to support this view. On the contrary, (Warwicker et al, 1970) reported that most but not all, fibre breaks occur immediately adjacent to reversal zones, concluding that reversal point in cotton is a strong point of the cotton fibre rather than weak points.

The inherent weak points as shown by many workers in cotton fibres, informs the textile industries carefulness in selecting cottons to suit the requirements of desired end-product quality. Commercial selections are currently made on the basis of fibre length, fineness, length uniformity ratio, maturity and strength.

1.1.2 CRYSTALLINITY AND AMORPHOSITY IN COTTON CELLULOSE

A single fibre of native cellulose fibre, is composed of chains of about 3 x $10^4\mu$m long by 15μm wide (Newell and Zeronian, 1985). The X-ray diffraction photomicrographs of a section of cotton cellulose show both regular pattern characteristics of crystalline and non-crystalline regions. In the crystalline region molecules would be arranged in regular order linked together by hydrogen bonds (Morton and Hearle, 1975). In the partly crystalline polymer samples without orientation, the molecules are arranged in fringed - micelles (the same molecules pass through many crystalline regions and several parts of the non-crystalline region; Newell and Zeronian, 1985). This explains why there must be some degree of order in the non crystalline regions, the consensus of opinion suggest (Rose, 1981) that the amount of actual material in any region of the samples that is not part of a crystal lattice is probably small, the disorder being mainly due to the fact that very small crystalline units are imperfectly packed together (Morton and Hearle, 1975).

The suggestions from X-ray diffraction studies is that crystallites are found. These crystallites are of the order of 50nm x 5nm and the chains are packed densely, so densely that even quite small molecules of other substances are unable to infiltrate and chemical reactions can

take place only slowly by erosion from boundaries. Other regions of same specimen where the spacing between the chains molecules appears to be more open, and also or a considerable, proportion, of the chain links in them are accessible to the action of acid (Newell and Zeronia, 1985). In between, the crystallites part of the chains pass through non-crystalline regions where their arrangement is of more or less ordered. The sub-microscopic crystalline particle were termed "micelles" (Morton and Hearle, 1975). The transition from the crystalline region to the amorphous regions is difficult to describe and this difficulty raises the question whether there are discrete crystalline region or not Kargin (1958). In the fringed micelle model the possibility of rather continuous transition from crystalline to amorphous region with the implied distortion of the crystalline lattice is taken seriously. The size of crystalline lattices are therefore not definite but varies from cellulose to cellulose varieties. The amorphosity in cellulose, is mainly due to the fact that the crystallites unit are imperfectly packed together (Hearle, 1958). The crystalline regions are also considered as a continuous fringed fibrils (Hearle, 1958) composed of molecules diverging from the fibre axis at different position along its length.

1.1.3 FIBRILS, MICROFIBRIL AND ELEMENTARY FIBRILS

Electron microscopic studies of cotton reveals that the diameter of a fibril (10nm or less) is a little greater than the supposed width of the crystallite from X-ray diffraction in a fibre (Hearle, 1958) and has led to the proposal of the fringed fibril structure.

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However, the nature and size of fibrils have been the subject of much controversy. Two views exist, one considers the microfibril (according to fringed-micelle concept, 15nm-25nm wide and contains about 600 molecules) as the ultimate building blocks of which all cellulose fibres are made (Bikales, 1970). The microfibril inturn are made up of a single crystalline core. This crystalline core is surrounded by a "paracrystalline sheath" with a smaller natural sub-unit (Egardo, 1976).

The second view considers the microfibrils as made up of small natural units called "elementary" or "protofibril" which contains about 15 to 40 cellulose molecules and cross-sectional dimensions of about 3.5nm (Manley, 1964; Nobert and Leon, 1971, Bangt 1968).

This appear to be at variance with earlier views which considers the crystalline building block of valonia cellulose as anisotropic paracrystalline fibres.

Many workers appear to agree that the smallest unit of crystalline region of the fibre is the "elementary" fibrils, (Blackwell and Kolgak, 1976).

1.1.4 THE CRYSTAL STRUCTURES OF CELLULOSE

In addition to the crystal lattice of cellulose I found in untreated and natural materials such as cotton, cellulose lattices II, III and IV have been identified (Newell and Zeronia, 1985), Kulshreshatha (1979), Attalla (1979). However, due to the difficulties in determination of

unit cell, Sarko (1976), Higgins and Roche (1976) proposed a predictive approach of chain packing i.e. chain approaching each other edge on for the purpose of sheet formation.

The first unit cell dimensions that was proposed for cellulose I is a rhombic unit cell with dimensions of a = 8.35A^0, b = 10.3A^0, C = 7.9A^0, later orthorhmbic unit cell with dimensions a = 6.10, b = 5.40, C = 10.25 was proposed. Investigation by Meyer and co-workers (Rose 1981) led to the postulation of a monoclinic unit cell with parameters a = 8.35A, b = 10.3A, C = 7.9A and B = 84^0. The plane of the glucose unit lie in the "a b" plane and the axis of the cellobiose unit are parallel to the "b axis of the cellulose I.

If cellulose is dissolved and precipitated from solutions or regenerated from some addition compound of cellulose I, such as alkali - cellulose which is formed on mercerization, the molecule do not re-assemble into the characteristics cellulose lattice but into an allotropic modification which give rise to cellulose II. The lattice structure of the cellulose II is based on the monoclinic unit cell found by Meyer and co-workers (Rose 1981) with axes a = 8.14A, b = 10.3A, C = 9.14A and B = 62^0. The molecules are displaced relative to one another along "a" axis and rotated about 30^0 out of the "a b" plane.

All native forms of cellulose have a parallel packing polarity while cellulose II should be capable of existing in both parallel and anti-parallel polarities though anti-parallel cellulose II is more favoured on energetic grounds.

1.1.5 CHARACTERISTICS OF IMPORTANT COTTON VARIETIES

Among various world cotton, may be found a variety of fibre properties based on slow or rapid development and environmental conditions which may hasten or slow down growth.

The Sea Island cotton, an important variety of American cotton differs from other cotton varieties in its staple length, fineness, number and uniformity of convolutions. It contain more thin walled flattened fibres than are encountered in cottons of shorter staple length (Herbert and Matthew, 1947).

Egyptian cotton is another variety of world cotton. This is similar to the Sea Island cottons. In general, cell wall diameter small with few circular fibres and a large percentage of elliptical formations (Herbert and Matthew, 1947). Egyptian cotton like Sea Island cotton is long and soft but as a group Egyptian cottons are as fine as long as the Sea Island group.

American upland cottons have both coarse and fine varieties (Herbert and Matthew, 1947). These cottons have normal characteristics with the finer sample coming from those of the longer staples cottons grown in Delta regions and the coarser from those cotton from the shorter staple grown in upland area.

Samples of Chinese and Indian cotton are short coarse cotton with very thick walls and mostly elliptical or circular shapes (Herbert, et al 1947). The number of convolutions per unit fibre length is small and they usually form a long open spirals, (Herbert, et al 1947), as contrasted with the tight spirals of Sea Island and Egyptian varieties.

Peruvian cotton are coarse cotton (Herbert, et al 1947), it differs from most other coarse types in that it is generally longer than other cotton of such coarseness. The fibres are thick walled, with few immature or thin walled fibres.

In Nigeria the drive to improve on commercial cotton with the changing patterns of consumer demands and preferences necessitated cotton breeding. At least ten varieties of Gossypium hirsutum species of cotton have been produced for export and for the textile industry from local breeding programmes in the last sixty years (Echekwu, 1991, Echekwu, 1990). The limited literature on the characteristics of Samaru bred cottons reveals that much attention have been directed only to the end - use characteristics such as fibre staple length, maturity and fineness. The commercial cotton varieties such as Samcot-6, Samcot-8, Samcot-9 and Samcot-10 have been reported to belong among the best in the world medium staple cottons. The Samaru varieties are also found to have both coarse and fine varieties, (I.A.R. Annual Report, 1990).

1.2 LITERATURE REVIEW

1.2.1 EFFECT OF MOISTURE ON THE COTTON FIBRE STRUCTURE

Wetting the fibre cause untwisting which is accompanied by reduction in crystallite alignment, especially in spiral angle and increase in cross-sectional area. (Hearle and Sparrow, 1979).

Moisture possibly lubricates surfaces of fibrils and growth layers, thus allowing relative movement during untwisting without large stress concentration.

The introduction of water molecules into non-rigid part of the cellulose structure is partly due to hydrogen bonding between water molecules and hydroxyl groups in the cellulose therefore when water is absorbed it provides the necessary energy to break down certain amount of hydrogen links between the cellulose molecules Nelson (1964 and 1970), Sesna (1962) thereby pushing the individual cellulose molecules still further apart. This increases the lattice spacing and produces that swelling of the fibre which characteristically accompanies its absorption of water.

Boiling the cotton hair under pressure causes an almost complete disappearances of both convolution, and reversals accompany by much swelling but on drying, the original character of the hair was reproduced (Rebenfeld, 1961).

1.2.2 EFFECT OF SODIUM HYDROXIDE SOLUTION ON CHARACTERISTICS OF COTTON FIBRES

The first quantitative estimation of swelling of cotton fibres in sodium hydroxide was made by Crum (Oka et al, 1967). Circularity of cotton fibres has been observed to increase with increase in concentration of caustic soda up to about 30% (Oka et al, 1967), while no appreciable changes is noticed with higher concentration (up to 50%). The percent increase in circularity of different cotton on treatment with caustic soda of varying concentration under slack conditions or with caustic soda of mercerizing concentration at different stretches depend on the circularity of the cotton in raw state, being mere pronounced for cotton that have low circularity in the raw state. Furthermore, the effect of sodium hydroxide on circularity of cotton fibres was confirmed to be appreciable and permanent (Orr et al, 1952).

Other results (Oka et al, 1967) show that the maximum change in fibre cross-sectional area in different concentration of caustic soda occurs at between 13% and 18%. Similar studies on bundles of fibres (Oka et all, 1967) shows that in 14% caustic soda solution, the contraction in fibre length was as high as 10%, which decreases sharply in higher concentration. Concentrated alkali solution also causes untwisting in cotton fibres. The shrinkage of cotton, the decrease in crystalline length and the increase in the fibre cross sectional area, as a result of treatment with sodium hydroxide is interpreted on the basis of partial untwisting of the helices (deconvolution) to form helices of large diameter (Rebenfeld, 1961). Swelling leads to decrease in crystallinity which could be considered to be due to untwisting of the helices, resulting in a more open structures (Rebenfeld, 1961), thereby

increases lattice spacing. These changes also increased accessibility, to moisture, dye uptake and chemical reaction. The changes in water content were found to be greater for immature fibres than those of mature fibres (Oka et al, 1967).

1.2.3 EFFECTS OF SODIUM HYDROXIDE SOLUTION ON FIBRE CRYSTALLINITY

During mercerization changes occur to the structure of the fibre. These include formation of alkali cellulose, intensive swelling and structural change in the arrangement of units in the cellulose molecule.

These transformation is from cellulose I lattice structure to cellulose II lattice structure (Jusuke, 1976). Cotton cellulose untreatment transforms from the cellulose I type to the alkali cellulose first, which on hydration forms water cellulose and on drying gives cellulose II (Higgins and Roche, 1976). Hydrated cellulose differs from cellulose I in three ways; macromolecular structure, morphological structure and the amount of hydrogen links between the cellulose molecules.

Sarko (1976) suggested that both polymorph should differ in crystallinity and crystal structure, this differences could be traced to alteration of crystal lattice during mercerization as earlier suggested.

Mercerization increases the percentage of amorphous cellulose as a result of transition from cellulose I to cellulose II crystal lattice. Therefore crystallinity is reduced and a large contraction in fibre length which means increase in spiral angle occur. Slack mercerization could cause a greater randomization of orientation in the amorphous regions of chain molecules (Rollin, 1954). Due to the increasing amorphous content and decreasing crystallite size, crystallite alignment especially as it relates to spiral angle reduces.

1.2.4 THE EFFECTS OF SODIUM HYDROXIDE ON MECHANICAL PROPERTIES OF COTTON FIBRES

Different cottons in yarn state subjected to identical chemical treatment e.g. mercerization, differ in their response to the chemical treatment (Rebenfeld, 1961; Grant, 1958; McDonald, 1957) and McDonald (1956).

Rebenfeld (1958) and Rahalkrishman et al (1959) study on a single fibre mercerization reported varying changes in fibre strength and extensibility. This was interpreted in the work of Zeronia (1976) to be as a result of reduction in length of crystallite and increase in crystallite orientation. Ahmad (1971) attributes loss of tenacity to crystallization during mercerization. Mercerization change spiral angle and hence modulus, extensibility, and tensile strength of the fibre (Herbert, 1968; Morosoft and Ingran, 1970).

Mechanical properties such as tensile strength, modulus and work of rupture in many cases are related to fibrillar orientation (Rebenfeld, 1961). Greater randomization of orientation of chain molecules as a result of transition from crystalline to the amorphous regions results

in increased elongation and since mercerization is known (Rebenfeld, 1961) to have effect on fibrillar orientation , it could be said that changes in mechanical properties which depend upon orientation would also be function of fibrillar orientation.

Mercerization also lead to decrease in density of interlinks and increase in crystallite orientation. This decrease in density of interlinks and increased crystallite orientation lead to decreased in initial modulus, and increase in tensile strength (Zeronia, 1976).

1.2.5 MOLECULAR STRUCTURE AND TENSILE PROPERTIES OF CELLULOSE FIBRES

There are indicators that differences in degree of order are important and that increased crystallinity raises the ultimate strength of fibres (Morton and Hearle, 1975). The mechanical properties of cellulose fibres are greatly influenced by degree of orientation of the molecules along the fibre axis (Morton and Hearle, 1975). Increase orientation is found to increase tenacity and decrease elongation. Also lower crystallinity, results in high increase in spiral angle (Morton and Hearle, 1975). The effect of orientation was found to be much more important than the effect of crystallinity on mechanical properties but it is difficult to alter orientation to give improved property in the desired direction without accompanying alteration in the degree of order (Hans, 1976).

High density of cross-links per microfibril could cause high initial modulus, lower extension and high tensile strength. Higher extension suggest higher spiral angle due to untwisting and unbending while lower spiral angle suggest higher tensile strength, higher initial modulus and

lower extension. Hans (1961) observe that tensile strength is a linear function of the reciprocal of the number average degree of polymerization which a minimum is required for any useful tensile properties (Owoicho 1980 and Buba, 1981).

1.2.6 GENERAL RESEARCH CONSIDERATION

At least ten varieties of Gossypium hirsutum species of cotton have been produced for export (Echekwu, 1990 and 1991).

Initial studies of gross-structure and tensile properties of Nigerian cotton varieties began a few years ago (Harrison and Aliyu, 1995). The present investigation of fibre structure using the infrared technique is a continuation of that work.

The number of varieties studied were increased. Samples used include (Samcot-8, Samcot-9 and Samcot-10) and so are the methods for the characterization of fibres. Accessibility, through moisture regain and iodine sorption, visual examination of the fibres through the light microscope as well as bundle tensile properties are included as part of the studies.

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CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1 MATERIALS

a) Cotton varieties - Samcot-8, Samcot-9 and Samcot-10 (IAR)

b) Sodium hydroxide (M & B)

c) Acetic acid glacial (BDH)

d) Trichloroethylene (M & B)

e) Ammonia solution (BDH)

f) Ammonium chloride

g) Sodium thiosulphate

h) Ethyl alcohol (BDH)

i) Starch solution

j) Ammonium sulphate

k) Transverse stage microscope fitted with an inbuilt condenser

l) 10 x Ocular (eyepiece), 10 x objective

m) Eyepiece metric unit.

2.2 METHODS

2.2.1 SOLVENT SCOURING

Loose cotton samples of Samcot-8, 9 and 10 were soxhlet extracted with trichloroethylene for four hours in order to dewax the samples. Three samples with the following code were obtained - 8S, 9S and 10S.

2.2.2 KIER BOILED

The dewaxed and dried cotton samples were boiled in 2% sodium hydroxide solution for 30 minutes. Excess alkali was neutralized with 1% acetic acid which was in turn removed by treatment with dilute ammonia solution.

Excess ammonia was removed by rinsing in warm water. A wash with ethanol after the rinse completed the process. Three samples with the following codes were obtained - 8KB, 9KB and 10KB

2.2.3 MERCERIZATION

The clean cotton was immersed in sufficient caustic soda liquor of concentrations 17.5% and 24% at 50°C. The material was kept in the liquor for 15 minutes and was frequently stirred with a glass rod to ensure complete reaction. Excess alkali was neutralized with 1% acetic acid which was in turn removed by treatment with dilute ammonia solution. Excess ammonia was removed with a water rinse. A wash with ethanol after the rinse completed the process.

Twelve samples (four from each cotton variety) with the following codes were obtained and dried in oven maintained at 105°C.

Samcot:- 8: 8S17.5%, 8S24%, 8KB17.5%, 8KB24%

Samcot:- 9: 9S17.5%, 9S24%, 9KB17.5%, 9KB24%

Samcot:- 10: 10S17.5%, 10S24%, 10KB17.5%, 10KB24%

2.2.4 MOISTURE REGAIN

A British Standard procedure with modification in temperature was used to determine the moisture regain of the cotton samples at relative humidity of 81% and standard tropical temperature of 27°C + 2°C.

Moisture regain was calculated as moisture absorbed to bone dry weight and the amorphous fraction was estimated using valentine equation (Newell and Zeronia, 1985).

2.2.5 IODINE SORPTION VALUE

A modification of the Schwerstassek procedure (Hessler and Power, 1954; Bailey, 1958) was used. 0.1g of each sample was treated with 0.2cm^2 of Iodine solution (5g iodine + 40g KI + 50cm^3 of distilled water) in a conical flask, the solution was diluted with 10cm^3 of a saturated solution of Sodium Sulphate decahydrate ($Na_2SO_4.10H_2O$) measured accurately into the flask and content plus cotton samples were stored in a dark place for about 2 hours.

The Iodine remaining in the solution was determined by titrating $5cm^3$ with about (2M) $Na_2 S_2 O_3$ to which had been added $5cm^3$ of distilled water and $1cm^3$ of starch solution (0.1g of starch per $100cm^3$ of water + 3g KI).

A blank on the original iodine solution was determined at the same time in a like manner. Calculations were made using (Schwertassek equation, Hessler (1954 and 1959) mg/g samples = a - b x 2.04 x 2.54 - g sample to estimate percentage amorphous fraction.

2.2.6 MICROSCOPIC STUDIES

The procedure consist of taking a small tuft of cotton fibres and "breaking" it by gripping firmly in both hands and pulling apart. Pinches of fibres were extracted from the freshly exposed surfaces of the cotton samples until ten single fibres were isolated and mounted per slide.

Observations were made using microscope fitted with a traversing stage with inbuilt condenser and having a magnification of 100 x (the magnification was obtained by 10 x eyepiece and 10 x objective). Observation of cotton fibres untreated and when swollen with 18% sodium hydroxide was carried out in batches, each batch consisting of 100 single fibres for maturity estimation, convolution length, convolution number per standard length of 1.5cm, wall thickness and ribbon width/ribbon diameter of the single fibres were estimated.

2.2.7 MECHANICAL TESTING OF COTTON SAMPLES

A single cotton fibre was mounted on a specimen card of 1.5cm gauge length. The tensile strength of such fibre was determined using the Instron tensile tester model 1026 with the following settings:

Cross head to chart speed ratio	=	1:5
Cross head speed	=	50mm/min
Gauge length	=	1.5cm
Maximum load (full scale deflection)	=	50g

2.2.8 LINEAR DENSITY MEASUREMENT

The single fibres were extracted from the surfaces of small tuft of cotton fibres. One hundred lengths of single fibres were extracted and formed into a bundle, then cut to 1.0cm. The weight of the bundle was determined on an analytical weighing balance and the weight of a single fibre was estimated in g/tex.

2.2.9 INFRA-RED SPECTRA USING PRESSED DISK TECHNIQUE

Samples of cotton fibres were ground and mixed with KBR (potassium bromide), Robert et al (1958) the ratio of KBR to cotton is about 150mg to 0.5mg (0.1%).

The mixture was evacuated for at least 2 minutes in an evacuable die and a pressure of 9 tons was applied for minimum of two minutes. The transparent pallets obtained were studied in a double beam pu9706 model Infrared Spectrophotometer calibrated with polystyrene film.

2.3 CRYSTALLINITY RATIO

For each sample, an attempt was made to calculate two crystallinity ratios a and b, spectral resolution. These were defined as follows:

$$a = \frac{a1425}{a895} \quad \text{and} \quad b = \frac{a1370}{a2900}$$

a1425, a945, a1370 are absorbance calculated from % transmittance of peak heights at 1425, 895, 1370 and 2900 cm^{-1} respectively.

2.4 STORAGE OF PREPARED SAMPLES

The cotton samples prepared were stored in different conditions. Some were stored in a desiccator maintained at 68% relative humidity (RH) with saturated solution of KNO_3 and NH_4Cl at $27^0C \pm 2^0C$, others were stored in a desiccator with drying agent and some stored at $105^0C \pm 2^0C$ for infrared spectroscopic studies.

CHAPTER THREE

3.0 RESULTS

3.1 INFRARED SPECTRA OF FIBRES IN 2000 - 4000cm^{-1} REGION

A broad band is observed at 3380cm^{-1} in the three cotton varieties as shown in the figures 1 - 7. The frequencies are within the O-H stretching region and therefore could be assigned to the OH absorption in the cellulose varieties (Liang, 1959 and Joseph, 1969). The fact that these bands are broad and shifted to relatively lower frequencies, than the usual bands for O-H groups, shows that hydrogen bonding of either inter or intra (or both) molecular is predominant in the three cotton varieties. Samcot-10 has stronger hydrogen bond than Samcot-8 and Samcot-9 from its relatively lower absorption band. This difference is however not much to provide any substantive evidence of differences in strength of hydrogen bonds. The stronger hydrogen bond of Samcot-10 may be the reason for its higher crystallinity. This is shown later in Table 14. Reference to figures 1 - 7 will show that the absorptions at 2729cm^{-1} in Samcot-8 and Samcot-9 which flattens out on mercerization are of structural importance to these varieties. Absorption bands are present at 2880 - 2900cm^{-1} in Samcot-8 and Samcot-9 and 2880 - 2900cm^{-1} in Samcot-10. These bands, occur in the C-H stretching region and could therefore be assigned to this type of motion in both varieties.

Liang (1956) work on other cellulose shows that most cellulose show symmetric and antisymmetric stretches in this region and on this basis the 2880-2900cm^{-1} for both Samcot-8 and Samcot-9 were assigned to CH_2 symmetrical and antisymmetrical stretching modes respectively.

3.1.1 INFRARED SPECTRA OF SAMCOT-8, SAMCOT-9 AND SAMCOT-10 IN 600CH^{-1} 1500CM^{-1}

Samcot-9 was observed to show a better resolution than Samcot-8 and Samcot-10. Although Samcot-8 shows better resolution than Samcot-10 this could mean less interaction of vibrating groups with each other in that same trend.

Bands occur in 1420-1425 for Samcot-8, Samcot-9 and Samcot-10 as shown in Table 3 to 6. These bands can be associated with CH_2 bending modes (Liang, 1959) as shown in Table 1 to 3. These bands are important in crystallinity studies and their intensities are qualitative indicators of crystallinity in a native cellulose samples. The 1370-1375 absorption bands are the most important in the structural studies of the three cotton varieties. The bands are used qualitatively and quantitatively in crystallinity studies and to monitor structural transformation from scoured to mercerized samples. Differences in the intensity of the bands indicates difference in the crystalline content and indirectly structural differences between the varieties.

The 895 band is important to crystallinity studies. This band is weak in Samcot-10, Samcot-8 but intense in Samcot-9. This could be due to vibrations of C1 and attached atoms or due to skeletal vibrations along the molecules. Bands occurring between 950-1000 in the cotton

varieties could probably represent skeletal complex stretching and bending modes of the C-C bonds.

Bands at 663, 700-740 was assigned to CH_2 rocking. Therefore the band at 665cm^{-1} of the cotton varieties under study will be assigned to O-H out of plane bending and bands at 705-710 will be assigned CH_2 rocking. For comprehensive band assignment, refer to Tables 1-3.

The strongest bands showing the greatest changes are those at 1370, 1335 and 1315cm^{-1}. The cotton differ chiefly in the resolution and intensity of bands at 1370, 1335 and 1315cm^{-1}. These bonds are merged into a diffuse regions in Samcot-8 and Samcot-10 but were resolved in Samcot-9. And also in the small bands at 1270 and 1230 which are weak and diffuse in Samcot-8 and Samcot-10 but slightly stronger and broader in Samcot-10.

It is clear from the spectra that the three varieties in their Raw and mercerized state differ mainly within the 1500 - 600 region. This region is also known to be the most sensitive to polymorphic change. This shows that untreated samples of this varieties and mercerized samples represent two distinct conformations of cellulose molecules in two forms called polymorph.

WAVE NUMBER cm^{-1}	INTENSITY	BREADTH	ASSIGNMENTS
665	Weak	diffuse	O-H out of plane bending
710	shoulder	diffuse	CH_2 rocking
890	weak	broaden	C-O stretching*
995	shoulder	strong	
1020	weak	diffuse	skeletal modes
1055	weak	broaden	antisym in phase ring stretching
1110	weak	broaden	
1160	sharp	strong	ring stretching C-O-C, C-O stretching
1200	shoulder	strong	
1280	weak	diffuse	ring stretching, O-H deformation
1290-1350	weak	diffuse	CH bending
			CH_2 wagging motion, O-H in plane bending
1370	weak	diffuse	
1420	much stronger	broad	C-H bending
1620	weak	broad	CH_2 scissoring absorbed water
2720	sharp	sharp	CH stretching vibration
2885	strong	broaden	CH_2 antisym stretching
3380	strong	broaden	O-H stretching

TABLE 1 **SAMCOT-8; ASSIGNMENTS OF BANDS**

* Ref: Liang et al (1956), Liang and Machessault (1958), Machessault and Liang (1960), Marrinan and Mann (1956) Mann and Marrinan (1958).

WAVE NUMBER cm^{-1}	INTENSITY	BREADTH	ASSIGNMENTS
665	sharp	strong	O-H out of plane bending
710	shoulder	strong	CH_2 rocking
890	weak	broaden	C-O stretching
995	shoulder	strong	skeletal modes
1020	weak	diffuse	
1055	sharp	strong	antisym in phase ring stretching
1110	sharp	strong	ring stretching
1160	sharp	strong	C-O-C, C-O stretching
1290(shift)	shoulder	strong	ring stretching, O-H deformation
1280	weak	diffuse	CH bending
1310	weak	diffuse	CH_2 wagging motion
1330	weak	diffuse	O-H in plane bending
1370	sharp	strong	C-H bending
1425	sharp	strong	CH_2 scissoring
1620	strong	broaden	absorbed water CH stretching vibration
2720	sharp	sharp	vibration
2885	strong	broaden	CH_2 antisym stretching
3380	strong	broaden	O-H stretching

TABLE 2 SAMCOT-9; SPECTRA ASSIGNMENTS

WAVE NUMBER cm^{-1}	INTENSITY	BREADTH	ASSIGNMENTS
665	weak	broaden	O-H out of plane bending
710	shoulder	diffuse	CH_2 rocking
850	weak	broaden	possible shift from 800^{-1}
890	weak	diffuse	ring breathing C-O stretching
965	shoulder	diffuse	
995	shoulder	strong	
1020	weak	diffuse	skeletal modes
1055	sharp	strong	antisym in phase ring stretching
1110	weak	broaden	ring stretching
1160	weak	broaden	C-O-C, C-O stretching
1200	shoulder	strong	ring stretching, O-H deformation
1310	-	diffuse	CH_2 wagging motion
1330	-	diffuse	O-H in plane bending
1370	weak	diffuse	C-H bending
1425	strong	broaden	CH_2 scissoring
1620	weak	diffuse	absorbed water
2885	strong	broad	CH_2 antisym stretching
3380	strong	broad	O-H stretching

TABLE 3 SAMCOT-10: SPECTRA ASSIGNMENTS

PURIFIED COTTON (cm^{-1})	8KB (cm^{-1})	8S17.5% (cm^{-1})	8S24% (cm^{-1})	8KB17.5% (cm^{-1})	8KB24% (cm^{-1})
665	670	665	670	670	
705	710	710	710	710	710
-	855	-	-	-	-
895	890	890	890	895	890
-	955	-	-	-	-
995	990	890	990	990	990
1030	1025	1025	1020	1025	1025
1060	1055	1055	1055	1060	1060
1110	1110	1110	1110	1110	1110
-	-	-	-	1160	1155
1160	1160	1160	1155	1200	1200
1200	1200	1200	1200	1235	1230
-	-	-	1235	-	-
1280	1275	-	1260	1265	1275
-	-	-	1280	1280	-
1315 Not well resolve	1310	1315	1315	1315	1315
1320-1350 Not resolve	-	-	1335	1335	1330
1370	1370	1370	1370	1370	1370
1425	1425	1425	1425	1425	1425
1480	-	-	-	-	-
1620	-	-	-	-	
2720	-	-	-	-	
2885	2885	2885	2882	2882	2882
3380	3380	3380	3380	3380	3380

TABLE 4: SAMCOT-8 SPECTRA ABSORPTION BAND POSITIONS (cm^{-1})

PURIFIED COTTON (cm^{-1})	9KB (cm^{-1})	9S17.5% (cm^{-1})	9S24% (cm^{-1})	9KB17.5% (cm^{-1})	9KB24% (cm^{-1})
660	665	665	670	665	665
705	710	710	710	710	710
895	890	890	890	890	895
995	-	990	990	990	990
1030	-	1025	1020	1020	1015
1064	1055	1055	1055	1060	1055
1110	1110	1110	1110	1110	1110
1160	1155	1160	1055	1160	1155
1200	1200	1200	1200	1200	1200
-	-	-	1230	1230	1235
1280	1275	-	1260	-	1275
1315 Not well resolved	1315	1315	1280	1315	1315
1370	-	1335	1315	1335	1330
1425	1370	1370	1335	1370	1370
1480	1425	1425	1370	1425	1425
1620	1480	-	1425	-	-
2720	-	-	-	2882	-
2882	2885	2885	2882	3380	2882
3380	3380	3380	3380	-	3380

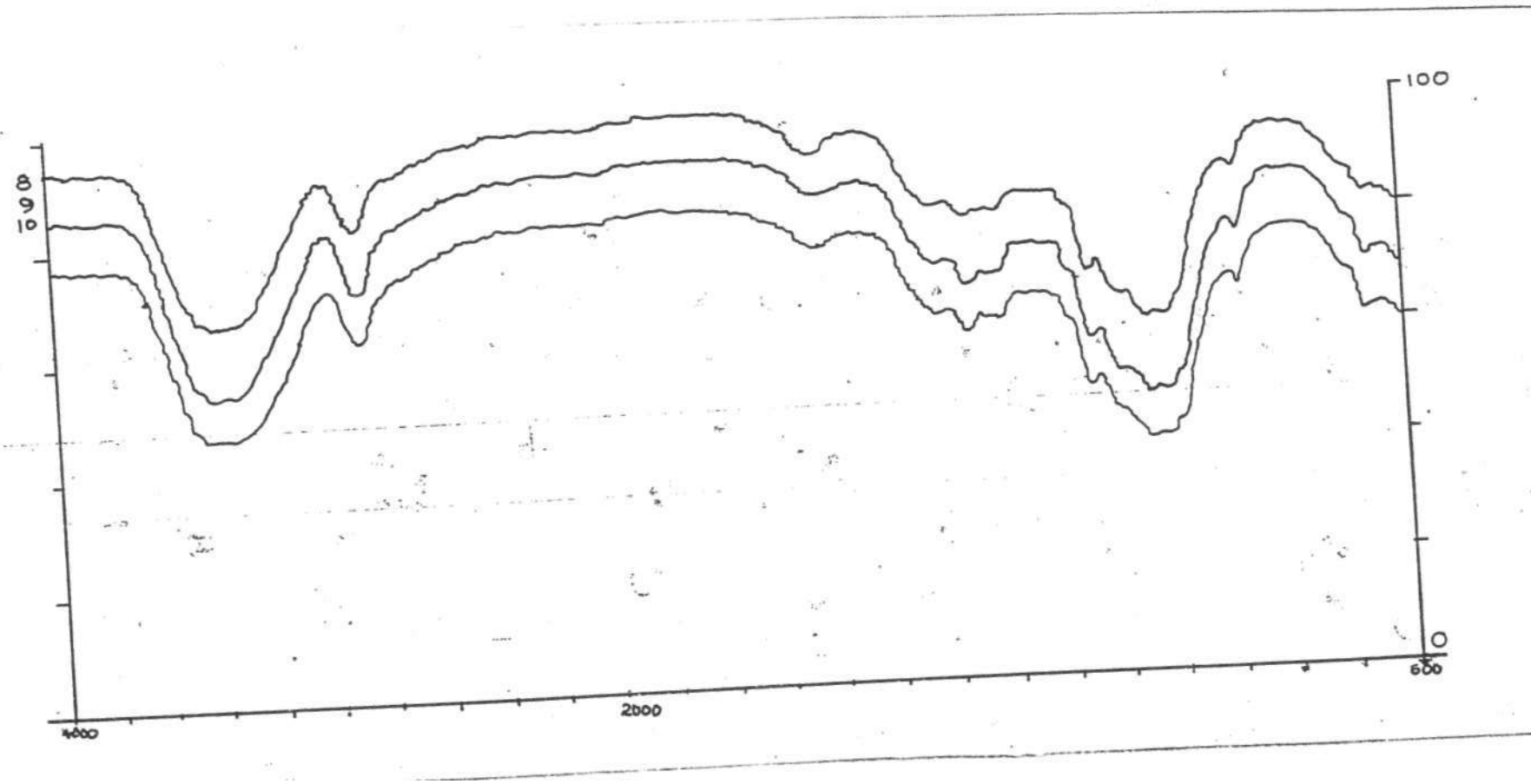
TABLE 5: SAMCOT-9 SPECTRA ABSORPTION BAND POSITIONS (cm^{-1})

PURIFIED COTTON (cm^{-1})	10KB (cm^{-1})	10S17.5% (cm^{-1})	10S24% (cm^{-1})	10KB17.5% (cm^{-1})	10KB24% (cm^{-1})
660	665	665	665	670	670
705	705	710	710	710	710
850	855	-	-	-	-
895	890	890	890	890	890
965	-	990	990	900	990
1000	-	-	-	-	-
1025	1025	1020	1020	1020	1020
1060	1055	1055	1060	1060	1060
1110	1110	1110	1110	1110	1110
1160	1155	1160	1160	1160	1150
1200	1200	1200	1200	1200	1195
1310-1350 Not well resolved	1315	1317	1315	1315	1225
1370	1370	1370	1370	1370	1260
1425	1425	1425	1425	1425	1275
2882	2885	2885	2882	2882	1315
3380	3380	3380	3380	3380	1330
				2882	1370
				3380	1425
					2882
	3380		3380		3380

TABLE 6: SAMCOT-10 ABSORPTION BAND POSITIONS (cm^{-1})

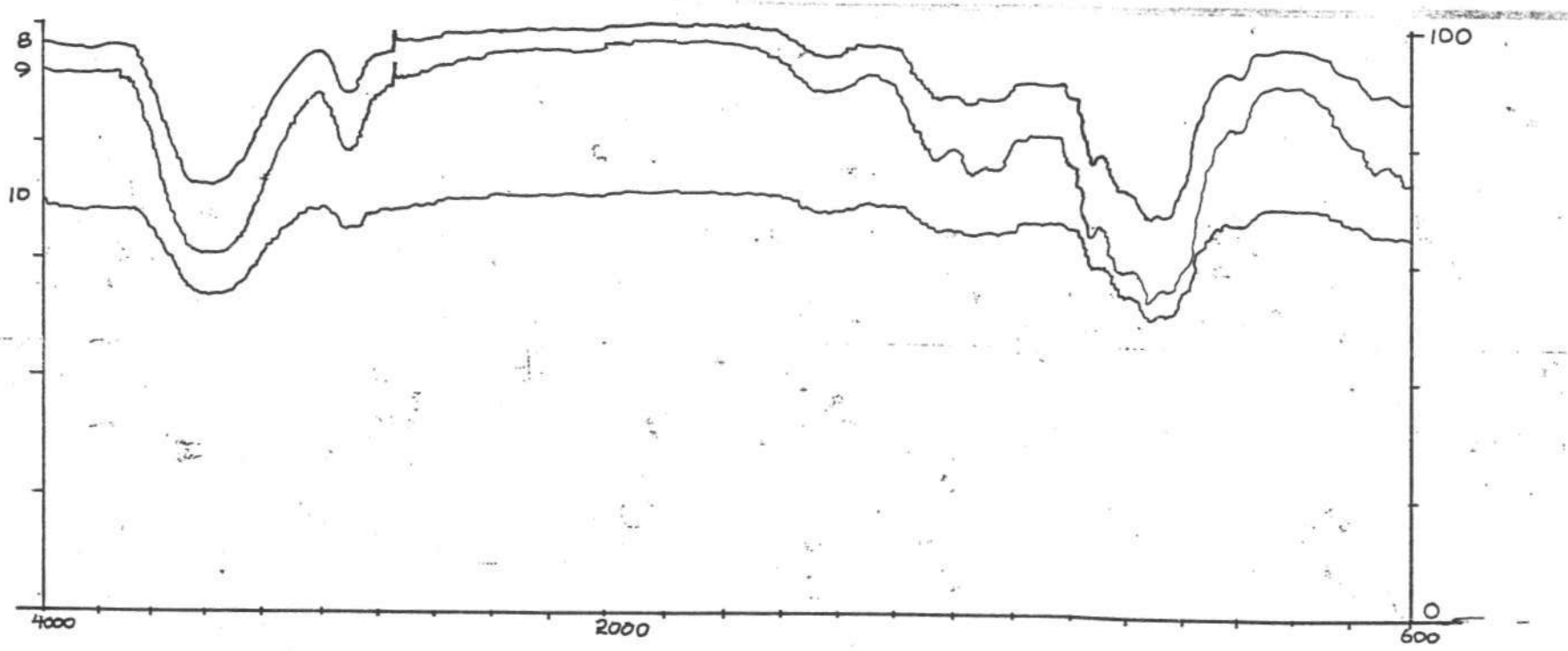
SOLVENT SOURCED (17.5%)

SPECTRAL DIAGRAM



RAW COTTON

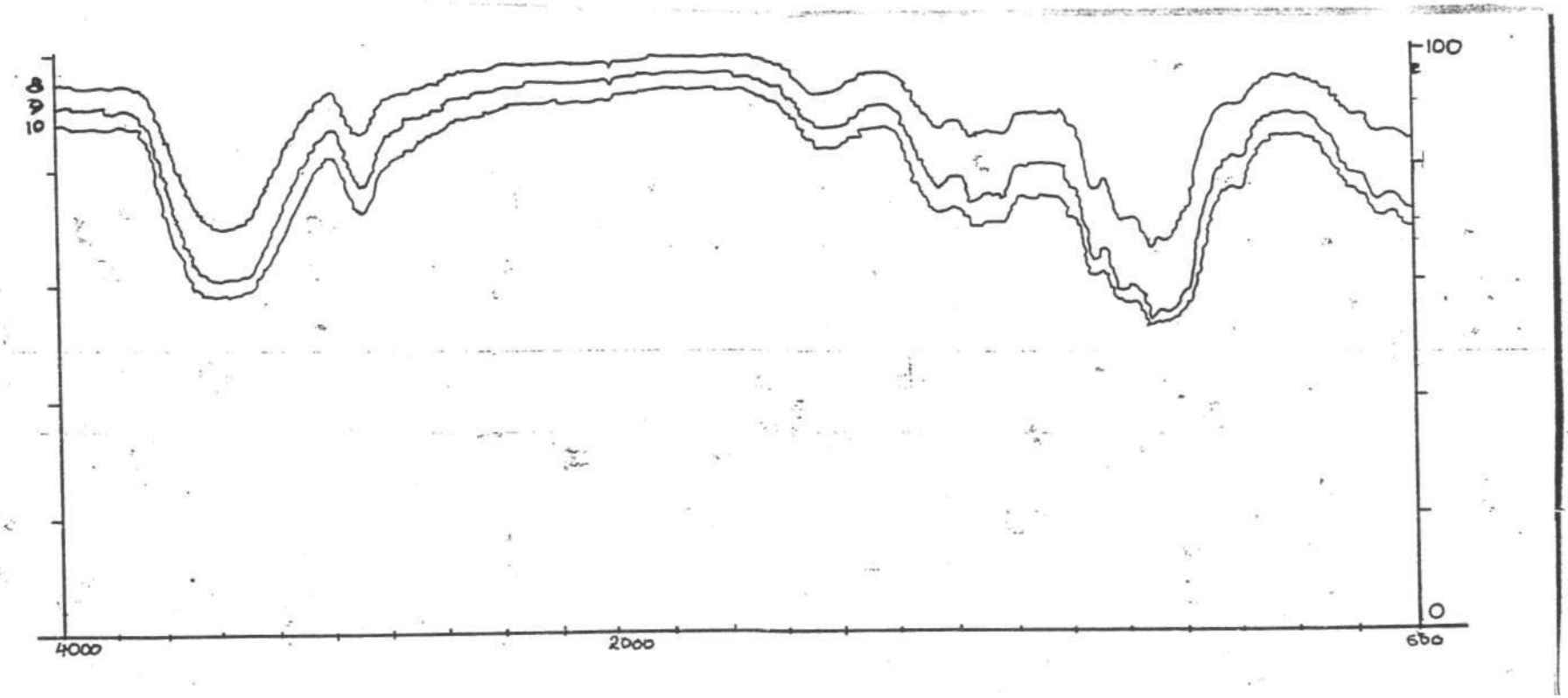
SPECTRAL DIAGRAM



SOLVENT SCOURED

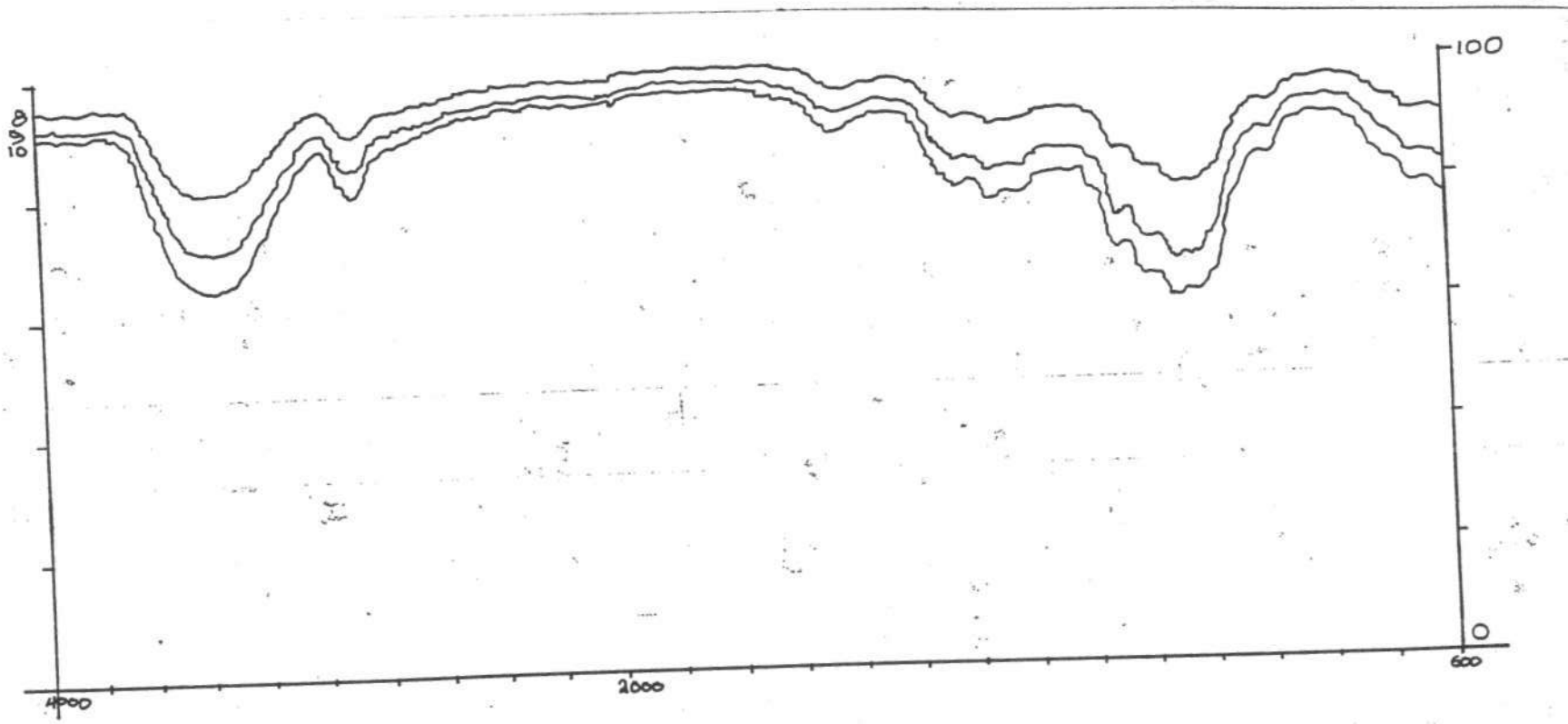
(PURIFIED)

SPECTRAL DIAGRAM

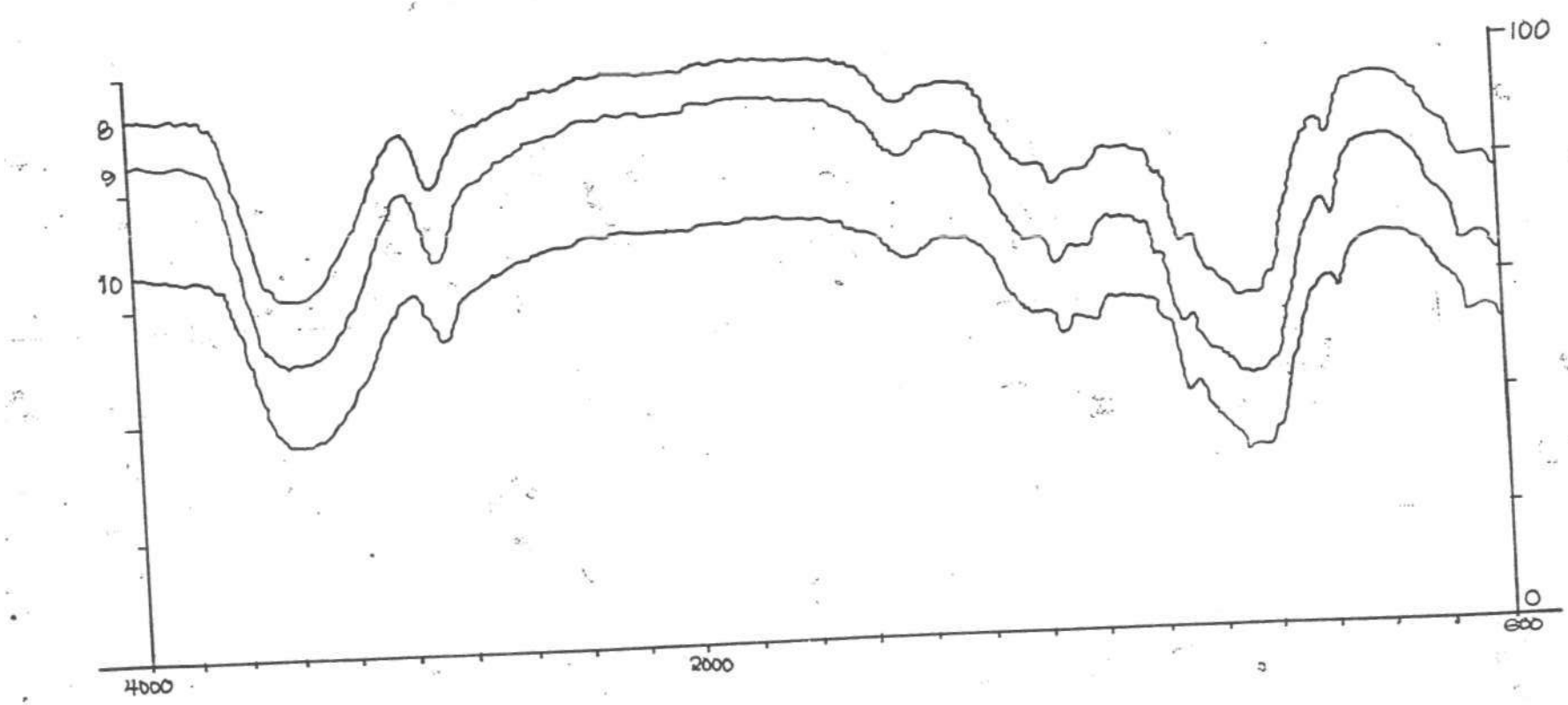


KIER - BOILED

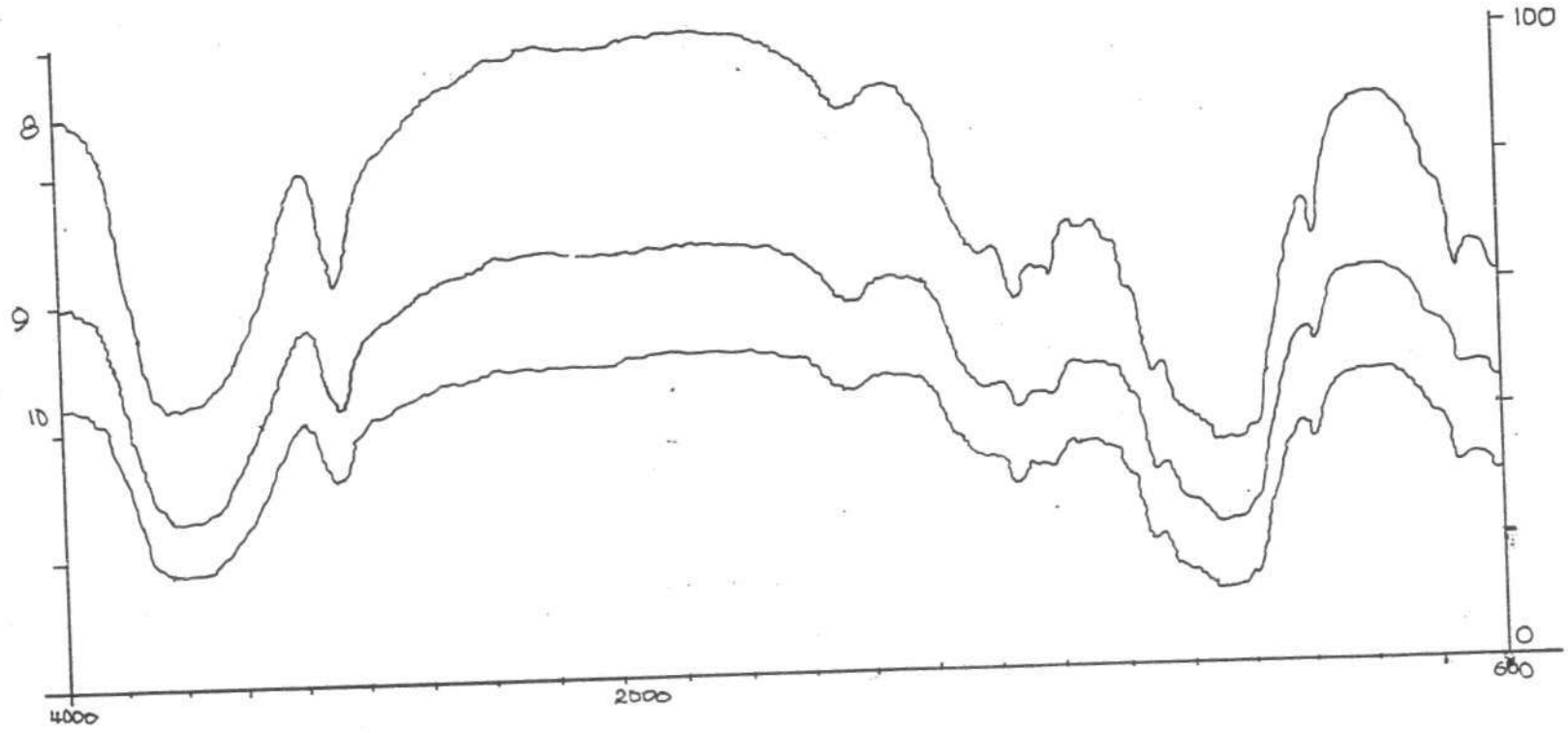
SPECTRAL DIAGRAM



SOLVENT SCOURED AND MERCERIZED (24%)
SPECTRAL DIAGRAM

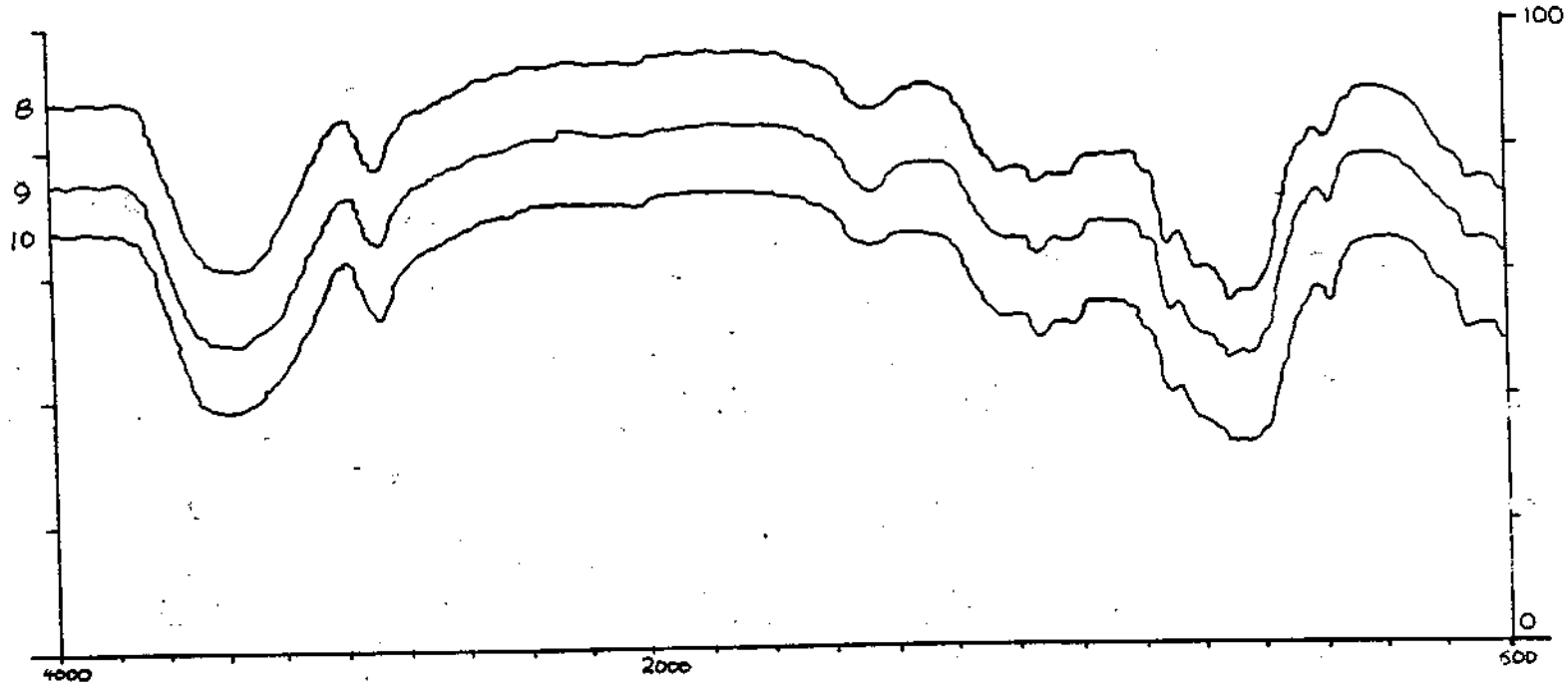


KIER BOILED & MERCERIZED (17.5%)
SPECTRAL DIAGRAM

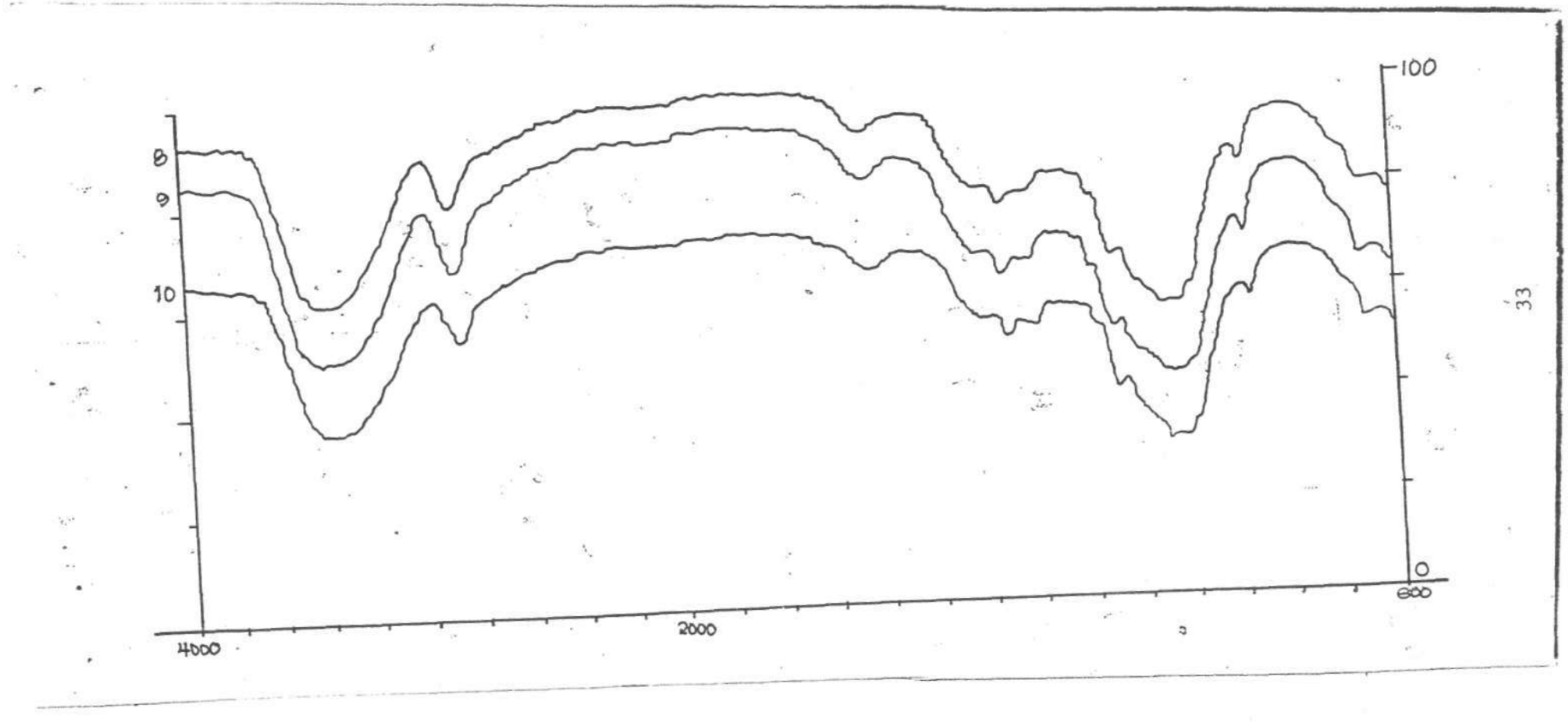


KIER BOILED AND MERCERIZED (24%)

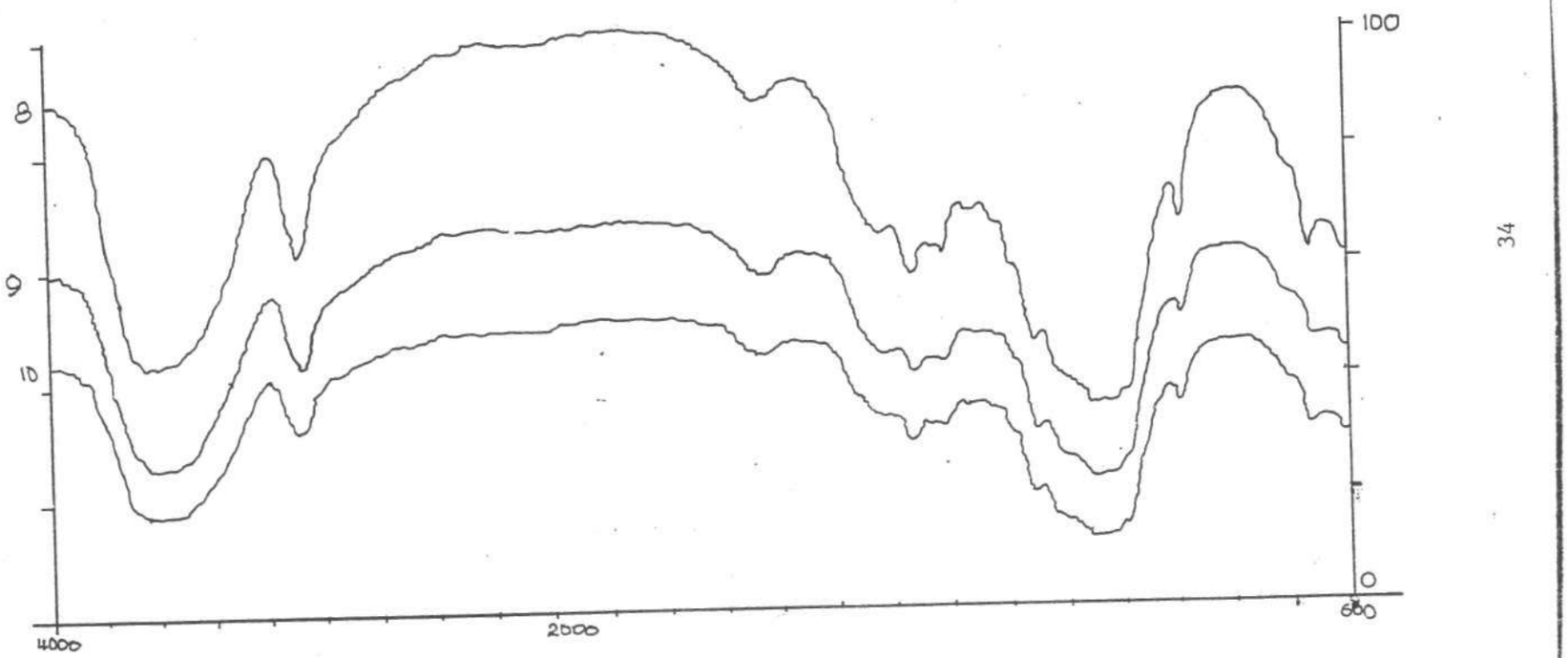
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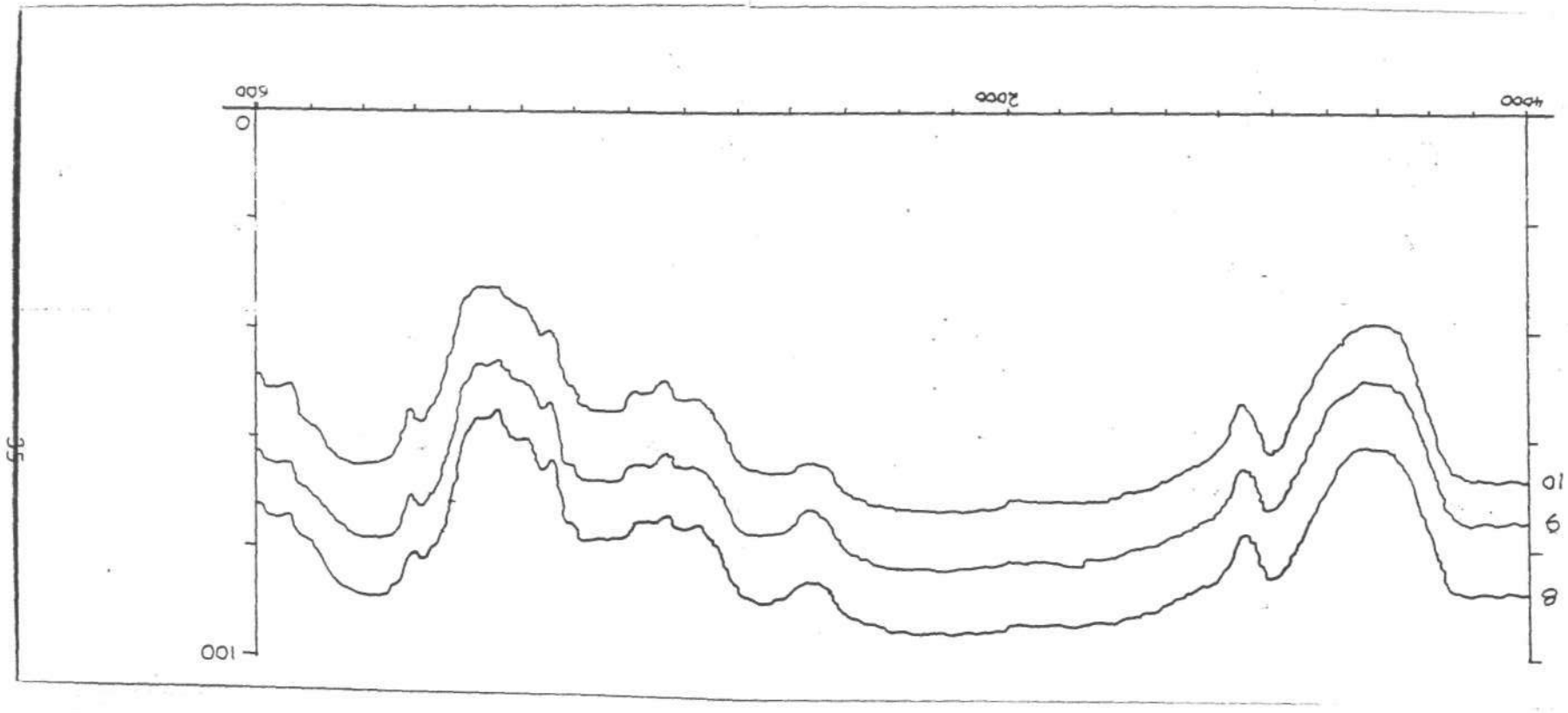


SOLVENT SCOURED AND MERCERIZED (24%)
SPECTRAL DIAGRAM



KIER BOILED & MERCERIZED (17.5%)
SPECTRAL DIAGRAM





KIER BOILED AND MERCERIZED (24%)
SPECTRAL DIAGRAM

3.1.2 CRYSTALLINITY INDEX (a) (b)

The crystallinity index (a) for samples R,S and KB as shown in table 7 not significantly different among the samples and between the varieties of Samcot-8, Samcot-9 and Samcot-10. Same also apply for the (b) crystallinity index for same. A decrease in (a) crystallinity index is observed on mercerization with S17.5%, KB17.5%, S24% in the order arranged except for KB24 which shows though a decreased crystallinity index(a) compared to the untreated but an increased crystallinity index(a) than SS17.5%, KB17.5% and S24% treated. No much significant difference was observed for the (b) crystallinity index among samples and between varieties.

SAMPLE	RAW	S	KB	S17.5%	KB17.5%	S24%	KB24%
Samcot-8	a = 1.3672	1.5129	1.3773	1.1066	0.8731	0.7923	1.2847
	b = 0.3703	0.5977	0.4608	0.5718	0.6812	0.7789	0.5221
Samcot-9	a = 1.4941	1.4303	1.5889	1.9217	0.7729	0.9441	1.9217
	b = 0.6628	0.7404	0.5869	0.7167	0.6815	0.9441	0.6420
Samcot-10	a = 1.7095	1.3608	1.4650	0.4217	0.8617	0.6992	0.9348
	b = 0.2517	0.6129	0.6478	0.6846	0.6916	0.7323	0.6681

TABLE 7: CRYSTALLINITY INDEX OF RAW AND TREATED COTTON FIBRES

3.2 FIBRE CHARACTERISTICS

The number of convolutions was observed as shown in Table 9 to be of the order Samcot-8> 10> 9. This was found to be significantly different at 99.9% level between Samcot-8 and Samcot-9 but no significant difference was observed between Samcot-9 and Samcot-10 and between Samcot-9 and Samcot-10. The minimum and maximum length of convolutions as shown in Table 10 is found to be of the order Samcot-9> 10> 8 for both measurements. This shows a significant difference between Samcot-8 and Samcot-9 in both measurements and also between Samcot-9 and Samcot-10 in the maximum length measurements, also between Samcot-8 and Samcot-10 in the minimum length measurement. No significant differences was observed between Samcot-8 and Samcot-10 in the maximum length and between Samcot and Samcot-10 in the maximum length measurements.

The wall thickness as shown in Table 11 follows the order of Samcot-10> 9> 8 and all are significantly different from each other. Also the ribbon width unswollen and ribbon width swollen as shown in Table 8 are observed to be in the order of Samcot-10 > 8> 9. The wall thickness and ribbon with unswollen shows a significant differences in the three varieties, while ribbon width swollen shows no significant difference but in only between samcot-9 and Samcot-10.

Finally, the fineness of the fibres are observed to be in the order Samcot-8 > 9 > 10. The staple length are shown Table 8 for the three varieties; these were observed to correlate with the order of fineness; Samcot-8 > Samcot-9 > Samcot-10. The maturity as shown in Table 8 was observed to be in the order of Samcot-10 > 8 > 9 and the fibrograph maturity ratio was observed to be slightly higher in Samcot-10 than Samcot-8 then Samcot-9 in that order.

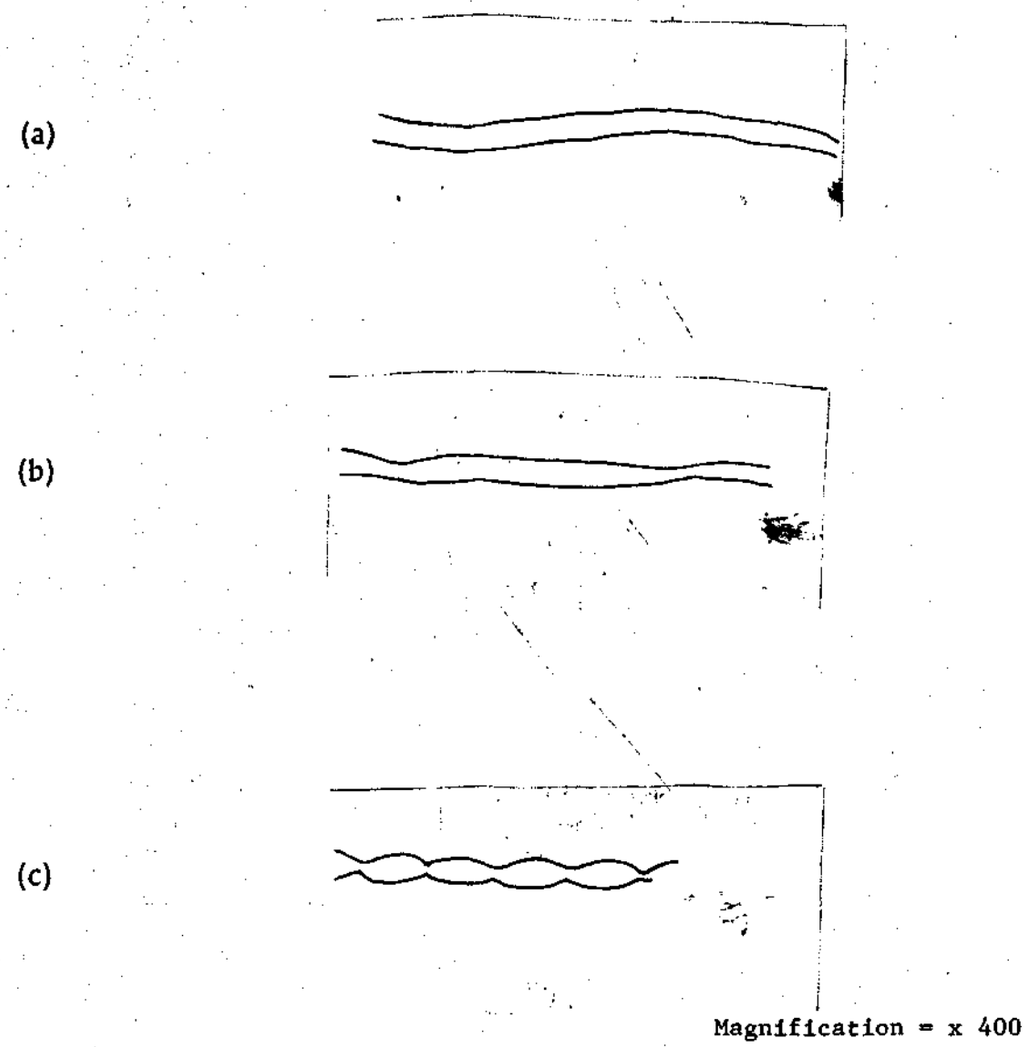


Fig. 8

DETERMINATION OF MATURITY IN 18% SODIUM HYDROXIDE SOLUTION

(a) NORMAL FIBRE Rod-like appearance, some with hardly any lumens, some lumens may be seen in places but not continuous

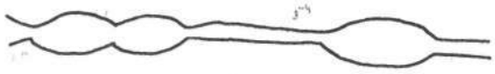
(b) THIN WALLED FIBRE Convoluted form non-convoluted form also exist.

(c) Dead fibre.

(a)



(b)



(c)



(d)



Magnification = x 400

Fig. 9

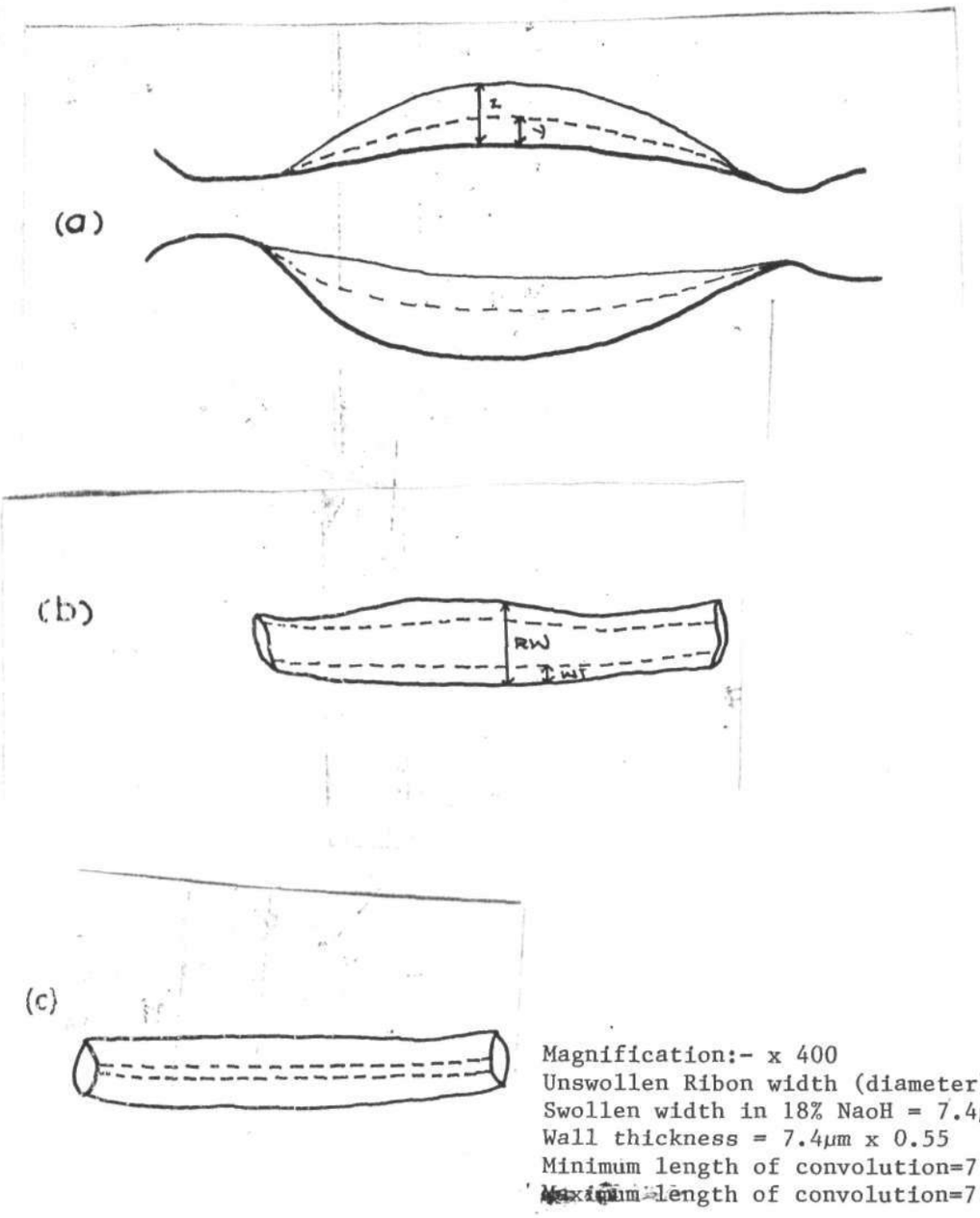
EFFECT OF CONDITIONING UNDER 68% RELATIVE HUMIDITY ON THE SINGLE COTTON FIBRES OF SAMCOT 8, 9, 10.

(a) Rod-like appearance

(b) Mixture of convoluted and rod-like appearance across the length in a random manner

(c) Highly convoluted middle, and rod-like ends

(d) Highly convoluted across the length.



Magnification:- x 400
Unswollen Ribon width (diameter)=7.44µm x 1.8
Swollen width in 18% NaoH = 7.4µm x 3
Wall thickness = 7.4µm x 0.55
Minimum length of convolution=7.4µm x 11.0
Maximum length of convolution=7.4µm x 18.5

Fig 10

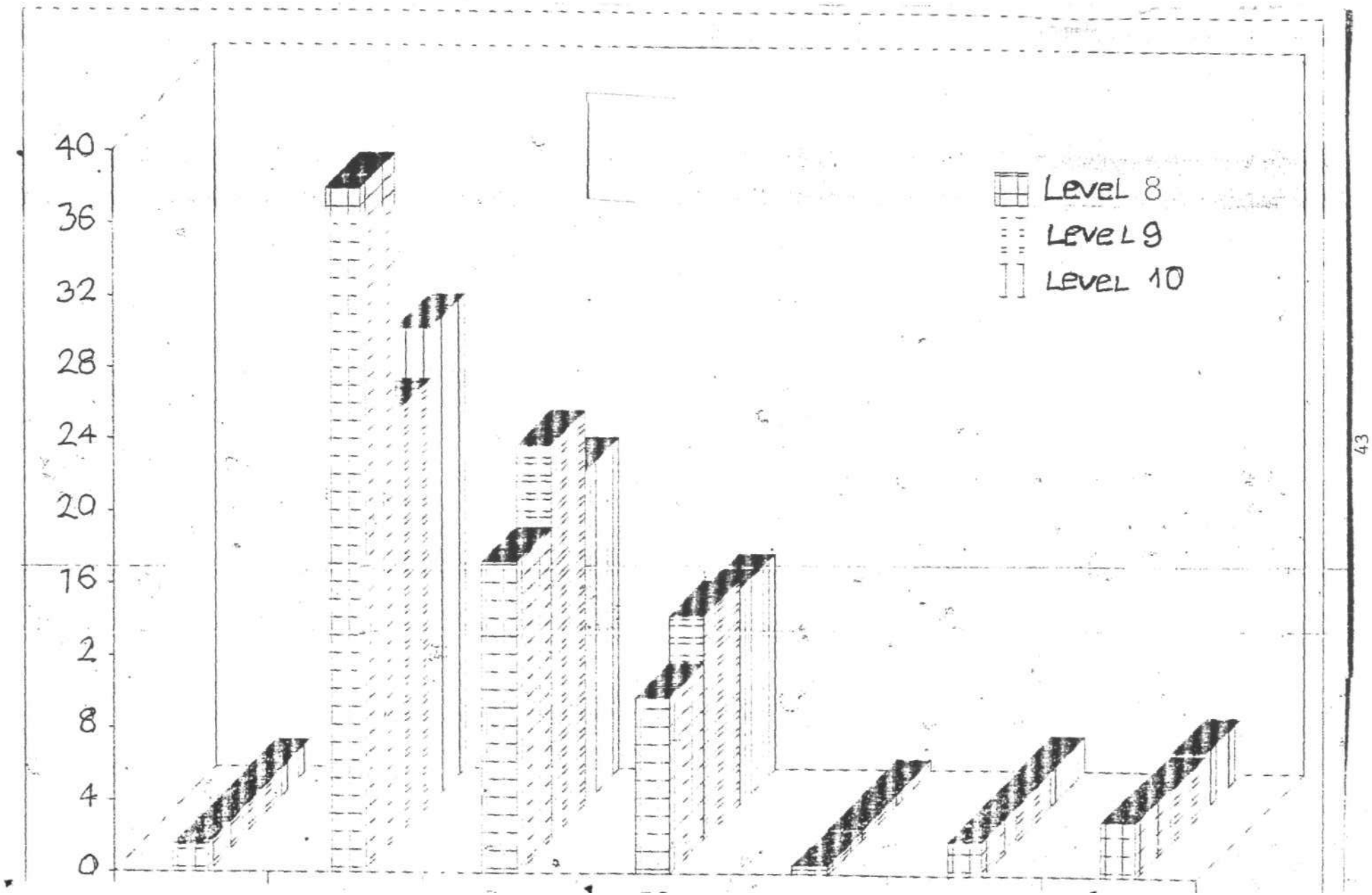
TYPICAL STRUCTURE OF CONVOLUTION PITCH AND LUMEN SIZES OBSERVED IN 18% SODIUM HYDROXIDE SWOLLEN FIBRES OF SAMCOT 8, 9. 10

(a) Z is the dense/dark portion of the wall thickness, Y is the transparent portion of the wall thickness

(b) Fibres with the cell wall thickness "WT", and the 1/5th of the ribbon width "RW"

(c) Thin walled fibres.

A = TEST LENGTH; D = NUMBER OF CONVOLUTION; E_1 = MAXIMUM LENGTH OF CONVOLUTION
E2 = MINIMUM LENGTH OF CONVOLUTION; F = WALL THICKNESS; G = UNSWOLLEN RIBBON WIDTH
H = SWOLLEN RIBBON WIDTH



SAMPLE	LENGTH UNIFORMITY RATIO	MICRONIAL VALUE FINENESS	FIBROGRAPH MATURITY RATIO	STAPLE LENGTH mm		MATURITY ESTIMATED FROM MICROSCOPICAL STUDIES		
				MAX	MIN	M	T.W	D
R_8 Samcot-8	0.4538	2.42	89.10	27.68	12.56	60	28	8
R_9 Samcot-9	0.4121	2.67	79.60	26.64	11.06	60	30	10
R_{10} Samcot-10	0.4074	3.89	89.80	26.90	10.96	72	16	12

M = Matured Fibres

T.W = Thin walled fibres

D = Dead Fibres

TABLE 8: FIBRE MATURITY, FINENESS STAPLE LENGTH AND UNIFORMITY RATIO OF SAMCOT COTTON FIBRES

SAMPLE	MEAN LIMIT	STANDARD DEVIATION LIMITS	F-RATIO OBSERVED	F-RATIO FROM TABLE	DIFFERENCE AT 5%, 1%	CALCULATED t FROM TWO MEANS	TABLE t	DIFFERENCE AT t (0.1%)
R_8 Samcot-8	40±2.61	16.58±1.99		2.99(F5%)	*	a 2.439	2.349	*
R_9 Samcot-9	24±3.0	16.62±2.12	17.62			b 1.426	1.428	NIL
R_{10} Samcot-10	26±3.84	18.31±2.72		4.60(F1%)	*	c 0.325	0.325	NIL

a = Mean between Samcot-8 and Samcot-9

b = Mean between Samcot-8 and Samcot-10

c = Mean between Samcot-9 and Samcot-10

TABLE 9: NUMBER OF CONVOLUTIONS PER 1.5cm FIBRE LENGTH SIGNIFICANCE DIFFERENCE AT 1%, 5% AND 0.1%

SAMPLE		MEAN LENGTH LIMIT	STANDARD DEVIATION LIMITS	F-RATIO OBSERVED	F-RATIO FROM TABLE	DIFFERENCE AT 5%, 1%	CALCULATED t FOR TWO MEANS	TABLE t	DIFFERENCE AT t (0.1%)
	MXL	17.23±0.68	4.03±0.48		2.99(5%)	*	A 5.36		*
Samcot-8	MNL	9.78±0.37	2.14±0.25			*	A 9.789		*
	MXL	21.80±1.36	7.58±0.96	13.09			b 1.418	1.65	NIL
Samcot-9	MNL	12.38±0.78	4.28±0.55	13.62min			b 7.091		*
	MXL	18.37±1.33	6.57±0.96		4.60(F1%)	*	c 4.88		*
Samcot-10	MNL	26±3.84	18.31±2.72			*	c 0.926		NIL

TABLE 10: MAXIMUM (MXL) AND MINIMUM (MNL) LENGTH OF CONVOLUTIONS x 7.4a OR 7.4 X 10^{-3}mm

SAMPLE	MEAN THICKNESS LIMIT	STANDARD DEVIATION LIMITS	F-RATIO OBSERVED	F-RATIO FROM TABLE	DIFFERENCE AT 5%,1%	CALCULATE D t FOR TWO MEANS	TABLE t	DIFFERENCE AT t (0.1%)
R8 Samcot-8	0.49+0.134	0.081±00093		2.99(F 5%)	*	240.88		*
R9 Samcot-9	0.56+0.025	0.15±0.0176	10.93			253.81	1.65	*
R10 Samcot-10	0.58+0.028	0.17±0.199		4.60(F 1%)	*	38.01		*

TABLE 11: WALL THICKNESS x 7.40 OR 7.4 x 10^{-5}mm

SAMPLE	MEAN WIDTH LIMIT	STANDARD DEVIATION LIMITS	F-RATIO OBSERVED	F-RATIO FROM TABLE	DIFFERENCE AT 5%,1%	CALCULATE D t FOR TWO MEANS	TABLE t	DIFFERENCE AT t (0.1%)
USRW	1.89±0.047	0.28±0.033		2.99(F 5%)	NIL	a 7.89		*
Samcot-8 SRW	3.03±0.0805	0.485±0.0569			*	a 25.32		*
USRW	1.88±0.037	0.22±0.026	0.98			b 28.39	}1.65	*
Samcot-9 SRW	2.91±0.0812	0489±0.0574	3.18 SR			b 11.38		*
USRW	1.92±0.042	0.25±0.029		4.60(F 1%)	NIL	c 36.68		*
Samcot-10 SRW	3.08±0.0750	0.452±0.0531			NIL	C 0.174		NIL

TABLE 12: UNSWOLLEN AND SWOLLEN RIBBON WIDTH/DIAMETER x 7.4u OR 7.4 x 10^{-3}mm

3.3 THE ABSORPTION PROPERTIES

The absorption properties are shown in Tables 13 and 14. The moisture regain increases in the order of Samcot-8 > 9 > 10. The results are consistent for raw, scoured and Kier-boiled samples. Mercerized samples show higher absorption for Samcot-10 than Samcot-8 and Samcot-9 except for 9KB24 which show higher absorption properties than its corresponding in Samcot-10. This may be due to breakage of inter-molecular or intra-molecular hydrogen bonds. Also 9KB24% and 9S24% is higher than its corresponding in Samcot-8 while 8S17.5% and 8KB17.5% show higher absorption than its corresponding in Samcot-9 but lower than that of Samcot-10.

Iodine absorption for raw, scoured, Kier-boiled are of the order Samcot-8 > Samcot-10 > Samcot-9 except for Kier-boiled Samcot-9 which is observed to be higher than its corresponding in Samcot-8. The Mercerized samples were observed to be in the order of Samcot-9 > 8 > 10. while Samcot-10 shows higher iodine absorption for 10KB17.5% and 10KB24% than Samcot-8; An equal value was observed for the both the mercerized samples of Samcot-8 and Samcot-10 in the SS24%. However, Samcot-8 shows a slightly higher value than Samcot-10 in the S17.5%. The crystallinity estimated from absorption results shows a reverse trend in each case stated above.

SAMPLE	R	S	KB	S17.5%	KB17.5%	S24%	KB24%
Samcot-8	a = 1.3672	1.5129	1.3773	1.1066	0.8731	0.7923	1.2847
	b = 0.3703	0.5977	0.4608	0.5718	0.6812	0.7989	0.5221
	MR = 10.00	10.09	10.30	11.55	12.75	12.73	13.60
	I.S.V = 38.86	41.95	36.227	46.63	44.04	69.95	64.67
Samcot-9	a = 1.4971	1.5889	1.5889	1.9217	0.7729	0.9441	1.9217
	b = 0.3703	0.5869	0.5569	0.7167	0.6815	0.6477	0.6420
	MR = 7.63	7.70	7.90	11.56	13.00	12.63	14.85
	I.S.V = 36.87	36.22	38.86	57.86	51.82	88.09	88.50
Samcot-10	a = 1.7098	1.3608	1.4650	0.8217	0.8614	0.6992	0.9345
	b = 0.2519	0.6478	0.6478	0.8446	0.6916	0.7323	0.6681
	MR = 6.53	6.83	6.72	13.77	13.77	13.37	13.38
	I.S.V = 31.09	36.27	33.68	44.04	44.04	72.54	64.94

TABLE 13: MOISTURE REGAIN (MR), IODINE SORPTION VALUE (I.S.V) AND INFRARED CRYSTALLINITY INDEX a & b

SAMPLE	R	S	KB	S17.5%	KB17.5%	S24%	KB24%
Samcot-8	a = 1.3672	1.5129	1.3773	1.1066	0.8731	0.7923	1.2847
	b = 0.3703	0.5977	0.4608	0.5718	0.6812	0.7989	0.5221
	c = 61.15	60.80	59.95	55.13	50.54	50.54	47.16
	d = 90.57	89.93	91.20	88.68	89.31	83.02	84.28
Samcot-9	a = 1.4941	1.5889	1.5889	1.9217	0.7729	0.9441	1.9217
	b = 0.6628	0.5869	0.7169	0.7167	0.6815	0.6477	0.6421
	c = 70.56	7.70	69.31	55.09	49.49	50.93	42.19
	d = 91.20	36.22	90.57	86.17	87.42	78.62	79.25
Samcot-10	a = 1.7095	1.3608	1.4650	0.8217	0.8614	0.6992	0.9345
	b = 0.2519	0.6478	0.6478	0.8446	0.6916	0.7323	0.6681
	c = 74.63	6.83	73.89	42.06	46.50	48.50	48.02
	d = 92.45	36.27	91.83	89.93	89.31	82.30	83.02

TABLE 14: INFRARED CRYSTALLINITY INDEX a & b, ESTIMATED CRYSTALLINITY FROM MOISTURE REGAIN (c) AND FROM IODINE SORPTION VALUE (d)

3.4 LOW STRESS AND HIGH STRESS TENSILE PROPERTIES OF SAMPLES

The initial young's modulus for raw samples is observed to be in the order 10R > 8R > 9R while the scoured and Kier-boiled samples show that the changed to order Samcot-8 > Samcot-10 > Samcot-9 Table 14. The bundle of five fibres was observed to show an order Samcot-8 > Samcot-9 > Samcot-10 for the raw, scoured and Kier-boiled samples respectively. The bundle of ten fibres shows the same trend except for 10R, 9S and 9KB are show in Table 15 the specific stress of the raw, scoured, and Kier-boiled samples for the "single fibres and bundle" are in the order Samcot-8 > Samcot-9 > Samcot-10 are shown in Table 16. However, the extension at break percent was observed to be in the order Samcot-9 > Samcot-8 > Samcot-10 except for the Kier-boiled which is observed to be in the order Samcot-8 > Samcot-9 > Samcot-10 as shown in Table 16.

MERCERIZED SAMPLES

Mercerization altered the trend of the young modulus. The initial moduli of S17.5% and S24% are in the order Samcot-8 > Samcot-10 > Samcot-9. The order however changes in the KB17.5% and KB24% to Samcot-8 > Samcot-9 > Samcot-10 and Samcot-9 > Samcot-8 > Samcot-10 respectively, as shown in Table 14. The moduli of bundle of five fires is in the order Samcot-9 > Samcot-8 > Samcot-10 except for samples 10KB24%, 8S17.5%, 10S24% and 8S24% respectively. The moduli of bundles of ten fibres is in the order Samcot-8 > Samcot-9 < Samcot-10 except for 9S17.5% and 10KB17.5% as shown in Table 15.

The specific stress of mercerized single fibres is in the order Samcot-8 > Samcot-9 > Samcot-10 except for 10S24% and 10KB24%. The specific stress of bundle of five fibres shows the same trend except for 10KB24%. Bundles of ten fibres also is in the same order except for 10KB17.5% and 10KB24% as shown in Table 16. Extension at break percent was observed to be in the order Samcot-8 > Samcot-9 Samcot-10 except for 10KB24%.

The work of rupture in Samcot-8 was found to be in the range of 0.30 - 0.36 and is higher than Samcot-9 in he range of 0.19 to 0.25 and Samcot-10 in the range of 0.15 - 0.17 except for 10KB24% which shows a higher value (0.34) than is corresponding in Samcot-9 (0.25).

TREATMENT	MOISTURE REGAIN (MR)			ESTIMATED AMORPHOUS FRACTION FROM (MR)			ESTIMATED AMORPHOUS FRACTION FROM (I.S.V)			YOUNG'S MODULUS (g/tex)		
	SAMCOT-8	SAMCOT-9	SAMCOT-10	SAMCOT-8	SAMCOT-9	SAMCOT-10	SAMCOT-8	SAMCOT-9	SAMCOT-10	SAMCOT-8	SAMCOT-9	SAMCOT-10
R	10.00	7.63	6.53	38.85	26.64	25.37	9.43	8.80	7.55	319.26	209.77	337.59
S	10.09	7.70	6.53	39.20	29.90	25.37	10.06	8.80	8.80	310.97	200.74	258.82
KB	10.30	7.90	6.72	40.02	30.69	26.11	8.80	9.43	8.17	419.67	191.11	340.70
S17.5%	11.55	11.56	13.37	44.87	44.91	51.94	11.32	13.83	10.06	366.92	208.89	244.36
KB17.5%	12.73	13.00	13.37	49.49	50.51	53.50	10.69	12.58	10.69	339.64	307.89	281.20
S24%	12.73	12.63	13.37	49.49	49.07	51.94	16.98	21.38	17.61	353.81	286.88	300.89
KB24%	13.60	14.85	13.38	52.84	57.81	51.98	12.72	20.75	16.98	386.81	272.92	199.25

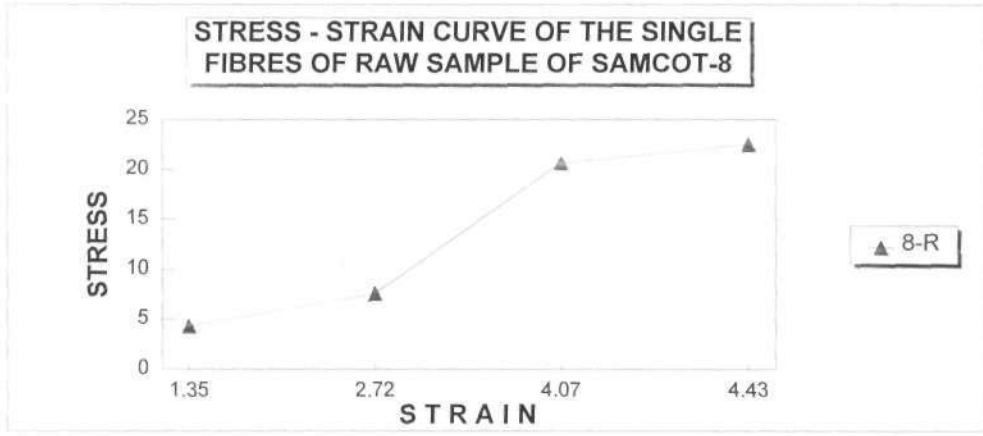
TABLE 15: ESTIMATION OF AMORPHOUS FRACTION, MOISTURE REGAIN, AND LOW STRESS TENSILE PROPERTIES OF SINGLE FIBRES OF SAMCOT-8, 9, 10

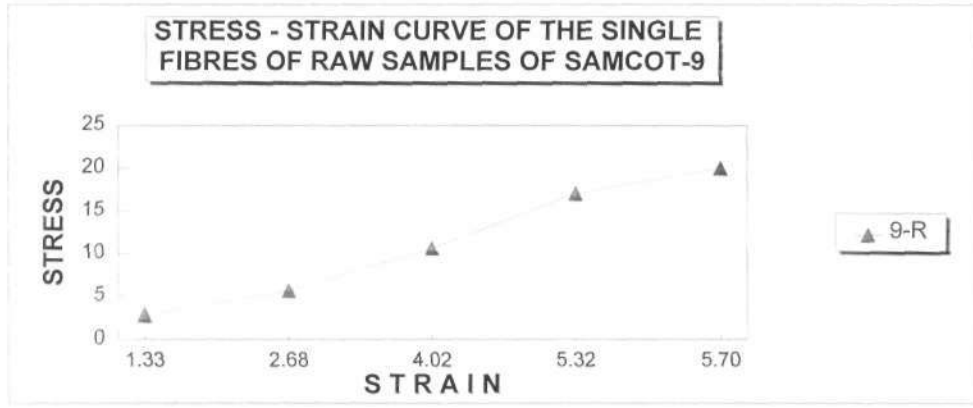
SAMPLES	*BUNDLE OF FIVE FIBRES				*BUNDLE OF TEN FIBRES		
	INITIAL MODULUS OF SAMCOT-8	INITIAL MODULUS OF SAMCOT-9	INITIAL MODULUS OF SAMCOT-10		INITIAL MODULUS OF SAMCOT-8	INITIAL MODULUS OF SAMCOT-9	INITIAL MODULUS OF SAMCOT-10
R	801.60	264.7	228.0		233	231.3	362
S	303.70	244	163		178.7	205.5	177.8
KB	401.5	208.1	174.8		310	317.3	220
S17.5%	282.2	263.2	251		235	404	141.3
S24%	274.3	417	277		330	273	136
KB17.5%	398	454.8	199.2		281.8	170	193
KB24%	279	269.9	322		428	270.7	234.5

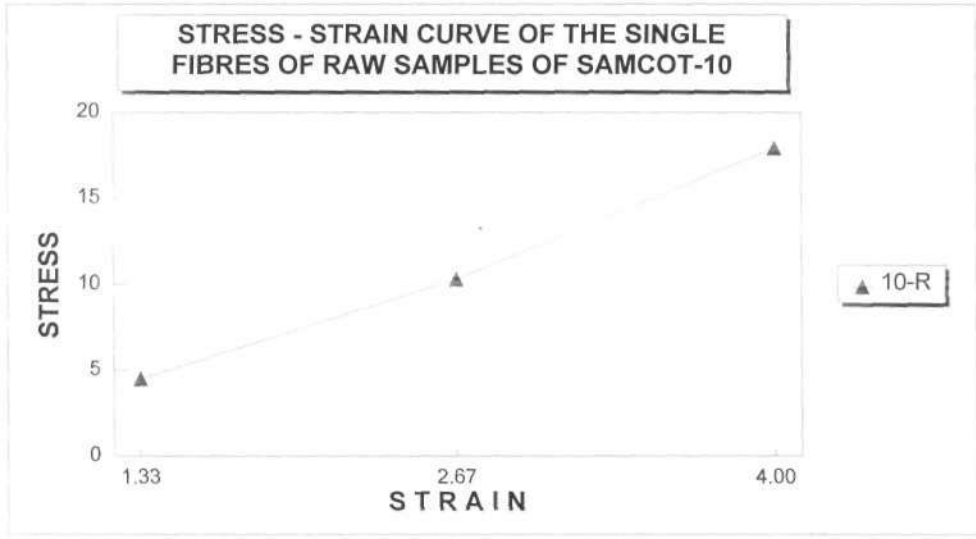
TABLE 16: LOW STRESS TENSILE PROPERTIES OF "BUNDLE OF FIVE FIBRES AND TEN OF SAMCOT-8, 9, 10

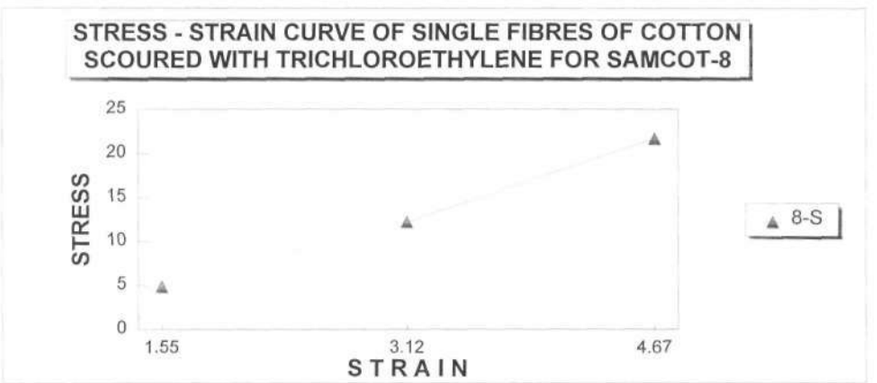
TREATMENT	SPECIFIC STRESS (g/tex)			EXTENSION AT BREAK %			WORK OF RUPTURE CALCULATED (C) (gcm/tex)			WORK OF RUPTURE FROM AREA UNDER THE GRAPH (A) (gcm/tex)		
	SAMCOT-8	SAMCOT-9	SAMCOT-10	SAMCOT-8	SAMCOT-9	SAMCOT-10	SAMCOT-8c	SAMCOT-9c	SAMCOT-10c	SAMCOT-8a	SAMCOT-9a	SAMCOT-10a
SINGLE FIBRES												
R	22.50	20.00	17.87	4.33	5.70	4.00	0.10	0.08	0.12	0.17	0.10	0.11
S	21.67	18.50	16.37	4.67	5.81	4.30	0.13	0.11	0.14	0.11	0.09	0.17
KB	28.00	21.00	17.60	6.50	5.99	4.70	0.24	0.30	0.62	0.25	0.10	0.12
BUNDLE OF FIVE FIBRES												
R	81.25	46.00	41.35	9.32	6.67	9.32	0.86	1.24	0.38	0.50	0.75	0.70
S	72.28	43.50	40.35	9.78	7.34	9.30	0.87	1.24	0.40	0.50	0.61	0.78
KB	67.50	56.40	49.26	9.99	8.42	9.33	0.79	0.75	0.59	0.62	0.62	0.84
BUNDLE OF TEN FIBRES												
R	97.50	73.50	67.28	9.86	10.38	9.77	0.97	1.38	0.95	2.19	1.00	1.29
S	92.50	71.00	62.96	11.00	10.02	12.00	1.07	1.36	0.98	1.47	1.30	1.40
KB	104.17	70	70.19	10.40	11.34	10.00	0.88	1.56	1.21	1.02	0.92	1.03
MERCERIZED												
SINGLE FIBRES												
S17.5%	32.50	23.00	21.67	10.67	7.00	5.44	0.36	0.38	0.19	0.33	0.15	0.13
KB17.5%	37.50	23.00	26.85	10.20	7.60	6.68	0.37	0.46	0.21	0.39	0.20	0.21
S24	32.00	25.00	21.30	9.24	8.00	6.39	0.30	0.45	0.22	0.41	0.17	0.24
KB24	37.50	25.40	28.30	9.32	8.96	10.08	0.31	0.42	0.25	0.49	0.34	0.43
BUNDLE OF FIVE FIBRES												
S17.5%	76.95	57.30	51.85	11.00	9.70	9.30	1.0	0.84	0.75	0.65	0.65	0.69
KB17.5%	86.25	62.00	55.35	9.00	8.65	9.30	0.84	0.80	0.70	0.71	0.70	0.46
S24%	82.50	54.00	55.00	9.30	9.34	10.20	0.77	0.86	0.67	0.69	0.81	0.99
KB24%	93.33	68.00	72.04	11.00	10.20	10.00	1.03	0.88	0.79	0.90	0.97	1.47
BUNDLE OF TEN FIBRES												
S17.5%	111.67	105.5	65.7	12.30	14.00	12.00	1.41	2.36	1.85	1.98	1.39	1.94
KB17.5%	117.50	80	83.33	12.00	10.12	11.30	1.31	1.14	0.91	1.99	1.42	1.94
S24%	106.67	86	118.27	11.09	12.00	16.40	1.16	1.65	1.29	1.13	2.62	2.64
KB24%	110.00	104	129.63	10.66	14.00	16.34	1.13	1.52	1.92	2.84	2.55	3.12

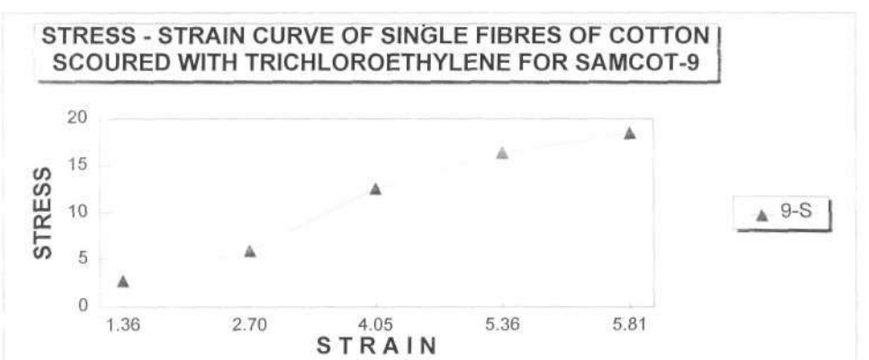
TABLE 17: MECHANICAL PROPERTIES OF SAMCOT-8, 9, AND 10

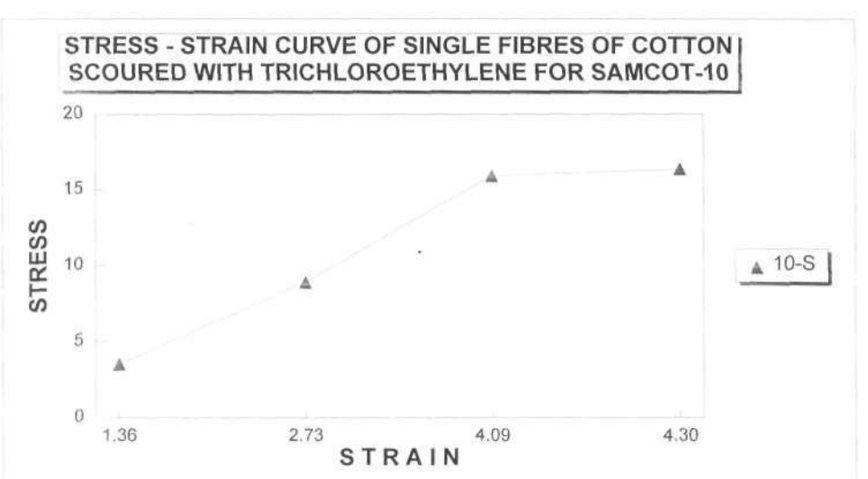

STRESS - STRAIN CURVE OF THE SINGLE FIBRES OF RAW SAMPLE OF SAMCOT-8
STRESS
25
20
15
10
5
0
1.35
2.72
4.07
4.43
STRAIN
8-R

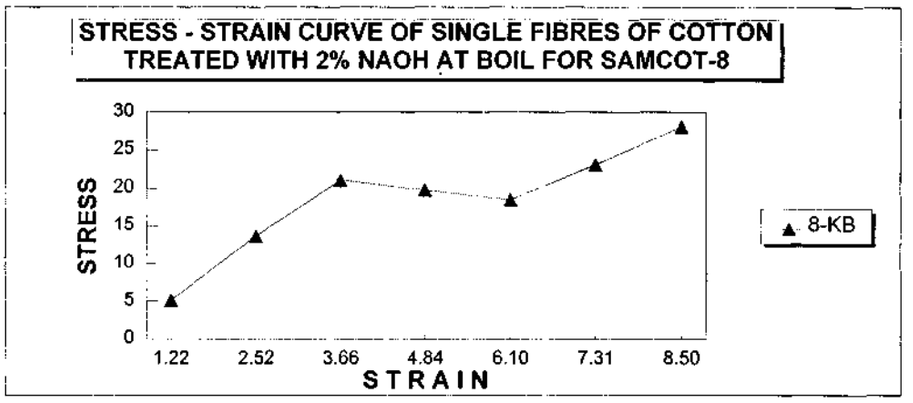

STRESS - STRAIN CURVE OF THE SINGLE FIBRES OF RAW SAMPLES OF SAMCOT-9
STRESS
25
20
15
10
5
0
1.33
2.68
4.02
5.32
5.70
STRAIN
9-R

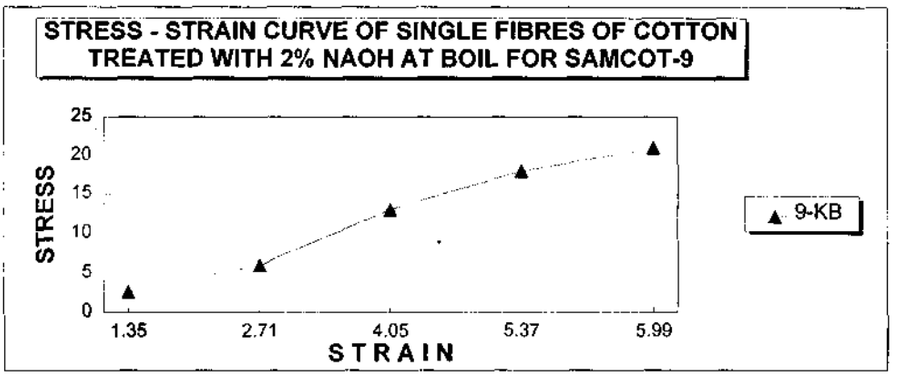

STRESS - STRAIN CURVE OF THE SINGLE FIBRES OF RAW SAMPLES OF SAMCOT-10
STRESS
20
15
10
5
0
1.33
2.67
4.00
STRAIN
10-R

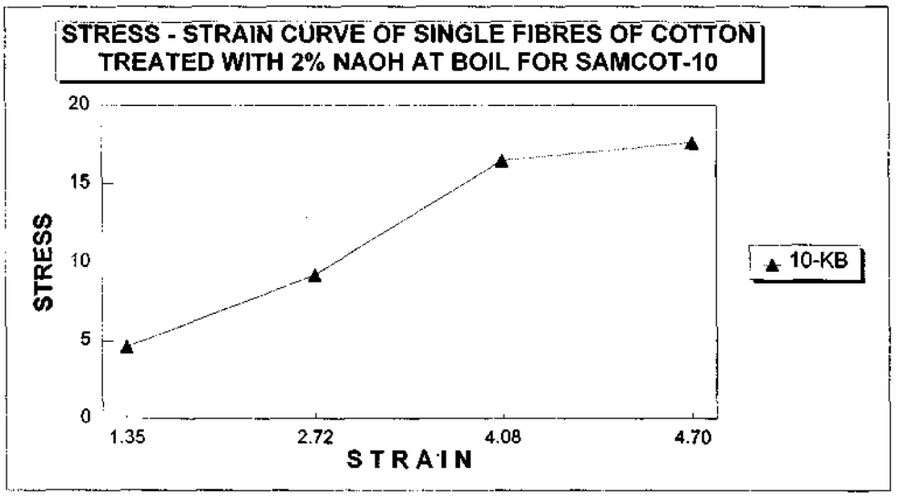

STRESS - STRAIN CURVE OF SINGLE FIBRES OF COTTON SCOURED WITH TRICHLOROETHYLENE FOR SAMCOT-8
STRESS
25
20
15
10
5
0
1.55
3.12
4.67
STRAIN
8-S

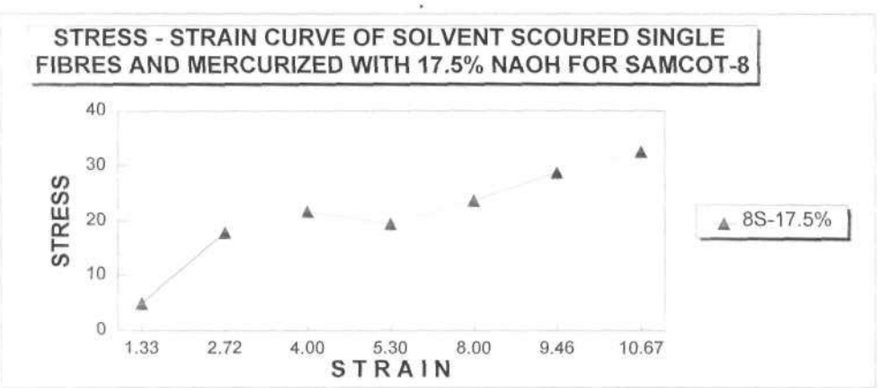

STRESS - STRAIN CURVE OF SINGLE FIBRES OF COTTON SCOURED WITH TRICHLOROETHYLENE FOR SAMCOT-9
STRESS
20
15
10
5
0
1.36
2.70
4.05
5.36
5.81
STRAIN
9-S

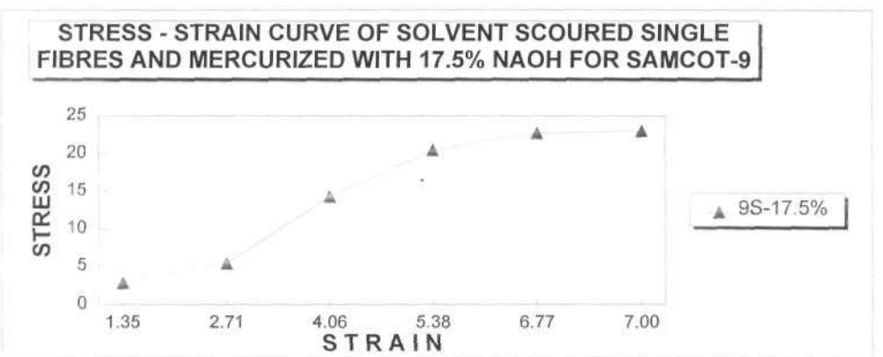

STRESS - STRAIN CURVE OF SINGLE FIBRES OF COTTON SCOURED WITH TRICHLOROETHYLENE FOR SAMCOT-10
STRESS
20
15
10
5
0
1.36
2.73
4.09
4.30
STRAIN
10-S

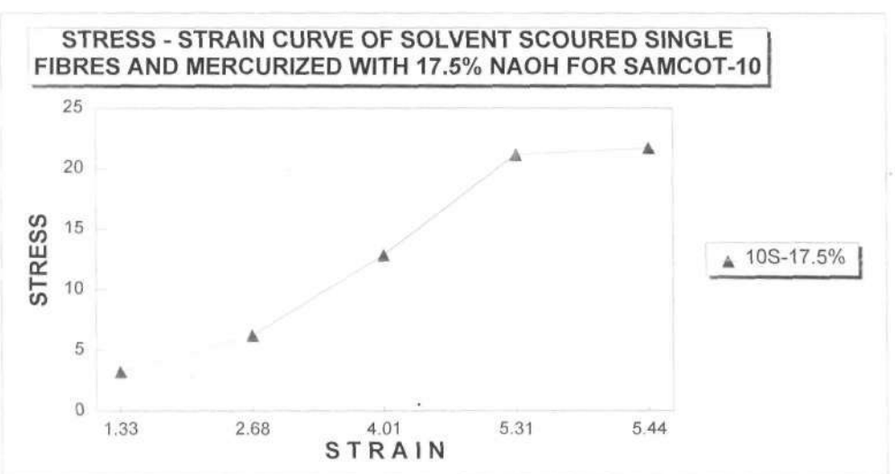

STRESS - STRAIN CURVE OF SINGLE FIBRES OF COTTON TREATED WITH 2% NAOH AT BOIL FOR SAMCOT-8
STRESS
30
25
20
15
10
5
0
1.22
2.52
3.66
4.84
6.10
7.31
8.50
STRAIN
8-KB

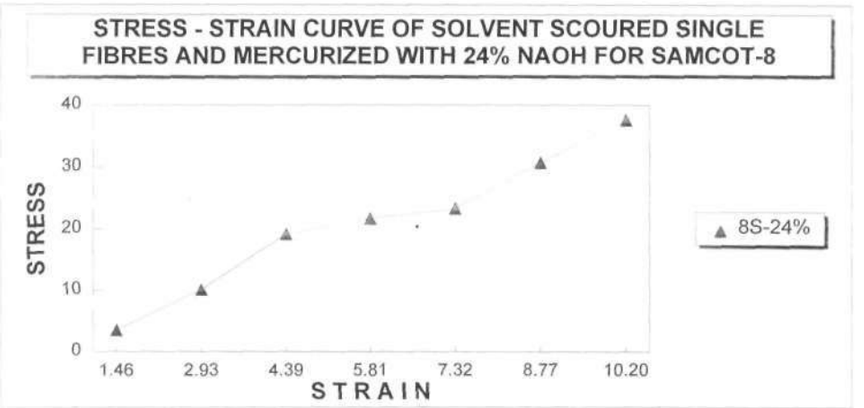

STRESS - STRAIN CURVE OF SINGLE FIBRES OF COTTON TREATED WITH 2% NAOH AT BOIL FOR SAMCOT-9
STRESS
25
20
15
10
5
0
1.35
2.71
4.05
5.37
5.99
STRAIN
9-KB

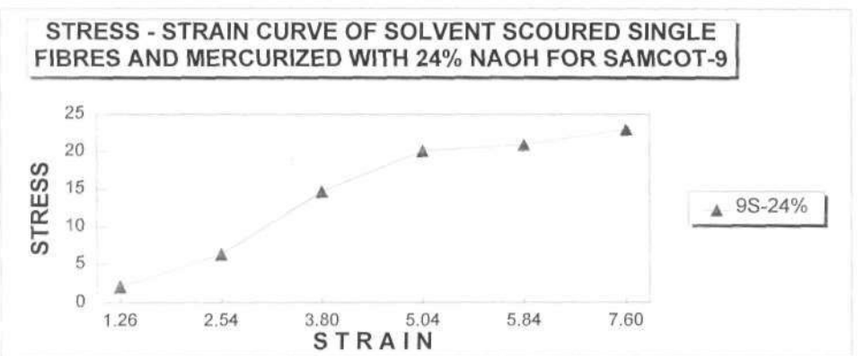

STRESS - STRAIN CURVE OF SINGLE FIBRES OF COTTON TREATED WITH 2% NAOH AT BOIL FOR SAMCOT-10
STRESS
20
15
10
5
0
1.35
2.72
4.08
4.70
STRAIN
10-KB

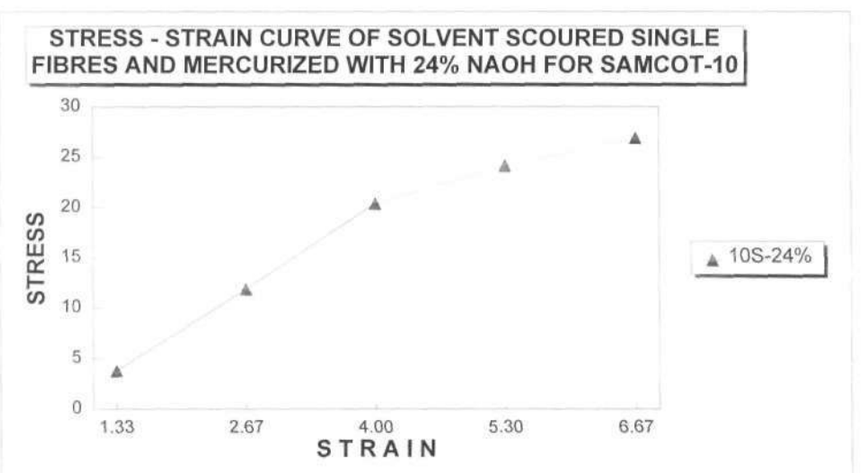

STRESS - STRAIN CURVE OF SOLVENT SCOURED SINGLE FIBRES AND MERCURIZED WITH 17.5% NAOH FOR SAMCOT-8
STRESS
40
30
20
10
0
1.33
2.72
4.00
5.30
8.00
9.46
10.67
STRAIN
8S-17.5%

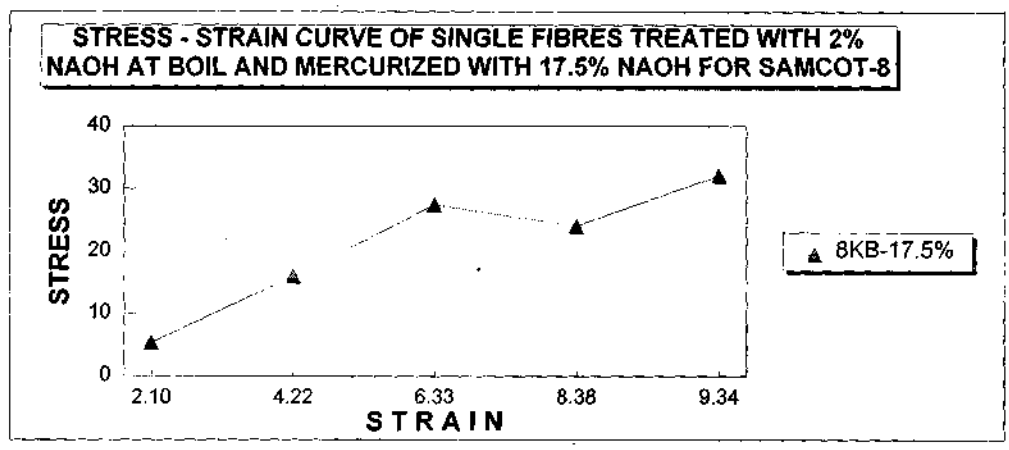

STRESS - STRAIN CURVE OF SOLVENT SCOURED SINGLE FIBRES AND MERCURIZED WITH 17.5% NAOH FOR SAMCOT-9
STRESS
25
20
15
10
5
0
1.35
2.71
4.06
5.38
6.77
7.00
STRAIN
9S-17.5%

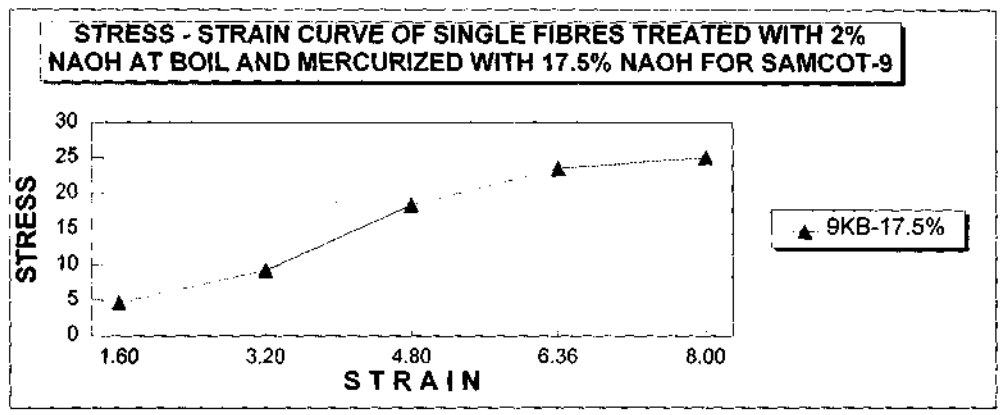

STRESS - STRAIN CURVE OF SOLVENT SCOURED SINGLE FIBRES AND MERCURIZED WITH 17.5% NAOH FOR SAMCOT-10
STRESS
25
20
15
10
5
0
1.33
2.68
4.01
5.31
5.44
STRAIN
10S-17.5%

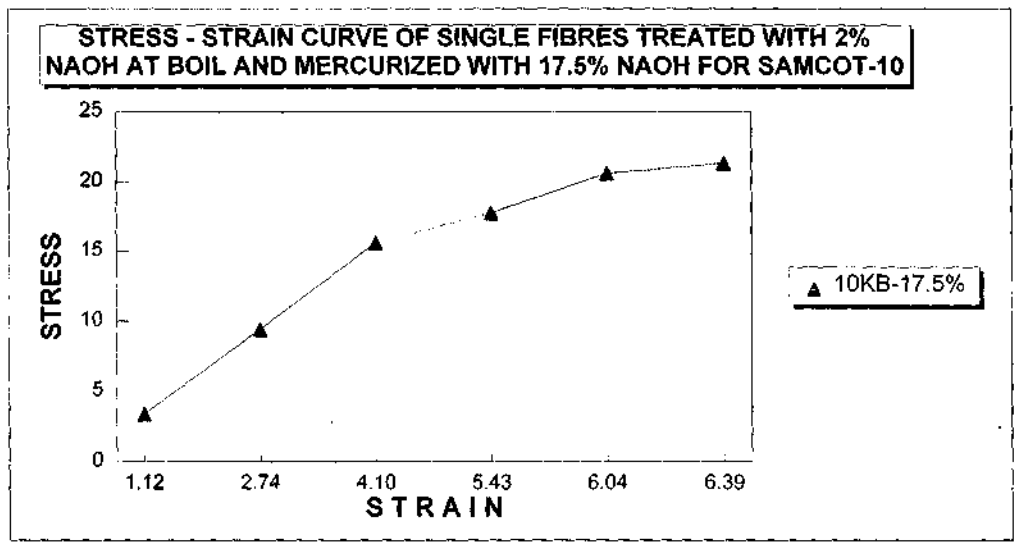

STRESS - STRAIN CURVE OF SOLVENT SCOURED SINGLE FIBRES AND MERCURIZED WITH 24% NAOH FOR SAMCOT-8
STRESS
40
30
20
10
0
1.46
2.93
4.39
5.81
7.32
8.77
10.20
STRAIN
8S-24%

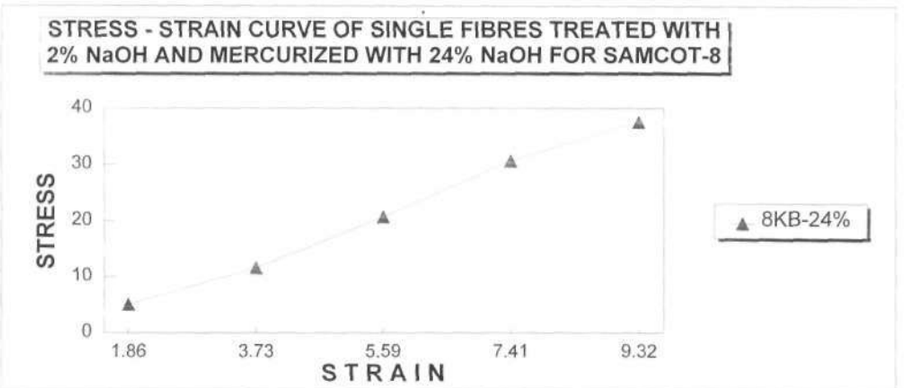

STRESS - STRAIN CURVE OF SOLVENT SCOURED SINGLE FIBRES AND MERCURIZED WITH 24% NAOH FOR SAMCOT-9
STRESS
25
20
15
10
5
0
1.26
2.54
3.80
5.04
5.84
7.60
STRAIN
9S-24%

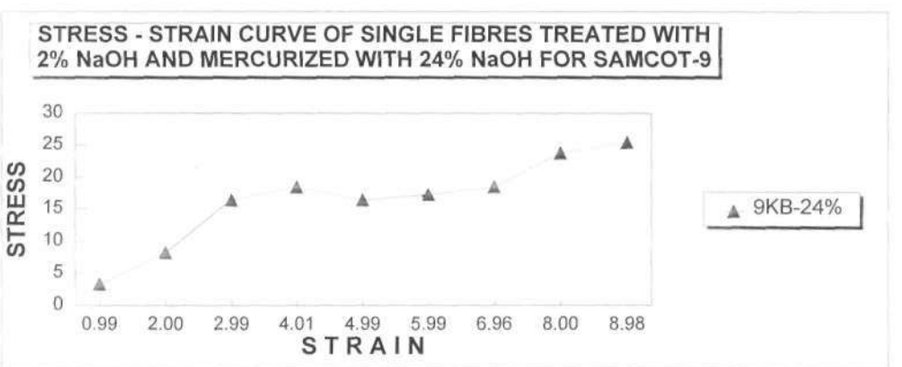

STRESS - STRAIN CURVE OF SOLVENT SCOURED SINGLE FIBRES AND MERCURIZED WITH 24% NAOH FOR SAMCOT-10
STRESS
30
25
20
15
10
5
0
1.33
2.67
4.00
5.30
6.67
STRAIN
10S-24%

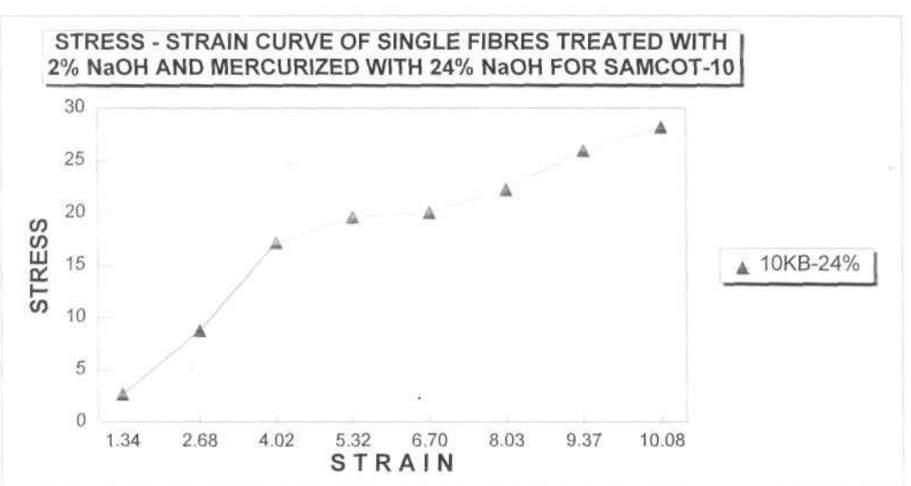

STRESS - STRAIN CURVE OF SINGLE FIBRES TREATED WITH 2% NAOH AT BOIL AND MERCURIZED WITH 17.5% NAOH FOR SAMCOT-8
STRESS
40
30
20
10
0
2.10
4.22
6.33
8.38
9.34
STRAIN
8KB-17.5%


STRESS - STRAIN CURVE OF SINGLE FIBRES TREATED WITH 2% NAOH AT BOIL AND MERCURIZED WITH 17.5% NAOH FOR SAMCOT-9
STRESS
30
25
20
15
10
5
0
1.60
3.20
4.80
6.36
8.00
STRAIN
9KB-17.5%


STRESS - STRAIN CURVE OF SINGLE FIBRES TREATED WITH 2% NAOH AT BOIL AND MERCURIZED WITH 17.5% NAOH FOR SAMCOT-10
STRESS
25
20
15
10
5
0
1.12
2.74
4.10
5.43
6.04
6.39
STRAIN
10KB-17.5%


STRESS - STRAIN CURVE OF SINGLE FIBRES TREATED WITH 2% NaOH AND MERCURIZED WITH 24% NaOH FOR SAMCOT-8
STRESS
40
30
20
10
0
1.86
3.73
5.59
7.41
9.32
STRAIN
8KB-24%


STRESS - STRAIN CURVE OF SINGLE FIBRES TREATED WITH 2% NaOH AND MERCURIZED WITH 24% NaOH FOR SAMCOT-9
STRESS
30
25
20
15
10
5
0
0.99
2.00
2.99
4.01
4.99
5.99
6.96
8.00
8.98
STRAIN
9KB-24%


STRESS - STRAIN CURVE OF SINGLE FIBRES TREATED WITH 2% NaOH AND MERCURIZED WITH 24% NaOH FOR SAMCOT-10
STRESS
30
25
20
15
10
5
0
1.34
2.68
4.02
5.32
6.70
8.03
9.37
10.08
STRAIN
10KB-24%

TREATMENT	MOISTURE REGAIN (MR)			ESTIMATED AMORPHOUS FRACTION FROM (MR)			ESTIMATED AMORPHOUS FRACTION FROM (I.S.V)			YOUNG'S MODULUS (g/tex)		
	SAMCOT-8	SAMCOT-9	SAMCOT-10	SAMCOT-8	SAMCOT-9	SAMCOT-10	SAMCOT-8	SAMCOT-9	SAMCOT-10	SAMCOT-8	SAMCOT-9	SAMCOT-10
S	10.09	7.70	6.53	39.20	29.90	25.37	10.06	8.80	8.80	310.97	200.74	258.82
S24%	12.73	12.63	13.37	49.49	49.07	51.95	16.98	21.38	17.61	353.81	286.88	300.89

TABLE 18: ESTIMATED AMORPHOUS FRACTION, MOISTURE REGAIN AND LOW TENSILE PROPERTIES OF SAMCOT-8, 9, 10

SAMPLES	SCOURED (S)				MERCERIZED (S 24)			
	a	b	c	d	a	b	c	d
Samcot-8	1.5129	0.5977	60.80	89.93	0.7923	0.7789	50.54	83.02
Samcot-9	1.4302	0.7404	70.09	91.20	0.9441	0.6477	50.923	78.60
Samcot-10	1.3608	0.6129	74.63	91.202	0.6992	0.7323	48.06	82.36

TABLE 19: INFRARED CRYSTALLINITY INDEX a AND b, ESTIMATED CRYSTALLINITY FROM MOISTURE ABSORPTION AND IODINE ABSORPTION d

- Literature Values

Crystallinity	a	b
Untreated Hopi scale	3.05	0.62
Mercerized Fortisan	0.78-1.03	0.58-0.59
Absorption properties	iodine (dilution)	moisture
Untreated	30±	9.9%
Mercerized	87.4	12.26
Amorphous fraction	untreated	mercerized
Hopi Acala	42%	51-52%
Specific stress		
Hopi Acala	23.3(g/tex)	34(g/tex)
Elongation	6.1%	13.0%

SAMPLE	R	S	KB	S17.5%	KB17.5%	S24	KB24
Samcot-8	a = 1.3672 b = 0.3703 MR = 10.00 I.S.V = 38.86	1.5129 0.5977 10.09 41.95	1.3773 0.4608 10.30 36.27	1.1066 0.5718 11.55 46.63	0.8731 0.6812 12.75 44.04	0.7923 0.7989 12.73 69.95	1.2847 0.5221 13.60 64.67
Samcot-9	a = 1.4971 b = 0.3703 MR = 7.63 I.S.V = 36.87	1.5889 0.5869 7.70 32.22	1.5889 0.5569 7.90 38.86	1.9217 0.7167 11.56 57.86	0.7729 0.6815 13.00 51.82	0.9441 0.6477 12.63 88.09	1.9217 0.6420 14.85 88.50
Samcot-10	a = 1.7098 b = 0.2519 MR = 6.53 I.S.V = 31.09	1.3608 0.6478 6.83 36.27	1.4650 0.6478 6.72 33.68	0.8217 0.8446 13.77 44.04	0.8614 0.6916 13.77 44.04	0.6992 0.7323 13.37 72.54	0.9345 0.6681 13.38 64.94

TABLE 20: INFRARED CRYSTALLINITY INDEX a & b, MOISTURE REGAIN (MR) AND IODINE SORPTION VALUE (I.S.V.)

SAMPLE	R	S	KB	S17.5%	KB17.5%	S24%	KB24
Samcot-8	a = 1.3672 b = 0.3703 c = 61.15 d = 90.57	1.5129 0.5977 60.80 89.93	1.3773 0.4608 59.95 91.20	1.1066 0.5718 55.13 88.68	0.8731 0.6812 50.54 89.31	0.7923 0.7989 50.54 83.02	1.2847 0.5221 47.16 84.28
Samcot-9	a = 1.4941 b = 0.6628 c = 70.56 d = 91.20	1.5889 0.5869 7.70 36.22	1.5889 0.7169 69.31 90.57	1.9217 0.7167 55.09 86.17	0.7729 0.6815 49.49 87.42	0.9441 0.6477 50.93 78.62	1.9217 0.6421 42.19 79.25
Samcot-10	a = 1.7095 b = 0.2519 c = 74.63 d = 92.45	1.3608 0.6478 6.83 36.27	1.4650 0.6478 73.89 91.83	0.8217 0.8446 42.06 89.93	0.8614 0.6916 46.50 89.31	0.6992 0.7323 48.50 82.30	0.9345 0.6681 48.02 83.02

TABLE 21: INFRARED CRYSTALLINITY INDEX a & b, CRYSTALLINITY ESTIMATED FROM MOIST REGAIBN (C) AND FROM IODINE SORPTION VALUE (D)

* Refer to definition of cords page (x)

- Literature values

Crystallinity	a	b
Untreated Hopi scale	3.05	0.62
Mercerized Fortisan	0.78-1.03	0.58-0.59
Absorption properties	iodine (dilution)	moisture
Untreated	30±0.7	9.9%
Mercerized	87.4	12.26
Amorphous fraction	untreated	mercerized
Hopi Acala	42%	51-52%

Specific stress

Hopi Acala	23.3(g/tex)	34(g/tex)
Elongation	6.1%	13.0%

CHAPTER FOUR

4.0 DISCUSSION

4.1 ACCESSIBILITY, FIBRE CHARACTERISTICS AND TENSILE PROPERTIES

Accessibility as measured by iodine and moisture sorption are given in Table 13. The values obtained through both measurements differ greatly from each other and therefore the direct comparison of the data may be difficult and misleading. This difference in the data obtained from both measurements, site between Na^+, SO_4^{2}, water molecules and iodine in the iodine solution. Volatilization of iodine and stabilization of the absorbing site by tri-iodine could also be responsible. Unlike in moisture regain where only where only water molecule is absorbed and the question of any competition in the absorbing theoretically this could be the moisture regain and iodine sorption values are generally conceded to be an empirical measure of accessibility.

From the results presented it is observed that the fibre absorption properties is not greatly altered by the dewaxing treatment. A slight increase in the accessibility of scoured samples over raw samples could have been as a result of heating which may have progressively opened up the crystallites for water molecules and iodine to penetrate (Rousselle and Nelson 1971). However, no significant decrease was observed in the crystalliinity content as shown in Table 14. This discussion of results therefore would be referring to scoured as untreated samples and the mercerized as the treated samples.

Moisture regain and iodine sorption value is observed to decrease from Samcot-8 through Samcot-10 in the untreated samples while in the treated samples, the trend changes to 10S > 8S > 9S for materials treated with 24% NaOH. The change in trend of absorption due to mercerization could mean that the fine structure of Samcot-10 is very much more sensitive to alkali treatment when compared with the other varieties. The reduced accessibility as could be observed for the untreated in the order Samcot-8 to 10 and mercerized in the order Samcot-10 through 9 for both accessibility measurements could mean an increasing crystallinity but infrared crystallinity index (a) and (b) did not quite agree with increasing crystallinity as suggested from moisture and iodine absorption, instead it suggest that crystallinity content apparently are fairly the same for the three varieties. Therefore, it is logical to suggest that the large differences in the accessibility of the three varieties as measured could have not been solely due to a slight differences in the absorption properties could be as a result of differences in the size of the sub-unit structures i.e. the crystallites of the three varieties. The crystallite sizes may be in the order of Samcot-10 > Samcot-9 > Samcot-8 for the untreated and Samcot-10 < Samcot-8 < Samcot-9 for the treated. If this is logical then, it therefore follows that the crystallite size of Samcot-10 may have been greatly altered by mercerization as shown in Table 13 and 14. In addition the differences in absorption properties of the varieties will also be suggesting that they may vary in their chain packing density. Therefore the reduced accessibility in the order Samcot-8 to 10 may have also resulted from the mechanical restraint on the amorphous region as moisture is been absorbed, since the absorbing elements (chains of molecules) passing through the amorphous region are firmly fixed in the crystalline region. It may be suggested that the result of the

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amorphous fraction as shown in Table 13 and 14 could also be the degree of the amorphous region and the -OH looseness in the chains passing through these same region; these may be functioning in the same manner with accessibility in the varieties Jeffries (1968). This assertion could also be the reason for observed increase in accessibility as shown in Table 20.

However, the initial young modulus for the varieties is in the order Samcot-8 > Samcot-10 > Samcot-9 as could be observed in Table 19 for both untreated and treated samples. The high initial modulus of Samcot-8 untreated and treated could be suggesting that the hydroxyl groups which may be greater in the amorphous region of Samcot-8 as suggested earlier may be bonded. It could also be that Samcot-8 have a lower value of spiral angle, and this could also be responsible for the observed lower extension and higher specific stress. The lower spiral angle argument could also be tenable for the higher initial modulus of Samcot-10. The convolution length was found to be in the order Samcot-9 > Samcot-10 > Samcot-8, this order of convolution length compares with the suggested order of the spiral angle in the varieties from the results of young's modulus, specific stress, and extension at break percent. Therefore, convolution length amy have been responsible for the difference in the spiral angle through convolution angle. The deviation of some tensile properties of Samcot-10 from conforming with the suggested trend of spiral angle and convolution angles could be due to its chain rigidity and friction between its fibrils as the fibre seeks an untwisted state. The specific stress of the varieties however shows a positive correlation with the staple length of the cotton fibre, this may be suggested that the degree of polymerization (chain lengths) may be responsible for lower specific stress of Samcot-10. On the other hand, the lower stress

could also be as a result of large crystallite size as suggested earlier, which could cause cracks and premature failure as tensile stress is applied to the fibre as the fibre seeks an untwisted state. This argument could also be extended further if one consider the possibilities of strain concentration on application of tensile force which also could cause cracks and premature failure. The result of fineness of the fibre of the cotton varieties is in the order Samcot-8 > Samcot-9 > Samcot-10 and the result of the unswallon and swollen ribbon width are in the order Samcot-10 > Samcot-8 > Samcot-9 same trend as the result of wall thickness. These, therefore implies that the ease of the redistribution of strain on application of tensile force in the fibre could be in the order Samcot-8 > Samcot-9 > Samcot-10 as suggested by the results of fineness of the fibre, ribbon width and wall thickness. From the results as shown in Tables 8 - 12 it could be observed that the ease of redistribution of strain on application of tensile force on the fibre could follow the trend Samcot-8 > Samcot-9 > Samcot-10 this could also be the reason of higher specific stress of Samcot-8.

Hearle and Sparrows (1979) suggest that different cotton varieties reflect in addition to crystallinity, differences in reversals, convolutions and other properties of fibre and that convolutions and reversals are of special importance in cotton fibre fracture. Zeronian et al (1976) have speculated that mercerization might change the convolution pattern of the cotton fibre as well as cause reduction in crystallite length i.e. degree of polymerization of the cellulose chains.

The convolution number in the different varieties as shown in Table 9 seems not to be in agreement with the specific stress trends, these could therefore mean that the structural reversals are possibly not the only source of weakness in the cotton varieties, other factors may be at play e.g. crystallite size, chain rigidity, etc which may be related to staple length (Table 4). The high values of energy at break as shown in table: 19 19 could be attributed to fibre deconvolution which may cause the fibre to shrink axially and by so doing provides large tensile strain as could be observed from the stress verse strain curve.

TREATMENT	SPECIFIC STRESS g/tex			EXTENSION AT BREAK cm^{-1}			WORK OF RUPTURE CALCULATED (C)			WORK OF RUPTURE FROM AREA UNDER GRAPH (A)		
	8	9	10	8	9	10	8c	8a	9c	9a	10c	10a
SS SINGLE	21.67	18.50	16.37	4.67	5.81	4.00	0.13	0.11	0.14	0.11	0.09	0.17
SS BUNDLE OF FIVE	72.28	43.50	40.35	9.78	7.34	9.30	0.87	1.24	0.40	0.50	0.61	0.17
SS BUNDLE OF TEN	92.50	71.00	62.96	11.00	10.02	12.00	1.07	1.36	0.98	1.47	1.30	1.40
SS24 SINGLE	32.00	25.00	21.30	9.34	8.00	6.39	0.30	0.45	0.22	0.41	0.17	0.24
SS24 BUNDLE OF FIVE	82.50	54.00	55.00	9.30	9.34	10.20	0.77	0.86	0.67	0.69	0.81	1.47
SS24 BUNDLE OF TEN	106.67	86.00	111.27	11.09	12.00	16.40	1.18	1.65	1.29	1.13	2.62	2.64

TABLE 22: THE TENSILE PROPERTIES

- Literature values (Herbert R. M. 1974)

Crystallinity	a	b
Untreated Hopi scale	3.05	0.62
Mercerized Fortisan	0.78-1.03	0.58-0.59
Absorption properties	iodine (dilution)	moisture
Untreated	30±0.7	9.9%
Mercerized	87.4	12.26
Amorphous fraction	untreated	mercerized
Hopi Acala	42%	51-52%

Specific stress

Hopi Acala	23.3(g/tex)	34(g/tex)
Elongation	6.1%	13.0%

4.2 TENSILE PROPERTIES AND CRYSTALLINITY

The tensile properties are discussed as modulus and fracture. The influence of amorphous areas and crystallinity on the different tensile properties are discussed under these groupings.

The initial young's modulus is obtained under low stress conditions (136.0 to 801.6 g/tex). In cotton the amorphous region would be expected to contribute more to the initial strain.

The lower extension at break percent and higher modulus are shown in Tables 18 and 20 for SS8 and SS10 is in the order 10S < 8S < 9S and 8S > 10S > 9S respectively. These could be associated withsize of crystallites, and values of spiral angle in this samples; Samcot-8 may have smaller crystallite size than Samcot-10, and both could have relatively smaller value of spiral angle than Samcot-9 these has earlier been suggested to be responsible for the lower extension for the raw samples of both varieties. However, lower value of initial modulus of 9S and 9S24% could not be due to crystallinity differences alone, therefore other factors such as structural factors e.g. hydroxyl groups bonding and the relative strength of the bonding forces may be responsible. Peterlin (1969) observed decrease in density of chain packing and crystallite orientation on mercerization. Treatment with sodium hydroxide could have led to the decrease in the crystallinity and possibly also in the density of chain packing and crosslinks as may be suggested from the increase amorphous fraction as could be observed in Tables 13 and 14. This could be responsible for the increase in extension at break by mercerization as can be seen in Table 17.

Higher initial modulus of 8S and 10S could also be as a result of higher crosslinks associated with hydrogen bonding in less ordered region while lower modulus of 9S could be associated with structural changes in the amorphous region. The fact that Samcot-8, Samcot-9 and Samcot-10 were observe to have varied values of modulus suggest that some structural differences may exist among the three varieties. The respective absorption properties of the samples and the intensity on infrared spectral bands of the varieties suggest that this difference may occur in chain packing and the apparent differences in the crystalline content of the varieties may be as a results of the differences in the packing and sizes of the "elementary fibril". The differences in crystallite size and possibly in the degree of orientation may be responsible for the variation in specific stress, since these factors may help in their redistribution of tensions in the various molecules when tensile force is applied, these could be the reason for the significant difference in the initial young's modulus in the three varieties.

The lower extension of 8S and 10S relative to the corresponding treated in Samcot-9 may be due to lower values of spiral angles. This may be responsible for higher initial modulus of same.

Hearle (1976) suggested that crystallinity and degree of molecular orientation determine renacity and modulus. The higher initial modulus in the order of Samcot-8 > Samcot-10 > Samcot-9 could be due to differences in the degree of orientation of the molecules in addition to the crystallinity differences.

In contrast to the initial young's modulus extension at break and work of rupture are obtained under high stress conditions in which less extensible parts of fibre, the crystalline regions bear a major part of the strain. The work of rupture of 8S, 9S and 10S are in the order predicted from crystallinity as estimated from moisture regain, iodine sorption and crystallinity index (a) and (b) except for insignificant deviations in crystallinity index, where fairly higher work of rupture. This may be suggesting that other factors besides crystallinity might be important in this case as suggested (Hearle and Sparrows, 1979). Zeronia et al (1976) have speculated that mercerization might cause reduction in crystallite length i.e. degree of polymerization of the cellulose chains, this may be responsible for changes observed in the mechanical properties of mercerized samples as could also be seen on a stress strain curve.

The specific stress of scoured single fibres and bundle was found to be in the order 8S > 9S > 10S while the extension at break percent is in the order 9S > 8S > 10S. The crystallinity values show that 10S have higher order, which may have caused the cotton fibre chain to be stiff and resistant to deformation on application of tensile force and this could be the reason for its lower extension at break percent. The possible large crystallite size of Samcot-9 and Samcot-10 as suggest earlier could also be responsible. Inter chain links which is thought to occur in many cellulose (Rebenfied, 1961) including cotton may be also responsible for the lower elongation and stress sustained. The lower extension of Samcot-8 and Samcot-10 untreated, could perhaps be due to lower value of spiral angle. This may be responsible for the higher specific stress of Samcot-8. The lower specific stress of Samcot-10 may be due partly to its apparent larger crystallite size and partly due to its lower degree of

polymerization (chain length) as suggested by its brittleness and relatively shorter staple length. On the other hand, the higher specific stress of Samcot-8 could also be due to smaller crystallite size, higher crystallite length i.e. degree of polymerization and the forces within and between its crystallite region.

An increase in specific stress was observed on mercerization this could mean that the probability of a very weak unit occurring within the fibre structure decreases, with decrease in convolution number and possibly the crystallite size may have also been reduced by the action of mercerization. A mercerized sample may therefore be of totally different morphology from the fibre prior to mercerization. This implies as stated earlier a change in fine structure and gross structure which may have permitted a relief and re-distribution of strain.

General observation shows that mercerized samples have a greater extension at break than the scoured samples. This could be due to the changes in fine structure and gross structure as earlier suggested by Rollins (1954) and Peterlin (1969), Sarko (1970) of the cotton varieties. In conclusion, increase in specific stress for mercerized samples could also be due partly to an increase in crystalline orientation and the reduction in crystallite length (Ahmad and Rapson (1971). A reduction in crystallite size as may be the case in mercerized samples may have facilitated the movement of the rods which may have been relatively inflexible when a tensile force is applied to the fibre and therefore this could be responsible for the increase extension at break on mercerization.

Samcot-8 can be used for a soft handle materials, can also be spun into a much finer yarn than Samcot-9 and Samcot-10 in that order, due to its fineness. Samcot-10 fibres are brittle, this may be attributed to its fine structures in the subunit level; the crystallites. High young modulus of Samcot-10 is consistent with its expected high rigidity, less young modulus of Samcot-9 is consistent with its less rigidity. However the higher young modulus of Samcot-8 than Samcot-9 can be hardly due to the rigidity of Samcot-8 but rather other factors like internal lubrication, rupture of hydrogen bonds by moisture etc.

4.3 THE EFFECT OF AQUEOUS SODIUM HYDROXIDE TREATMENT ON COTTON CELLULOSE OF SAMCOT-8, 9, 10 AND TENSILE PROPERTIES

Observation of changes in absorption bands due to the transformation nature to mercerized cellulose of the cotton varieties in the 1420/875 and 1370/2900 was studied. An important band in this study is the 1420/895 in mercerized samples which differ in intensity from the native cellulose as shown in the figures on pages 30 - 37.

The 890cm^{-1} an 1420cm^{-1} band appears as weak band in the three varieties of raw, scoured and Kier-boiled samples, but increased in intensity in the mercerized samples appear sharper, better defined and strong. The 1420cm^{-1} and 890cm^{-1} are different in terms of intensity in those varieties.

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The strongest bands showing the greatest change are those 1335 and 1315cm^{-1}. The fibre samples differ chiefly in the resolution, of bands and intensity of bands in this wavelength. The merged and diffused region centering around 1310cm^{-1} in 8R and 10R were resolved

to 1315cm^{-1} and 1335cm^{-1} on mercerized spectra. This is the most important indication of spectra changes during mercerization. When crystallinity indices of the native varieties are related to those of mercerized samples, decreases could be observed in going from untreated to mercerized forms (Tables 13 and 14) in 1420/895 band ratio.

There is a fairly constant value in 1379/2900 ratio except for 8R and 10R which was found to have low values 8R (0.3703) and 10R (0.2519). This could be as a result of amorphous fraction arising from underdevelopment or, extraneous material. Lower extension and high initial modulus observed for untreated samples relative to mercerized, samples suggest a major decrease in crystallinity, in this transformation process. The mercerized samples have lower modulus, high extension at break, increased work of rupture which are properties associated with less crystalline material, the mechanical properties was found not to be linearly related with crystalline content in the varieties.

The higher specific stress of Samcot-8 relative to Samcot-9 and Samcot-10 as suggested earlier could be that Samcot-8 has smaller crystallites, higher degree of polymerization and lower spiral angle than Samcot-9, and Samcot-10 in that order.

The higher extension of 8R could be that the packing of its "elementary microfibril" is loose which may have allowed the freedom of movement of the chains this assertion could be observed from the greater intensity of bands of Samcot-9 relative to the others in the infrared spectra.

The dimensions and imperfections of the crystallites may be the source of inconsistencies in mechanical properties.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

i. The mechanical properties of Samcot-8, Samcot-9 and Samcot-10, suggest that Samcot-8 has greater specific stress than Samcot-9 and Samcot-9 has greater specific tensile stress than Samcot-10.

ii. Samcot-8 has lower percentage elongation and higher initial modulus than Samcot-9 while Samcot-10 has lower percentage elongation than Samcot-8 but higher initial modulus.

iii. The iodine sorption, moisture regain and crystallinity index from the IR show the opposite trend. Mercerized varieties of Samcot-8 and Samcot-10 have greater elongation than untreated ones and also lower initial modulus. Samcot-9 shows greater elongation for the mercerized samples than untreated ones but higher initial modulus. This has been attributed to reduction in crystallite length and crystallinity as a result of sodium hydroxide treatment Table 15 and 19. The 10KB24 mercerized Samcot-10 was observed to have higher tensile strength than the corresponding samples.

Differences shown by the moisture regain, iodine sorption and infrared spectra of the samples would inevitably be due to formation of different size of elementary fibrils (Sarko, 1970), whose perfection and size is responsible for the major differences in

mechanical properties of the three cellulose studied. The difference in mechanical properties could therefore be explained in terms of different levels of crystal lattice, crystallite size, degree of crystallinity amorphous composition and also molecular orientation within the crystallites.

iv. The spectral differences among the three cotton varieties is mainly in relative intensities of the bands and resolutions of bands, except for the one or two differences in bands position.

v. Fibre maturity was found not to have a strong independent effect on tensile strength. Fibre staple length and fibre fineness were observed to have effect on tensile strength. There is however, much positive correlation between specific tensile strength and fineness in general.

It may be concluded that a structural difference exists among the three cotton varieties since absorption properties of the cotton fibres is believed to function in the same manner with structural difference in the crystalline lattice spacing. It may then be safe, to conclude that from accessibility data that structural may difference exist among the three varieties. Mechanical and infrared studies also points to this direction. The closer correlation of the trend of the infrared crystallinity ratio in the three varieties to accessibility data from moisture sorption and iodine sorption indicates that they are both measuring degree of order at the same level of organization of fine structure.

vi. Moisture sorption data may be a measure of the number of hydroxyl group that are sufficiently free from neighboring molecules to allow absorption of water.

vii. Decrease in intensities of infra bands in some samples could be due to the closeness of packing of adjacent molecules which would interfere with vibrations of atomic groups. Thus the differences in the three cotton varieties is at the molecular level possibly could extend also to the level of the larger sub units; the crystallite.

viii. Chemical treatment reveals that Sancot-10 is more susceptable to alkaline treatment.

ix. The 1420 bands confirm structural differences in the three varieties.

It is not possible on the basis of the infrared data to determine definitely the kinds of intrachain hydrogen bonding in the cotton varieties. However, the data shows some strong similarities and some marked differences. The 1420cm^{-1} and 890cm^{-1} are different in terms of intensity in the three varieties. 890cm-1 shifts to 895cm^{-1} on mercerization and the increase intensity of 1425cm^{-1} could be due to changes in the hydrogen pattern due to strong alkali resulting in an unorganized hydrogen bonding.

5.2 RECOMMENDATIONS

i. More fundamental research should be carried out to establish

   a. The nature of orientations in the 3 - varieties

   b. sizes of the crystallites

   c. How convolution angle affects the spiral angle of each variety

   d. How convolution length affects the convolution angle in the three varieties.

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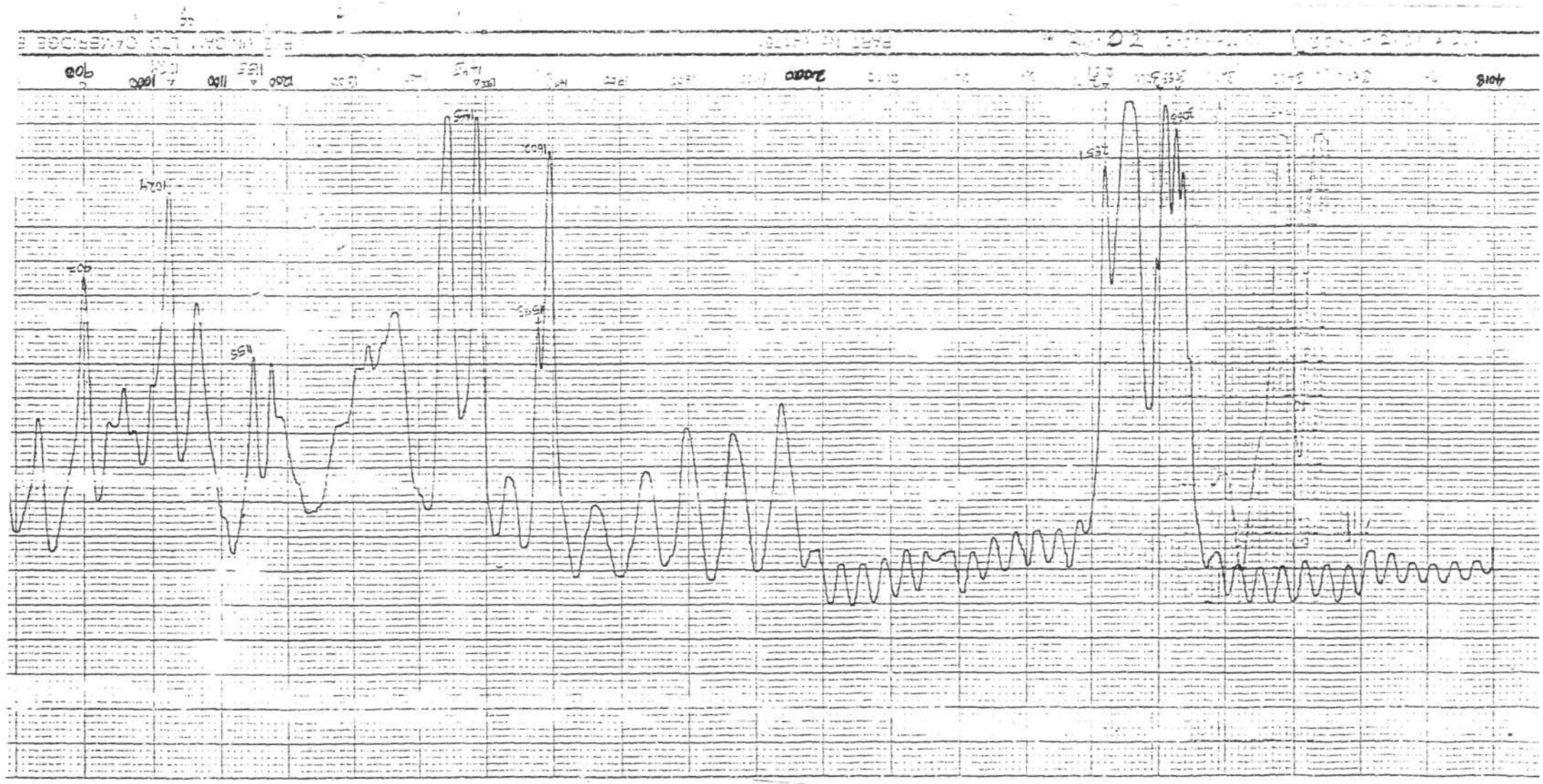
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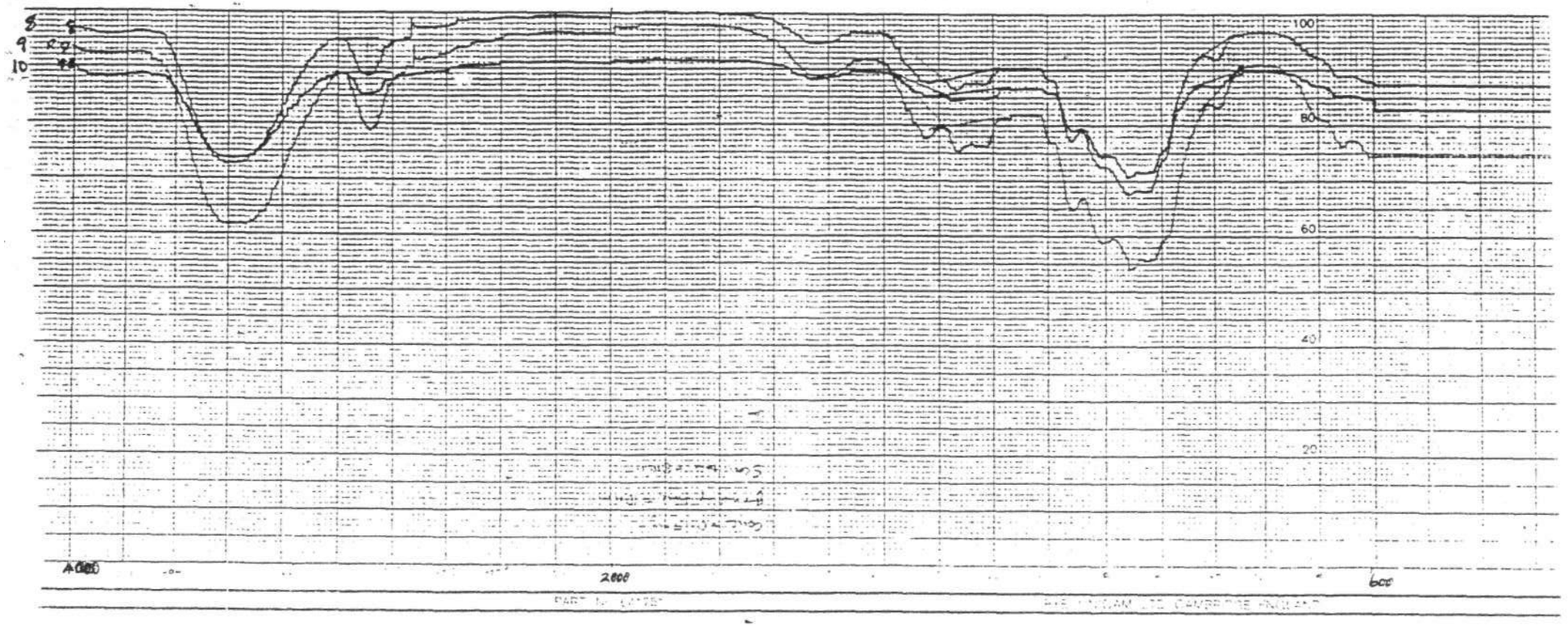
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SPECTRAL DIAGRAM OF POLYSTYRENE



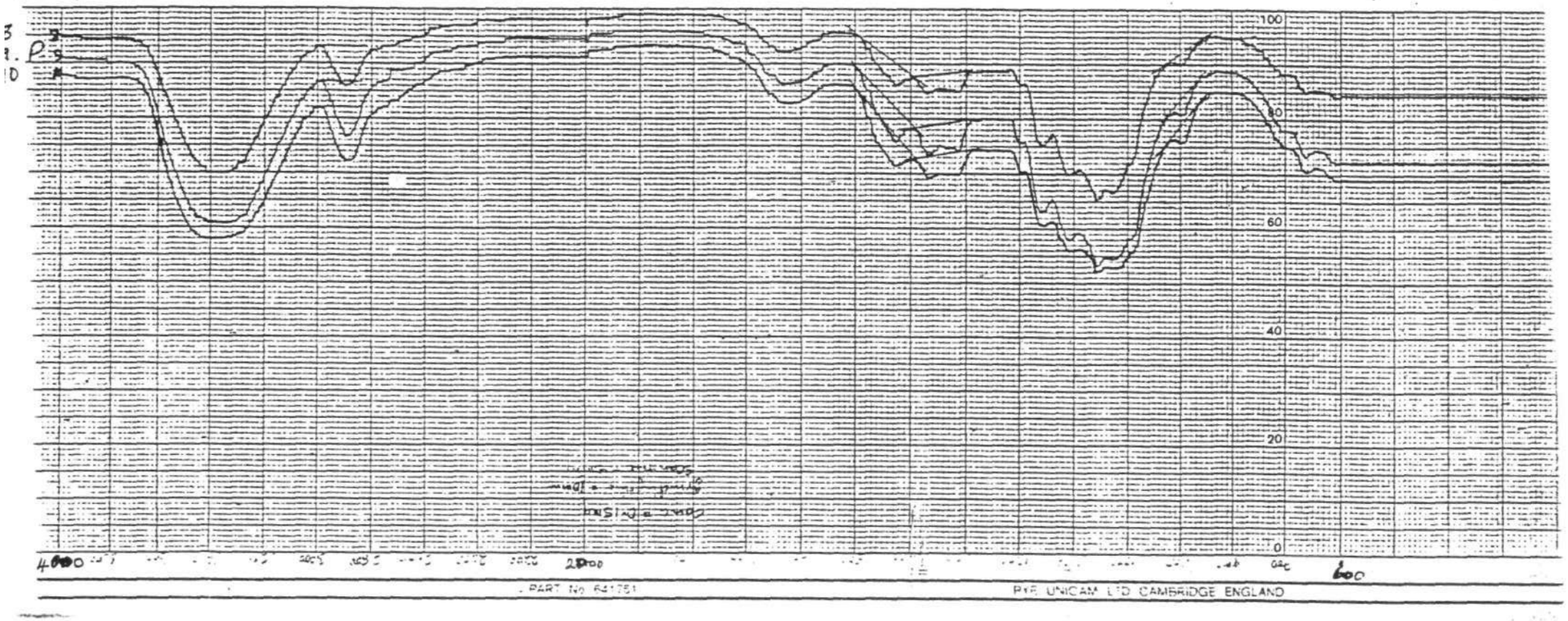
APPENDIX 1

SPECTRAL DIAGRAM OF RAW COTTON FIBRES



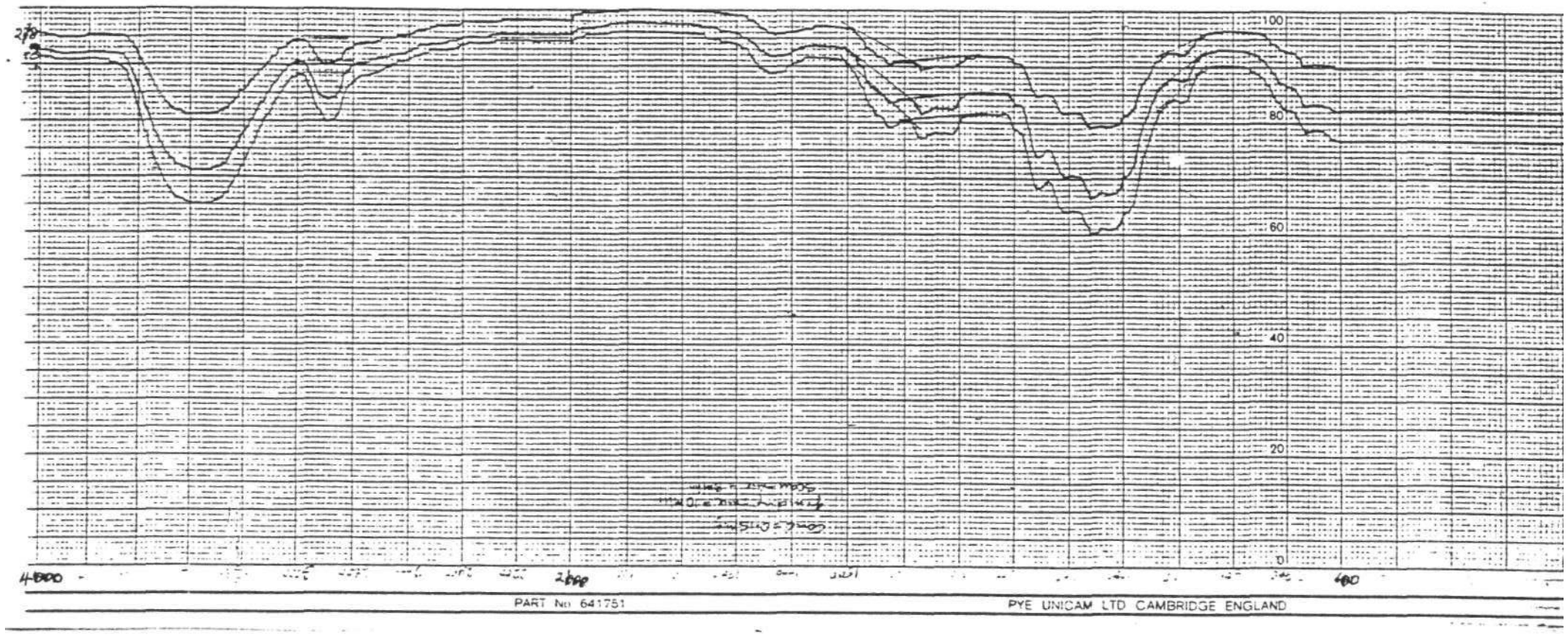
APPENDIX 2

SPECTRAL DIAGRAM OF SCOURED COTTON FIBRES



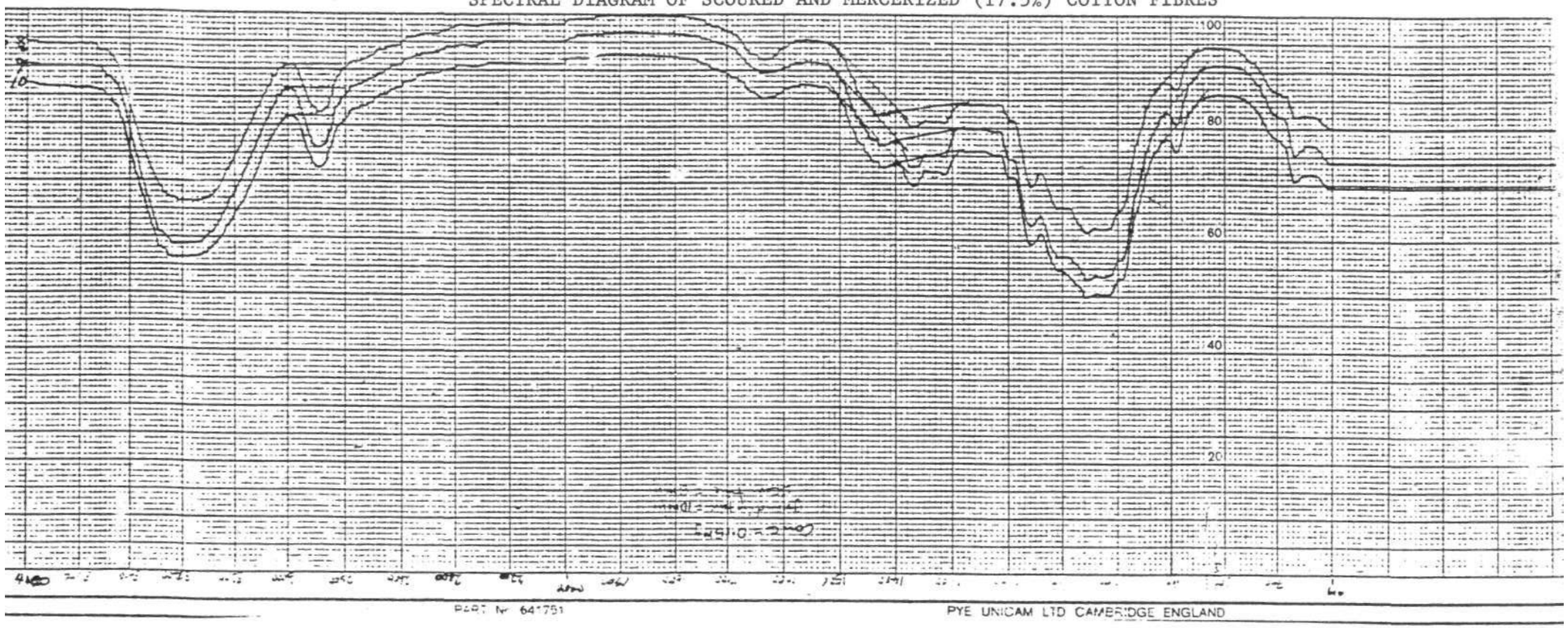
APPENDIX 3

SPECTRAL DIAGRAM OF KIER-BOILED COTTON FIBRES



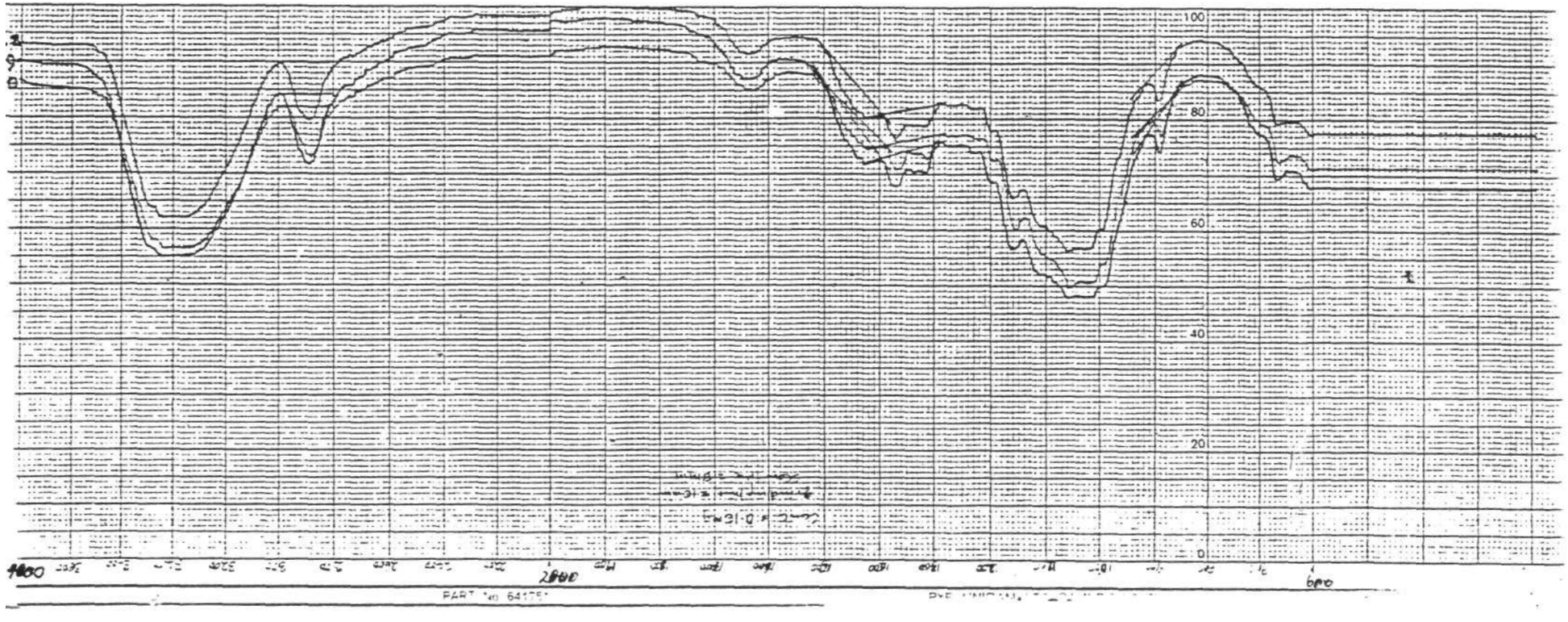
APPENDIX 4

SPECTRAL DIAGRAM OF SCOURED AND MERCERIZED (17.5%) COTTON FIBRES



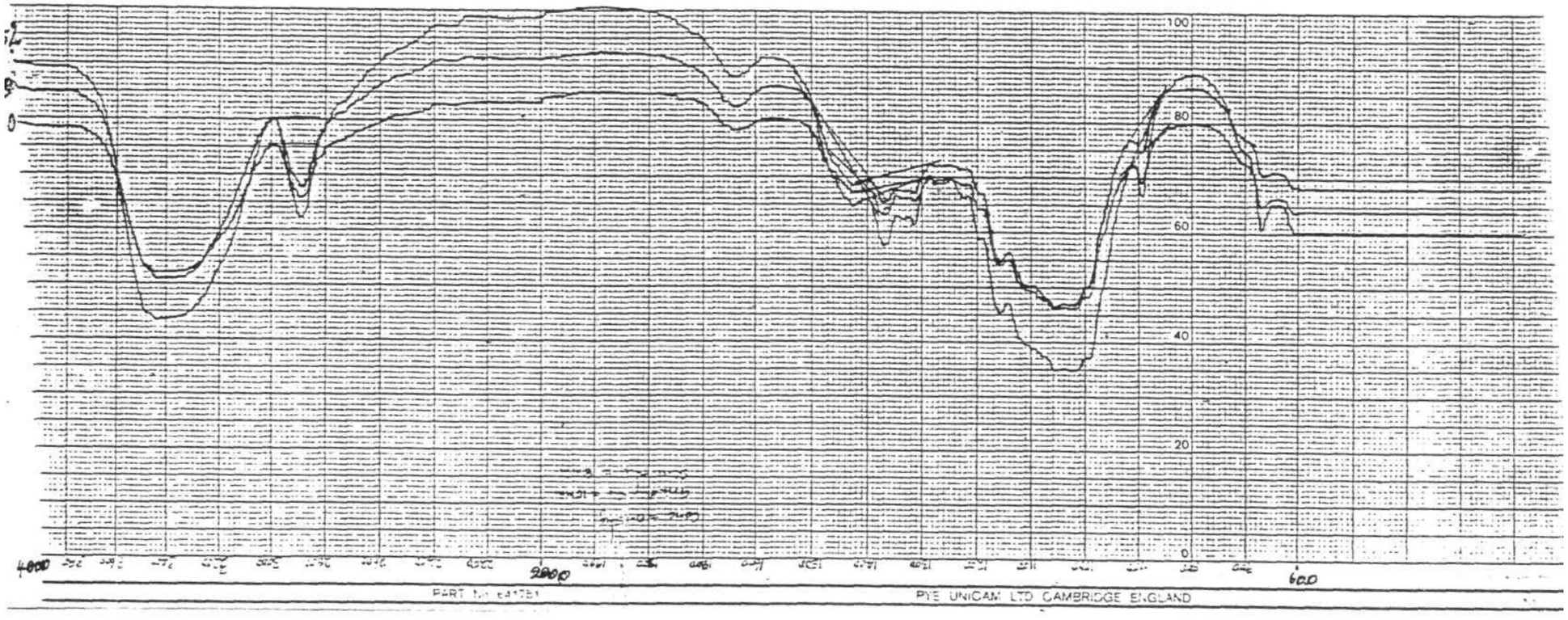
APPENDIX 5

SPECTRAL DIAGRAM OF SCOURED AND MERCERIZED (24%) COTTON FIBRES



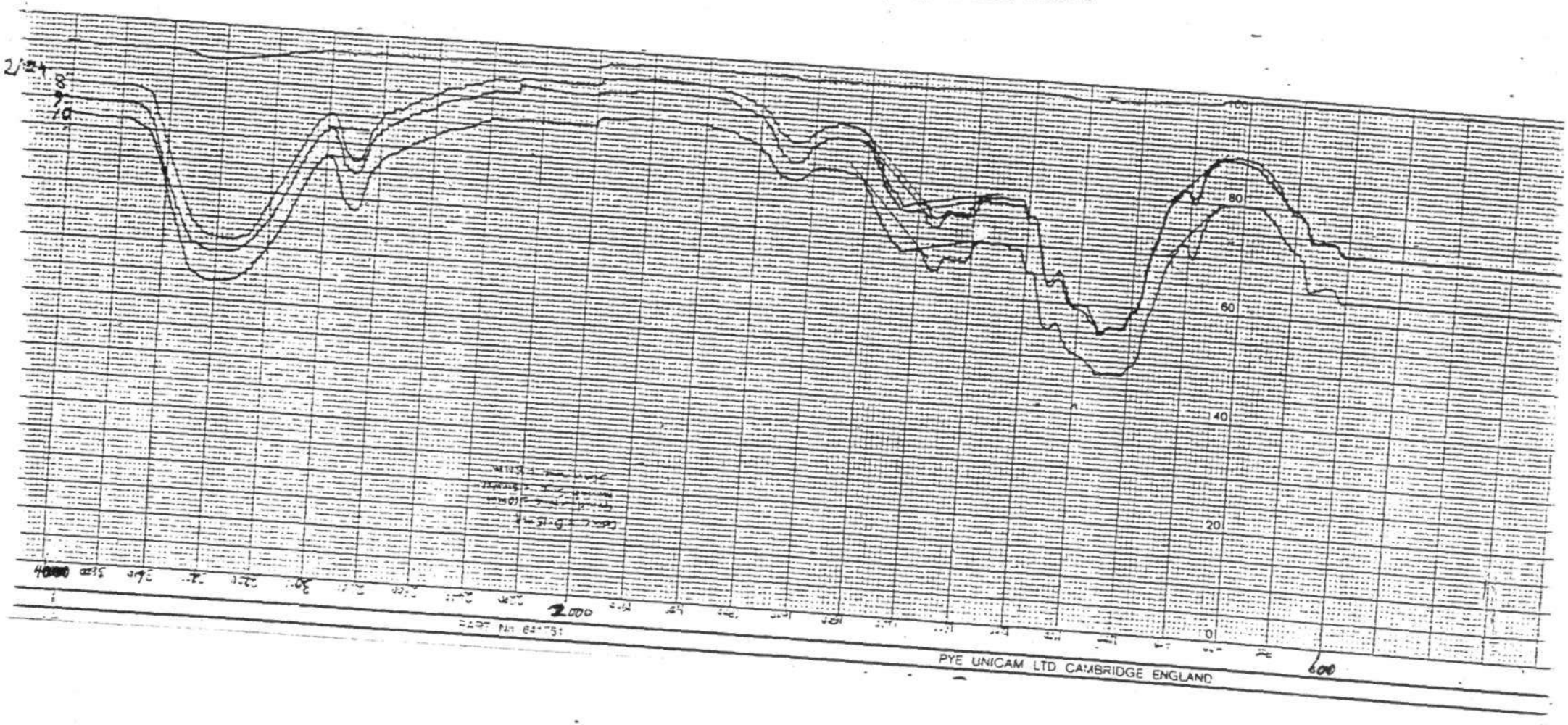
APPENDIX 6

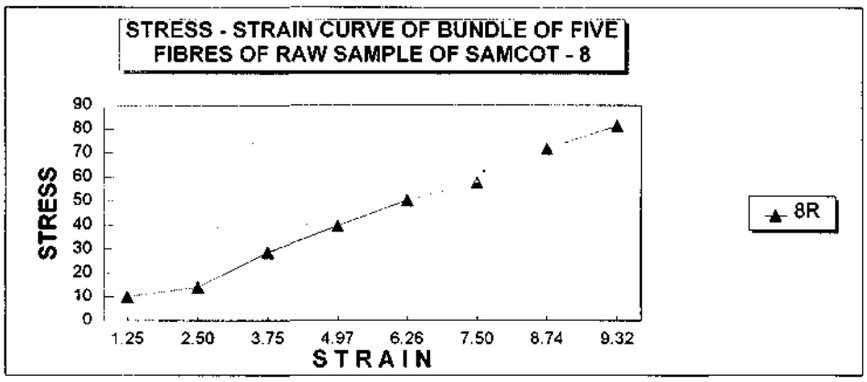
SPECTRAL DIAGRAM OF KIER BOILED AND MERCERIZED (17.5%) COTTON FIBRES

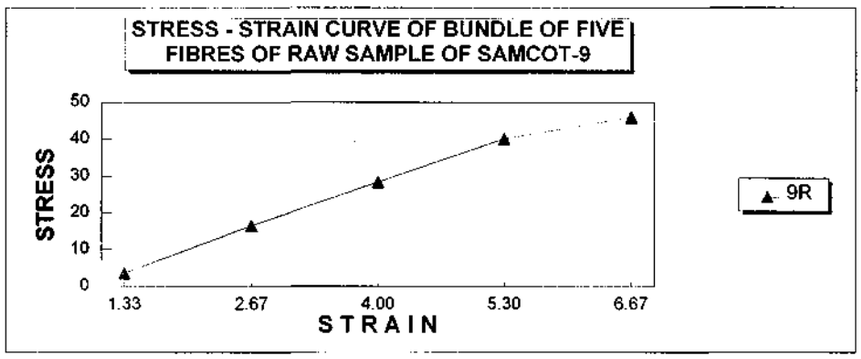


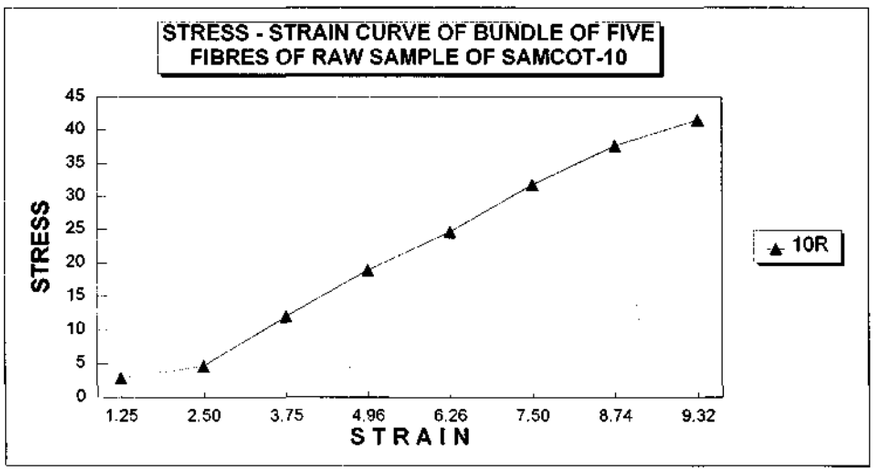
APPENDIX 7

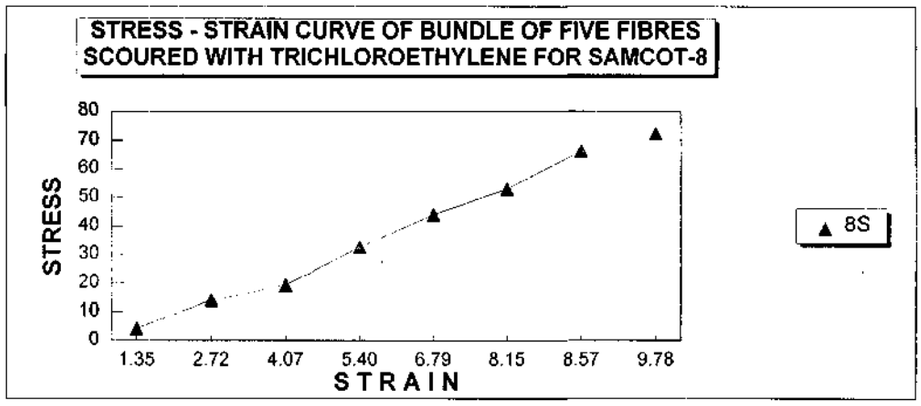
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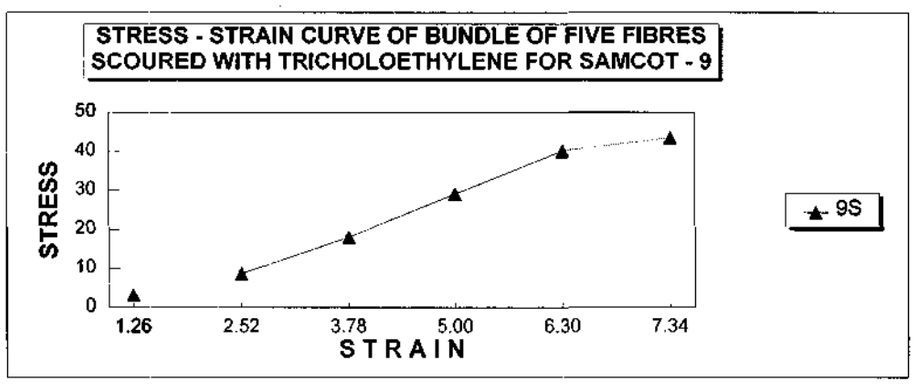


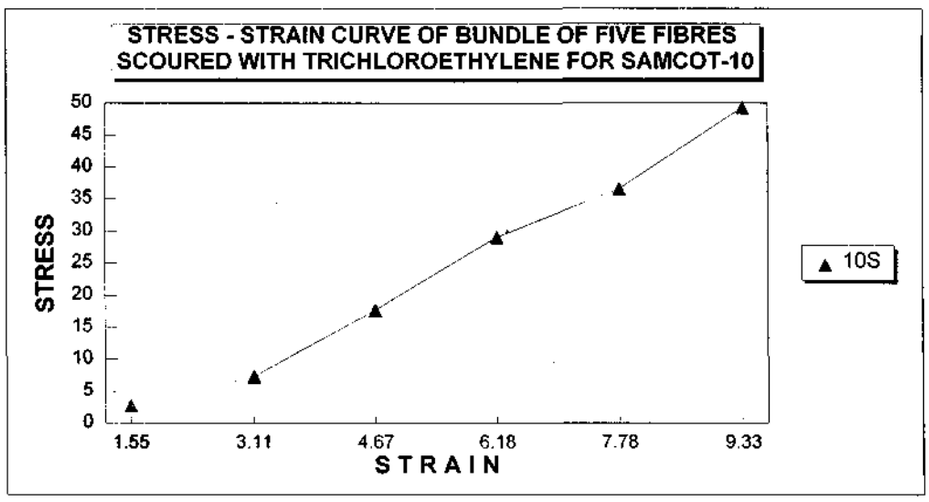

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES OF RAW SAMPLE OF SAMCOT - 8
STRESS
90
80
70
60
50
40
30
20
10
0
1.25
2.50
3.75
4.97
6.26
7.50
8.74
9.32
STRAIN
8R

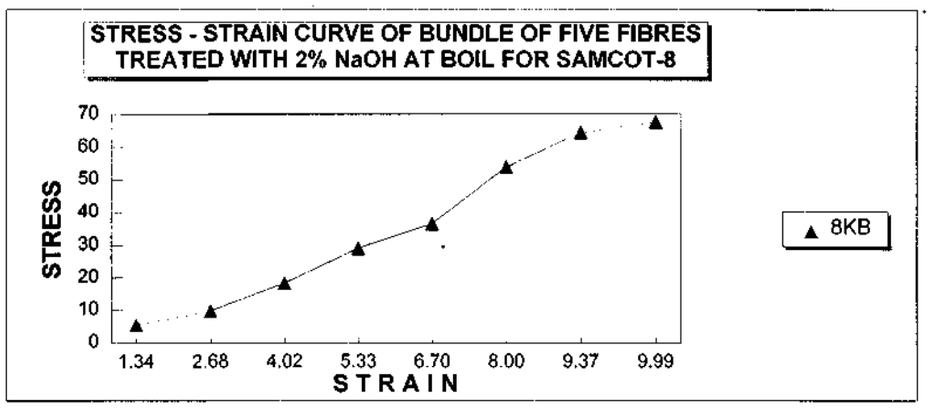

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES OF RAW SAMPLE OF SAMCOT-9
STRESS
50
40
30
20
10
0
1.33
2.67
4.00
5.30
6.67
STRAIN
9R

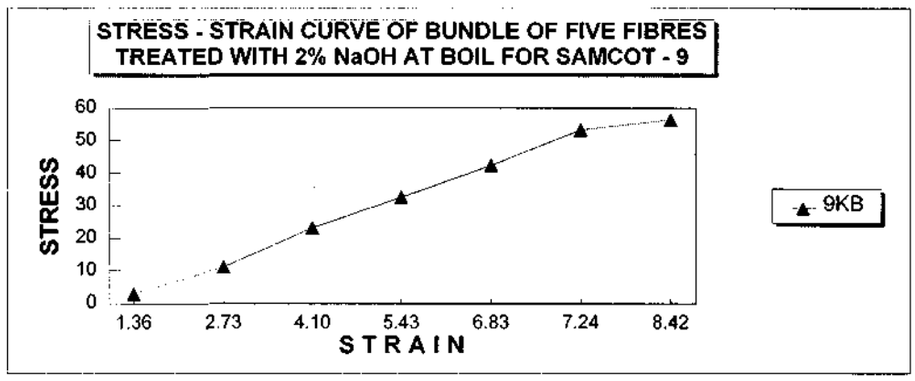

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES OF RAW SAMPLE OF SAMCOT-10
STRESS
45
40
35
30
25
20
15
10
5
0
1.25
2.50
3.75
4.96
6.26
7.50
8.74
9.32
STRAIN
10R

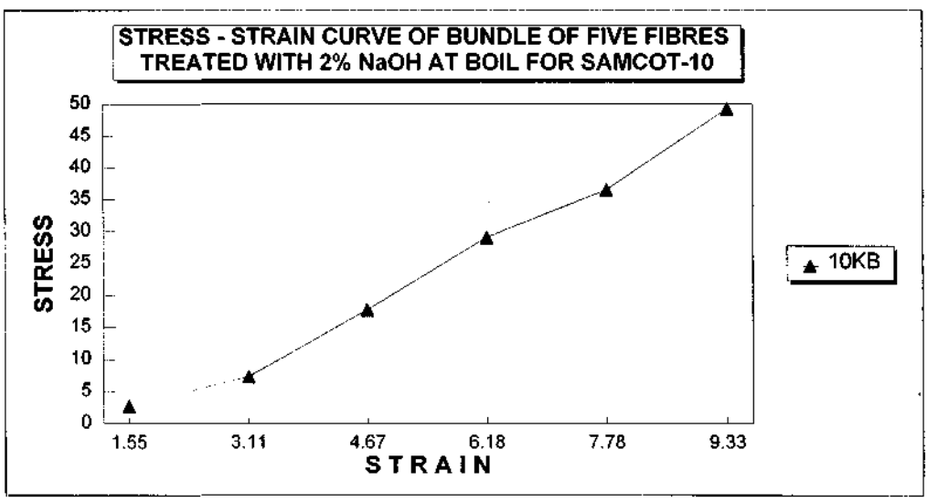

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SCOURED WITH TRICHLOROETHYLENE FOR SAMCOT-8
STRESS
80
70
60
50
40
30
20
10
0
1.35
2.72
4.07
5.40
6.79
8.15
8.57
9.78
STRAIN
8S

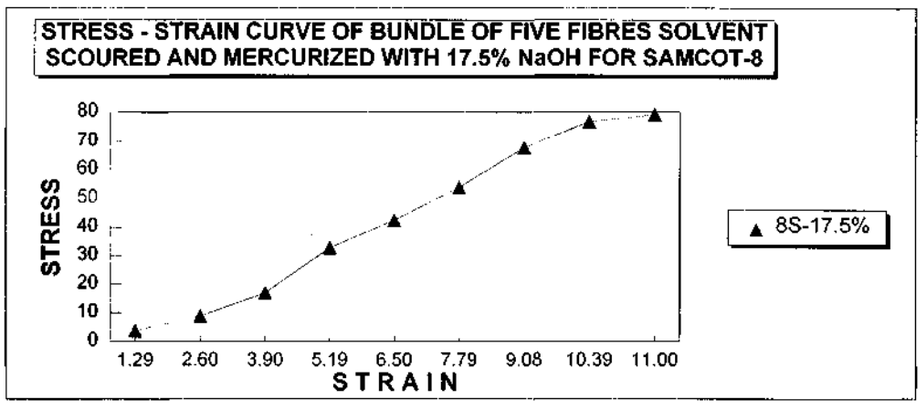

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SCOURED WITH TRICHOLOETHYLENE FOR SAMCOT - 9
STRESS
50
40
30
20
10
0
1.26
2.52
3.78
5.00
6.30
7.34
STRAIN
9S

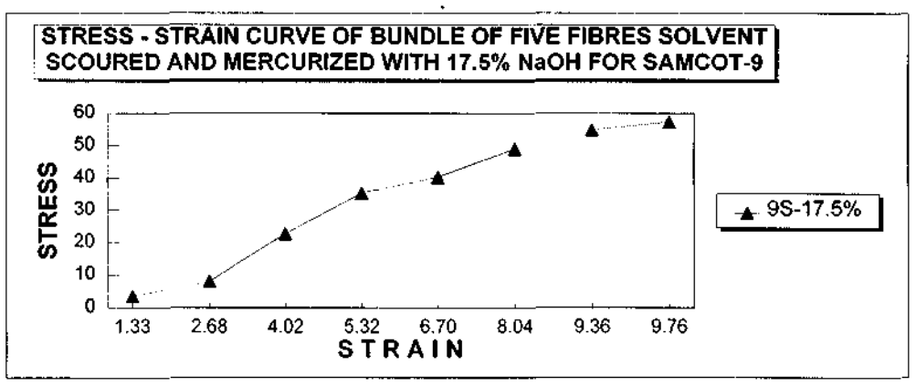

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SCOURED WITH TRICHLOROETHYLENE FOR SAMCOT-10
STRESS
50
45
40
35
30
25
20
15
10
5
0
1.55
3.11
4.67
6.18
7.78
9.33
STRAIN
10S

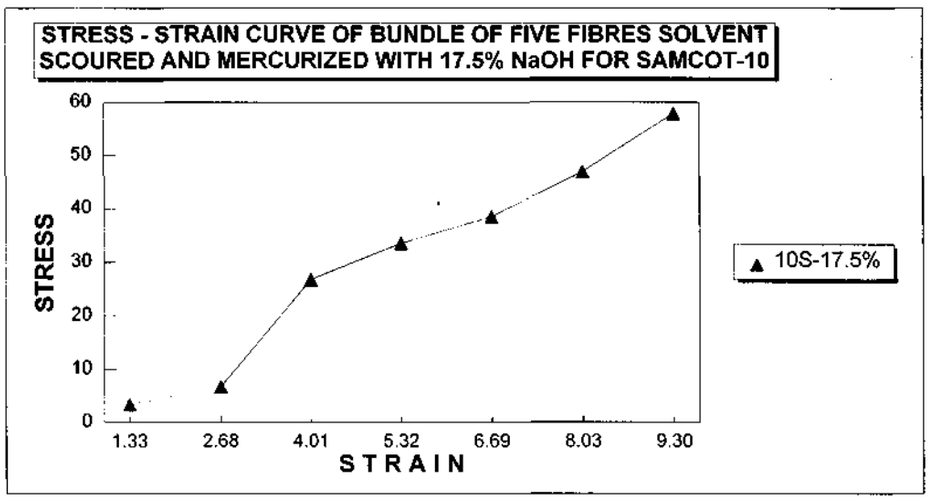

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES TREATED WITH 2% NaOH AT BOIL FOR SAMCOT-8
STRESS
70
60
50
40
30
20
10
0
1.34
2.68
4.02
5.33
6.70
8.00
9.37
9.99
STRAIN
8KB

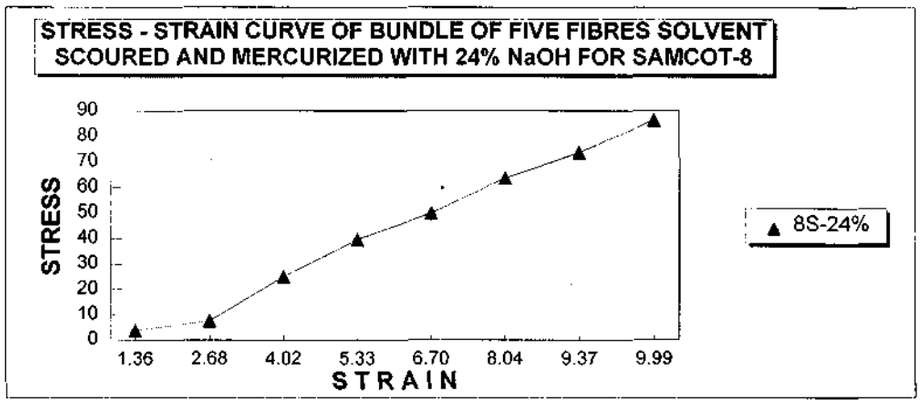

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES TREATED WITH 2% NaOH AT BOIL FOR SAMCOT - 9
STRESS
60
50
40
30
20
10
0
1.36
2.73
4.10
5.43
6.83
7.24
8.42
STRAIN
9KB

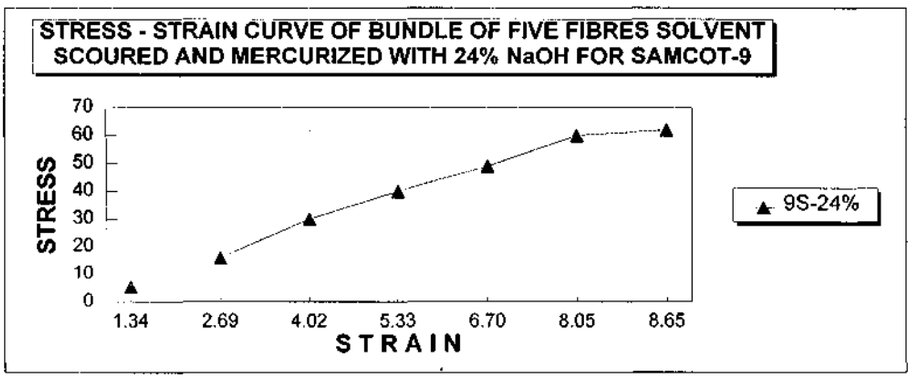

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES TREATED WITH 2% NaOH AT BOIL FOR SAMCOT-10
STRESS
50
45
40
35
30
25
20
15
10
5
0
1.55
3.11
4.67
6.18
7.78
9.33
STRAIN
10KB

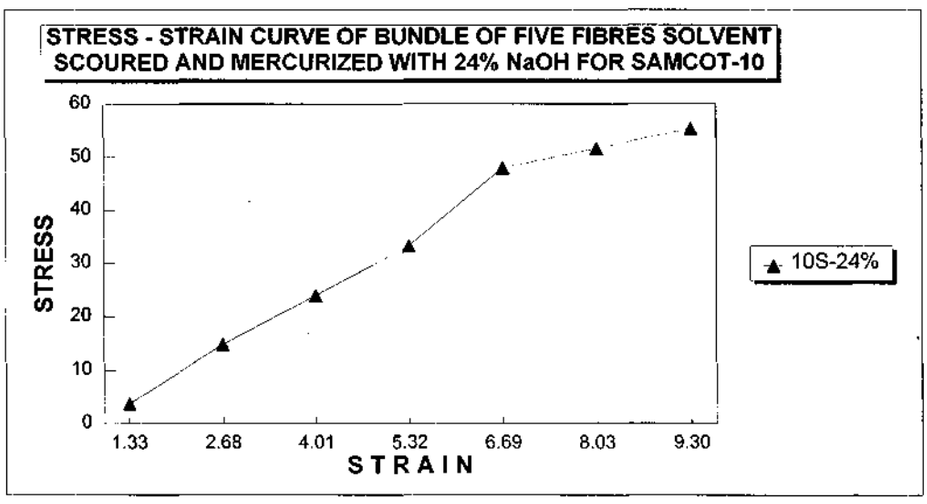

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SOLVENT SCOURED AND MERCURIZED WITH 17.5% NaOH FOR SAMCOT-8
STRESS
80
70
60
50
40
30
20
10
0
1.29
2.60
3.90
5.19
6.50
7.79
9.08
10.39
11.00
STRAIN
8S-17.5%

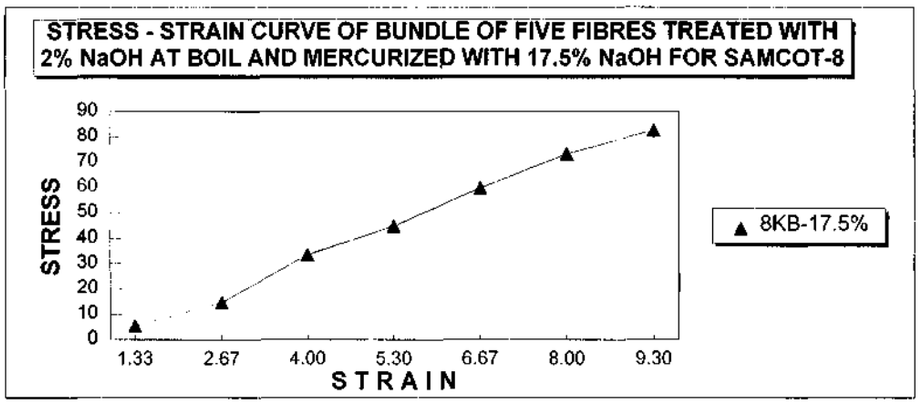

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SOLVENT SCOURED AND MERCURIZED WITH 17.5% NaOH FOR SAMCOT-9
STRESS
60
50
40
30
20
10
0
1.33
2.68
4.02
5.32
6.70
8.04
9.36
9.76
STRAIN
9S-17.5%

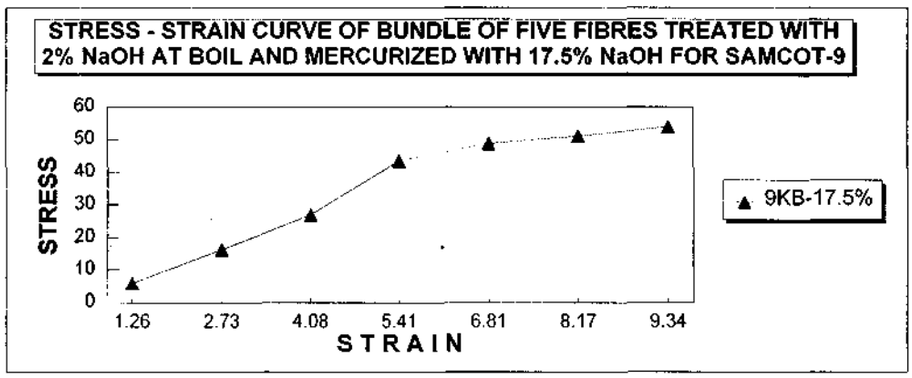

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SOLVENT SCOURED AND MERCURIZED WITH 17.5% NaOH FOR SAMCOT-10
STRESS
60
50
40
30
20
10
0
1.33
2.68
4.01
5.32
6.69
8.03
9.30
STRAIN
10S-17.5%

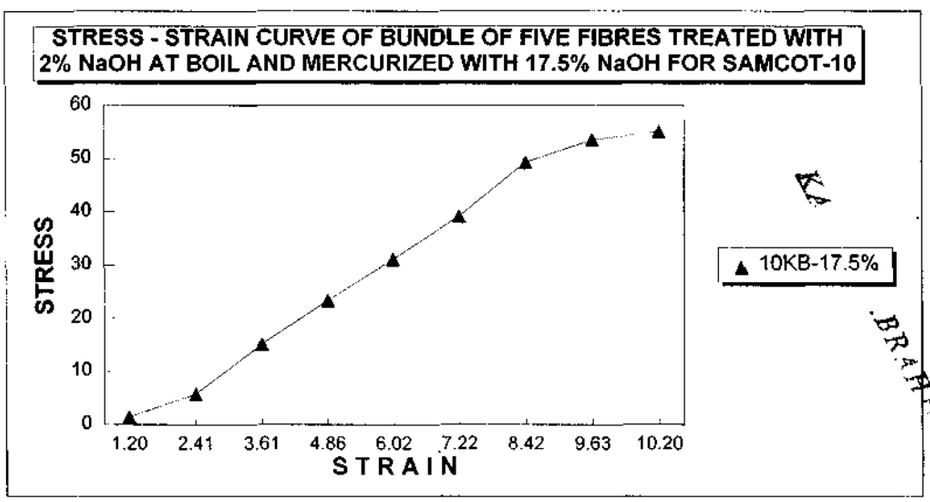

STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SOLVENT SCOURED AND MERCURIZED WITH 24% NaOH FOR SAMCOT-8
STRESS
90
80
70
60
50
40
30
20
10
0
1.36
2.68
4.02
5.33
6.70
8.04
9.37
9.99
STRAIN
8S-24%


STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SOLVENT SCOURED AND MERCURIZED WITH 24% NaOH FOR SAMCOT-9
STRESS
70
60
50
40
30
20
10
0
1.34
2.69
4.02
5.33
6.70
8.05
8.65
STRAIN
9S-24%


STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES SOLVENT SCOURED AND MERCURIZED WITH 24% NaOH FOR SAMCOT-10
STRESS
60
50
40
30
20
10
0
1.33
2.68
4.01
5.32
6.69
8.03
9.30
STRAIN
10S-24%

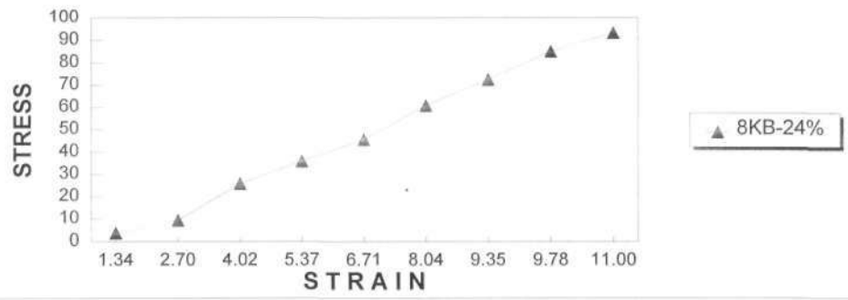




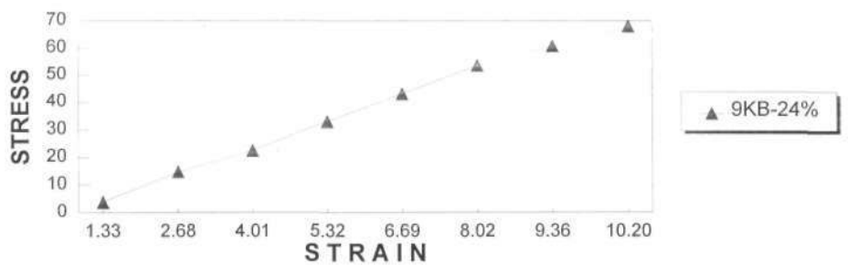


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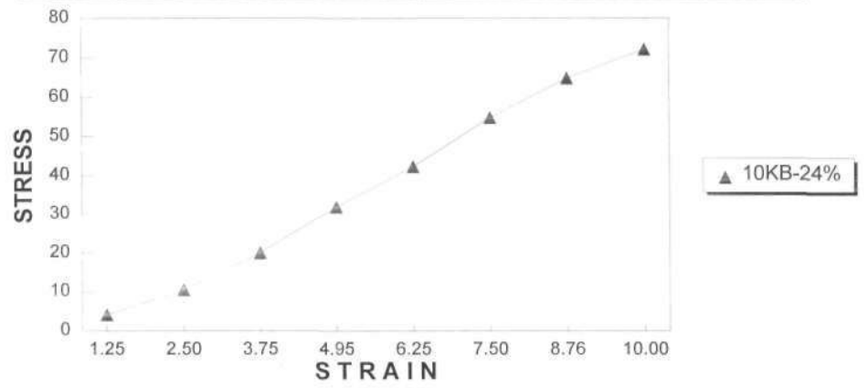
STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES TREATED WITH 2% NaOH AT BOIL AND MERCURIZED WITH 24% NaOH FOR SAMCOT-8

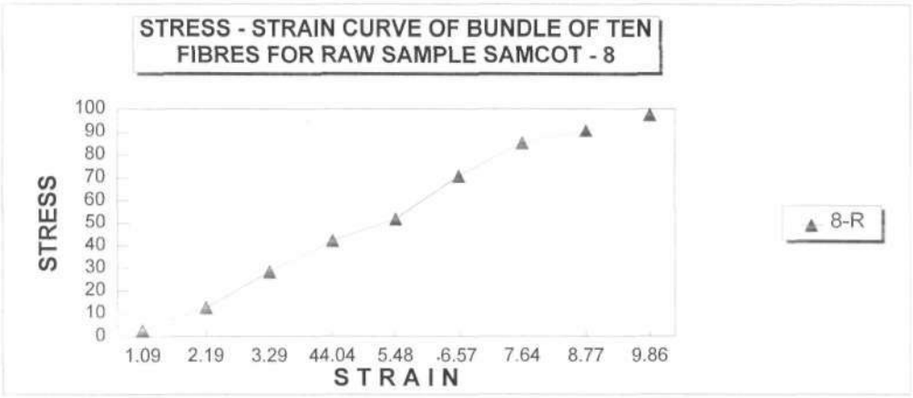


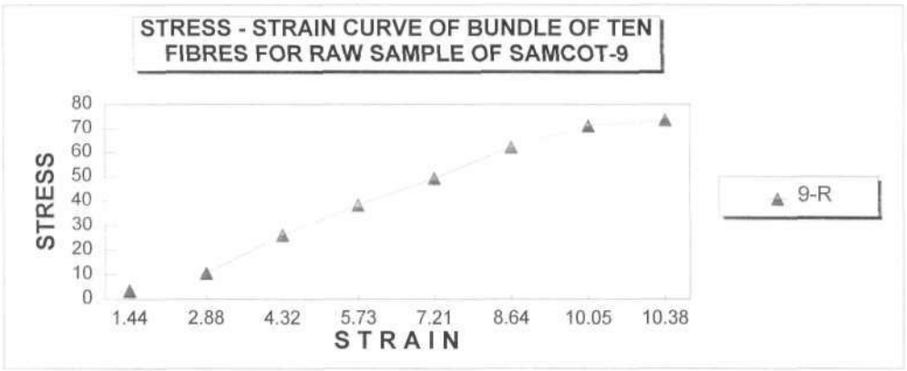
STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES TREATED WITH 2% NaOH AT BOIL AND MERCURIZED WITH 24% NaOH FOR SAMCOT-9

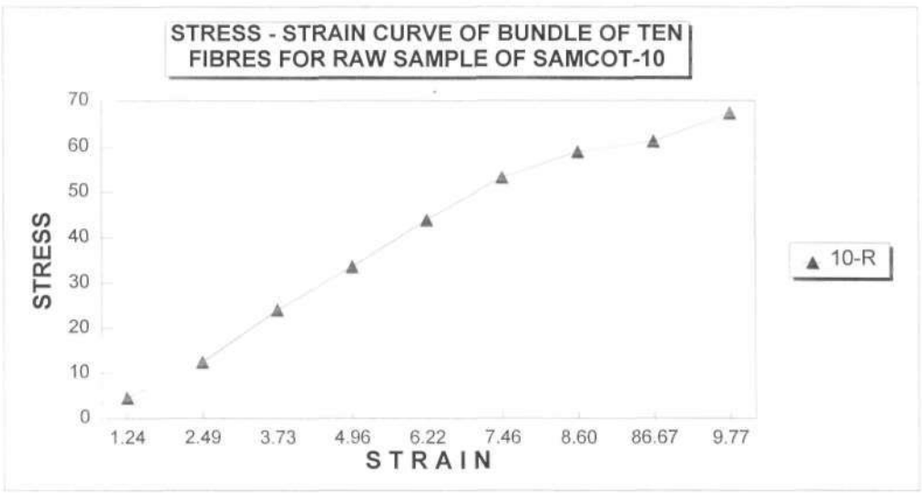


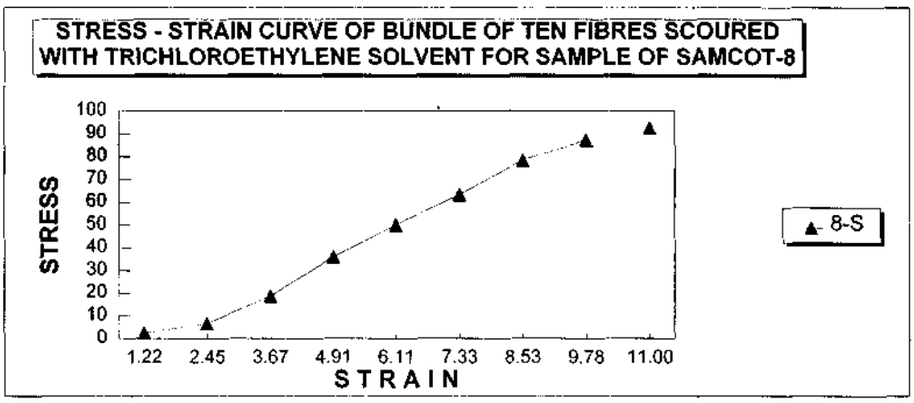
STRESS - STRAIN CURVE OF BUNDLE OF FIVE FIBRES TREATED WITH 2% NaOH AT BOIL AND MERCURIZED WITH 24% NaOH FOR SAMCOT-10

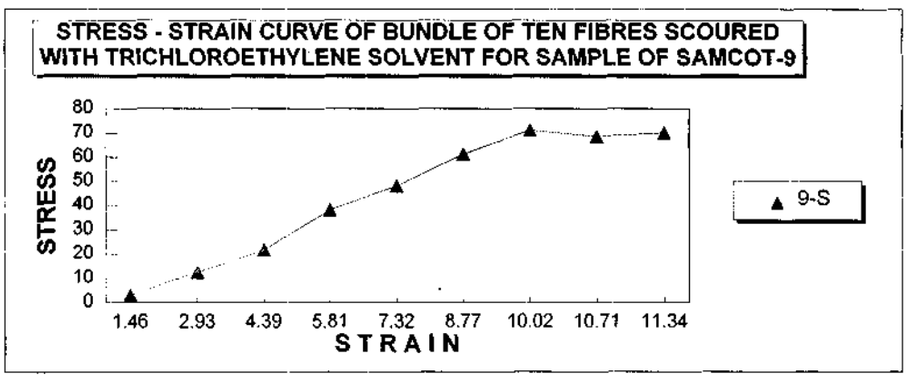


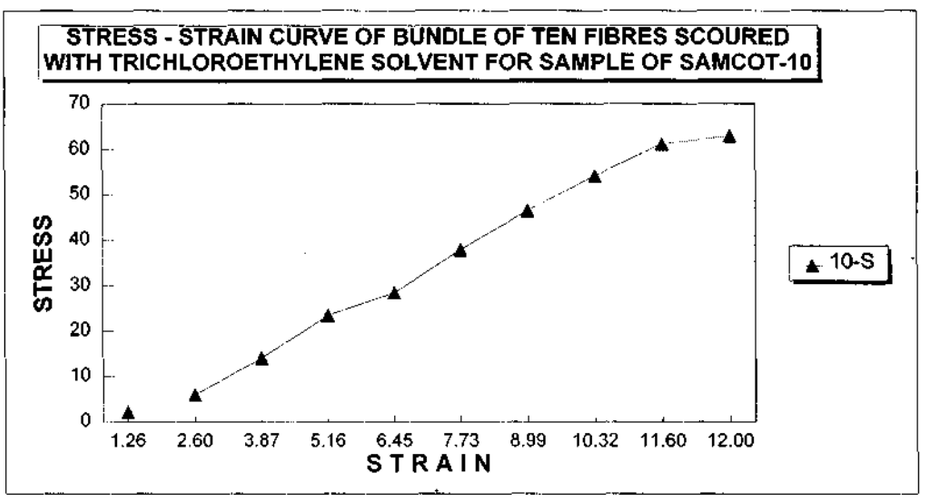

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES FOR RAW SAMPLE SAMCOT - 8
STRESS
100
90
80
70
60
50
40
30
20
10
0
1.09
2.19
3.29
44.04
5.48
.6.57
7.64
8.77
9.86
STRAIN
8-R

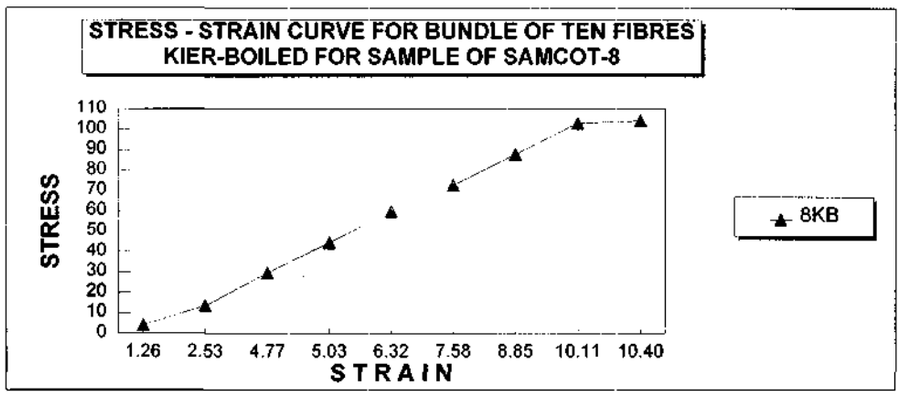

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES FOR RAW SAMPLE OF SAMCOT-9
STRESS
80
70
60
50
40
30
20
10
0
1.44
2.88
4.32
5.73
7.21
8.64
10.05
10.38
STRAIN
9-R

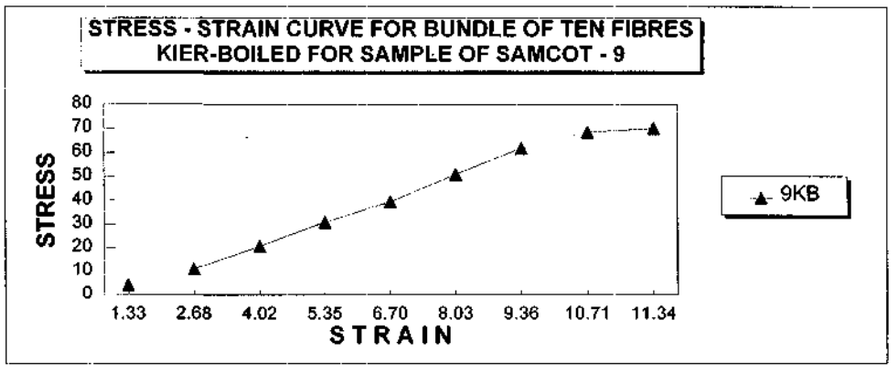

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES FOR RAW SAMPLE OF SAMCOT-10
STRESS
70
60
50
40
30
20
10
0
1.24
2.49
3.73
4.96
6.22
7.46
8.60
86.67
9.77
STRAIN
10-R

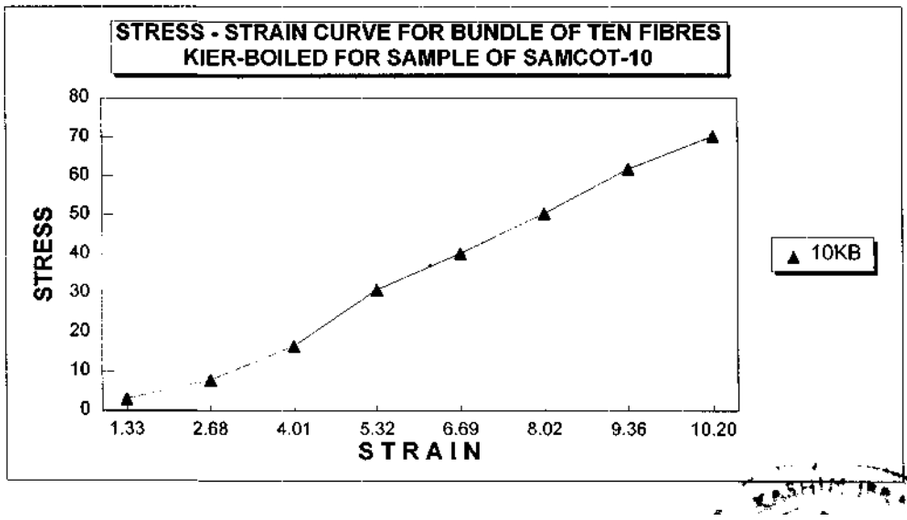

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SCOURED WITH TRICHLOROETHYLENE SOLVENT FOR SAMPLE OF SAMCOT-8
STRESS
100
90
80
70
60
50
40
30
20
10
0
1.22
2.45
3.67
4.91
6.11
7.33
8.53
9.78
11.00
STRAIN
8-S

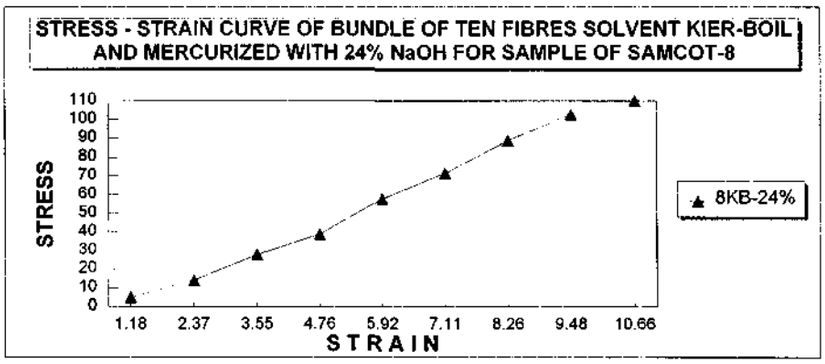

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SCOURED WITH TRICHLOROETHYLENE SOLVENT FOR SAMPLE OF SAMCOT-9
STRESS
80
70
60
50
40
30
20
10
0
1.46
2.93
4.39
5.81
7.32
8.77
10.02
10.71
11.34
STRAIN
9-S

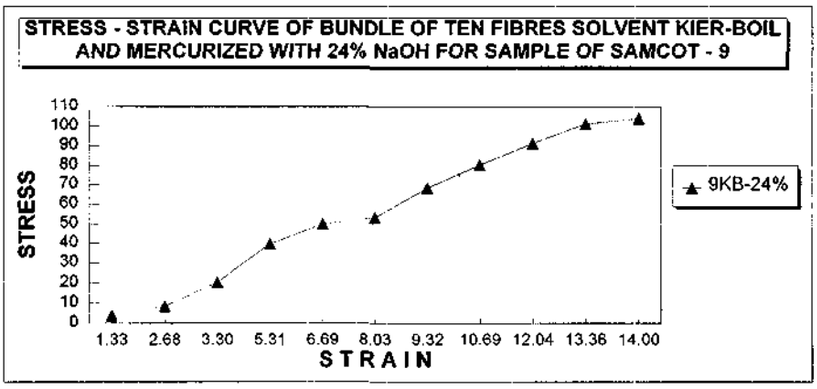

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SCOURED WITH TRICHLOROETHYLENE SOLVENT FOR SAMPLE OF SAMCOT-10
STRESS
70
60
50
40
30
20
10
0
1.26
2.60
3.87
5.16
6.45
7.73
8.99
10.32
11.60
12.00
STRAIN
10-S

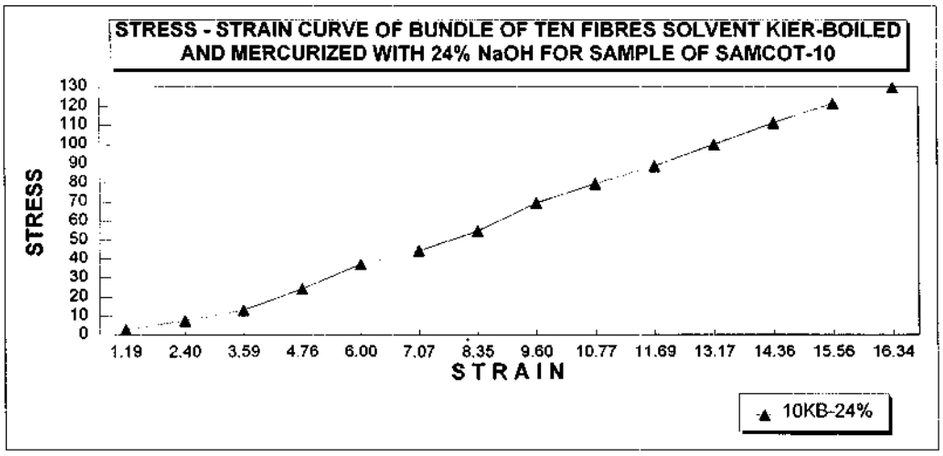

STRESS - STRAIN CURVE FOR BUNDLE OF TEN FIBRES
KIER-BOILED FOR SAMPLE OF SAMCOT-8
STRESS
110
100
90
80
70
60
50
40
30
20
10
0
1.26
2.53
4.77
5.03
6.32
7.58
8.85
10.11
10.40
STRAIN
8KB

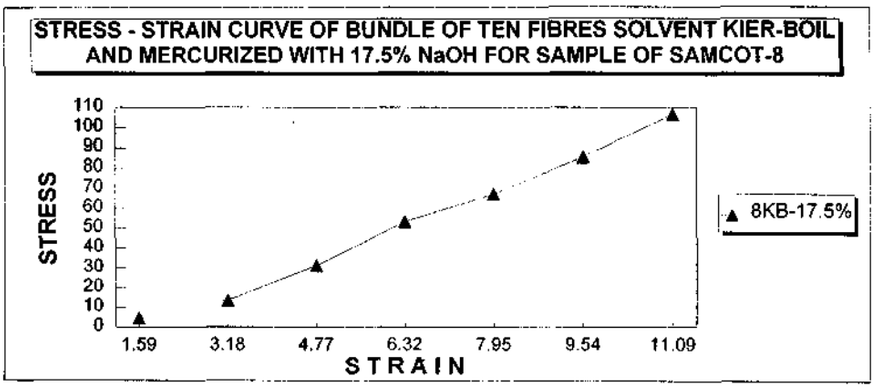

STRESS - STRAIN CURVE FOR BUNDLE OF TEN FIBRES
KIER-BOILED FOR SAMPLE OF SAMCOT - 9
STRESS
80
70
60
50
40
30
20
10
0
1.33
2.68
4.02
5.35
6.70
8.03
9.36
10.71
11.34
STRAIN
9KB

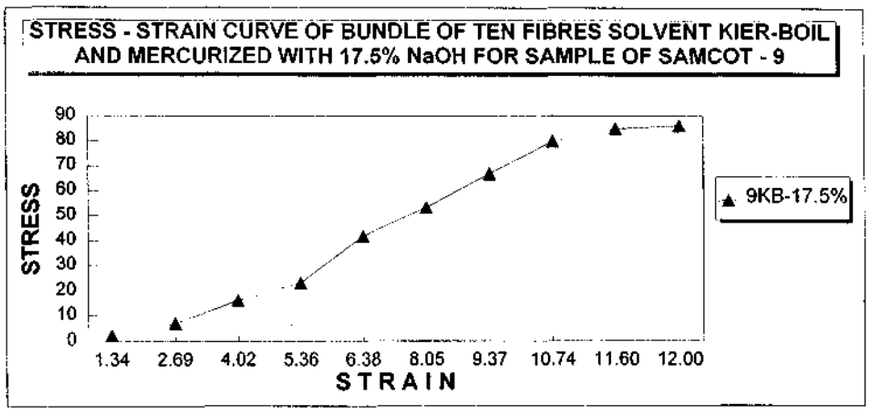

STRESS - STRAIN CURVE FOR BUNDLE OF TEN FIBRES
KIER-BOILED FOR SAMPLE OF SAMCOT-10
STRESS
80
70
60
50
40
30
20
10
0
1.33
2.68
4.01
5.32
6.69
8.02
9.36
10.20
STRAIN
10KB

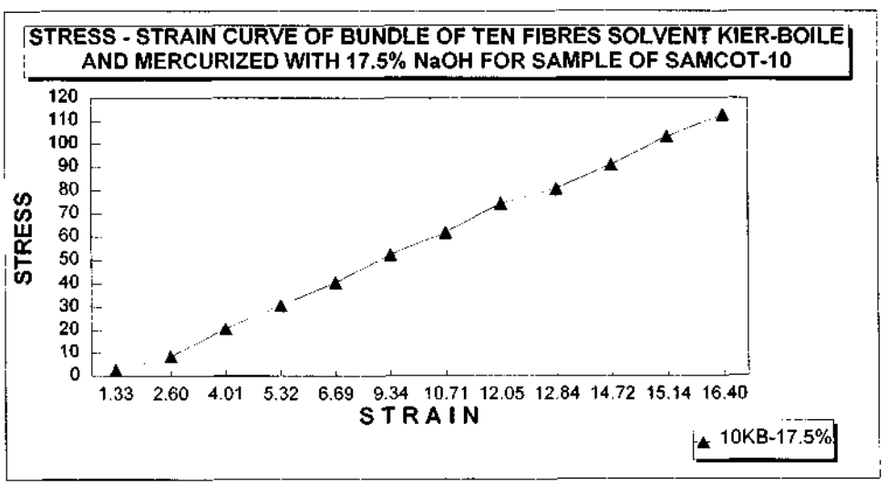

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT KIER-BOIL AND MERCURIZED WITH 24% NaOH FOR SAMPLE OF SAMCOT-8
STRESS
110
100
90
80
70
60
50
40
30
20
10
0
1.18
2.37
3.55
4.76
5.92
7.11
8.26
9.48
10.66
STRAIN
8KB-24%

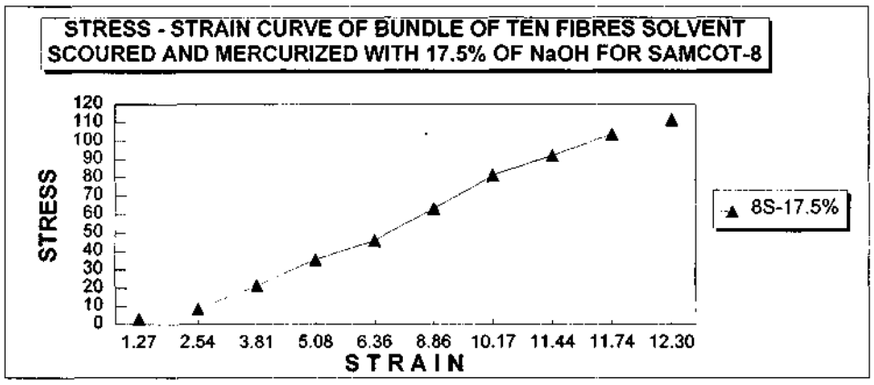

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT KIER-BOIL AND MERCURIZED WITH 24% NaOH FOR SAMPLE OF SAMCOT - 9
STRESS
110
100
90
80
70
60
50
40
30
20
10
0
1.33
2.68
3.30
5.31
6.69
8.03
9.32
10.69
12.04
13.36
14.00
STRAIN
9KB-24%

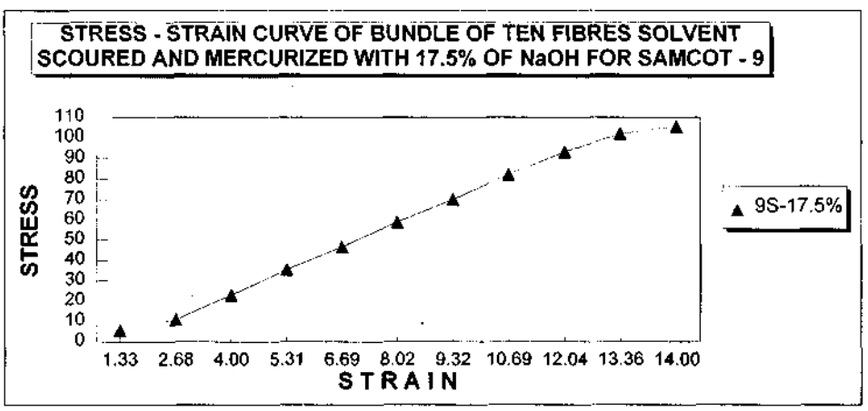

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT KIER-BOILED AND MERCURIZED WITH 24% NaOH FOR SAMPLE OF SAMCOT-10
STRESS
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1.19
2.40
3.59
4.76
6.00
7.07
8.35
9.60
10.77
11.69
13.17
14.36
15.56
16.34
STRAIN
10KB-24%

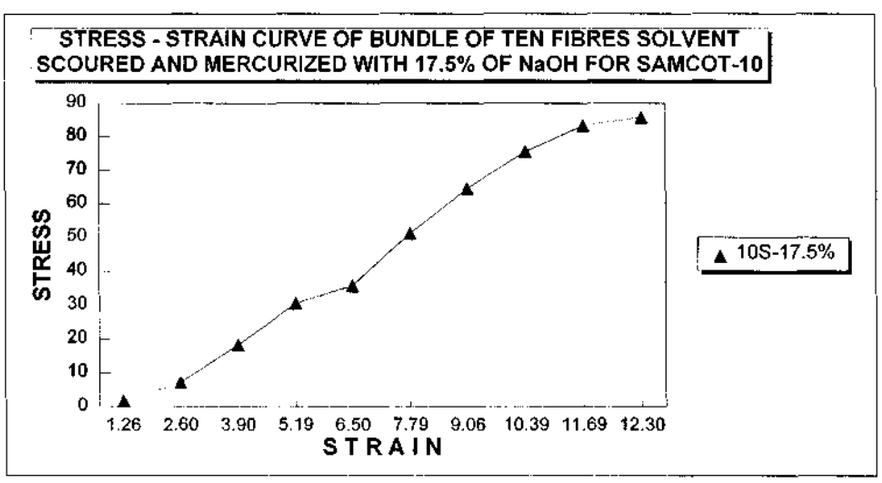

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT KIER-BOIL AND MERCURIZED WITH 17.5% NaOH FOR SAMPLE OF SAMCOT-8
STRESS
110
100
90
80
70
60
50
40
30
20
10
0
1.59
3.18
4.77
6.32
7.95
9.54
11.09
STRAIN
8KB-17.5%

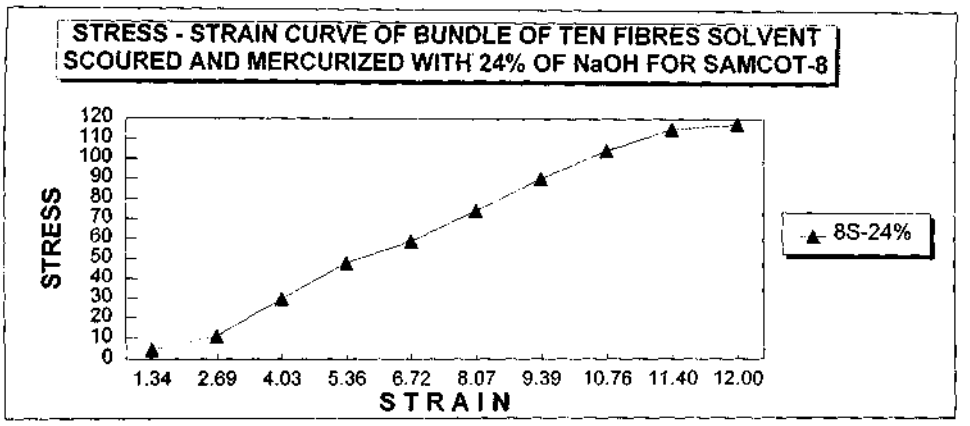

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT KIER-BOIL AND MERCURIZED WITH 17.5% NaOH FOR SAMPLE OF SAMCOT - 9
STRESS
90
80
70
60
50
40
30
20
10
0
1.34
2.69
4.02
5.36
6.38
8.05
9.37
10.74
11.60
12.00
STRAIN
9KB-17.5%

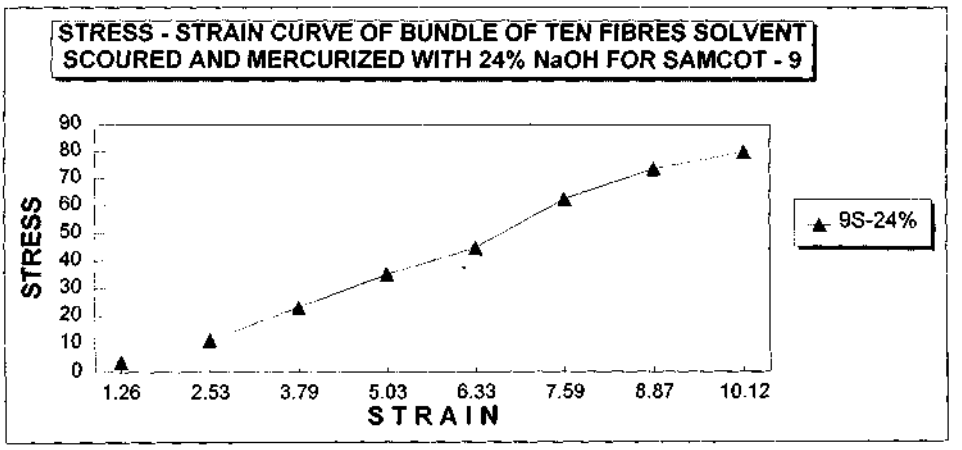

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT KIER-BOILE AND MERCURIZED WITH 17.5% NaOH FOR SAMPLE OF SAMCOT-10
STRESS
120
110
100
90
80
70
60
50
40
30
20
10
0
1.33
2.60
4.01
5.32
6.69
9.34
10.71
12.05
12.84
14.72
15.14
16.40
STRAIN
10KB-17.5%

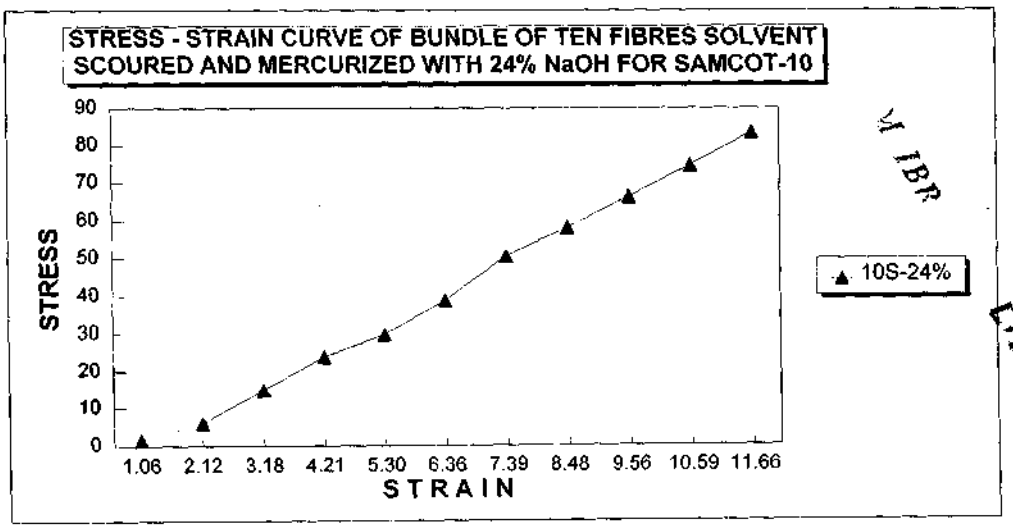

STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT SCOURED AND MERCURIZED WITH 17.5% OF NaOH FOR SAMCOT-8
STRESS
120
110
100
90
80
70
60
50
40
30
20
10
0
1.27 2.54 3.81 5.08 6.36 8.86 10.17 11.44 11.74 12.30
STRAIN
8S-17.5%


STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT SCOURED AND MERCURIZED WITH 17.5% OF NaOH FOR SAMCOT - 9
STRESS
110
100
90
80
70
60
50
40
30
20
10
0
1.33 2.68 4.00 5.31 6.69 8.02 9.32 10.69 12.04 13.36 14.00
STRAIN
9S-17.5%


STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT SCOURED AND MERCURIZED WITH 17.5% OF NaOH FOR SAMCOT-10
STRESS
90
80
70
60
50
40
30
20
10
0
1.26 2.60 3.90 5.19 6.50 7.79 9.06 10.39 11.69 12.30
STRAIN
10S-17.5%


STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT SCOURED AND MERCURIZED WITH 24% OF NaOH FOR SAMCOT-8
STRESS
120
110
100
90
80
70
60
50
40
30
20
10
0
1.34
2.69
4.03
5.36
6.72
8.07
9.39
10.76
11.40
12.00
STRAIN
8S-24%


STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT SCOURED AND MERCURIZED WITH 24% NaOH FOR SAMCOT - 9
STRESS
90
80
70
60
50
40
30
20
10
0
1.26
2.53
3.79
5.03
6.33
7.59
8.87
10.12
STRAIN
9S-24%


STRESS - STRAIN CURVE OF BUNDLE OF TEN FIBRES SOLVENT SCOURED AND MERCURIZED WITH 24% NaOH FOR SAMCOT-10
STRESS
90
80
70
60
50
40
30
20
10
0
1.06
2.12
3.18
4.21
5.30
6.36
7.39
8.48
9.56
10.59
11.66
STRAIN
10S-24%

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