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Title: EFFECT OF SELECTED METHODS OF ABRASION ON CERTAIN PHYSICAL PROPERTIES OF HIGH WET MODULUS RAYON

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The purpose of the study was to compare the effects of certain abrasion procedures upon specific physical properties of a high wet modulus rayon. The type of abrasion applied included surface abrasion in dry and wet condition, edge abrasion in dry condition, and flexing abrasion in dry condition. Dry flexing abrasion was performed only in the Stoll tester but all other abrasion procedures were performed both in the Accelerator and Stoll tester. Breaking load or bursting strength, elongation, weight of fabric and microscopy were the criteria used to evaluate abrasion damage.

Five null hypotheses were tested to determine whether any significant correlations existed (1) among the percentage losses in physical properties or (2) between period of abrasion and the percentage losses in physical properties as a result of abrasion; to

determine whether any significant differences in the percentage losses in physical properties occurred (3) between warpwise and fillingwise abraded specimens or (4) between specimens abraded wet and dry; and to determine (5) whether each side of a specimen was evenly abraded in the Accelerotor. Analysis of data obtained was based on the regression analysis and the t-test.

Damage of the fabric, yarn and fiber observed under a microscope seemed to increase with the increasing period of abrasion. The yarn and fabric tended to deteriorate continuously. Fibrillation of the fiber was observed at the end point on specimens subjected to wet surface abrasion in the Stoll tester.

Correlations among the percentage losses in physical properties were positive and generally significant. The rate change in physical properties had a positive linear relationship with period of abrasion. Some abrasion procedures had significantly different effects upon certain physical properties of warpwise specimens and filling specimens. There were significantly greater percentage losses in breaking load and weight of specimens subjected to dry surface abrasion than to wet surface abrasion in the Accelerotor. Each side of specimens subjected to dry surface abrasion in the Accelerotor was unevenly abraded in terms of the percentage losses in breaking load and elongation, and those subjected to wet surface abrasion in the Accelerotor were unevenly abraded in terms of the percentage losses in elongation.

It was concluded that different abrasion procedures affected a physical property differently, and a given procedure of abrasion affected various properties of the fabric differently.

Effect of Selected Methods of Abrasion on Certain Physical Properties of High Wet Modulus Rayon

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TABLE OF CONTENTS

LIST OF FIGURES

Figure		Page

LIST OF PLATES

LIST OF TABLES

EFFECT OF SELECTED METHODS OF ABRASION ON CERTAIN PHYSICAL PROPERTIES OF HIGH WET MODULUS RAYON

CHAPTER I

INTRODUCTION

Some researchers (12, 26, 35) have stated that the resistance of a textile fabric to abrasion is one of the most important factors affecting fabric serviceability. Abrasion is thought to involve a combination of complex factors (6, 26). The abrasion in actual use of fabric is usually a combination of flat, flexing, and edge abrasion, and it may occur either in the dry or wet conditions. Attempts to determine wearability of textile fabric led to the development of various instruments and the procedures to measure resistance to abrasion; however, there is no universally applicable instrument or testing procedure (6).

In most studies of abrasion, researchers have tried to measure the abrasion damage at a certain point of abrading, but less frequently they have measured the rate of change in physical properties of textile materials as a result of abrasion. There have been relatively limited attempts to inter-relate the changes in several physical properties, such as weight, breaking load or elongation as a result of abrasion.

In the evaluation of abrasion damage, some workers examined abraded specimens under a microscope, and others measured the changes in physical properties. However, a few tried to use these two criteria together for evaluating abrasion damage.

Because the abrasion of a textile material is a complex phenomenon and there is no universally applicable instrument or procedure to measure resistance to abrasion, it is necessary to compare different procedures of abrasion by means of different instruments, under different conditions.

High wet modulus rayon is one of the recent and significant improvements in rayon. With its improved wet modulus and high tenacity, the new rayon has an important position in the textile field.

The Objectives of the Study

The objectives of the study are:

1. To compare the effects of abrasion by certain procedures upon selected physical properties of high wet modulus rayon, using the Accelerotor and Stoll instruments. The physical properties measured included fabric and fiber microscopy, fabric breaking load or bursting strength, fabric elongation, and weight. The procedures included wet and dry surface, dry edge, and dry flexing abrasion.
2. To examine the correlation among the percentage changes in

weight, breaking load, and elongation at break of specimens as a result of abrasion.

3. To determine the rate of changes in physical properties of specimens as a result of abrasion, based upon measuring at 9 periods where possible.
4. To compare the warpwise and fillingwise percentage changes in physical properties of the fabric.
5. To determine whether specimens abraded evenly in the Accelerotor.

Hypotheses

The null hypotheses tested were:

1. There was no significant relationship among the percentage losses in (a) breaking load, (b) elongation, and (c) weight after a given abrasion test.
2. There was no linear relationship between period of abrasion and the percentage loss in physical properties of specimens subjected to abrasion.
3. There was no significant difference between the warpwise direction and the fillingwise direction in changes of breaking load, elongation, and weight of specimen as a result of abrasion.

4. There was no difference between the effects of wet and dry abrasion on the percentage losses in weight, elongation, and breaking load of specimens subjected to abrasion.
5. Each side of a specimen was abraded evenly in terms of loss in elongation and in breaking load as a result of abrasion in the Accelerotor.

CHAPTER II

REVIEW OF LITERATURE

Definition of Abrasion and Wear

The literature reveals the fact that wear is recognized to be a set of complex functions involving many factors, mechanical or chemical in nature, while abrasion is only one of the several factors contributing to wear. Therefore, these two words cannot be used interchangeably. Ball (6, 134 p.) makes a clear distinction between them.

> . . . abrasion derived from the verb 'to abrade' very distinctly suggests a 'rubbing off'. The word 'abrasion' as an adjective might properly be applied therefore to those machines or tests in which rubbing is the only, or at least the major characteristic.
>
> . . . 'wear' be considered as a broader scope than 'abrasion' and be used to apply wherever other important destructive actions, with or without abrasion, are existent or are intentionally introduced by the machine or test method . . .

Textile wear is a complex process involving a wide variety of different mechanical and chemical actions. Mechanical wear includes both gradual deterioration resulting from abrasion, tensile stressing, and accidental cause of failure such as rips and/or cuts. Chemical wear results from such actions as microbial attack, damage during laundering due to the detergents, sunlight degradation and other effects of chemicals (26). Wear of textile fabric also involves end uses; for example, tensile stress would be a more important factor in sporting apparel when body motion causes frequent stretching, but sunlight degradation is the major factor for drapery fabric. Although for most end uses the importance of all the factors contributing to mechanical wear have not been determined, salvage studies of textiles worn in military service have shown that abrasion is a major cause of failure.

Abrasive damage during actual wear probably is of three types: a combination of direct rubbing on the fabrics, which is called surface or flat abrasion; flexing and bending, which is called flexing abrasion; and edge abrasion, in which the folded fabric is rubbed against an abrasive surface (26, 35).

Mechanism of Abrasion

A general mechanism of cloth abrasion differs from the process of surface attrition of solid bodies because of the complex geometry of fabric surface and the visco-elastic properties of textile fibers. The total cloth abrasion is supposed to be comprised of three elements, the relative magnitude of which depends upon the nature of the abradant, the behavior of the fiber in a fabric structure and general conditions of rubbing (6).

Three possible mechanisms have been proposed (5, 15, 25, 26) which may result in mechanical break-down of textile structure in abrasion. These three possible elements of abrasion mechanism are frictional wear, surface cutting, and plucking or snagging of fibers. Frictional wear and cutting were believed to result in direct damage to the fiber at local points of contact, while fiber plucking was thought to cause immediate or dynamic fatigue rupture of the fiber at the point along the fiber length where the maximum stress concentration was built up. The mechanism most often employed in reported research has been cutting, probably because this mechanism produces destruction more rapidly than the other two. Many end uses, however, may involve primarily frictional abrasion (19).

Friction has been described as "...the spontaneous force which resists relative motion between bodies in contact..." (p. 455). Frictional wear occurs when the surface of the abradant is relatively smooth and fibers are firmly held in the yarn structure, and the mechanism of abrasion is analogous to the sliding of smooth metal surfaces over each other (4).

Some writers have stated (26, 30) that molecular adhesion plays the principal role in frictional phenomena. Others have attributed the friction to the ploughing of a soft surface by a hard surface and to electrical forces or to surface roughness. Backer (5) believed that all three of these mechanisms should contribute to the total frictional forces.

According to the surface roughness hypothesis (4, 25), the surface roughness and mechanical interlocking of surface protuberances are the main causes of frictional resistance, but many researchers (26) felt that this theory does not vary systematically with the frictional forces. In the plowing hypothesis, it is believed (25) that the soft surface is plowed by a harder surface; however, this may or may not involve an interchange of material between fabric and abradant. The adhesion hypothesis, which was originally developed in relation to sliding metals, is the one most widely held today (25). According to this hypothesis, when two bodies are rubbed together, the atoms of the protuberances of the upper and lower surface are moved into the other's electrostatic field of attraction, where they form minute welds or adhesion.

It has been postulated (4, 26) that only a very small portion of frictional energy goes into direct wear and that most frictional energy is transformed into thermal energy. The continuing vibration of surface and surface atom also produces thermal energy which is caused by the release of elastic energy at rupture. This heat may cause damage by itself, especially when the fiber is sensitive to heat.

When the protuberances of the abradant are large and sharp, the abrasion mechanism can bring about the shearing of the fiber.

If the abrasion is relatively weak, wear may take place through the mechanism of successive local adhesion rupture between the protuberances of the two rubbing surfaces (4, 26). The greater the load applied in frictional abrasion, the greater the area of fiber which will be damaged, since a high inter-surface load causes a large total area of true contact fabric and abrasion than does a small load (4).

Cutting can occur when abradant surface areas are very sharp and small relative to the fiber diameter. When fine abrasive paper, such as emery or sandpaper, was used in laboratory abrasion testing, a cutting action was the major mechanism for causing damage (4, 26). The cutting mechanism is isolated with the development of complex stress patterns which can cause fiber tensioning, bending or slippage in addition to the damage caused directly (14, 26). It has been postulated (5) that increases in load in cutting would not increase the surface area contact but cause deeper damage over the same area.

Plucking or snagging would occur most often when the normal forces between the abradant and fabric are large, since deeper yarn penetration would occur (26). This mechanism could cause rupture, slippage, or repeated stressing, depending upon the forces of the abradant and the extent to which the fiber was bound in the yarn (4, 26).

Loosely woven fabrics with low-twist yarns were found to be more accessible to plucking action than tightly woven fabrics with highly twisted yarns (26).

Plucking is believed (4) to develop components of force along the fiber axis of higher magnitude than those imposed in direction of the relative motion. The plucking also may cause dynamic fatigue rupture of the fiber length where maximum stress is built up.

Factors Which are Related to Abrasion Resistance

Resistance to abrasion means the ability of fabric to withstand the various stress applications without being damaged under the conditions of intended use (4). Many factors are claimed to affect this ability, but they can be classified into two main categories: the inherent factors and the non-inherent factors. The inherent factors are the fiber properties such as strength, elongation and elastic recovery. Non-inherent factors include yarn and fabric geometry, finishes, and moisture (5, 15).

Fiber Properties

Hamburger stated that, to have high resistance to abrasion, a fiber must be capable of absorbing energy when stress is applied and release this energy upon removal of the stress without any occurrence of failure. He also stated that such properties as immediate elastic deflection, high ratio of primary to secondary creep, high magnitude of primary creep, and high rate of primary creep would be the requirements for high resistance to abrasion (22). There are several studies (19, 25, 26) which show that, when a fiber has a great capacity to absorb work under repeated stretching, its resistance to abrasion is high, and they indicate that the ability of a fiber to absorb work during the repeated stress, which can be measured by the area under the mechanically conditioned stress-strain curve, is a good indicator of a fiber's abrasion resistance.

The elongation, elastic recovery and tenacity determine a fiber's capacity for work absorption on repeated stretching; however, it has been theorized (26) that elongation and elasticity are more important factors than strength in producing good abrasion resistance.

The bending resistance of fiber, as well as the tensile stress developed from interfiber friction, are determining factors for internal abrasion damage resulting from fabric flexing (3). Extensibility is also an important factor in flexing abrasion resistance;

however, too high extensibility, accompanied by a heavy resin treatment, causes decreased cross-sectional area and reduced resistance to shear (12, 21).

The physical structure of a textile fiber influences its frictional behavior. When a frictional force, such as abrasion, is exerted on fiber of high orientation, the fiber will have greater resistance than on fiber with low orientation (17). Fiber length, surface roughness, and cross-sectional shape are also believed to influence abrasion resistance (26).

High Wet Modulus Rayons

High wet modulus rayons are classified as rayon by the Federal Trade Commission because they are composed of regenerated cellulose, but they are closer to cotton than to the ordinary viscose rayons in their physical properties (13).

During the manufacturing process, increased time is allowed for stretching the fiber. This difference results in increased crystallinity because stretching further orients molecules, which tend to crystallize when they are parallel. The high degree of polymerization and high orientation of the fiber molecules cause these new rayons to be less affected by water and alkalies and to have a higher ratio of wet to dry strength, better resistance to swelling agents, and a higher wet modulus than ordinary rayons (20).

Present high wet modulus rayon producers in the United States and their respective trade names are as follows:

Producer	Trade Names
American Viscose (FMC)	Avril
American Enka	Zantrel
Courtaulds of North America	Lirelle
I R C (Midland Ross)	Nupron

Avril was announced in April, 1960 by American Viscose Corporation (28). The manufacturer claimed a whole new concept in cellulose chemistry for the new fiber because Avril offered low elongation, dry strength ten percent higher and wet strength thirty percent higher than for regular rayon, inherent dimensional stability equal to cotton, resistance to caustic treatment and the ability to accept compressive shrinkage treatments (28).

The cross-sectional shape of the fiber, which is unserrated but irregular, results in stability of Sanforized fabric and no progressive shrinkage. The stress-strain properties of high wet modulus rayon place it in a class with cotton (37). The fiber is also claimed to have the highest strength of all commercial rayon staples (37).

Like other high wet modulus rayons, Avril is relatively free of imperfections. A high degree of polymerization and skin-core configuration (Avril, 20 percent skin) offers some protection against abrasion. But all core fibers, being fibrillar, tend to break off, producing subtle color change and decreasing the wear life, and 100 percent high wet modulus rayons do not exhibit sufficient durability to give adequate wear life to the garment (7).

Yarn and Fabric Geometry

Backer stated as follows: (4, 454 p.)

> Through the use of various combinations of cylindrical diameter, spacings, and the manner of interlacing, numerous factors of orientation and geometry can be introduced to ensure that the fabric does not behave mechanically like the bulk material of which it is chemically constituted.

It has been emphasized (8) that yarn and fabric geometry are very important because the fiber properties are preserved and translated into yarns and fabrics. Fiber migration, yarn twist and yarn crimp determine yarn properties and subsequently abrasion properties.

Abrasion resistance of a yarn is an indicator of the yarn's cohesion (8, 29). Yarns composed of staple fibers are more susceptible to abrasion than filament yarns. The individual staple fibers are shorter in length than filament fibers and more easily pulled from the yarn during abrasion, which contributes to a loosening and untwisting of the yarns (31).

Yarn diameter plays an important part in abrasion resistance. The use of large yarn diameters can improve the flat abrasion resistance of fabrics; however, this is not true of flexing abrasion. Heavy yarns which contain many fibers can distribute stress for a given load and require the displacement of a larger number of fibers before the occurrence of failure than do yarns made of coarse fibers (26).

A certain amount of twist of yarns is believed (4, 26) to increase resistance to abrasion because it improves fiber cohesion and minimizes the fibers' removal through displacement by snagging, and it also minimizes friction. The firm binding of yarns which can be achieved by increased yarn solidarity, higher twists or tighter weaves, can reduce the plucking of the fiber.

But the increase of twists beyond an optimum point is thought to stiffen the yarn so that little contact between yarn and abrasive is allowed, and this stiffness causes high local abrasive pressures and early breakdown of yarn structure. Also twist increased beyond a certain value restricts the motility of the fibers in the yarn so that the yarn cannot flatten out or rotate to allow the abrasive forces to act over a large area. Consequently, there is a decrease in abrasion resistance (26).

Yarn crimp, which can be measured by the ability of a yarn to extend under load, increases the resistance to abrasion because the crimp creates a bulkier fabric which has a more distinct crown (5). Unbalance in crimp would result in early failure of the fabric because damage would be imposed less unevenly on the yarn system (26).

It was determined that lower attrition rate can be obtained by increasing the contact between fabric and abradant. The Southern Regional Research Laboratory found that the wear performance of fabrics increased with the freedom of the yarns to move about within the structure (4, 5, 26).

If all other factors are held constant, it has been postulated (5) that the flat abrasion resistance of plain weave fabrics would increase with an increase in the thread count to an optimum point at which the structure becomes jammed. With the greater number of interlacings, yarn cohesion would be increased, and the large surface area exposed to rubbing would allow better distribution of stress. The structural rigidity in fabric caused by too high thread counts, as well as by yarns with too high twist, increases damage by abrasion (5). Damage from flexing abrasion, however, increases considerably with increasing tightness of woven structure (5).

Yarn diameter, yarn crimp, and the presence or absence of a nap or pile determine fabric thickness. Fabrics made from thicker yarns are better in abrasion resistance than the fabrics made from fine yarns. Uniform shape and diameter of yarns also increase the abrasion resistance (5). But the thickness provided by crimp is thought to do little to prolong fabric life (5, 26).

The relative crimp distribution between warp and filling yarns determines the direction in which yarns are damaged most seriously. In studies of abrasion of fabrics with high warp and low filling crimp, a high rate of warp damage was observed, with little filling damage occurring until the warp was almost worn away (5, 26). When stress is applied in all directions, an unbalanced crimp results in the early occurrence of failure of the fabric because of excessive damage to the yarn system which is more exposed.

In twill or sateen weave fabric, the length of the float is a determining factor in abrasion resistance. The longer the float, the less restraint on the yarn system, the less cohesion between yarns, and consequently less resistance to abrasion (26).

Abrasion Testers

The complexity of the abrasion mechanism has been shown by the development of numerous instruments to measure resistance to abrasion. The Stoll, Accelerotor, Schiefer, Taber, and Wyzenbeek instruments are abrasion testers commonly used in the United States (26). Each instrument has been developed to measure certain factors which may cause fabrics to wear. A fabric is held flat and taut during abrasion in the Schiefer, Taber, and Wyzenbeek instruments.

The Stoll tester can be used to apply either flat or flexing abrasion. Its rubbing action is a reciprocating motion between the abradant and the fabric specimen (2, 26, 29). For flexing abrasion tests, the fabric fastens to a reciprocating table and passes over a steel bar or blade abradant which maintains it in a folded condition during the testing. The specimen is rubbed over the steel bar. For flat abrasion testing, the specimen is placed in a circular clamp over a rubber diaphragm under which controlled air pressure is maintained. The clamp assembly is connected to the reciprocating table so that the specimen is rubbed in intended directions against the abradant which is located on the upper plate (2).

In the Accelerotor, the specimen is placed in the chamber with an impeller (rotor) which drives the specimen in a zigzag path (2, 26). The movement of the impeller applies specimen flexing, rubbing, shock, compression, stretching, and other forces during a test. This is the only instrument which allows the specimen to move away from the force instead of being held taut or under a load. The degree of abrasion can be varied by different rotor speeds, lengths of abrasion time and types of abradant (2). Grit liners having several different sizes of grits, neoprene liners, plastic liners, ribbed rubber liners and ribbed metal liners are commonly used in the Accelorotor.

The smooth surface of a plastic liner in the Accelerotor causes mild loss in strength while the grit liner produces a severe decrease in strength. A grit liner produces a greater degree of fiber cutting, plucking, and friction, which in turn causes greater loss in fabric weight, strength and elongation than when milder liners are used (16). The specimen can be run in the Accelerotor chamber either dry, wet, or totally immersed in water.

Measurement of Abrasion Resistance and Evaluation of the Damage

When the inter-relationship between laboratory abrasion tests and actual wear is compared, the danger involved in drawing far-reaching conclusions from laboratory tests also becomes evident. There may be big differences between abrasion actually occurring in service and the nature of the abrading action produced in the laboratory (26, 32). McNally and McCord stressed the fact that abrasion is only a single factor among the complex variables involved in actual wear, and most rates of destruction in laboratory testing are much higher than in actual wear (26).

Skinkle (33) classified wear quality as follows: 50 percent friction, 26 percent folding, 22 percent stretching, and 8 percent chemical action.

It was estimated (35, 38) that the mechanical factors in wear of military uniforms consisted of 30 percent flat abrasion, 20 percent edge and projection abrasion, 20 percent flexing and bending abrasion, 20 percent tearing abrasion and 10 percent all other mechanical action. However, these figures are only approximations, and these percentages could vary for different materials and different uses.

Results using the same type of abrader in different laboratories have varied (18). It was pointed out in the final report on "Interlaboratory Abrasion Tests" (18) that, in a study using nine different abraders, a wide variation in results occurred among the laboratories using the same abraders. The main cause of variation would be different estimates of endpoints, both visual and physical. Also differences may have occurred with variations in pressure, abrasive paper and fabric.

Several studies (9, 11, 15) showed that there were differences between the mechanisms of wet and dry abrasion. Caldwell (9) found that cotton (untreated or cross-linked) and cross-linked rayon tended to have a lower weight loss after being abraded in the wet state than after abrasion in the dry state; however, rayon without resin finishes lost more weight when wet than dry. She also found that wet abrasion of all rayon specimens caused more loss in breaking strength than dry abrasion.

Several criteria may be used to evaluate the damage by abrasion. Weight loss, loss in strength and elongation, changes in thread count, changes in fabric thickness, and fiber microscopy are methods widely used to evaluate abrasion damage (9, 11, 12, 20).

Fibers and small particles are removed from fabric during abrasion; however, the damage could be done to the fabric before a large weight loss has occurred. Occasionally a very slightly damaged specimen has been found (9) to gain weight during abrasion.

Breaking strength generally decreases with increased abrasion (25). Loss of breaking strength has been attributed to damage of fiber and to loss of yarn cohesion (20).

It has been pointed out (33) that the advantage of microscopic evaluation is that only a small sample area is needed and that the specimen is not destroyed by analysis.

Clegg's study (12) showed there are some inter-relationships between strength loss of a fabric and fibrillation, cuticle damage, and transverse cracking of the fiber in the fabric. The observation of de Gruy *et al.* (15) showed that fiber mashing, fragmentation as well as longitudinal splitting occurred during abrasion. The longitudinal splitting was chiefly observed in dry flex-abraded specimens, and fiber mashing was seen in specimens flex abraded alternately wet and dry.

CHAPTER III

METHOD OF PROCEDURE

Selection of the Fabric

Plain weave 100 percent Avril rayon fabric without color or finish was purchased from a company which supplies fabrics for laboratory use. The fabric was 45 inches wide and was priced at $0.89 per yard.

Fiber Identification

The burning test, longitudinal and cross-sectional microscopical examination of both the warp and filling yarns, and zinc-chlor-iodide reagent test proved that the fiber consisted of modified regenerated cellulose.

Preparation of Specimens

The sampling plan for the study was a randomized complete block experimental design which consisted of seven blocks. A set of specimens cut in a given direction within a block for a specific method of test was arranged to have the least difference in physical properties between specimens for different periods of test. A set of warpwise specimens in a block shared the same warp yarns, and a set of fillingwise specimens was arranged to have the closest possible filling yarns because the width of the fabric was not wide enough for a set of fillingwise specimens to be cut from the same filling yarns. The cutting diagrams for blocks are shown in Appendix A-1, and the number of specimens in each block was arranged as indicated in Table 1.

After specimens were cut, they were marked to indicate the warp direction and the specimen number. All prepared specimens were conditioned and tested at 70 degrees ±2 degrees Fahrenheit and 65 percent ±2 percent relative humidity.

Measurement of Physical Properties of Original Fabric

Each test was performed according to the procedure recommended by the American Society for Testing and Materials and the American Association of Textile Chemists and Colorists with slight variations when required. The abbreviations ASTM and AATCC with their designated numbers will be used to indicate these standard procedures when necessary. Determinations of count, elongation and breaking load of yarn, fabric thickness, fabric weight, yarn number, bursting strength of fabric, and breaking load and elongation of fabric were performed on the original fabric.

Table 1. Number of specimens per block for different procedures.

Property	Direction	Block Number 1	2	3	4	5	6	7
Yarn properties	Warp	1	1	1	1	1	1	1
	Filling	1	1	1	1	1	1	1
Abrasion resistance								
Accelerotor, surface, dry	Warp	9	9	-	9	-	9	9
	Filling	9	-	9	-	9	9	9
Accelerotor, edge, dry	Warp	-	9	9	9	9	-	9
	Filling	9	9	-	9	9	9	-
Accelerotor, surface, wet	Warp	9	-	9	-	9	9	9
	Filling	9	9	9	9	-	-	9
Stoll, surface, dry	----	8	8	8	8	8	8	8
Stoll, surface, wet	----	6	6	6	6	6	6	6
Stoll, Flexing, dry	Warp	11	11	11	11	11	11	11
	Filling	11	11	11	11	11	11	11
Stoll, edge, dry	Warp	11	11	11	11	11	11	11
	Filling	11	11	11	11	11	11	11
Weight	----	3	3	3	4	4	4	4
Count and thickness	----	2	2	2	1	1	1	1
Breaking load and elongation	Warp	1	2	2	1	2	2	2
	Filling	2	2	1	2	2	1	2
Bursting strength	----	1	2	2	2	2	2	1

Fabric Count

The number of yarns per inch in the warp and filling directions was counted according to ASTM Designation: D 1910-64.

Thickness

The thickness of the fabric was measured according to the ASTM Designation: D1777-64, using a Randall-Stickney gage. The diameter of the foot was 0.375 inch, and a dead weight of 6 ounces was used. Ten specimens 2x2 inches in size were measured.

Weight

The procedure for weight of fabric was ASTM Designation: D1910-64. Five 2-inch squares were weighed together on a balance to ±0.001 gram. The weight in ounces of one square yard was calculated from the average of five weights.

Breaking Load and Elongation of Yarn

ASTM Designation: D2256-69 outlined the testing procedure. To measure the yarn breaking load and elongation, an inclined plane tester was used. All of the specimens were broken with a 500-gram load. Sixty single yarn specimens for both the warp and filling directions were broken. Calculations of the average percentage elongation of the basis of the nominal (10 inches) gage length were made.

Yarn Number

The testing procedure for yarn number followed ASTM Designation: D1059-69 T. The clamps on the twist tester were set 50 cm apart with the tensioning device at the center of the distance. Twenty specimens were measured by means of the twist tester under 3 grams of tension and were cut to give specimens 10 meters in length. Seven sets of yarns 10 meters in length were weighed for both the warp and filling directions, and the averages of the seven weights were multiplied by 100 to calculate the yarn number in Tex.

Breaking Load and Elongation of Fabric

The ravelled-strip test for fabric breaking load and elongation was performed according to ASTM Designation: D1682-64. A pendulum tester (constant rate of traverse) with a capacity of 100 pounds was used. The distance between the two clamps was set at 3 inches ±0.05 inch at the start of test. The front and back jaws were the same size, 3 inches in width and 2 inches in length. Each specimen was cut 1-1/2 inches wide and 8 inches long and then ravelled approximately 1/4 inch from each side to make the width of the specimen exactly 1 inch excluding fringes. Twelve specimens were tested in both directions. The average breaking loads for the warp and filling directions were calculated separately to the nearest 0.5 pound.

The elongation of the specimens in inches was measured, and the percentage elongation was calculated.

Bursting Strength

ASTM Designation: D 231-62 outlined the procedure for measurement of bursting strength by the ball burst method. Twelve specimens were tested, and the mean was calculated.

Resistance to Abrasion

To understand the rate of the changes in selected physical properties during abrasion, the specimens were abraded at several different periods which were determined by pre-tests. Surface abrasion resistance, both in the dry and wet conditions, and edge abrasion resistance of the fabric were measured using the Accelerotor and the Stoll tester. Flexing abrasion resistance of the fabric was measured with the Stoll tester.

When the end point could be measured, the length of period or the number of cycles to reach this point was measured and divided by 10 to decide the intervals. When the end point could not be measured, as in Accelerotor tests, the period which was required almost to destroy the specimen was estimated by several pre-tests and divided by 10 to determine the interval of periods. In period 1, a specimen was slightly abraded, while in period 9, it was abraded very deeply.

Microscopical examination and the percentage loss in strength, weight and elongation of abraded specimens were the criteria for evaluating the damage by abrasion.

Dry Surface Abrasion by the Accelerotor

Specimens were cut 4 x 8 inches for both the warp and filling directions, and the warp direction was marked. Adhesive glue which was made by mixing equal volumes of rubber adhesive and methyl ethyl ketone was spread over the edge of each specimen.

Conditioned specimens with adhesive were weighed. The weighed specimens were abraded by an Accelerotor with No. 250 grit liner. The directions for the installation and breaking-in of liners followed ASTM Designation: D 1175-24. The rotor speed was 3000 rpm.

Because of wear on the edges of the specimens, the maximum period for this test was 13.5 minutes, and the interval was 1.5 minutes.

After specimens had been run for 15 minutes, the collar assembly was removed from the chamber and replaced in such a way that the rim which was next to the door went to the back of the chamber, and the reversed liner was discarded after running for 15 more minutes.

Specimens of each period were tested in the following order:

1. Period 1 (1.5 min.) and period 9 (13.5 min.) ... reverse liner
2. Period 2 (3.0 min.) and period 8 (12.0 min.) ... discard liner
3. Period 3 (4.5 min.) and period 7 (10.5 min.) ... reverse liner
4. Period 4 (6.0 min.) and period 6 (9.0 min.) ... discard liner
5. Period 5 (7.5 min.) and period 5 (7.5 min.) ... reverse liner
6. Period 9 (13.5 min.) and period 1 (1.5 min.) ... discard liner
7. Period 8 (12.0 min.) and period 2 (3.0 min.) ... reverse liner

After the specimens were abraded, they were reconditioned and weighed in order to calculate the percentage loss in weight during abrasion. The weighed specimens were prepared for breaking load determinations and microscopical examination. Two strips 1-1/2 inch wide were cut for ravelled strip breaking load determinations, and the remaining fabric between the two strips in a specimen was used for microscopical study. Appendix A-2 shows the sampling diagram in detail.

The specimens prepared for ravelled strip breaking load were marked with the warp direction and specimen number. To find out whether a specimen abraded evenly, the two strips from each side of a specimen were broken, and the differences in breaking load and elongation of the two strips were analyzed statistically. The procedure for breaking load followed ASTM Designation: D 1682-64.

Wet Surface Abrasion by the Accelerotor

Specimens for the wet surface abrasion by the Accelerotor were prepared in the same way as for dry surface abrasion by the Accelerotor. All specimens were weighed before being abraded.

Several pre-tests were performed to determine the rotor speed, amount of water used for a specimen, and the length of intervals between periods. The speeds of 3000, 3500, and 4000 rpm were tried with 50, 100, and 150 ml of distilled water, using a ribbed metal liner. A rotor speed of 4000 rpm and 150 ml water were required to circulate a specimen evenly around the chamber. The specimens tended to rest on the bottom part of the chamber unless the rotor speed was sufficiently high. The length of interval between each period was the same as for dry surface abrasion by the Accelerotor, 1.5 minutes.

The prepared and conditioned specimen was placed in the chamber which had been fitted with a ribbed metal collar. The door of the chamber was closed; then 150 ml of distilled water which had been in a standard atmosphere for 24 hours was added through the opening at the top of the chamber. After a specimen was run for the intended period at 4000 rpm, it was removed from the chamber and washed under running water to remove the pieces of fiber which had been separated from the specimen by abrasion. The specimen was then laid on a screen to dry.

The reconditioned specimens were weighed and prepared for ravelled strip breaking strength and microscopical examination in the same way as the specimens subjected to dry surface abrasion in the Accelerotor, which is shown in Appendix A-2. Because specimens may shrink during the wet abrasion process, the percentage loss in breaking strength per yarn was calculated. The number of yarns in one-inch strips was counted before breaking.

Dry Edge Abrasion by the Accelerotor

Specimens 4 x 8 inches were cut for both the warp and filling directions, and the same adhesive was applied to the edges as for the surface abrasion by the Accelerotor. After the adhesive dried, each specimen was folded across the long dimension 3 inches from an end, making it into a 4 x 5 inch rectangle. The folded part (3 x 4 inches) was stitched 1/4 inch from the fold and the 3 raw edges, using 11 stitches per inch with size A Nymo white nylon thread. A Schmet 70 ball point needle was used for sewing.

AATCC Test Method 93-1970 (Method B) was used. On the basis of pre-tests, 0.6-minute intervals were used.

Specimens were run in the following order at 3000 rpm.

1. Period 1 (0.6 min.), period 9 (5.4 min.), period 2 (1.6 min.), period 8 (4.8 min.) . . . . reverse liner

2. Period 3 (1.8 min.), period 7 (4.2 min.), period 4 (2.4 min.), period 6 (3.6 min.) . . . . discard liner
3. Period 5 (3.0 min.), period 5, period 9, period 1 . . . . reverse liner
4. Period 8, period 2, period 7, period 3. . . . . . . discard liner
5. Period 6, period 4, period 1, period 9. . . . . . . reverse liner
6. Period 2, period 8, period 3, period 7. . . . . . . discard liner
7. Period 4, period 6, period 5, period 5. . . . . . . reverse liner
8. Period 9, period 1, period 8, period 2 . . . . . . discard liner
9. Period 7, period 3, period 6, period 4 . . . . . . reverse liner
10. Period 1, period 9, period 2, period 8 . . . . . . discard liner

The abraded specimens were prepared for ravelled strip breaking load and microscopical study as shown in Appendix A-2.

Dry Surface Abrasion by the Stoll Tester

ASTM Designation: D 1175-64 T was followed for dry surface abrasion by the inflated diaphragm method. The test involved multidirectional abrasion with 600-A Norton abrasive paper. The air pressure was set at 4 psi, and the load on the abradant plate was 0.5 pound. After one specimen was abraded, the abrasive paper was discarded.

The average end point of 14 specimens was 42.5 cycles, and specimens were abraded at three different periods excluding the end point: period 2 (10 cycles), period 4 (20 cycles), and period 6 (30 cycles). The bursting strength of the abraded specimens was measured after specimens were reconditioned, but two specimens from each period were saved for microscopical examination.

Wet Surface Abrasion by the Stoll Tester

The preparation of specimens for wet surface abrasion by the Stoll tester, abrasive paper, air pressure, amount of load on the abradant plate, and direction of the test were exactly the same as for dry surface abrasion by the Stoll tester. The only difference between wet and dry abrasion was the addition of 10 ml distilled water at 70 degrees ±2 degrees Fahrenheit over the dry specimen after it was clamped into the instrument. Every specimen was abraded with unused abrasive paper.

The average end point of 14 specimens was 16.5 cycles, and the fabric was tested at 2 periods excluding the end point: period 3 (5 cycles), and period 6 (10 cycles). The abraded specimens were dried on a screen, and bursting strength was measured after reconditioning.

Dry Edge Abrasion by the Stoll Tester

The test procedure for edge abrasion by the Stoll tester followed the directions for The Stoll CSI Quartermaster Tester (pp. 7-8).

Specimens for both the warp and filling directions were 1-1/4 x 9 inch strips. Each strip was ravelled to exactly 1 inch in width by removing from each side about the same number of yarns. The ravelled specimen then was folded at the middle of the strip to make a 1-1/4 x 4-1/2 inch rectangle, including fringes. The folded edge was slightly pressed with a dry iron set at the rayon temperature, and the specimen was conditioned.

The edge abrasion clamp was assembled into the surface specimen head. Norton abrasive paper 600-A was used. The pre-test showed that the fabric had too low edge abrasion resistance to use the abrasive paper without a break-in procedure. The standard unfinished white cotton fabric which is recommended for breaking-in of grit liners in the Accelerotor was used to break in the abrasive paper. After breaking in the abrasive paper for 100 cycles with 1/4-pound load on the head bar, the 1-1/2 inch wide cotton strip was removed, and the machine was flushed.

The folded edge of a prepared specimen was inserted into an edge abrasion clamp from the bottom until 3/64 inch of the folded edge projected from the top of the clamp. The fixed clamp was assembled into the surface abrasion head. The folded specimen was abraded by the prepared abrasive paper with a 1/4-pound load on the head bar. After 31-34 cycles, the specimen edge for both warp and filling directions was almost worn into two parts. The interval of the periods was 3 cycles, and specimens were abraded for 9 periods in each direction. Seven specimens were tested for each period, and one of them was saved for microscopical examination, while the bursting strength of the others was measured after reconditioning. Each abrasive paper was discarded after abrading one specimen.

Dry Flexing Abrasion by the Stoll Tester

The procedure for flexing abrasion on the Stoll tester followed ASTM Designation: D 1175-64 T (Flexing and Abrasion Method, 12-22), with a 1-pound load on the head bar and 4 pounds on the back.

Specimens were 1-1/4 x 9 inch strips ravelled to exactly 1 inch in width by removing from each side approximately the same number of yarns. The average end point of 14 specimens was 225 cycles for the warp direction and 116.5 cycles for the filling direction. Therefore, the interval selected for the warp direction was 22 cycles and for the filling direction 11 cycles. Specimens were flex abraded in each direction for 9 periods. After each specimen was abraded, it was reconditioned, and its breaking load and elongation were measured. One specimen out of seven for each period was saved for microscopical study.

Microscopical Study

The abraded fabric and fiber were examined under a microscope. A fabric specimen was set between two slide glasses and observed with 30 power magnification. No mountant was used. Yarn damage, yarn cohesion, yarn size, surface hairiness, and size of interstices between yarns were the criteria for evaluating abrasion damage.

Yarns were untwisted to separate fibers, and the fibers were placed on a slide glass. A drop of 1 percent methylene blue was applied over the fibers, and the excess solution was removed by using a filter paper. After dyeing the fibers, a drop of glycerine-water was used as a mountant. The slide glass was covered with a dry coverglass, and the specimen was examined under a microscope with 300 power magnification. Damage on the surface of fibers and at ends of fibers was studied.

Freshly prepared fiber specimens were photographed with Kodak plus X film, using a 1/2-second exposure with 300 power magnification. For fabric photomicrographs, a 1/10-second exposure with 30 power magnification was selected.

Statistical Analysis

The regression analysis was used to find out whether any significant relationships existed among the variables. The Pearson correlation coefficient (r) was computed to determine whether a relationship was significant at the 0.01 and the 0.05 confidence levels. The regression equation for a relationship among the variables was also computed. The t-test was used to determine whether significant differences occurred between variables at the 0.01 and the 0.05 confidence levels. To unify the unit of the properties measured, the percentage loss for each property after a given abrasion procedure was used.

CHAPTER IV

PRESENTATION AND DISCUSSION OF DATA

Physical Properties of the Original Fabric

Count

The fabric was unbalanced in count. The mean warpwise count of 93.1 yarns per inch was greater than the mean fillingwise count of 66.2 yarns per inch.

Yarn Number

The warp and filling yarns were similar in yarn number. The mean yarn number in tex was 13.99 for the warp and 14.52 for the filling. These results indicated that the fabric was made of relatively fine yarns.

Thickness

The thickness of 0.0084 inch showed that the fabric was relatively thin.

Weight

The fabric was light in weight, for it weighed about 2.73 ounces per square yard.

Breaking Load and Elongation of Yarn

The warp and filling yarns were well balanced in their breaking load and elongation. The mean breaking load of the warp yarn was 249.1 grams, and that of the filling yarn was 233.3 grams. The mean percentage elongation at break was 10.4 percent for the warp yarn and 11.8 percent for the filling yarn.

Breaking Load and Elongation of Fabric

The fabric was unbalanced in breaking load and elongation between the warp and filling directions. In view of the fact that the breaking loads of the warp and filling yarns were relatively well balanced, the unbalance in fabric count appeared to be a major factor in the unbalanced breaking load of the fabric. The mean breaking load of the warpwise specimens was 56.0 pounds, and that of the fillingwise specimens was 38.0 pounds. The mean elongation of fabric at break was 13.5 percent for the warpwise specimens and 17.5 percent for the fillingwise specimens.

Bursting Strength

The mean bursting strength of the fabric was 60.1 pounds.

Table 2. The means of physical properties of the original fabric.

Property	Unit of measure	Direction	Mean
Count	No. of yarns per inch	Warp	93.1
		Filling	66.2
Yarn number	Tex	Warp	13.99
		Filling	14.52
Thickness	Inch		0.0084
Weight	Ounces per square yard		2.73
Breaking load of yarn	Grams	Warp	249.1
		Filling	233.3
Elongation of yarn	Percent	Warp	10.4
		Filling	11.8
Breaking load of fabric	Pounds	Warp	56.0
		Filling	38.0
Elongation of fabric	Percent	Warp	13.5
		Filling	17.5
Bursting strength	Pounds		60.1

Discussion of Abrasion Resistance

Dry Surface Abrasion by the Accelerotor

In general, the percentage losses in weight, elongation, and breaking load of warpwise and fillingwise specimens increased with the increasing period of dry surface abrasion by the Accelerotor (Table 3, Figures 1 and 2). By the ninth period, the greatest percentage loss occurred in the breaking load, and the smallest percentage loss was in elongation.

Table 3. Mean percentage loss in three physical properties at each period of dry surface abrasion by the Accelerotor.

Property	Direction	Period								
		1	2	3	4	5	6	7	8	9
Weight	Warp	1.4	3.3	4.9	7.6	9.2	12.4	12.8	13.8	15.4
	Filling	2.0	4.75	6.8	7.9	9.5	10.9	14.2	16.1	20.2
Breaking load	Warp	11.5	18.7	20.1	32.1	38.4	43.3	47.8	45.6	49.1
	Filling	16.0	22.2	30.4	33.3	33.4	41.9	46.2	46.4	52.6
Elongation	Warp	0.5	7.1	7.9	12.6	20.8	25.5	27.7	28.7	32.4
	Filling	8.3	11.4	17.4	20.1	23.3	33.5	31.1	32.2	39.0

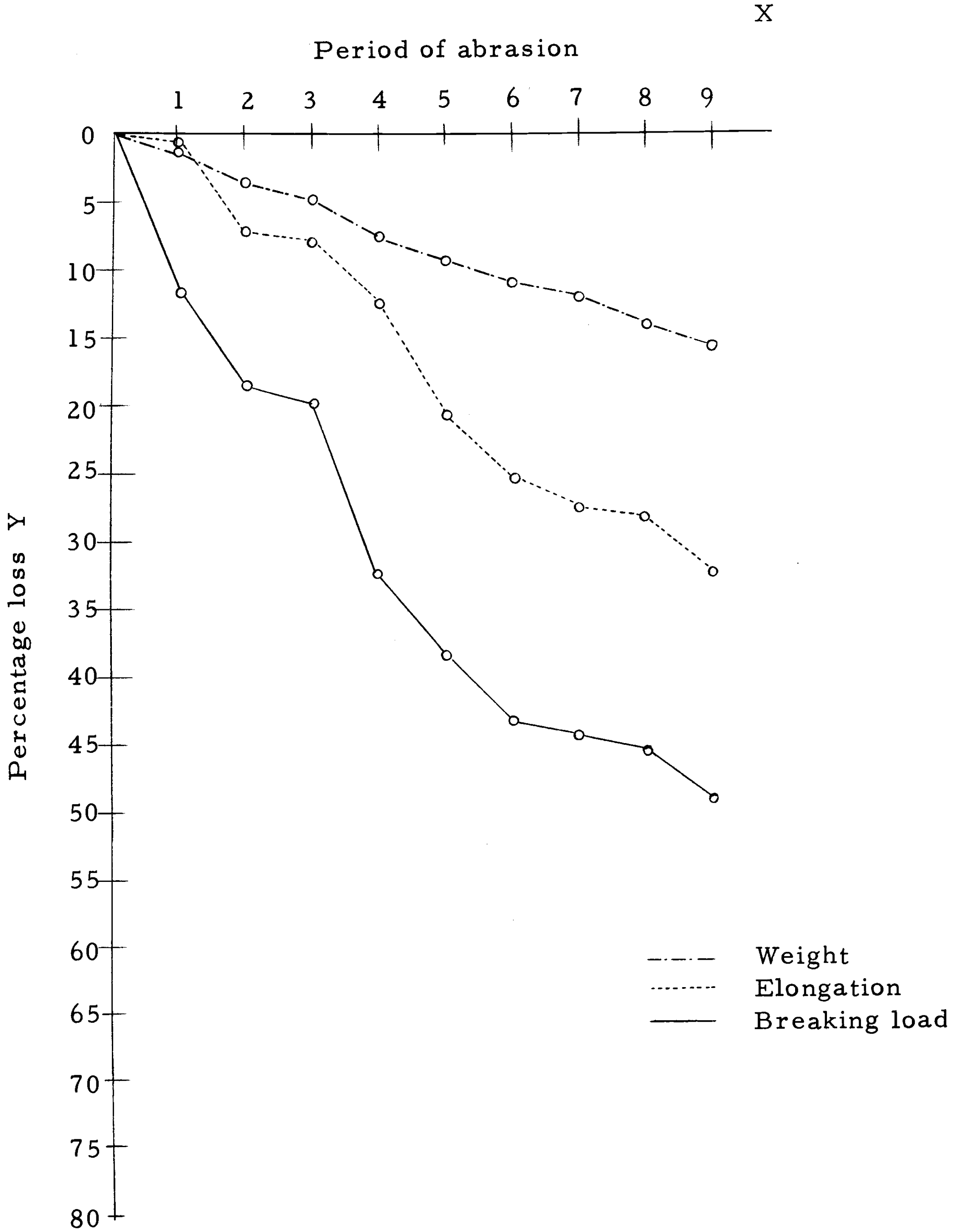


Figure 1. Mean percentage loss in breaking load, elongation and weight of warpwise specimens as a result of dry surface abrasion in Accelerotor after each period.

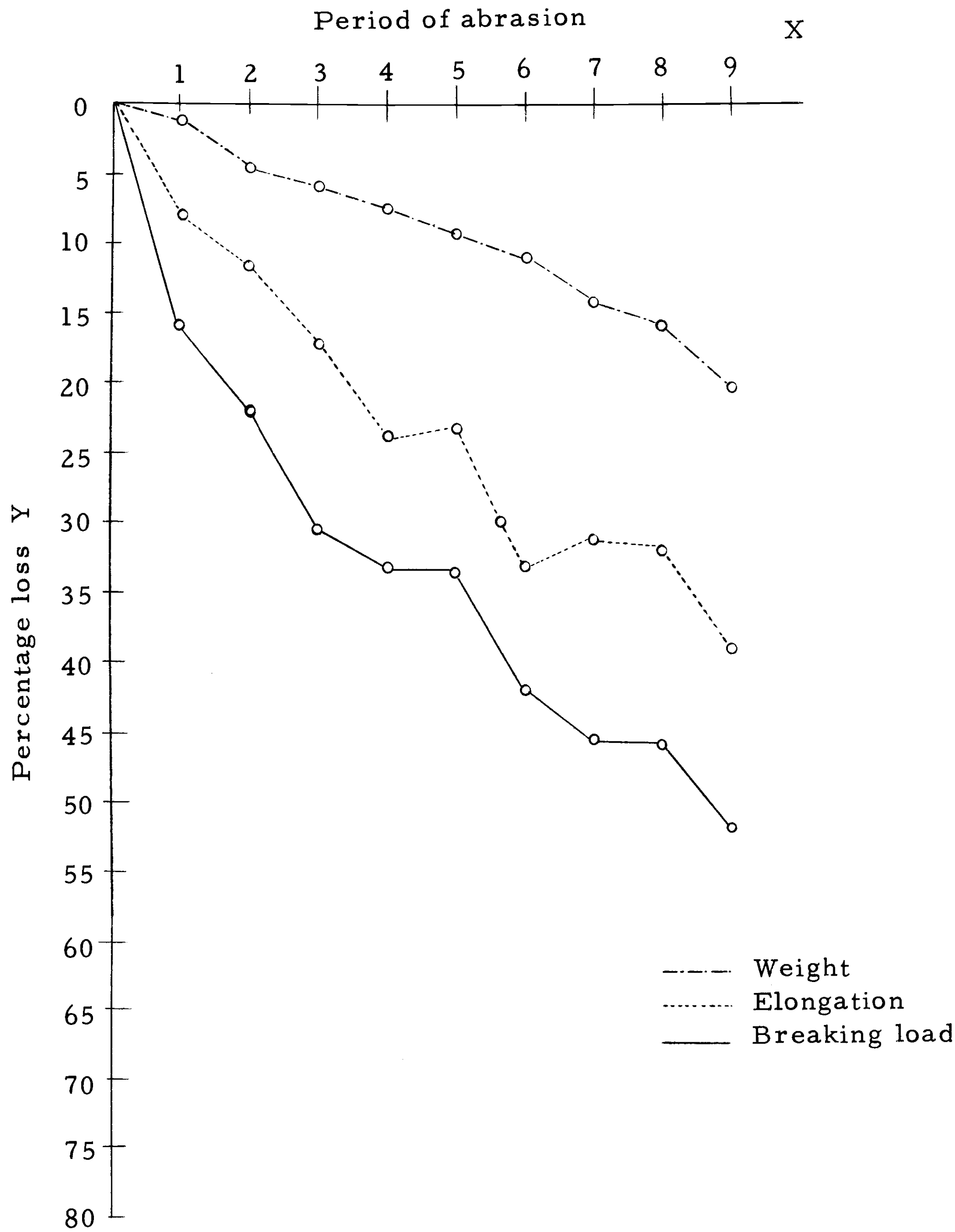


Figure 2. Mean percentage loss in weight, breaking load and elongation of fillingwise specimens as a result of dry surface abrasion in the Accelerator.

Wet Surface Abrasion by the Accelerotor

There was very little change in weight during wet surface abrasion by the Accelerotor (Table 4, Figures 3 and 4). The warpwise and the fillingwise specimens showed differences in breaking load and elongation after abrasion; the fillingwise specimens showed more percentage loss in elongation than in breaking load but the opposite phenomenon was observed in the warpwise specimens.

Table 4. Mean percentage loss in three physical properties at each period of wet surface abrasion by the Accelerotor.

Property	Direction	Period								
		1	2	3	4	5	6	7	8	9
Weight	Warp	+0.7	0.0	0.1	0.1	0.3	0.2	0.6	1.2	0.5
	Filling	+0.4	+0.1	0.1	0.3	0.1	0.2	0.6	1.7	1.3
Breaking load	Warp	22.8	21.1	22.3	23.1	22.8	22.5	23.1	38.9	41.6
	Filling	5.4	12.2	12.4	16.4	18.1	21.3	21.3	29.4	40.9
Elongation	Warp	0.7	2.0	4.0	5.2	2.5	2.2	5.0	17.8	23.0
	Filling	24.1	20.5	21.3	21.8	32.4	33.1	35.6	43.0	45.6

(+) value indicates percentage increase

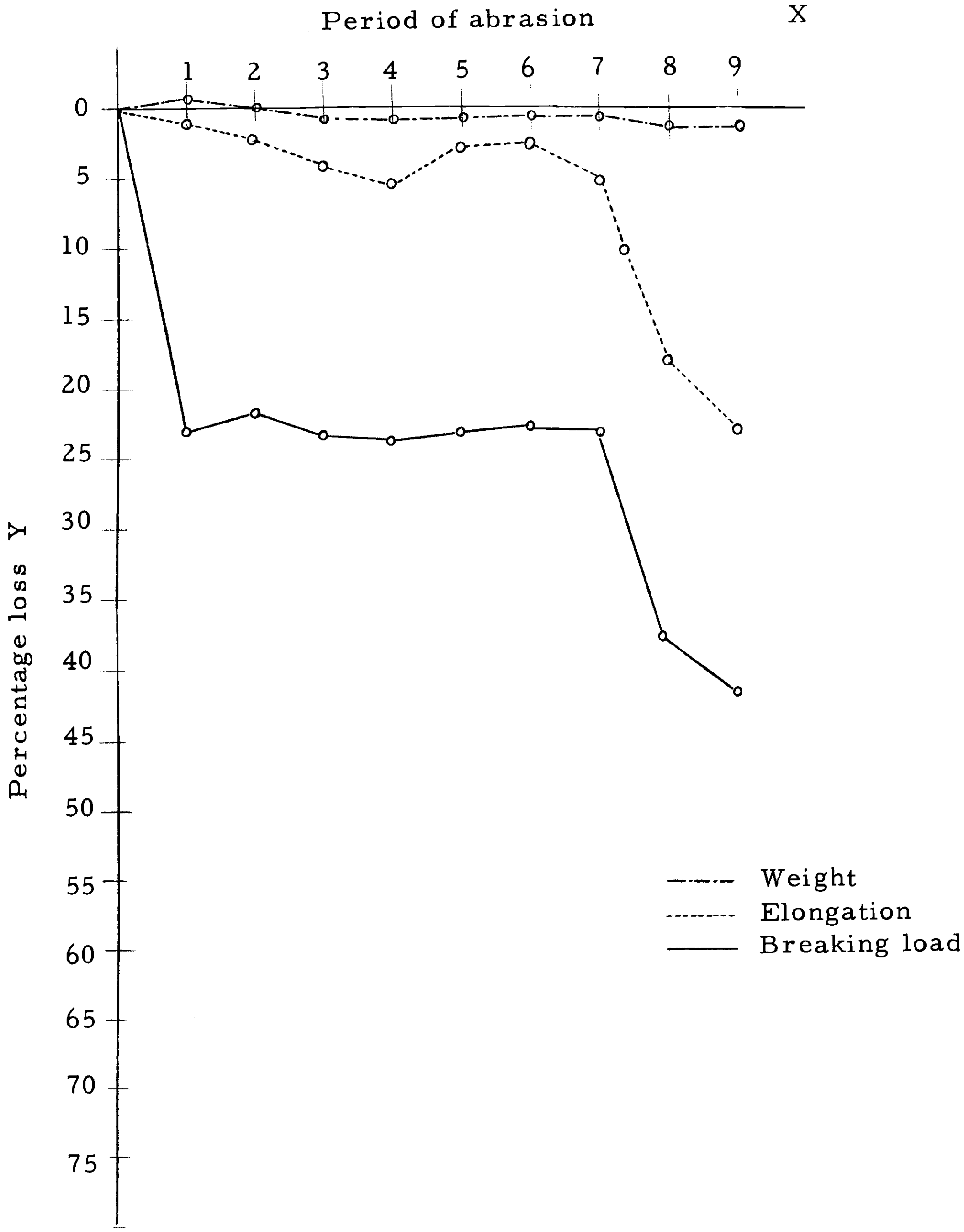


Figure 3. Relationship between period of abrasion and the percentage loss in weight, elongation and breaking load of warpwise specimens subjected to wet surface abrasion in the Accelerotor.

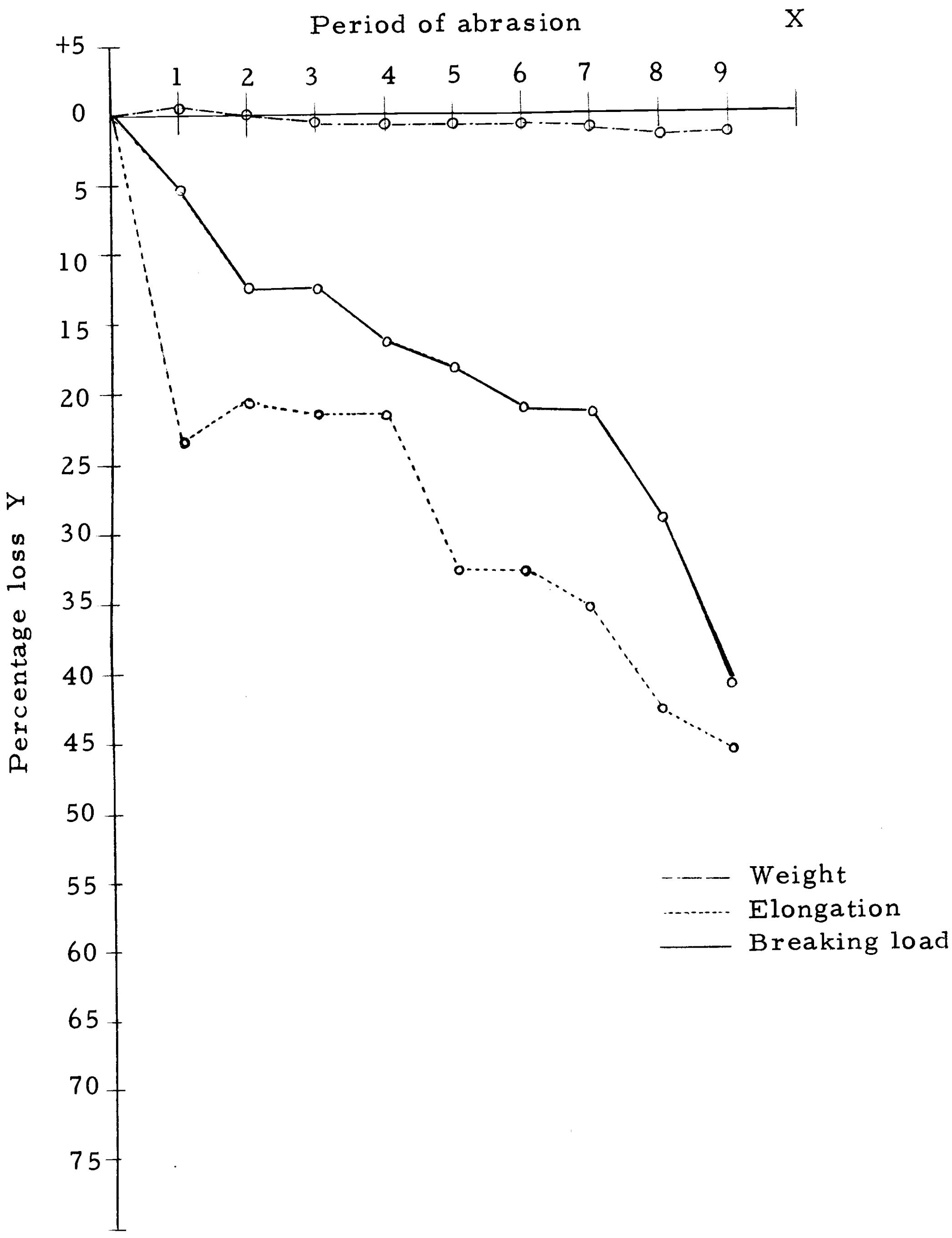


Figure 4. Mean percentage loss in weight, breaking load and elongation of fillingwise specimen as a result of wet surface abrasion in the Accelerotor at each period.

Dry Edge Abrasion by the Accelerotor

The percentage losses in elongation and breaking load tended to increase with the period of dry edge abrasion in the Accelerotor (Table 5, Figures 5 and 6). Compared with the dry surface abrasion by the Accelerotor, more rapid deterioration was observed in the dry edge abrasion by the Accelerotor. Period 5 of the edge abrasion was equivalent to period 2 of the dry surface abrasion because the interval of the period was 1.5 minutes in dry surface abrasion and 0.6 minutes in edge abrasion, while these two procedures involved the same rotor speed and same abrasive paper. After three minutes of abrasion, the elongation of surface abraded specimens decreased 7.1 percent in the warp direction, and 11.4 percent in the filling direction while the elongation of edge abraded specimens decreased 35.2 percent in the warp direction and 34.5 percent in the filling direction. At the same time, the breaking load of surface abraded specimens decreased 18.7 percent warpwise and 22.2 percent fillingwise; the breaking load of edge abraded specimens decreased 39.3 percent warpwise and 36 percent fillingwise.

Because the breaking loads of some fillingwise specimens in period 9 of dry edge abrasion by the Accelerotor were below the capacity of the machine, it was not possible to measure them.

Table 5. Mean percentage loss in breaking load and elongation after dry edge abrasion by the Accelerotor.

Property	Direction	Period								
		1	2	3	4	5	6	7	8	9
Breaking load	Warp	16.7	24.7	33.0	40.4	39.3	48.5	53.7	57.0	58.9
	Filling	17.8	25.1	31.4	35.1	36.2	50.0	50.7	58.9	--
Elongation	Warp	16.8	31.2	26.5	39.1	35.2	45.8	51.0	61.9	63.6
	Filling	19.5	16.9	20.1	28.0	34.5	36.7	41.7	52.7	--

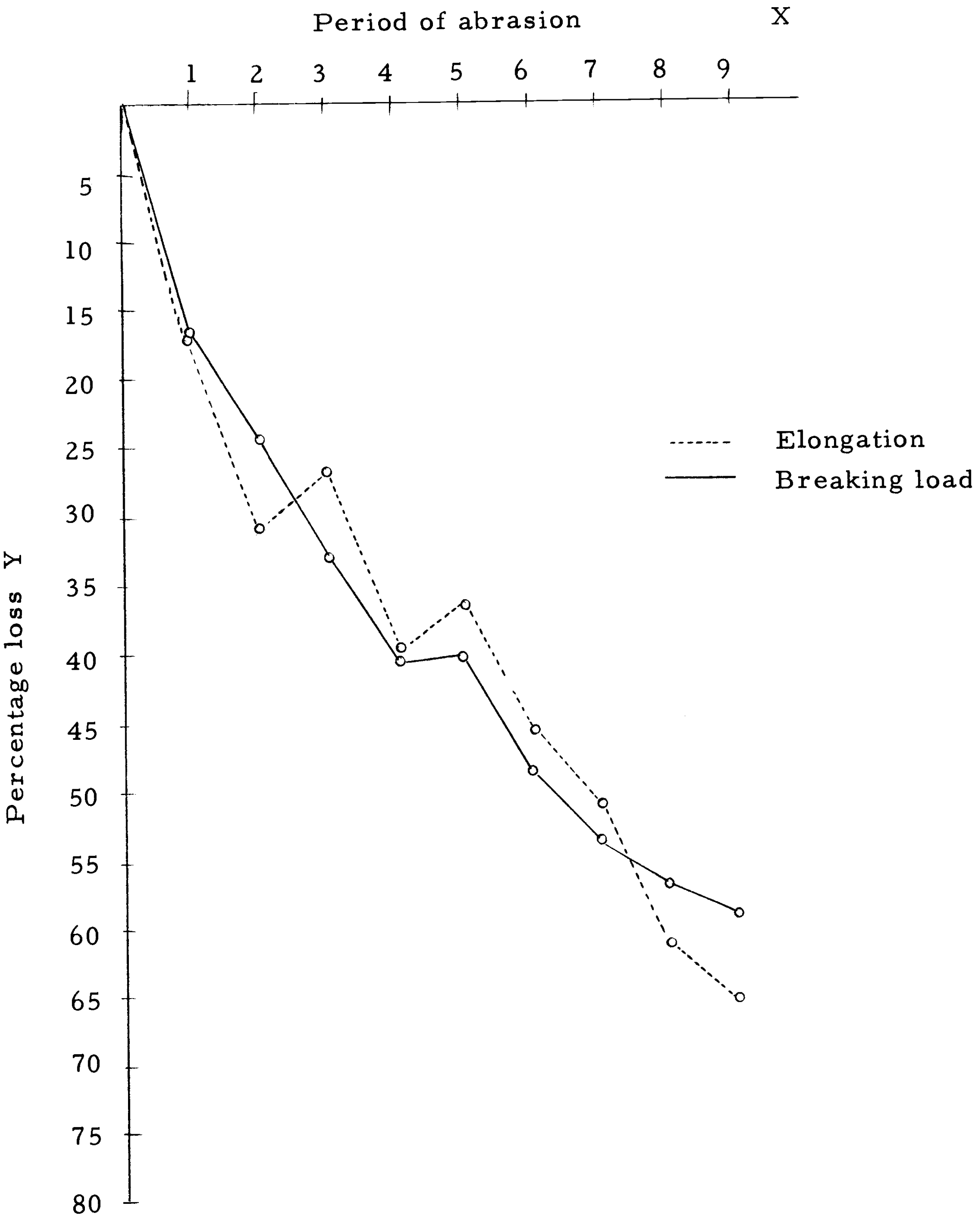


Figure 5. Mean percentage loss in breaking load and elongation of warpwise specimen as a result of dry edge abrasion in the Accelerotor at each period.

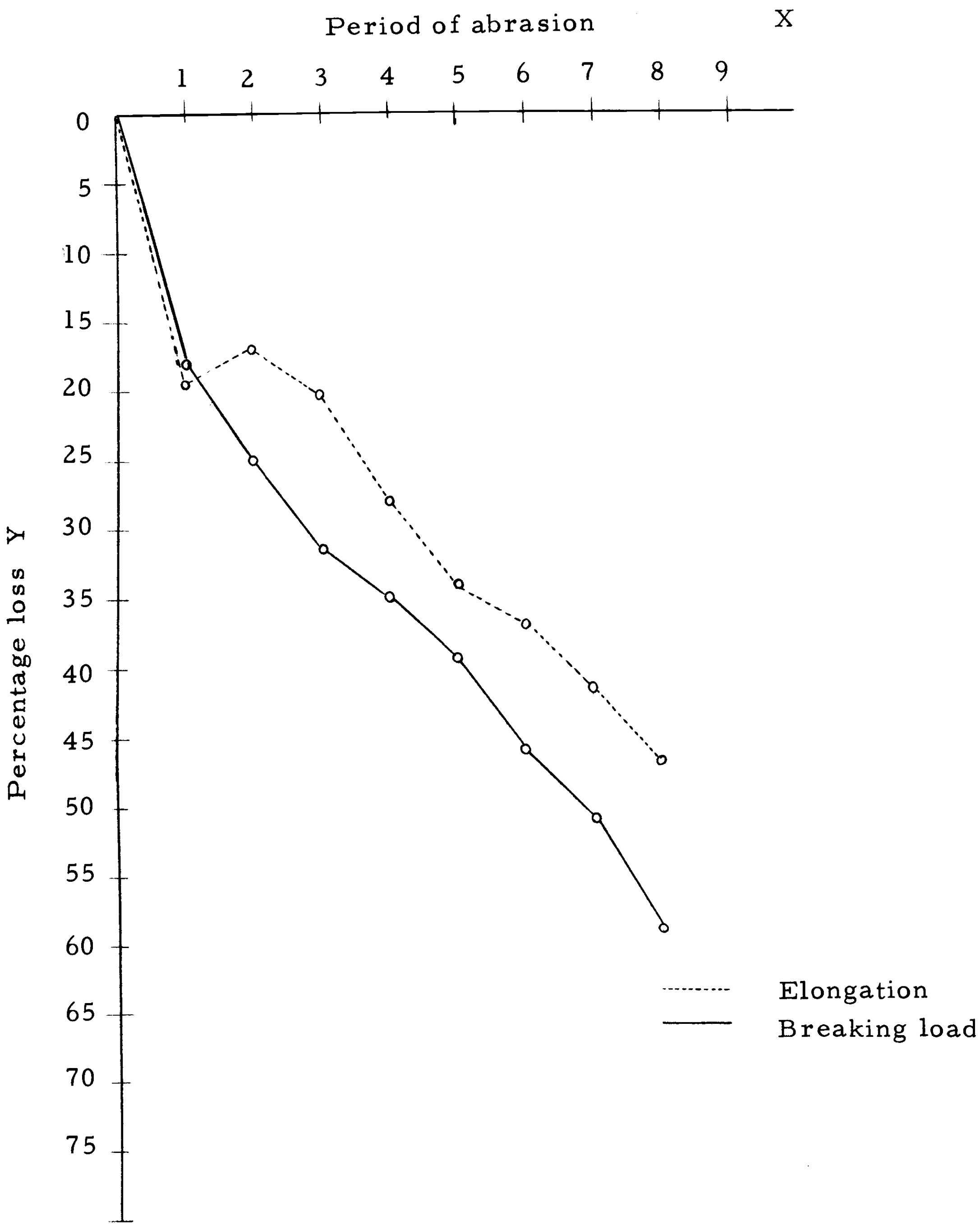


Figure 6. Mean percentage loss in breaking load and elongation of fillingwise specimen as a result of dry edge abrasion in the Accelerotor after each period.

Wet Surface Abrasion and Dry Surface Abrasion by the Stoll Tester

A drastic drop in bursting strength appeared after surface abrasion by the Stoll tester both in the dry and wet conditions (Tables 6 and 7, Figure 7). The mean end points were 42.5 cycles in the dry condition and 16.8 cycles in the wet condition, which alone indicated that the rate of deterioration in the wet condition was more rapid than in the dry condition. The average percentage loss in bursting strength at the end point was 72.5 percent after abrasion in the wet condition and 67.6 percent in the dry condition.

Table 6. Mean percentage loss in bursting strength at each period after dry surface abrasion by the Stoll tester.

Cycle	Percentage loss in bursting strength
10 (period 2)	49.8
20 (period 4)	59.4
30 (period 6)	65.3
42.5 (end point)	67.4

Table 7. Mean percentage loss in bursting strength at each period after wet surface abrasion by the Stoll tester.

Cycle	Percentage loss in bursting strength
5 (period 3)	53.5
10 (period 6)	63.8
16.8 (end point)	72.5

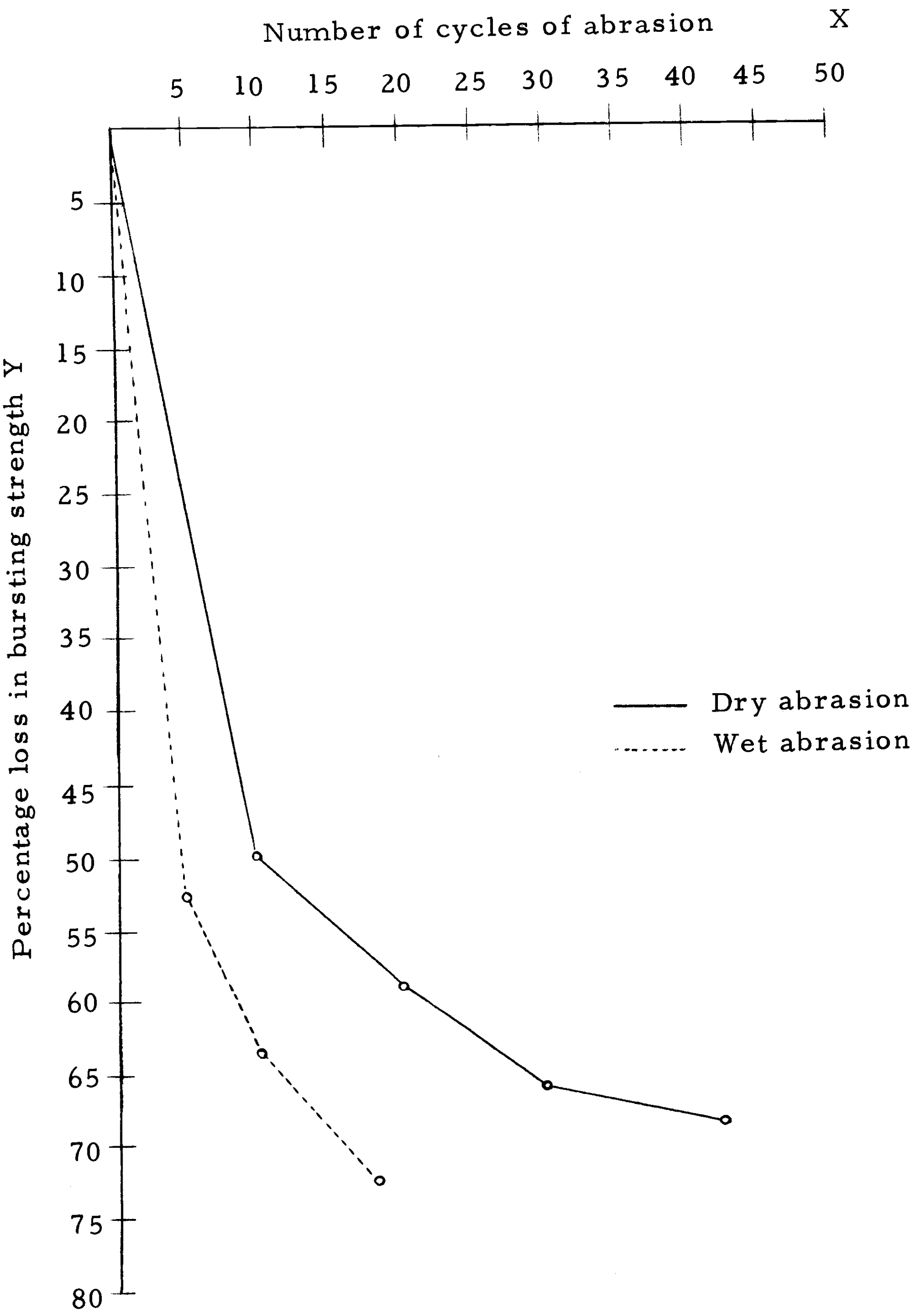


Figure 7. Mean percentage loss in bursting strength of specimen as a result of wet and dry surface abrasion in the Stoll tester after selected cycles.

Dry Edge Abrasion by the Stoll Tester

The rate of deterioration both in the warpwise and fillingwise specimens was so fast in the dry edge abrasion by the Stoll tester that it was hardly possible to measure it (Table 8).

Breaking loads were below the capacity of the instrument beyond the second period in the warp direction and the first period in the filling direction.

Table 8. Mean percentage loss in breaking load and elongation at each period after dry edge abrasion by the Stoll tester.

Property	Direction	Period 1	Period 2
Breaking load	Warp	50.1	60.3
	Filling	48.7	--
Elongation	Warp	45.6	57.9
	Filling	35.3	--

Dry Flexing Abrasion by the Stoll Tester

The percentage loss both in breaking load and in elongation increased with the increasing period of dry flexing abrasion by the Stoll tester (Table 9, Figures 8 and 9). Comparing the percentage loss in breaking load between the warpwise and fillingwise specimens on the period base, which was determined by measuring the end points, the warpwise specimens generally deteriorated faster than

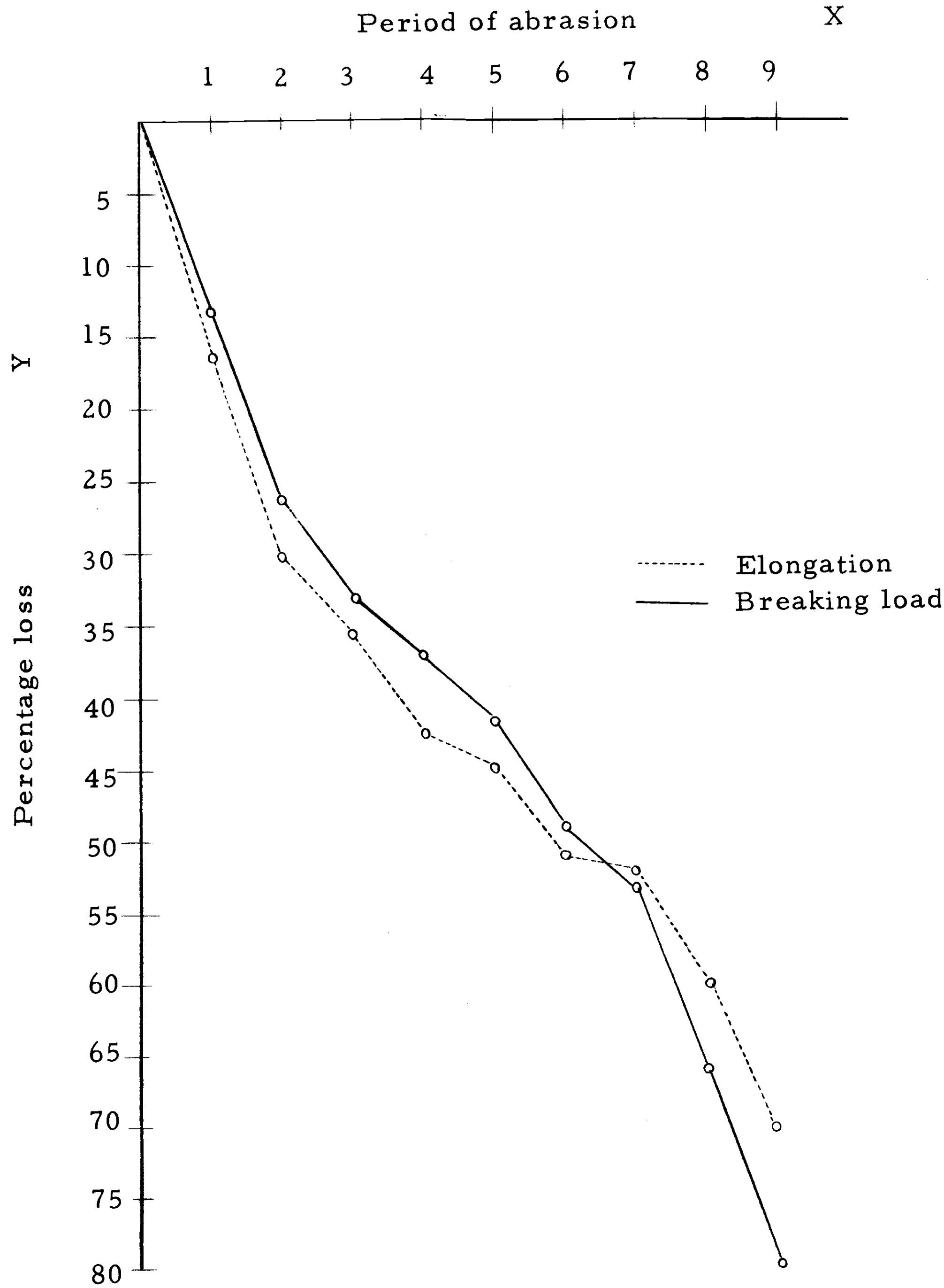


Figure 8. Mean percentage loss in breaking load and elongation of warpwise specimen as a result of dry flexing abrasion in the Stoll tester at each period.

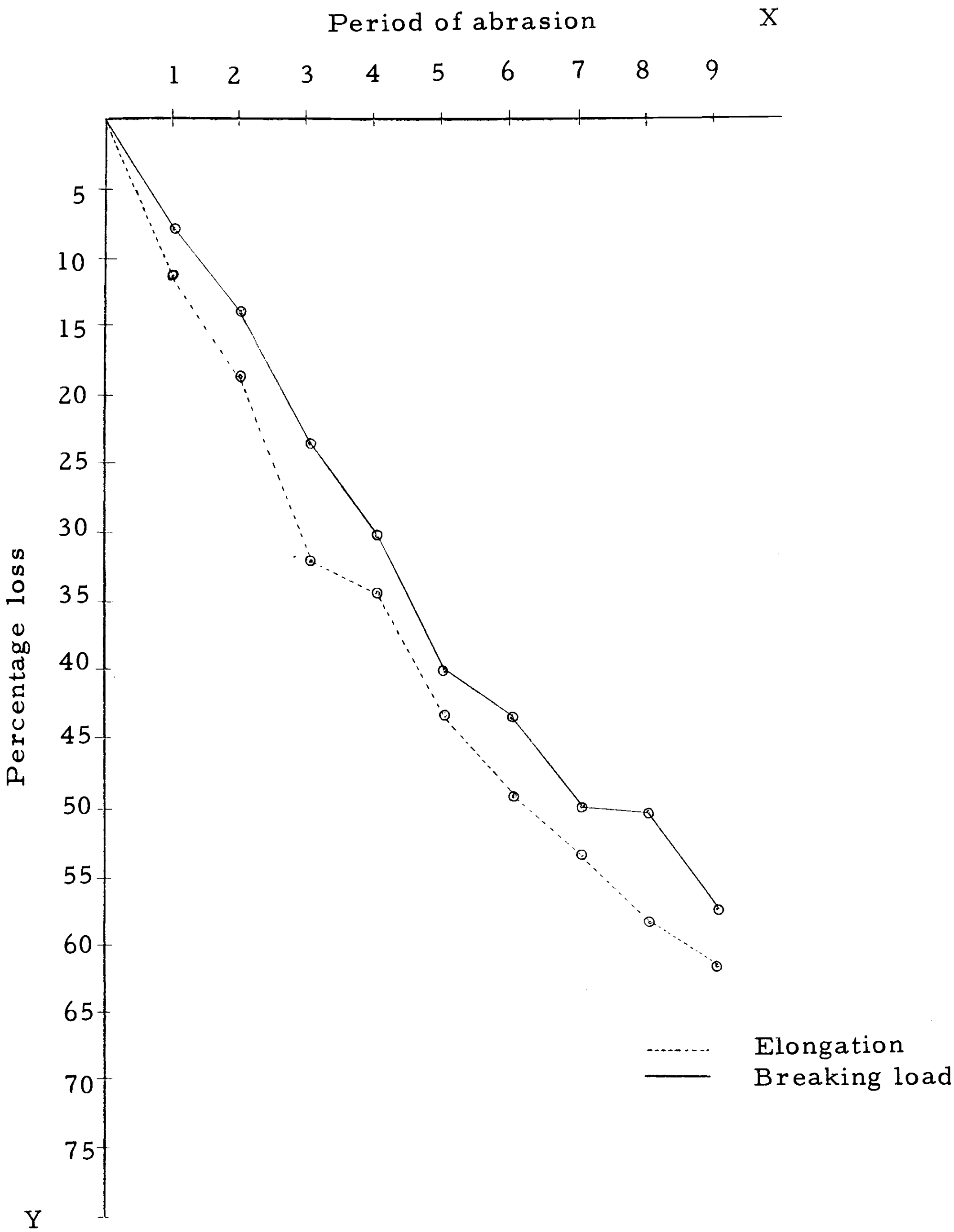


Figure 9. Mean percentage loss in weight, breaking load and elongation of fillingwise specimen as a result of dry flexing abrasion in the Stoll tester at each period.

the fillingwise specimens. However, on the cycle base, the fillingwise specimens deteriorated more both in breaking load and elongation than did the warpwise specimens (Table 10). The average end point was 116 cycles for fillingwise specimens and 225 cycles for warpwise specimens.

Table 9. Mean percentage loss in breaking load and elongation after each period of dry flexing abrasion by the Stoll tester.

Property	Direction	Period								
		1	2	3	4	5	6	7	8	9
Breaking load	Warp	14.2	23.4	33.2	37.2	41.8	49.5	53.7	66.5	78.0
	Filling	8.2	14.4	23.9	30.1	40.2	43.4	50.1	55.4	57.2
Elongation	Warp	15.8	30.3	35.6	42.7	45.1	51.3	52.5	60.8	70.7
	Filling	11.9	18.9	30.4	34.3	43.5	49.5	53.6	58.7	61.8

Table 10. Mean percentage loss in breaking load and elongation after selected cycles of dry flexing by the Stoll tester.

Property	Direction	Cycles			
		22	44	66	88
Breaking load	Warp	14.2	23.4	33 2	37.2
	Filling	14.4	30.2	43.4	50.4
Elongation	Warp	15.8	30.3	35.6	42.7
	Filling	18.9	34.3	49.5	58.7

Microscopical Study

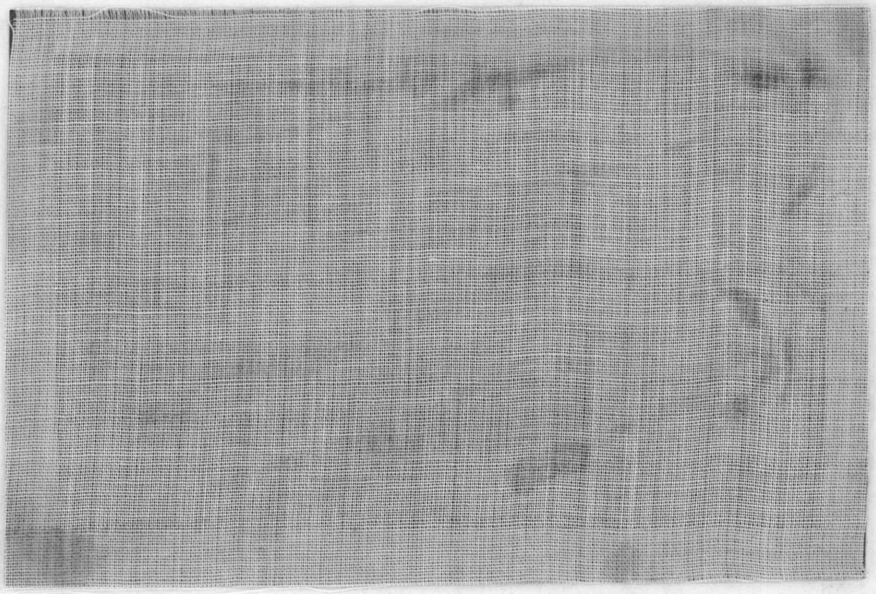
Dry Surface Abrasion by the Accelerotor

As a result of dry surface abrasion in the Accelerotor, the hairiness of the surface of the fabric increased until period 3: after that period, it decreased slowly. At periods 8 and 9, yarns were very thin and smooth on the surface due to the loss of surface hairs, and there appeared to be little remaining twists or cohesion between fibers (Plates I and II). Consequently, the spaces between the yarns became larger in highly abraded specimens than in specimens which were abraded little. The yarn and fabric seemed to be abraded evenly, and little yarn cutting was observed.

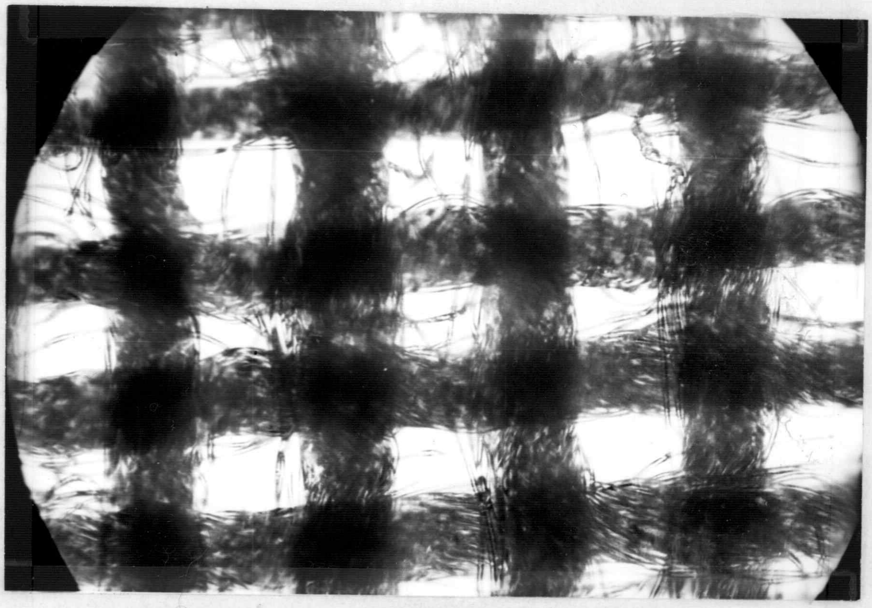
Fibers showed slight damage both at the ends and on the surface but no fibrillation or split ends were observed (Plate III).

Wet Surface Abrasion by the Accelerotor

After wet surface abrasion in the Accelerotor, yarns became bulkier from period 1 without visible increase in hairiness until period 4. There was less space between yarns at the lower periods of abrasion. After period 5, the bulkiness of yarns decreased and spaces between yarns increased, but these changes were small compared to those which resulted from dry surface abrasion by the Accelerotor.

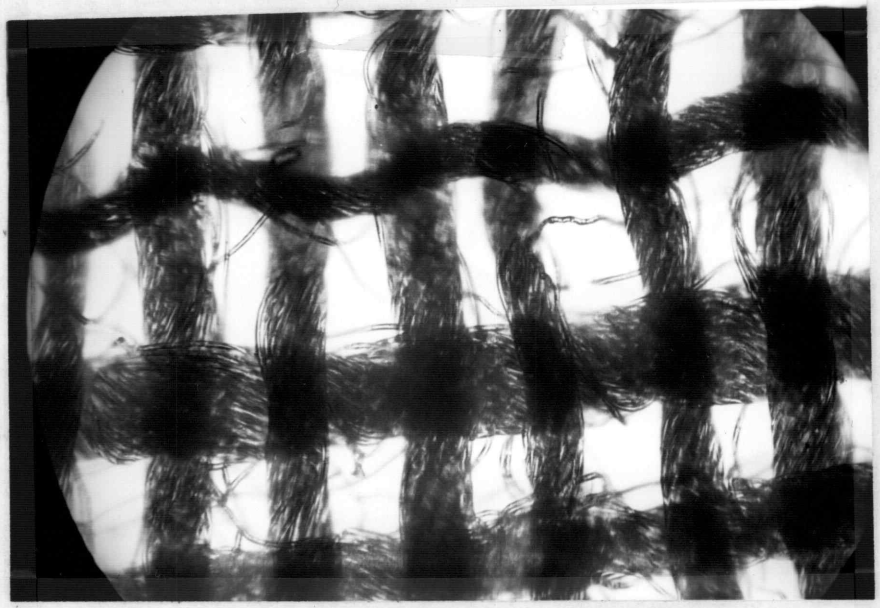


Original Fabric

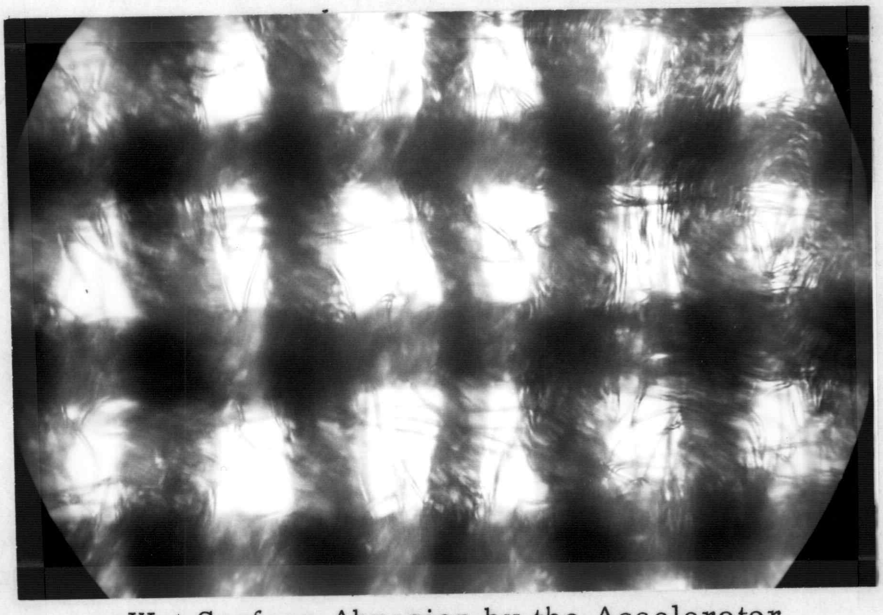


Photomicrography of Original Fabric
Magnification 30x.

Plate I. Original Fabric and Photomicrography of the Original Fabric.

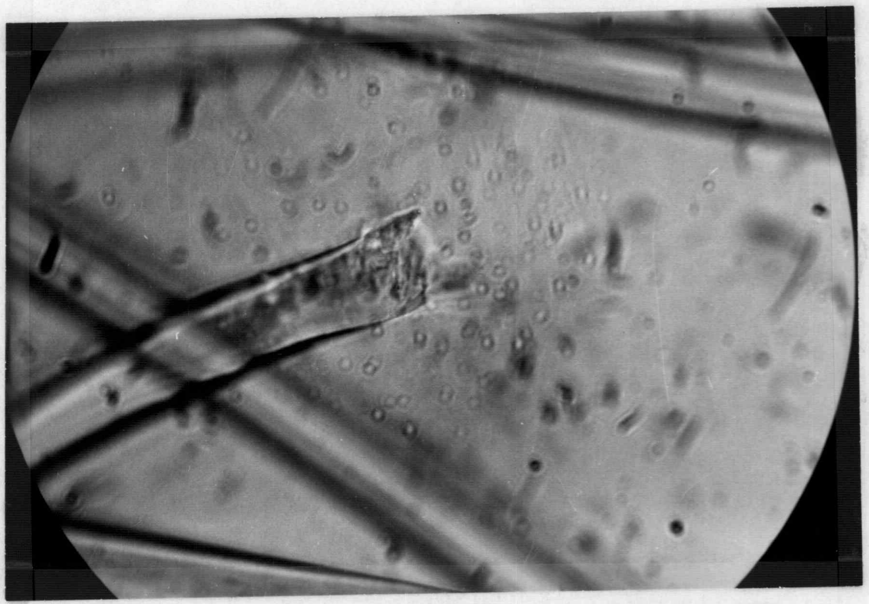


Dry Surface Abrasion by the Accelerotor

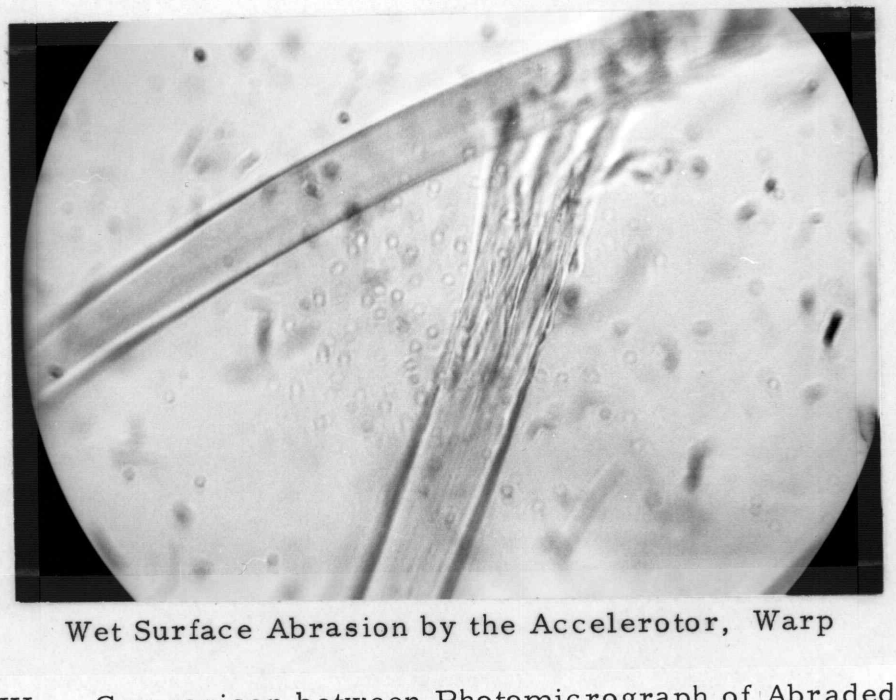


Wet Surface Abrasion by the Accelerotor

Plate II. Photomicrographs of Abraded Fabrics. Comparison between Wet Surface Abrasion and Dry Surface Abrasion in the Accelerotor, after Period 9. Magnification 30x.



Dry Surface Abrasion by the Accelerotor, Warp



Wet Surface Abrasion by the Accelerotor, Warp

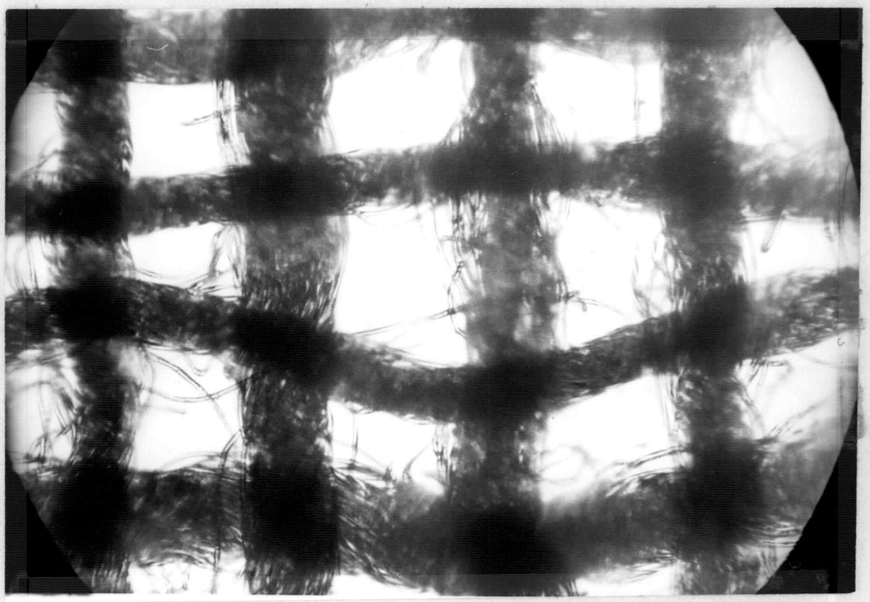
Plate III. Comparison between Photomicrograph of Abraded Fiber from Specimen Subjected to Dry Surface Abrasion and Wet Surface Abrasion in the Accelerotor after Period 9. Magnification 300x.

Little yarn damage occurred at lower periods of abrasion, but at higher periods of abrasion, such as periods 8 and 9, the surfaces of the fabric and yarns were covered with long hairs, including long loop-type hairs (Plate II). At these periods, slightly split fiber ends were observed (Plate III). Compared to dry surface abrasion in the same instrument, less visible yarn and fabric damage appeared in wet surface abrasion. But after wet surface abrasion in the Accelerotor, the fibers appeared more deeply damaged both at the ends and on the surface than the fibers subjected to dry surface abrasion in the Accelerotor.

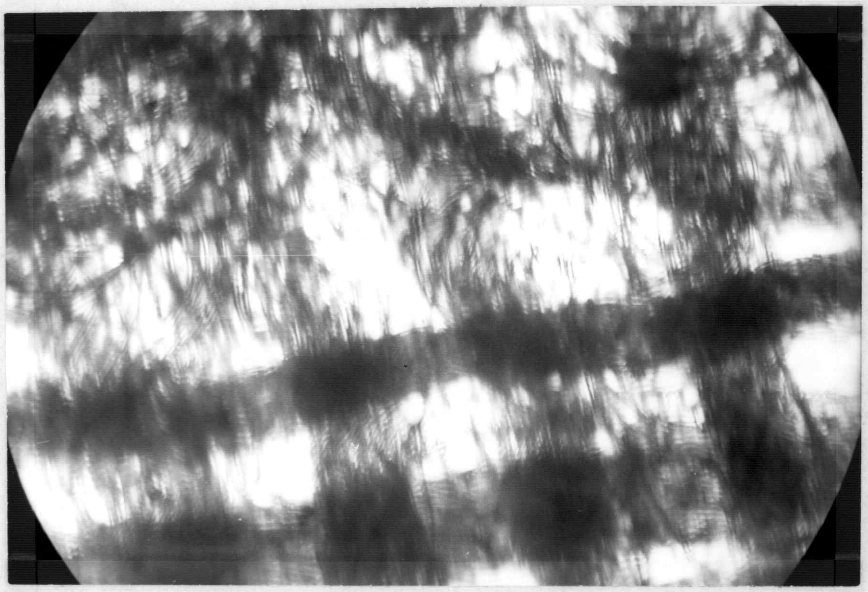
Dry Edge Abrasion by the Accelerotor

As the result of dry edge abrasion by the Accelerotor, yarns became bulkier, and hairiness increased until period 5. As abrasion increased, yarns at the folded area appeared to have fewer remaining twists. The hairiness of the surface of the fabric at the abraded area decreased after period 5, and longer spaces were observed between the yarns in the direction perpendicular to the direction of abrasion. Yarn damage, including cut fibers, appeared at and after period 8 (Plate IV).

At period 9, the fiber surfaces were damaged, and ends were slightly split (Plate V). Fillingwise specimens appeared to deteriorate faster than did warpwise specimens.

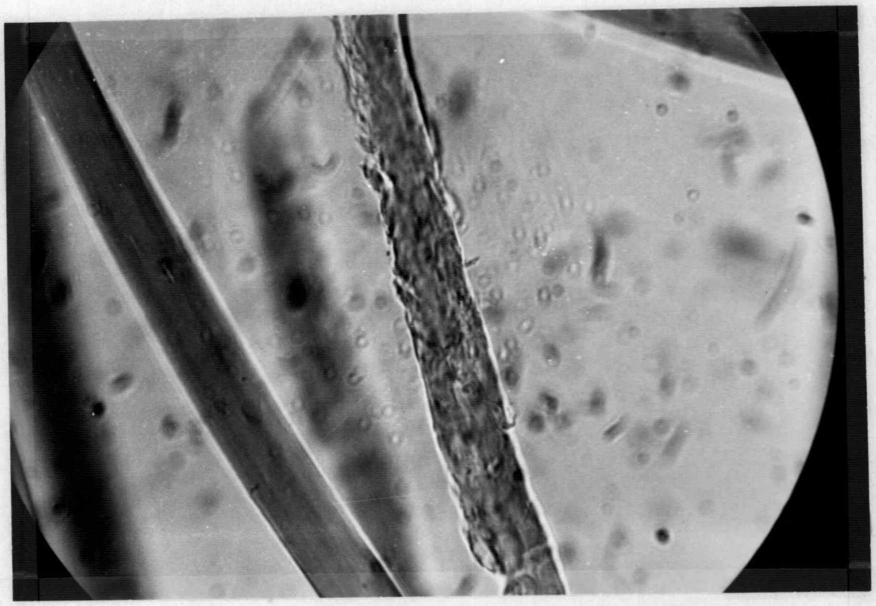


Dry Edge Abrasion by the Accelerotor

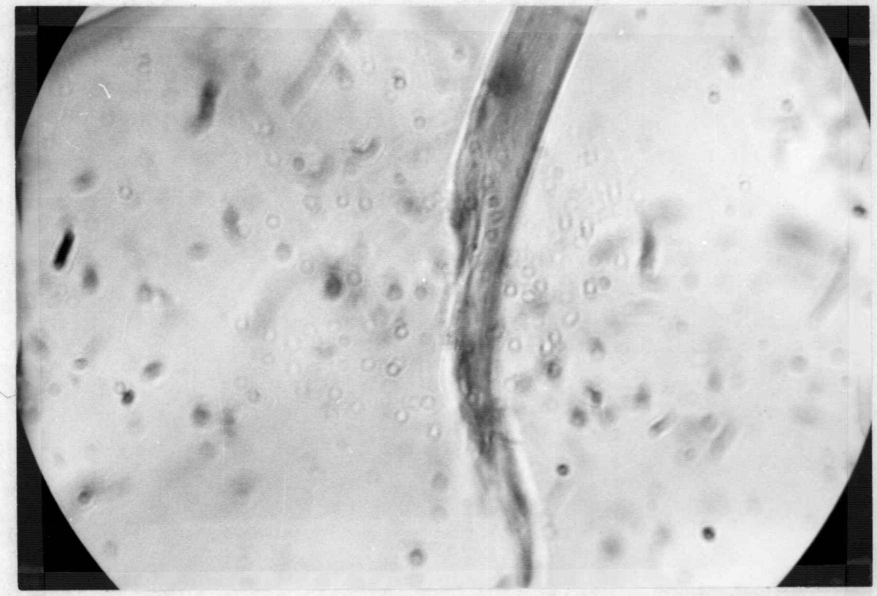


Dry Edge Abrasion by the Stoll Tester

Plate IV. Photomicrographs of Abraded Fabrics. Comparison between the Accelerotor and Stoll Tester with Filling-wise Specimens Subjected to Dry Edge Abrasion after Period 9. Magnification 30x.



Dry Edge Abrasion by the Accelerotor



Dry Edge Abrasion by the Stoll Tester

Plate V. Photomicrographs of Abraded Fibers. Comparison between the Accelerotor and Stoll Tester. Fibers from Warpwise Specimen Subjected to Dry Edge Abrasion after Period 9. Magnification 300x.

Dry Surface Abrasion by the Stoll Tester

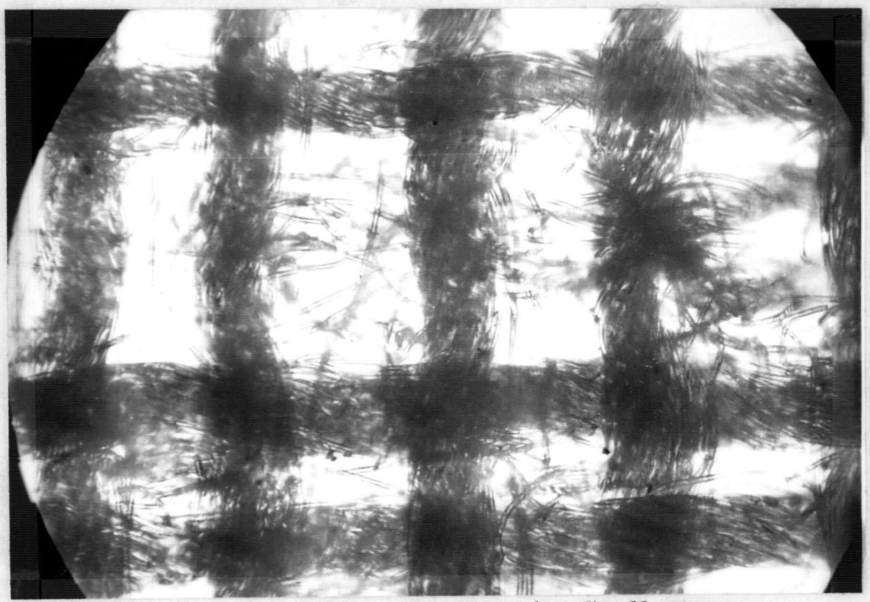
When the fabric was subjected to dry surface abrasion in the Stoll tester, yarn damage appeared from period 2 (10 cycles), and the rate of deterioration of the fabric seemed to be very fast with increasing abrasion (Plate VI). Yarns in the abraded area became bulkier. Minor degrees of end split and other fiber damage appeared after 10 cycles of abrasion (Plate VII).

After period 4, yarn damage became so serious that a tiny hole developed at the abraded area. The filling yarns of the abraded area were almost broken, but warp yarns remained in fairly good condition. Fiber microscopy indicated that more fiber damage appeared in filling yarns than in warp yarns.

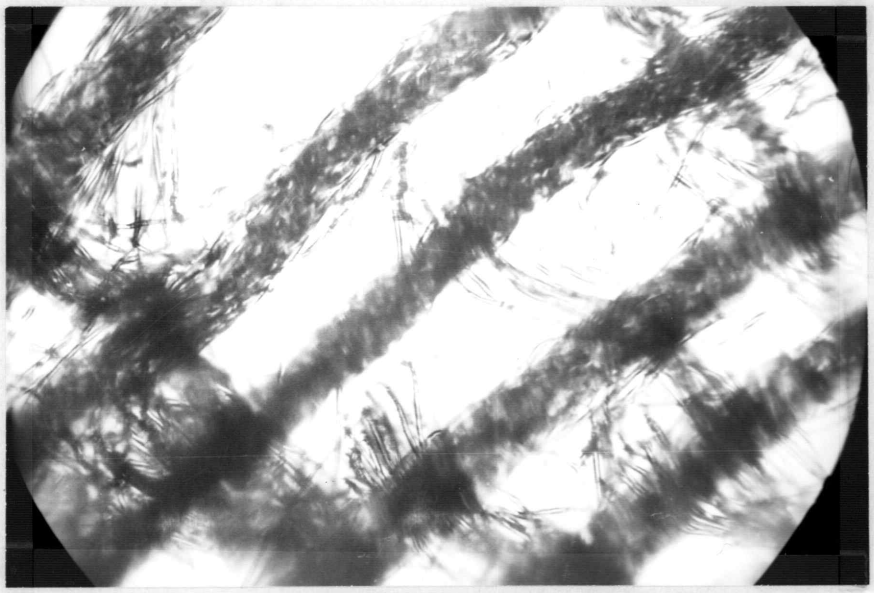
At period 9, most of the filling yarns were removed by abrasion, and thin warp yarns which appeared to have little remaining twist or cohesion between fibers were left. Heavy fiber damage was observed both on surfaces and at the ends.

Wet Surface Abrasion by the Stoll Tester

The speed of fabric wear in the wet condition on the Stoll instrument was faster than in the dry condition, and more serious damage appeared in abraded specimens when wet rather than dry. Even after 5 cycles of abrasion, the surfaces of the fabric were damaged

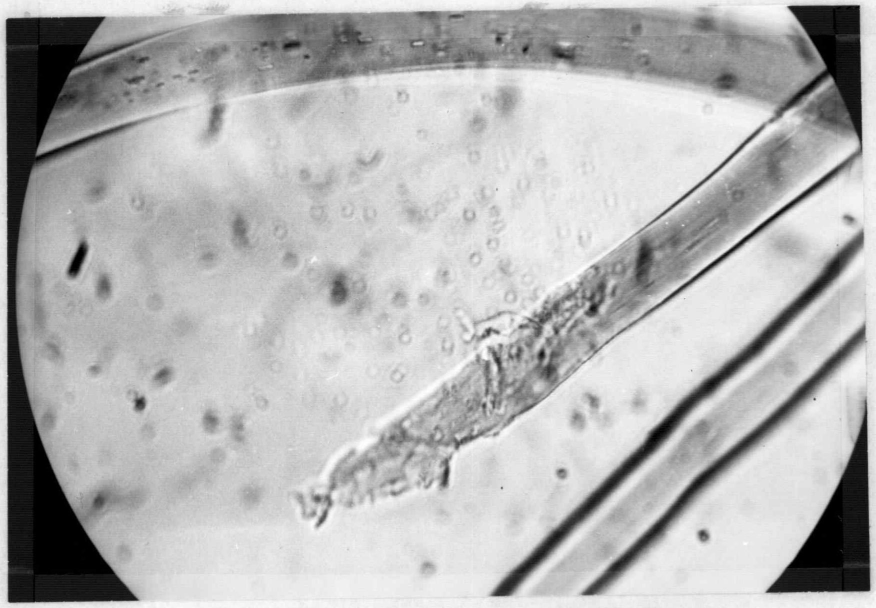


Dry Surface Abrasion by the Stoll Tester



Wet Surface Abrasion by the Stoll Tester

Plate VI. Photomicrographs of Abraded Fabrics. Comparison between Wet Surface Abrasion and Dry Surface Abrasion of 10 Cycles in the Stoll Tester. Magnification 30x.



Dry Surface Abrasion by the Stoll Tester

Wet Surface Abrasion by the Stoll Tester

Plate VII. Photomicrographs of Abraded Fibers. Comparison between Wet Surface Abrasion and Dry Surface Abrasion by the Stoll Tester at the End Point. Magnification 300x.

(Plate VI).

Most of the fibers in the abraded area showed end splits, surface damage, and even fibrillation at the end point of abrasion (Plate VII).

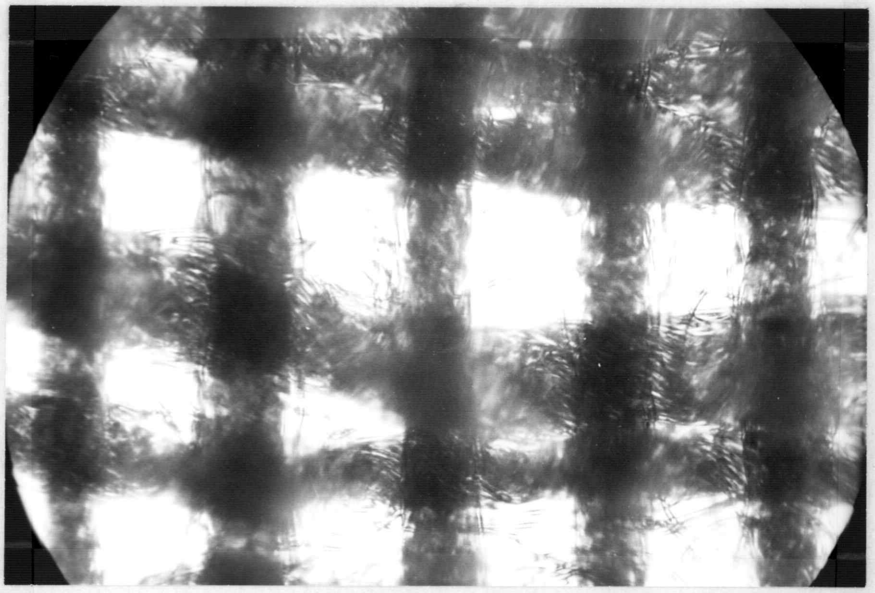
Dry Edge Abrasion by the Stoll Tester

At the lowest level of dry edge abrasion by the Stoll tester, the spaces between yarns jammed with napping and hairiness. There was uneven distribution of yarns which lay perpendicular to the direction of abrasion; some parts of the specimen contained very tightly spaced yarns while other parts had very long spaces between yarns (Plate IV). Broken yarns appeared at and after period 3 for the warpwise direction and period 4 for the fillingwise direction.

Fibers from the yarns at the folded part showed slight end splits (Plate V). However, compared to the visible yarn damage, the fiber damage was mild.

Dry Flexing Abrasion by the Stoll Tester

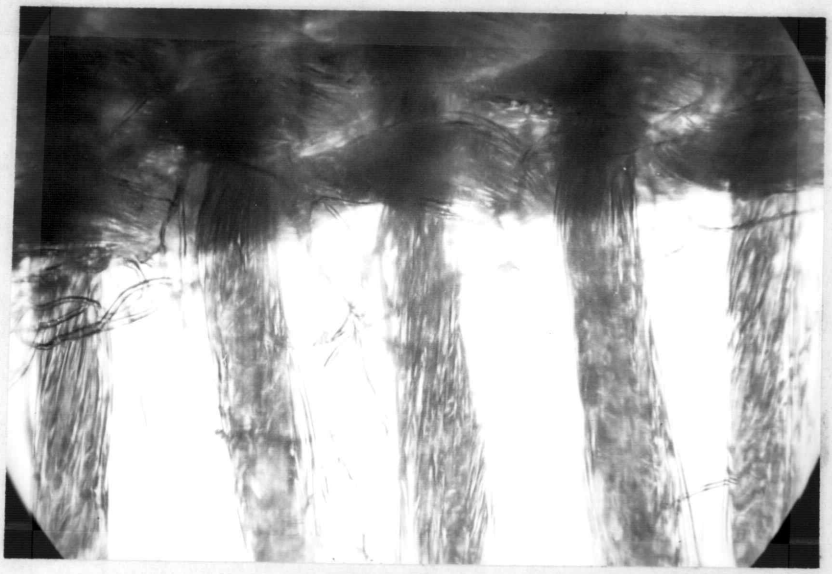
The spaces between the yarns became longer with increasing exposure to dry flexing abrasion in the Stoll tester (Plates VIII, IX, and X). The stretched yarns became bulkier until period 5, but after that period, they lost the bulkiness continuously. Broken fibers and yarns with long hairs on the surface were observed after period 7.



Period 1

Period 3

Plate VIII. Photomicrographs of Progressive Wear of Specimens. Damage at Selected Periods of Dry Flexing Abrasion by the Stoll Tester, Filling. Magnification 30x.



Period 5

Period 7

Plate IX. Photomicrographs of Progressive Wear of Specimens. Damage at Selected Periods of Dry Flexing Abrasion by the Stoll Tester, Filling. Magnification 30x.

Period 9

End Point

Plate X. Photomicrographs of Progressive Wear of Specimens. Damage at Selected Periods of Dry Flexing Abrasion by the Stoll Tester, Filling. Magnification 30x.

The warp and filling specimens showed similar degrees of wear.

Fibers of the flexed part showed damage especially at the ends of broken fibers (Plate XI).

Discussion of Microscopical Examination

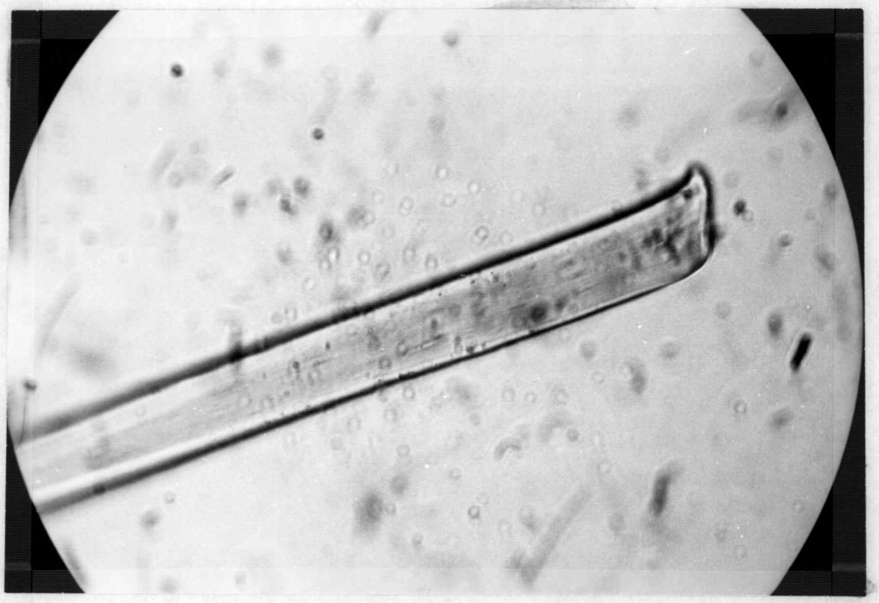
Damage on the fiber, yarn and fabric tended to increase continuously with increasing periods of abrasion. However, fibers suddenly showed damage at a certain period.

The warpwise and fillingwise specimens seemed to show similar patterns of wear as a result of a given method of abrasion, but filling yarns usually showed earlier deterioration than did warp yarns abraded by a given method of abrasion.

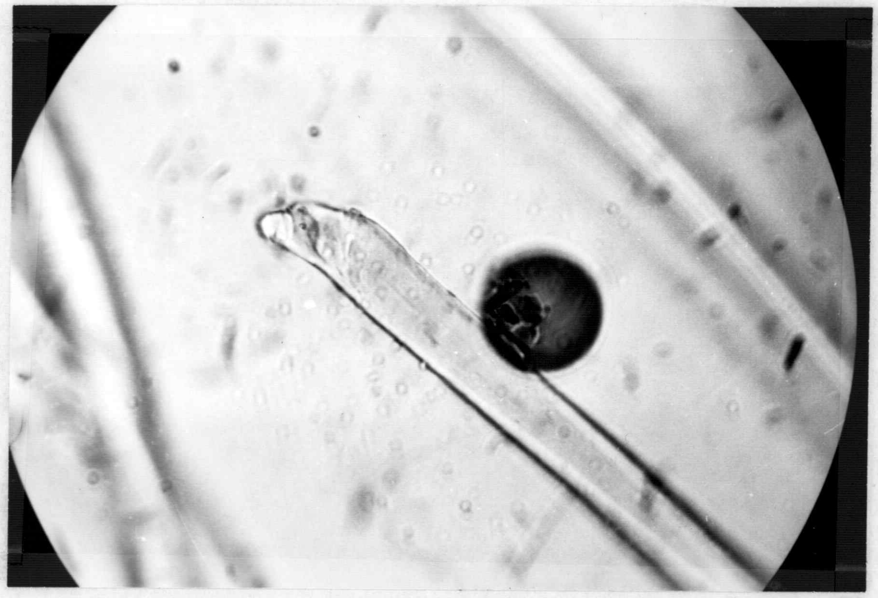
Wet and dry abrasion seemed to affect specimens differently. Fiber damage occurred most rapidly in the wet condition. In the Accelerotor, more fiber damage but less visible yarn and fabric damage occurred in the wet surface abrasion than the dry surface abrasion. But the Stoll tester seemed to cause more damage on the fabric, yarn and fibers in the wet condition than when dry.

The Stoll tester seemed to cause faster deterioration of the specimen at the small abraded area, but the Accelerotor gave relatively mild abrasion all over the specimen.

The fibrillation was observed only at the end point of wet surface abrasion by the Stoll tester.



Original Fiber



Dry, Flexing Abrasion by the Stoll Tester, the End Point, Warp

Plate XI. Photomicrography of Original and Abraded Fibers. Magnification 300x.

Relationship Among Variables

Relationship Among the Percentage Losses in Different Properties after Abrasion

Null hypothesis 1: There was no significant relationship among the percentage losses in (a) breaking load, (b) elongation and (c) weight after a given abrasion test.

Dry Surface Abrasion in the Accelerotor

There was a significant relationship among the percentage loss in weight, elongation, and breaking load as a result of dry surface abrasion by the Accelerotor (Appendix B-1). The regression equation was $Y = 0.15X + 0.16Z + 0.1$ (where Y = percentage loss in weight, X = percentage loss in breaking load, and Z = percentage loss in elongation). The relatively high Pearson correlation coefficient value indicated a high positive correlation among the variables. ($r = 0.77$, $df = 179$). The null hypothesis was rejected at the 0.01 confidence level.

There was a significant positive relationship between the percentage loss in weight and breaking load as a result of dry surface abrasion in the Accelerotor (Figure 10). The regression equation was $Y = 0.27X + 0.14$ (where Y = percentage loss in weight and X = percentage loss in breaking load). The null hypothesis was rejected at the 0.01 confidence level. (r = 0.80, df = 179).

There was a significant positive relationship between the percentage loss in weight and elongation as a result of dry surface abrasion by the Accelerotor (Figure 11). The regression equation was Y = 0.3X + 3.21 (where X = percentage loss in elongation and Y = percentage loss in weight). The relationship was significant (r=0.76), and the null hypothesis was rejected at the 0.01 confidence level (df=179).

A significant positive relationship existed between the percentage loss in breaking load and in elongation of specimens subjected to dry surface abrasion in the Accelerotor (Figure 12). The regression equation was Y = 0.95X + 14.8 (where Y = percentage loss in breaking load, X = percentage loss in elongation). The relationship between the two variables was significant at the 0.01 confidence level (r=0.85, df=179).

Dry Edge Abrasion in the Accelerotor

The relationship between the percentage losses in elongation and breaking load after dry edge abrasion by the Accelerotor was examined. A high positive correlation coefficient value was computed (Figure 12). The regression equation was Y = 0.79X + 11.23 (where Y = percentage loss in breaking load, X = percentage loss in elongation). The null hypothesis was rejected at the 0.01

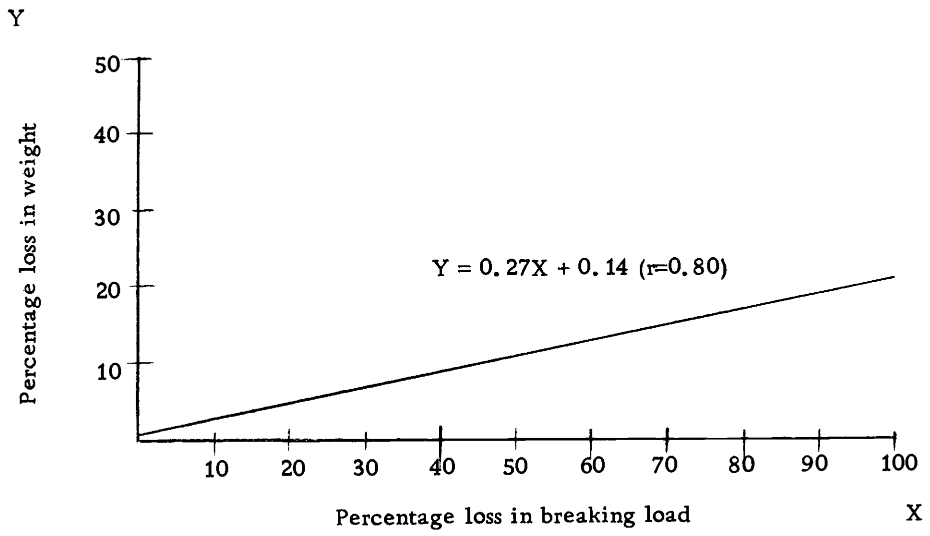


Figure 10. Relationship between the percentage loss in breaking load and weight of specimen as a result of dry surface abrasion in the Accelerotor.

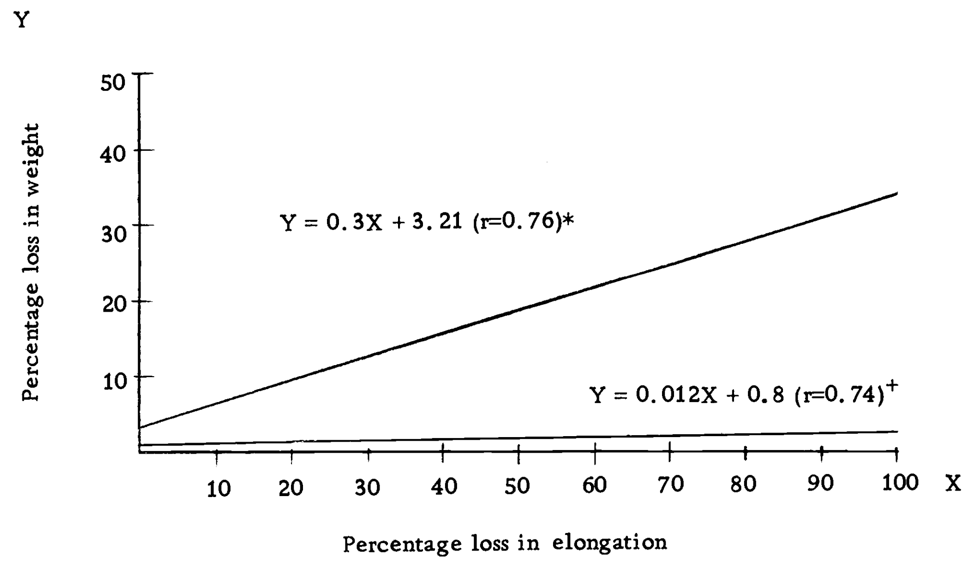


Figure 11. Relationship between the percentage loss in elongation and in weight of specimen as a result of abrasion.

Key: Regression equations for

*Dry surface abrasion by the Accelerotor

+Wet surface abrasion by the Accelerotor

Key: Regression equations for:

* Dry flexing abrasion in the Stoll tester

\+ Dry surface abrasion in the Accelerotor

‡ Dry edge abrasion in the Accelerotor

§ Wet surface abrasion in the Accelerotor

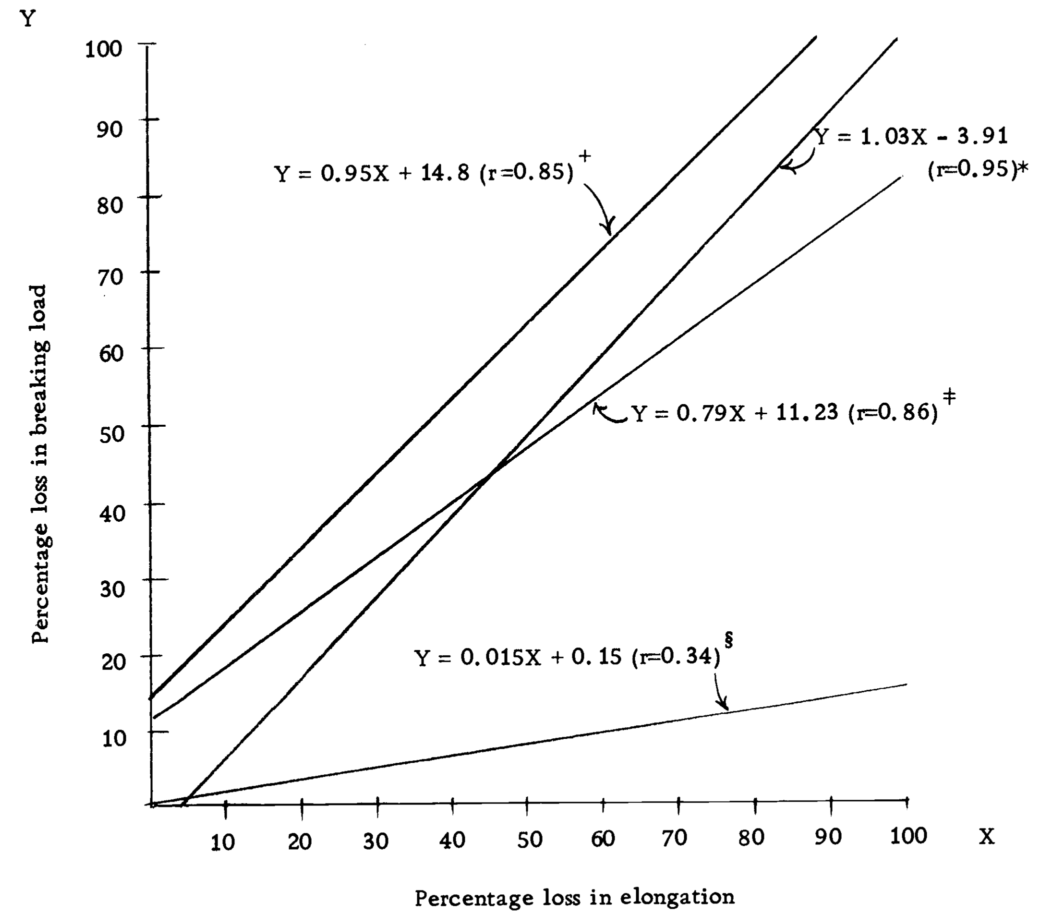


Figure 12. Relationship between the percentage loss in elongation and breaking load as a result of abrasion.

confidence level (r=0.86, df=168).

Dry Flexing Abrasion by the Stoll Tester

The relationship between the percentage losses in elongation and breaking load after dry flexing abrasion by the Stoll tester was examined (Figure 12). An almost perfect positive relationship (r=0.96) existed between the two variables. The regression equation was Y = 1.03X - 3.91 where Y = percentage loss in breaking load, X = percentage loss in elongation). The null hypothesis was rejected at the 0.01 confidence level (df=95).

Wet Surface Abrasion in the Accelerotor

The relationship among the percentage losses in weight, elongation, and breaking load of specimens subjected to wet surface abrasion in the Accelerotor was studied. The regression equation was Y = 0.15X - 0.014Z + 0.8 (where Y = percentage loss in weight, X = percentage loss in breaking load, and Z = percentage loss in elongation). The null hypothesis was rejected at the 0.01 confidence level (r = 0.80, df=169).

The relationship between the percentage loss in breaking load and elongation was examined for specimens subjected to wet surface abrasion in the Accelerotor (Figure 12). The computed regression equation was Y = 0.015X + 0.15 (where X = percentage loss in elongation and Y = percentage loss in breaking load). Although the positive correlation was low, the null hypothesis was rejected at the 0.01 confidence level ($r = 0.34$, $df = 169$).

No relationship was found between the percentage losses in weight and breaking load of specimens subjected to wet surface abrasion in the Accelerotor (Appendix B-1). The null hypothesis was not rejected at the 0.05 confidence level ($r = 0.02$, $df = 169$).

It may be concluded that for null hypothesis 1, there were high positive correlations among the changes in weight, breaking load, and elongation of specimens subjected dry abrasion. A significant relationship among the percentage losses in weight, elongation, and breaking load existed at the 0.01 confidence level. The relationship between the percentage losses in breaking load and elongation of specimens subjected to wet surface abrasion by the Accelerotor was significant at the 0.01 confidence level. However, the low level of the Pearson correlation coefficient indicated that there was relatively lower correlation between changes in weight and breaking load of specimens subjected to wet surface abrasion by the Accelerotor than dry surface abrasion by the Accelerotor. The null hypothesis was rejected at the 0.01 confidence level except for the relationship between the percentage changes in weight and breaking load of specimens subjected to wet surface abrasion by the Accelerotor.

The Relationship Between the Percentage Changes in Physical Properties and Period of Abrasion

Null hypothesis 2: There was no linear relationship between period of abrasion and the percentage loss in physical properties of specimens subjected to abrasion.

Dry Surface Abrasion in the Accelerotor

The relationship between the percentage loss in weight of specimens subjected to dry surface abrasion in the Accelerotor and period of abrasion was examined. The Pearson correlation coefficient value of 0.95 indicated a nearly perfect linear relationship (Figure 13). The regression equation was $Y = 1.97X - 0.27$ (where X = period, Y = percentage loss in weight). The null hypothesis was rejected at the 0.01 confidence level (df=179).

A significant linear relationship existed between period of abrasion and the percentage loss in breaking load of specimens as a result of dry surface abrasion by the Accelerotor (Figure 13). The regression equation was $Y = 4.61X + 11.9$ (where X = period, Y = percentage loss in breaking load). The null hypothesis was rejected at the 0.01 confidence level ($r = 0.78$, df=179).

The regression equation for the correlation between the period of abrasion and percentage loss in elongation of specimens subjected to dry surface abrasion by the Accelerotor was computed (Figure 13). The equation

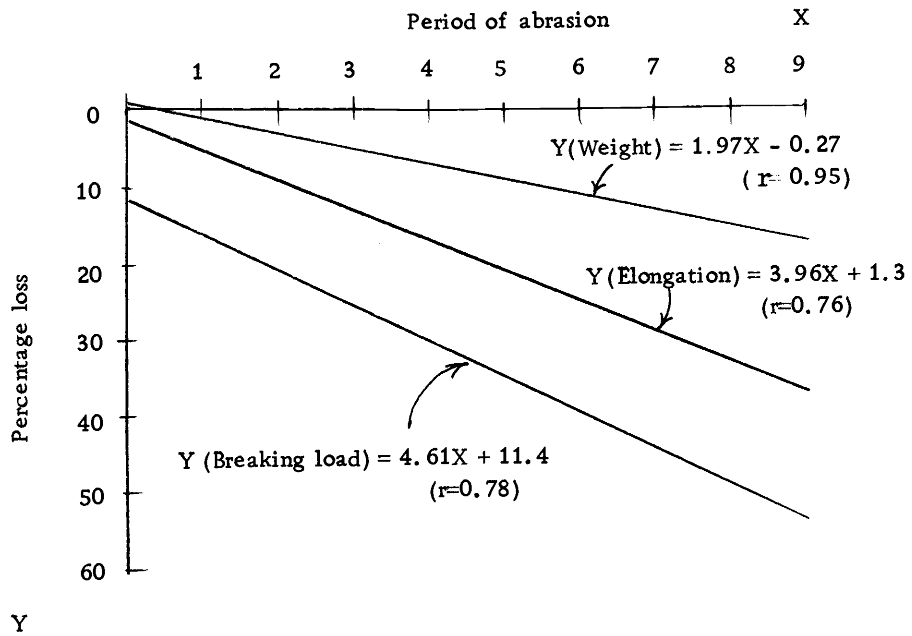


Figure 13. Relationship between period of abrasion and the percentage loss in weight, breaking load, and elongation as a result of dry surface abrasion in the Accelerotor.

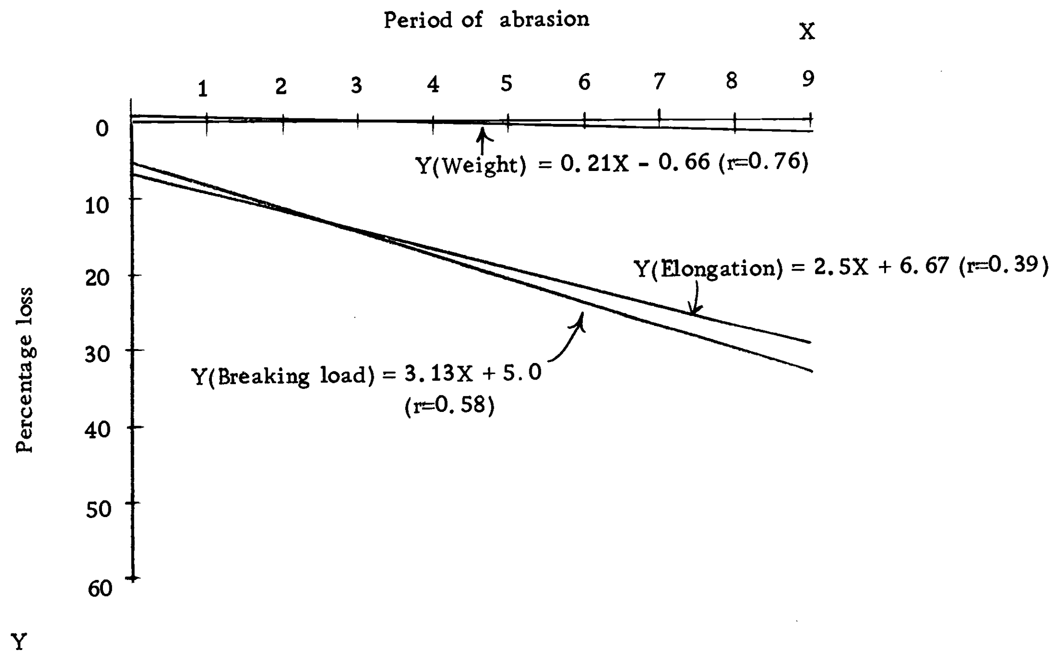


Figure 14. Relationship between period of abrasion and the percentage loss in weight, breaking load, and elongation as a result of wet surface abrasion in the Accelerotor.

was Y = 3.96X + 1.3 (where X = period, Y = percentage loss in elongation). The null hypothesis was again rejected at the 0.01 confidence level (r=0.76, df=179).

Dry Edge Abrasion in the Accelerotor

The relationship between the period of abrasion and the percentage loss in breaking load of specimens subjected to dry edge abrasion in the Accelerotor was examined (Figure 15). The regression equation was Y = 5.42X + 14.17 (where X = period, Y = percentage loss in breaking load). The null hypothesis was rejected at the 0.01 confidence level (r =0.92, df = 168).

A significant positive relationship existed between period of abrasion and the percentage loss in elongation of specimens subjected to dry edge abrasion in the Accelerotor (Figure 15). The regression equation was Y = 5.43X + 10.36 (where X = period, Y = percentage loss in elongation). The null hypothesis was rejected at the 0.01 confidence level (r=0.86, df=168).

Dry Flexing Abrasion by the Stoll Tester

There was a significant positive relationship between period of abrasion and the percentage loss in elongation of specimens as a result of dry flexing abrasion by the Stoll tester (Figure 16). The regression equation was Y = 6.73X + 11.4 (where X = period,

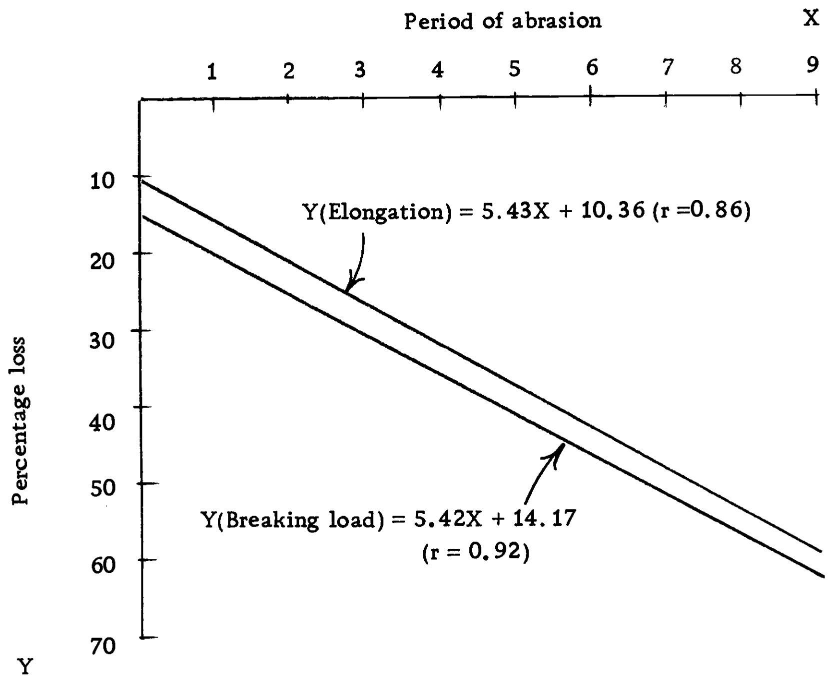


Figure 15. Relationship between period of abrasion and percentage loss in breaking load and elongation of specimen as a result of dry edge abrasion in the Accelerotor.

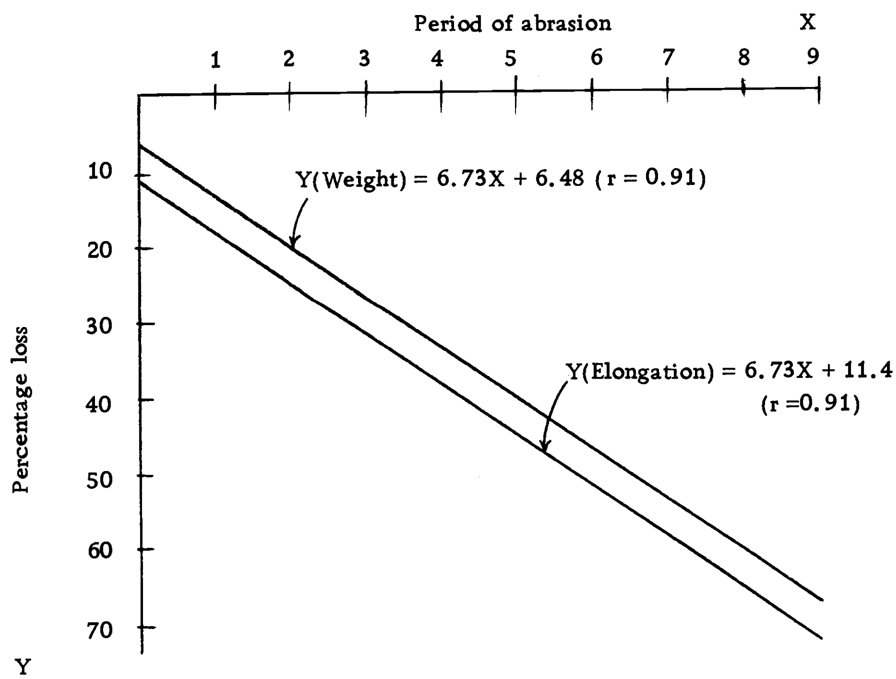


Figure 16. Relationship between period of abrasion and percentage loss in breaking load and elongation of specimen as a result of dry flexing abrasion in the Stoll tester.

Y = percentage loss in elongation). The null hypothesis was rejected at the 0.01 confidence level ($r=0.91$, $df=95$).

A significant positive correlation was also found between the period of abrasion and the percentage loss in breaking load of specimens subjected to dry flexing abrasion in the Stoll tester (Figure 16). The regression equation was $Y = 6.73X + 6.48$ (where X = period and Y = percentage loss in breaking load). The null hypothesis was rejected at the 0.01 confidence level ($r=0.91$, $df=95$).

Wet Surface Abrasion in the Accelerotor

There was a positive relationship between period of abrasion and the percentage change in weight of specimens subjected to wet surface abrasion in the Accelerotor (Figure 14). The regression equation was $Y = 0.21X - 0.66$ (where X = period, Y = percentage loss in weight). The null hypothesis was rejected at the 0.01 confidence level ($r=0.76$, $df=169$).

The positive correlation between period of abrasion and the percentage loss in breaking load of specimens as a result of wet surface abrasion in the Accelerotor was significant at the 0.01 confidence level (Figure 14). The regression equation was $Y = 3.13X + 5.0$ (where X = period, Y = percentage loss in breaking load). The null hypothesis was rejected at the 0.01 confidence level ($r=0.58$, $df=169$).

A significant relationship at the 0.01 confidence level was found between period of abrasion and the percentage loss in elongation of specimens subjected to wet surface abrasion in the Accelerotor (Figure 14). The regression equation was $Y = 2.5X + 6.67$ (where X = period, Y = percentage loss in elongation). The null hypothesis was rejected at the 0.01 confidence level ($r = 0.39$, $df = 169$).

There were significant relationships between period of abrasion and the percentage loss in weight, breaking load, and elongation of specimens as a result of abrasion. The null hypothesis was rejected at the 0.01 confidence level. But the Pearson correlation coefficient values for wet surface abrasion in the Accelerotor were smaller than those in dry abrasion procedures, and this fact may have indicated that the correlation between period of abrasion and change in properties as a result of wet abrasion was lower than the correlation between the variables as a result of dry abrasion.

Difference Between the Warpwise Direction and Fillingwise Direction in the Percentage Loss in Physical Properties as a Result of Abrasion

Null hypothesis 3: There was no significant difference between the warpwise direction and the fillingwise direction in changes of breaking load, elongation, and weight of specimens as a result of abrasion.

In dry surface abrasion in the Accelerotor, no significant difference existed between the two directions in the percentage loss in breaking load or in weight (Table 11). But the percentage loss in elongation in the filling direction was significantly higher than in the warp direction at the 0.01 confidence level (Table 11). The null hypothesis was rejected for the differences in the percentage loss in warpwise and fillingwise elongation as a result of dry surface abrasion in the Accelerotor at the 0.01 confidence level.

The percentage loss in elongation as a result of dry edge abrasion by the Accelerotor was significantly greater in the warp than the filling direction (Table 11). The null hypothesis was rejected at the 0.01 confidence level. But no significant difference occurred between breaking load in the warp and filling directions after dry edge abrasion in the Accelerotor.

In dry flexing abrasion by the Stoll tester, there was no significant difference between the percentage losses in elongation in the two directions (Table 11). Significantly higher percentage losses in breaking load occurred in warpwise specimens than in fillingwise specimens. The null hypothesis was rejected at the 0.05 confidence level when comparing losses in warpwise and fillingwise breaking load as a result of dry flexing abrasion by the Stoll tester (Table 11).

In wet surface abrasion by the Accelerotor, there were significantly greater percentage losses in breaking load in the warpwise direction than in the fillingwise direction, but there were significantly

Table 11. Difference between the warp and filling directions in the percentage loss in weight, breaking load and elongation of specimens as a result of abrasion.

Type of Abrasion	Instrument	Property	t-value		
			Computed	0.05 CL*	0.01 CL*
Dry, surface	Accelerotor	Weight	1.76	1.96	2.58
Dry, surface	Accelerotor	Breaking load	1.01	1.96	2.58
Dry, surface	Accelerotor	Elongation	3.93	1.96	2.58
Dry, edge	Accelerotor	Breaking load	1.51	1.96	2.58
Dry, edge	Accelerotor	Elongation	4.01	1.96	2.58
Dry, flexing	Stoll tester	Breaking load	2.02	1.98	2.63
Dry, flexing	Stoll tester	Elongation	1.07	1.98	2.63
Wet, surface	Accelerotor	Weight	.31	1.96	2.58
Wet, surface	Accelerotor	Breaking load	8.16	1.96	2.58
Wet, surface	Accelerotor	Elongation	14.38	1.96	2.58

*CL is confidence level.

Table 12. Differences between effects of wet surface abrasion and dry surface abrasion in the Accelerotor on percentage loss in weight, elongation, and breaking load of specimens.

Property	t-value		
	Computed	0.05 CL*	0.01 CL*
Weight	22.1	1.96	2.58
Breaking load	8.92	1.96	2.58
Elongation	1.01	1.96	2.58

*CL is confidence level.

greater percentage losses in fillingwise than in warpwise elongation at the 0.01 confidence level (Table 11). As would be expected, there were no significant differences between the two directions in weight changes as a result of abrasion at the 0.05 confidence level (Table 11). The null hypothesis was rejected when comparing changes in warpwise and fillingwise elongation or breaking load as a result of wet surface abrasion by the Accelerotor.

In a conclusion, there were significant differences between the warpwise and fillingwise directions in elongation changes as a result of dry surface abrasion and wet surface abrasion by the Accelerotor, and of dry edge abrasion by the Accelerotor. In these cases the null hypothesis was rejected at the 0.01 confidence level. There was a significant difference at the 0.05 confidence level between the two directions in breaking load changes as a result of dry flexing abrasion by the Stoll tester. The difference between the percentage changes in physical properties on the basis of direction of test, was dependent upon the property measured and the type of abrasion applied.

Differences Between Effects of Wet Abrasion and Dry Abrasion

Null hypothesis 4: There was no difference between the effects of wet and dry abrasion on the percentage losses in weight, elongation, and breaking load of specimens subjected to abrasion.

Dry surface abrasion generally caused significantly greater losses in weight and breaking load than did wet surface abrasion in the Accelerotor (Table 12). There was no significant difference between the effects of the two procedures of abrasion on elongation at the 0.05 confidence level.

The null hypothesis was rejected at the 0.01 confidence level for the effects of wet and dry surface abrasion in the Accelerotor on the percentage losses in weight or breaking load.

Difference in Breaking Load and Elongation Losses Between Two Strips of a Specimen Subjected to Abrasion in the Accelerotor

Null Hypothesis 5: Each side of a specimen was abraded evenly in terms of loss in elongation and in breaking load as a result of abrasion on the Accelerotor.

Significant differences between two strips occurred in the percentage losses in elongation (0.05 confidence level) and in breaking load (0.01 confidence level) of the strips as a result of dry surface abrasion in the Accelerotor (Table 13). The null hypothesis was rejected for differences in elongation at the 0.05 confidence level and for differences in weight at the 0.01 confidence level.

No significant difference occurred between two strips from a specimen subjected to dry edge abrasion in the Accelerotor on the basis of the percentage losses in breaking load and elongation. The null hypothesis was not rejected at the 0.05 confidence level.

The difference in the percentage loss in breaking load between two strips from a specimen as a result of wet surface abrasion by the Accelerotor was significant at the 0.05 confidence level. No significant difference occurred in the percentage loss in elongation between two strips of a specimen as a result of wet surface abrasion in the Accelerotor.

Table 13. Difference between the percentage losses in breaking load and elongation of two strips from specimens subjected to abrasion in the Accelerotor.

Type of Abrasion	Property	t-value		
		Computed	0.05 Cl*	0.01 CL*
Dry, surface	Breaking load	4.23	1.96	2.58
Dry, surface	Elongation	2.57	1.96	2.58
Dry, edge	Breaking load	1.87	1.96	2.58
Dry, edge	Elongation	.34	1.96	2.58
Wet, surface	Breaking load	2.22	1.96	2.58
Wet, surface	Elongation	.91	1.96	2.58

*CL is confidence level

CHAPTER V

SUMMARY AND CONCLUSION

This study was designed to compare the effects of certain abrasion procedures upon specific physical properties of a high wet modulus rayon. Three abrasion procedures were followed. Fabric and fiber microscopy, fabric breaking load or bursting strength, fabric elongation, and weight were the criteria used to evaluate effects of abrasion.

The Avril fabric was lightweight, white, plain weave, and without any finish. The sampling plan for the study was a randomized complete block experimental design which consisted of seven blocks.

The tests were conducted according to the standard procedures recommended by the American Society for Testing and Materials and the American Association of Textile Chemist and Colorists, with minor variations when required. All specimens for the study were conditioned and tested in the standard atmosphere of 70 degrees ±2 degrees Fahrenheit at 65 percent ±2 percent relative humidity.

The microscopical appearance of specimens subjected to abrasion was observed with 30-power magnification for fabric and 300-power magnification for fibers. Photomicrographs were taken of fabric and fibers.

The type of abrasion applied included surface abrasion in dry and wet condition, edge abrasion in dry condition, and flexing abrasion in dry condition. Dry flexing abrasion was performed only in the Stoll tester, but all other abrasion procedures were performed both in the Accelerotor and the Stoll tester.

The regression analysis was used to determine whether any significant correlation existed among variables. Regression equations and Pearson correlation coefficients were computed. The t-test was used to determine whether any significant differences occurred between variables.

There were positive correlations among the percentage loss in weight, breaking load, and elongation of specimens as a result of abrasion except between the percentage loss in weight and in breaking load of specimens subjected to wet surface abrasion by the Accelerotor.

A significantly positive relationship existed between the periods of abrasion and the percentage losses in weight, breaking load, and elongation of specimens as a result of abrasion. Higher values of the Pearson correlation coefficient occurred for specimens subjected to dry abrasion than for those abraded when wet.

Decrease in elongation in the fillingwise direction as a result of abrasion in the Accelerotor in either the wet or dry condition was significantly higher than in the warpwise direction. Significantly greater percentage loss in breaking load occurred in the warpwise direction than in the fillingwise direction as a result of wet surface abrasion in the Accelerotor. There was significantly greater loss in breaking load in the warpwise direction than in the fillingwise direction as a result of dry flexing abrasion on the basis of period.

Dry abrasion and wet abrasion in the Accelerotor affected physical properties differently. There was significantly greater loss in weight and breaking load of specimens subjected to dry surface abrasion than to wet surface abrasion in the Accelerotor. There was not a significant difference between the effects of dry and wet abrasion on loss in elongation after surface abrasion in the Accelerotor.

Specimens subjected to dry surface abrasion in the Accelerotor were unevenly abraded, judging from the differences in changes in elongation and breaking load between two strips from a specimen. The difference between two strips from a specimen on the basis of changes in elongation and breaking load as a result of dry edge abrasion in the Accelerotor was not significant (at the 0.05 level). In wet surface abrasion in the Accelerotor, there was a significant difference in breaking load change between two strips of a specimen (at the 0.05 level) but not a significant difference in elongation change (at the 0.05 level).

The damage of fabric, yarn and fiber which was observed under a microscope seemed to increase with the increasing period of abrasion. Yarn and fabric tended to deteriorate continuously. Visible yarn and fabric damage did not always indicate the degree of fiber damage observed under high magnification. Fiber damage caused by the Stoll tester seemed to be different from fiber damage caused by the Accelerotor. Fibrillation was observed at the end point on specimens subjected to wet surface abrasion by the Stoll tester.

It may be concluded that different abrasion procedures affected a physical property of the fabric differently, and a given procedure of abrasion affected various properties of the fabric differently. The measurement of the abrasion resistance of the fabric in both directions is necessary because some abrasion procedures had significantly different effects upon certain physical properties of warpwise specimens and fillingwise specimens. In general, the rate of change in physical properties had a linear relationship with period of abrasion. Measurement of the properties at several periods of abrasion may help to understand the rate of change of fabric properties during abrasion.

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APPENDICES

APPENDIX A-1

SPECIMEN LAYOUT

Key to the Specimen Layout

A. Yarn properties

B. Dry surface abrasion by the Accelerotor

C. Dry edge abrasion by the Accelerotor

D. Wet surface abrasion by the Accelerotor

E. Dry sruface abrasion by the Stoll tester

F. Wet surface abrasion by the Stoll tester

G. Dry flexing abrasion by the Stoll tester

H. Dry edge abrasion by the Stoll tester

I. Weight

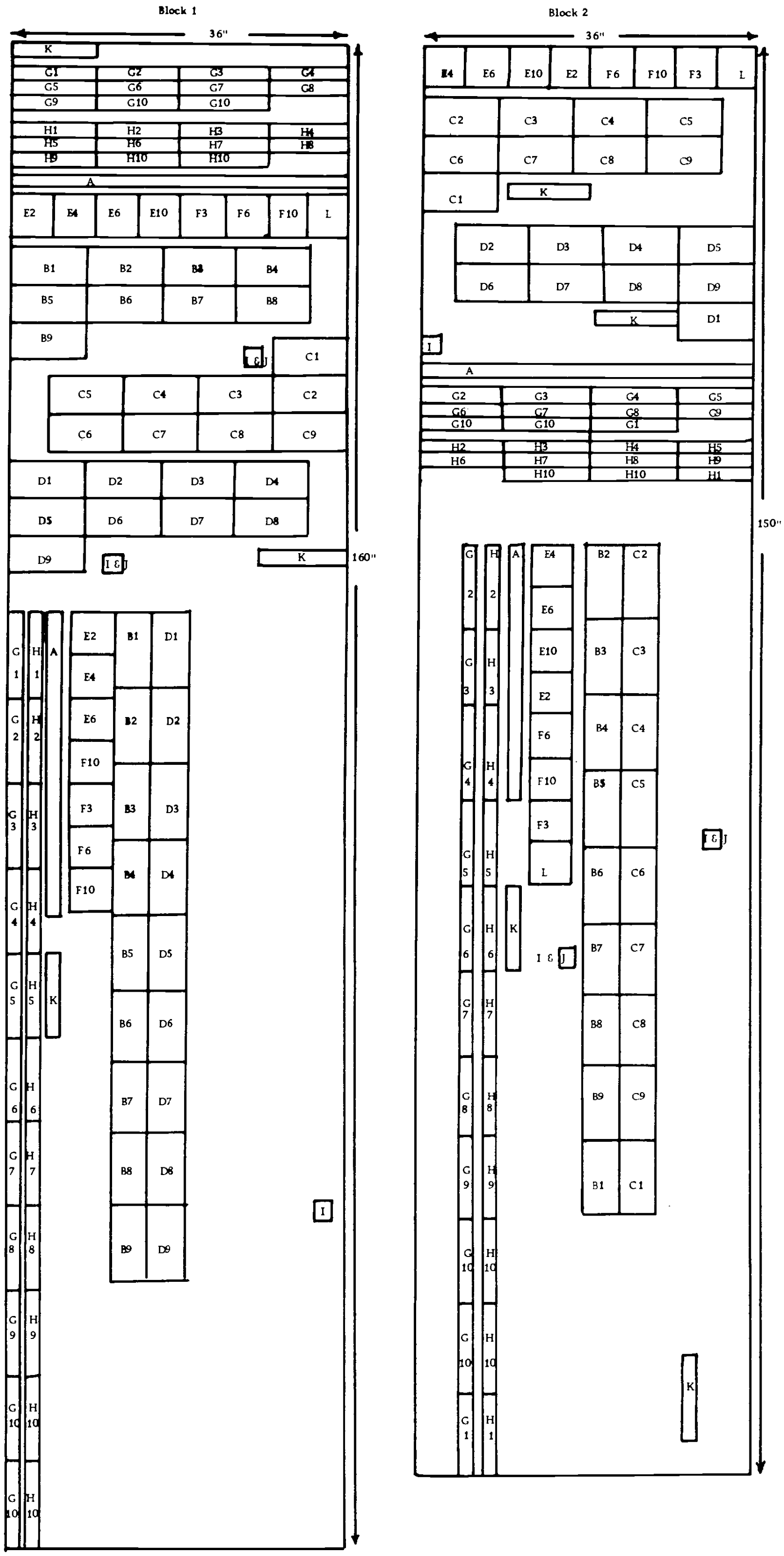
J. Count and Thickness

K. Breaking load and elongation of fabric

L. Bursting strength

The Arabic numerals from 1 to 9 indicate the period to abrade specimens, and 10 indicates the end point.

APPENDIX A-1



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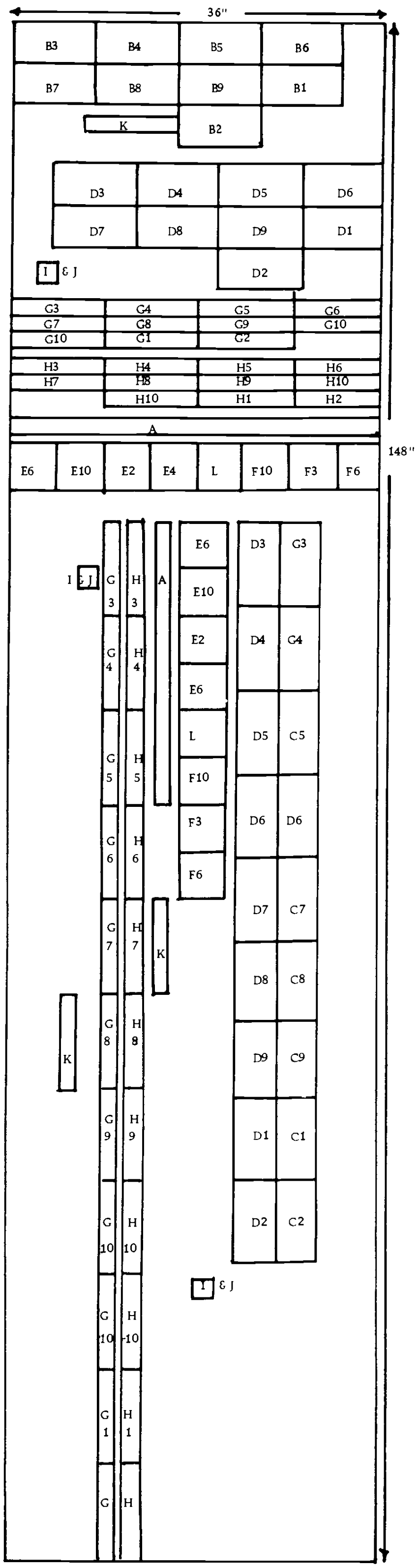

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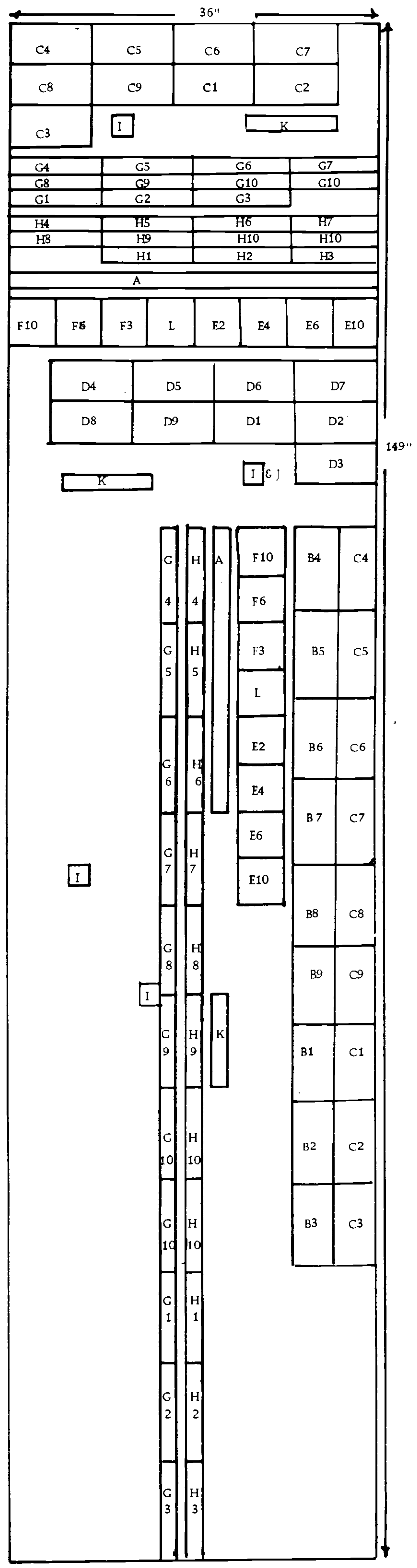

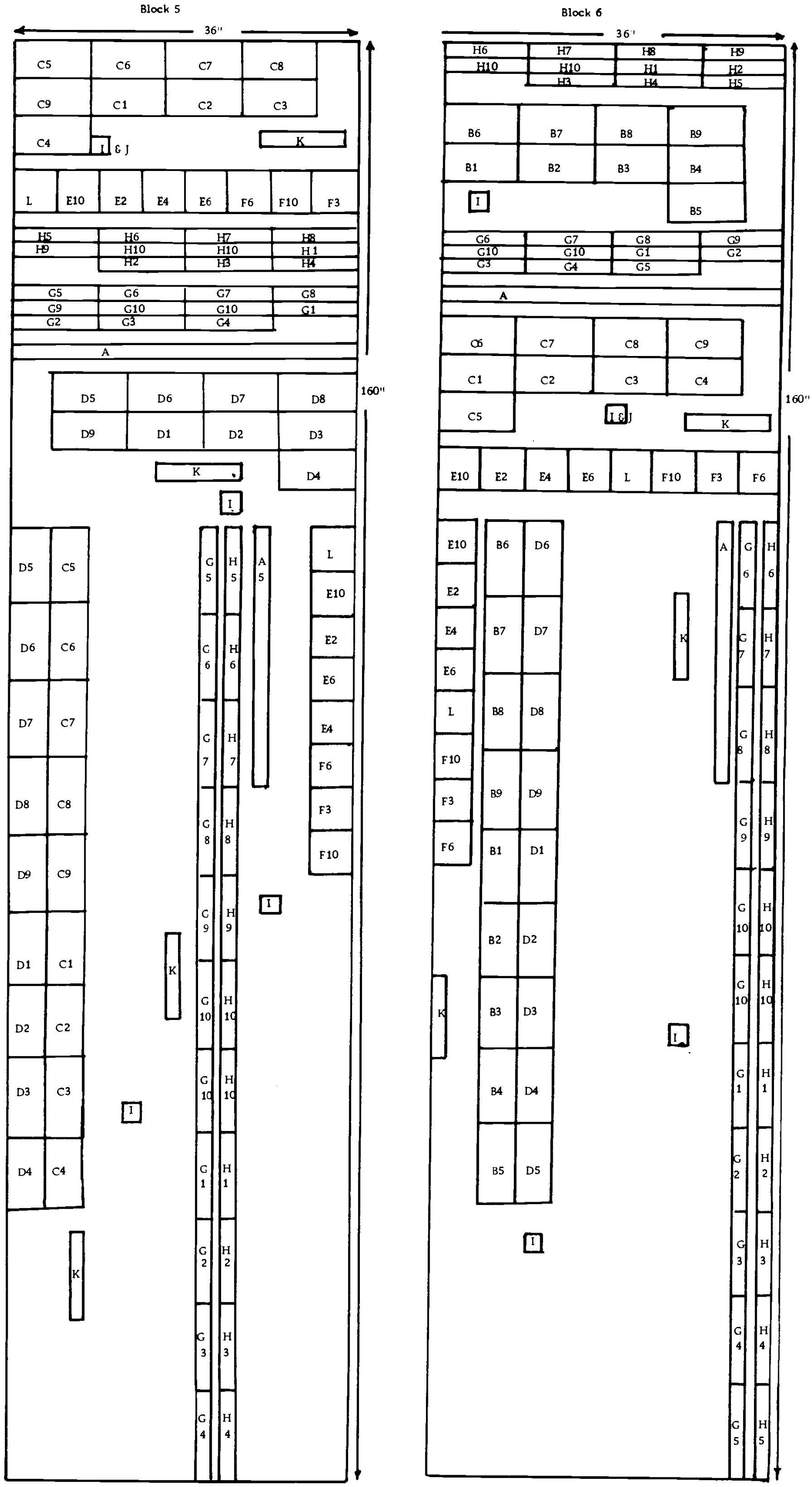
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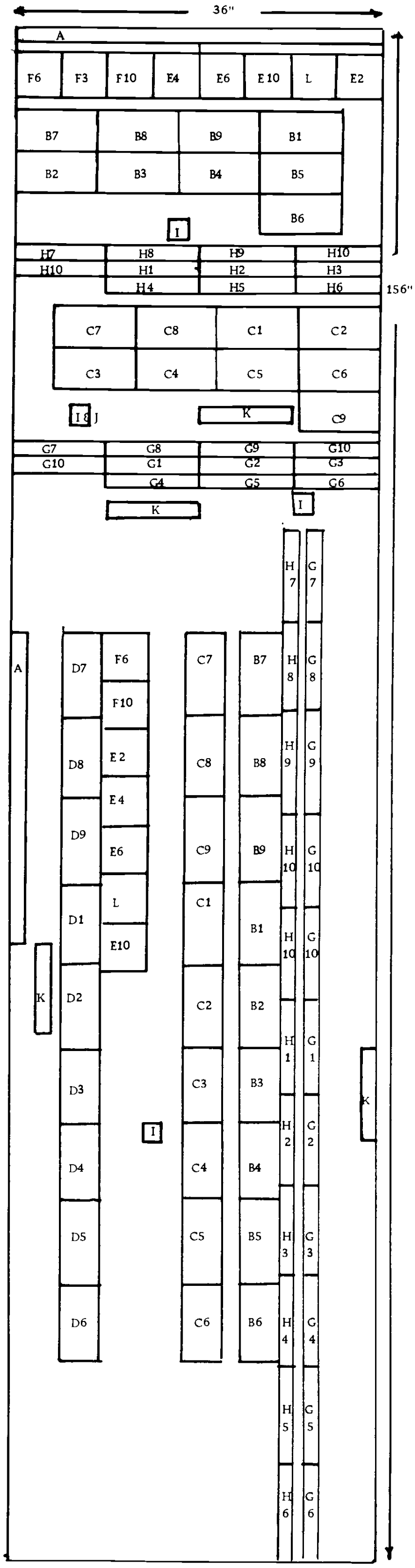
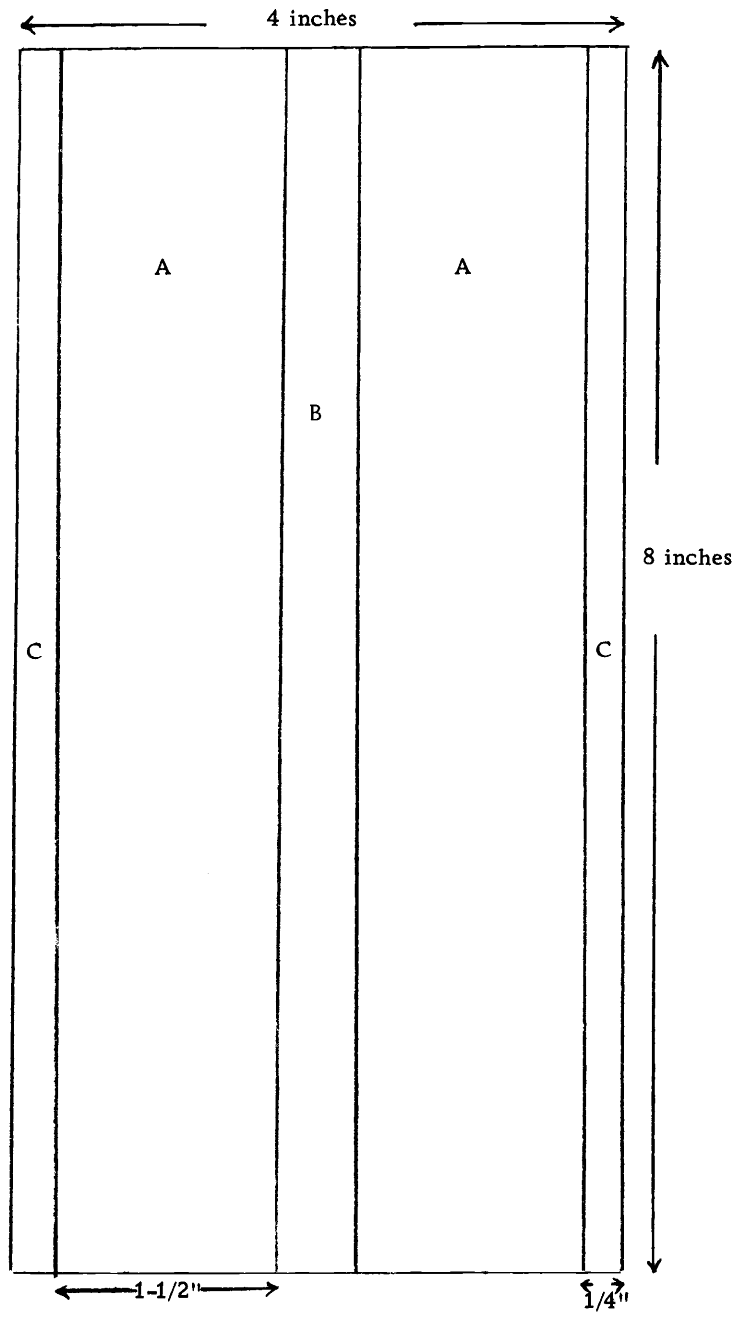
160"
Block 6
36'
160"

APPENDIX A (Cont.)

Block 7





APPENDIX A-2

Cutting Diagram for Measuring Breaking Load and Elongation of Specimen Abraded in the Accelerotor

*A Specimen for ravelled strip breaking load
B Specimen for microscopical study
C Cut off edge

APPENDIX B-1

Correlation among the Percentage Losses in Weight, Breaking Load, and Elongation of Specimens as a Result of Abrasion

Type of Abrasion	Instrument	Variable	Regression Equation	r	df	Level of Confidence
Dry, surface	Accelerotor	W. B. E. *	Y(W) = 0. 15X(B) + 0. 16Z(E) + 0. 1	0.77	179	0.01
Dry, surface	Accelerotor	W. B.	Y(W) = 0. 27X(B) + 0. 14	.80	179	.01
Dry, surface	Accelerotor	W. E.	Y(W) = 0. 3X(E) + 3. 21	.76	179	.01
Dry, surface	Accelerotor	B. E.	Y(B) = 0. 95X(E) + 14. 8	.85	179	.01
Dry, edge	Accelerotor	B. E.	Y(B) = 0. 79X(E) + 11. 23	.86	168	.01
Dry, flexing	Stoll tester	B. E.	Y(B) = 1. 03X(E) - 3. 91	.95	95	.01
Wet, surface	Accelerotor	W. B. E.	Y(W) = 0. 15X(B) - 0. 014 Z(E) + 0. 8	.80	169	.01
Wet, surface	Accelerotor	W. E.	Y(W) = 0. 022X(E) = 0. 8	.74	169	.01
Wet, surface	Accelerotor	W. B.	Y(W) = 0. 0076X(B) + 0. 003	.02	169	not significant
Wet, surface	Accelerotor	B. E.	Y(B) = 0. 015X(E) + 0. 15	.34	169	.01

*W is the percentage loss in weight, B is the percentage loss in breaking load, E is the percentage loss in elongation.

APPENDIX B-2

Correlation between Period of Abrasion and the Percentage Loss in Weight, Breaking Load, or Elongation of Specimens as a Result of Abrasion.

Type of Abrasion	Instrument	Property	Regression Equation*	r	df	Level of Confidence
Dry, surface	Accelerotor	Weight	Y(W) = 1.97X - 0.27	0.95	179	0.01
Dry, surface	Accelerotor	Breaking load	Y(B) = 4.61X + 11.9	.78	179	.01
Dry, surface	Accelerotor	Elongation	Y(E) = 3.96X + 1.3	.76	179	.01
Dry, edge	Accelerotor	Breaking load	Y(B) = 5.42X + 14.17	.92	168	.01
Dry, edge	Accelerotor	Elongation	Y(E) = 5.43X + 10.36	.86	168	.01
Dry, flexing	Stoll tester	Breaking load	Y(B) = 6.73X + 6.48	.91	95	.01
Dry, flexing	Stoll tester	Elongation	Y(E) = 6.73X + 11.4	.91	95	.01
Wet, surface	Accelerotor	Weight	Y(W) = 0.21X - 0.66	.78	169	.01
Wet, surface	Accelerotor	Breaking load	Y(B) = 3.13X + 5.0	.58	169	.01
Wet, surface	Accelerotor	Elongation	Y(E) = 2.5X + 6.67	.39	169	.01

*W is the percentage loss in weight, B is the percentage loss in breaking load, E is the percentage loss elongation.