A SCIENTIFIC AND SYSTEMATIC EVALUATION OF THE DISTINGUISHING QUALITIES OF BLENDS OF ACRYLIC FIBERS AND THE NEW HIGH WET MODULUS RAYONS

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Approved: ______________________

Chairman

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Date approved by Chairman: Jan 5, 1965

DEDICATED TO

MY FATHER

ROGER H. DICKINSON

(August 31, 1905 to January 1, 1964)

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SUMMARY

Whenever new or improved fibers are introduced, it is of interest to the textile scientist and the textile manufacturer to investigate these fibers from the following standpoints:

(a) The properties which the fiber possesses individually in its respective yarns and fabrics.

(b) The properties which the fiber possesses as a reinforcing and complementing fiber when used in combination with other established fibers.

It is this second point, that of blending new or improved fibers with established fibers, which is the subject of this investigation.

The high wet modulus rayons are a new class of fibers which have gained recognition. A literature survey was made to determine if these fibers had been used in blends with other established fibers. It was found that all of the high wet modulus rayons had been utilized extensively in blends with cotton and to some degree with polyesters. The possibility of blending with acrylics was mentioned, but actual information relating to yarn and fabric properties was not found.

Thus, an investigation was initiated to study blends of acrylics and the new high wet modulus rayons. As the properties of the acrylics and high wet modulus rayons of different fiber producers may vary widely, specific fibers were selected. Orlon, produced by DuPont, was selected as the acrylic, and Lirelle, produced by Courtaulds North America Inc., was selected as the high wet modulus rayon. The following

blend levels were produced:

100% Lirelle
75% Lirelle/25% Orlon
50% Lirelle/50% Orlon
25% Lirelle/75% Orlon
100% Orlon

A 20's cotton count singles yarn with a twist multiplier varying from 2.75 to 4.00 in 0.25 increments was produced on the cotton system giving a total of thirty yarns. Each of these yarns was woven across a standard warp.

In order to determine the effect of blend composition, the yarn was characterized by wet and dry single end breaking strength, elongation, modulus, and lea product; and skein breaking strength and lea product. The fabric was analyzed for breaking strength, tear strength, and flex abrasion.

The data were plotted and statistically analyzed by the computer to determine the accuracy.

The 100% Lirelle had the highest single end yarn strength, and additions of up to 75% Orlon caused a significant decrease in strength. The dry 100% Orlon yarns were third in strength, while the wet yarn was second.

Addition of up to 50% Orlon had no effect on the dry and wet elongation, while the elongation of the 75% and 100% Orlon yarns was significantly higher.

Dry and wet single end modulus assumed a progressively smaller value due to continuing additions of Orlon.

Addition of up to 75% Orlon effected a constant loss in skein strength, while the strength of the 100% Orlon was unusually low in relation to the value in the literature and was essentially the same as the 75% Orlon.

For the dry fabric tests, the 100% Lirelle was the strongest, and additions of up to 75% Orlon caused a continuing loss in strength. The 100% Orlon was second in strength.

The 100% Lirelle and 100% Orlon shared the high wet fabric strength, while the 50/50 and 25% Lirelle/75% Orlon shared the low strength.

An increase in twist caused the skein, single end, and fabric strengths, both wet and dry, to increase to a maximum and further increase in twist brought about a loss in strength. The point of maximum strength for each property was not the same for all blend levels.

Twist had a negligible effect on both wet and dry single end elongation and modulus.

The fabric tongue tear and flex abrasion tests were discontinued.

The work done in this investigation shows that the fibers are compatible in blends and the yarns have physical properties which are capable of producing fabrics which can compete in the market.

CHAPTER I

INTRODUCTION

Purpose of the Study

This investigation has as its object the determination of significant factors which influence the characteristics of yarns and fabrics made by blending acrylic fibers with a new high wet modulus rayon.

Scope of the Study

In scope, the research includes blends of 0%, 25%, 75%, and 100% of each fiber. Yarns are constructed at six different twist levels as expressed in twist multipliers. These are 2.75 to 4.00 in increments of 0.25. Each yarn is woven across a standard warp.

Limitations of the Study

As the properties of the acrylics and high wet modulus rayons of different fiber producers may vary over a wide range, and because the fiber produced by a specific producer may be available in several different types, the results of this investigation are limited to the specific fibers and types used.

Methods of Evaluation

The physical properties of the yarns and fabrics are characterized by selected tests. The data obtained are statistically analyzed on the Burroughs-220 computer.

Significance of Fiber Blending

Before the introduction of man-made fibers, blending of fibers of different types was a rarity. On the whole, these different natural fibers were incompatible, the divisions of the textile industry were clearly defined, and the blending of different natural fiber types was at a minimum.

Today, a diverse range of man-made fibers of widely different characteristics is available, and the possibilities for blending has increased significantly. A look at the advertisements in the daily newspaper and a glance at the apparel labels in the local store is dramatic proof of the emphasis which is being placed on blending by the textile industry.

The mixing of different fibers can be effected in various ways. The following are important examples (1):

(a) Blending of different staple fibers in the raw stock from which a staple fiber yarn is spun.

(b) Mixing of continuous filament yarns.

(c) Construction of multi-ply yarn from different spun single yarns.

(d) Core-spinning of staple fibers around a core yarn which may be a continuous filament yarn.

(e) Mixing of different yarns during knitting or weaving.

Of this list, the blending of different staple fibers in the raw stock is the method by which the predominance of the blended yarns and fabrics are produced. This type of blending involves the thorough mixing of two or more different fibers to produce an intimately blended yarn. The fiber combinations consists of natural and/or man-made fibers. After extensive experimentation with multi-component blends, the industry has tended to concentrate on bi-component blends.

Charnley (2) states that the usual explanation of the utilization of fiber blends is that no individual fiber is perfect and that perfection is more closely obtained by incorporating different fibers which have desirable properties.

By scientific and systematic selection of the fibers and utilization of the fibers in correct proportions, it is possible to produce yarns and fabrics which possess properties that are not obtainable when using either fiber alone. To accomplish this objective, the selected fibers must be compatible and, at the same time, be reinforcing. Some fibers combine simply, while others combine in a complex manner.

Thus, through blending it is possible to exploit to the maximum the outstanding characteristics of the fibers in the blend and yield a yarn or fabric with improved performance and greater consumer appeal (3).

In addition to producing a superior yarn or fabric, blending is of economic importance in that it allows the dilution of costly quality fibers with less expensive fibers (4). Again, by scientific and systematic selection of the less expensive fiber and its respective blend level, the desirable properties of the quality fiber can be maintained in yarns and fabrics, but at a reduced price.

Recognizing the advantages of blending, it can be realized that any new or improved fiber which is introduced is important not only for the properties which it individually possesses in its respective yarns and fabrics, but also as a possible reinforcing and complementing fiber when used in combination with other established fibers.

It is this second point, that of blending new or improved fibers with established fibers, which is the subject of this thesis investigation. The qualities of the established fiber, Orlon[1] acrylic and the new or improved fiber, Lirelle[2] high wet modulus rayon, and the basis for this study are discussed in some detail in the following section.

Orlon Acrylic Fiber

Acrylic fibers entered commercial production when E.I. duPont de Nemours and Co. began producing Orlon at its Camden, South Carolina, plant in 1950.

Orlon took its place as a new member of a small, but increasingly important group of fibers of truly synthetic nature (5). The discovery of nylon by Wallace H. Carothers and its subsequent introduction in 1939 marked the advent of textile fibers produced entirely from synthetic high polymers.

The early laboratory name for Orlon was Fiber A. Research by DuPont was initiated in the early 1940's, and the U.S. Government received samples in 1942 for consideration of possible military application. A semi-works was constructed for the fiber in 1945, and the Orlon trademark was announced by DuPont in 1948.

To make the fiber, single molecules of acrylonitrile ($CH_2{=}\underset{CN}{CH}$) are processed in a reactor containing water and a catalyst to produce polyacrylonitrile $(-CH_2-\underset{CN}{CH}-)_n$ (6). The mechanism is a free radical addition

1. Orlon is the registered trade-mark for E.I. duPont de Nemours and Co. acrylic fiber.

2. Lirelle is the registered trade-mark for Courtaulds North America Inc. high wet modulus rayon.

polymerization. The value of "n", the degree of polymerization, is about 2,000, corresponding to a molecular weight of about 100,000 (7).

Subsequent to the production of the polymer in the reactor, the water is removed, and the polymer pressed through perforated plates and cut into a shape resembling broken noodles. The noodles of polymer are dissolved in a suitable solvent, filtered, and extruded through a spinneret, which is a small, round metal plate with tiny holes. The extruded polymer is drawn down a long cell where it is exposed to hot gases for drying and simultaneously drawn. The drawing causes the long-chain molecules to undergo some degree of orientation (8).

The filaments from several cells are combined into a long rope. Several of these ropes are combined, drawn again in hot water, and mechanically crimped. The hot water drawing further orients the molecules, thus controlling the stretch and improving the strength of the fiber. Crimping is necessary to improve the cohesion of the fibers.

The product of the hot water drawing operation is called tow. The tow can be dried in its continuous form and packaged, or it can be cut, dried, baled, and marketed as staple.

Originally, Orlon was produced as continuous filament yarn, and, due to its dyeing problems, application was primarily in the industrial area. By co-polymerizing the acrylonitrile with about 10% of another constituent, the polymer chain was opened and dye receptive sites attached (9). Increasing the dye affinity enabled Orlon to enter and enjoy huge success in the apparel market.

Orlon is currently available in "acid dyeable" or "basic dyeable" staple and tow which can be high shrinkage (20%) or regular shrinkage (1-3%). The many combinations of denier, staple length, shrinkage, dye behavior, and finish, which are possible in the production of Orlon fiber greatly enhance its versatility and place it in an excellent competitive position in several markets.

The fiber is best known for its soft, luxurious hand. It is warm and pleasing to the touch. It has excellent resistance to deterioration by sunlight, soot, smoke, and acid fumes. These properties are essential for many industrial applications and uniform fabrics (10).

Besides having specific individual properties, Orlon shares many properties with nylon and polyester fibers. It is easy to care for, dries quickly, and resists mildew damage. Fabrics of Orlon are wrinkle resistant and are capable of being heat-set.(11).

Yarns and fabrics of Orlon, when appropriately constructed, have the ability to transfer moisture. The cross section is dog bone shaped (∞), and this surface irregularity, together with the physical properties of the fiber, permit a fabric of Orlon to wick moisture away from the body, allowing it to evaporate, thus contributing to body comfort (12).

By taking advantage of the differential shrinkage properties of the fiber, it is possible to produce a high bulk yarn by blending low and high shrinkage fibers. After production of the yarn, it is relaxed and the high shrinkage fibers go to the core of the yarn and cause the low shrinkage fibers to bulk to the outside. Fabrics made with high bulk Orlon provide spendid warmth because the ability of a fabric to keep one warm depends on its ability to entrap air.

In blended fabrics, the major contributions offered by Orlon are press retention, soft hand, and dimensional stability. When the percentages of Orlon are high, enough, texture and high bulk are also obtained.

Carpets produced from 100% Orlon have recently been introduced. This is further evidence of the many applications for the fiber. Orlon is now being produced in Camden, South Carolina; Waynesboro, Virginia; Maitland, Ontario; and Dordrecht, Holland.

The Orlon acrylic fiber has been on the market for only fifteen years and its growth has been marked. A continued expanding market is predicted for the fiber, thus yielding a bright future.

Lirelle High Wet Modulus Viscose Rayon Fiber

Two dedicated cellulose chemists, C.F. Cross and E.J. Bevan, discovered the process of marking viscose rayon yarn. Their work accomplished a much better understanding of the chemistry of cellulose. This process was discovered in 1891 and patented in 1892, but considerable time was necessary for establishment (13).

The greatest single factor in the development of the viscose process has undoubtedly been the support given to it by Courtaulds, Limited, although other viscose producers have naturally appeared. Courtaulds was a pioneer in that it not only founded and developed an important new industry, but also introduced it to this country under the name "The American Viscose Company". During World War II the company was purchased by American interests in order to provide dollars for Britain (14).

Viscose rayon is regenerated cellulose. Cellulose is the most abundant natural occurring long chain polymer, and it is possible to produce rayon fiber at a low cost.

(a) Wood is purified to yield pure cellulose.

(b) The cellulose is treated with a 17.5% solution of caustic soda to yield alkali cellulose.

$$\underset{\text{cellulose}}{(C_6H_{10}O_5)_n} + \underset{\text{caustic soda}}{n\ NaOH} \longrightarrow \underset{\text{soda cellulose}}{(C_6H_9O_4ONa)_n} + n\ H_2O$$

(c) The soda cellulose is treated with carbon disulfide which converts it to sodium cellulose xanthate.

$$\underset{\text{soda cellulose}}{(C_6H_9O_4ONa)_n} + nCS_2 \longrightarrow \underset{\text{sodium cellulose xanthate}}{(C_6H_9O_4OCS \cdot SNa)_n}$$

(d) The sodium cellulose xanthate is dissolved in dilute caustic soda to yield a solution of viscose.

(e) The solution is ripened for 4-5 days at 10-18 degrees centigrade.

(f) The ripened solution is extruded into a sulfuric acid bath which regenerates the cellulose in the form of long filaments. These are viscose rayon.

$$\underset{\text{sodium cellulose}}{(C_6H_9O_4OCS \cdot SNa)_n} + 1/2\ H_2SO_4 \longrightarrow \underset{\text{regenerated cellulose}}{(C_6H_{10}O_5)_n} + 1/2\ Na_2SO_4 + CS_2$$

(g) The rayon is marketed as continuous filament yarn or staple fiber.

Rayon possesses a versatility which has made it of great value to all phases of the textile industry, including apparel, household, and industrial uses. This versatility stems from the fact that rayon fibers can be tailored to meet specific requirements. Fiber formation occurs as a result of chemical reactions, as distinct from other synthetic fibers where molten polymer merely solidifies or a solvent is evaporated. By varying the way in which the viscose reactions proceed, the fine structure, and hence, the properties of rayon can be varied (14).

Through modification and better control of the viscose reactions, the rayon produced now is stronger, softer, more dyeable, drapes better, and produces more beautiful articles than the rayon of twenty to thirty years ago (15).

In spite of the improvements made in rayon, the fiber still possesses certain deficiencies which impair its competitive position in its own markets, and prevents expansion into new areas. Consequently research continuous with the aim of eleminating or alleviating the weaknesses of rayons.

Rayon has a low initial modulus when wet. Modulus is measured by the slope of the first part of the stress-strain curve, and is related to stiffness (resistance to elongation) of the fiber. This low wet modulus allows rayon fabrics to be extended easily during continuous dyeing and finishing operations. This deficiency makes it impossible to process these fabrics on continuous ranges in spite of the potential savings. It follows, therefore, that the satisfactory production of fabrics stable to laundering is almost impossible after dyeing on continuous machines (16).

Ordinary rayon swells to a gel of very low physical strength during the dilution phase of mercerization where the effective concentration of caustic soda passes through the peak of maximum swelling. This limits the practical use of rayon. It is restricted to rather low blend levels with cotton, and makes the mercerization of 100% rayon fabrics impossible (17).

Through extensive research and development, the rayon industry has endeavored to correct these limiting properties. The degree of polymerization and orientation of molecules of ordinary rayon is low in comparison with the natural cellulosic fibers. As these natural cellulosic fibers possess excellent resistance to extension when wet, research was directed towards increasing the degree of polymerization and orientation of rayon, while still maintaining the desirable textile properties of ordinary rayon.

When rayon is produced by the normal viscose process, the cellulose molecules are regenerated and crystallized in the unoriented state. The subsequent stretching of the fiber tends to align the crystalline regions, but this cannot endure for any degree of time without causing distortion in the amorphous regions and breaking chains which are already anchored in the crystalline region (18).

Superior results are obtained when the orientation of the long-chain molecules occurs before the cellulose is regenerated and can crystallize. As the molecules are already aligned, packing into regular crystalline lattices is facilitated, initiates at many more places, and yields a final structure which has a large number of small crystallites rather than fewer larger ones. The amorphous regions also tend to be more highly ordered due to the pre-orienting of the molecules, and, this, combined with finer texture, gives a greater resistance to extension (higher modulus) and better stability. As the total crystallinity is higher, the swelling is also reduced.

The initial successes in obtaining a rayon fiber with a higher degree of polymerization and orientation was produced by a method which deviated from the normal viscose process. The result was a fiber which was stronger, but highly inextensible and only had specialized industrial applications.

The first break-through was made by the late Schozo Tachikawa, president of the independent Tachikawa Research Institute in Japan. Research work which commenced in 1938 was first published in the literature in 1951 (19).

This new method used the usual viscose process as a basis. The sodium cellulose xanthate was caused to coagulate prior to regeneration without decomposition by extruding the normal viscose solution into a bath of low acid and salt concentration. These chemicals neutralized the caustic soda, but as it was not a strong acid, a pH was obtained which was high enough to prevent extensive regeneration of the cellulose. These coagulated filaments were then stretched prior to regeneration. Utilization of this process made it possible to produce rayon fibers which had a higher degree of polymerization and orientation and were still applicable for general textile purposes (20). A typical degree of polymerization for ordinary rayon was 250 to 300 while the rayon fiber produced by this new process was around 500 (21).

Other new rayons have resulted from Tachikawa's work. Courtaulds produces their new fibers SM-27 and SM-28 by a process which differs from the Tachikawa process, although the resulting fibers are similar. In spite of the difference in the process, it should be noted that in a paper presented at the Textile Research Institute Annual Meeting in March of 1962, G.V. Lund and J. Wharton of Courtaulds acknowledged that Tachikawa's work provided the clue for the development of SM-27 and SM-29 (22).

Courtaulds Limited again established manufacturing facilities in this country in the early 1950's when it opened a viscose rayon plant in Mobile, Alabama. The company is called Courtaulds North America, Inc. and has steadily increased its market position here.

Recently, Courtaulds North America, Inc. announced a further improved rayon called W-63. When this fiber is used in fabrics which have been approved by a Courtaulds' technical panel, the fiber is known as Lirelle (23).

Lirelle is produced by a process similar to SM-27 and SM-28, but certain manufacturing refinements have yielded an improved fiber.

Probably the most important characteristic of this new rayon is the higher modulus. There is an increase in the dry modulus, but the considerable increase in wet modulus is responsible for Lirelle and other similar new rayons being designated as "high wet modulus rayons".

It should be emphasized at this point that although there are numerous commercial high wet modulus staples produced throughout the world, there are great differences in the fiber properties. All of these fibers have a higher modulus and increased strength, but the actual values vary over a wide range. Consequently, statements which apply to Lirelle are not necessarily applicable to competitive fibers (24).

In addition to drastically increasing the wet modulus of rayon, Lirelle possesses the following additional improvements (25):

(a) Increased wet and dry strengths

(b) Lower wet and dry extensibility

(c) Low water imbibition[1]

(d) Good resistance to caustic soda

Lirelle combines most of the desirable properties of rayon and cotton while essentially eliminating the shortcomings of both. The new fiber has the dimensional stability and good wearing qualities of the natural cellulosic fiber and also has the uniformity of a manufactured fiber.

The following table compares some of the physical properties of Lirelle, cotton, and ordinary rayon fiber:

Table 1. Comparative Physical Properties of Ordinary Rayon, Cotton, and Lirelle (26)

	Rayon	Cotton	Lirelle
Tenacity (grams per denier)			
Dry	2.5	2 to 3	5.1
Wet	1.4	2.25 to 3.25	4.0
Breaking Elongation (per cent)			
Dry	18	5 to 7	6.5
Wet	24	6 to 8	7.0
Modulus[2] (grams per denier)			
Dry	1.0	1.75 to 2.0	4.5
Wet	0.5	1.50 to 1.75	2.7

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1. Water imbibition is defined as the percentage weight of water retained after wetting and centrifuging at 1000 grams for five minutes (based on the bone dry weight of fiber).

2. Modulus is defined as the stress expressed in grams per denier at 5 per cent elongation.

When Lirelle is woven into fabrics of proper construction, the following fabric performance is realized (27):

(a) Better dimensional stability, even after repeated washings.

(b) More luxurious handling.

(c) Capabilities for compressive shrinkage.

(d) Improved crease recovery with reduced resin contents.

(e) Good crease recovery angles without sacrificing tensile and tear strengths.

There is no truly all purpose fiber. However, rayon staple is the most versatile man-made fiber which is at present available in volume. An investigation of the range of end uses for which rayon is utilized is strong evidence of its versatility. Thus, a fiber such as Lirelle, which possess most of the advantages of ordinary rayon, but has a high wet and dry modulus, and good resistance to caustic, will be able to enter markets previously closed to rayon.

Survey of the Literature and Statement of the Problem

Whenever new or improved fibers are introduced, it is of interest to the textile scientist and the textile manufacturer to investigate these fibers from the following standpoints:

(a) The properties which the fiber possesses individually in its respective yarns and fabrics.

(b) The properties which the fiber possesses as a reinforcing and complementing fiber when used in combination with other established fibers.

The high wet modulus rayons are a new class of fibers which have gained recognition. They possess certain individual properties discussed previously.

A literature survey was made to determine if these fibers had been used in blends with established fibers. It was found that all of the high wet modulus fibers have been investigated in blends with cotton. Specific blend levels along with the processing conditions for each fiber have been published in their respective technical information media (28 (29) (30).

Regarding past and future possibilities of blending with other established fibers, Courtaulds (31) states that while the emphasis on Lirelle thus far has been in cotton blends, it is quite likely that blends of Lirelle and other man-made fibers will ultimately be developed.

Regan (32) of American Enka Corporation states that blends of Zantrel[1] with polyesters, acrylics, and other synthetics are beginning to find acceptance. He further shows yarn strength graphs of polyester and Zantrel blends and discusses these blends (33). Other than mentioning the possibility of blending with acrylics, information on acrylic/Zantrel blends was not found.

A similiar situation exists in the literature published by American Viscose Corporation (34) where it is stated that Avril[2] is capable of being blended with polyesters, acrylics, and triacetates. Blends of Avril/polyester are treated extensively, but no recommendations on Avril/acrylic blend proportions appear.

Thus, all of the United States producers have investigated their respective high wet modulus rayon fibers in blends with cotton while two of the producers have conducted investigations with polyesters. Each mentioned the possibility of blending with acrylics, but have not

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1. Zantrel is the registered trademark for American Enka Corporation's high wet modulus rayon fiber.

2. Avril is American Viscose Corporation's registered trademark for its high wet modulus rayon fiber.

published any information relating to yarn and fabric properties at different blend levels.

A literature survey of information other than that published by the rayon fiber producers indicated that a minimum amount of information was available on acrylic/high wet modulus rayon blends. The North Carolina State School of Textiles (35) published a pamphlet entitled "Literature Survey of Fiber Blending for the Years 1952-1963", and this survey did not cite any information on acrylic/high wet modulus rayon blends. This is further evidence of the paucity of information which is currently available on these blends[1].

Acrylic fibers have been used extensively as a blend fiber. As Orlon was the first acrylic fiber and has continued to maintain a leading position, most of the blend investigations with acrylic fibers involved Orlon. Quig (36) studied Orlon in blends with wool, cotton, and rayon in 1953. Sayre (37) investigated Orlon in bicomponent and tri-component blends with ordinary viscose rayon, nylon, wool, acetate, and Dacron[2] in 1955, while Goodwin and Nair (38) also studied blends of Orlon/cotton yarns in 1957. "The most prominent contribution of Orlon as a blend fiber was added bulk, dimensional stability, better press retention, and melt resistance" (39).

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1. The literature survey for this investigation was conducted from April to June of 1964. In November of 1964, DuPont published a Technical Bulletin on blends of Orlon acrylic fiber and Avril high wet modulus rayon (40).

2. Dacron is the registered trademark for E.I. duPont de Nemours and Co., Inc., polyester fiber.

Thus, acrylic fibers have been investigated thoroughly in blends with all of the established fibers. Blends of acrylics with these fibers are very prevalent on the market today.

Because acrylics have been proven as an excellent blend fiber, and specific information was not available in the literature on blends of acrylic fibers and the new high wet modulus rayons, an investigation of blends of these fibers are initiated. As the acrylics and high wet modulus rayons of each different fiber manufacturer may have widely different properties, a specific acrylic and high wet modulus fiber was selected for this study. It was decided to use Orlon acrylic fiber and Lirelle high wet modulus rayon fiber.

The blend levels selected were:

(a) 100% Lirelle

(b) 75% Lirelle/25% Orlon

(c) 50% Lirelle/50% Orlon

(d) 25% Lirelle/75% Orlon

(e) 100% Orlon

A 20's cotton count singles yarn with a twist multiplier varying from 2.75 to 4.00 in 0.25 increments was produced on the cotton system giving a total of thirty different yarn samples. Each yarn sample was woven across a standard warp. In order to determine the effect of blend composition, the yarn and fabric was characterized by specific physical tests to provide data for statistical analysis and comparison.

CHAPTER II

INSTRUMENTATION AND EQUIPMENT

Raw Materials Used

The raw materials used in this investigation were Lirelle high wet modulus rayon staple and Type 72 Orlon acrylic staple.

The Lirelle was 1½ denier and 1 9/16 inches staple length. The luster was bright.

The Orlon was 1½ denier and 1½ inches staple length. The luster was semi-dull.

The data on the wet and dry tenacity, elongation, and modulus for each fiber are contained in Table 16 a, b.

Processing Equipment

The following processing equipment was used in this investigation:

(a) Saco-Lowell Picker, Model F-5

(b) Whitin 40 inch Flat Top Card, Model H, Metallic Wire Clothing

(c) Saco-Lowell Drawing Frame, Model DS-1, Three Over Four Drafting System

(d) Whitin Superdraft Roving Frame, Model GC 10, 9 x 4½

(e) Saco-Lowell Z-5 Spinning Frame

(f) Foster Coner - Model 102

(g) Leesona "Unifil" Bobbin Winder

(h) Hunt Cam Loom, Single Shuttle

Testing Equipment

The following testing equipment was used in this work:

(a) Instron Tensile Tester - Floor Model

(b) Scott Pendulum Tester

(c) Shadograph Cotton Count Determinator

(d) Stoll Abrasion Tester

(e) Browne and Sharpe Hand Skein Winder - 1½ Yard Circumference

(f) Uster Evenness Tester

CHAPTER III

PROCEDURE

Processing of Blended Yarns

The sequence of operations used in producing the blends of Orlon acrylic fiber and Lirelle high wet modulus rayon is displayed in the flow chart in Figure 1. All blend levels were processed on the same equipment. All processes were carried out under controlled conditions of 55 per cent relative humidity and 74 degrees Fahrenheit.

The yarn was produced in the Textile Laboratory of the Textile Research and Development Division of Courtaulds North America, Inc. in Mobile, Alabama. The organization of weights and drafts is shown in Table 2.

To produce the desired blend levels, the following poundages of fibers were individually hand-blended prior to the picking operation:

(a) 60 pounds of Lirelle - 100% Lirelle Blend

(b) 45 pounds of Lirelle and 15 pounds of Orlon - 75% Lirelle/25% Orlon Blend

(c) 30 pounds of Lirelle and 30 pounds of Orlon - 50% Lirelle/50% Orlon Blend

(d) 15 pounds of Lirelle and 45 pounds of Orlon - 25% Lirelle/75% Orlon Blend

(e) 60 pounds of Orlon - 100% Orlon Blend

These hand-blended fibers were processed through a Saco-Lowell picker involving the following operations:

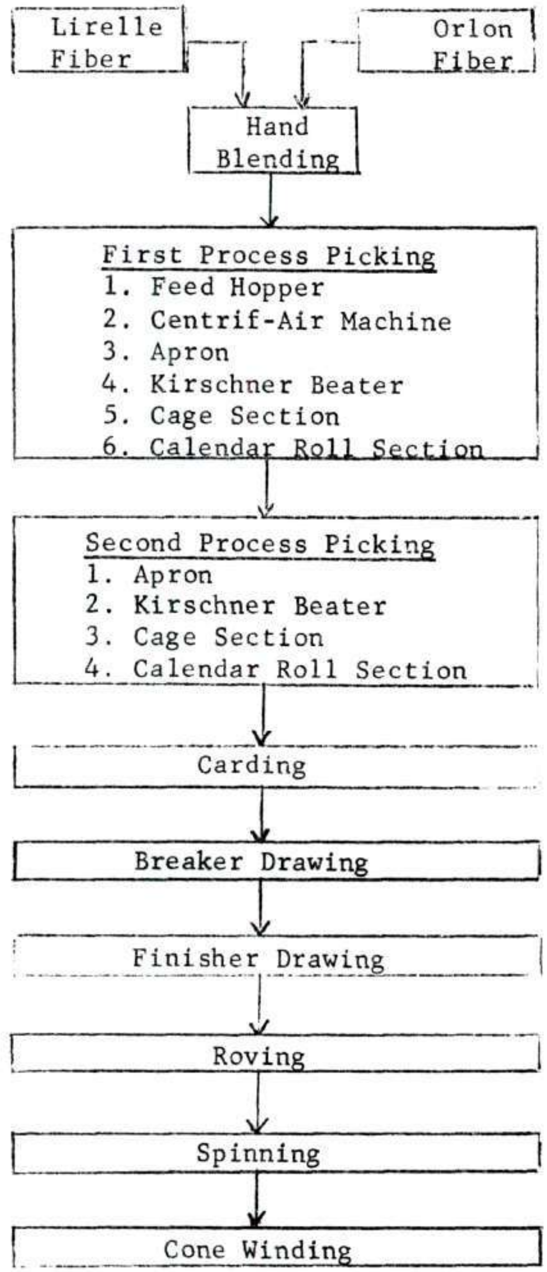

Figure 1. Sequence of Operations for Production of Lirelle/Orlon Blend

Table 2. Organization of Weights and Drafts

	Weight of Material Fed	Weight of Material Delivered	Number of Doublings	Actual Draft
Picking		14 ozs/yd		
Carding	14 ozs/yd	55 grs/yd	1	111.4
Breaker Drawing	55 grs/yd	55 grs/yd	8	8
Finisher Drawing	55 grs/yd	55 grs/yd	8	8
Roving	55 grs/yd	1.80 hank	1	11.9
Spinning	1.80 hank	20's cotton count	2	11.1

(a) Feed Hopper

(b) Centrif-Air Machine

(c) Apron

(d) Kirschner Beater at 900 rpm

(e) Cage Section

(f) Calendar Roll Section

Three picker laps from this picking process were then placed on the apron (c) and a second pass was made through sections d, e, and f as indicated above. A final lap weight of 14 ounces per yard was produced.

These picker laps were processed on a Whitin 40 inch flat top card clothed with metallic wire. A 55 grain sliver was produced at a rate of 12 pounds per hour.

Eight ends of the 55 grain card sliver were processed through a Saco-Lowell DS-1 drawing frame to produce a 55 grain breaker drawing sliver. The drawing speed was 174 feet per minute, and a three rolls over four rolls drafting system was used.

Finisher drawing was identical to breaker drawing.

Using a Whiten Superdraft C-4 GC10 roving frame, a 1.80 hank roving was produced. The spindle speed was 940 rpm; the front roll diameter was 1 3/8 inches and had a J-490 roll covering.

Yarn having a cotton count of 20/1 was spun on a Saco-Lowell Z-5 spinning frame from doubled roving. Each blend level was spun with the following series of twist multipliers:

(a) 2.75 Twist Multiplier

(b) 3.00 Twist Multiplier

(c) 3.25 Twist Multiplier

(d) 3.50 Twist Multiplier

(e) 3.75 Twist Multiplier

(f) 4.00 Twist Multiplier

The total yarn prepared consisted of five different blend levels of Orlon and Lirelle, each with six different twist multipliers. Thus, the investigation was characterized by thirty different yarns.

For each test, the spun yarn was wound on cones. A Foster Coner, Model 102, was used, and a total of five cones was wound for each test.

Fabric Preparation

Five different filling bobbins from each test were wound on the Unifil bobbin winder. The test filling was woven across a standard 20/1 cotton warp. The weave was a 2/1 twill which contained 64 ends per inch and 74 picks per inch. The fabric width was 40 inches.

As there were thirty different yarn samples, thirty different fabric samples were woven.

Yarn Physical Tests

All of the physical tests were conducted under the standard atmospheric conditions of 70 degrees Fahrenheit and 65 per cent relative humidity. The samples were conditioned for at least twenty-four hours prior to testing.

Tests for Wet and Dry Breaking Strength, Elongation, and Modulus of Yarn

The determination of the wet and dry breaking strength, elongation, and modulus of yarn was done on the Instron Tensile Strength Tester. The Instron is an electronic loading instrument which imparts an extremely accurate pre-determined rate of extension on the sample being tested. Through suitable mechanisms and controls, the continuing combination of load and elongation is transmitted to a chart which is also moving at a pre-determined rate of speed. Thus a stress-strain diagram of the sample is recorded and through suitable calculations, the breaking strength, elongation, and modulus can be calculated. The Instron was equipped with pneumatic air jaws, thus assuring a constant jaw pressure on each test.

For each different yarn sample, ten wet and dry tests were made. The ten tests consisted of two samples from each of the five cones. Several yards were reeled off between tests on an individual cone to insure that a different portion of the yarn was being tested.

The preparation of the wet samples required special technique. To insure that untwisting of the yarn did not occur during wetting-out, the yarn sample to be tested was very carefully wound by hand on to a filling bobbin and submerged in room temperature distilled water for thirty minutes. When the sample was ready for testing, the loose yarn end was held in the Instron upper jaw and sufficient length was unwound slowly off the side of the bobbin in order to hold untwisting to a minimum. While still maintaining a light tension, the yarn was clamped in the bottom jaw. The sample was then ready for testing.

From the individual chart for each sample, the breaking strength in pounds, the per cent elongation, and modulus were determined. The modulus measured was in reality a relative modulus. Fiber tensile modulus is defined as the ratio of fiber stress to the resultant fiber extension. If the fiber stress-strain is linear, the modulus would be constant for any extension. Few, if any, textile yarn stress-strain diagrams are linear. Consequently, it was decided to use the stress in grams per denier at five percent extension as a relative measure of the modulus. Thus, the relative modulus was calculated by determining the stress at five per cent elongation in grams and dividing by the denier of the yarn tested. The denier was determined by converting the average cotton count of ten 120 yard skeins to denier.

Using the average single end breaking strength, a single end lea product was calculated by multiplying the average breaking strength in ounces by the average cotton count of ten 120 yard skeins.

The operating data for the yarn tests on the Instron are contained in Table 17.

Tests for Breaking Strength and Cotton Count Determination of the 120 Yard Skein

The determination of the breaking strength of the 120 yard skein was done on the Scott Pendulum Tester. This instrument has an upper jaw which is attached by means of a chain and sprocket to a pendulum. As the bottom jaw is pulled downward the force is transmitted through the specimen and causes the chain and sprocket to rotate the pendulum outward and upward. When the specimen breaks, the pendulum stops, and the breaking strength is read from a dial calibrated directly as a function of the pendulum position.

Pendulum testers are called "constant rate of traverse" machines. While the lower pulling jaw does move downward at a constant speed, the instrument itself neither loads nor extends the specimen at a constant rate. This is because as the load is applied to the specimen, the sprocket-chain arrangement causes the upper jaw to feed downward as the pendulum extends and rises. When the specimen is highly deformable and considerable elongation results at low loads, such as Orlon, the upper jaw does not feed downward as rapidly as it does when the specimen has lower extensibility. The amount and rate at which the upper jaw feeds down vaires, depending on the load-elongation properties of the test specimen. Thus, the specimen is neither loaded nor extended at a constant rate, nor does failure occur within a constant time period.

In spite of the aforementioned disadvantages of this machine, it is used in predominance in the textile industry for measuring skein breaking strength. As an attachment for breaking skeins was not available for the Instron, the skeins were broken on the pendulum tester.

Using the hand skein winder, ten 120 yard skeins were prepared for each yarn sample. The ten skeins consisted of two skeins from each of five cones.

These skeins were broken on the Scott Pendulum Tester and the cotton count of the skein determined on the Shadograph. The Shadograph is an instrument which reads the cotton count directly.

The lea product for each skein was calculated by multiplying the breaking strength in pounds times its respective cotton count.

Fabric Physical Tests

All of the tests were conditioned under the standard atmospheric conditions of 70 degrees Fahrenheit and 65 per cent relative humidity. The samples were conditioned for at least 24 hours prior to testing.

Grab Test for Wet and Dry Fabric Breaking Strength

In accordance with U.S. Government Specification CCC-T-191-b, Method 5100, twenty 3 inch by 6 inch fabric samples were prepared for each different test fabric. The six inch dimension was in the filling direction as these were the yarn which were tested.

Ten of the fabric samples were broken dry on the Instron. The other ten samples were wet-out in room temperature distilled water for thirty minutes and then broken on the Instron. The Instron operating data for these tests are displayed in Table 17.

Tongue Tear and Flex Abrasion Fabric Tests

The tongue tear and flex abrasion tests were discontinued due to highly inconsistent results.

Analyses of Data

Ten determinations were made for each physical test. All of the analysis of data was performed on the Burroughs-220 Computer in the Rich Electronic Computer Center at Georgia Institute of Technology.

Each set of numbers was averaged, and the variation within the mean was indicated by the coefficient of variation and the standard deviation of the mean.

The percent coefficient of variation is equal to the standard deviation (s) divided by the mean ($\bar{X}$) expressed as a percentage. The standard deviation is defined as the square root of the average squared deviation from the mean; i.e.

$$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n - 1}}$$

The standard deviation of the mean ($s_{\bar{X}}$) is equal to the standard deviation (s) divided by the square root of the number of observations ($\sqrt{n}$).

CHAPTER IV

DISCUSSION OF RESULTS

Yarn Results

Before beginning a discussion of the results, it should be realized that certain inconsistencies in results can occur due to the small poundages of the yarn samples used for this investigation.

The raw data for all yarn tests are found in Table 20 through Table 49 .

Dry Single End Breaking Strength and Lea Product

A summary of the yarn dry single end breaking strength and lea product is listed in Table 3. The per cent coefficient of variation and the standard deviation of the mean for the breaking strength also appear in Table 3. Figure 2a, b graphically represents the single end lea product. It should be stressed that the single end lea product is the product of the average breaking strength in ounces and the cotton count, therefore, is a measure of yarn strength.

Referring to Figure 2a, it can be seen that there is a significant difference in the lea products of the five blend levels. Treating each blend level individually, it is possible to observe the effect of twist. The strength for each level increases to a maximum with increasing twist, and a further increase in twist causes a decrease in strength. This point of maximum strength is not the same for all blend levels.

Referring to Figure 2b, it can be shown that when up to 75% Orlon is added to Lirelle, the yarn strength decreases in a direct proportion

Table 3. Summary of Yarn Dry Single End Breaking Strength and Lea Product

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Breaking Strength (lbs.)	1.43	1.30	1.01	0.86	1.16
Per Cent Coefficient of Variation	7.68	4.21	6.18	8.38	10.6
Standard Deviation of the Mean	0.034	0.017	0.019	0.021	0.039
Lea Product	447	413	330	274	369
3.00 TM					
Mean Breaking Strength (lbs.)	1.44	1.34	1.03	0.94	1.23
Per Cent Coefficient of Variation	6.89	4.58	8.23	6.39	6.55
Standard Deviation of the Mean	0.031	0.019	0.027	0.019	0.025
Lea Product	443	425	324	291	378
3.25 TM					
Mean Breaking Strength (lbs.)	1.47	1.34	1.06	0.94	1.22
Per Cent Coefficient of Variation	5.78	6.54	4.22	7.97	5.73
Standard Deviation of the Mean	0.027	0.028	0.014	0.024	0.022
Lea Product	458	428	340	297	378
3.50 TM					
Mean Breaking Strength (lbs.)	1.53	1.27	1.07	0.94	1.24
Per Cent Coefficient of Variation	5.24	3.80	5.59	6.35	6.19
Standard Deviation of the Mean	0.025	0.015	0.019	0.019	0.024
Lea Product	481	401	337	300	387
3.75 TM					
Mean Breaking Strength (lbs.)	1.43	1.27	1.01	0.95	1.17
Per Cent Coefficient of Variation	5.87	4.93	5.78	6.33	7.27
Standard Deviation of the Mean	0.026	0.019	0.018	0.019	0.027
Lea Product	433	394	306	294	362
4.00 TM					
Mean Breaking Strength (lbs.)	1.40	1.28	1.02	0.90	1.15
Per Cent Coefficient of Variation	7.06	5.24	6.40	8.06	6.06
Standard Deviation of the Mean	0.03	0.02	0.02	0.023	0.022
Lea Product	424	394	316	274	353

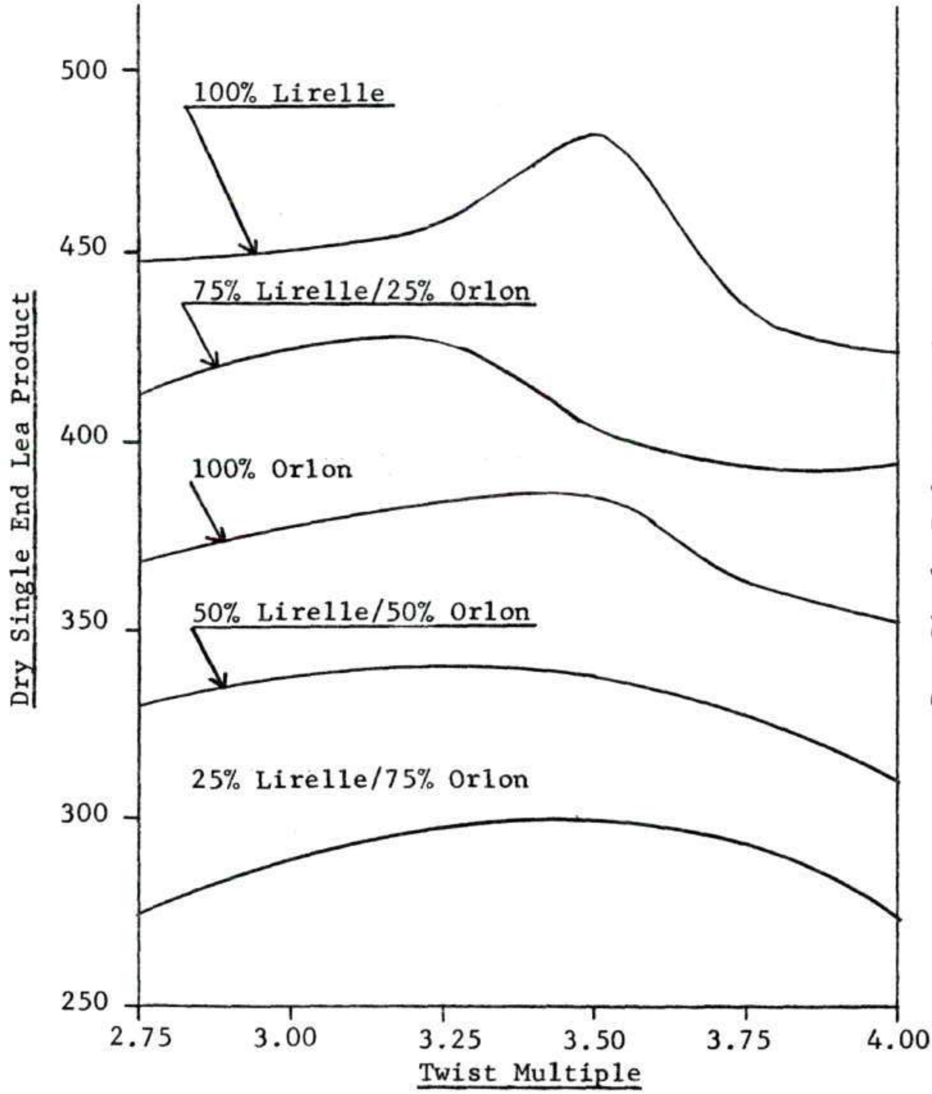

Figure 2a. The Effect of Twist Multiple on Dry Single End Lea Product

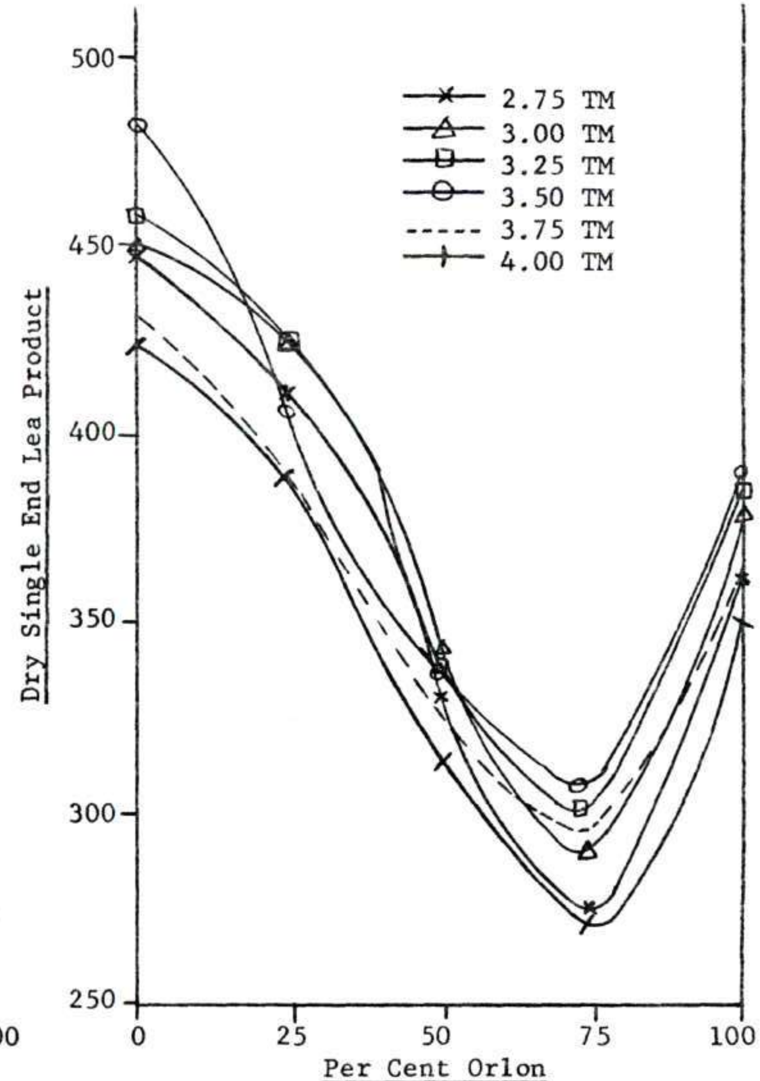

Figure 2b. The Effect of Blend Level on Dry Single End Lea Product

to the percentage of Orlon. This is anticipated because Orlon has a lower fiber tenacity, and it might be further predicted that this decrease in strength would occur in a linear fashion between the strength of 100% Lirelle and 100% Orlon. Figure 2b clearly contradicts this latter hypothesis since the strength of the 25%, 50%, and 75% Orlon blends are considerably below any such line. In fact, the strengths of the 50% and 75% Orlon blends are significantly less than the strength of 100% Orlon.

This phenomenon can be accounted for by referring to the average stress-strain diagrams of 100% Orlon and 100% Lirelle yarns. A twist multiplier of 3.50 is selected for illustration and the diagram is shown below:

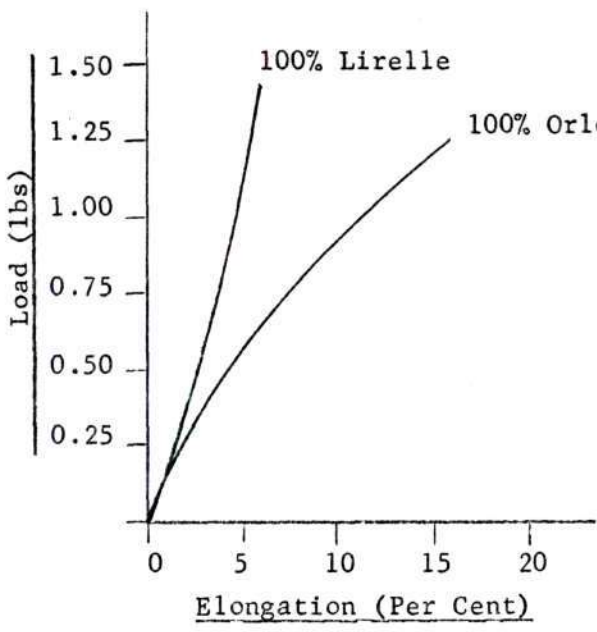

Figure 3. Stress-Strain Diagram of 100% Lirelle - 3.50 TM and 100% Orlon - 3.50 TM, 20's yarn

The breaking elongation is 6.2 per cent for Lirelle and 16.8 per cent for Orlon. Referring to Table 5, the breaking elongation of 50% Lirelle/50% Orlon - 3.50 TM is found to be 6.0 per cent. Thus, when this yarn breaks, Lirelle is contributing almost 100% of its available strength while Orlon is only contributing a fraction of its potential strength. Referring to Figure 3, the stress of Orlon at 6.0 per cent elongation is 0.65 pounds. Hence, in the 50/50 blend, the strength contributed by Orlon is 50 per cent of 0.65 pounds or 0.325 pounds, and by Lirelle is 50 per cent of 1.43 pounds, i.e., 0.715 pounds. By this reasoning the breaking strength of the 50/50 - 3.50 TM yarn should be 0.325 plus 0.715 or 1.04 pounds, and referring to Table 3, it can be seen that the actual value measured in this investigation was 1.07 pounds. Thus, the differences in the stress-strain behavior of the Orlon and Lirelle may well account for the low strengths of the 25%, 50%, and 75% Orlon yarns.

Wet Single End Breaking Strength and Lea Product

A summary of the yarn wet single end breaking strength and lea product is listed in Table 4. The per cent coefficient of variation and the standard deviation of the mean for the breaking strength also appear in Table 4. Figure 4a, b graphically represents the single end lea product.

Referring to Figure 4a, it can be seen that, as with the dry tests, there is a difference in the lea product for the five blend levels. Twist also has a similar effect in that each blend level exhibits a maximum strength with increasing twist.

Referring to Figures 2a and 4a, it can be shown that while the 100% Orlon is the third in strength for the dry tests, it is second in

Table 4. Summary of Yarn Wet Single End Breaking Strength and Lea Product

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Breaking Strength (lbs.)	1.17	1.00	0.83	0.78	1.03
Per Cent Coefficient of Variation	9.85	4.67	7.99	9.75	4.58
Standard Deviation of the Mean	0.036	0.014	0.021	0.024	0.015
Lea Product	366	317	272	249	328
3.00 TM					
Mean Breaking Strength (lbs.)	1.21	1.04	0.89	0.82	1.08
Per Cent Coefficient of Variation	4.07	7.54	5.11	6.46	8.04
Standard Deviation of the Mean	0.016	0.025	0.014	0.016	0.027
Lea Product	372	330	280	254	332
3.25 TM					
Mean Breaking Strength (lbs.)	1.25	1.04	0.88	0.82	1.07
Per Cent Coefficient of Variation	5.21	6.36	7.20	6.29	9.94
Standard Deviation of the Mean	0.021	0.020	0.020	0.016	0.033
Lea Product	389	332	282	259	331
3.50 TM					
Mean Breaking Strength (lbs.)	1.28	1.00	0.88	0.86	1.07
Per Cent Coefficient of Variation	3.93	5.02	5.99	6.01	5.89
Standard Deviation of the Mean	0.016	0.016	0.017	0.016	0.020
Lea Product	403	316	278	274	334
3.75 TM					
Mean Breaking Strength (lbs.)	1.21	1.00	0.89	0.80	1.04
Per Cent Coefficient of Variation	5.87	3.93	6.80	9.12	7.44
Standard Deviation of the Mean	0.022	0.012	0.019	0.023	0.025
Lea Product	366	310	270	248	322
4.00 TM					
Mean Breaking Strength (lbs.)	1.15	0.99	0.85	0.78	1.06
Per Cent Coefficient of Variation	4.72	4.65	3.82	8.21	7.07
Standard Deviation of the Mean	0.017	0.015	0.010	0.020	0.024
Lea Product	349	305	264	228	325

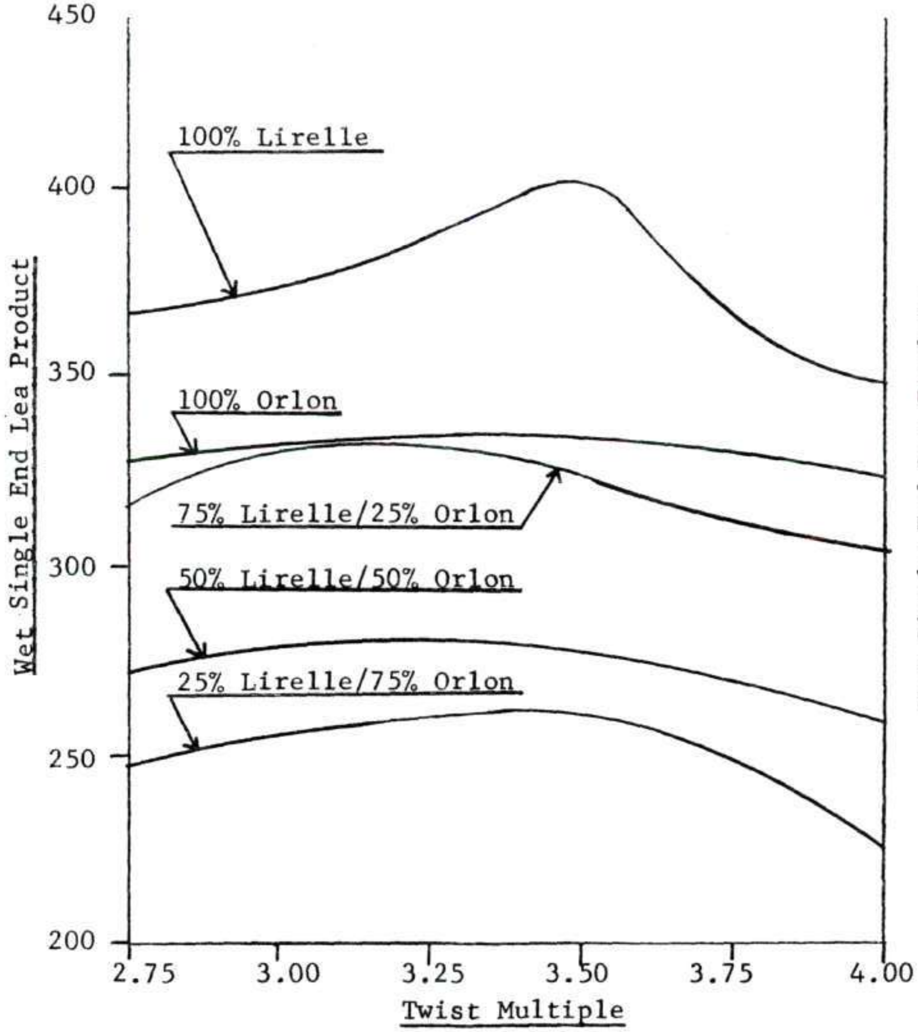

Figure 4a. Effect of Twist Multiple on Wet Single End Lea Product

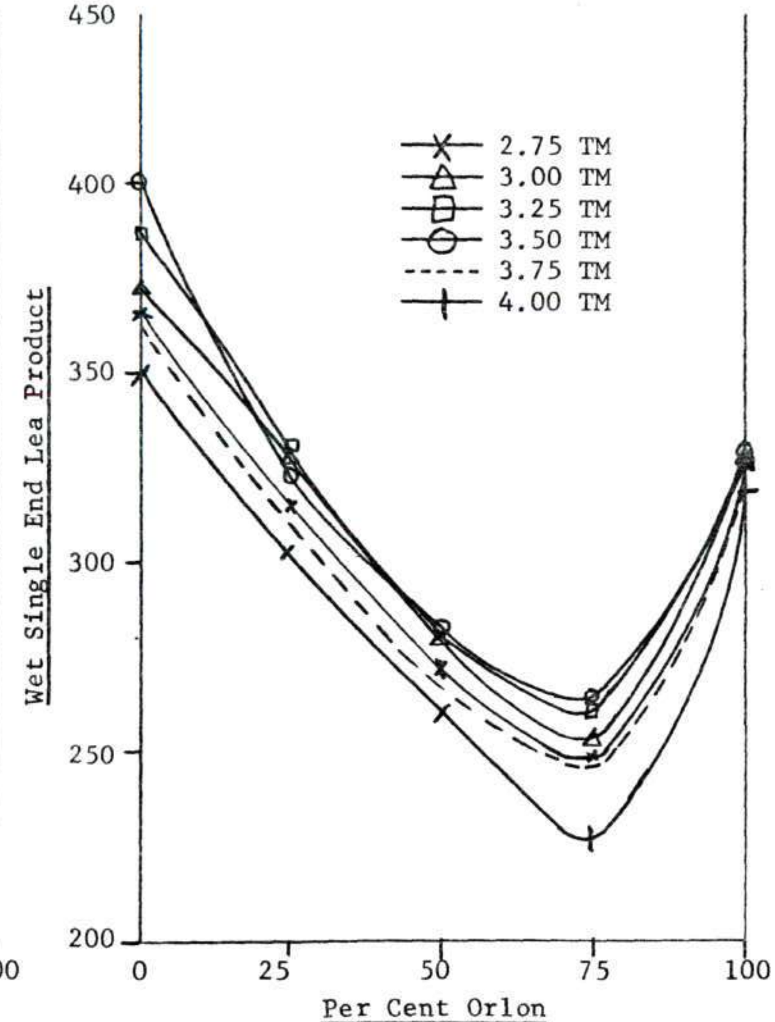

Figure 4b. Effect of Blend Level on Wet Single End Lea Product

strength for the wet tests. Table 9 expresses the wet lea product as a percentage of the dry, and Orlon has a range of 86.3 to 92.1 per cent while 75% Lirelle/25% Orlon has a range of 76.9 to 78.7 per cent. This accounts for the Orlon yarn assuming a higher wet strength than the 75% Lirelle/25% Orlon while having a lower dry strength.

Dry Single End Elongation at the Break

A summary of the yarn dry single end elongation at the break is listed in Table 5. The per cent coefficient of variation and the standard deviation of the mean for the elongation at the break also appear in Table 5. Figure 5a, b graphically represents the elongation at the break.

Referring to Figure 5a, it is shown that the elongation at break of the 100% Lirelle, 75% Lirelle/25% Orlon, and 50% Lirelle/75% Orlon blends is at the same level. The 25% Lirelle/75% Orlon blend has a significantly higher elongation at break. The elongation at break of the 100% is the highest, and it is significantly greater than the 25% Lirelle/75% Orlon.

Referring to Figure 5b, it can be seen that the addition of up to 50% Orlon has no effect on the elongation at break. Addition of 75% Orlon causes a significant increase in the elongation at break. Because the Orlon yarn has an elongation at break which is about three-fold that of the Lirelle yarn, it might be theorized that additions of Orlon to Lirelle would yield a yarn with a higher elongation at break; however, it was previously stated that additions of up to 50% Orlon has no effect on the breaking elongation.

By referring to the stress-strain diagram (Figure 3) of the 100%

Table 5. Summary of Yarn Dry Single End Elongation at the Break

	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Per Cent Elongation	5.9	5.9	5.5	10.0	15.8
Per Cent Coefficient of Variation	7.68	4.99	6.52	10.61	14.53
Standard Deviation of the Mean	0.10	0.92	0.20	0.34	0.72
3.00 TM					
Mean Per Cent Elongation	5.9	5.7	5.4	11.5	16.7
Per Cent Coefficient of Variation	7.95	4.29	7.83	8.71	12.00
Standard Deviation of the Mean	0.14	0.08	0.25	0.32	0.55
3.25 TM					
Mean Per Cent Elongation	6.2	6.1	5.5	11.2	16.8
Per Cent Coefficient of Variation	5.62	3.13	5.83	12.46	8.12
Standard Deviation of the Mean	0.11	0.06	0.10	0.44	0.43
3.50 TM					
Mean Per Cent Elongation	6.2	5.6	6.0	10.5	17.4
Per Cent Coefficient of Variation	8.97	4.8	10.6	13.68	8.33
Standard Deviation of the Mean	0.17	0.10	0.20	0.45	0.46
3.75 TM					
Mean Per Cent Elongation	6.2	5.9	5.6	10.2	17.3
Per Cent Coefficient of Variation	8.97	4.81	10.2	10.73	11.58
Standard Deviation of the Mean	0.17	0.90	0.18	0.35	0.63
4.00 TM					
Mean Per Cent Elongation	6.3	6.1	5.8	9.8	16.8
Per Cent Coefficient of Variation	7.29	7.36	6.05	17.81	4.26
Standard Deviation of the Mean	0.15	0.14	0.11	0.55	0.22

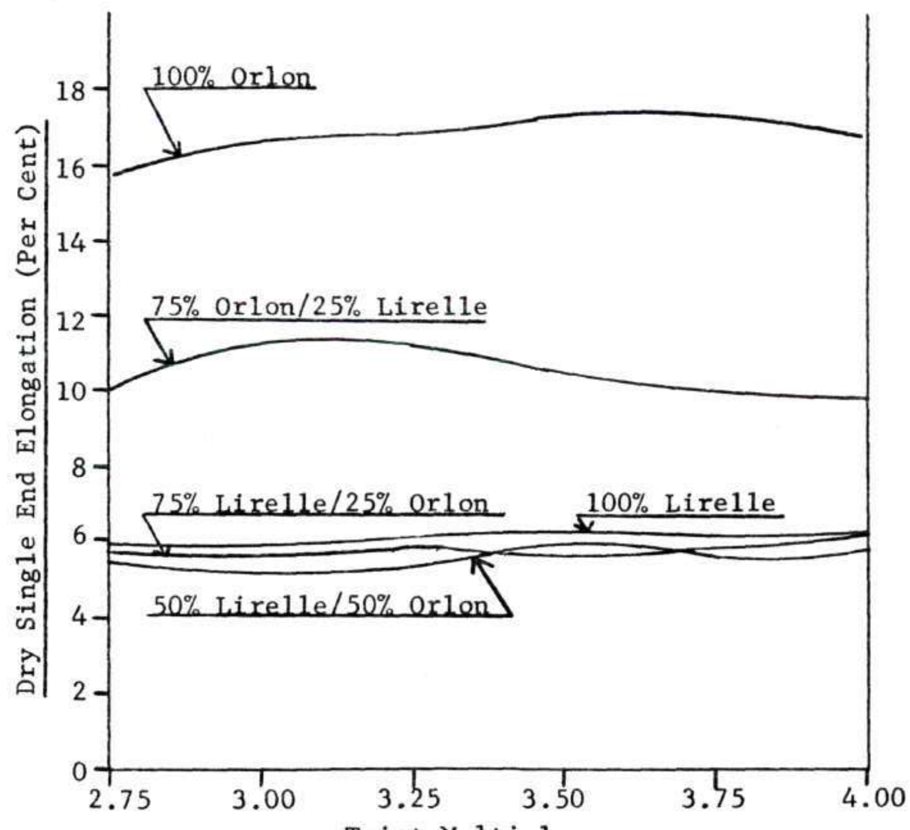

Figure 5a. Effect of Twist Multiple on Dry Single End Elongation at the Break

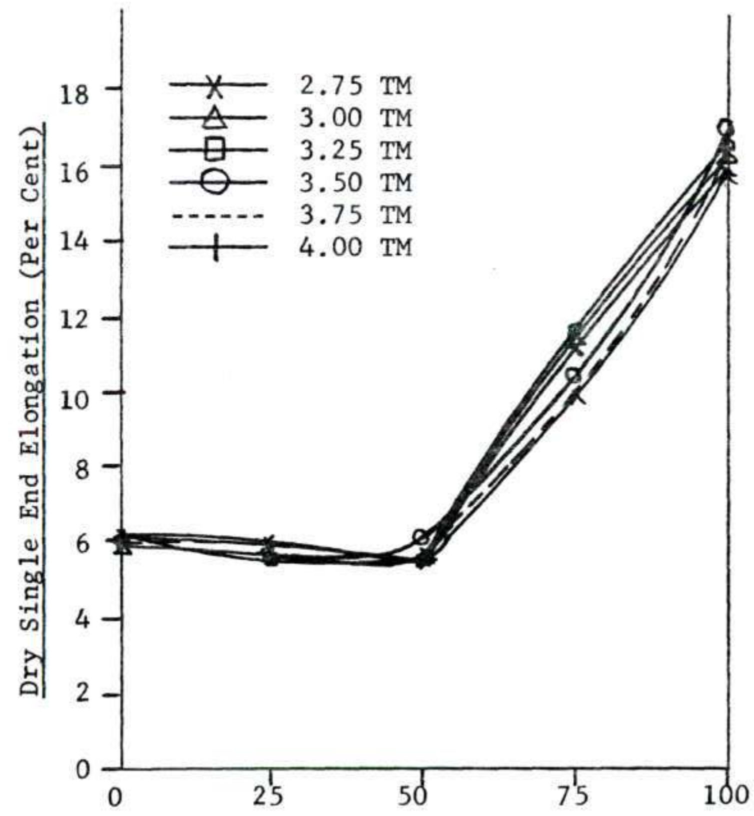

Figure 5b. Effect of Blend Level on Dry Single End Elongation at the Break

Orlon and 100% Lirelle yarns, the following explanation can be offered. When the 50/50 yarn is strained to the 6.0 per cent level, the Lirelle breaks and transfers the majority of the stress to the Orlon. If there is not a sufficient percentage of Orlon present in the yarn to support the transferred load, the blended yarn fails. This is the case for the 25% and 50% Orlon yarns. The 75% Orlon yarns are able to support the transferred load, thus, elongation of the yarn continues past the level at which the Lirelle fails. This concept of transferring the majority of the load to the Orlon upon failure of the Lirelle may well account for the low elongations of the 25% and 50% Orlon yarns. Treating each blend level individually and referring to Figure 5a, it is seen that twist has a minimum effect on the breaking elongation.

Wet Single End Elongation at the Break

A summary of the yarn wet single end elongation at the break is listed in Table 6. The per cent coefficient of variation and the standard deviation of the mean for the elongation at the break also appear in Table 6. Figure 6a, b graphically represents the elongation at break.

Referring to Figure 6a, it is shown that, as with the dry tests, the 50%, 75%, and 100% Lirelle yarns break at the same level of elongation, while the 75% Lirelle yarns are at a significantly higher level. The elongation at break of the 100% Orlon yarns is the highest, and it is significantly greater than the 25% Lirelle/75% Orlon yarns.

Treating each blend level individually, it is concluded that twist in the range investigated has a minimum effect on breaking elongation.

Figure 6b shows the effect of blend level on the wet elongation

Table 6. Summary of Yarn Wet Single End Elongation at the Break

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Per Cent Elongation	6.7	6.5	6.5	10.7	16.2
Per Cent Coefficient of Variation	8.17	4.47	6.29	12.84	6.08
Standard Deviation of the Mean	0.17	0.09	0.13	0.43	0.31
3.00 TM					
Mean Per Cent Elongation	6.7	6.7	7.0	8.8	16.3
Per Cent Coefficient of Variation	7.33	4.14	6.97	21.52	13.52
Standard Deviation of the Mean	0.16	0.08	0.15	0.60	0.69
3.25 TM					
Mean Per Cent Elongation	6.7	6.8	6.8	9.7	17.9
Per Cent Coefficient of Variation	6.98	7.90	6.79	17.43	10.27
Standard Deviation of the Mean	0.15	0.17	0.15	0.54	0.58
3.50 TM					
Mean Per Cent Elongation	7.4	7.0	7.0	10.5	17.8
Per Cent Coefficient of Variation	8.87	6.23	7.54	20.02	13.19
Standard Deviation of the Mean	0.20	0.14	0.16	0.66	0.74
3.75 TM					
Mean Per Cent Elongation	7.7	7.0	6.6	10.1	18.1
Per Cent Coefficient of Variation	5.88	6.08	8.29	18.18	8.93
Standard Deviation of the Mean	0.14	0.13	0.55	0.58	0.51
4.00 TM					
Mean Per Cent Elongation	7.7	6.9	7.1	10.4	17.0
Per Cent Coefficient of Variation	6.62	6.14	7.25	15.61	12.70
Standard Deviation of the Mean	0.16	0.13	0.16	0.51	0.66

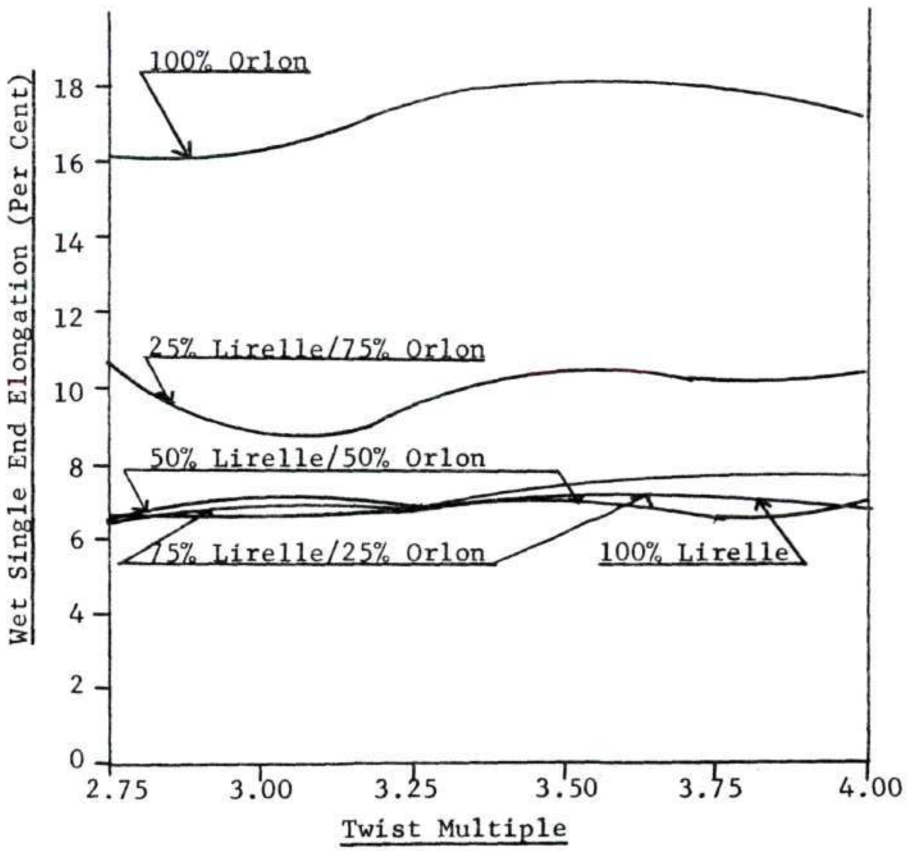

Figure 6a. Effect of Twist Multiple on Wet Single End Elongation at the Break

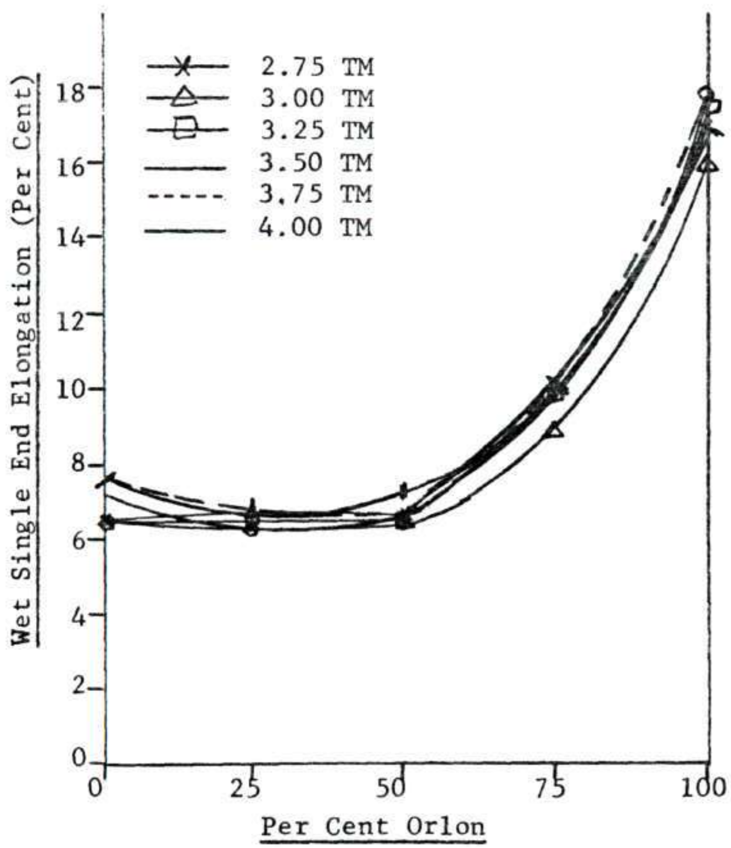

Figure 6b. Effect of Blend Level on Wet Single End Elongation at the Break

at the break, and the behavior is similar to that encountered with the dry elongation at the break.

Table 9 expresses the wet elongations as a percentage of the dry values. In all but four instances, the wet value is greater. The four exceptions were the 3.00, 3.25, and 3.75 twist multiples of the 25% Lirelle/75% Orlon yarns and the 3.25 TM of the 100% Orlon yarns. When the 25% Lirelle yarns were tested on the Instron, a wavy stress-strain diagram was recorded. This indicates that inter-fiber slippage is occurring, and this might account for those three dry elongations exceeding their respective wet values. Since the Orlon breaking elongation is only slightly increased in the wet states, unevenness in the yarn could allow the wet value to assume a value which, when based on the dry result, might be lower than expected.

Slippage of the fibers in the jaws would also produce a wavy stress-strain curve, but this possibility is remote indeed, because the pneumatic air jaws exert a very positive and constant force on the yarn.

Dry Single End Modulus

It should be emphasized that the modulus measured in this experiment is the stress in grams per denier at five per cent elongation.

A summary of the yarn dry modulus with its per cent coefficient of variation and standard deviation of the mean is given in Table 7. As the modulus measurement is a function of a pre-determined point on the stress-strain diagram, varying results within a blend level or between blend levels do exist; therefore, no attempt is made to graphically depict the results.

Table 7. Summary of Yarn Dry Single End Modulus

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Modulus (grams per denier)	2.06	1.83	1.66	1.30	1.04
Per Cent Coefficient of Variation	7.62	4.36	4.32	6.58	5.59
Standard Deviation of the Mean	0.049	0.025	0.022	0.027	0.018
3.00 TM					
Mean Modulus (grams per denier)	2.04	1.94	1.65	1.41	1.04
Per Cent Coefficient of Variation	10.22	3.41	6.68	4.98	4.97
Standard Deviation of the Mean	0.066	0.021	0.034	0.022	0.014
3.25 TM					
Mean Modulus (grams per denier)	2.03	1.91	1.62	1.40	1.06
Per Cent Coefficient of Variation	5.66	3.87	4.60	4.50	4.89
Standard Deviation of the Mean	0.037	0.023	0.024	0.020	0.016
3.50 TM					
Mean Modulus (grams per denier)	1.99	1.95	1.54	1.40	1.08
Per Cent Coefficient of Variation	4.26	2.40	4.43	3.83	4.84
Standard Deviation of the Mean	0.027	0.015	0.021	0.017	0.017
3.75 TM					
Mean Modulus (grams per denier)	1.87	1.80	1.58	1.35	1.03
Per Cent Coefficient of Variation	7.50	2.77	4.09	4.70	3.73
Standard Deviation of the Mean	0.044	0.015	0.020	0.020	0.012
4.00 TM					
Mean Modulus (grams per denier)	1.98	1.76	1.50	1.39	1.01
Per Cent Coefficient of Variation	5.79	2.79	5.82	4.93	5.04
Standard Deviation of the Mean	0.036	0.015	0.027	0.019	0.015

Table 7 shows that for a given twist multiple, modulus is indirectly proportional to the percentage of Orlon contained in the yarn. Due to the previously mentioned problem associated with the modulus measurement, it is difficult to make any positive statement as to the effect of twist, but, on the whole, it is felt that twist has little significance on modulus.

Wet Single End Modulus

A summary of the yarn wet single end modulus is given in Table 8. As can be seen, the results do not conform to any pattern in relation to blend level or twist. The effect of adding increased amounts of Orlon is different for each twist level. Twist also has a varying effect on each blend level.

No attempt is made to draw any conclusions as to the effect of blend level or twist, but it can be said that, of all the wet and dry tests conducted in this investigation, wet modulus is least affected by blend level.

Table 9, however, does show a definite pattern related to the wet modulus measurement. As the proportion of Orlon is increased, the wet modulus value more closely approaches its respective dry value.

Yarn Skein Breakage and Lea Product

A summary of the skein breaking strength is listed in Table 10, while Table 11 shows the summary of the skein lea product. The per cent coefficient of variation and the standard deviation of the mean for the breaking strength and lea product appear in their respective summary tables. Figure 7a, b graphically represents the skein lea product. It should be emphasized that the skein lea product is the

Table 8. Summary of Yarn Wet Single End Modulus

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Modulus (grams per denier)	1.17	1.21	1.08	1.14	0.88
Per Cent Coefficient of Variation	7.85	5.68	5.08	4.15	3.37
Standard Deviation of the Mean	0.026	0.022	0.016	0.015	0.094
3.00 TM					
Mean Modulus (grams per denier)	1.08	1.20	1.07	1.28	0.90
Per Cent Coefficient of Variation	7.32	5.38	3.45	4.25	4.81
Standard Deviation of the Mean	0.025	0.020	0.011	0.017	0.016
3.25 TM					
Mean Modulus (grams per denier)	1.14	1.14	1.12	1.21	0.92
Per Cent Coefficient of Variation	5.86	5.33	4.12	5.62	3.70
Standard Deviation of the Mean	0.021	0.019	0.014	0.021	0.011
3.50 TM					
Mean Modulus (grams per denier)	1.15	1.10	1.06	1.09	0.90
Per Cent Coefficient of Variation	6.87	6.05	4.24	5.03	3.97
Standard Deviation of the Mean	0.024	0.021	0.014	0.017	0.011
3.75 TM					
Mean Modulus (grams per denier)	1.05	1.04	1.13	1.01	0.95
Per Cent Coefficient of Variation	4.53	4.48	5.36	5.32	4.52
Standard Deviation of the Mean	0.015	0.19	0.019	0.017	0.013
4.00 TM					
Mean Modulus (grams per denier)	1.07	1.02	1.00	0.95	0.95
Per Cent Coefficient of Variation	5.79	5.63	4.09	5.37	4.94
Standard Deviation of the Mean	0.019	0.015	0.013	0.016	0.014

Table 9. Summary of Yarn Wet Single End Lea Product, Elongation, and Modulus Expressed as a Percentage of Its Respective Dry Property

Blend Level	100% Litrelle	75% Litrelle	50% Litrelle	25% Litrelle	100% Orlon
2.75 TM					
Lea Product	81.8	76.9	82.2	90.7	88.7
Elongation	113.4	110.2	118.2	107.0	102.5
Modulus	51.5	66.1	65.0	87.6	84.6
3.00 TM					
Lea Product	84.0	77.6	86.4	87.2	87.8
Elongation	113.5	117.5	129.6	76.5	97.6
Modulus	53.4	61.9	64.8	90.8	86.5
3.25 TM					
Lea Product	85.0	77.6	82.2	87.2	87.7
Elongation	108.0	111.5	123.6	86.6	106.5
Modulus	56.2	59.7	69.1	86.4	86.8
3.50 TM					
Lea Product	83.7	78.7	83.0	91.5	86.3
Elongation	119.4	125.0	116.6	100.0	102.2
Modulus	57.8	56.9	68.8	77.0	83.3
3.75 TM					
Lea Product	84.6	78.7	88.1	84.2	88.9
Elongation	124.2	118.6	117.8	99.0	109.6
Modulus	56.1	57.8	71.5	74.8	92.2
4.00 TM					
Lea Product	82.1	77.3	83.3	86.7	92.1
Elongation	122.2	113.1	122.4	106.1	101.2
Modulus	54.0	57.9	66.6	70.4	94.1

Table 10. Summary of Yarn Skein Breaking Strength

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Breaking Strength (lbs.)	167	151	117	103	92
Per Cent Coefficient of Variation	7.26	2.37	8.93	5.76	4.65
Standard Deviation of the Mean	3.83	1.13	3.31	1.87	1.35
3.00 TM					
Mean Breaking Strength (lbs.)	170	154	129	107	100
Per Cent Coefficient of Variation	3.50	6.35	2.63	6.57	10.03
Standard Deviation of the Mean	1.89	3.12	1.08	2.23	3.18
3.25 TM					
Mean Breaking Strength (lbs.)	169	154	122	104	106
Per Cent Coefficient of Variation	3.10	4.64	9.33	7.69	4.50
Standard Deviation of the Mean	1.66	2.26	3.61	2.53	1.51
3.50 TM					
Mean Breaking Strength (lbs.)	177	150	124	103	106
Per Cent Coefficient of Variation	5.17	5.12	3.68	10.54	6.10
Standard Deviation of the Mean	2.90	2.43	1.46	3.43	2.04
3.75 TM					
Mean Breaking Strength (lbs.)	168	147	130	102	104
Per Cent Coefficient of Variation	2.49	2.89	5.48	7.25	5.72
Standard Deviation of the Mean	1.32	1.35	2.25	2.33	1.87
4.00 TM					
Mean Breaking Strength (lbs.)	157	144	123	100	100
Per Cent Coefficient of Variation	5.99	2.25	1.70	11.28	4.90
Standard Deviation of the Mean	2.97	1.03	0.66	3.57	1.54

Table 11. Summary of Yarn Skein Lea Product

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Lea Product	3257	2983	2395	2041	1824
Per Cent Coefficient of Variation	5.94	2.56	8.17	2.70	5.76
Standard Deviation of the Mean	61.31	24.24	61.99	17.43	33.22
3.00 TM					
Mean Lea Product	3281	3075	2548	2079	1925
Per Cent Coefficient of Variation	4.56	6.12	3.24	4.61	8.79
Standard Deviation of the Mean	47.41	59.64	26.14	30.34	53.58
3.25 TM					
Mean Lea Product	3288	3076	2442	2044	2062
Per Cent Coefficient of Variation	3.61	4.43	6.66	5.32	4.18
Standard Deviation of the Mean	37.65	43.13	51.48	34.45	27.31
3.50 TM					
Mean Lea Product	3479	2961	2463	2048	2065
Per Cent Coefficient of Variation	4.46	3.73	3.26	4.83	6.10
Standard Deviation of the Mean	49.06	34.81	22.28	21.24	39.87
3.75 TM					
Mean Lea Product	3186	2855	2472	1938	2003
Per Cent Coefficient of Variation	5.98	3.10	5.01	5.50	5.63
Standard Deviation of the Mean	60.34	28.03	39.20	34.17	35.44
4.00 TM					
Mean Lea Product	2967	2760	2390	1901	1907
Per Cent Coefficient of Variation	5.94	2.80	2.08	10.81	4.62
Standard Deviation of the Mean	55.82	24.50	15.77	62.08	27.79

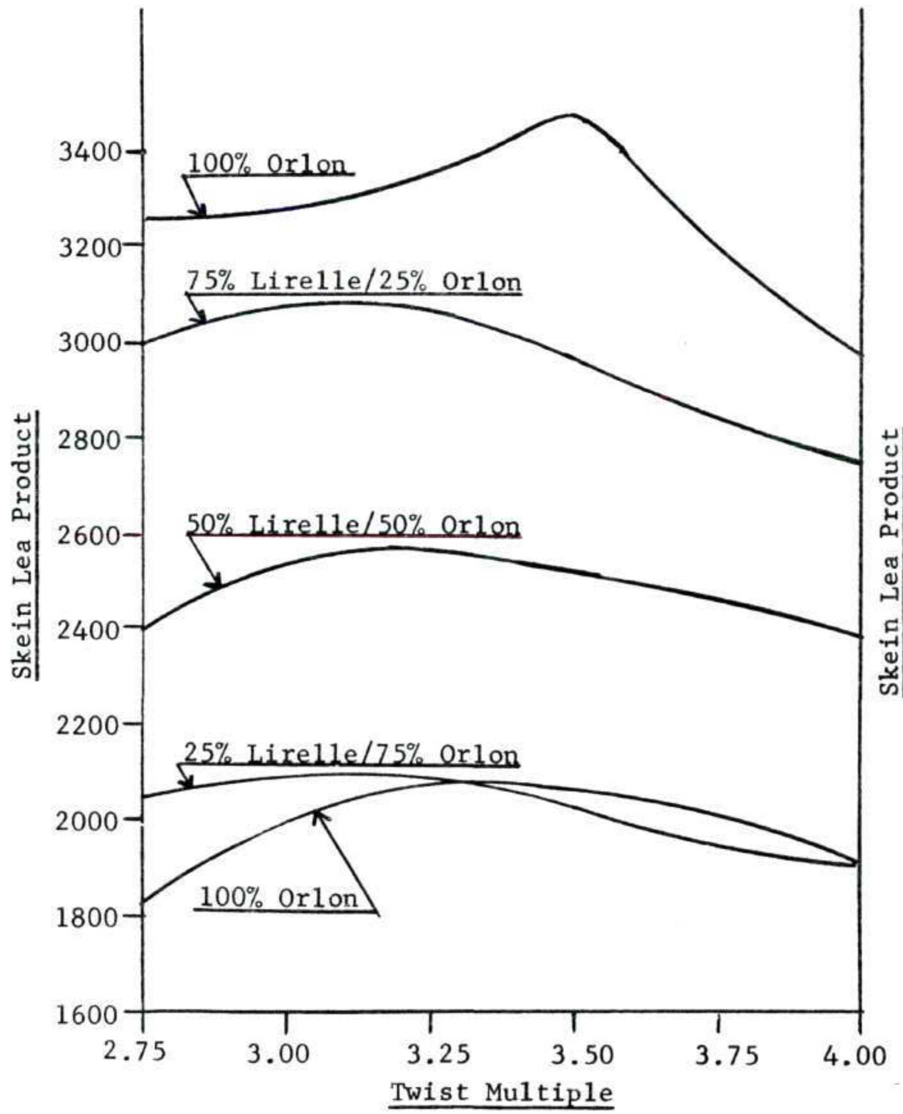

Figure 7a. Effect of Twist Multiple on Skein Lea Product

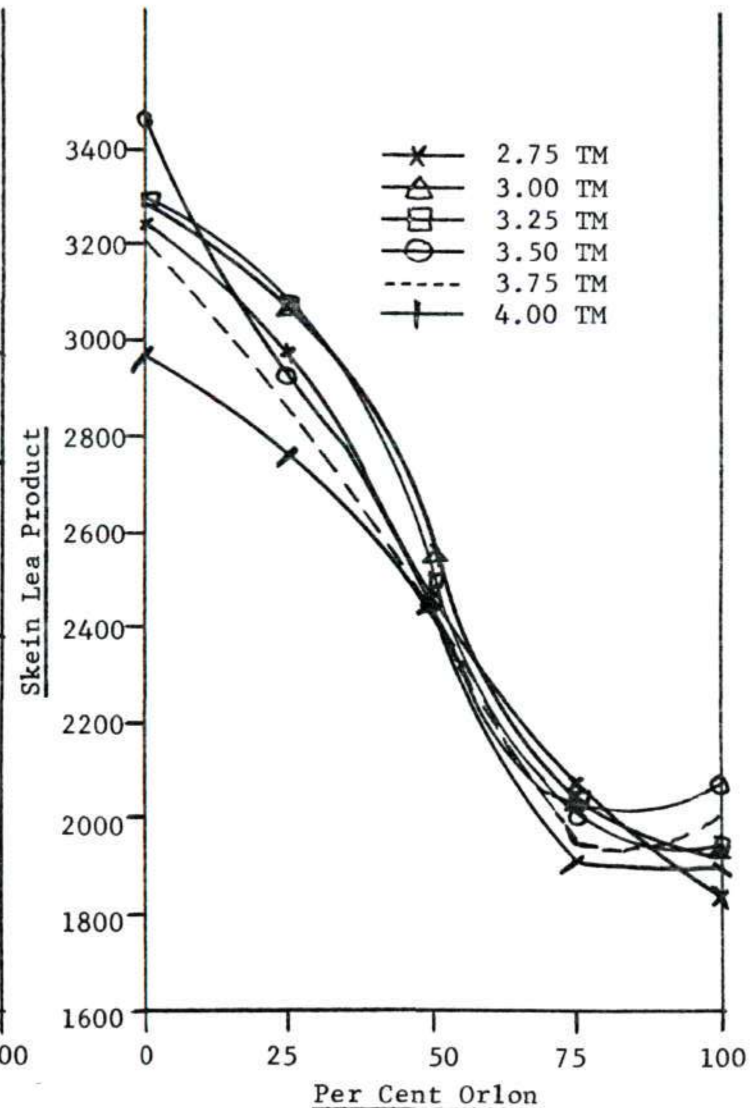

Figure 7b. Effect of Blend Level on Skein Lea Product

product of the skein breaking strength and its respective cotton count.

Referring to Figure 7a, it can be seen that there is a significant difference in the lea product of the 100% Lirelle, 75% Lirelle/25% Orlon, and 50% Lirelle/50% Orlon blend levels. The 25% Lirelle/75% Orlon blend levels have some common lea product values, and the yarn strength of these blend levels is significantly less than the other three blend levels.

The strength of each blend level increases to a maximum with increasing twist, and a further increase in twist causes a decrease in strengths. The point of maximum strength is not the same for all blend levels.

It will be remembered that in Figure 2a, which depicts the dry single end lea product as a function of twist, that the single end lea product of all five blends is at significantly different levels. Also, the 100% Orlon yarn is third in strength. Referring to Figure 2b, it is seen that the 25% Lirelle/75% Orlon yarn is the weakest for all twist multiples.

Hence, the strength of the 100% Orlon yarn is not at the same level for the single end and skein lea products. While the 100% Orlon single end yarn strength is singificantly greater than the 50% Lirelle/50% Orlon and 25% Lirelle/75% Orlon, the skein yarn strength is significantly less than the 50/50 yarn and at the same level as the 25% Lirelle/75% Orlon yarns.

In an attempt to account for this unexpected disagreement relating to the strength level of Orlon, the evenness of the yarn was measured. Using the Uster Evenness Tester, one evenness test was made from each of the five cones for the six twist multipliers. The unevenness was expressed as a per cent coefficient of variation and the summary of these results follows:

Table 12. Summary of 100% Orlon Yarn Unevenness

Twist Multiplier	Mean Per Cent Coefficient of Variation
2.75	13.82
3.00	13.00
3.25	12.92
3.50	13.12
3.75	13.15
4.00	13.08

In relation to staple yarns, the per cent variations of the Orlon yarn are not excessive; hence, it is concluded that unevenness in the yarn is not responsible for the strength difference. The raw data for the yarn unevenness tests appears in Table 19.

The manufacturer's literature was then consulted. In a recently published bulletin, DuPont (41) depicts the effect of twist on skein lea product for T-72 Orlon. The graph for 20's yarn is duplicated below:

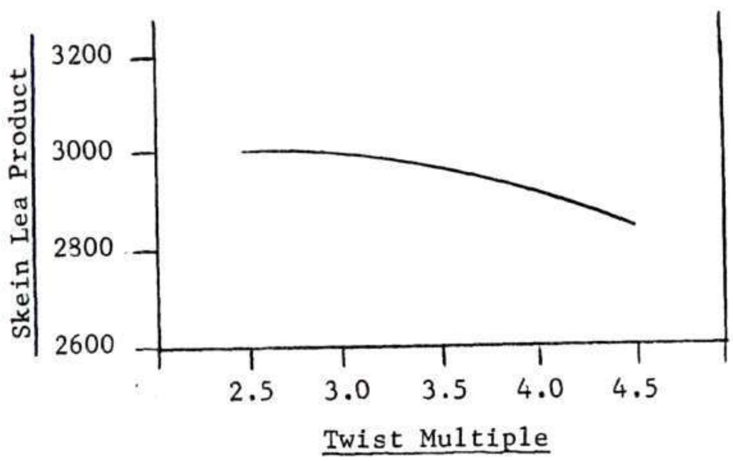

Figure 8. The Effect of Twist Multiple on Skein Lea Product for 20's T072 Orlon Yarn

As is displayed in Figure 8, the skein lea product for the 3.50 twist multiple is slightly less than 3000, while Table 11 shows that the value measured in this investigation is 2065. Thus, the strength measured in this investigation is only 70 per cent of the value obtained by DuPont.

It should be noted that the single end and skein strength for the 100% Lirelle yarns is in agreement with the fiber manufacturer's results. For a 3.50 twist multiplier, Courtaulds lists a skein lea product of 3500 and a single end lea product of 360, while the comparable values measured in this experiment are 3479 and 381 respectively.

Consulting Table 16a, it can be seen that the unprocessed Orlon fiber has a tenacity 3.46 grams per denier. A skein lea product of about 2800 could be expected from a 20's yarn spun of fiber with this tenacity.

The fiber in the 100% Orlon yarn with a 3.50 twist multiplier was analyzed to determine if there had been any loss in fiber tenacity in processing. The results are listed in Table 18, and the tenacity is 2.82 grams per denier.

As can be seen some loss in fiber tenacity occurred during processing; however, a skein lea product of 2500 could be expected with this fiber tenacity. This loss in tenacity can be used to partially explain the low yarn strength, but is not a total explanation.

In private communication with Mr. Sam T. Price, Manager of Orlon Technical Service, it was learned that the single end yarn strength of 20's Orlon yarn with a 3.50 twist multiplier is 2.13 grams per denier. Table 3 shows that the breaking strength measured in this experiment is 1.24 pounds, and this is equivalent to 2.07 grams per denier. Thus, the yarn single end strength is in close agreement with the DuPont determination.

Since the single end value is in close agreement with DuPont's, while the skein value is in disagreement, the methods of testing were considered. It should be noted that the pendulum tester was used by DuPont. In this investigation, the Instron was used for the single end tests, while the pendulum tester was used for the skein breaks. It will be remembered that the disadvantages of the pendulum tester were discussed in Chapter III. It was stated that when the test specimen is highly deformable and considerable elongation results at low loads, such as Orlon, the upper jaw does not feed downward as rapidly as it does when the specimen has lower extensibility, such as Lirelle. As the movement of the pendulum is a function of the movement of the upper jaw, it is possible for yarns with low modulus and high elongation to have an apparent, but not actual, lower strength.

In support of this theory, it can be noted that Goodwin and Nair (42) encountered a similar problem with blends of Orlon and cotton. They found a decided disagreement in the relative strengths of the 100% Orlon yarns compared to the strength of the other blends depending on the method of strength evaluation. The skein method indicated that the Orlon yarns were the weakest, whereas the single end method indicated they were second in strength. The inclined plane tester was used for the single end tests, while the pendulum tester was used for the skein breaks.

It is beyond the scope of this investigation to expound on the merits of the testing equipment. However, it is the author's conclusion that the subject warrants further investigation.

Yarn Cotton Count

The summary of the cotton count for all tests is shown in Table 13. The per cent coefficient of variation and standard deviation of the mean also appear.

Fabric Results

The raw data for all fabric results are found in Table 20 through Table 49.

All fabric testing was done in the filling direction since the tests yarns were woven across a standard cotton warp. Because the warp does not contain the same yarns as the filling, all fabric results will be relative and the numerical results will have meaning only in relation to this investigation.

Fabric Dry Breaking Strength

A summary of the fabric dry breaking strength is listed in Table 14. The per cent coefficient of variation and the standard deviation of the mean also appear in Table 14. Figure 9a, b graphically represents the fabric breaking strength.

Referring to Figure 9a, it can be seen that there are four levels of breaking strength. The 100% Lirelle is the highest; the 100% Orlon level is second in strength; the 75% Lirelle/25% Orlon and the 50/50 blends are at the same level and third in strength; and the 25% Lirelle/75% Orlon is the weakest. There is a significant difference between each of the four levels.

Table 13. Summary of Yarn Cotton Count

	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Cotton Count	19.52	19.84	20.45	19.93	19.90
Per Cent Coefficient of Variation	2.17	1.85	1.28	4.81	2.03
Standard Deviation of the Mean	0.134	0.116	0.083	0.303	0.128
3.00 TM					
Mean Cotton Count	19.24	19.81	19.70	19.38	19.22
Per Cent Coefficient of Variation	3.25	1.18	1.12	2.61	1.44
Standard Deviation of the Mean	0.98	0.74	0.069	0.160	0.088
3.25 TM					
Mean Cotton Count	19.46	19.97	20.02	19.72	19.39
Per Cent Coefficient of Variation	2.03	0.91	4.03	3.28	1.85
Standard Deviation of the Mean	0.125	0.057	0.255	0.205	0.114
3.50 TM					
Mean Cotton Count	19.66	19.75	19.73	19.93	19.52
Per Cent Coefficient of Variation	0.90	2.15	1.38	6.29	0.59
Standard Deviation of the Mean	0.056	0.134	0.086	0.397	0.036
3.75 TM					
Mean Cotton Count	18.94	19.38	18.98	19.37	19.37
Per Cent Coefficient of Variation	4.30	0.78	1.88	2.63	1.29
Standard Deviation of the Mean	0.257	0.048	0.113	0.161	0.078
4.00 TM					
Mean Cotton Count	18.95	19.23	19.40	19.06	19.19
Per Cent Coefficient of Variation	1.08	1.64	1.63	1.68	1.11
Standard Deviation of the Mean	0.065	0.100	0.099	0.101	0.067

Table 14. Summary of Fabric Dry Breaking Strength - Filling Direction

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Per Cent Elongation	125	113	103	96	113
Per Cent Coefficient of Variation	5.27	5.24	4.95	4.56	5.90
Standard Deviation of the Mean	2.08	1.88	1.61	1.38	2.10
3.00 TM					
Mean Per Cent Elongation	124	113	113	97	117
Per Cent Coefficient of Variation	6.11	7.57	3.88	6.95	4.22
Standard Deviation of the Mean	2.39	2.72	1.38	2.13	1.55
3.25 TM					
Mean Per Cent Elongation	128	117	113	100	120
Per Cent Coefficient of Variation	4.80	3.80	3.85	6.02	5.01
Standard Deviation of the Mean	1.94	1.40	1.64	1.89	1.95
3.50 TM					
Mean Per Cent Elongation	134	111	109	100	125
Per Cent Coefficient of Variation	4.78	4.48	3.43	6.96	2.67
Standard Deviation of the Mean	2.03	1.57	1.19	2.14	1.05
3.75 TM					
Mean Per Cent Elongation	132	104	105	97	116
Per Cent Coefficient of Variation	5.10	5.51	3.24	6.96	7.12
Standard Deviation of the Mean	2.12	1.18	1.25	2.14	2.62
4.00 TM					
Mean Per Cent Elongation	127	105	102	99	110
Per Cent Coefficient of Variation	4.99	5.04	2.59	6.18	7.00
Standard Deviation of the Mean	2.00	1.67	0.83	1.93	2.43

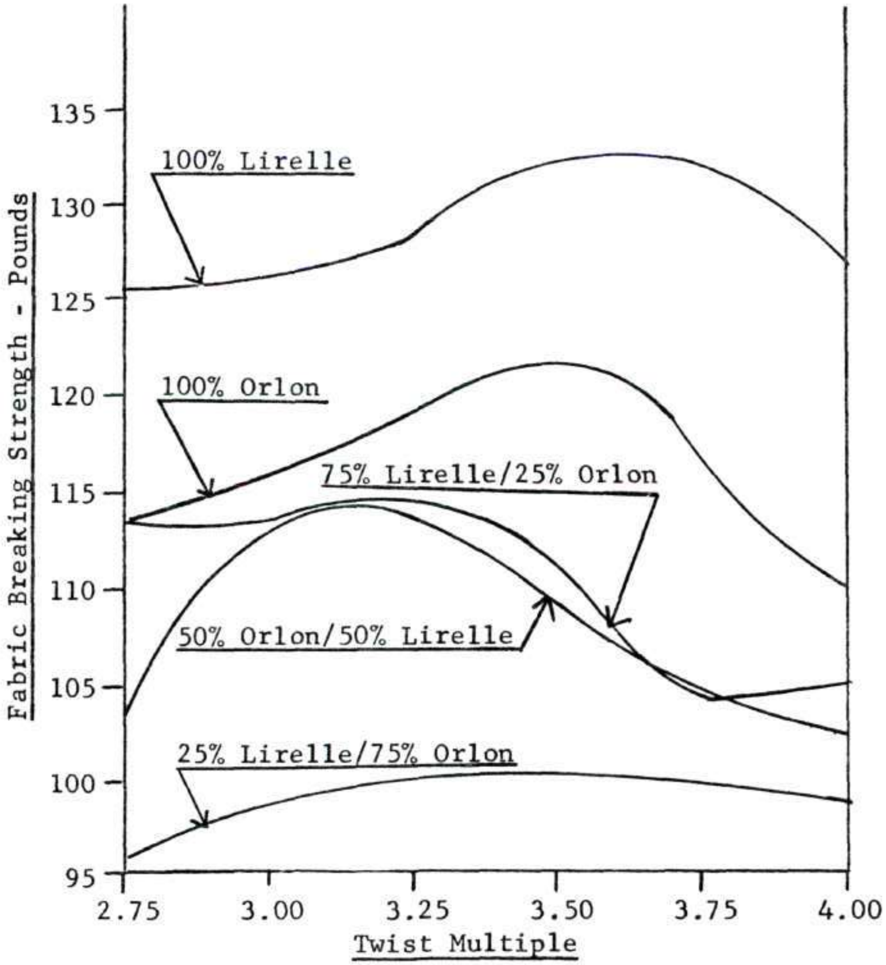

Figure 9a. The Effect of Twist Multiple on Fabric Dry Breaking Strength

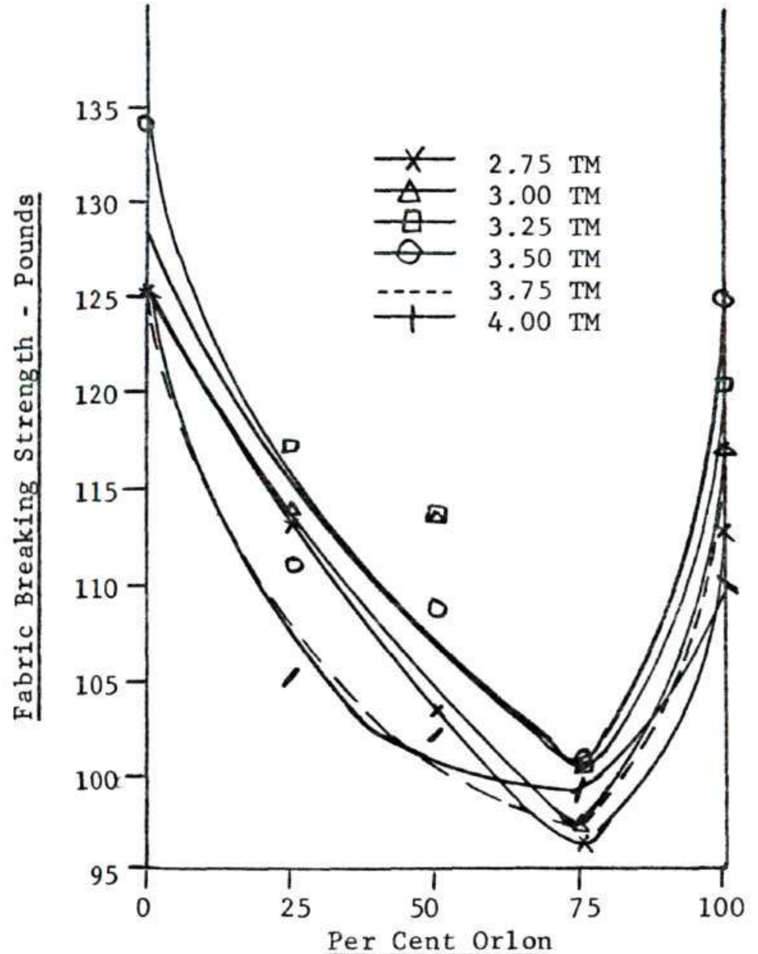

Figure 9b. The Effect of Blend Level on Fabric Breaking Strength

Treating each blend individually, it is concluded that increasing twist increases the fabric strength to a maximum, and a further increase causes a loss in strength. The point of maximum strength is not the same for all blends.

Figure 9b shows that additions of up to 75% Orlon causes a decrease in breaking strength. The point of minimum strength is at the 25% Lirelle/75% Orlon blend level. The strength of the 100% Orlon fabrics is second only to 100% Lirelle, hence, the yarn to fabric strength translation of the 100% Orlon appears better than that of the 75% Lirelle/25% Orlon since the 75% Lirelle/25% Orlon has the higher single end breaking strength.

Fabric Wet Breaking Strength

A summary of the fabric wet strength is listed in Table 15. The per cent coefficient of variation and the standard deviation of the mean also appear in Table 15. Figure 10a, b graphically represents the fabric breaking strength.

Referring to Figure 10a, it can be shown that there are three levels of breaking strength. The 100% Orlon and 100% Lirelle are at the same level and have the highest breaking strength; 75% Lirelle/25% Orlon is the middle level and the 50/50 and 25% Lirelle/75% Orlon comprise the lower level.

Treating each blend individually, it is concluded that increasing twist increases the fabric strength to a maximum, and a further increase in twist causes a loss in strength. The point of maximum strength is not the same for all blend levels.

Figure 10b shows that additions of up to 75% Orlon causes a

Table 15. Summary of Fabric Wet Breaking Strength - Filling Direction and the Wet Fabric Strength Expressed as a Percentage of the Dry Strength

Blend Level	100% Lirelle	75% Lirelle	50% Lirelle	25% Lirelle	100% Orlon
2.75 TM					
Mean Breaking Strength (lbs.)	91	83	90	83	106
Per Cent Coefficient of Variation	7.52	5.30	5.08	7.33	5.78
Standard Deviation of the Mean	2.35	1.39	1.44	1.94	1.93
Per Cent of Dry	72.8	73.4	87.0	88.3	93.8
3.00 TM					
Mean Breaking Strength (lbs.)	101	88	99	88	108
Per Cent Coefficient of Variation	8.33	6.98	5.34	7.61	7.46
Standard Deviation of the Mean	2.56	1.95	1.66	2.12	2.38
Per Cent of Dry	81.5	77.8	87.6	90.7	92.3
3.25 TM					
Mean Breaking Strength (lbs.)	101	90	96	88	107
Per Cent Coefficient of Variation	5.32	5.69	5.40	7.64	6.62
Standard Deviation of the Mean	1.91	1.61	1.64	2.13	2.24
Per Cent of Dry	78.9	76.9	84.6	88	89.1
3.50 TM					
Mean Breaking Strength (lbs.)	113	86	97	86	110
Per Cent Coefficient of Variation	7.37	5.79	4.79	6.57	6.55
Standard Deviation of the Mean	2.36	1.58	1.48	1.76	2.27
Per Cent of Dry	84.3	77.9	89	86	88
3.75 TM					
Mean Breaking Strength (lbs.)	108	81	96	85	105
Per Cent Coefficient of Variation	5.80	9.12	4.56	6.57	5.56
Standard Deviation of the Mean	1.98	2.34	1.39	1.76	1.74
Per Cent of Dry	81.8	77.8	91.4	87.6	90.5
4.00 TM					
Mean Breaking Strength (lbs.)	102	83	95	90	97
Per Cent Coefficient of Variation	6.06	7.07	3.49	5.21	4.54
Standard Deviation of the Mean	1.95	1.85	1.04	1.48	1.40
Per Cent of Dry	80.3	79	93.1	90.9	88.1

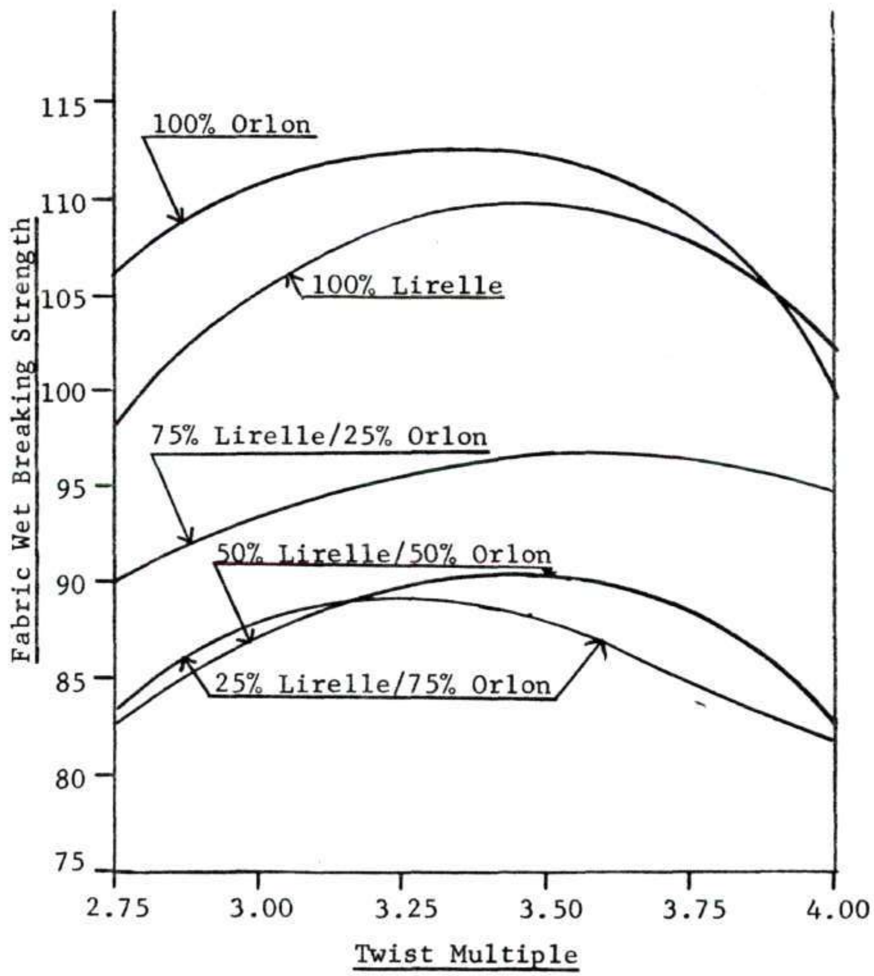

Figure 10a. The Effect of Twist Multiple on Fabric Wet Breaking Strength

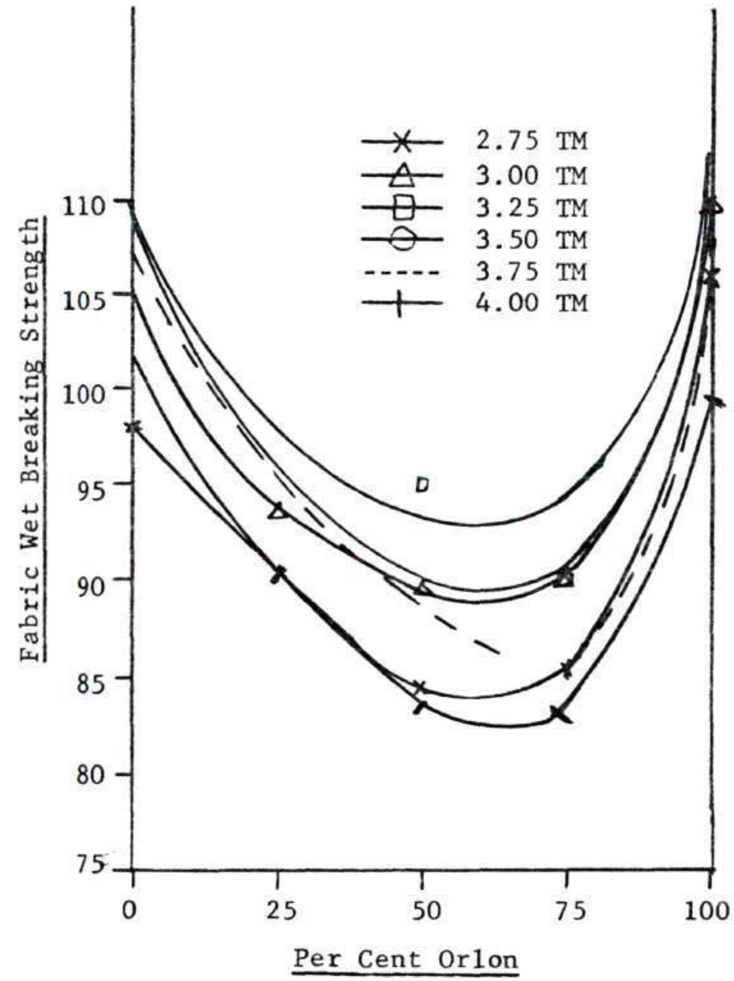

Figure 10b. The Effect of Blend Level on Fabric Wet Breaking Strength

decrease in strength. The 50/50 and the 25% Lirelle/75% Orlon together share the points of minimum strength.

Table 15 shows the wet strength expressed as a percentage of the dry strength and it displays that the 100% Orlon fabrics have a significantly higher percentage of wet strength to dry strength. Referring again to Figure 10a, it is seen that the 100% Orlon fabrics appear to have slightly greater strength than the 100% Lirelle for some twist multipliers. The significantly higher percentage wet strength of the 100% Orlon fabrics could explain why the fabric wet strength is at the same or slightly greater level as 100% Lirelle, while the single end dry and wet yarn strength was significantly less than the 100% Lirelle.

<u>Fabric Tongue Tear and Flex Abrasion</u>

These tests were discontinued due to highly inconsistent results.

CHAPTER V

CONCLUSIONS

From the statistical analysis and interpretation of the data obtained from this experiment, the following conclusions have been reached:

1. The spinning of satisfactory yarns demonstrates that the fibers are compatible in blends.

2. The degree to which the fibers complement each other is dependent on blend level and twist. The specific contributions of these factors in yarns and fabrics are:

a. The 100% Lirelle yarns had the highest single end yarn strength, and additions of up to 75% Orlon caused a significant decrease in strength. The dry 100% Orlon yarns were third in strength, while the wet yarn was second.

b. Addition of up to 50% Orlon had no effect on the dry and wet elongation, while the elongation of the 75% and 100% Orlon yarns was significantly higher.

c. Dry and wet single modulus assumed a progressively smaller value due to the additions of Orlon.

d. Addition of up to 75% Orlon effected a constant loss in skein strength, and the strength of the 100% Orlon was unusually low and essentially the same as the 75% Orlon.

e. For the dry fabric tests, the 100% Lirelle was the strongest, and additions of up to 75% Orlon caused a continuing loss in strength. The 100% Orlon was second in strength.

f. The 100% Lirelle and the 100% Orlon shared the high wet fabric strength, while the 50/50 and 25% Lirelle/75% Orlon shared the low strength.

g. An increase in twist caused the skein, single end, and fabric strengths, both wet and dry, to increase to a maximum and a further increase in twist brought about a loss in strength. The point of maximum strength for each property was not the same for all blend levels.

h. Twist in ranges studied had a negligible effect on both wet and dry single end elongation and modulus.

i. The fabric tongue tear and flex abrasion tests were discontinued due to inconsistent results.

3. The work done in this limited investigation shows that satisfactory yarns of blends of these fibers can be produced, and indicates that fabrics of commercial quality can be made.

CHAPTER VI

RECOMMENDATIONS

In view of the unusually low breaking strength obtained in this experiment for the 100% Orlon yarns, it is recommended that a skein breaking attachment be adapted to the Instron and that the Orlon skeins be retested in order to determine if this apparent low strength is indeed real. In the event that a significantly higher skein breaking strength is realized, these comparative tests could be expanded to different fibers possessing a wide range of elongations and modulus. It is quite conceivable that, for fibers with a high modulus and low extension, that the results on the pendulum tester and the Instron would be equivalent, but when the modulus becomes lower and the elongation higher, this close agreement could cease to exist.

The work done in this investigation shows that the fibers are compatible in blends and the yarns have physical properties which are capable of producing fabrics with breaking strength which could put them in a competitive position in the market. In order to ascertain what area this fabric could best compete, it is recommended that the fabric performance be evaluated in detail. Some suggested avenues are:

(a) Crease Recovery

(b) Liveliness

(c) Press Retention

(d) Static

(e) Bulk

(f) Abrasion Resistance

(g) Dimensional Stability

It is recommended that the 50/50 level be used for the evaluation.

The use of "slack mercerization" to produce stretch fabrics from cellulosic fibers is gaining recognition. As Lirelle and Orlon both have good resistance to caustic, it is recommended that the possibility of "slack mercerizing" these blends be investigated. The author has conducted an extensive literature survey on the subject of slack mercerization, and this can be obtained from Dr. J.L. Taylor, Director of the A. French Textile School, Georgie Institute of Technology.

APPENDIX

Table 16a. Wet and Dry Tenacity, Elongation, and Modulus of Unprocessed Orlon Fiber

Tenacity (gpd)			Elongation (Per Cent)			Modulus (gpd)	
Dry	Wet		Dry	Wet		Dry	Wet
3.70	2.90		24.0	23.0		1.63	1.20
3.58	3.02		22.0	25.5		1.65	1.23
3.52	2.97		25.0	23.2		1.49	1.30
3.10	2.70		18.0	18.7		0.99	1.19
3.62	3.32		23.0	26.4		1.50	1.27
3.64	2.83		22.0	21.8		1.52	1.31
3.07	2.87		18.0	21.9		1.51	1.28
3.75	3.11		24.0	24.2		1.56	1.32
3.64	3.09		25.0	23.8		1.41	1.17
3.49	3.13		22.0	23.3		1.55	1.23
3.78	2.98		22.0	23.0		1.67	1.26
3.38	3.21		21.0	26.2		1.46	1.29
3.33	2.73		22.0	20.1		1.50	1.33
3.19	3.14		21.0	23.3		1.46	1.20
3.44	3.18		20.0	23.8		1.58	1.25
3.60	2.84		23.0	20.0		1.56	1.24
3.78	2.94		22.0	21.8		1.54	1.21
3.35	2.97		20.0	20.3		1.66	1.14
3.12	3.01		18.0	23.5		1.51	1.13
3.39	2.95		22.0	22.3		1.43	1.20
3.47	2.99	Mean	21.7	22.8	Mean	1.51	1.24

Table 16b. Wet and Dry Tenacity, Elongation, and Modulus for Unprocessed Lirelle Fiber

Tenacity (gpd)			Elongation (Per Cent)			Modulus (gpd)	
Dry	Wet		Dry	Wet		Dry	Wet
5.02	3.78		6.9	6.5		4.20	2.21
4.91	4.13		5.8	7.8		4.16	2.62
4.70	3.80		5.5	6.8		4.18	2.23
4.68	4.15		5.6	7.5		4.10	2.61
5.07	3.94		5.6	7.5		4.10	2.61
4.93	4.31		6.3	8.9		4.21	2.71
4.87	4.27		6.0	8.3		4.16	2.68
4.95	4.15		6.5	8.0		4.19	2.60
4.87	3.82		5.9	7.1		4.13	2.29
5.04	3.78		6.7	7.3		4.35	2.20
5.10	4.00		7.0	7.5		4.40	2.50
4.98	3.98		6.7	6.8		4.21	2.47
4.93	3.87		6.7	6.0		4.18	2.37
5.07	4.05		7.1	7.2		4.33	2.57
5.09	4.03		7.2	7.3		4.35	2.53
4.84	3.84		6.1	6.2		4.12	2.31
4.97	3.80		6.5	6.7		4.17	2.39
5.11	3.94		7.2	7.7		4.39	2.57
5.15	4.07		7.2	7.8		4.37	2.57
4.82	4.11		6.0	8.2		4.07	2.60
4.95	3.99	Mean	6.5	7.3	Mean	4.17	2.46

Table 17. Operating Data for Instron Tensile Strength Tester

	100% Lirelle 75% Lirelle/25% Orlon 50% Lirelle/50% Orlon Single End Yarn Tests	25% Lirelle/75% Orlon 100% Orlon Single End Yarn Tests	Fabric Grab Tests
Load Cell	C	C	D
Full Scale Load (lbs.)	2	2	200
Gauge Length (inches)	10	10	3
Rate of Sample Extension (inches per minute)	6	6	12
Chart Speed (inches per minute)	20	10	10

Table 18. Dry Tenacity, Elongation, and Modulus of Processed Orlon Fiber

Tenacity (gpd) Dry		Elongation (Per Cent) Dry		Modulus (gpd) Dry
3.44		21.0		1.50
3.14		20.0		1.43
1.53		5.0		1.53
3.48		24.0		1.43
3.48		22.0		1.45
1.57		5.0		1.57
3.27		22.0		1.40
3.66		24.0		1.42
3.40		20.0		1.47
2.21		12.0		1.58
2.70		17.0		1.46
1.73		7.0		1.50
3.60		23.0		1.40
3.72		22.0		1.58
2.64		16.0		1.38
1.96		10.0		1.42
3.73		23.0		1.50
2.29		13.0		1.45
3.70		22.0		1.60
2.28		14.0		1.50
2.87	Mean	17.1	Mean	1.48

Table 19. 100% Orlon Yarn Unevenness Expressed as a Per Cent Coefficient of Variation

	2.75 TM	3.00 TM	3.25 TM
	14.04	13.00	13.08
	13.77	14.04	13.00
	12.96	12.96	13.00
	14.17	13.00	12.48
	14.17	12.00	13.08
Mean	13.82	13.00	12.92

	3.50 TM	3.75 TM	4.00 TM
	13.00	13.52	12.96
	13.00	13.62	13.00
	13.00	13.00	13.50
	13.00	13.63	12.96
	13.62	12.00	13.00
Mean	13.12	13.15	12.98

Table 20. Physical Testing Data on Yarn and Fabric for 100% Lirelle - 2.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.26	6.0	1.85
	1.42	6.3	1.94
	1.44	6.0	2.04
	1.34	5.4	1.99
	1.56	6.3	2.02
	1.34	6.0	2.30
	1.52	5.7	2.37
	1.62	6.0	2.07
	1.38	6.0	2.02
	1.44	5.4	2.02
Average	1.43	5.9	2.06

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.05	6.0	1.06
	1.27	6.9	1.19
	1.05	6.3	1.11
	1.09	6.3	1.06
	1.21	7.2	1.17
	1.27	6.9	0.95
	1.27	7.2	1.12
	1.17	6.9	1.04
	0.98	5.7	1.00
	1.25	7.2	0.95
Average	1.17	6.7	1.17

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	157	19.85	3117
	154	19.62	3021
	177	19.77	3499
	186	18.81	3498
	165	19.88	3280
	188	18.98	3568
	161	19.80	3187
	160	19.78	3164
	163	18.98	3093
	160	19.79	3166
Average	167	19.52	3257

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	124	98
	126	100
	133	108
	119	90
	125	104
	138	94
	123	86
	126	104
	121	108
	115	96
Average	125	91

Table 21. Physical Testing Data on Yarn and Fabric for 100% Lirelle - 3.00 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.54	5.7	1.94
	1.38	5.4	1.99
	1.44	5.4	2.32
	1.54	6.3	1.74
	1.58	6.6	1.92
	1.38	6.0	2.04
	1.52	6.0	2.02
	1.30	6.6	1.84
	1.40	5.7	2.34
	1.32	5.4	2.30
Average	1.44	5.9	7.04

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.23	6.6	1.10
	1.14	5.7	1.19
	1.29	7.2	1.10
	1.23	6.6	1.14
	1.23	6.9	1.02
	1.14	6.6	0.99
	1.25	6.6	1.17
	1.21	6.9	1.00
	1.17	6.3	1.12
	1.25	7.5	0.97
Average	1.21	6.7	1.08

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	161	20.01	3221
	171	18.29	3127
	175	19.81	3466
	174	20.20	3514
	168	18.78	3155
	162	19.33	3151
	165	19.16	3161
	177	19.25	3407
	178	19.16	3410
	173	18.50	3200
Average	170	19.24	3281

Fabric Grab Test Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs)
	136	100
	120	108
	116	106
	112	105
	130	101
	132	98
	120	111
	128	88
	120	92
	125	105
Average	124	101

Table 22 . Physical Testing Data on Yarn and Fabric for 100% Lirelle - 3.25 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.40	5.7	1.94
	1.54	6.6	1.99
	1.42	6.6	2.22
	1.38	6.3	1.94
	1.52	6.6	1.92
	1.40	5.7	2.04
	1.48	6.0	2.02
	1.38	6.3	1.92
	1.60	6.3	2.14
	1.58	6.0	2.20
Average	1.47	6.2	2.03

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.23	6.9	1.11
	1.23	6.0	1.11
	1.19	6.0	1.08
	1.21	7.2	1.07
	1.21	6.9	1.10
	1.39	6.3	1.21
	1.33	7.2	1.14
	1.30	6.9	1.22
	1.20	6.3	1.27
	1.25	6.9	1.12
Average	1.25	6.7	1.14

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	175	19.24	3367
	172	18.93	3255
	170	19.70	3349
	162	19.38	3140
	172	19.06	3278
	160	19.40	3104
	167	20.19	3371
	176	19.97	3514
	166	19.52	3240
	170	19.24	3270
Average	169	19.46	3288

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	116	110
	120	88
	128	103
	130	109
	128	99
	134	92
	134	107
	124	106
	134	95
	130	102
Average	128	101

Table 23 . Physical Testing Data on Yarn and Fabric for 100% Lirelle - 3.50 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.66	6.6	2.00
	1.58	6.6	2.04
	1.54	6.0	2.07
	1.46	6.0	1.84
	1.52	6.0	2.02
	1.50	6.3	1.87
	1.42	5.4	2.05
	1.54	6.0	2.03
	1.42	5.4	2.07
	1.62	7.2	1.91
Average	1.53	6.2	1.99

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.27	6.9	1.08
	1.21	6.9	1.04
	1.32	8.1	1.14
	1.36	8.1	1.16
	1.26	7.8	1.02
	1.30	7.5	1.20
	1.24	6.9	1.20
	1.35	8.1	1.26
	1.25	6.3	1.18
	1.24	6.9	1.18
Average	1.28	7.4	1.15

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	181	19.53	3534
	179	19.54	3497
	168	19.91	3344
	182	19.45	3539
	184	19.59	3604
	178	19.81	3526
	183	19.77	3618
	189	19.36	3659
	161	19.80	3187
	165	19.66	3285
Average	177	19.66	3479

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	142	118
	136	120
	140	115
	130	117
	126	111
	128	106
	142	114
	128	119
	140	101
	130	112
Average	134	113

Table 24 . Physical Testing Data on Yarn and Fabric for 100% Lirelle - 3.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.32	6.6	1.73
	1.30	6.6	1.80
	1.52	6.0	1.86
	1.38	6.0	1.73
	1.46	6.0	2.09
	1.52	6.3	2.02
	1.50	5.4	2.09
	1.50	6.0	1.80
	1.36	5.4	1.86
	1.44	7.2	1.77
Average	1.43	6.2	1.87

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.27	7.8	1.07
	1.23	7.8	1.02
	1.17	7.2	0.98
	1.10	8.1	1.00
	1.34	8.1	1.12
	1.20	7.2	1.06
	1.20	8.4	1.04
	1.18	7.2	1.01
	1.14	7.2	1.06
	1.28	7.8	1.12
Average	1.21	7.7	1.05

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	166	20.01	3321
	171	18.29	3127
	175	19.81	3466
	174	20.20	3535
	168	18.78	3155
	163	19.33	3151
	165	18.16	2996
	167	18.25	3047
	168	18.16	3050
	163	18.50	3015
Average	168	18.94	3186

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	140	104
	140	110
	140	106
	130	104
	130	102
	122	110
	124	110
	126	100
	130	120
	134	116
Average	132	108

Table 25. Physical Testing Data on Yarn and Fabric for 100% Lirelle - 4.00 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.55	6.0	2.00
	1.54	6.0	1.89
	1.45	6.3	1.83
	1.49	6.6	2.00
	1.30	6.6	2.05
	1.30	6.3	2.04
	1.38	6.3	1.97
	1.33	7.2	2.10
	1.32	5.7	2.17
	1.34	5.7	1.81
Average	1.40	6.3	1.98

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.16	7.5	1.00
	1.21	7.8	1.10
	1.20	8.4	1.15
	1.19	7.2	1.08
	1.05	8.1	0.96
	1.21	7.8	1.14
	1.19	8.1	1.12
	1.11	6.6	1.06
	1.14	7.8	1.06
	1.10	7.8	1.02
Average	1.15	7.7	1.07

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	165	18.85	3110
	151	19.37	2925
	161	18.82	3030
	172	18.82	3237
	158	19.04	3008
	158	18.91	2987
	144	19.10	2750
	149	18.72	2789
	164	19.15	3140
	144	18.77	2702
Average	157	18.95	2967

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	138	101
	130	101
	124	99
	136	94
	128	95
	120	103
	118	111
	124	99
	126	105
	126	113
Average	127	102

Table 26 . Physical Testing Data on Yarn and Fabric for 75% Lirelle/25% Orlon - 2.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.26	5.4	1.79
	1.28	5.7	1.82
	1.36	6.3	1.82
	1.30	5.7	1.76
	1.20	5.7	1.76
	1.38	6.0	1.89
	1.36	6.3	2.03
	1.28	6.0	1.79
	1.34	5.7	1.82
	1.32	6.0	1.86
Average	1.30	5.9	1.83

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.00	6.6	1.75
	1.06	6.3	1.28
	0.98	6.3	1.21
	0.94	6.0	1.21
	1.02	6.9	1.11
	1.06	6.9	1.21
	0.92	6.6	1.14
	1.02	6.3	1.25
	1.04	6.6	1.28
	1.00	6.3	1.28
Average	1.00	6.5	1.21

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	149	19.74	2921
	155	19.98	3096
	150	19.87	2980
	155	20.01	3101
	154	19.63	3023
	146	20.55	3000
	150	19.38	2907
	153	19.52	2986
	147	19.49	2865
	146	20.26	2957
Average	151	19.84	2983

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	120	90
	115	85
	108	79
	106	81
	123	83
	116	86
	118	75
	110	85
	112	87
	106	80
Average	113	83

Table 27. Physical Testing Data on Yarn and Fabric for 75% Lirelle/25% Orlon - 3.00 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.42	6.0	1.99
	1.28	5.4	1.96
	1.42	6.0	1.99
	1.38	5.7	1.89
	1.36	5.4	1.99
	1.26	5.4	1.86
	1.32	5.7	2.03
	1.28	5.7	1.89
	1.40	6.0	1.93
	1.30	5.7	1.83
Average	1.34	5.7	1.94

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.10	6.6	1.21
	1.20	7.2	1.25
	0.94	6.6	1.11
	1.02	6.9	1.25
	1.06	6.6	1.25
	0.95	6.3	1.15
	0.97	6.6	1.15
	1.02	6.9	1.11
	1.06	6.3	1.28
	1.08	6.6	1.25
Average	1.04	6.7	1.20

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	150	20.00	3000
	161	20.02	3223
	152	19.60	2979
	134	20.01	2681
	159	19.90	3164
	161	19.42	3212
	160	20.08	3209
	144	19.90	2865
	163	19.60	3195
	165	19.59	3232
Average	154	19.81	3075

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	118	94
	105	96
	125	76
	98	90
	108	86
	122	89
	109	91
	121	80
	118	92
	112	88
Average	113	88

Table 28. Physical Testing Data on Yarn and Fabric for 75% Lirelle/75% Orlon - 3.25 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.32	6.0	1.88
	1.42	6.3	1.98
	1.30	6.0	1.88
	1.20	5.7	1.84
	1.26	6.3	1.81
	1.32	6.0	1.88
	1.30	6.0	1.88
	1.44	6.3	1.95
	1.48	6.0	2.05
	1.40	6.0	1.98
Average	1.34	6.1	1.91

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.08	7.2	1.12
	0.96	6.6	1.12
	1.16	6.9	1.19
	1.06	6.9	1.06
	0.98	7.3	1.19
	1.04	7.8	1.10
	1.10	6.3	1.12
	1.00	6.0	1.09
	1.08	6.9	1.19
	0.96	6.3	1.26
Average	1.04	6.8	1.14

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	159	20.07	3191
	153	19.82	3032
	153	20.15	3082
	146	20.18	2946
	156	20.00	3120
	143	20.00	2860
	160	20.10	3216
	163	19.92	3246
	162	19.57	3170
	146	19.90	2905
Average	154	19.97	3076

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	108	93
	118	86
	120	87
	114	90
	119	92
	124	97
	118	96
	115	82
	113	83
	119	90
Average	117	90

Table 29 . Physical Testing Data on Yarn and Fabric for 75% Litrelle/25% Orlon - 3.50 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.24	6.0	1.88
	1.32	6.0	1.91
	1.34	5.7	1.98
	1.26	5.7	1.95
	1.28	5.4	1.98
	1.22	5.4	1.95
	1.18	5.1	1.95
	1.30	5.4	2.05
	1.24	6.0	1.91
	1.28	5.4	1.95
Average	1.27	5.6	1.95

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.02	6.9	1.18
	0.98	6.6	1.14
	1.08	7.2	1.05
	1.02	6.3	1.14
	1.00	6.6	1.14
	0.96	6.9	1.05
	1.00	7.4	1.05
	1.06	6.9	1.18
	0.90	7.2	1.08
	1.00	7.8	0.98
Average	1.00	7.0	1.10

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	149	19.49	2904
	155	19.29	2989
	160	19.52	3123
	156	19.38	3023
	152	19.45	2956
	149	20.34	3030
	159	19.47	3095
	142	20.19	2866
	140	20.37	2851
	129	20.01	2781
Average	150	19.75	2961

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	112	82
	110	91
	115	80
	102	85
	110	88
	116	95
	119	92
	111	81
	106	84
	108	87
Average	111	86

Table 30. Physical Testing Data on Yarn and Fabric for 75% Litrelle/25% Orlon - 3.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.22	6.0	1.75
	1.36	6.0	1.89
	1.20	5.7	1.79
	1.30	6.0	1.82
	1.34	6.3	1.85
	1.30	6.3	1.82
	1.22	5.7	1.79
	1.20	6.0	1.76
	1.20	5.7	1.72
	1.30	5.4	1.82
Average	1.27	5.9	1.80

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Percent)	Modulus (gpd)
	1.02	7.2	1.09
	1.00	6.9	1.00
	1.02	7.5	1.02
	0.96	6.6	1.08
	1.04	7.5	1.00
	0.98	6.9	1.00
	0.96	6.3	1.06
	0.96	6.9	0.97
	1.00	6.6	1.09
	1.08	7.5	1.09
Average	1.00	7.0	1.04

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	143	19.29	2758
	148	19.10	2826
	148	19.30	2856
	151	19.27	2909
	149	19.62	2923
	153	19.57	2994
	146	19.42	2835
	152	19.41	2950
	143	19.47	2784
	140	19.41	2717
Average	147	19.38	2855

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	106	92
	95	78
	108	89
	108	69
	107	76
	103	88
	100	84
	94	73
	110	79
	108	83
Average	104	81

Table 31. Physical Testing Data on Yarn and Fabric for 75% Lirelle/25% Orlon - 4.00 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.34	6.6	1.80
	1.32	6.6	1.77
	1.36	6.3	1.83
	1.26	5.7	1.70
	1.20	5.7	1.70
	1.18	5.4	1.77
	1.30	6.6	1.74
	1.24	6.0	1.77
	1.22	5.7	1.75
	1.36	6.3	1.85
Average	1.28	6.1	1.76

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.06	6.6	1.11
	1.00	7.2	1.00
	1.04	6.3	1.08
	1.02	6.6	1.08
	0.94	6.9	1.00
	0.92	6.6	0.98
	1.00	6.6	0.98
	1.02	7.2	1.02
	0.94	7.5	0.95
	1.00	7.5	1.04
Average	0.99	6.9	1.02

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	145	19.10	2769
	142	19.19	2724
	149	19.53	2909
	149	19.10	2845
	140	19.12	2676
	142	19.49	2767
	142	19.65	2790
	141	18.79	2649
	141	19.61	2765
	144	18.80	2707
Average	144	19.23	2760

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	111	89
	102	77
	105	70
	115	84
	106	89
	98	85
	101	80
	107	84
	104	82
	98	87
Average	105	83

Table 32. Physical Testing Data on Yarn and Fabric for 50% Lirelle/50% Orlon - 2.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.08	5.7	1.75
	1.02	5.4	1.71
	1.08	5.7	1.75
	1.04	6.0	1.66
	0.90	4.5	--
	1.01	6.0	1.64
	0.91	4.2	--
	1.03	6.0	1.68
	0.98	5.4	1.50
	1.04	5.7	1.62
Average	1.01	5.5	1.66

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.88	6.9	1.08
	0.82	6.3	1.15
	0.76	6.0	1.05
	0.78	6.0	1.08
	0.80	6.3	1.10
	0.90	6.9	1.05
	0.92	6.9	1.12
	0.76	6.3	1.05
	0.88	6.9	1.12
	0.74	6.0	1.04
Average	0.83	6.5	1.08

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	98	20.90	2048
	121	20.23	2447
	130	20.18	2623
	120	20.40	2448
	119	20.52	2441
	129	20.23	2609
	115	20.57	2365
	117	20.88	2442
	101	20.42	2062
	122	20.25	2470
Average	117	20.45	23.95

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	98	96
	106	94
	96	88
	106	92
	110	86
	108	84
	102	92
	96	92
	100	82
	106	92
Average	103	90

Table 33. Physical Testing Data on Yarn and Fabric for 50% Lirelle/50% Orlon - 3.00 TM

	Dry Single End Results			Wet Single End Results		
	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.04	5.7	1.66	0.90	6.6	1.10
	1.02	5.8	1.51	0.90	7.2	1.04
	1.00	5.1	1.61	0.90	6.9	1.10
	0.94	3.9	--	0.90	7.8	1.01
	0.99	5.1	1.61	0.88	6.9	1.04
	1.18	6.6	1.81	0.94	7.5	1.01
	0.90	4.5	--	0.94	7.2	1.08
	1.02	5.1	1.71	0.90	6.9	1.10
	1.08	6.0	1.49	0.80	6.3	1.14
	1.14	6.0	1.83	0.82	6.3	1.10
Average	1.03	5.4	1.65	0.89	7.0	1.07

	Dry Skein Results			Fabric Grab Tests Results	
	Breaking Strength (lbs.)	Cotton Count	Lea Product	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	1.31	19.94	2612	120	97
	129	19.79	2552	110	95
	128	19.46	2490	106	100
	133	19.64	2612	114	102
	134	19.68	2637	118	90
	131	19.76	2588	116	92
	127	19.84	2519	114	100
	130	19.66	2558	110	108
	128	20.02	2562	108	102
	122	19.27	2350	112	100
Average	129	19.70	2548	113	99

Table 34. Physical Testing Data on Yarn and Fabric for 50% Lirelle/50% Orlon - 3.25 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.04	5.1	1.68
	1.10	6.0	1.66
	1.12	5.7	1.62
	1.00	5.4	1.55
	1.06	6.9	1.55
	1.02	5.1	1.53
	1.04	5.4	1.62
	1.00	5.7	1.52
	1.10	5.4	1.73
	1.10	5.7	1.69
Average	1.06	5.5	1.62

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.86	6.3	1.13
	0.92	7.5	1.13
	1.00	7.5	1.09
	0.80	7.2	1.13
	0.92	6.9	1.06
	0.82	6.3	1.12
	0.80	6.3	1.15
	0.92	6.6	1.18
	0.88	6.9	1.16
	0.90	6.9	1.06
Average	0.88	6.8	1.12

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	122	20.19	2463
	123	19.67	2419
	92	22.10	2033
	121	10.97	2416
	130	19.97	2596
	122	20.33	2480
	133	10.61	2608
	124	19.18	2378
	128	19.49	2594
	129	19.70	2541
Average	122	20.02	2442

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	118	101
	112	100
	108	102
	110	100
	112	95
	106	93
	116	89
	112	99
	120	87
	114	95
Average	113	96

Table 35. Physical Testing Data on Yarn and Fabric for 50% Lirelle/50% Orlon - 3.50 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.06	6.3	1.56
	1.12	6.9	1.49
	1.10	6.3	1.60
	1.08	5.1	1.58
	0.98	5.1	1.43
	1.14	6.6	1.56
	1.12	6.0	1.56
	1.04	6.0	1.42
	1.14	6.6	1.62
	0.98	5.4	1.53
Average	1.07	6.0	1.54

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.94	6.9	1.08
	0.92	6.3	1.12
	0.88	7.2	1.08
	0.98	7.5	1.14
	0.80	6.0	1.09
	0.87	7.5	1.08
	0.86	6.9	1.01
	0.83	6.6	0.99
	0.90	7.5	1.05
	0.86	7.2	1.05
Average	0.88	7.0	1.06

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	122	20.00	2440
	128	19.67	2512
	120	20.03	2403
	120	19.98	2397
	129	19.14	2469
	119	19.52	2328
	128	19.68	2519
	123	19.70	2423
	132	19.64	2592
	128	19.93	2551
Average	124	19.73	2463

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	110	100
	112	96
	108	90
	104	104
	114	94
	110	100
	106	98
	108	99
	116	101
	106	90
Average	109	97

Table 36. Physical Testing Data on Yarn and Fabric for 50% Lirelle/50% Orlon - 3.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.94	5.1	1.52
	0.94	5.4	1.50
	1.04	6.0	1.53
	1.10	6.0	1.65
	1.10	6.3	1.69
	0.96	5.4	1.59
	0.98	4.5	--
	1.00	5.4	1.55
	1.00	5.4	1.66
	1.02	6.3	1.59
Average	1.01	5.6	1.58

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.84	5.7	1.20
	0.98	7.2	1.23
	0.92	6.9	1.10
	0.94	6.6	1.16
	0.88	6.6	1.07
	0.90	6.9	1.10
	0.90	7.2	1.07
	0.80	6.3	1.07
	0.94	6.9	1.13
	0.80	5.7	1.20
Average	0.89	6.6	1.13

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	125	19.62	2452
	129	19.15	2476
	142	18.68	2652
	126	19.50	2457
	129	18.57	2395
	140	19.02	2662
	125	18.75	2343
	120	19.00	2280
	130	18.81	2445
	137	18.73	2566
Average	130	18.98	2472

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	108	101
	108	88
	108	97
	102	95
	100	91
	104	95
	98	100
	106	102
	102	98
	110	95
Average	105	96

Table 37. Physical Testing Data on Yarn and Fabric for 50% Lirelle/50% Orlon - 4.00 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.06	6.0	1.46
	0.89	5.1	1.40
	1.07	6.3	1.59
	1.08	6.0	1.58
	1.00	5.7	1.46
	1.00	6.0	1.46
	1.12	5.4	1.64
	1.00	5.7	1.43
	0.98	6.0	1.39
	0.99	6.0	1.55
Average	1.02	5.8	1.50

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.82	6.6	1.01
	0.86	8.1	0.99
	0.84	6.9	1.02
	0.88	7.8	1.06
	0.87	7.5	0.96
	0.90	6.8	0.99
	0.90	7.2	1.06
	0.81	7.2	0.93
	0.86	6.9	1.02
	0.82	6.5	0.99
Average	0.85	7.1	1.00

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	125	19.20	2400
	125	19.28	2410
	125	19.61	2451
	124	19.48	2415
	125	19.18	2397
	121	19.20	2323
	120	20.08	2409
	123	19.10	2349
	124	19.12	2445
	120	19.18	2301
Average	123	19.40	2390

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	102	99
	102	93
	98	97
	100	91
	106	97
	100	93
	104	95
	98	90
	104	94
	102	100
Average	102	95

Table 38. Physical Testing Data on Yarn and Fabric for 25% Lirelle/75% Orlon - 2.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.88	9.6	1.29
	0.82	10.8	1.25
	1.00	12.0	1.45
	0.98	9.6	1.44
	0.81	9.0	1.28
	0.80	11.4	1.19
	0.84	10.4	1.25
	0.84	9.6	1.30
	0.84	9.0	1.34
	0.80	9.0	1.23
Average	0.86	10.0	1.30

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.82	10.8	1.19
	0.70	12.0	1.10
	0.72	12.0	1.02
	0.92	12.0	1.17
	0.88	10.4	1.17
	0.72	9.0	1.22
	0,74	9.6	1.12
	0.72	9.0	1.12
	0.78	9.6	1.19
	0.84	12.6	1.12
Average	0.78	10.7	1.14

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	95	21.58	2050
	93	21.80	2027
	106	19.13	2027
	100	19.82	1982
	100	19.63	1963
	101	19.81	2000
	111	19.11	2121
	105	19.50	2047
	105	19.51	2059
	110	19.41	2135
Average	103	19.93	2041

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	89	90
	94	88
	95	85
	87	81
	102	78
	98	74
	91	77
	99	89
	94	92
	88	82
Average	94	83

Table 39. Physical Testing Data on Yarn and Fabric for 25% Lirelle/75% Orlon - 3.00 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.92	12.0	1.45
	1.00	12.6	1.48
	0.92	12.6	1.35
	1.02	12.6	1.48
	0.98	11.4	1.48
	0.96	11.4	1.45
	0.84	10.8	1.35
	0.90	10.8	1.31
	0.86	9.6	1.33
	0.98	10.8	1.47
Average	0.94	11.5	1.41

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.76	9.0	1.22
	0.80	7.2	1.29
	0.82	7.8	1.29
	0.90	9.0	1.33
	0.82	6.6	1.32
	0.90	12.6	1.36
	0.86	11.4	1.32
	0.78	7.2	1.22
	0.78	9.0	1.22
	0.76	8.4	1.22
Average	0.82	8.8	1.28

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	102	19.41	1979
	117	18.62	2178
	100	20.40	2040
	100	19.51	1951
	115	18.90	2173
	106	19.22	2037
	113	19.20	2169
	110	19.33	2126
	113	19.29	2179
	98	20.00	1960
Average	107	19.38	2079

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	100	91
	86	84
	91	84
	107	89
	103	103
	95	82
	90	93
	103	90
	100	80
	94	85
Average	97	88

Table 40. Physical Testing Data on Yarn and Fabric for 25% Lirelle/75% Orlon - 3.25 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.00	12.6	1.46
	0.86	10.2	1.36
	0.84	12.6	1.34
	1.02	10.2	1.32
	0.96	10.2	1.49
	0.92	9.6	1.49
	1.02	13.8	1.42
	0.98	11.4	1.46
	0.88	10.2	1.39
	0.90	10.8	1.36
Average	0.94	11.2	1.40

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.90	12.6	1.30
	0.90	12.0	1.28
	0.78	7.8	1.19
	0.84	9.0	1.25
	0.76	8.4	1.15
	0.80	10.2	1.22
	0.86	9.0	1.29
	0.80	9.0	1.19
	0.78	7.8	1.12
	0.78	10.8	1.12
Average	0.82	9.7	1.21

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	113	19.01	2148
	102	20.51	2092
	111	19.34	2146
	111	19.10	2120
	100	20.35	2035
	93	20.66	1921
	97	19.62	1903
	92	20.24	1862
	110	19.41	2135
	109	19.03	2074
Average	104	19.72	2044

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	94	89
	99	82
	108	82
	96	87
	98	101
	110	85
	97	82
	92	97
	103	93
	95	84
Average	100	88

Table 41. Physical Testing Data on Yarn and Fabric for 25% Lirelle/75% Orlon - 3.50 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.96	9.0	1.46
	0.98	12.6	1.42
	0.96	10.8	1.48
	0.86	9.0	1.36
	0.86	9.6	1.32
	0.84	9.0	1.34
	0.98	12.6	1.39
	1.00	10.4	1.46
	0.94	12.0	1.42
	0.98	10.4	1.39
Average	0.94	10.5	1.40

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.90	10.8	1.20
	0.90	12.6	1.15
	0.82	8.4	1.08
	0.90	15.0	1.05
	0.84	9.0	1.08
	0.94	12.0	1.09
	0.80	9.0	1.05
	0.84	9.6	1.08
	0.78	9.0	1.05
	0.84	9.6	1.18
Average	0.86	10.5	1.09

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	116	18.76	2176
	90	21.28	1915
	113	18.51	2091
	98	20.80	2038
	110	19.55	2150
	112	18.48	2069
	112	18.81	2106
	94	21.29	2001
	91	21.10	1920
	97	20.80	2017
Average	103	19.93	2048

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	101	81
	99	92
	99	79
	101	90
	101	91
	100	75
	100	86
	98	83
	102	90
	109	89
Average	100	86

Table 42. Physical Data on Yarn and Fabric for 25% Lirelle/75% Orlon - 3.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.98	10.8	1.31
	0.88	9.0	1.28
	0.96	9.6	1.31
	1.00	10.8	1.41
	1.00	12.6	1.43
	0.84	10.8	1.28
	0.98	9.6	1.37
	1.04	9.6	1.36
	0.94	9.0	1.26
	0.92	10.2	1.42
Average	0.95	10.2	1.35

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.84	9.6	1.02
	0.84	10.4	1.05
	0.90	13.8	0.95
	0.78	10.8	0.98
	0.82	10.8	1.02
	0.70	8.4	1.11
	0.70	7.8	0.98
	0.80	12.0	0.95
	0.70	8.4	0.95
	0.86	9.2	1.05
Average	0.80	10.1	1.01

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	107	18.88	2020
	100	20.14	2014
	96	19.20	1843
	102	19.15	1953
	90	20.04	1803
	92	20.11	1850
	113	19.00	2147
	108	18.92	2043
	102	19.20	1958
	107	19.12	2045
Average	102	19.37	1938

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	94	94
	85	80
	105	84
	106	87
	103	91
	99	78
	100	92
	89	77
	98	81
	95	85
Average	97	85

Table 43. Physical Testing Data on Yarn and Fabric for 25% Lirelle/75% Orlon - 4.00 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.90	10.8	1.42
	0.92	13.8	1.33
	0.96	9.2	1.46
	0.84	8.6	1.30
	1.00	9.0	1.48
	1.04	11.4	1.46
	0.82	9.0	1.29
	0.86	9.0	1.36
	0.86	8.4	1.36
	0.86	8.4	1.39
Average	0.90	9.8	1.39

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.70	7.8	0.83
	0.88	12.0	0.96
	0.82	12.0	0.96
	0.80	10.8	0.97
	0.79	8.4	1.03
	0.68	9.0	0.93
	0.84	12.0	0.93
	0.82	12.0	0.97
	0.72	9.6	0.97
	0.78	10.8	0.93
Average	0.78	10.4	0.95

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	105	19.15	2010
	114	19.22	2191
	117	18.50	2165
	95	19.08	1812
	88	19.20	1690
	87	19.29	1678
	107	19.05	2038
	86	19.50	1677
	105	18.50	1943
	95	19.08	1812
Average	100	19.06	1901

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	106	86
	92	90
	91	93
	101	82
	101	88
	110	94
	95	97
	97	90
	94	92
	98	84
Average	99	90

Table 44. Physical Testing Data on Yarn and Fabric for 100% Orlon - 2.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.16	16.2	1.06
	1.18	18.0	1.06
	0.96	13.2	1.00
	1.06	14.4	1.03
	1.28	17.4	1.03
	1.30	18.6	0.97
	1.00	12.8	0.97
	1.12	13.2	1.03
	1.29	16.2	1.16
	1.25	18.6	1.10
Average	1.16	15.8	1.04

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.06	15.6	0.85
	1.06	16.2	0.91
	1.08	16.8	0.88
	1.04	15.0	0.88
	1.14	18.0	0.94
	1.02	15.6	0.85
	1.04	16.2	0.91
	1.06	17.4	0.88
	1.04	16.6	0.88
	0.96	15.0	0.85
Average	1.03	16.2	0.88

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	96	19.59	1880
	99	20.11	1990
	92	20.25	1863
	95	19.40	1843
	91	19.95	1815
	86	20.26	1742
	91	19.20	1747
	90	19.71	1892
	85	20.32	1605
	92	20.25	1863
Average	92	19.90	1824

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	104	117
	108	108
	125	100
	114	105
	116	105
	108	113
	112	104
	121	199
	112	109
	106	98
Average	113	106

Table 45. Physical Testing Data on Yarn and Fabric for 100% Orlon - 3.00 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.30	16.8	1.08
	1.20	15.6	1.05
	1.26	16.2	0.99
	1.32	19.8	1.02
	1.34	20.4	1.05
	1.12	15.6	0.99
	1.16	15.0	0.96
	1.16	15.0	1.02
	1.18	15.0	1.05
	1.32	18.0	1.14
Average	1.23	16.7	1.04

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.08	13.2	0.88
	1.18	18.0	0.97
	1.22	21.0	0.88
	1.04	18.0	0.85
	0.96	15.0	0.88
	1.10	15.0	0.85
	0.94	15.6	0.97
	1.04	15.0	0.94
	1.08	15.6	0.85
	1.10	16.2	0.97
Average	1.08	16.3	0.90

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	120	18.72	2246
	104	19.22	1998
	92	19.15	1761
	96	19.18	1841
	102	19.24	1962
	90	19.78	1780
	92	19.38	1782
	90	19.45	1750
	107	19.12	2045
	110	19.02	2092
Average	100	19.22	1925

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	110	113
	115	102
	126	111
	119	99
	115	121
	122	117
	115	109
	114	106
	119	103
	111	104
Average	117	108

Table 46. Physical Testing Data on Yarn and Fabric for 100% Orlon - 3.25 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.12	16.2	1.02
	1.28	16.8	1.14
	1.30	18.6	1.05
	1.32	19.2	1.13
	1.20	15.0	1.01
	1.26	17.4	1.05
	1.18	17.4	1.01
	1.24	16.8	1.14
	1.16	15.0	1.05
	1.14	16.2	1.05
Average	1.22	16.8	1.06

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.08	18.6	0.91
	1.04	18.0	0.97
	1.18	19.2	0.97
	1.06	17.4	0.90
	0.94	15.6	0.91
	0.98	16.2	0.88
	0.92	15.0	0.90
	1.18	19.2	0.88
	1.22	20.4	0.94
	1.16	19.8	0.95
Average	1.07	17.9	0.92

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	107	19.65	2102
	111	19.90	2208
	110	19.20	2112
	98	20.04	1964
	105	19.28	2024
	112	19.20	2150
	104	19.10	2117
	103	19.30	1986
	102	19.30	1968
Average	106	19.39	2062

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	122	115
	126	116
	118	99
	115	108
	120	98
	126	111
	114	103
	111	112
	118	98
Average	120	107

Table 47. Physical Testing Data on Yarn Fabric for 100% Orlon - 3.50 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.22	17.4	1.08
	1.24	18.6	1.02
	1.38	18.0	1.15
	1.35	16.2	1.12
	1.18	18.0	1.12
	1.28	19.2	1.05
	1.28	19.2	1.15
	1.16	17.4	1.02
	1.22	15.6	1.08
	1.16	15.0	1.02
Average	1.24	17.4	1.08

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.12	19.2	0.90
	1.14	21.0	0.93
	1.00	18.0	0.90
	1.16	21.6	0.87
	1.08	16.2	0.87
	1.04	15.6	0.87
	1.12	19.2	0.96
	0.96	15.0	0.87
	1.06	15.6	0.96
	1.06	16.8	0.90
Average	1.07	17.8	0.90

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	113	19.63	2218
	98	19.37	1848
	113	19.53	2207
	100	19.60	1960
	109	19.40	2114
	110	19.54	2149
	96	19.68	1889
	105	19.34	2030
	102	19.61	2000
	112	19.52	2186
Average	106	19.52	2065

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	130	112
	124	98
	127	106
	120	116
	122	117
	126	116
	120	102
	124	102
	126	112
	128	117
Average	125	110

Table 48. Physical Testing Data on Yarn and Fabric for 100% Orlon - 3.75 TM

Dry Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.18	16.2	1.02
	1.20	19.2	1.06
	1.04	15.0	1.00
	1.08	15.6	1.03
	1.24	19.2	1.03
	1.22	18.6	0.97
	1.12	15.6	0.97
	1.10	15.0	1.08
	1.26	19.2	1.03
	1.30	19.8	1.06
Average	1.17	17.3	1.03

Wet Single End Results

	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	0.90	16.2	0.87
	1.04	16.8	0.96
	1.15	21.0	0.99
	1.14	19.8	0.96
	1.08	19.2	0.99
	1.06	18.6	0.96
	1.06	18.6	0.96
	1.04	18.0	0.96
	0.98	16.8	0.87
	0.96	16.2	0.96
Average	1.04	18.1	0.95

Dry Skein Results

	Breaking Strength (lbs.)	Cotton Count	Lea Product
	114	19.72	2248
	106	19.22	2037
	102	19.15	1953
	103	19.18	1975
	102	19.24	1962
	96	19.78	1898
	95	19.62	1863
	107	19.12	2045
	110	19.23	2115
	100	19.42	1942
Average	104	19.37	2003

Fabric Grab Tests Results

	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	120	104
	116	106
	100	96
	117	106
	125	96
	116	112
	121	112
	104	104
	120	108
	125	105
Average	116	105

Table 49. Physical Testing Data on Yarn and Fabric for 100% Orlon - 4.00 TM

	Dry Single End Results			Wet Single End Results		
	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)	Breaking Strength (lbs.)	Elongation (Per Cent)	Modulus (gpd)
	1.20	18.0	1.01	1.18	20.4	0.96
	1.12	16.8	0.98	1.16	21.0	1.02
	1.20	16.8	1.04	1.04	16.2	0.90
	1.20	18.0	1.07	1.06	16.8	0.90
	1.18	16.2	1.04	1.00	15.6	0.96
	1.18	17.4	1.04	0.98	15.0	0.99
	1.00	16.2	0.84	1.11	16.8	1.02
	1.19	16.8	1.01	1.12	16.8	0.90
	1.06	16.2	0.98	0.96	14.4	0.93
	1.19	16.2	1.04	1.04	16.2	0.93
Average	1.15	16.8	1.01	1.06	17.0	0.95

	Dry Skein Results			Fabric Grab Tests Results	
	Breaking Strength (lbs.)	Cotton Count	Lea Product	Dry Breaking Strength (lbs.)	Wet Breaking Strength (lbs.)
	98	19.31	1892	102	98
	105	19.11	2006	108	100
	101	19.02	1921	125	90
	98	19.32	1893	114	95
	93	19.41	1805	116	97
	102	19.20	1958	98	104
	101	18.71	1889	104	102
	102	19.40	1978	110	94
	105	19.10	2005	112	101
	90	19.31	1729	108	93
Average	100	19.19	1907	110	97

BIBLIOGRAPHY

LITERATURE CITED

1. Hearle, J.W.S., "Blending Fibers: What To Use and Why", Textile Manufacturer, Vol. 89, No. 1057, p. 3, January, 1963.

2. Charnley, F., "Production and Uses of Blended Yarns", Textile Weekly, Vol. 57 (2), No. 1554, p. 1854, December 27, 1957.

3. Caldwell, S.A.G., "Modern Fibre Blending Practice", Man-Made Textiles, Vol. 38, No. 444, p. 51, June 1961.

4. Hearle, loc. cit.

5. Houtz, R.C., "Orlon Acrylic Fiber: Chemistry and Properties", Textile Research Journal, Vol. 20, No. 9, p. 786, September, 1950.

6. Anon., "Orlon and You", E.I. DuPont de Nemours and Co., Inc., Wilmington, Delaware.

7. Moncrieff, R.W., Man-made Fibers, Third Edition, John Wiley and Sons, Inc., New York, New York, 1959, p. 405.

8. Anon., "Orlon and You", loc. cit.

9. Moncrieff, loc. cit.

10. Anon., "Orlon and You", op.cit.

11. Ibid.

12. Ibid.

13. Moncrieff, op. cit., p. 118.

14. Hearle, J.W.S., "The New Rayons", Man-Made Textiles, Vol. 37, No. 435, p. 42, September, 1960.

15. Anon., "Rayon and You", E.I. DuPont de Nemours and Co., Inc., Wilmington, Delaware.

16. Lund, G.V., Wharton, J., "All the Advantages of Rayon Plus SM-27, a Man-Made High Modulus Cellulosic Fibre", Textile Mercury and Argus, Vol. 143, No. 3723, p. 205, August 12, 1960.

17. Cheatham, A.F., "An Introduction to Textile Properties of "Corval" and "Topel" Fibres", Canadian Textile Journal, Vol. 77, No. 27, p. 55, December 23, 1960.

18. Hearle, "The New Rayons", loc. cit.

19. Tachikawa, Schozo, U.S. Patents 2,592,355 (April 8, 1952) and 2,732,279 (January 24, 1956).

20. Tachikawa, Schozo, "Tachikawa's New Viscose Staple", Rayon Synthetic Textiles, vol. 32, No. 3.

21. Hearle, J.W.S., "The New Rayons", op.cit.

22. Lund, Wharton, op.cit., p. 206.

23. Cheatham, A.F., "Lirelle, Courtaulds' New High Wet Modulus Rayon", Modern Textiles Magazine, Vol. 45, p. 114, January, 1964.

24. Anon., "Lirelle Technical Bulletin", Courtaulds North America, Inc., Mobile, Alabama, p. 3.

25. Abbenheim, P., "Britain's Polynosic Fibre", Man-Made Textiles, Vol. 39, No. 454, p. 34, April, 1962.

26. Anon., "Lirelle Technical Bulletin", op.cit., p. 7, 8.

27. Abbenheim, op.cit.

28. Anon., "Lirelle Technical Bulletin", op.cit.

29. Regan, R.W., "Some New Types of Rayon Staple and Fields of Application", American Enka Corp., Paper presented to Thirty-Second Meeting of Textile Research Institute, New York City, March 19, 20, 21, 1962, p. 1.

30. Anon., "Fiber 40 (Avril Rayon), Technical Bulletin of American Viscose Corporation, Marcus Hook, Pennsylvania, April 15, 1961.

31. Anon.,"Lirelle Technical Bulletin", op.cit., p. 4.

32. Regan, op.cit., p. 1.

33. Regan, op.cit., p. 9, 10.

34. Anon., "Fiber 40 (Avril Rayon)", op.cit., p. 3.

35. Gupta, S.B., Bogdan, J.F., Grover, E.B., "Literature Survey of Fiber Blending for the years 1952-1963", North Carolina State School of Textiles, July, 1964.

36. Quig, J.B., "Fiber Blending With Nylon, Orlon, and Dacron", Textile World, Vol. 103, No. 9, p. 129, September, 1953.

37. Sayre, J.F., "A Basic Study of Blends", Textile Fibers Department, Merchandising Division, E.I. DuPont de Nemours and Co., Inc., Wilmington, Delaware, March 15, 1966.

38. Goodwin, J.A., Nair, B., "Cotton and Orlon Blends in Yarns", Lowell Technical Institute Bulletin, Ser. 61, No. 2, p. 15, November, 1957.

39. Sayre, op.cit., p. 4.

40. Anon., "Blends of Orlon with Cotton or Rayon", Technical Bulletin of E.I. duPont de Nemours and Co., Inc., Wilmington, Delaware, OR-139, November, 1964.

41. Ibid., p. 8.

42. Goodwin, Nair, op.cit., p. 7, 8.