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METHOD OF PREPARING CRIMPED YARNS

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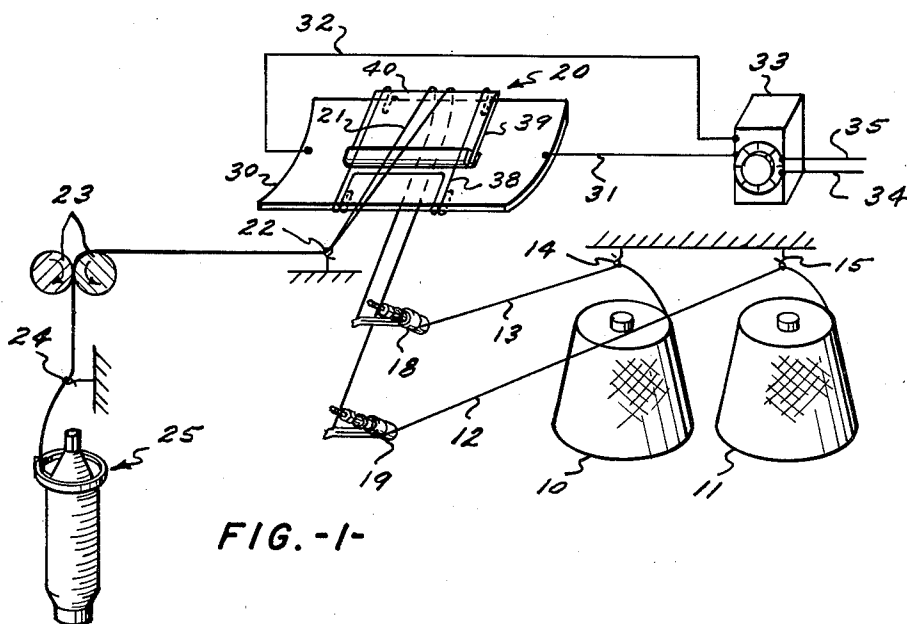


FIG. -1-

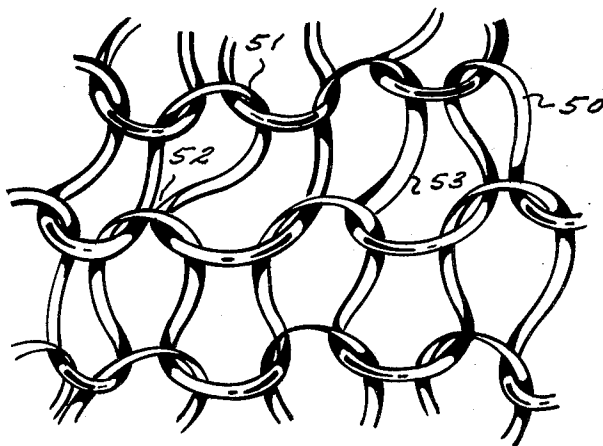


FIG. -2-

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3,035,328

METHOD OF PREPARING CRIMPED YARNS

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Original application Nov. 2, 1955, Ser. No. 544,521, now Patent No. 2,919,534, dated Jan. 5, 1960. Divided and this application Mar. 2, 1959, Ser. No. 796,423 7 Claims. (Cl. 28—72)

This invention relates to methods for producing fabrics and yarns having an elastic nature and is a division of U.S. application Serial Number 544,521, filed November 2, 1955, now U.S. Patent 2,919,534, and a continuation-in-part of application Serial Number 274,358, filed March 1, 1952.

A number of methods for producing fabrics and yarns which have an elastic nature are now well known in the art. For example, it is known that a thermoplastic yarn having an elastic nature can be produced by twisting an uncrimped, continuous filament thermoplastic yarn, heat setting the highly twisted yarn, and thereafter untwisting, and it is also known that a yarn having an elastic nature can be produced by passing a thermoplastic yarn into a heated stuffing box or between heated intermeshing gear wheels. However, such prior art methods are not satisfactory in all respects since either the yarn has an inadequate degree of elasticity or else the yarn is so highly crimped that handling of the same, for example during weaving and knitting operations, is difficult.

It is an object of the invention to provide methods for the production of yarns which tend to assume a highly convoluted configuration which are not subject to the disadvantages of prior art processes and to methods for processing yarns free of torsional stresses but containing latent differential longitudinal stresses.

Yarns free of torsional stresses but containing latent differential longitudinal stresses can be produced by passing a thermoplastic yarn under tension from a source of supply along a linear path having a curved portion providing an abrupt change of direction, followed immediately by a portion having a lesser amount of curvature i.e., having a relatively great radius of curvature or a straight line path which can be regarded as having an infinite radius of curvature. The yarn is heated so that at least during its passage through the curved portion of the path it is at an elevated temperature but preferably is allowed to cool during its passage through the curved portion of the path having a relatively large radius of curvature. After being allowed to cool under tension, the latent differential longitudinal stresses in the yarn are released by reheating the yarn under such conditions as to permit it to assume a distorted linear configuration, and this second heating operation fully develops the elastic nature of the yarn.

The yarn, subsequent to passage through the angular course but before the second heating operation, is hereinafter referred to as "latently" elasticized yarn, since, as explained above, it is not until after the second heating operation that the yarn develops its full elastic nature. The filaments in the latently elasticized yarn are characterized by a slightly wavy or coiled appearance when in an untensioned condition and in most instances have a slightly flattened cross section. The linear distortions or coils are generally relatively small in number, occurring in some instances as infrequently as 5 or 6 per inch, and are generally of a relatively large amplitude, having diameters of from about 1 to 3 millimeters in the case of filaments smaller than about 30 denier. For example, in a 15 denier monofilament nylon yarn the loops were found to have an average diameter of 1.85 mm. and in the case of a 70 denier, 34 filament nylon yarn the loops were found to

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have an average diameter of 1.58 millimeters. The loops are generally of random sizes but on occasion yarn will be found in which all of the loops appear to be of a substantially constant size. Where the yarn is composed of a plurality of filaments, the loops in adjacent filaments will frequently be found to be running in opposite directions so that the yarn is very bulky in nature.

It is a feature of the invention that if the starting yarn is free of torsional stresses and if no torsional stresses are deliberately introduced during processing, the latently elasticized yarn will be substantially free of torsional stresses and only localized torsional stresses resulting from loop or coil formation will be present when in either a tensioned or untensioned condition. The loops or coils are formed such that about 50% of the loops in each filament are in one direction and the remaining half of the loops are in the opposite direction so that there is no overall tendency for the yarn to twist when the loops are removed by tensioning the yarn. This does not mean, however, that there is a reversal point between each individual loop, but to the contrary the yarn will generally carry several adjacent loops running in one direction before a reversal point is encountered, and in some instances the loops will run in the same direction for as much as several inches before reversing their direction. Latently elasticized yarns according to this invention are, however, characterized by approximately 50% of the loops in each filament running in one direction and 50% in the other only when the filaments are retained substantially free of torsional stresses, and if the yarn is twisted prior to processing or if torsional stresses are deliberately introduced during processing, the loops will form in a manner to largely relieve these stresses. In other words, by employing a twisted monofilament yarn as a starting material, or by twisting the yarn during processing, a latently elasticized yarn having the loops all running in the same direction can readily be prepared. Of course, as will be apparent to those skilled in the art, the torsional stresses in such instances are reintroduced when the coils in the yarn are removed under tension so that a twisted yarn should not be employed where torsional stresses are objectionable after weaving or knitting.

The appearance of the yarn in its final form depends upon a number of factors including the conditions under which the second heating operation is performed. If the latently elasticized yarn is developed by heating a skein of the yarn in an untensioned condition, the fully elasticized yarn will be characterized by an appearance approximating that of the latently elasticized yarn except that the loops or curls will be smaller in diameter and more closely spaced. If the yarn filaments are substantially free of torsional stresses in the first instance, the small loops are formed such that about 50% of the loops are in one direction and the remaining half of the loops are in the opposite direction just as in the latently elasticized yarn. The groups of coils will be of random lengths and the coils will be of random pitch. If the yarn filaments are tensioned, there will be substantially no overall tendency for them to twist, but differential transverse stresses will be developed which will cause the filaments, when relaxed, to reassume their coiled configurations. If torsional stresses are deliberately introduced, it is possible, as in the latently elasticized yarn, to cause the loops in the fully elasticized yarn to form such that they are all running in one direction. The loops, in either instance, will vary in size, but in a well elasticized yarn sample with filaments smaller than about 30 denier the loops will have an average diameter of from 0.2 to 0.9 millimeter and will be so closely spaced as to form a substantially closed helix between reversal points.

The above description of the fully elasticized yarn ap-

plies only where the second heating operation is conducted before the yarn is woven or knitted into fabrics.

It is a feature of the invention that it permits the use of elasticized yarns, and even of elasticized monofilament yarns without plying or similar measures in the manufacture of knit fabrics. This has been previously impossible, because prior art processes are incapable of producing a stable, elasticized, monofilament yarn substantially free of torsional stresses. Knit fabrics formed from non-torsionally stressed yarns according to this invention can be readily distinguished from fabrics formed from conventional elasticized yarns by the loop configuration in the untensioned fabric and by loop behavior upon contraction of the fabric. If one examines a knit fabric formed from elasticized yarns made according to this invention without being torsionally stressed to a high degree, it will be found, when the fabric is stretched to the maximum of its elasticity, that it has a generally normal appearance as if it were made from plain yarns, except that there may be some variation in the size of the interlocking loops of the fabric. When, however, the tension is relaxed and the fabric is allowed to contract in surface area, it will be noticed that a number of things occur. In the first instance, the loops bow and cup so that the previously flat faces of the loops become arcuate and the individual loops no longer lie in a single plane. In a properly finished fabric formed from a well elasticized sample of yarn, the bowing of the loops is frequently so pronounced that in most instances the previously flat face of the loop or, in other words, the surface generally defined by the yarn in the periphery of the loop, is bowed through an arc of from 60 to 180°. Bowing of the loops tends to be especially pronounced near the base or, in other words, the open part of the loop, but is also generally quite apparent near the top of the loop. Secondly, the loop tends to close so that there is a smaller opening at the base of the loop and the yarn forming the loop extends through a greater arc. In some fabrics a portion of the loops will close completely, and in most well elasticized fabrics the yarn in forming the loop will extend through an arc of at least about 270° to 300° when the fabric is completely relaxed. A third change noticeable in many instances and particularly in fabrics knit from monofilament yarns, is that the loops become canted with respect to one another so that they are randomly positioned with respect to the plane of the fabric. The random positioning of the loops with respect to the plane of the fabric is a result of the non-torque elasticization procedure of the invention and does not result in a tendency for the courses of the fabric to become skewed with respect to the wales thereof. High torque elasticized yarns must either be plied or knit "double carrier" with alternating courses or groups of courses of S and Z yarn to prevent or minimize skewing.

A phenomenon which is observed as a result of the above-described elasticizing process is the imparting to the yarn of latent stresses or, in other words, stresses that do not make themselves immediately apparent by changing the linear configuration of the yarn when the tension on the yarn is relaxed. This phenomenon is, of course, quite desirable since it is the release of these stresses during the second heating operation, referred to above, that causes the yarn to develop its full elastic nature and while the exact mechanism involved in the creation of these stresses has not been fully determined, it is known that the stresses are not torsional in nature. For lack of a better phrase, the stresses are referred to as "differential longitudinal stresses" since their potential action is to cause a differential lengthening or shortening of one cross sectional area of the fiber. While their exact nature is not fully understood, the factors which contribute to the creation of these stresses have been accurately determined and will be discussed in subsequent paragraphs.

The yarn to be elasticized according to the new process

of this invention can satisfactorily comprise any continuous filamentary strand composed of an organic, hydrophobic, thermoplastic fiber material; however, nylon yarns such as those formed from the reaction product of hexamethylene diamine and adipic acid or from polymers of caprolactam, are preferred since they can be processed with fewer precautions, are operative through a wider range of conditions and give a higher degree of elasticization than other types of yarn. The invention can, however, also be employed with polyester yarns, such as those prepared from a reaction product of ethylene glycol and terephthalic acid and sold under the name of "Dacron," and under certain conditions, the invention can be employed for the elasticization of polyacrylic fibers formed by the polymerization of acrylonitrile or by the copolymerization of acrylonitrile with a minor amount of another polymeric monomer. Esters of cellulose, such as cellulose triacetate or cellulose diacetate, are also satisfactory in some instances and a suitable material of this type is available under the trade name of "Arnel." Some yarns give difficulty not so much because of their chemical composition or inherent physical properties but because of their cross sectional configuration. For example, an acrylic fiber sold under the name of "Orlon" has a cross sectional shape resembling the silhouette of a dumbbell and is very difficult to elasticize by the process of this invention. Yarns wherein the filaments have a generally circular cross section and a smooth surface are most readily employed and give the most satisfactory results.

The denier and filament size of the yarn to be processed may vary within wide limits and almost any of the commercially available yarns within the previously specified class can be satisfactorily employed. As an illustration of the wide range of denier and filament sizes which can be employed, excellent results have been obtained by employing nylon yarns of the following descriptions: 15 denier monofilament; 12 denier 4 filament; 100 denier 34 filament; 70 denier 34 filament; 200 denier 34 filaments; 400 denier 68 filament; and 800 denier 51 filament. Under suitable conditions the denier per filament can range from 1 to 20 and the total denier can readily be as high as 2000 or more. For example, excellent results in preparing a nylon yarn for use in the rug industry have been achieved by processing a filamentary nylon strand having a total denier of approximately 2,000 in the manner previously described.

Reference will now be made to the accompanying drawings in which

FIGURE 1 is a schematic view in perspective of apparatus suitable for performing the first step of the process of this invention.

FIGURE 2 is an enlarged view in perspective of a knit fabric according to the invention.

With reference to FIGURE 1 of the drawings, there is illustrated a pair of yarn supply means 10 and 11 mounted on a suitable frame or support member, not illustrated. Yarn ends, indicated by the reference numerals 12 and 13, are led from supply packages 10 and 11 through a pair of guide eyes 14 and 15, about a pair of tension regulating devices 18 and 19 and then to a blade assembly generally indicated by the reference numeral 20. The tension regulating devices 18 and 19 serve the dual purposes of removing the fluctuations in tension resulting from the removal of the yarn from the supply packages 10 and 11 and of supplying the yarn ends to the blade assembly 20 at a proper tension, while the guides 14 and 15 are for the purpose of removing the yarn from the yarn supply packages 10 and 11 as smoothly as possible. From the blade assembly 20, which will be subsequently described in greater detail, the yarn ends are drawn through a portion of the yarn path at 21 having a relatively great radius of curvature, shown in FIGURE 1 as a straight line which would provide the maximum change in curvature and therefore is ordinarily preferred, and are then brought together and passed through a guide 22 to a pair of driven rolls

23. The two yarn ends are then passed through a guide 24 and to a conventional ring and spindle array generally indicated by the reference numeral 25.

The blade assembly, generally indicated by the reference numeral 20, is here illustrated as comprising an arcuate heater strip 30, preferably formed of stainless steel or the like, which has been bent to a radius of about 4 inches in order to present a slightly curved surface to the yarn. The resistance heater strip 30 is adapted to be heated by means of an electric current passed therethrough and is connected by a pair of electrical conductors 31 and 32 to a variable transformer 33 which is supplied with power from any suitable source, not illustrated, through leads 34 and 35. Mounted on the heater strip 30 by means of a holder 38 is a blade member 39 here illustrated as a common razor blade of a type which is commercially available under a number of trade names such as Schick, Gem, etc. The acute edge 40 of the blade extends beyond the rear edge of the heater strip 30 a short distance so that the yarn ends 12 and 13 pass in contact with the underside of the heater strip and over the edge of blade 39 in an angular path with the edge 40 of blade 39 positioned at the apex of the angular path.

In operation, yarn ends 12 and 13 are threaded through the apparatus in the manner previously described to rolls 23 and the rolls placed in operation so that both yarn ends can be passed together through guide 24 to the spindle array 25. Before further operation of the rolls 23, the adjustable transformer 33 should be set to give sufficient energy to heater element 30 so that it is heated to the desired temperature. With the heater element 30 at the desired temperature and with the apparatus properly threaded, the rolls 23 and the spindle array 25 are placed in operation and thereafter the apparatus requires no further attention unless an end breaks or a yarn supply becomes depleted. By this arrangement two single ends are processed to give them a potentially elastic nature while plying them together to form a two-ply yarn. It will be understood, however, that the yarn ends can be collected singly if desired and that conventional apparatus which does not impart a twist to the yarn can be employed for the collection thereof.

It will be readily apparent to those skilled in the art that apparatus of the type described can readily be constructed by modification of a conventional spinning or twister frame. In either instance all that need be added is the blade assembly 20, the tension devices 18 and 19 and in some instances the guide member 22. In the case of a twister frame, the rolls 23 can constitute the conventional yarn feed means and in the case of a spinning frame the rolls 23 can constitute the delivery pair of the drawing rolls. It will also be apparent that a single heater strip of considerable length can serve a multiplicity of blades spaced at selected intervals corresponding to each position of the frame. In such an arrangement it is usually desirable for the heating element to be insulated, for example, with foam glass insulation, between the various blade positions to reduce the heat loss.

In the type of apparatus described, the yarn is forced through an abrupt change of direction by passing the same over an acute edge and while this is presently the most convenient method of accomplishing the desired result, it will be apparent that the yarn may be caused to undergo the required abrupt change of direction in other ways.

With particular reference to FIGURE 2 of the drawings, there is illustrated a knit fabric according to this invention formed from monofilament yarn. For ease of illustration the fabric is shown stretched to an extent short of the maximum although it will be understood that the distinguishing characteristics of the fabric are most pronounced when the fabric is in a completely untensioned condition. Canting of the loops with respect to each other and with respect to the plane of the fabric is illustrated by the loops indicated by the reference numerals 50 and 51. This characteristic is among the first to disappear

upon stretching of the fabric and as illustrated in the drawings, the loops have been, to a large extent, drawn into the plane of the fabric. The closed nature of the loops is illustrated, for example at 52, and it will be noticed that a majority of the other loops are more nearly closed than might be expected in a conventional knit fabric although the loops have, in most instances, been opened to some extent by stretching of the fabric. Bowing of the loops is clearly evident, for example at 53. This is presently believed to be perhaps the most important characteristic, as far as the elasticity of the fabric is concerned, and is generally the last to disappear as the fabric is stretched.

Although the apparatus for producing yarn containing latent differential stresses is relatively simple, there are several variables which affect the nature of the yarn produced. For example, the radius of curvature of the blade edge, the tension in the strand of yarn as it is passed over the blade, the temperature of the heater element, the rate of cooling of the yarn after it passes the acute edge and the linear velocity of the yarn can all have their effect upon the nature of the yarn produced and in subsequent paragraphs operative and optimum limits will be set forth for all such variables.

The radius of curvature of the acute edge can vary within reasonably wide limits but is preferably as small as possible without severing the yarn. The smallest possible radius of curvature of the blade in turn depends upon the nature of the yarn being passed over the edge, the size of the filaments in the yarn and upon the texture of the material from which the blade is formed. With a blade formed from a finely grained material, it is possible for the radius of curvature of the edge to be as small as one or two microns when running nylon yarn composed of filaments of about 2 denier or less, but with larger filaments or with other types of yarn, the radius of curvature of the edge should generally be at least about 3 to 6 microns. Even with nylon yarns composed of very small filaments, it is frequently necessary that the radius of curvature be as much as 4 or 5 microns in order for satisfactory results to be obtained if the blade is formed from a coarse textured material. A new razor blade of the blue steel variety generally has a radius of curvature in the vicinity of 1 or 2 microns, but this material is so coarse textured that it is generally necessary for the edge to be smoothed very slightly for best results and this can be accomplished by rubbing the blade a few strokes over a finely abrasive material such as crocus cloth or by polishing the edge with a material such as jeweler's rouge. Stainless steel razor blades, because of their finer texture, can frequently be employed as they are received from the manufacturer, although it is generally preferable, even when processing nylon, to also polish the edges of these blades very slightly to thereby reduce the number of ends down.

The maximum radius of curvature of the acute edge depends primarily upon the size of the yarn filaments being passed thereover, but will also vary to some extent with the chemical nature of the yarn being employed. However, with any type of yarn, it is a general rule that the radius of curvature should be no more than about 1 to 4 times the diameter of the yarn. For example, when using 70 denier 34 filament nylon a good degree of elasticization is generally obtained, only if the radius of curvature of the angular portion of the yarn path is less than about 30 microns, but with a yarn having large filaments, such as 15 denier monofilament nylon, a blade having an edge with a radius of curvature as great as about 70 to 150 microns can sometimes be employed with good results. Even in the latter instance, however, an edge with a radius of curvature less than about 30 microns generally gives the greatest degree of elasticization.

Nylon yarn can be passed over the acute edge in a dry unlubricated condition, but all other yarns generally require the use of a lubricating oil for completely satis-

factory results, and, even with nylon, better results can be achieved by lubricating the yarn prior to its passage over the acute edge. In the case of multi-filament nylon yarns, it has been found advantageous to employ a lubricating agent which at least partially vaporizes at the temperature of the heater element and while the exact reason for this is not known it is believed that the vaporization of the lubricant results in better heat transfer among the various filaments. In the case of other types of yarn, it is generally preferable to employ a lubricating agent which vaporizes only to an inappreciable extent at the temperature of the heater strip since the yarn needs to be fully lubricated at the time it is passed over the acute edge or else breakage might occur. In the case of nylon yarns, the preferred lubricating agent has been found to be a low viscosity mineral oil such as that sold under the trademark of "Esso Mentor 20A." In the case of other yarns, the preferred lubricant has been found to be one with a low viscosity and a high flash point and one which can be readily removed from the treated yarn. Sorbitan trioleate is an example of a material which is generally satisfactory. The lubricant can be applied by means of a felt wick, by means of capillary action or by any other means generally used in the textile industry for the application of lubricants to yarns.

The angle of approach and the angle of departure of the yarn to the blade may also vary within wide limits, although the total of these two angles should be less than about 120° and preferably less than about 100°. It is generally advantageous to make the angle of approach relatively large, for example from 30° to 100°, so that the blade is displaced from the heater element and is, therefore, at a lower temperature. On the other hand, it is generally advantageous that the angle of departure be less than about 50° and preferably as small as the grind of the acute edge will permit. When the angle of approach is relatively large, better than average results can be achieved by allowing the yarn to follow the surface of the blade across its entire width after the yarn passes over the acute edge. The exact reason or reasons for this are not known with certainty, but it is known that the yarn should preferably be cooled as soon and as rapidly as possible after its contact with the acute edge, and it is believed that contact across the width of the blade results in a more rapid dissipation of heat from the yarn than is achieved by simply air cooling the yarn as it travels from the acute edge. If desired, various expedients can be employed to retain the blade at a temperature appreciably below that of the heater element. For example, the blade can be isolated from the heater element by means of heat resistant insulation or a cooling medium can be circulated in contact with the blade to retain it at any desired temperature. While satisfactory results have been achieved with the blade at a temperature equal to that of the heater element, a very marked improvement can be achieved by retaining the blade at a temperature of at least about 20° to 50° F. lower than that of the heater element and preferably at a temperature of at least about 150 to 250° below the temperature of the heater element.

The tension in the yarn passing over the blade is another important factor and this variable must be maintained within specified limits to obtain maximum elasticity. Tension measurements are made on the yarn immediately after it leaves the blade edge since it has been found that under near optimum conditions tension in the yarn before it reaches the heating means is too low to be accurately measured. Operative limits for the tension in the yarn following its contact with the acute edge vary depending upon a number of factors including the temperature of the yarn and the type of yarn being employed but as a general rule, the operative range extends from about .05 gram per denier to approximately 1 gram per denier with the preferred range being from about .1 to .4 gram per denier. The optimum tension will not only vary

with the temperature of the yarn and the yarn composition but also appears to vary slightly with yarns of substantially the same composition made by different manufacturers or even for different lots of yarn made by the same manufacturer. By carefully controlled tests it has been determined that the optimum tension for du Pont type 200 at a temperature of from about 220 to 360° F. at the acute edge is generally from about 0.15 to 0.28 gram per denier.

The linear velocity of the yarn over the blade may also vary within wide limits depending upon the temperature of the heater element, the distance through which the yarn is in contact with the heater element, the distance of the heater element from the edge of the blade and the type of yarn being passed over the blade. It is important that the yarn velocity be such that the yarn accumulates sufficient heat to be at the proper temperature at the moment it contacts the acute edge and it will be apparent that the yarn velocity required to accomplish this result will vary with the above factors. In other words, with the yarn in contact with the heater element for a given distance and with the heater element at a given temperature, it will take an appreciably longer period of contact for a 70 or 100 denier yarn to be heated than will be required for a 15 or 7 denier yarn, so that a lower yarn velocity must be employed with larger yarn. Likewise, if the acute edge is too far from the heater element, there is a tendency for the yarn to cool between the heater element and the acute edge, and it will be apparent that a smaller yarn will cool more rapidly than a larger yarn so that a higher linear yarn velocity must be employed in the first instance. It should also be mentioned that in some instances the average temperature of the heater element may be above the melting temperature of the yarn, and in these instances the linear velocity of the yarn must be sufficiently high to prevent the yarn from melting. As a general rule it may be stated that the operable range for the linear velocity of the yarn over the heater element and acute edge is from about 1 to 2,000 feet per minute or even higher with the preferred range at present being from 200 to 400 feet per minute.

Although the distance of the acute edge from the heater element may vary within reasonably wide limits and may be as much as two inches or more, as a general rule it is preferred that the acute edge be placed as close to the heater element as is possible without actual contact therewith. By placing the acute edge as close to the heater element as possible, it is only necessary to heat the yarn to substantially that temperature at which it is desired that the yarn contact the acute edge, whereas if the heater element is removed from the acute edge, it is necessary that the yarn be heated sufficiently above the temperature at which it is desired that it contact the acute edge to compensate for the cooling of the yarn that occurs during its passage from the heater element to the edge. Heating the yarn above the optimum temperature for contact with the acute edge is generally undesirable, since nearly all yarns are weakened to some extent by heat and since temperature control is thereby made more difficult.

The distance over which the yarn is in contact with the heater element should, for optimum results, be as great as is possible without resulting in an undesirably high tension in the yarn. It will be apparent that the greater the distance that the yarn is in contact with heater element, the greater will be the area of contact and the higher will be the tension required to transport the yarn, but under some conditions it has been found that the yarn may be maintained in contact with a heater element for as much as 12 to 20 inches or more without introducing excess tension. A heater element which results in the yarn being in contact therewith for a distance of approximately 1 to 10 inches is presently preferred in most instances since this length of contact is adequate for most small yarns (i.e. below 100 denier) at yarn velocities below

about 400 to 1000 feet per minute. With yarn velocities in excess of 400 to 1000 feet per minute or with high denier yarns, it is generally preferable that the yarn be retained in contact with the heater element for a greater distance and under these conditions, a heater element having a width of 10 to 12 inches or more is frequently advantageous. No minimum distance for retaining the yarn in contact with the heater element can be specified since by employing low yarn velocities, an almost infinitesimal distance can be satisfactory and good results have been achieved by employing only the edge of the blade itself as a heater element. There is, however, generally no advantage in attempting to employ a heater element such that the yarn is retained in contact therewith for less than about $\frac{1}{4}$ inch and as previously stated, if higher yarn velocities are to be employed, greater distances of yarn contact should be utilized.

A further factor which need be considered in the production of the latently elasticized yarn is the temperature of the heater element and it will be appreciated that the operative range for this variable depends upon the type of yarn being employed, the linear velocity of the yarn, and the distance for which the yarn is in contact with the heater element. If a moderately high yarn velocity is employed, for example 100 to 1000 feet per minute, and the contact of the yarn with the heater strip is limited to a short distance, for example 1 inch or less, it is possible to obtain satisfactory results with the heater element at an average temperature appreciably higher than the melting point of the yarn. For example, under such conditions operative results can be achieved with nylon yarns with the heater element at a temperature of 500° F. or even higher. On the other hand, if the yarn is maintained in contact with the heater element for a relatively long distance, for example from 3 to 9 inches, it is possible to obtain operative results with the heater element at a temperature as low as about 180° F. with nylon yarn. The optimum temperature for the heater element will, of course, depend upon the type of yarn being employed as well as the other factors considered above, but even with yarns of the same composition, the optimum temperature of the heater element appears to depend upon the filament size in the yarn being employed. For example, with the yarn in contact with the heater element for a distance of approximately 3 inches and with a yarn velocity of 120 feet per minute, an operating temperature of from about 320 to 360° F. has been found to be optimum for processing 15 denier monofilament nylon (type 66, semidull) while a temperature of from about 330 to 380° F. for the heating element appears to be optimum when processing 30 denier 10 filament nylon. In other words, since the optimum temperature of the heater element will vary slightly depending upon many factors, it is generally advantageous to conduct a series of tests to determine the optimum temperature for the heater element for each particular set of conditions encountered.

The temperature of the heater element has been emphasized since under normal operating conditions the exact temperature of the yarn passing over the acute edge is difficult to measure, but it will be apparent that the really important consideration is the temperature of the yarn as it contacts the blade edge. With all yarns of a given construction and chemical composition there is a well defined operative temperature range for the yarn at this point and some of the values for the heater element temperature set forth above are only made necessary or possible because of other variables. Although the exact lower operative limit for any given type of yarn will vary slightly, it can be stated as a general rule that the lower limit is that temperature which is sufficient to at least largely relax the stresses normally present in the yarn or in other words, sufficient to relieve the yarn of a large part of the residual shrinkage present therein. The yarn as it passes over the heating element is generally under such a low tension that it readily contracts and a tem-

perature which will result in the yarn contracting to the extent that it has a residual shrinkage of no more than about 1 to 5% at the time of its contact with the acute edge is generally sufficient to result in operative conditions. For nylon yarns, the lower operative limit will vary from about 180° F. for type 6, 15 denier monofilament up to approximately 240° F. for nylon yarns which are very difficult to elasticize. For other types of yarns the operative lower limit will vary from about 190° F. to 300° F. The upper operative temperature for the yarn as it contacts the acute edge is generally that temperature at which the yarn begins to display a tendency to stick to surfaces with which it is in contact, or as it is called in trade and scientific publications, the "sticking temperature" of the yarn. The optimum temperature for the thermoplastic strand as it contacts the acute edge will vary with a number of factors including filament size and chemical composition and generally must be empirically determined for each specific yarn. For example, by actual operation it has been found that the optimum temperature for du Pont type 200 nylon, 15 denier monofilament yarn is about 320 to 340° F., while the optimum temperature for type 200 nylon, 70 denier, 34 filament yarn is about 340 to 370° F. A simple test, which has been found to be of some value in estimating an optimum temperature for most types of yarn, comprises measuring the tension developed in a given length of the yarn as the temperature is raised. As the temperature of the yarn is increased, a point is reached where the tension developed in the yarn falls off rapidly and this point is generally a near optimum for passing this particular type of yarn to the acute edge.

While it is not absolutely necessary that the thermoplastic end of yarn be cooled after its contact with the acute edge, cooling the yarn is generally more convenient than retaining it at an elevated temperature and, in most instances, rapidly lowering the temperature of the yarn 100 to 200° F. or more results in a better product. As a general rule the temperature of the yarn should be reduced until it is at least 20 to 80° F. below the minimum temperature at which the yarn may satisfactorily be passed through the acutely angular portion of the yarn path. For example, with nylon the temperature of the yarn should be lowered at least to about 160° F. One convenient method of cooling the yarn comprises subjecting the yarn, immediately subsequent to its contact with the acute edge, to the atmosphere so that the yarn end is cooled by air currents. Still another and generally more satisfactory method comprises passing the yarn into contact with a cold metallic surface such as the side of the blade when the blade is so positioned that it is not heated to a high temperature by the heating means. Other means of cooling the yarn end after its contact with the acute edge will readily suggest themselves to those skilled in the art.

The radius of curvature of the portion of the yarn path immediately following the point where the yarn passes about the acute edge and wherein the yarn is subjected to cooling conditions, should be relatively large as compared to the radius of curvature of the acutely curved portion of the yarn path. This is most conveniently achieved by passing the yarn through a straight line path, as shown in FIGURE 1, although as stated previously a definitely curved path is acceptable if its radius of curvature is considerably greater than that at the blade edge. It is believed that the lack of liveliness in the latently elasticized yarn is at least partially a result of passing the yarn from the highly curved portion of the path into a portion of the path having a relatively large radius of curvature. As a general rule, the radius of curvature of the portion of the path immediately following the acutely curved portion should be no less than about 600 microns and should preferably be at least one inch. The length of this portion of the path need not be great and adequate cooling of the yarn can generally be accomplished in $\frac{1}{8}$

inch or less, although a length of one inch or more is generally preferred.

To transform the latently elasticized yarn to a fully elasticized condition, it is necessary to positionally relax the stresses created in the yarn as a result of its being passed through the angular path in a heated condition.

If the full elastic nature of the latently elasticized yarn is to be developed before the yarn is formed into fabrics, the heating can be conducted by overfeeding a single end of the potentially elastic yarn into a heated fluid or into contact with a heated surface so that the yarn is allowed to coil freely at the time its temperature is elevated. A high temperature is not required and satisfactory results can generally be obtained if the yarn is heated to a temperature of only about 120° F. although a temperature of from about 140 to 400° F. is generally preferred. Care should be exercised to insure that the yarn at the time it is heated is under as little tension as possible, and if the tension in the yarn is allowed to rise above about .004 to .01 gm./denier, good elasticizing may not be obtained. If the tension in the yarn is at a proper level, the yarn assumes a highly convoluted linear configuration almost immediately so that the heating need not be continued for more than 1 or 2 seconds. As an alternative to the above procedure, the yarn can be formed into skeins and the skeins immersed in a hot liquid or passed through a heated chamber to result in the yarn developing its full elastic nature. When the yarn is fully elasticized by either of these procedures before its formation into fabric, no special manipulations of the woven or knitted fabrics are required, although it is generally advantageous to weave or knit the yarn in a loose manner so that upon relaxation of the tension necessary for weaving or knitting, the yarn is free to curl or kink to provide the desired effect.

Having thus described my invention, what I desire to claim and secure by Letters Patent is:

1. A method of crimping a continuous filament thermoplastic yarn which comprises the steps of continuously passing said yarn in an acutely angular path such that at the apex of the acute angle in the yarn path, the yarn is conformed to an arch having a mean radius of curvature of from 1 to 150 microns, continuously heating the yarn in one segment of the yarn path so that at least the segment of the yarn transiently disposed at said apex is at a temperature sufficient to plasticize but insufficient to melt the yarn and thereafter heating the yarn before the yarn is formed into fabric to a temperature of at least 120° F. while it is under insufficient tension to prevent the same from contracting in length.

2. A method of crimping a continuous filament thermoplastic yarn which comprises continuously passing said yarn through a heating zone maintained at a temperature sufficient to plasticize but insufficient to melt the yarn,

immediately thereafter passing the heated yarn in an angular path over the sharp edge of a blade while under tension, said edge being disposed at the apex of the acute angle formed between the path of delivery to, and the path of withdrawal of the yarn from said edge and thereafter heating the yarn before the yarn is formed into fabric to a temperature of at least 120° F. while it is under insufficient tension to prevent the same from contracting in length.

3. A method according to claim 1 wherein the heating operation is conducted by forming the yarn into skeins and subjecting the skein to the action of a heated fluid.

4. A method according to claim 1 wherein the heating operation is conducted on a running length of yarn.

5. A method for processing a continuous filament thermoplastic yarn, the filaments of which are substantially free of torsional stresses and which, when relaxed, contain at least 5 loops per inch of from about 1 to 3 millimeters in diameter, about half of which are in one direction and the remaining half are in the opposite direction, and which contain latent differential longitudinal stresses sufficient to produce, when the yarn is heated in an untensioned condition, loops about half of which are in one direction and the remaining half in the opposite direction, which have an average diameter of from 0.2 to 0.9 millimeter and which are so closely spaced as to form a substantially closed helix between reversal points, said method comprising heating the yarn before the yarn is formed into fabric to a temperature of at least 120° F. by overfeeding the yarn at a tension of less than 0.01 gm./denier into contact with a heated surface for less than two seconds so that the yarn is allowed to coil freely at the time its temperature is elevated.

6. The method of claim 5 wherein the yarn is heated to a temperature of from about 140 to 400° F.

7. The method of claim 6 wherein the yarn is nylon.

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