This invention relates to a method for texturing yarns and more particularly, to a method for texturing yarns of acryliclonitrile polymer filaments.

Yarns of filaments produced from largely acrylonitrile polymers, such as those polymers, copolymers, and blends of polymers and copolymers containing at least 70 percent of acrylonitrile by weight in polymerized form, possess a series of properties which render them peculiarly adapted to texturing operations. The polymers from which such yarns are produced become plastic and ductile when heated such that they will assume more or less permanent form in response to various deformations induced while heated, such as twisting. In addition, such yarns possess the further property of stretching when heated under tension to a molten, or dimensionally unstable, form subject to high longitudinal shrinkage. The dimensional instability can be reduced to a normally stable state by heating and stretching the yarns. This series of properties combine to enable the production of textured yarns of particularly excellent properties. Yarns can be produced with greater compactness, bulk, and covering power than have been produced by other texturing processes applied to other natural and synthetic filaments and fibers. Such yarns can be produced with less physical damage to the filaments, such as in their tensile strength and elongation, principally because of the absence of severe mechanical action directly on the filament.

Previous methods of texturing other synthetic yarns have depended upon deformation of filaments in the yarns by means of drawing over a sharp blade, crimping by stuffing into confined heated or unheated vessels, and highly twisting while heating and then untwisting, all of which procedures have resulted in various degrees of more or less permanent crimp imparted to the yarns so treated. Other methods of producing textured yarns have included those which are directed toward increasing the bulk or voluminosity of yarns to approach or surpass that of spun yarns but have involved no self-creimping of the yarns. Such procedures have included entangling filaments by jets of air or gases and bulking acrylic yarns by stretching acrylonitrile polymer filaments under heat prior to breaking or cutting into fibers and subsequently relaxing the fibers when the yarns have been blended or plied with already relaxed or untreated dimensionally stable yarns. None of these prior methods have resulted in yarns of acrylonitrile filaments possessing increased bulk and voluminosity, good uniformity, and greater covering power and at the same time greater compactness and the elasticity associated with the so-called "stretch" yarns.

The principal object of the present invention is to provide a method for producing textured acrylonitrile polymer yarns having greatly increased voluminosity, bulk, covering power, and compactness as well as elasticity. A further object is the provision of a method for producing such acrylonitrile polymer yarns in sizes appropriate for woven and tufted carpets, Other objects will appear from the detailed description hereinafter.

It has been found that the objects of the instant invention can be accomplished by a method of texturing acrylonitrile polymer filament yarn which comprises continuously drawing an acrylonitrile polymer filament yarn from a source of supply, stretching the yarn while heated to a temperature above the second order transition point of the acrylonitrile polymer to produce a dimensionally unstable yarn, and concurrently inserting twist in the yarn, cooling the yarn to set the latent twist, untwisting the yarn, and thereafter heating the stretched and twisted yarn to relax, longitudinally shrink, and develop crimp therein, and thus produce a dimensionally stable yarn having increased uniformity voluminosity, compactness and elasticity.

Yarns produced by the method of the instant invention can be processed through all the steps outlined above and used in their finished form for weaving, knitting or tufting into fabrics. Alternatively, the dimensionally unstable yarn with heat set latent twist may be packaged and stored for subsequent use before conducting the relaxation, shrinking, and crimp development operation. The yarn in the latter condition can be plied with other similarly treated yarns before relaxation, shrinking and crimp development to afford similar desirable qualities in the plied yarn. Further, the dimensionally unstable yarn prior to relaxation, shrinking and crimp development can be woven, knitted or tufted into fabrics and thereafter relaxed by suitable heat treatment with the relaxation in fabric form has been found to be particularly desirable in certain construction of knitted goods and carpets.

The yarns produced by the method outlined above possess greater compactness and covering power than any of the prior textured yarns, as well as good elasticity. These properties of compactness and high covering power make the yarns produced by the method of the instant invention peculiarly adapted for use in woven and tufted carpets as well as knitted pile fabrics and high voluminosity woven fabrics.

The method of the instant invention is more specifically described with reference to the attached drawing wherein:

FIGURE 1 is a diagrammatic view of the method of the invention, in which various well-known forms of apparatus are generally indicated; and

FIGURE 2 is a diagrammatic side elevation of one form of apparatus for conducting the relaxation step of the instant method.

With reference to FIGURE 1, yarn or tow 2 of oriented acrylonitrile filaments is drawn from a source of supply 3 by feed rolls 4 and forwarded by the feed or stretching rolls 7, which are driven at a higher peripheral speed than feed rolls 4. Intermediate the feed rolls 4 and stretching rolls 7 the yarn or tow 2 is passed through a heating means 8 and false twist spindle 6. From stretching rolls 7 the yarn or tow 2 is fed to take-up rolls 9 through heated relaxation means 8 and forwarded by the take-up rolls 9 to package winding means 10.

The source of the yarn or tow of oriented acrylonitrile polymer filaments may be any suitable yarn package such as a bobbin, pirn, or cone, such as illustrated in FIGURE 1, or, in the case of tow the source can be the spinning line where such tow is produced directly or cans or boxes of tow obtained from such production line. The feed rolls 4 are controlled variable speed driven rolls of any desired design while the stretching rolls 7 are likewise controlled variable speed rolls adapted to apply tension to and prevent slipping of the yarn 2. The stretching rolls 7 may comprise nip rolls, godets, or the like. The yarn or tow 2 is passed through the heating means 8 wherein it is heated and while heated it is twisted through the action of false twist spindle 6 and stretched by stretching rolls 7. The ratio of the peripheral speed of the stretching rolls 7 to the feed rolls 4 is referred to as "stretch ratio." In the instant method the stretch ratio can be varied from approximately 1.1 to 3.0 or more, but for best results it is generally preferred that the stretch ratio be between 1.2 and 1.8.
As stated above, the stretching of the acrylonitrile polymer yarn or tow 2 to produce dimensional instability and the setting of the yarn 2 after stretching and twisting and while the yarn is heated by heating means 5. The heating means can employ any convenient source of heat, either hot to water, or can take any convenient form suitable to heat all the filaments of the yarn to a temperature sufficient to induce a condition of delayed elastic recovery. Delayed elastic recovery is that property of the polyacrylonitrile polymer when they are heated above the second order transition temperature of the acrylonitrile polymer of which the filaments are composed. The second order transition temperature varies with the polymer composition and the heating conditions, but is generally in the range of 160° to 175° C. In 153 heat and 195° to 215° F. in dry heat. Thus, any form of heating means adapted to bring all the filaments in the yarn or tow to such a temperature can be employed in the instant method. For example, a steam tube or steam treating chamber may be used to heat the filaments while they are being stretched and twisted. Such steam tubes with a relatively large bore through which a steam is passed while steam is admitted to and withdrawn from the tube and steam-treating chambers, with confined entrance and exit ports and steam maintained in an enlarged volume by infusing steam forming the heating means. When saturated steam is used any pressure of steam sufficient to produce a temperature of from about 260° to about 310° F. in the chamber or tube is satisfactory, i.e. pressures of about 25 to 60 p.s.i.g. Likewise, dry heat from a heated surface has been found to be satisfactory. Thus, a heated metal block such as conventionally used for heat treating yarns, preferably grooved for improved evaporation of the yarn passing therethrough, can be used. The surface or block may be internally heated by steam or other hot vapors, or it can be conveniently heated electrically. Temperatures of heated surfaces of from 240° to 275° F. in the instant method have been found satisfactory. The heating means 5 must be of sufficient length that all of the bundle of filaments can be brought to the second order transition temperature. This is best achieved by selecting the heating means 5 so that a residence time of about 1 second or longer in the heating means is assured. Thus, in processing a 2200 denier continuous filament acrylonitrile tow 2, a steam tube employing saturated steam at 50 p.s.i.g. having a temperature of approximately 350° F. and a length sufficient to afford a residence time of two seconds is satisfactory. When the individual filaments 1.1 in the bundle, a heated grooved block maintained at 370° F. of a length affording a residence time of about 1.3 seconds against the block was satisfactory for processing a 750 denier, 50 filament continuous filament yarn. For larger yarns or tows of greater total fiber increases in the residence time within the heating means 5 are necessary while for smaller yarns a shorter residence time can be used. Likewise, if high processing speeds are desired greater lengths of the heating means 5 are required to afford a sufficient residence time to bring all the filaments in the yarns to their second order transition temperature. The false twist spindle 6 induces twist in the yarn 2 which is set therein by the heating thereof in heating means 5. Such heat-set twist is latent in the yarn 2 after passage through the false twist spindle 6 where the induced twist is removed. The false twist spindle 6 can be of any desired design, many of which are available in the textile processing art. The higher speed false twist spindles afford greater rates of production of yarn and hence are more desirable for use in the instant method. The amount of twist to be heat-set in the yarn 2 or tow will vary in accordance with the thickness of the yarn or tow being processed. The number of turns per inch of twist to be inserted and heat-set in any particular size yarn can be conveniently determined by the use of a twist multiplier factor. The twist multiplier factor is a positive number determined by dividing the turns per inch in a yarn by the square root of the yarn number or the total number of filaments in the yarn. Thus, the turns per inch to be inserted in any size yarn can be determined by multiplying the desired twist multiplier factor by the square root of the yarn number on the cotton system. The yarn number on the cotton system refers to the size of the yarn, and for determining the yarn number on the cotton system of 2.35 would require 18.5 turns per inch twist inserted. Likewise, a yarn of 750 denier which has yarn number on the cotton system of 7.1 would require 32 turns per inch twist inserted when the twist multiplier factor is 12. Yarns and tows can be successfully and efficiently processed by the instant invention when employing a twist multiplier factor of from 8 to 15 and consequently, a factor within this range is preferred. As shown diagrammatically in FIGURE 1, the false twist spindle 6 is positioned sufficiently distant from the heating means 5 that the heated yarn cools below the second order transition temperature before the twist which has set the yarn while being removed by the action of the false twist spindle. The heat-set twist will therefore be stabilized in latent form in the untwisted yarn. The yarn or tow 2 which is forwarded from the stretching rolls 7 has latent twist set therein and is in a dimensionally unstable condition longitudinally. This yarn is thereafter subjected to relaxation conditions in order to relax the yarn and to restore the yarn to the instant invention. This relaxation is carried out by heating the yarn while the yarn is untensioned and free to relax. As a result of relaxation by heat while untensioned several physical changes simultaneously occur, both in the individual filaments and in the yarn comprised thereby. The filaments 1.1 of the yarn 2 have experienced a change in the crystal structure, the as-drawn structure of the yarn has been relaxed and the yarn has undergone an increase in the elongation at break. The strains induced by the heat-set latent twist are released, but since the filaments are free to relax but prevented from twisting by the nip of both the stretching rolls and the take-up rolls and the interference of other filaments, the yarn is essentially in a condition of strain and the resultant results in an increase in amplitude of the initial deformations present. The frequency of the deformations is likewise increased by the shrinkage of the filaments longitudinally. Thus, the liquid units or deformations present after the heat stretching and twisting are developed into deep, approximately sinusoidal crimps very closely spaced and with a somewhat helical arrangement due to the tendency of the filaments to reassume their twisted state. The yarn composed of the individual filaments is vastly increased in bulk and voluminosity as a result of the development of the crimp units and filaments. With the development of the crimping and the simultaneous shrinkage in the length of the filaments the yarn is rendered much more compact and possesses greatly increased covering power. At the same time the yarn, which was not elastic prior to relaxation, is rendered quite elastic so that it can be elongated approximately 100 percent or more from its untensioned length and immediately recover from this elongation in the nature of the so-called "stretch" yarns. The overall length of the yarn as it emerges from the stretching rolls is reduced by approximately 50 to 70 percent when untensioned upon relaxation by heat depending upon the stretch ratio and the turns per inch of twist imposed during the stretching and twisting operation.
matically in FIGURE 1, the yarn is relaxed as a continuous traveling yarn. Again with reference to FIGURE 1, the yarn or tow 2 is fed into heated relaxation means 8 by means of stretching rolls 7 and forwarded to package winding means 10 by the take-up rolls 5. The heated relaxation means may take any of a number of forms, such as a steam table, steam trough, water bath or the like. Likewise, dry heat from a polished surface or a heated continuous even is satisfactory, so long as good heat distribution to all the filaments is maintained in any form of the heated relaxation means employing steam or dry heat. Preferably, superheated steam at about 200°F. is used for a time sufficient to relax the yarn. When a heated aqueous bath is used a temperature of at least 160°F. is generally satisfactory. The yarn 2 must be under no tension and completely free to relax while heated. The yarn must not be confined by contact with walls or other surfaces and must not be studied tightly in any form of heated relaxing means since any relaxed and still strained portions will render the yarn unsatisfactory.

The package-winding means 10 may take the form of a cone-winder which produces cones of the finished relaxed and dimensionally stable yarn 6 or may transfer the yarn to any desired size and type of bobbin, pin or beam for storage and shipment in conventional manner. Alternatively, the final packaging may take place directly from the take-up rolls 5 by employing other well-known package winding means 10 in place of a cone-winder.

In another form of the instant method the yarn or tow which emerges from the stretching rolls 7 can be relaxed in a steam-in a similar manner without damage or loss of dimensional instability due to relaxation. Relaxation subsequent to weaving, knitting, or tufting can be achieved by subjecting the resulting fabrics to heat in a similar manner as the yarn is relaxed. Thus, the fabric can be heated by steam or dry heat in a similar manner as the yarn is relaxed. The fabric may be heated in an aqueous medium maintained at least at about 160°F. Suitably this heating in an aqueous medium may be carried out in a separate operation, or preferably, in conjunction with dyeing, scouring, finishing, etc., of textile fabrics. Relaxation can also take place over any subsequent processing steps through which the yarn is put, such as plying, where the unrelaxed yarn is pliced with other yarns before relaxation. Thus, one method for obtaining good textural definition in a cut-pile tufted carpet has been found to consist in first plying two or more ends of unrelaxed yarn and then relaxing said yarn and developing the crimp before tufting a carpet fabric therefrom.

The alternative method shown by the broken line of FIGURE 1 illustrates the application of the principles discussed above. With reference to the broken line of FIGURE 1, the dimensionally unstable yarn 4 after the latent twist set therein from stretching rolls 7 is processed through the desired fabrication operation 18 of knitting, weaving, or tufting and the yarn in the resulting fabric 19 thereafter relaxed by means of heat. The heating as applied in heating zone 20, may occur in a separate operation in the subsequent operations of dyeing, scouring, finishing, etc. The relaxed fabric 19 is forwarded by conventional rolls 21 to conventional fabric take-up means 22 from which the fabric may be suitably packaged for storage or shipment. Heat of at least 160°F. or dry heat of at least 200°F. is sufficient to relax the yarn in the form of knitted, woven or tufted fabric. Since temperatures of at least 160°F. are customarily maintained in aqueous baths during the operations of scouring, dyeing, finishing, etc., this alternative method of relaxation is convenient. Upon relaxation in the form of fabric, the previously unrelaxed yarns in the fabric will have shrunk and rendered dimensionally stable and the latent twist thereby will have been developed as crimp in the yarns.

The method of the instant invention pertains to all continuous multifilament yarns, tows, etc. and to plied yarns resulting from plying two or more ends of such continuous composite yarns or predominately acrylonitrile polymers. It is applicable to all acrylonitrile polymer yarns of filaments produced from polymers, including copolymers and interpolymers, containing 70 or more percent by weight of acrylonitrile in polymerized form and blends of such polymers with blending polymers, which preferably contain acrylonitrile. The copolymers and interpolymers can be polymers of 70 or more percent of acrylonitrile and minor proportions of other mono-olefinic monomers copolymerizable therewith. Among the mono-olefinic monomers useful for copolymerization with acrylonitrile are vinyl acetate and other vinyl esters of monocarboxylic acids having up to four carbon atoms, methyl acrylate and other acrylates having up to four carbon atoms in the alkyl radical, methyl methacrylate and other alkyl methacrylates having up to four carbon atoms in the alkyl radical, vinyl chloride and other vinyl halides, methacrylonitrile, methyl vinyl acrylate, acrylonitrile, vinyl furane, and vinyl or alkyl-substituted N-heterocyclic tertiary amines, such as the vinylpyridines and alkyl-substituted vinylpyridines, vinylimidazoles and alkyl-substituted vinylnizidaoles, vinylnolines and alkyl-
substituted vinylquinolines, vinylpyrazines and alkyl-substituted vinylquinolines and vinylpyrazines and alkyl-quinolines and alkyl pyrazoles. The blended compositions can be blends of any of the above copolymers and interpenetrating mixtures with minor proportions of one or more blending polymers containing at least 30 percent of a readily dyeable bed component such as the vinyl or allyl-substituted N-heterocyclic tertiary amine of the invention and one or more olefinic monomer copolymerizable therewith. Among the mono-olefinic monomers useful for copolymerization with the vinyl or allyl N-heterocyclic tertiary amine monomers to form the blending polymers are styrene, alkyl methacrylate, vinyl naphthalene, vinyl chloride, vinylidene chloride, vinyl acetate and other vinyl carbonyl compounds, acrylonitrile, methacrylonitrile, acryl and methacrylic acids, the alkyl acrylates, alkyl methacrylates, alkyl isocyanates, alkyl fumates, alkyl maleates, and vinyl ethers. Acrylonitrile is the preferred comonomer for the blending polymers because of the good thermal stability and solvent resistance of such compositions.

There are set out below examples of types of textured yarns which can be produced by the method of the instant invention. To produce a satisfactory carpet yarn for weaving or tufting into carpets there are made the following continuous filament yarns composed of a blend of 35 percent by weight of a copolymer of 94 percent acrylonitrile and 6 percent vinyl acetate by weight and 12 percent of a copolymer of 50 percent acrylonitrile and 50 percent 2-methyl-3-vinylpyridine by weight. The continuous multifilament tow was composed of 15 denier fibers from each polymer and the tow was stretched at a temperature above the second order transition temperature of the acrylonitrile polymer to produce a dimensionally unstable tow, concurrently inserting twist simultaneously with the heat set the last insertion after which the yarn was removed, and thereafter heating the resulting yarn at a temperature selected from the group consisting of at least 200° F. wet and at least 250° F. for a time sufficient to relax, shrink, and develop crimp in the yarn which can be produced in a dimensionally stable, crimped and elastic carpet yarn. The method as defined in claim 2 wherein the yarn is fabricated into a woven fabric. This method as defined in claim 2 wherein the yarn is fabricated into a tufted fabric.