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APPARATUS FOR PRODUCING A CRIMPED TOW

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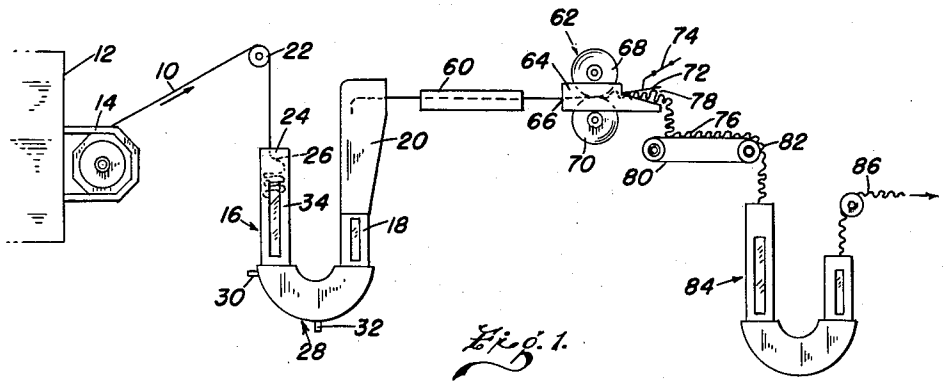

Fig. 1.

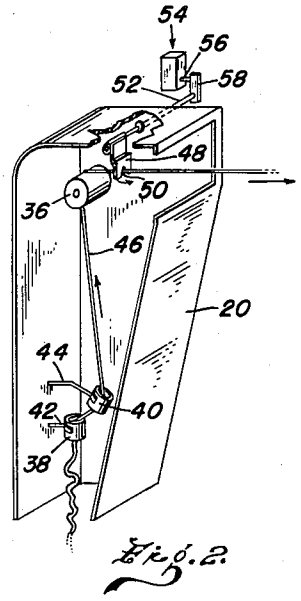

Fig. 2.

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APPARATUS FOR PRODUCING A CRIMPED TOW

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Original application Nov. 4, 1955, Ser. No. 545,043, now Patent No. 2,960,752, dated Nov. 22, 1960. Divided and this application Jan. 27, 1960, Ser. No. 5,074

1 Claim. (Cl. 28—1)

This application is a division of my copending application Serial No. 545,043, filed November 4, 1955, now Patent No. 2,960,752, dated November 22, 1960.

This invention relates broadly to an apparatus for producing a crimped tow of filamentary material, more particularly a synthetic filamentary material, and specifically a polyacrylonitrile filamentary material, that is, one which is comprised of a polymer (fiber-forming polymer) of acrylonitrile. The invention is especially concerned with certain new and useful improvements in apparatus for producing a crimped tow of a polyacrylontrile filamentary material, advantageously one comprised of a polymer of acrylonitrile containing a major proportion (preferably at least 75%) by weight of acrylonitrile combined in the polymer molecule.

It was suggested prior to my invention that certain vegetable fibers (especially cotton, hemp, jute, ramie and flax) and certain uncrosslinked thermoplastic synthetic fibers (specifically viscose and acetate rayons, nylon, fibers made from condensation products of terephthalic acid and glycol, and fibers made from polyvinylidene chloride) be mechanically crimped while hot and then immediately crimp-set by cooling, while compacted under a substantially constant pressure, in a cooling zone of the same apparatus. Such a method and apparatus for practicing the same are described in, for example, Rainard U.S. Patent No. 2,575,839.

The present invention has, as its primary object, certain new and useful improvements in processing a tow of a polyacrylonitrile filamentary material (oriented polyacrylonitrile filamentary material), and more particularly one comprised of a polymer of acrylonitrile containing a major proportion by weight of acrylonitrile combined in the polymer molecule, whereby a crimped tow having more crimp and greater uniformity of crimp is secured, with less damage to the individual filaments, than was obtainable by prior practices.

Briefly described, the improvement of this invention comprises continuously feeding a hot, wet tow of polyacrylonitrile filamentary material under substantially uniform tension, for example, a substantially uniform low tension of the order of from about 0.005 to about 0.5 gram per denier, preferably from 0.005 to about 0.2 or 0.3 gram per denier, to the feed-in end of a crimping zone. The aforesaid tow, as it is thus fed to the crimping zone, is wet with an aqueous fluid comprising mainly water that is applied after the tow previously had been dried. The wetted tow usually contains water in an amount corresponding to from about 100% to about 700%, by weight, based on the weight of the bone-dry tow. Both the tow and the said aqueous fluid are at a temperature of from about 155° F. to about 205° F., and preferably at a temperature of from about 160° F. to about 195° F., when the wetted tow is fed to the crimping zone. The wetted and heated tow is continuously crimped while it is within the aforesaid temperature range, after which the crimped, hot tow is continuously passed from the crimping zone to a separate cooling zone while it is in a relaxed state. Thereafter the crimped, hot tow is continuously passed, while relaxed, through the aforesaid cooling zone wherein it is cooled to a temperature below 120° F. and preferably to a temperature not higher than about 100° F., e.g., 80°–90° F. The scope of the invention also includes apparatus features.

The novel features of the invention are set forth in the appended claim. The invention itself, however, will be understood most readily from the following detailed description thereof when considered in connection with the accompanying drawing, which is illustrative of the invention, and in which:

FIG. 1 is a somewhat schematic view of apparatus embodying the invention; and

FIG. 2 is a perspective view of a portion of the apparatus indicated in FIG. 1 and with the front side thereof removed so that the working parts thereof will be visible.

It was suggested prior to the present invention (e.g., in Wicker U.S. Patent No. 2,698,970 dated January 11, 1955) that a tow or bundle of polyacrylonitrile fibers or filaments be mechanically crimped or crinkled while in a stretched (oriented), wet-gel state. Such fibers are produced by wet-spinning, for instance as described in Cresswell U.S. Patent No. 2,558,730 dated July 3, 1951. Contrary to this suggested practice of crimping of tow of polyacrylonitrile filaments in gel state, I have found that if the polyacrylonitrile tow to be crimped is dried (or, in general, if the structure of the fiber is collapsed) prior to crimping, it is subject to less damage during crimping than if it is crimped in the wet-gel state. This is apparent by the geometry of the crimp, which is different in the two cases, viz., rounded peaks when the dried polyacrylonitrile tow is crimped as compared with sharp, splintered corners that result when a polyacrylonitrile tow of wet-gel filaments is crimped.

I have also found that if crimping of a tow of polyacrylonitrile filaments is carried out at room temperature (20°–30° C.), the tow is not as receptive to crimping and is subject to greater damage than when crimping is effected at a higher temperature. More particularly, I have found that the higher the crimping temperature, the less the loading at the crimping chamber in producing the same degree of crimp and the higher the tenacity of (that is, the less the damage to) the filaments.

I have further found that the temperature of the tow of polyacrylonitrile filaments, when subjected to crimping, should not exceed an upper limit of about 205° F.; or, for optimum results, that upper limit which corresponds approximately to the second order of transition temperature for the particular polyacrylonitrile. Taking as an example a tow of polyacrylonitrile filaments composed of a polymer containing, by weight, about 88% acrylonitrile, about 6% vinyl acetate and about 6% 2-methyl-5-vinylpyridine, the upper temperature limit of crimping, for optimum results, should not exceed about 195° F., which corresponds approximately to the second order of transition temperature of this particular polymer. The criticality of the temperature at which the tow of polyacrylonitrile filaments is crimped is due, for one reason, to the fact that the loading at the crimping chamber that is necessary for crimping, despite the fact that it is relatively low, is sufficient to fuse the filaments together at this point if the temperature is excessive. In such cases the tenacity of the filaments is lowered to a very great extent, and may approach that of unoriented polyacrylonitrile filaments.

The present invention is based on my further discovery that successful crimping of a tow of polyacrylonitrile filaments in a stuffing-box type of tow crimper is contingent, to a great extent, upon feeding the tow under substantially uniform tension to the feed-in side of the crimper and complete relaxation of the tow at the outlet of the crimper. The introduction of the tow under ten-

sion to the inlet of the crimper can be effected in various ways, for example, by the use of suitable guides or feed rolls prior to the crimping-machine rolls. Relaxed delivery of the tow from the crimper can be secured by preventing the tow from being subjected to any tension (even its own weight) until the temperature of the tow has been lowered sufficiently to set the crimp. After crimping the tow as hereinbefore described, it should be cooled or quenched to prevent the crimp from being removed when subjected to the tension of subsequent operations.

Referring to the drawing there is shown somewhat schematically in FIG. 1 apparatus by the use of which the method of the invention can be carried into effect and illustrative thereof. The tow that is processed in practicing the present invention may be one that has been produced either by a dry-spinning or by a wet-spinning method. In the latter case the oriented, gelled tow is commonly first dried. Thus, as shown in FIG. 1, a dried tow **10** of polyacrylonitrile filamentary material (that is, a tow of continuous, oriented filaments comprised of a polymer of acrylonitrile) is led from a dryer **12**, which may be of any suitable form, e.g., a tunnel dryer, and through which the tow is passed while supported, in relaxed state, on a moving support or apron **14**.

If the dried tow **10** is to be freed of residual shrinkage (assuming that the polyacrylonitrile tow being processed is capable of being further shrunk), this advantageously can be done by the method disclosed (using the apparatus illustrated) and claimed in Cresswell et al. copending application Serial No. 538,618, filed October 5, 1955, now Patent No. 3,000,691, dated September 19, 1961. Briefly described, this Cresswell et al. method comprises continuously passing a tow of the kind with which this invention is concerned, in a relaxed or free-to-shrink state, through a zone comprised of liquid, e.g., water or other liquid alone or water or other liquid admixed or in contact with a hot gaseous medium, e.g., steam. The temperature of this zone is within the range of from about 99° C. (210° F.) to about 110° C. (230° F.), and when the zone is composed of water the temperature is generally of the order of from about 99° C. to 100° C. (212° F.). The hot treating-liquid is introduced into the treating zone either continuously or intermittently, as desired or as conditions may require. For example, the liquid may be introduced alternately first from one side of the zone, e.g., at or near the inlet end to the zone, and then from the opposite side. A portion of the tow to be treated is maintained in the treating zone in contact with the hot liquid for a period sufficient to reduce the residual shrinkage to from 0% to not more than about 2% or 3%. To effect this result the contact period is usually at least 5 seconds, e.g., from 5 seconds to 30 minutes or longer. The tow is retained in the treating zone for the required residence time while continuously introducing untreated tow into the inlet end of the treating zone and continuously withdrawing treated tow from the outlet end of said zone.

The tow **10**, if it is to be freed of residual shrinkage as described briefly above and more fully in the aforementioned copending Cresswell et al. application Serial No. 538,618 advantageously is first wetted with water by suitable means in order to facilitate subsequent handling, although it is not necessary that this be done. A wetting device (not shown in the drawing of the instant case), if employed, may be of any suitable form, e.g., a spray, trough, tube, wiper, etc.; or it may be of the kind illustrated and described in the aforementioned Cresswell et al. copending application.

From the moving support **14**, or from a wetting device, if used, the tow **10** moves continuously to a treating zone for removing residual shrinkage. Such a zone advantageously is provided by means of the J-box **16** having attached to the short leg **18** of the J a section **20**. En route to the J-box the tow advantageously is passed through a traverse mechanism (not shown), thence over a fluted lower roll (not shown), an upper roll (not shown) provided with a pinch roll (not shown), the weight of which is such that the tow is pinched against the surface of the aforesaid upper roll. Such a pinch roll provides traction so that the tow is under tension at least sufficient to move it to the point of contact of the pinch roll upon the surface of the aforesaid upper roll, and is under little or no tension after it leaves that point. From such an arrangement of rolls, if employed (as preferably is done), the tow passes over the fluted feed roll **22**, and then falls downwardly in a relaxed, free-to-shrink condition into the inlet end **24** of the J-box **16**.

The J-box **16** is preferably provided at its inlet end **24** with spray means on one side and separate spray means on the opposite side. The action of the alternate application of a spray of liquid first from one side of the inlet end of the J-box and then from the opposite side causes the tow to be deposited in the treating zone in the desired configuration, for instance, as indicated at **26** in FIG. 1. In the absence of suitable means, e.g., alternating spraying means such as that herein described, the tow piles up or tends to pile up in a narrow pile directly under the discharge side of the feed roll **22**, finally toppling over and causing or tending to cause tangling on the discharge side of the J-box.

The plaited tow is carried downwardly to the middle portion **28** of the J-box which is jacketed. A hot fluid medium, for example, water at 99° C. to 100° C., steam or other hot fluid of the desired temperature, is introduced through the inlet conduit **30** into the jacket and withdrawn through the outlet conduit **32**. The water or other liquid introduced into the upper portion of the J-box through the spray means occupies the space, along with the tow, in the middle portion of the J-box. Suitable means (not shown) are provided for draining off excess water from long leg **34** of the J-box, while suitable openings (not shown) in the short leg **18** permit the water which has flowed with and through the mass of tow to escape into a suitable receptacle or conduit (not shown). Inlet conduit **30** provides means for introducing a hot fluid medium, e.g., hot water, steam, oil, etc., to the jacket surrounding the middle portion **28** of the J-box; while outlet conduit **32** provides means for withdrawing the said hot fluid medium. Circulation of this hot fluid medium through the said jacket maintains the temperature of the liquid and tow in the middle portion **28** at the desired point.

In operation, a head of liquid normally builds up in the leg **34** of the J-box, and this liquid head assists in carrying the deposited tow through the middle portion of the J-box. The middle portion of the J-box through which the tow passes is to constructed that there are no sharp corners and hence there are no obstructions to the free movement of the tow through this portion of the box. The tow is retained in contact with the hot liquid in the bottom portion of the J-box **16** for the desired period and which may range from 5 seconds to 30 minutes or more. While the tow is retained in this bottom portion of the J-box, untreated tow is being continuously introduced into the inlet end **24** of the J-box as above described and treated tow is continuously being withdrawn from the outlet end of the J-box at such a rate that the amount of retained tow within the J-box remains substantially constant.

In the foregoing description reference has been made specifically to the use of water at a temperature of from about 99° C. to 100° C. as the liquid that is introduced into the treating zone, e.g., a J-box. As alternative liquids in place of water for shrinking the tow in the treating zone may be used such non-solvent liquids (that is, liquids which do not dissolve or harmfully affect the tow) as ethylene glycol, diethylene glycol, ethylene glycol monoethyl ether, glycerol, propylene glycol and the like. It is desirable that such alternative treating liquids, if employed (either alone or with water or other liquid), be

miscible with water so that they may be readily and economically removed subsequent to the shrinking treatment by washing the tow with water. The use of liquids of the type described above permits the shrinking operation to be carried out at temperatures above 100° C., say 110° C., at atmospheric pressure without distillation of the liquid.

The section **20** attached to the short leg **18** of the J-box **16** contains apparatus, specifically a tow processing device, which is especially adapted for use in practicing the present invention, although it is not limited thereto. This tow-processing device is claimed in my copending application Serial No. 610,027, filed September 14, 1956, as a division of my aforementioned copending parent application Serial No. 545,043. Application Serial No. 610,027 has now matured into Patent No. 2,950,520, dated August 30, 1960.

As shown in FIG. 2, this apparatus includes a guide roll **36** over which the tow passes and a plurality of guides **38** and **40** through which the tow passes en route to the guide roll **36**. At least one of the guides **38** and **40** is rigidly held in position. In FIG. 2 both guides are shown as being rigidly held in position by means of the supports **42** and **44**. If desired, only the guide **38** may be rigidly held in position while the guide **40** rides freely above the guide **38**, in which case it is of sufficient weight that it will subject the upwardly moving, shrunken tow **46** to frictional contact and thereby place the latter under a least some tension. The guides **38** and **40** aid in aligning the filaments of the tow **46** along their longitudinal axis. They are so positioned with respect to each other and to the guide roll **36** that the moving tow **46** is under tension both before and after it leaves the guide roll **36**. The tow is drawn by the feed rolls of the crimper against the action of the friction of the free-running guide roll **36**, guides **40** and **38**, and the weight of the tow.

A notched guide **48** is positioned adjacent to the take-off side of the guide roll **36**. The apex of the notch **50** is upward so that a knot-free tow will pass through the notch. The notched guide **48** is suitably mounted on a support **52**, e.g., the support **52** can be a pivotal support and the notched guide **48** can be fixedly mounted thereon. The mounting of the guide **48** on the support **52** advantageously is such that, when a knot in the tow contacts the apex of the notch in the notched guide, the resulting movement, specifically upward and backward movement, of the latter will immediately actuate a micro-switch **54** provided with the plunger **56** when the rod **58** attached to the support **52** swings backward and actuates the plunger **56**, thus stopping the driven crimping rolls **68** and **70**.

From the guide roll **36** the shrunken tow **46** is passed to a conditioning device **60** wherein the tow is contacted with an aqueous fluid comprised mainly or composed solely of water. This aqueous fluid is at a temperature of from about 155° F. to about 205° F. The conditioning device **60** may take the form of spray means; or it may comprise a trough or other receptacle wherein the shrunken tow is continuously passed through a bath of the aqueous fluid; or it may take the form of a receptacle and a series of lower and upper rolls whereby the tow is passed in a serpentine fashion first through the bath of aqueous fluid (that is, over a lower roll immersed in said bath), then upwardly and over an upper roll, and thence downwardly through the bath as before, repeating this operation as many times as may be desired or required in order to provide effective contact between the aqueous fluid and the tow being processed. In this way the tow is brought to the desired elevated temperature at which it is to be fed, under substantially uniform tension, to the feed-in end of the tow crimper **62**.

The hot aqueous fluid with which the tow is contaced by device **60** may be hot water alone or it may be an aqueous fluid comprising mainly water and a lesser amount of an effect agent, e.g., an antistatic material containing a low viscosity mineral or other suitable oil; a lubricant; or any other additive that will alter the properties of the tow or improve its processability either during manufacture or in subsequent textile operations.

The tow crimper **62** advantageously is of the "nip-rolls and stuffing-box" type, or, for brevity, sometimes designated merely as "stuffing-box" type. A type of tow crimper for use in practicing the present invention is disclosed and claimed in my Patent No. 2,846,729, dated August 12, 1958, and which matured from application Serial No. 545,023, filed November 4, 1955, that is, concurrently with parent application Serial No. 545,043. The hot, wet tow from the conditioning device **60** enters an extension of the stuffing box **64** of the crimper at the feed-in end **66**, and then passes between the top crimping roll **68** and the bottom crimping roll **70**. In the preferred tow crimper, and as is more fully described in my aforementioned copending application, the stuffing-box body is extended toward the feed-in end in order to confine the tow at the nip of the crimping rolls and to form a feed trumpet. The confinement at the nip of the rolls prevents the sides of the tow from being differently crimped than the middle of the tow. The extension of the stuffing box on the feed side of the crimper further serves to provide rigid support for the stuffing box proper, the length of which is kept to a minimum in order to obtain maximum uniformity of crimp. The gate **72** permits the discharge of the crimped tow, while the loading rod **74** attached to said gate provides the proper load for crimping the particular tow to the desired degree.

The crimped, hot tow **76** is discharged continuously from the discharge end **78** of the tow crimper. The temperature of the tow at this point ranges from about 150° F. to about 200° F. and, more particularly, from about 165° F. to about 195° F. It contains, for example, from about 50% to about 150% or 200% by weight of water, based on the weight of the bone-dry tow. The crimp in the tow is set by continuously passing the hot tow, while in a relaxed state (preferably while in a supported, relaxed state), to a cooling zone wherein the temperature of the tow is reduced to below 120° F. and preferably to a temperature not higher than about 100° F., e.g., 80°–90° F. By cooling or quenching the hot-crimped tow in a separate cooling zone while in a relaxed state in accordance with my invention, there is greater assurance of obtaining a more uniform product since there is less chance for physical damage to the crimped tow. A uniform product is a matter of considerable practical importance, not only from the standpoint of dye uniformity but also from the standpoint of uniformity in mill processing and in end uses.

Any suitable means may be employed in cooling or quenching the hot, crimped tow, while it is in a relaxed state, in order to set the crimp therein. For example, it could be exposed to blasts of cold air or other gas sufficient to cool the tow quickly and to set the crimp; or it could be continuously passed through water or other cooling fluid, or sprayed with such fluids, while it is in a relaxed state; or it could be brought to or near room temperature by conveying it through air at room temperature for a considerable distance while it is in a relaxed state on a continuously moving support, such as a belt or apron. A suitable method for quenching the hot, crimped tow is that disclosed and claimed in Sellers Patent No. 2,874,446, dated February 24, 1959. This patent matured from application Serial No. 544,847, filed November 4, 1955, that is, concurrently with parent application Serial No. 545,043.

As is described in the aforementioned Sellers patent, a tow of a polyacrylonitrile filamentary material is passed directly from a tow crimper, wherein it has been hot-crimped mechanically, to a quenching zone in which cooled gas (e.g., cooled air, nitrogen, flue gas, etc.) is circulated. The tow-quenching apparatus or so-called "tow quencher," as with the other means mentioned hereinbefore, is separate and distinct from the crimping apparatus, as a consequence of which the hot-crimped tow

is readily available for inspection prior to setting of the crimp therein and the practical advantages of which will be immediately apparent to those skilled in the art. The hot tow in relaxed state is supported on a moving support, e.g., a continuously moving apron or screen formed of metal or other suitable material. This support is preferably porous, e.g., by being provided with orifices or slots, or by the use of wire screening, so as to facilitate the passage of the cooled gas through the thusly supported tow. The supported, relaxed tow is passed continuously through the quenching zone. The temperature of the quenching zone and the time the tow is present therein are correlated so that the tow is at a temperature below 120° F., and preferably not higher than about 100° F., when it leaves the said zone.

In the embodiment of the invention illustrated in FIG. 1, the crimped, hot tow **76** is shown as being continuously discharged from the tow crimper to the feed-in end of a continuously moving support or conveyor **80**, e.g., a belt or apron, which carries the tow, while relaxed, to the take-off end **82** of said conveyor. The conveyor **80** advantageously may be positioned so that it is at about the same level (or only slightly below the same level) as the discharge end of the tow crimper, so as to obviate or minimize crimp damage of the hot, wet tow while falling any substantial distance upon the conveyor **80**.

From the take-off end **82** of the conveyor the tow is continuously passed, as illustrated in FIG. 1, to a suitable cooling device, e.g., a J-box **84**, which contains a relatively cold aqueous fluid, e.g., cold water (for instance, at 15°–30° C. as charged to the J-box), thereby coloing or quenching the tow to a temperature within the range hereinbefore mentioned. Cold water or other aqueous fluid can be introduced into, and withdrawn from, this J-box (and also to and from the jacket thereof) in the same manner fully described hereinbefore and in the aforementioned Cresswell et al. copending application with respect to the introduction of hot water to and from J-box **16**. When this method of quenching the tow is employed, the water that is taken up by the crimp-set tow **86** (thereby forming a substantially saturated tow) is removed by passing the tow through a squeeze roll or other suitable device to press out a maximum amount of the entrained water. Thereafter it can be cut into staple lengths, e.g., by means of centrifugal cutters, and thence dried, opened and baled for shipment; or, alternatively, it can be dried in the form of tow, and the dried tow then plaited into a suitable container for shipment as tow.

Various modifications obviously can be made in the method and apparatus described hereinbefore and illustrated in the accompanying drawing. Thus, the tow used in practicing the present invention may be one produced either by a dry-spinning or by a wet-spinning method; in the latter case the oriented, gelled tow is commonly first dried in a suitable dryer. Such drying means may take the form of, for example, an apron dryer or the obvious equivalent thereof and whereby the tow is dried in a gaseous atmosphere, for instance, an atmosphere of air. Tow produced by a dry-spinning process may be processed as herein described, for example, after the freshly spun tow has been washed to remove residual solvent, oriented by stretching and the wet material then dried, if necessary, in a gaseous atmosphere.

When so-called "bulk" yarns are to be produced and wherein the residual shrinkage is desirable, then the J-box **16** (employed in reducing residual shrinkage to from 0% to about 3%) may be by-passed; or the tow may be passed therethrough without contacting it with any liquid whatsoever. If J-box **16** is by-passed, as in, for example, the production of bulk yarns, then suitable tensioning means (e.g., a guide roll and a pinch roll, and between which the tow is passed) are provided a short distance before the tow is led through the conditioning device **60**.

The polyacrylonitrile used in forming the tow of filamentary material (oriented continuous filaments) may be comprised of, for example, a homopolymer of acrylonitrile; or of a copolymer of, by weight, about 95% acrylonitrile and about 5% methyl acrylate; or of a ternary polymer of, by weight, about 88% acrylonitrile, about 6% of vinyl acetate and about 6% of a vinylpyridine, e.g., 2-methyl-5-vinylpyridine. Other acrylonitrile copolymers (thermoplastic acrylonitrile copolymers) of which the tow may be composed or comprised are acrylonitrile copolymers containing in the polymer molecules an average of, for example, at least about 35%, preferably at least about 75%, by weight of combined acrylonitrile. Taking as an example the expression "an acrylonitrile polymer containing in the polymer molecules an average of at least about 35% by weight of combined acrylonitrile," this means herein a polymerization product (homopolymer, copolymer or graft polymer or mixtures thereof) containing in the molecules thereof an average of at least about 35% by weight of the acrylonitrile unit, which is considered to be present in the individual polymer molecule as the group

$$\begin{array}{l} | \\ CH_2-CH-CN \end{array}$$

or, otherwise stated, at least about 35% by weight of the reactant substance converted into and forming the polymerization product is acrylonitrile. The expression "an acrylonitrile polymer containing in the polymer molecules an average of at least about 75% by weight of combined acrylonitrile" has a similar meaning herein.

Illustrative examples of monomers which may be copolymerized with acrylonitrile to yield a polymerization product containing in the polymer molecules an average of at least about 35%, preferably at least about 75%, by weight of combined acrylonitrile are compounds containing a single $CH_2=C<$ grouping, for instance, the vinyl esters and especially the vinyl esters of saturated aliphatic monocarboxylic acids, e.g., vinyl acetate, vinyl propionate, vinyl butyrate, etc.; vinyl halides, e.g., the vinyl chlorides, bromides and fluorides; allyl-type alcohols, e.g., allyl alcohol, methallyl alcohol, ethallyl alcohol, etc.; allyl, methallyl and other unsaturated monohydric alcohol esters of monobasic acids, e.g., allyl and methallyl acetates, laurates, cyanides, etc.; acrylic and alkacrylic acids (e.g., methacrylic, ethacrylic, etc.) and esters and amides of such acids (e.g., methyl, ethyl, propyl, butyl, etc., acrylates and methacrylates, acrylamide, methacrylamide, N-methyl, -ethyl, -propyl, -butyl, etc., acrylamides and methacrylamides, etc.); methacrylonitrile, ethacrylonitrile and other hydrocarbon-substituted acrylonitriles; unsaturated aliphatic hydrocarbons containing a single $CH_2=C<$ grouping, e.g., isobutylene, etc.; and numerous other vinyl, acrylic and other compounds containing a single $CH_2=C<$ grouping which are copolymerizable with acrylonitrile to yield thermoplastic copolymers. Alkyl esters of alpha, beta- unsaturated polycarboxylic acids also may be copolymerized with acrylonitrile to form copolymers, e.g., the dimethyl, -ethyl, -propyl, -butyl, etc., esters of maleic, fumaric, citraconic, etc., acids.

Ordinarily, the molecular weight (average molecular weight) of the polyacrylonitriles (homopolymeric or copolymeric acrylonitriles) used in making the tow of filaments is within the range of 25,000 or 30,000 to 200,000 or 300,000 or higher, and advantageously is of the order of 50,000 to 100,000, e.g., about 70,000–80,000, as calculated from a viscosity measurement of the said polymerization product in dimethyl formamide using the Staudinger equation (reference: U.S. Patent No. 2,404,-713).

The tow of polyacrylonitrile filamentary material may be produced from an acrylonitrile polymerization product by any suitable method and using any suitable apparatus, but advantageously is produced as is described in, for example, my Patent No. 2,849,751, dated September 2, 1958, and which matured from application Serial No. 536,-479, filed September 26, 1955. This application was co-

pending with my parent application Serial No. 545,043, filed November 4, 1955.

I claim:

Apparatus for use in continuously producing a crimped tow of filamentary material including polyacrylonitrile filamentary material comprising, in combination: means for continuously wetting a tow with a hot aqueous fluid comprising mainly water; a tow crimper of the stuffing-box type; means for continuously feeding the hot, wetted tow under substantially uniform tension to the feed-in end of said crimper, said means including a guide roll over which the tow passes and a plurality of guides through which the tow passes enroute to said guide roll, at least one of said guides being rigidly held in position, said guides aiding in aligning the filaments along their longitudinal axis and being so positioned with respect to each other and to the said guide roll that the moving tow is under tension both before and after it leaves said guide roll; a conveyor adjacent the outlet end of said tow crimper for continuously removing the crimped, hot tow therefrom in a relaxed state; and quenching means comprising a J-box for continuously cooling the crimped, hot tow to a temperature below 120° F.

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