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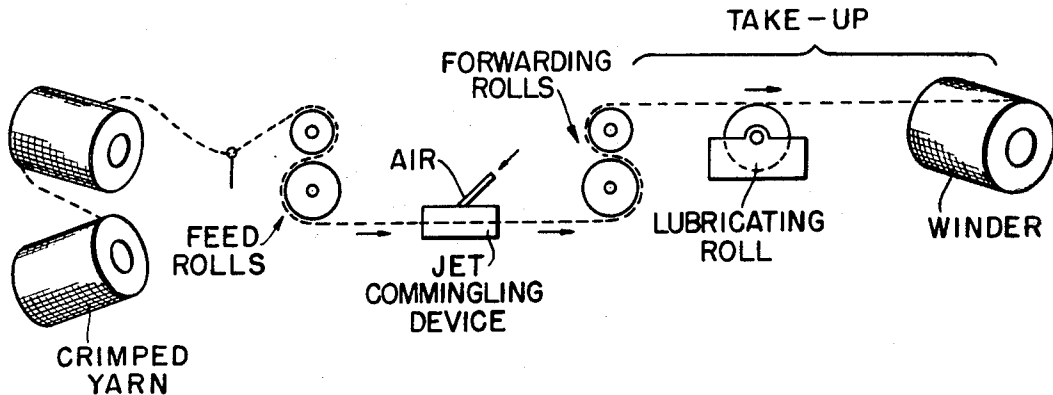
[50] Field of Search..... 28/1.4,  
72.12; 57/34, 157

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[54] **PROCESS FOR COMMINGLING CRIMPED YARN**  
4 Claims, 3 Drawing Figs.  
[52] U.S. Cl..... 28/72.12  
[51] Int. Cl..... D02q 1/16

**ABSTRACT:** A process is provided for commingling a crimped multifilament yarn in a tubular passageway wherein the yarn is maintained under a slight tension while being subjected to a stream of gas directed against said yarn at an angle whereby substantially all of said gas flows through the tubular passageway countercurrent to the travel of the yarn.



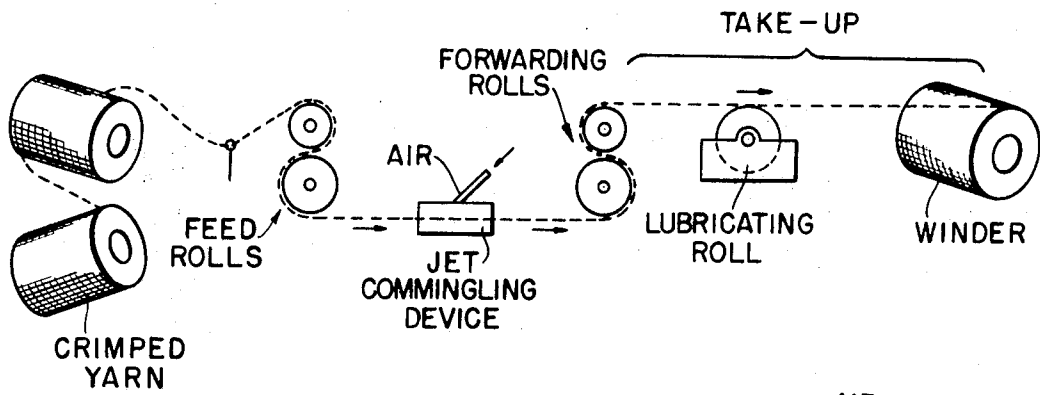


FIG. 1.

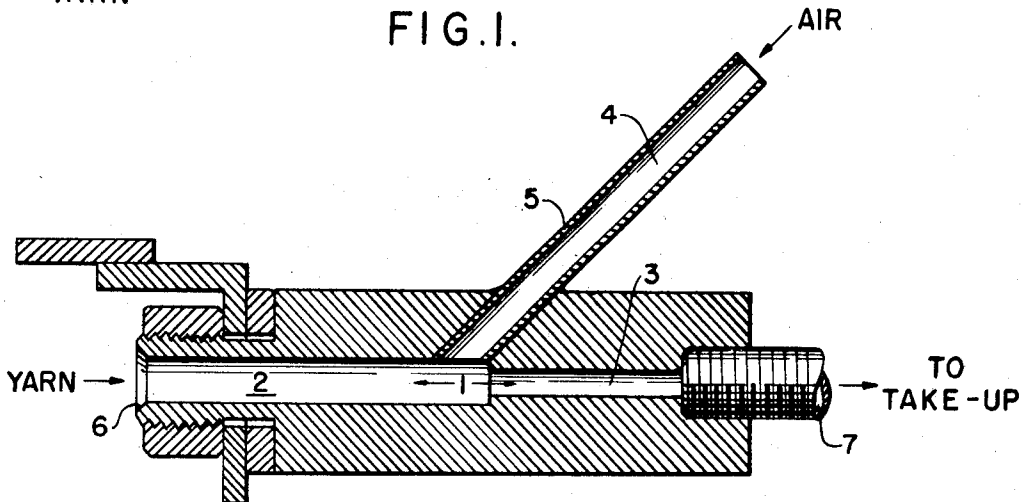


FIG. 2.

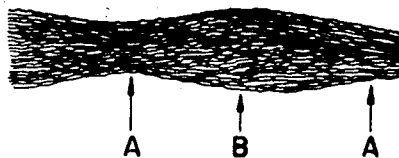


FIG. 3.

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**PROCESS FOR COMMINGLED CRIMPED YARN**

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**COMMINGLED CRIMPED YARN**

This invention relates to a process for the continuous gas jet treatment of a running yarn, and a crimped multifilament synthetic yarns of improved filament bundle cohesion containing sites of fugitive commingling of filaments.

Synthetic continuous multifilament textured or bulked yarns enjoy successful application in textile uses which formerly employed spun staple yarn produced by expensive carding and twisting operations. In most textile uses however, it is found that continuous multifilament yarns must still be twisted in order to facilitate the handling or runnability of the yarn in textile operations, since otherwise the individual filaments of the yarn bundle tend to separate out and snag on fine needles, guides and reeds of textile machinery. As an approach to obviating the expensive twisting operation, multifilament synthetic yarns have been rendered more coherent or integral by mechanically interlacing the individual filaments of the bundle, generally with a gas jet device as described in U.S. Pat. No. 2,985,995. The interlacing process however renders a bulked yarn more compact in view of the interfilamentary forces which contribute to the cohesion of the yarn bundle, and thus destroys the desirable covering power and softness required of textured or bulked yarns in various textile products.

In the production of carpets, for example, it is desirable to utilize yarns which have sufficient bundle coherency to be runnable in the weaving or tufting apparatus but which will nevertheless yield carpet structures having a high degree of covering power or bulk. It is further desirable in the production of carpets to utilize yarn which develops additional covering power or "bloom" during hot aqueous carpet finishing operations, said bloom being the result of the ability of filaments to migrate from the confinement of the yarn bundle structure.

It is an object of this invention to provide an economical process for treating a crimped continuous multifilament synthetic yarn whereby the yarn will display improved runnability in textile operations, and in textile articles will display covering power approximating that of the untreated yarn. Other objects and advantages will become apparent from the following specification and claims.

The objects of this invention are accomplished in general by providing a synthetic continuous multifilament crimped yarn having periodically spaced sites of interfilament commingling occurring at a visual frequency of between 10 and 30 per meter of yarn length, said yarn having a packaged crimp index between 6 percent and 12 percent, an "index of commingling" not greater than 40, and a "removal factor" of at least 40 percent. Said yarn can be prepared by the process of this invention which comprises advancing at constant velocity successive lengths of a crimped multifilament yarn at a tension, measured with the yarn static, between 0.003 and 0.015 gram per denier through a straight tubular passageway, contacting said yarn in said passageway with a stream of gas entering said passageway at an acute angle as measured between the line of flow of said stream of gas and the yarn exit segment of said tubular passageway, with the central axis along the line of flow of said entering stream of gas and the central axis of said tubular yarn passageway being in the same plane within not more than at most about 10 percent deviation, generally not more than 2 percent deviation based on the mean diameter of the tubular passageway; and causing at least 90 percent of the gas which contacts said yarn to flow countercurrent to the direction of yarn travel through the tubular passageway.

The invention will be more fully understood by reference to the accompanying drawings, showing diagrammatically various embodiments of the invention; and wherein:

FIG. 1 is a flow chart illustrating the various steps through which a crimped yarn will generally pass in conjunction with treatment in accordance with the process of this invention; and in which the treatment in accordance with the invention occurs at the point labeled "Jet Commingling Device" in FIG. 1;

FIG. 2 illustrates in cross-sectional elevation the essential features of a jet commingling device of preferred structure for use in the process of this invention;

FIG. 3 illustrates the commingled yarn product of this invention.

Referring now to FIG. 1, a crimped yarn is represented as being removed from a creel and passed via feed rolls through a jet commingling device in which the process of this invention is effected. The yarn passes to forwarding rolls which rotate at a fixed speed ratio to that of the feed rolls, so that desired constant conditions of tension and overfeed in the jet commingling device can be maintained. The yarn leaving the commingling jet is suitably lubricated if required and wound into a package.

FIG. 2 illustrates in more detail the jet commingling device shown generally in FIG. 1. In FIG. 2, cylindrical yarn passageway 1 consists of a horizontal segment of large diameter 2 and concentric adjoining segment of small diameter 3. Segment 2 has entrance end 6, and segment 3 has exit end 7. Cylindrical gas passageway 4 in cylindrical tube 5 intersects said first segment of the yarn passageway, 2, for above and near its junction with the second segment, to form an acute angle with said second segment, suitably from about 15° to about 75°, as measured between the axis of gas passageway 4 and the axis of the small diameter segment 3 of the yarn passageway. Moreover the central axis along the line of flow of the gas, i.e. the axis of passageway 4, lies in the vertical plane within a deviation of not more than about 2 percent based on the diameter of the larger segment 2.

In operation, untwisted, crimped multifilament yarn enters the yarn passageway 1 at the larger diameter end 6 thereof, passes in straight line travel and contacts gas entering said yarn passageway 2 through gas passageway 4, and emerges through the smaller diameter end 7 of said yarn passageway. By virtue of the angle of the gas passageway, and the downstream constriction of the yarn passageway, due to the small diameter of segment 3, at least 90 percent of the gas entering the region of confinement defined by the yarn passageway travels countercurrent to the yarn travel and emerges from the entrance end 6 of said yarn passageway.

FIG. 3, illustrating a commingled yarn of the present invention shows spaced zones of commingling, A, alternating with zones B of no commingling. It is seen that in the zone of commingling there are essentially no peripheral filaments which completely wrap about the yarn bundle or about major portions of said bundle, although there appears to be some twisting of the bundle as a whole. The commingling is seen to involve isolated filament interactions affecting only closely adjacent filaments, without extensive transmission of said effects across the diameter of the yarn bundle or along the length of the yarn. In view of this nature of commingling, it is seen that the yarn structure of the present invention is essentially free of configurations which tend to hold the entire cross section of the bundle together and thereby maintain the bundle integrity or cohesiveness, as would be done by configurations wherein groups of filaments encircle or otherwise interact across the entire cross section of a bundle or major portions thereof. The yarn treating process of this invention seeks to avoid those configurations of the yarn bundle in which the yarn bundle has been split, and one group of filaments has revolved about the yarn. Accordingly in the process of this invention the gas stream is made to contact the yarn in a highly symmetrical fashion. There is little or no production in the process of this invention of steady velocity gradients which produce torques that tend to separate the yarn into rotating groups of filaments. Instead, in the process of this invention the gas stream enters symmetrically and vertically above the yarn, and

probably the yarn and/or the gas stream shifts periodically from one side of the centerline to the other side thereof. These shifts could be occasioned by false twisting within the bundle as a whole reaching a certain tightness and then tending to reverse itself. Such action could explain the criticality of having the central axis of the entering stream of gas in the same plane with the central axis of the yarn passageway. In this same connection, it has been noted that the yarn passageway must have a smooth interior surface, which may again facilitate shifting and reversal of the relation between the yarn therein and the entering gas stream. However, even high speed motion pictures of yarn undergoing the process of this invention do not fully reveal what happens; so that the foregoing is to be regarded as at least in part theoretical and not necessarily fully descriptive of the process of the invention.

It has been found that relatively low gas pressures in the process of this invention minimize the occurrence of filament grouping and rotating. Thus, in general suitable pressures in the gas stream supplied to the apparatus are not greater than 40 p.s.i.g., and preferably in the range of 10 to 25 p.s.i.g., said pressures being measured at the head of gas passageway 4 and with a constant pressure supply source feeding gas passageway 4. These pressures drop along the gas passageway and drop within the yarn passageway from the gas entrance toward the ends of the yarn passageway.

It has been found that large, abrupt expansion of the gas while in contact with yarn in the yarn passageway is undesirable since this leads to bulking and undesirably stable intertwining of the filaments. Accordingly, in preferred embodiments, apparatus and process conditions are chosen so that the gas as it enters and flows along the yarn passageway will undergo no abrupt volume change greater than about fivefold. Thus suitably the ratio of the cross-sectional area of the gas passageway 4 to the cross-sectional area of the yarn passageway at their point of intersection is between 0.2 and 2.0. In this manner, the gas employed undergoes only minor volume change at its point of contact with the yarn, and, by comparison with prior art technology wherein small diameter gas jets are employed with large diameter yarn passageways for various purposes, the gas of the present process may be considered essentially nonexpanding. The gas employed is preferably air, but other inert inexpensive gases such as nitrogen, carbon dioxide, steam, etc., and mixtures thereof may be suitably employed. The gas may be at room temperature, or at elevated temperature for drying or plasticizing effects. The gas may contain suspended or volatilized yarn finish ingredients or other chemical ingredients to secure desired modifications of the yarn properties.

An essential feature of the process of this invention is that at least 90 percent of the yarn treating gas is made to flow countercurrent through the upstream yarn passageway and out the entrance end of said yarn passageway. Securement of this flow arrangement may be achieved either by suitable selection of upstream and downstream yarn passage diameters, or by proper inclination of the gas passageway in the direction of the yarn entrance, or various combinations of these expedients. For any given apparatus, the extent of gas flow through either end of the yarn passageway may be conveniently determined by connecting a rotameter to the feed gas supply stream entering the gas passageway, and sealing off either end of the yarn passageway to detect the overall percentage drop in feed gas supplied to the device.

The yarn passageway may generally have a diameter in the range of 1/16 inch to 12/16 inch, and is preferably circular in cross-sectional configuration. It is generally found preferably for the yarn passageway to have a larger diameter in the region where it communicates with the gas passageway than the diameter of the downstream segment of yarn passageway, from which the yarn exits. The apparatus may be separable into two halves to facilitate yarn string up. In such instance the plane of separation passes through the yarn passageway, and suitable hinges and clamps may be employed to facilitate opening and closing of the device. It has also been found that,

in order to avoid formation of loops, or interlacing effects, the yarn should enter and leave the gas jet device on a straight line path.

Yarn may be treated by the process of this invention at rates of 150 to 3000 yards per minute. It is important to control tension on the yarn entering the treating apparatus, tensions in the range of 0.002 to 0.015 gram per denier being suitable. These tensions are as measured under static conditions, i.e. by halting the movement of the rolls and thus halting the yarn strand, and with the gas jet in operation, measuring the tension on the yarn strand ahead of the entrance to the jet commingling device. Much lower tensions than the above are found to lead to uncontrolled bulking effects wherein loops or other undesired configurations are created sporadically in the yarn, and much higher tensions tend to prevent suitable commingling action. Control of yarn tension can be effected by the use of upstream yarn control means such as yarn feed rolls, tension gates, tension wheels or pins; in conjunction with downstream yarn removing means such as driven forwarding rolls, windup devices, etc.

The tension of the yarn during the treatment process of this invention is affected by the gas pressure acting on the yarn. For example, using a device such as shown in FIG. 2, the following tensions are developed by various air pressures acting on a 3600 denier yarn:

Air pressure (p.s.i.g.):	Tension (grams per denier)
10	. 0031
15	. 0059
20	. 0102
25	. 0114
30	. 0125
35	. 0132

Under dynamic conditions of standard yarn treating operations, i.e. on a continuously advancing yarn, it is difficult to measure the low yarn tensions employed therein without disrupting the system. The tension on the moving yarn will be related to the ratio between rate of yarn feed to the jet entangling device:rate of yarn exit; it will be recognized that this ratio will be affected by the extent to which the crimp in the yarn is pulled out or recovered as the yarn passes through the system. The rates of yarn feed to the gas jet device and removal therefrom are related to the peripheral velocities of the feed rolls and removal or forwarding rolls; these velocities should differ by not more than 4 percent. If the feed rolls have peripheral velocity more than 4 percent higher than that of the removal rolls an undesirably looped and kinked yarn results; and if their peripheral velocity is more than 4 percent slower than that of the removal rolls, little commingling effect is secured.

The process of this invention can be carried out in conjunction with conventional textile operations, such as crimping, winding, plying, packaging, finishing, and the like. By so doing, advantage is made of existing means for handling and forwarding yarn in continuous, controlled fashion. Yarn-tension, and feed and emergence rates during the commingling process may be controlled by various means. In general, adequate control is afforded by cooperating rolls located up and downstream from the commingling device and provided with nip rolls, cot rolls, separator rolls, or multiple wraps to avoid slippage. By adjustment of the relative peripheral speeds of these rolls, controlled and uniform yarn speed and tension can be achieved. In the windup or packaging step, the tension employed should be as low as possible consistent with the requirements of good package formation.

Although the apparatus involves no moving parts or intentional fluctuation of process parameters, it is found unexpectedly that the process effects a periodic commingling action. The sites of commingling occur repetitively along the length of the yarn, their visually discernible frequency of occurrence being between about 10 and 30 per meter. The sites of com-

mingling are generally visibly distinguishable as more dense portions of the yarn bundle, generally varying between about one-third inch and seven-eighths inch in length. When too few sites of commingling are present the yarn exhibits poor tuftability. If however the number exceeds about 30 per meter the resultant yarn exhibits poor covering power in textile articles.

The total length of yarn occupied by sites of commingling should be at least 15 percent. This may be achieved either with numerous sites of short length or by relatively few sites of long length. No advantages are secured by yarns having over 55 percent commingled length, and in fact adverse covering power is then encountered. The determination of the frequency of occurrence of sites of commingling and the percentage of yarn length occupied by sites of commingling may be accomplished by visual count and measurement, using an average value derived from a study of at least 25 samples. The volume or bulk of a package of the commingled crimped yarn convolutely would as on a spool is found to be at least 3 percent more than for the crimped feed yarn package wound under identical conditions of tension and traversing.

Although the number of sites of commingling can be visually perceived and counted, the exact length of each site is difficult to ascertain visually since its boundaries may diffuse gradually into the adjacent yarn segments having essentially no commingling. In order to secure a more objective quantitative description of the yarn product, test methods have herein been devised and applied as described below.

#### HOOK DROP TEST

Meter lengths of yarn to be tested are clamped at the upper end and allowed to hang in the vertical position under the tension provided by a weight in grams which is 0.20 times the yarn denier (but not greater than 100 grams), inserting through the yarn bundle approximately midway within a region of no apparent commingling a weighted hook having a total weight in grams numerically equal to the mean denier per filament of the yarn (but not weighing more than 10 grams), and lowering the hook at a rate of 1 to 2 centimeters per second until the weight of the hook is supported by the yarn. The distance of hook travel is measured. Since the commingling is fairly random in nature, 100 separate meter lengths are tested to define a representative sample for a given package of yarn or for a multitude of presumably identical packages of yarn. Of the 100 separately obtained hook drop distances, the upper 20 and lower 20 values are discarded, and the remaining 60 are averaged to determine the average distance of hook travel. This value, D, measured in centimeters, is essentially one-half the average distance between sites of strong enough commingling to stop the hook travel.

#### INDEX OF COMMINGLING

The Index of Commingling is calculated from the formula: Index of Commingling =  $100 - (2D \times N)$  where N is the average number of sites of commingling per meter visually observable in the samples tested. Values of Index of Commingling for the yarn of this invention are below 40, since higher values are sharply indicative of the presence of undesired interlacing. Values of the Index of Commingling may have negative sign in view of the fact that the hook may pass completely through some regions of commingling which, although visibly distinguishable, have insufficient degree of commingling to stop passage of the hook. Said negative values should however be above -50. With yarn samples having a value of N between about 20 and 30, the numerical value of the Index of Commingling is close to the percent by length of commingled yarn in the total yarn length as measured visually. With samples having a value of N below 20, this approximate correlation does not hold.

#### REMOVAL FACTOR

The commingled bonds or forces are fugitive or nonpermanent in view of the facile separation of the individual filaments by mild tensile forces applied to the yarn and also by

standard dyebath treatments which permit filament migration. As a simple criterion of the fugitivity of the forces of commingling, a definitive and characteristic property has been ascertained, which will be referred to hereinafter as the "removal factor." In the removal factor test method, a one meter length of yarn having previously been tested by the hook drop method above, and free of sizing or finishing agents is fastened at one end to a fixed support. A weight equal to 0.1 gram per yarn denier is fastened to the other end, and said weighted end is allowed to fall under full force of gravity a distance of 6 inches in a straight line beneath the point of fastening of the other end of the sample; and the cycle of thus raising and dropping the weight is carried out a total of five times. The sample thus treated is retested by the hook drop method and a new value D' is thus ascertained as half the average distance between sites of commingling. The percentage increase of the new hook drop value, D' over the similarly measured value of the yarn before the removal test, D, is the "removal factor." This test method may be applied for purposes of comparison and control to yarns outside the scope of this invention. The yarns of this invention will have a removal factor of at least 40 percent, and are concordantly found to undergo release of commingling forces under normal textile finishing operations such as scouring and dyeing which utilize hot aqueous conditions. With removal of the commingling, the yarn is restored to essentially the original filamentary configuration which it has prior to the commingling treatment, except for additional migratory changes undergone by the filaments during finishing treatment.

The crimped, commingled yarn of this invention contains a high degree of crimp or bulk as may be measured by the standard crimp index method. In the crimp index test, a length of fiber is measured hanging under an added load of 0.1 gram per denier for a period of 2 seconds (length  $L_1$ ), under which condition the crimp waves, angles, or other bulk imparting configurations are fairly straightened to 180°, and measuring the length of the same fiber hanging under no added weight after an elapsed time of at least 15 seconds from any previous stress (length  $L_2$ ). The crimp index is then calculated in accordance with the formula

$$\text{Crimp index} = \frac{L_1 - L_2}{L_1} \times 100\%$$

For satisfactory balance of fabric bulk and yarn runnability, it is found that crimp index values of the yarn of this invention, as measured on as-packaged yarn and hereinafter referred to as packaged crimp index, are preferably in the range of about 6 percent to 12 percent. Packaged crimp index values below 6 are found to cause the yarn to afford unsatisfactory covering power in textile articles. Packaged crimp index values above about 12 percent are found to result in poor pattern definition in nonflat textile articles such as tufted and high pile woven structures. The crimp index of the yarn is essentially unaffected by the commingling process of this invention.

In a further preferred embodiment, commingled yarns of this invention are provided which, in view of internal filament stresses, are capable of increasing their crimp index 12 to 16 percentage units with relaxing treatments such as exposure to hot, moist conditions while under essentially no restraint. The value of said increased crimp index will hereinafter be referred to as the relaxed crimp index. The virtue of the increased relaxed crimp index is that, under the relaxing conditions of dyeing and finishing, the yarn in the textile article develops increased bulk and covering power.

Textured or crimped multifilament yarn suitable for treatment by the process of this invention can have a denier in the range of 500 to 10,000, and can have individual filament deniers in the usual ranges such as 5-35. As individual filament deniers become smaller, under otherwise constant conditions, the intertwining tends to become more stable, i.e. the removal factor decreases. This tendency can be counteracted by adjusting air pressure, inasmuch as lower air pressures lead to higher removal factors.

The yarn to be treated should be essentially untwisted and free of any size or finishes which impart interfilament adhesion. Suitable polymers from which the yarns may be

produced include synthetic linear polymers such as polyamide, polyester, polyolefin, polyacrylonitrile, and the like, and blends thereof, said polymer preferably being capable of producing yarns exhibiting stress-relieving characteristics in hot aqueous dye bath. The method of texturing or crimping said yarns may consist of stuffer box methods such as described in Pike, U.S. Pat. Nos. 3,037,260 of June 5, 1962 and No. 3,031,734 of I, 1962; jet-impingement methods such as described in Hallden et al. U.S. Pat. No. 3,005,251 of Oct. 24, 1961; belt or gear crimping processes such as described by Shattuck, U.S. Pat. No. 2,751,661 of June 26, 1956; and other processes analogous thereto. The preferred type of crimp is that characterized in having distinct angular blends separated by straight segments, said crimp being obtained for example by stuffer box methods. After crimping, and prior or subsequent to the gas jet treatment of this invention, the yarn may be subjected to a stressing operation which imparts latent contraction or expansion properties to the yarn so that during the stress-relieving conditions of the fabric dyeing operation, the yarn develops increased crimp index as described above, and thereby achieves additional bulk and covering power. The individual filaments of the yarn can have the same or different uniform or nonuniform denier, and can have any cross-sectional configuration such as round, oval, heart-shaped, hollow, Y-shaped, multilobal, polygonal, or mixtures thereof. The filaments can also consist of two different polymers in contiguous side by side or other eccentric configurations.

The yarns may be made to contain various additive ingredients which impart specialized properties. For example, ingredients which can be added to the yarn either by incorporation within the polymer prior to spinning, or by after-treatments of the yarn or fabric include flame retardant agents such as compounds of antimony, phosphorous, and halogens; titanium dioxide delustrant; antistatic agents; adhesion promoting agents such as isocyanates and epoxides; heat and light stabilizers such as inorganic reducing ions, metal ions such as manganese, copper and tin, phosphites, and organic amines such as alkylated aromatic amines and ketone-aromatic amine condensates; thermally stable pigments such as Quindo Magenta (Allied Chemical Corporation) and inorganic pigments; fluorescent agents and brighteners such as Tinopal PCR; crosslinking agents; bacteriostats such as phenols and quaternary amines; colloidal silica and boehmite; and other known additives and treatments. Lubricating finishes which reduce yarn-to-metal friction while increasing yarn-to-yarn friction, are found helpful in the practice of the present invention.

The following specific examples are given to illustrate preferred methods of carrying out the present invention. It is to be understood however that the examples are not to be considered as limitative of the scope of the invention.

#### EXAMPLE 1

The apparatus of FIG. 2 was employed in the treatment of an untwisted 3600 denier, 210 filament nylon 6 yarn containing a zigzag stuffer box crimp, and having a packaged crimp index of 8.5 percent and a relaxed crimp index of 23.5 percent. The specific apparatus employed had the following characteristics:

Overall length of yarn passageway	3.5 in.
Length of large diameter segment of yarn passageway	2.0 in.
Diameter of large diameter segment of yarn passageway	0.25 in.
Diameter of small diameter segment of yarn passageway	0.125 in.
Length of small diameter segment of yarn passageway	1.5 in.
Diameter of gas passageway	0.20 in.
Ratio of area of gas passageway to area of yarn passageway	0.64
Per cent of gas which exits from entrance end of yarn passageway	94 percent

Angle of gas passageway 45°

The yarn was fed into the apparatus on a straight line path at a rate of 265 yards/minute and a tension of 22 grams (0.006 gram per denier). The yarn emerged from the device in a straight line, and a speed of 263 yards per minute. In order to properly center the air stream, the cylindrical air passageway 4 of FIG. 4 was constructed to be slightly off center within the cylindrical walls of tube 5; and this tube was adjusted by twisting it to achieve smooth operation forming yarn with alternating zones of commingling and no commingling. A deviation of as much as 6 mils in the position of the central axis of air passageway 4 away from the plane which is parallel to said axis and also contains the central axis of yarn passageway 2, was found to make the yarn twist off the feed rolls, and failed to give the yarn product of the invention having alternating sites of commingling and no commingling; and even 3 mils deviation caused the device to run less smoothly.

The yarn passageway of FIG. 2 has been shown as being horizontal, however it has proven immaterial what attitude this passageway assumes nor is it material what attitude is assumed by the gas inlet tube, as long as the central axis of this tube lies at an acute angle measured along the yarn passageway and lies in or nearly in a plane containing the central axis of the yarn passageway, as previously explained.

In separate experiments, air at different pressures was supplied to the gas passageway. The air pressures were measured by a gauge at the entrance to the gas passageway; measurements made at the end of this passageway just ahead of the yarn passageway showed a drop of about 2—3 p.s.i.g. from an initial pressure of 25 p.s.i.g.

The yarns thus prepared were employed in making loop pile tufted carpets having 6 tufts per inch and 20 ounces of fiber per square yard of carpet, employing a woven jute backing of 12 ounces per square yard. The tufting needle had an oval-shaped eye 12/64 in. high and 6/64 in. wide and operated at a rate of 520 tufts per minute. As a measure of runnability, the number of stoppages or quality defects due to the behavior of the yarn was counted per 10 square yards of tufted carpet. Good operation is generally considered to require less than 24 occurrences of stoppage or defects per 10 square yards. Greater occurrence of stoppages are indicative of fair to poor runnability of the yarn.

The samples of the tufted carpet were scoured at 212° F., and rope dyed in a beck. A standard latex dispersion was subsequently applied to the backings of the samples. The carpet samples were then evaluated for covering power by visual determination of whether the white-colored carpet backing could be seen through the pile surface when view from above. A panel of 10 experienced observers was employed in a qualitative evaluation of covering power.

For purposes of comparison, control trials were carried out using carpets of identical construction made from a) the untreated feed yarn of this Example, b) said freed yarn given 2 turns per inch Z twist, and c) said feed yarn given an interlacing treatment by the process of U.S. Pat. No. 3,110,151. The experiments performed, and results obtained are reported in Table I below.

As the data of Table I indicate, the process of this Example at air pressures between 10 and 25 p.s.i.g., produces yarns of the present invention having acceptable runnability and which provide acceptable carpet quality. It is seen that, for the specific apparatus employed, air pressure is extremely critical, since pressures as high as 46 p.s.i.g., or below 10 p.s.i.g. give unsatisfactory results. The data also show the dependency of runnability on the extent of commingling, and the dependency of carpet quality on the removal factor. The control samples permit comparison of the yarn of this invention with untreated yarn and with twisted and interlaced yarns of the prior art. Although both twisted and interlaced yarns possess good runnability, they produce poor carpet quality as determined herein.

## EXAMPLE 2

The feed yarn, apparatus, and process conditions of Example 1 were employed using an air pressure of 15 p.s.i.g. in a series of tests designed to ascertain the effect of yarn tension on securing the desired commingled yarn product of this invention. Accurate control of tension was secured by means of an adjustable tension gate acting upon the yarn in advance of a feed roll which forwards the yarn without slippage to the commingling device. The tests performed and results obtained are presented in Table II.

TABLE I

Pressure (p.s.i.g.):	Visual commingled sites per meter	2D <sup>1</sup>	Index of commingling	Removal factor (percent)	Packaged crimp index	Relaxed crimp index	Runnability	Carpet quality
5	9	15.0	-35	81	8.5	23.0	Poor	Good.
10	15	7.2	-8	70	8.0	23.5	Fair	Do.
15	21	5.5	-15	61	7.5	22.5	Good	Do.
25	24	2.9	30	50	7.5	23.0	do	Do.
45	28	1.8	50	33	7.0	20.5	do	Poor.
Control Samples:								
(a) Feed yarn				93			Poor.	Good.
(b) Feed yarn plus 2 t.p.l.				4			Good	Poor.
(c) Feed yarn—Interlaced				22			do	Do.

<sup>1</sup> D = Average distance of drop in hook drop test.

TABLE II

Tension (g.p.d.)	Visual commingled sites per meter	2D, cm.	Index of commingling	Runnability	Carpet quality
.0010	34	1.6	46	Good	Poor.
.0020	30	2.3	31	do	Fair.
.0040	26	3.0	22	do	Good.
.0060	24	5.1	-22	do	Do.
.0080	17	7.6	-29	Fair.	Do.
.0100	14	10.3	-44	do	Do.
.0170	10	18.5	-85	Poor	Do.

Except for the sample prepared at a tension of 0.0010 g.p.d., the yarns were found to have removal factors about 40 percent. As the data of Table II indicate, tensions in the range of 0.0020 to 0.0100 inclusive, produce commingled yarns of acceptable runnability, from which acceptable quality carpets can be produced in accordance with Example 1 above. At tensions as high as 0.0170, or below 0.0020 gm/denier and thus outside the prescribed limits of the process of this invention, either poor yarn runnability or poor carpet results. The optimum tension values for securement of the desired product may be found to vary slightly for different yarns, devices, and process conditions.

## EXAMPLE 3

Employing the feed yarn and process conditions of Example 1 and adjusting the air pressure to secure a flow rate through the apparatus of 20 cubic ft. per minute, a series of tests was carried out employing devices similar to that employed example 1 except in that different ratios of area of the gas passageway/area of the yarn passageway were employed. The tests performed and data obtained are presented in table III.

TABLE III

Area ratio: <sup>1</sup>	Removal factor (percent)
.1	25
.3	43
.7	65
1.0	70
2.0	50

<sup>1</sup> Area of gas passageway/area of yarn passageway, at their point of intersection.

As the data of Table III indicate, area ratios of about 0.2 and greater produce yarns having satisfactory removal factor. Lower ratios are seen to result in yarn of unsatisfactory removal factor.

## EXAMPLE 4

In order to test the effect of individual filament denier in the production of commingled yarn by the process of this invention, a series of 2400 denier gear crimped polyacrylonitrile yarns of various individual filament denier were treated by the process of Example 1, using an air pressure of 20 p.s.i.g. The tests performed and the data obtained are presented in Table IV.

TABLE IV

Filament denier	Visual commingling sites/meter	2D, cm.	Index of commingling	Removal factor (percent)
7	26	1.8	53	22
10	24	2.9	30	40
15	21	4.2	12	62
18	23	5.3	-22	73
25	24	6.1	-46	49
35	16	13.6	-118	76

As the data of Table IV demonstrate, the degree of commingling, as determined by the Index of Commingling, and the fugitivity of the commingling, as determined by the removal factor, are critically dependent upon the individual filament denier. At filament denier below about 10, the commingling becomes less fugitive, approaching in its characteristics the permanent or irreversible nature typical of interlaced structures of the prior art. At filament deniers above about 25, too little commingling is secured to enable the yarn to be runnable in textile operations.

## EXAMPLE 5

The effect of the degree of countercurrent gas flow in the process of this invention was studied by utilizing the yarn and process conditions of Example 1 with gas jet devices similar to FIG. 1 wherein the angle of the gas passageway and the relative diameters of the small and large diameter portions of the yarn passageway were varied to secure different gas flow rates through the entrance and exit ends of the yarn passageway. The gas flow through either end of the yarn passageway for each device was measured by the aforementioned method of employing a rotameter in the gas feed stream and alternately covering each end of the yarn passageway. The tests performed and results obtained are presented in Table V.

TABLE V

Percent gas flow countercurrent to direction of yarn travel:	Removal factor (percent)
55	27
63	32
77	31
86	36
92	53
96	67

As the data of Table V demonstrate, unless the per cent of gas flow countercurrent to the direction of yarn travel is at least 90 percent, unacceptable yarn properly obtained, particularly unsatisfactory removal factor. It is also observed that at lower

levels of countercurrent gas flow, there is an increased tendency toward the formation of undesired loops in the yarn.

Although the yarn of this invention has been exemplified primarily in conjunction with utility in carpet applications, it is to be understood that said yarn is also useful in other textile applications wherein good runnability with high bulk is required, for example; apparel products such as woven suiting, shirtings, lingerie, tricot, circular knitted fabrics, broadcloths, and the like, upholstery, drapery, curtains, ducks, high pile fabrics, and other applications. The yarn may be utilized in twisted or untwisted form and may be combined with other yarns or treated with sizing agents prior to use.

As many widely different embodiments may be employed or made without departing from the spirit and scope of this invention, it is to be understood that the invention is to be in no wise restricted save as set forth in the appended claims.

I claim:

1. Process for the treatment of multifilament yarn comprising advancing at constant velocity successive lengths of a crimped multifilament yarn at a tension, measured with the yarn static, between 0.002 and 0.015 gram per denier through a straight tubular passageway; contacting said yarn in said passageway with a stream of gas entering said passageway at an acute angle as measured between the line of flow of said stream of gas and the yarn exit segment of said tubular passageway, with the central axis along the line of flow of said entering stream of gas and the central axis of said tubular yarn passageway being substantially in the same plane; and causing at least 90 percent of the gas which contacts said yarn to flow countercurrent to the direction of yarn travel through the tu-

bular passageway.

2. Process of claim 1 wherein said gas undergoes no change of volume greater than about five fold as said yarn enters into and flows through said tubular yarn passageway; wherein said tubular yarn passageway consists of two successive cylindrical segments, the segment first traversed by the yarn being of the greater diameter and being concentric with the second segment; wherein the gas used is air at a pressure in the incoming air stream between about 10 p.s.i.g. and about 25 p.s.i.g.; and wherein the air is introduced into the larger segment of the yarn passageway through a cylindrical gas passageway, the central axis of which lies in the same plane as the central axis of the yarn passageway within a deviation of not more than 2 percent based on the diameter of the larger segment of the yarn passageway, said gas passageway intersecting said larger segment of the yarn passageway near its junction with said smaller segment; and wherein said yarn is entered into said region of confinement at a speed between 150 and 1500 yards per minute, and removed from said region of confinement at a speed differing by not more than 4 percent from said entering speed, these yarn speeds being as measured by the peripheral velocity of the yarn feed rolls and the peripheral velocity of the yarn removal rolls respectively.

3. Process of claim 1 wherein the crimped multifilament yarn is overfed into said tubular passageway at a rate approximately 4 percent greater than removal therefrom.

4. Process of claim 3 wherein the stream of gas is at a pressure between about 10 and 25 p.s.i.g. and the central axis of the yarn passageway within a deviation of not more than 10 percent.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,577,615 Dated May 4, 1971

Inventor(s) Fred W. LeNoir

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 12, line 28, claim 4 should be corrected to read as follows:

"4. Process of claim 3 wherein the stream of gas is at a pressure between about 10 and 25 psig and the central axis of said stream lies in the same plane as the central axis of the yarn passageway within a deviation of not more than 10 percent."

Signed and sealed this 14th day of September 1971.

(SEAL)  
Attest:

EDWARD M. FLETCHER, JR.  
Attesting Officer

ROBERT GOTTSCHALK  
Acting Commissioner of Patents