

Jan. 4, 1966

D. STARKIE ET AL

3,226,792

METHOD AND APPARATUS FOR CRIMPING YARN

Filed April 7, 1958

3 Sheets-Sheet 1

FIG. 1.

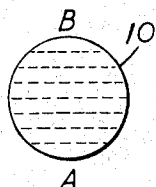


FIG. 2.

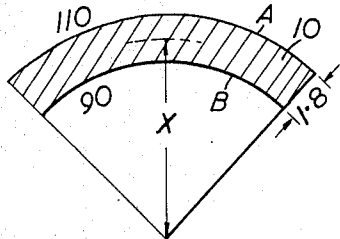


FIG. 3.

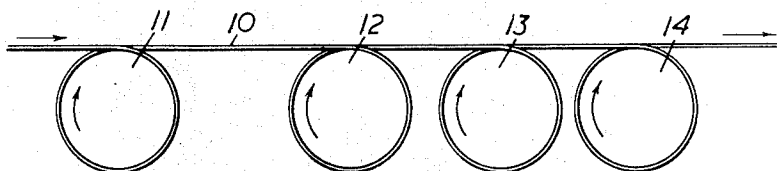


FIG. 4.



Inventors
David Starkie
Marcus William Rott
By *Albert J. [Signature]*
Attorney

Jan. 4, 1966

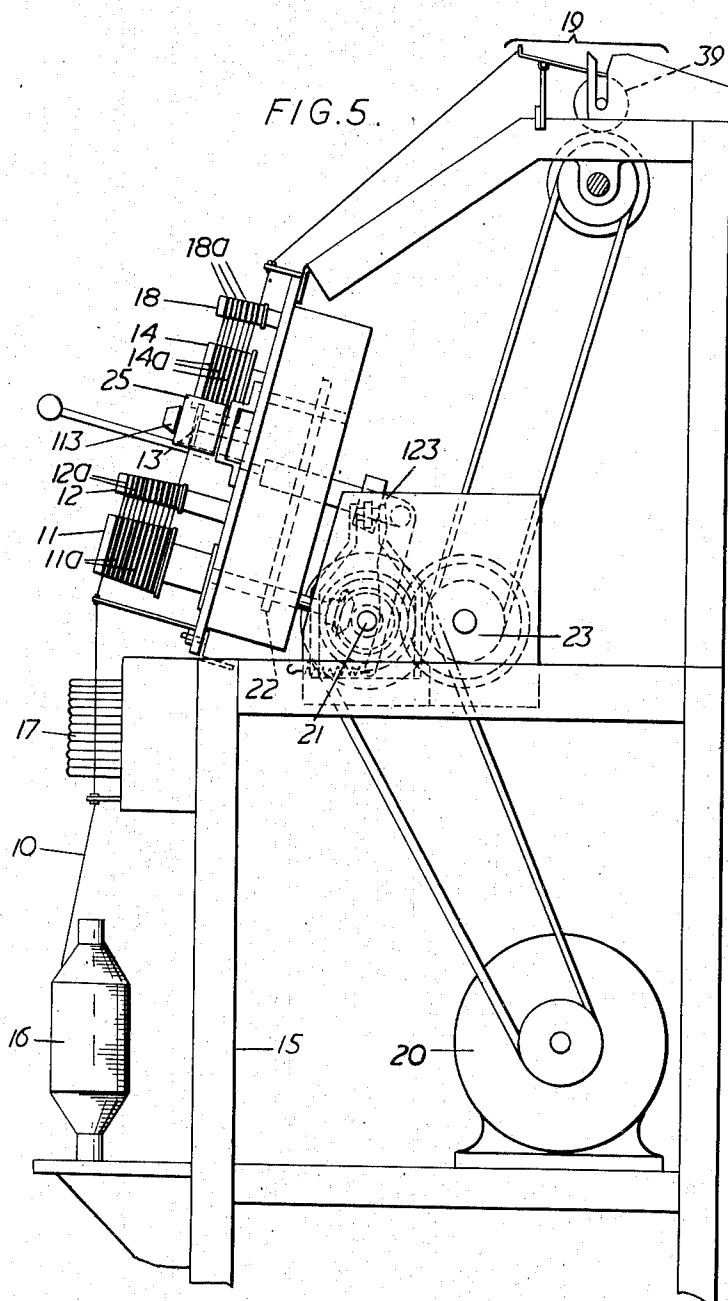
D. STARKIE ETAL

3,226,792

METHOD AND APPARATUS FOR CRIMPING YARN

Filed April 7, 1958

3 Sheets-Sheet 2



Inventors
David Starkie
Marcus William Little-Flatt
By *Albert J. Jacobs*
Attorney

1

3,226,792

METHOD AND APPARATUS FOR CRIMPING YARN

David Starkie and Marcus William Astle-Fletcher,
Somercotes, England, assignors to English Rose Limited
Filed Apr. 7, 1958, Ser. No. 726,928

Claims priority, application Great Britain, Apr. 16, 1957,
12,436/57

31 Claims. (Cl. 28—1)

Various types of crimped synthetic fibre yarns are in use in the manufacture of textiles, and particularly of knitted fabrics and garments. The materials from which they are made, such as nylon and other polyamides, "Terylene" and "Orlon," are all thermoplastic materials; that is, when a yarn made from them is held in a folded or crimped form while being subjected to an elevated temperature, it becomes "set" in that form and retains its crimp at all temperatures below the setting temperature. It will be appreciated that the insertion of crimps in a yarn gives it "stretch" properties. When the yarn is pulled, the crimps unfold and the yarn extends in length; when the pull is removed, the crimps reform and the yarn contracts in length. This crimped form has proved to be of particular value in the construction of fully-fashioned hose. The many desirable properties of a material like nylon for the construction of fully-fashioned hose are well known. By using the same yarn in a crimped form, there are added to these properties the equally desirable characteristics in the hose of close fit and "cling" during wear, "give" to the movements of the leg of the wearer, the ability of the hose to fit a range of sizes, and extra warmth and softness to the touch.

One form of crimp which has been used successfully in the manufacture of fully-fashioned hose, is a helical construction. In this form the yarn acts as an easily extensible and recoverable spring, and fabrics made from it have these same characteristics of easy extension under pull, together with warmth in wear and softness of handle. One yarn, having this particular construction, is already on the market and is finding wide application in the manufacture of fully-fashioned hose. It is made by drawing a hot yarn, under tension, over an edge. When on subsequently being subjected to a relaxing treatment, the yarn develops a helical crimp. It is important to note that during the drawing over the edge in preparing this particular yarn, one side of the yarn, i.e., that in contact with the edge, becomes flattened, and it will be observed, when the crimp in the yarn has been fully developed, that the flattened side is on the inside of the helix.

The present invention represents an entirely new and improved method of making a "stretch" yarn of construction similar to the above. The principle, upon which the method is based, has come from observations made during the course of research carried out on the physical properties of thermoplastic fibre-forming materials.

The present invention provides a method of imparting a crimped effect to thermoplastic yarn, which comprises stretching the yarn, heating it, while stretched, in such manner that a temperature gradient is set up across the yarn, cooling it and permitting it to relax. The expression "cooling it" is employed to include permitting

2

it to cool. This method permits the ready production of yarn having stretch properties. The properties of the resultant fabric are enhanced if the yarn, desirably after having been formed into fabric, is submitted while in a relaxed state to further heat treatment at a temperature intermediate the low temperature of the gradient and the highest temperature the fabric is likely to be subjected to. Particularly in the case of stockings this highest temperature is encountered in the pre-boarding operation and may be about 180° C.

The invention further provides a method of imparting a crimped effect to thermoplastic yarn, which consists in stretching the yarn, and rendering permanent the stretch along one side of the yarn by heat treatment.

The invention also provides a method of imparting a substantially helical crimped effect to thermoplastic yarn, which comprises stretching the yarn, and causing one side of the yarn to retain permanently a greater proportion of the applied stretch by establishing a temperature gradient across the stretched yarn and thereafter cooling and relaxing the yarn.

The invention further provides apparatus for imparting a crimped effect to thermoplastic yarn, comprising means for stretching the yarn, heating means for heating it while stretched and for producing a temperature gradient across the yarn, and means for cooling and relaxing the yarn.

The invention still further provides a crimped yarn produced by the above method and fabric manufactured from the yarn.

The above and other features of the invention set out in the appended claims are incorporated in the construction which will now be described as a specific embodiment with reference to the accompanying drawings in which:

FIGURE 1 is a section through a filament;

FIGURE 2 is a longitudinal section through a short length of filament treated according to this invention;

FIGURE 3 illustrates the main components of apparatus for carrying out this invention, while,

FIGURE 4 illustrates a length of the crimped yarn in its final form.

FIGURE 5 is a side view of one construction of apparatus according to the invention,

FIGURE 6 is a front view of part of FIGURE 5.

FIGURE 7 is a plan view of FIGURE 6.

Experiments have shown that, if a thermoplastic filament is stretched by a given amount, and heated to a high temperature while in this state of extension, it will retain all this extension permanently. At lower temperatures, a much smaller amount of extension is retained until a temperature is reached when the filament recovers immediately from the extension. In the case of nylon, the high temperature to cause retention of all the extension must be 210° C. or higher, up to the melting point (250° C.). When the temperature is as low as 80° C., the filament does not retain any permanent extension, recovery being complete once the stretching load has been removed. This fact has been used in devising the new method. Referring to FIGURE 1, the idea is to hold the filament 10 so that it is under strain, and to heat one side of the filament A, but apply no heat to the opposite side B. The heating conditions are selected so that there

is formed a suitable temperature gradient across the cross-section of the filament from A to B.

Let it be supposed that a nylon "66" monofilament is extended almost to its limit, and surface A is heated to say, 230° C., whereas the temperature of surface B is kept down to about 80° C. On removing the extending force, surface A will retain its extension of about 10%, while surface B will recover from the extension. The filament must, therefore, curl and form a helix. If the filament is then taken and treated in boiling water (the further heat treatment hereinbefore mentioned), the helix will tighten up further. The reason is that the boiling water temperature will cause a further shrinkage on surface B but will have no effect on the heavily heat-treated surface A. The total differential shrinkage between the two surfaces A and B, due to these two treatments, will be approximately 20%, and a closely spiralled filament will result. The helix will reverse its spiralled direction every so often in order to avoid overall torsion.

Let it be supposed that the conditions of heating have been selected so that the amount of shrinkage at any point across the filament is proportional to the distance of that point from surface A. FIGURE 2 shows, in diagrammatic form, a section of filament 10 which has been bent into a curve by differential heating and after-treatment in boiling water as described. If the length of the original filament was 100 units, and the outer surface was permanently stabilised under an extension of 10%, it will have a fixed length of 110 units. Upon boiling water treatment, the inner surface would contract a further 10%, say, to give a length of 90 units, i.e. there would be a difference in length between the inner and outer surface of 20 units. The diameter of a 15 denier nylon monofilament is approximately 1.8 thousandths of an inch. Let x be the radius of curvature of the section of filament

Then

$$\frac{x+0.9}{x-0.9} = \frac{110}{90}$$

or

$$90x+81=110x-99$$

∴ $20x=180$ and $x=9$ thousandths of an inch. From this, the length of a single spiral, $2\pi x$, =56.5 thousandths of an inch.

If such a filament is knitted up to form a fine gauge hose, it has been found that, when the length of one spiral of the filament coincides with that of filament contained in (or constituting) a knitted stitch, the resulting fabric remains virtually uncrimped. It happens that the two, spiral length and stitch length, do approach each other in yarns of this type and, in consequence, the selection of spiral length and curvature must be chosen very carefully indeed. It has been found that a hose fabric has the best appearance and stretch characteristics when the length of the spiral is close to $\frac{2}{3}$ of the stitch length. For fine gauge hose, the stitch length is of the order of 100 thousandths of an inch, and 66 thousandths of an inch would be the ideal length of spiral. As shown by the calculation, the present method applied to a nylon monofilament would allow this, and even a smaller, spiral length to be obtained.

Yarns of denier higher than 15, are composed of a number of 3 denier filaments. Such yarns would be treated, according to our invention, in a virtually untwisted state with the filaments lying side by side to form a flat ribbon. The individual 3 denier filaments would be capable of even a shorter crimp length since, for a fixed differential shrinkage, the coil radius and pitch length are proportional to the diameter of the filament.

A number of methods of producing the differential shrinkage of yarns and filaments, constrained in length, are available. Some of these are:

(1) Using heat conduction by contact with a hot surface;

(2) Using differential absorption of radiation, i.e. infra-red rays, which is dissipated within the filament in the form of heat;

(3) Treating one side of the yarn with a swelling agent;

(4) By subjecting the yarn to a controlled direction convection draught.

The method which has been used to produce the helical yarn in experimental quantities is method 1. Certain precautions must be taken if the desired effect is to be obtained. If the yarn is heated, at one time, over an appreciable length, it must not be allowed to rotate about its axis, otherwise its whole surface will be heated to the same high temperature. In the case of nylon "66," the hottest temperature must exceed 210° C. if all the extension is to be retained and the smallest size of coil in the stretch yarn is to be obtained. In instances where larger coil sizes are required, this is governed by the amount of extension and the height of the temperature, and conveniently in practice the amount of extension is maintained constant and the temperature is varied according to requirements. For a given temperature at the cool side of the yarn and for a given amount of extension, the size of coil is dependent upon the temperature at the hot side of the yarn. It is preferred to keep the cool side below 80° C. so that in the case of nylon, that side does not retain any permanent extension and to heat the other side to at least 180° C. The yarn must make good contact with the heating surface, and the use of nip rollers may be desirable. If, during heating, the surface of the yarn in contact with the hot surface becomes flattened slightly, there will be a better transference of heat to the yarn. Apart from this, the flattening of the surface has no other significance; it does not correspond to the flattening which takes place during the processing of an existing stretch yarn which has been described earlier. In that case, as already stated, the flattened face is on the inside of the helix; in the crimped yarn made according to the present invention, the flattened face would be on the outside of the helix. In operating the present method successfully, the yarn should preferably be fully extended before the differential heating is applied, and not while the heating is being applied, in order to obtain the best results. Finally, any sliding over the surfaces used should be avoided in order to prevent rotation of the yarn and obtain the best crimp.

An apparatus for processing the yarn according to the present invention is shown in diagrammatic form in FIGURE 3. It consists of four positively driven rollers 11, 12, 13 and 14, of which roller 13 is heated. Roller 11 is rotated at a slightly slower peripheral speed than rollers 12, 13 and 14; if the peripheral speed of 11 is S , than those of the other rollers 12, 13 and 14 is $S+10\%$ S . The yarn 10 is wrapped around each of the rollers one or more times. Between rollers 11 and 12, the yarn is extended or "drawn" 10% in length, and it is taken by the heated roller 13 in that condition. Finally, it is delivered by roller 14 to the usual yarn package. Subsidiary pulleys or guides can be used at each roller to prevent slippage of the yarn. In general, the yarn will be wrapped once only round the heated roller 13, and it may even be wrapped only over a portion of the circumference of that roller. It may be considered advisable to use an auxiliary nip roller in contact with, and rotating at the same speed, as roller 13 in order to ensure a better transfer of heat to the yarn surface. This auxiliary roller might, with advantage, be chilled in order to regulate the temperature gradient across the yarn. The form of the final crimped yarn is indicated in FIGURE 4.

It will be appreciated that by employing the auxiliary nip roller to promote the heat transference the apparatus is capable of processing a helical crimped yarn at high speed. At high speeds it may be necessary to have the temperature of the heated roller in excess of the melting point of the yarn material being processed in order to

5

compensate for the very short time during which the yarn is in contact with the heated surface.

The further heat treatment hereinbefore mentioned can be carried out on the yarn, while the latter is in a relaxed condition, prior to the yarn being knitted into fabric but since this makes the yarn more difficult to deal with, it is preferred to carry out the further treatment on the relaxed fabric itself. The use of boiling water, in which the relaxed fabric is immersed (preferably with agitation) is a convenient way of carrying out the further treatment but heat may be applied in other ways.

The apparatus of FIGURES 5 to 7 can be satisfactorily employed to obtain an economic production of the crimped yarn.

Referring first to FIGURES 5 to 7, there is provided a support structure 15 supporting the rollers 11, 12, 13, 14 on substantially parallel axes. The yarn 10 travels upwardly from a supply package 16, through conventional tensioning means 17, over stretching rollers 11 and 12 a number of times, partly around a heating roller 13, over drawing-off or let-off rollers 14, 18 a number of times, and to take off means 19.

Drive from a motor 20 is transmitted through a gear unit 21 and chain and sprocket means 22 to the stretching roller 11, the heating roller 13, and drawing-off roller 14. There is also a take-up drive transmission 23 and a clutch control 123. The stretching roller 12 and the roller 18 are idler rollers.

All the rollers 11, 12, 14, 18 are drum-like and formed with annular grooves 11a, 12a, 14a, 18a for the yarn 10 to travel round them a number of times from one end to the other of the rollers. The stretching rollers 11, 12 step up in diameter from groove to groove so as to be of conical-like form and the drawing-off rollers 14, 18 are of parallel form. The idler stretching roller 12 is on an axis slightly inclined (e.g. at 3°) to the axis of the driven stretching roller 13, and the idler roller 18 is on an axis slightly inclined (e.g. at 3°) to the axis of the driven roller 14.

The peripheral speed of roller 11 at its smallest diameter is 10% less than, and at its largest diameter is the same as, that of roller 14: thereby giving 10% extension to the yarn. By the particular arrangement of the stretching rollers 11, 12 the yarn 10 is extended in a series of small steps up to a point whereat it leaves stretching rollers 11, 12, in a state of the full 10% extension, and the risk of yarn breakage when starting up is at a minimum. The risk of the yarn rolling or twisting, due to the slightly inclined attitude of the yarn coils on both the stretching rollers 11, 12 and the rollers 14, 18, is minimised by the axial inclination of the idler rollers 12, 18 which cause the transfer of the yarn 10 from step to step to take place as nearly as possible in the direction of rotation.

To avoid "creep" of the yarn 10 in a tendency to reduce the considerable tension on it after it leaves the stretching rollers 11, 12, the driven stretching roller 11 is disposed as close as practicable to the heating roller 13.

The heated roller 13, conveniently of light disc construction, is heated in this example, by disposing round it a block 25 of steel or other metal which is held at the required temperature by any suitable heating means such for example as by two electrical heating elements (not shown) of the resistance type embedded in the block 25, or by other means. Heat losses are reduced by the heated roller 13 being disposed in a close fitting cavity in the block 25 leaving only sufficient of the heated roller 13 exposed for the yarn's contact with it, and the outer part of the block 25 is covered with asbestos heat-insulating compound. Mountings for the heated roller 13 are conveniently located outside the block 25 through the medium of an extended spindle and outer bearings; these being consequently kept cool to avoid difficulties of high temperature lubrication. Heat is accurately controlled con-

6

veniently by a thermostat in the block 25 and a hand control 113 therefor.

The yarn 10 is pressed into contact with the heated roller 13 by a small diameter auxiliary roller 26 (FIGURE 6) which is of light disc construction and is mounted on a pivoted arm 27 capable of being swung about an axis A' parallel to the heated roller axis B'. Care is taken to ensure that the axes of the auxiliary roller 26 and of the heated roller 13 are accurately parallel to avoid twisting of the yarn. The two rollers should operate accurately without wobble. This accuracy is important having regard to the critical dimensions of yarn section and nip between the rollers; for example when the yarn 10 is a mono-filament nylon yarn of 3 denier filament, the nip size is no greater than 0.00076 inch. The auxiliary roller 26 can be chilled for example by directing a flow of cold air on to it say from a pneumatic system which also controls the relation of the auxiliary roller to the heated roller 13. More specifically the auxiliary roller 26 is biased away from the heated roller 13 by gravity and towards it by a pneumatic piston and cylinder 28 acting on a tail 27a of the pivoted arm 27 (although controllable spring means may be provided for the latter purpose if desired).

There is also provided a yarn deflecting roller 29 which is mounted similarly to the auxiliary roller 26 but spaced therefrom to determine the arc of contact of the yarn 10 with the heated roller 13. The deflecting roller 29 is carried by a pivoted arm 30 capable of being swung about an axis "C" parallel to the heated roller axis "B" and gravity biased away from the heated roller 13. A pneumatic piston and cylinder 31 (or controllable spring means) acts on the pivoted arm 30 to bias it towards the heated roller 13.

In the pneumatic arrangement there is also provided (in the pneumatic circuit) an operator's "on" and "off" valve 32 (FIGURE 7), a key operated needle valve (illustrated at 41 and conveniently disposed remote from the operator's valve) and a sensitive gauge (not shown). The turning of an operator's "on" and "off" handle 33 on a spindle 34 rotates a cam 35 which operates the "on" and "off" valve 32 and causes a sequence of operations to take place; first, the air pressure line is opened a certain amount; then the deflecting roller 29 is moved to the limit of an adjustable stop 36 (FIGURE 6) to deflect the yarn 10 into contact with a predetermined arc of the heated roller 13 (the stop 36 controlling the final distance of the deflecting roller 29 away from the heated roller 13); and finally the full air pressure is applied against the auxiliary roller 26 to trap the yarn 10 between it and the heated roller 13. The key operated valve 41 is for a supervisor only who alone can operate this (when the operator's valve 32 is opened) to control the air pressure applied to the auxiliary roller 26.

There is further provided a pair of eccentrics 37, 38 on the spindle 34 co-operating with the tail 27a and a tail 30a of the pivoted arms 27, 30 respectively for adjustably displacing the two rollers 26, 29 away from the heated roller 13 when the valve 32 is "off" thereby allowing for threading up of the yarn 10. When the valve 32 is "on" there is a gap between the tail 27a and the eccentric 37 to allow necessary resilience of the auxiliary roller 26 under the applied air pressure.

There may also be a start and stop switch 39 and an operating cam 40 therefor on the spindle 34.

In threading up, a length of yarn 10 is pulled from the supply package and its free end is attached to the take-off means; the pulled-off yarn is then wrapped round the grooves of the rollers 14, 18 in the correct sequence; the yarn is then passed through the spaces between the separated heated roller, auxiliary roller and deflecting roller, and next it is passed around the grooves in the stretching rollers 11, 12 in the correct sequence; finally the yarn is passed through the tensioning device adjacent the supply package.

It will be appreciated that in operation of the apparatus,

the yarn is stretched to the appropriate extent by rollers 11, 12, and while in the stretched condition has one side heated and is received by rollers 14, 18. These rollers 14, 18 maintain the yarn substantially in its stretched condition while it cools. When the yarn is surrendered by rollers 14, 18, it relaxes and cools (or may cool) further. In the relaxed and cooled yarn, that side thereof which was heated retains at least some of the applied extension and so the yarn assumes a helical form.

We claim:

1. A method of imparting a crimped effect to thermoplastic yarn, which comprises stretching the yarn, heating it to a temperature below the melting point thereof, while stretched, in such manner that a temperature gradient is set up across the yarn to thereby permanently elongate one side of the yarn relative to the other, cooling it and permitting it to relax to form the crimped effect with the outside of a crimp constituted by the elongated side of the yarn.

2. A method of imparting a substantially helical crimped effect to thermoplastic yarn, which comprises stretching the yarn, and causing one side of the yarn to retain permanently a greater proportion of the applied stretch by establishing a temperature gradient across the stretched yarn substantially without destroying the molecular orientation thereof and thereafter cooling and relaxing the yarn to establish the crimped effect with the outside of a crimp constituted by the side which retains the greater proportion of stretch.

3. A method according to claim 1, wherein the yarn is subjected, while in a relaxed state, to further heat treatment at a temperature intermediate the low temperature of the gradient and the highest temperature to which the yarn is likely to be subjected.

4. A method according to claim 1 wherein the yarn is heated on one side and cooled on the other side.

5. A method of imparting a crimped effect to thermoplastic yarn, which comprises stretching the yarn by passing it over stretching rollers revolving at differing peripheral speeds, heating the travelling yarn while stretched to a temperature below the melting point thereof, in such manner as to establish a temperature gradient across the yarn by passing it over a heating roller without destroying the molecular orientation thereof, cooling the travelling yarn, and permitting the yarn to relax by passing it over a let-off roller to thereby establish the crimped effect with the outside of a crimp constituted by the side of the yarn corresponding to the warmer side of the gradient.

6. A method according to claim 5 in which the yarn is pressed over an adjustable predetermined arc of the heating roller.

7. A method of imparting a crimped effect to nylon yarn, which comprises stretching the nylon yarn, and causing one side of the yarn to retain permanently a greater proportion of the applied stretch than the other by establishing a temperature gradient across the yarn and thereafter cooling and relaxing the yarn to establish the crimped effect with the outside of a crimp constituted by the side of the yarn having the greater proportion of the applied stretch permanently retained therein.

8. A method according to claim 7, wherein the high-value of the temperature gradient is at least 180° C.

9. Apparatus for imparting a crimped effect to thermoplastic yarn, comprising means for substantially uniformly stretching the yarn, heating means for non-uniformly heating it while stretched to a maximum temperature below the melting temperature thereof and for producing a temperature gradient across the yarn which effects a permanent greater elongation on one side of the yarn, and means for cooling and relaxing the yarn to establish the crimped effect with the outside of a crimp formed by said one side.

10. Apparatus for imparting a crimped effect to thermoplastic yarn while the latter travels serially through a stretching zone, a heating zone, and a cooling and

relaxing zone, comprising means in the stretching zone for stretching the yarn passing through that zone, means in the heating zone for heating one side of the stretched yarn to a temperature below the melting point of the yarn and for establishing a heat gradient across the stretched yarn passing through that zone thereby permanently setting in a greater portion of the elongation on said one side, and means in the cooling and relaxing zone for permitting the travelling yarn to cool and relax thereby to form the crimped effect with the outside of a crimp constituted substantially by said one side.

11. Apparatus for imparting a crimped effect to thermoplastic yarn while the latter travels serially through a stretching zone, a heating zone, and a cooling and relaxing zone, comprising means in the stretching zone for stretching the travelling yarn, heating means in the heating zone for permanently elongating one side relative to the opposite side by heating one side of the stretched yarn and for establishing a heat gradient across the stretched yarn passing through that zone, and means in the cooling and relaxing zone for maintaining the heated yarn in the stretched condition while cooling and for then permitting it to relax.

12. Apparatus according to claim 11 wherein some of said means include an idle stretching roller and an idle draw-off roller, and driven stretching and draw-off rollers, each of said rollers having an axis, and the axes of said idle stretching roller and of said idle draw-off roller being slightly inclined to the axes of said driven stretching and draw-off rollers.

13. Apparatus for imparting a crimped effect to thermoplastic yarn, comprising stretching rollers over which the yarn passes from a supply, a heater roller over which the yarn passes from the stretching rollers for heating one side of the stretched yarn and thereby establishing a temperature gradient across the yarn, an auxiliary roller forming a nip between it and the heater roller for the passage of the yarn, a deflecting roller spaced from the auxiliary roller for engaging the yarn and for deflecting it into contact with the heater roller in a predetermined arc of contact, pneumatic means for biasing the auxiliary roller and deflecting roller towards the heater roller, and means for relaxing the yarn after leaving the heater roller and permitting it to cool.

14. Apparatus according to claim 13 having an adjustable limit stop to control the distance of the deflecting roller from the heater roller and consequently control the length of arc of contact of the yarn with the heater roller.

15. Apparatus according to claim 14 having cam means operable to displace the auxiliary and deflecting rollers away from the heater roller when required.

16. Apparatus according to claim 15 having lost motion between the auxiliary roller and its cam to allow required resilience of pressure of the auxiliary roller towards the heater roller.

17. A method of imparting a crimped effect to a thermoplastic yarn, which comprises progressing the yarn through a zone wherein it is stretched longitudinally and substantially uniformly and thereafter permitting the yarn to relax, and prior to relaxing the yarn rendering the stretch permanent, to differing extents at opposite sides of the yarn, by non-uniform heat treatment of the opposite sides of the yarn below the melting temperature of the yarn.

18. A method of imparting a helical crimped effect to a thermoplastic yarn, which comprises tensioning the yarn and thereby elongating it, heat-setting the elongation to differing extents at opposite sides of the yarn at a temperature below the melting point of the yarn so as not to destroy the molecular orientation thereof, and relaxing the yarn to establish the crimped effect.

19. Apparatus for imparting a crimped effect to a thermoplastic yarn, comprising means for traversing the yarn through a stretching zone and for temporarily tensioning and thereby elongating the yarn in passage through that

zone, and means for heat-setting the elongation to differing extents at opposite sides of the yarn by ensuring that one side of the running yarn is, while under tension, hotter than the other but below the melting temperature of the yarn so as not to destroy the molecular orientation thereof.

20. A method of imparting a crimped effect to thermoplastic continuous-filament yarn, which consists in stretching the yarn by passing it over annular grooves of progressively increasing diameter in a pair of spaced stretching rollers, heating the travelling yarn, while stretched, below the melting temperature thereof in such a manner as to establish a temperature gradient across the yarn by passing it over a heating roller substantially without destroying the molecular orientation thereof, cooling the travelling yarn, and permitting the yarn to relax by passing it over a let-off roller, whereby the relaxed yarn is caused to retain a greater proportion of the stretch at one side of the yarn than the other which one side forms the outside of a crimp.

21. A method of imparting a crimped effect to continuous-filament thermoplastic yarn which consists in drawing the yarn continuously from a supply source, traversing the yarn through stretching and heating zones in which stretching zone the running yarn is stretched rectilinearly and in which heating zone the yarn is heated at one side to a temperature below the melting point thereof to establish, in the rectilinearly-stretched yarn travelling through the stretching zone, a temperature gradient across the running yarn without disturbing the molecular orientation thereof, further traversing the yarn through a relaxing and cooling zone in which the yarn is relaxed and cooled, and winding the relaxed and cooled yarn into a wound package; whereby the relaxed and cooled yarn wound into the package permanently retains a higher proportion of the applied stretch along one side of the yarn than along the other side and adopts a helical form with the outside of a crimp formed by said one side.

22. Apparatus according to claim 9, wherein the stretching means comprises stretching rollers over which the yarn passes from a supply, the heating means is a heater roller over which the yarn then passes, and the means for cooling and relaxing the yarn comprises let-off rollers over which the yarn next passes.

23. Apparatus for imparting a crimped effect to thermoplastic yarn, comprising stretching rollers for receiving the yarn from a supply and stretching it, a heater roller for receiving the stretched yarn from the stretching rollers and for heating it while stretched and for establishing a temperature gradient across the stretched yarn, an auxiliary roller for pressing the yarn against the heater roller, a deflecting roller, spaced from the auxiliary roller, for deflecting the yarn into contact with the heater roller over a predetermined arc of the latter, and let-off rollers for receiving the stretched yarn from the heater roller and for surrendering it in relaxed condition.

24. Apparatus for imparting a crimped effect to thermoplastic yarn while the latter travels serially through a stretching zone, a heating zone, and a cooling and relaxing zone, comprising at the stretching zone means for receiving the yarn, gradually stretching it, and then forwarding the stretched yarn, which means comprises a pair of stretching rollers each having annular yarn-receiving grooves of progressively-increasing diameters affording a yarn speed-up path around the two rollers, means at the heating zone for receiving the stretched yarn and heating one side of it to a temperature below the melting point thereof and for thereby establishing a heat gradient across the stretched yarn passing through the heating zone, and means, comprising a pair of let-off rollers, in the cooling and relaxing zone for receiving the yarn from the heating means and for surrendering it in relaxed condition.

25. Apparatus according to claim 24, wherein the pair of stretching rollers consists of a driven roller and an

idle roller rotatable about an axis slightly inclined to that of the driven stretching roller, and wherein the pair of let-off rollers consists of a driven roller and an idle roller rotatable about an axis slightly inclined to that of the driven let-off roller.

26. A method of imparting a helically-crimped effect to thermoplastic yarn, which consists in drawing the yarn continuously from a supply thereof, stretching the travelling yarn lengthwise, causing one side of the yarn to retain permanently a greater proportion of the applied stretch than the other side by establishing a temperature gradient across the cross-section of the travelling yarn by nipping the travelling yarn between hot and cold surfaces, and thereafter cooling and relaxing the yarn.

27. Strand-treating apparatus comprising forwarding means including a pair of counter-rotating nip rolls adapted to admit and forward a strand in oriented condition therebetween, a tensioning device adapted to apply restraining tension to said strand entering the roll nip, heating means effective to increase the temperature of the peripheral surface of one of the rolls, and cooling means effective to maintain the peripheral surface of the other roll at a lower temperature than that of the first roll.

28. A method of imparting a crimped formation of a thermoplastic filament which comprises the steps of withdrawing the filament continuously from a supply thereof, passing the running filament through a stretching zone and in passage through said zone extending the filament longitudinally with an extension which is substantially uniform across the section of the filament, and causing the greater proportion of the longitudinal extension to be permanently set into the filament at one side thereof than at the opposite side by passing the uniformly extended running filament through a heating zone and during passage therethrough establishing a heat gradient across the section of the filament from a high value less than the melting point of the filament at said one side to a lesser value at said opposite side and thereafter relaxing and cooling the filament, whereby said filament is given a tendency to assume a helical disposition with said one side at the outside of the helix.

29. Strand-treating apparatus comprising forwarding means to forward a strand in oriented condition, a tension device adapted to apply tension to said strand, heating means including at least one roll and effective to increase the temperature of the peripheral surface of said one roll, means for passing said strand over said one roll on one side thereof, and cooling means effective to maintain the opposite side of said strand at a lower temperature than said one side thereof.

30. Apparatus for imparting a crimped effect to a thermoplastic yarn, comprising first means for receiving the yarn from a supply and stretching it, a heater roller for receiving the stretched yarn from said first means and for heating it while stretched and for establishing a temperature gradient across the stretched yarn, means for causing the yarn to engage at least a portion of the heater roller, and let-off rollers for receiving the stretched yarn from the heater roller and for surrendering it in relaxed condition.

31. A method of imparting a crimped formation to a thermoplastic filament which comprises the steps of withdrawing the filament continuously from a supply thereof, passing the running filament through a stretching zone and in passage through said zone extending the filament longitudinally with an extension which is substantially uniform across the section of the filament, and causing the greater proportion of the longitudinal extension to be permanently set into the filament at one side thereof than at the opposite side by passing the uniformly extended running filament through a heating zone and during passage therethrough establishing a heat gradient across the section of the filament from a high value less than the melting point of the filament at said one side to a

11

lesser value at said opposite side, by passing the uniformly extended running filament between and in simultaneous contact with two opposed surfaces traveling in the same direction, and at substantially the same speed as the filament, one of which surfaces is hot and the other of which is cold, and thereafter relaxing and cooling the filament, whereby said filament is given a tendency to assume a helical disposition with said one side at the outside of the helix.

References Cited by the Examiner

UNITED STATES PATENTS

1,983,326	12/1934	Taylor	28—72
2,087,606	7/1937	Oppenlaender et al.	28—71.3 X

12

2,368,637	2/1945	Bruenner et al.	28—72
2,369,395	2/1945	Heymann	28—72
2,669,001	2/1954	Keen	28—72
2,708,813	5/1955	Bourgeaux	28—72
2,881,504	4/1959	Billion	28—71
2,919,534	1/1960	Bolinger et al.	28—72
2,921,358	1/1960	Cox et al.	57—34 X
2,974,391	3/1961	Speakman et al.	28—72

10

DONALD W. PARKER, *Primary Examiner*.

RUSSELL C. MADER, *Examiner*.