United States Patent [19]

Blezard et al.

[11] **3,808,840**

[45] **May 7, 1974**

[54] **THREE-STRAND YARN KNITTING MACHINE AND METHOD OF KNITTING**

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[73] Assignee: **Smithfield Fibers, Inc.**, Providence, R.I.

[22] Filed: **Apr. 16, 1973**

[21] Appl. No.: **351,576**

Related U.S. Application Data

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[52] **U.S. Cl.** **66/87,** 66/170, 66/195

[51] **Int. Cl.** **D04b 23/02**

[58] **Field of Search** 66/195, 194, 193, 191, 66/202, 192, 87, 5, 6, 170

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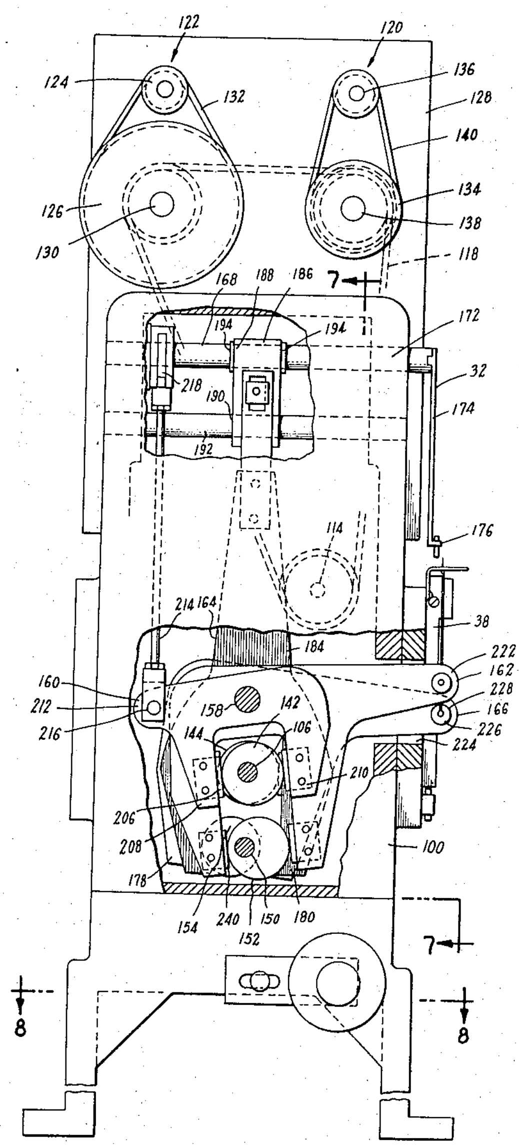
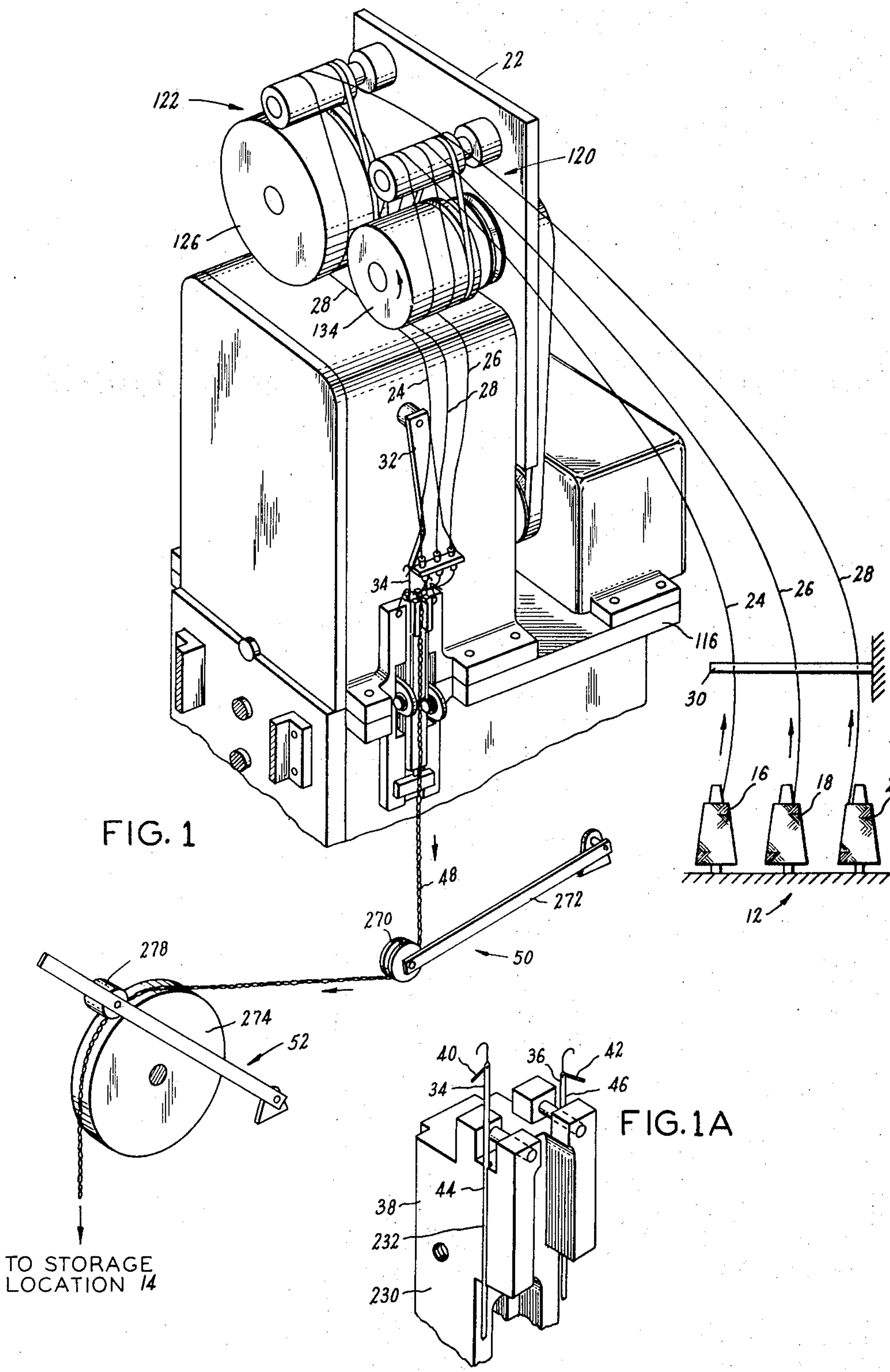
Primary Examiner—Ronald Feldbaum
Attorney, Agent, or Firm—Salter & Michaelson

[57] **ABSTRACT**

A method and machine for knitting three strands of yarn in two interlocking chains, wherein stitches in first and second strands of said yarn are formed about one reciprocating latch needle of said machine and stitches in said second strand and a third strand are formed about a second parallel reciprocating latch needle of said machine. Each needle pulls a newly formed stitch through a preceding stitch and casts-off the preceding stitch.

19 Claims, 10 Drawing Figures

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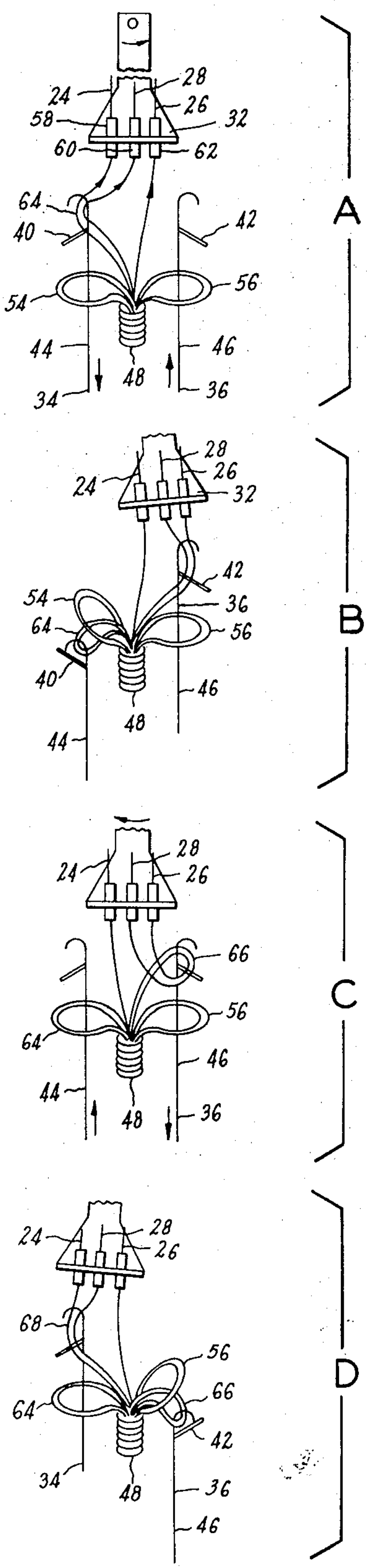
122
120
126
28
134
26
24
28
32
34
24
26
28
116
30
16
18
20
12
48
270
272
50
278
274
52
TO STORAGE
LOCATION 14
40
36
42
34
46
44
38
232
230

FIG. 1

FIG.1A


A
B
C
D
24
26
28
32
34
36
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42
44
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48
54
56
58
60
62
64
66
68

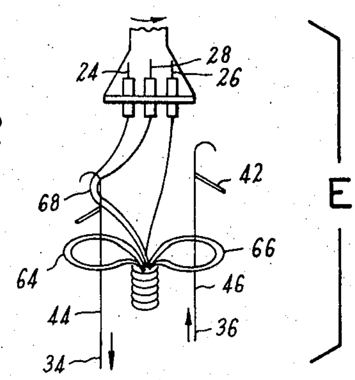

E
24
26
28
34
36
42
44
46
64
66
68

FIG. 2

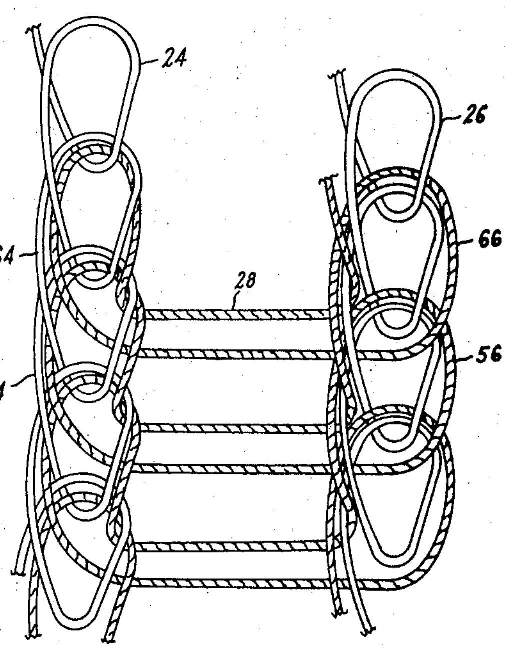

24
26
28
54
56
64
66

FIG. 3

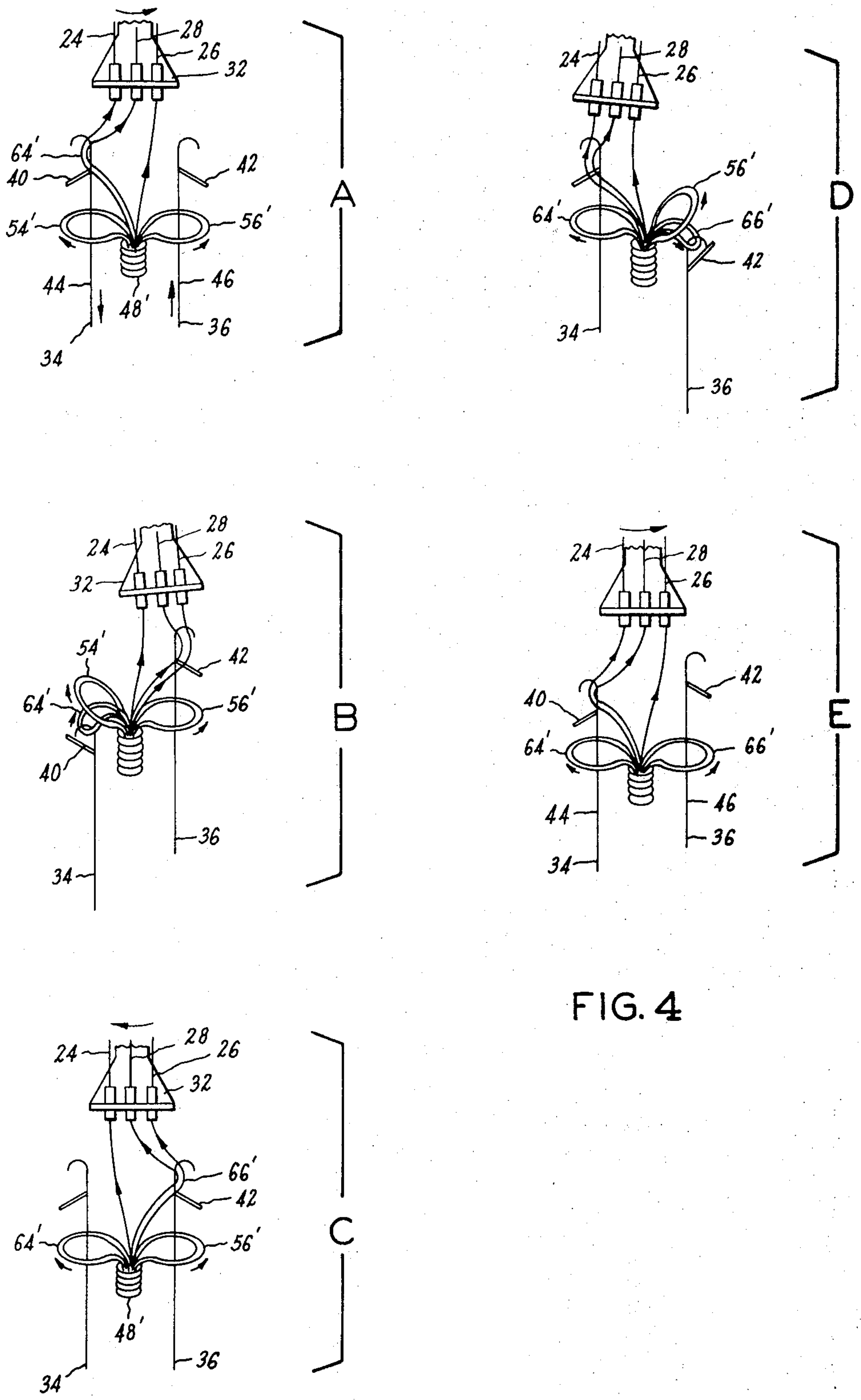
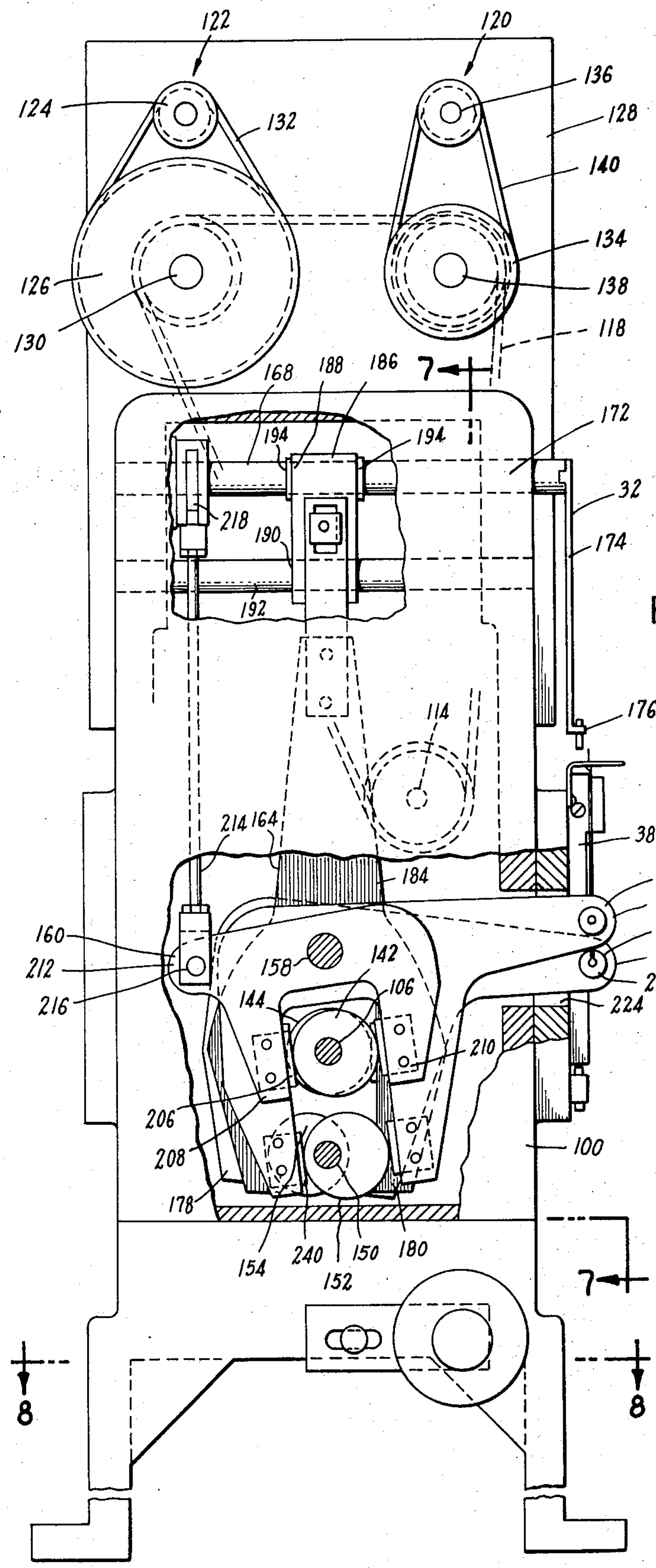


FIG. 4


122
120
124
136
132
128
140
126
134
138
130
118
168
188
186
7
172
194
194
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218
190
174
192
114
176
214
164
38
184
222
162
160
228
212
158
142
166
106
226
144
216
224
210
206
208
100
178
154
240
150
180
152
7
8
8

FIG. 5

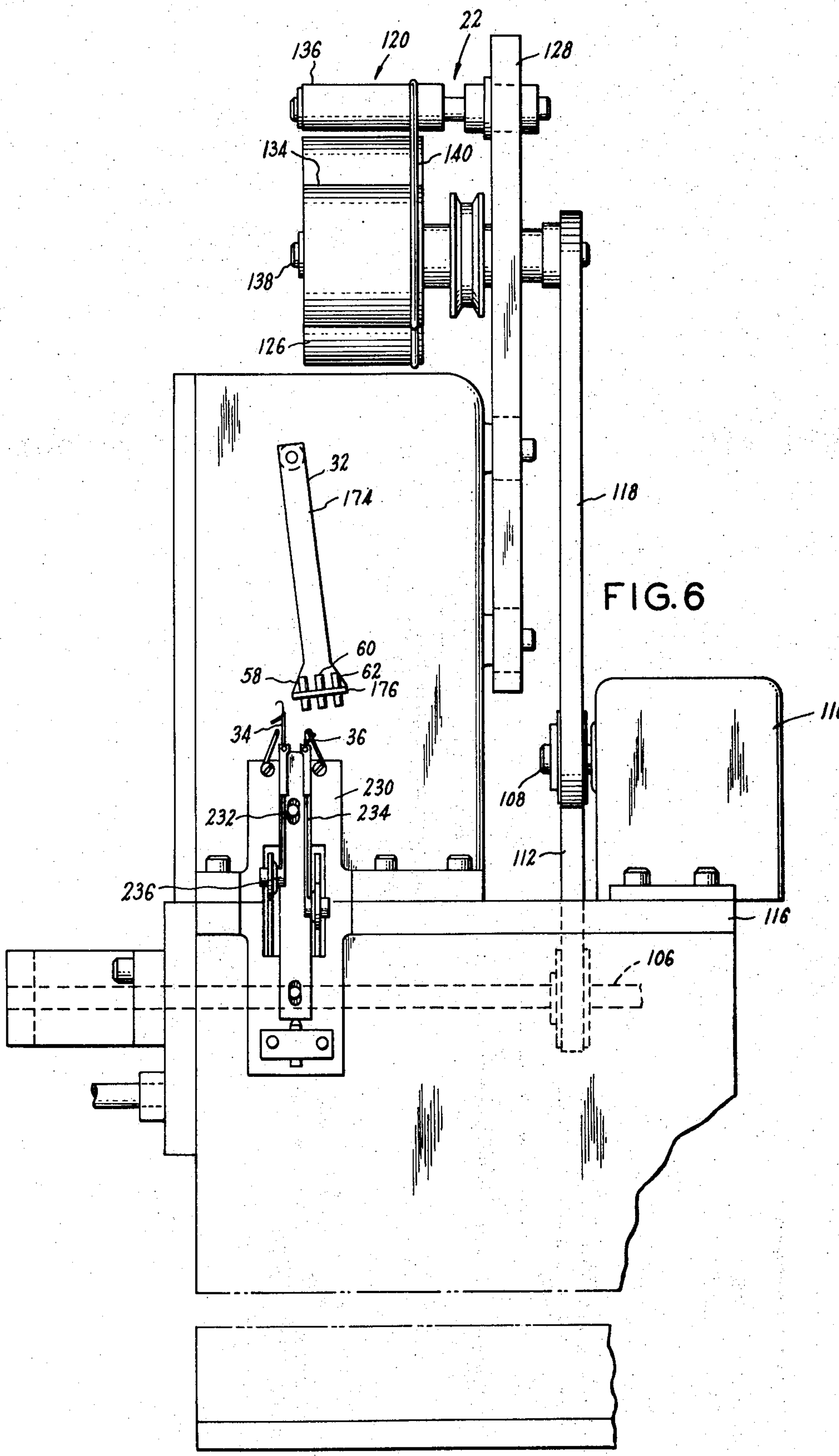
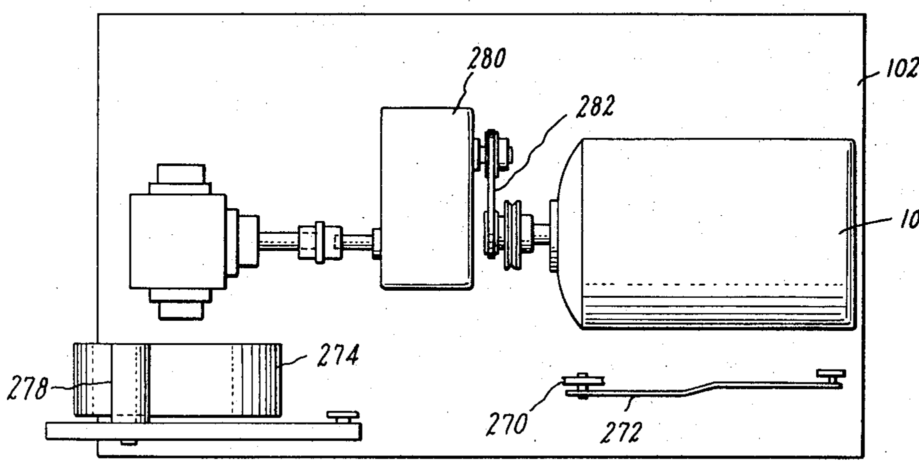

22
120
136
128
134
140
138
126
32
174
118
60
58
62
176
110
34
36
230
108
232
234
112
236
116
106

FIG. 6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282
102
104
274
278
270
272

FIG. 8

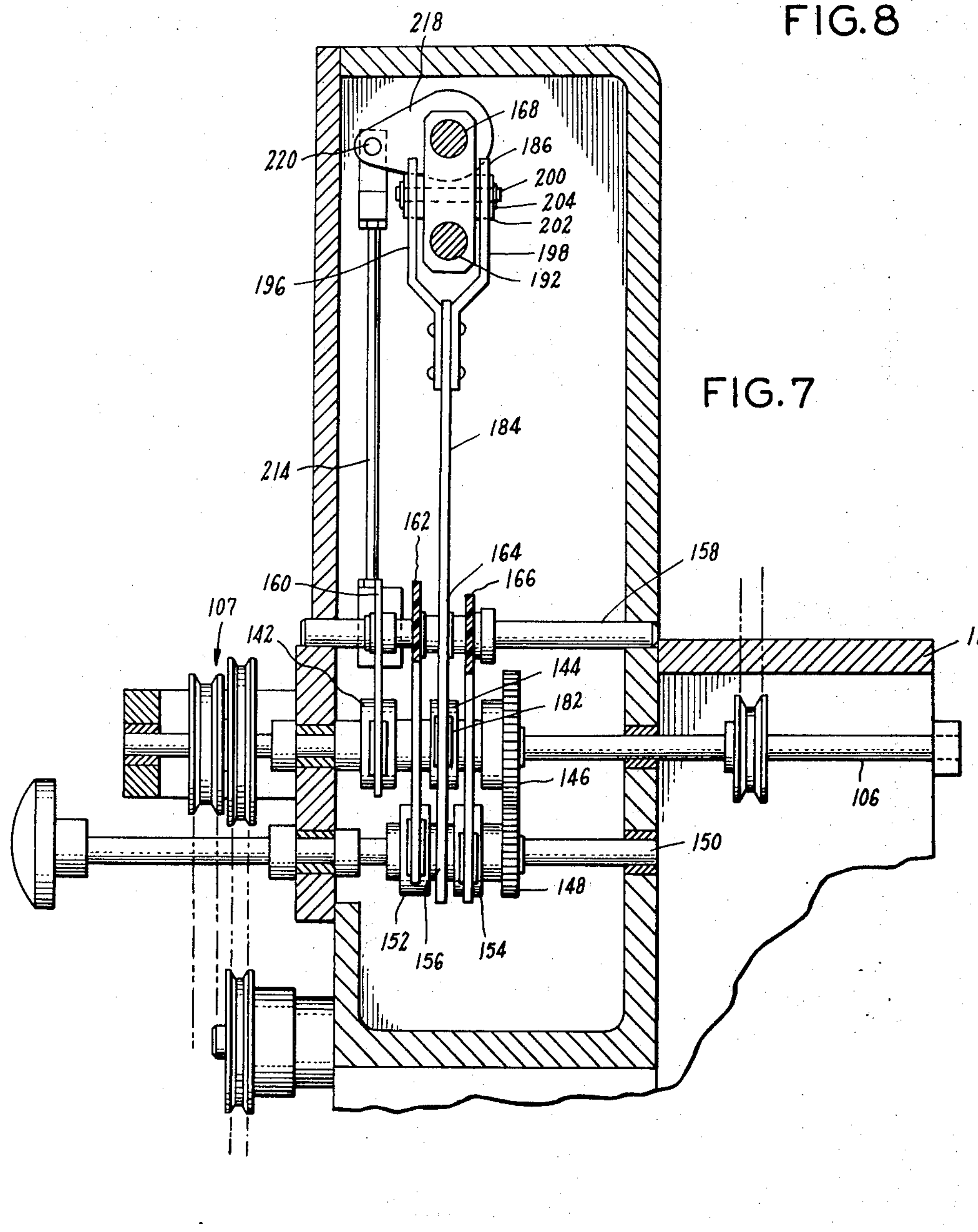
218
168
220
186
200
204
202
198
196
192
184
214
162
164
166
158
160
107
142
144
116
182
146
106
150
148
152
156
154

FIG. 7

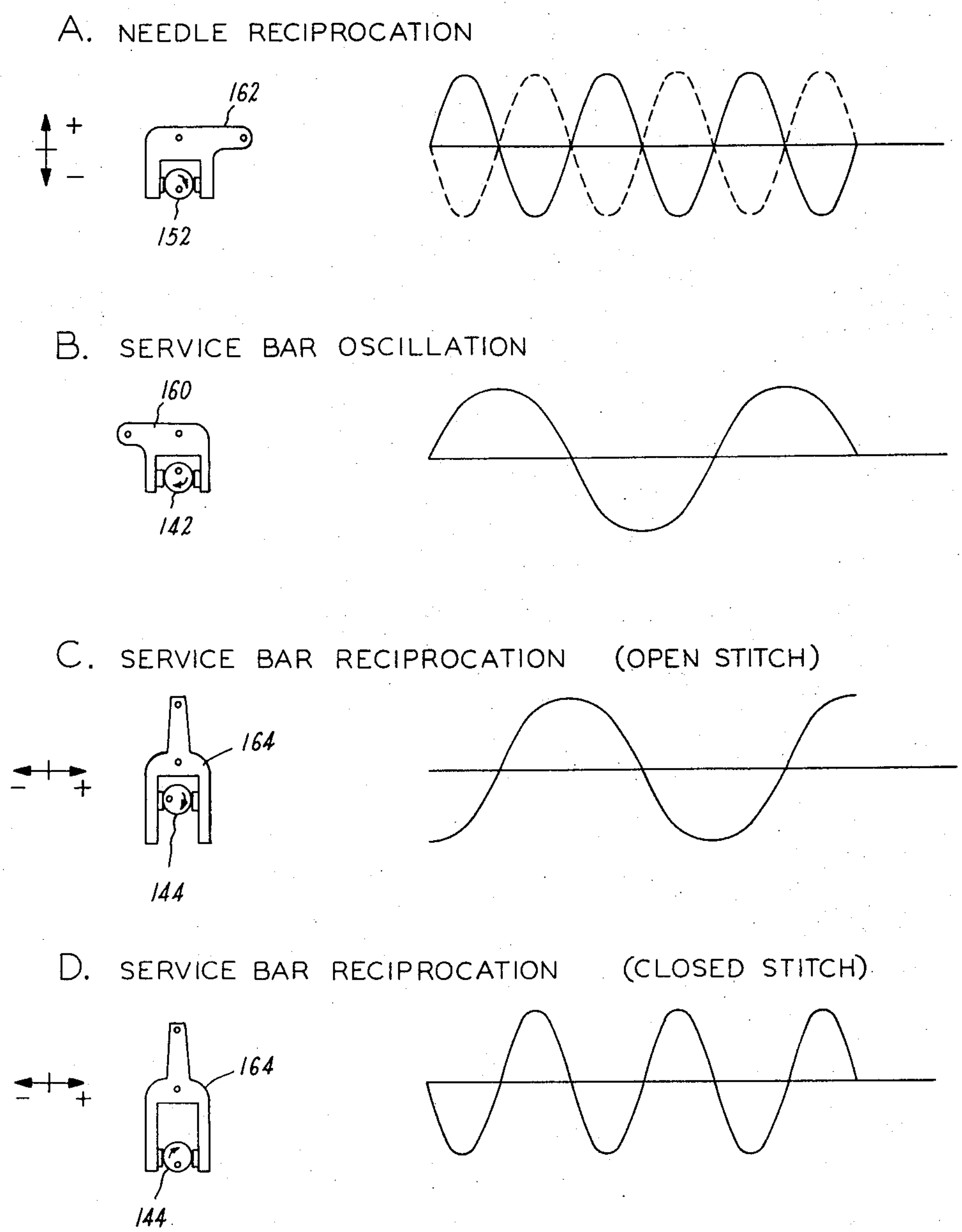
A. NEEDLE RECIPROCATION
162
+
−
152
B. SERVICE BAR OSCILLATION
160
142
C. SERVICE BAR RECIPROCATION (OPEN STITCH)
164
−
+
144
D. SERVICE BAR RECIPROCATION (CLOSED STITCH)
164
−
+
144

FIG. 9

THREE-STRAND YARN KNITTING MACHINE AND METHOD OF KNITTING

This is a division of copending application Ser. No. 96,059, filed Dec. 8, 1970, now U.S. Pat. 3,738,125 and entitled "Three Strand Knitted Yarn."

BACKGROUND OF THE INVENTION

This invention generally relates to textile manufacturing and more specifically to a novel yarn and a method and apparatus for manufacturing such a yarn.

Prior yarn manufacturing processes include draw-twisting, braiding, and knitting. In draw-twisting, a positive feed mechanism supplies strands to a drawing area at a controlled rate. A traveller on a vertically reciprocating ring in the drawing area guides the strands onto a bobbin which rotates about a vertical axis. The combined motion of the bobbin and ring causes the strands to twist as they accumulate on the bobbin as yarn. Once the bobbin fills, an operator interrupts the process, replaces the bobbin and transfers the full bobbin to another twisting operation or final storage cone.

In braided yarn, a number of strands are interwoven or braided to form the final yarn. Two sets of feed spools counter-rotate on two tracks while paying out the strands that make up the yarn. Each spool moving in one direction passes on alternate sides of the spools moving in the other direction. As a result, each strand on one set of feed spools interweaves with all other strands from the other set.

In a prior knitting manufacturing process, two strands are deposited as alternate stitches on one or two reciprocating latch needles. As each needle reciprocates it draws a newly formed stitch through a preceding stitch to form an interlocked yarn.

Each of the prior twisted, braided and knitted yarns has specific characteristics, advantages and disadvantages. For example, twisted and braided yarns have a substantially circular cross-section while prior knitted yarns have either a circular or rectangular cross-section. None of these manfuacturing processes can produce a ribbon-like yarn.

Braided yarn has a greater breaking strength than equivalent twisted or knitted yarn (i.e., yarn with an equal weight per unit length). Prior knitted and braided yarns do not unravel and splay when cut. Twisted yarns do. Prior knitted yarns are manufactured at a much greater rate than either the twisted or braided yarns. Neither the knitted nor braided yarns have an inherent internal torque which characterizes twisted yarn, so they do not tend to kink and break in use or knit on a bias. A prior knitting machine can knit yarns of widely divergent sizes while yarn drawing and braiding machines are limited to producing a single size of finished yarn or, at most, a narrow range of sizes. Finally, braided yarns are relatively inelastic while both twisted and knitted yarns have a certain inherent elasticity.

As is apparent, no one yarn has all the foregoing characteristics. In those applications where these characteristics are desirable, a compromise is made. For example, if a yarn with a maximum strength and minimum weight is desired, a braided yarn is chosen even though it is expensive to produce and limited to a circular configuration.

Therefore, it is a general object of this invention to provide a novel knitted yarn which incorporates many advantages previously found only in different prior yarns.

Specifically, it is an object of this invention to provide a yarn which can be knitted with a thin, rectangular cross-section.

Another object of this invention is to provide a yarn which can be knitted with a breaking strength approaching that of equivalent braided yarn.

Yet another object of this invention is to provide a yarn which can be knitted to be relatively inelastic, but which is more economical to manufacture than braided yarn.

Still another object of this invention is to provide a method and apparatus for continually knitting the novel yarn at a high rate.

A further object of this invention is to provide a method and apparatus for knitting the novel yarn in a wide range of yarn sizes.

SUMMARY

In accordance with this invention, our yarn comprises three strands arranged in two interlocked chains. Successive stitches in each chain comprise two strands with one strand being common to both chains.

This yarn is produced by feeding the strands to a pair of generally parallel, counter-reciprocating latch needles. As the first latch needle moves in one direction, a yarn feeding mechanism loops the first and third strands around that needle to form a stitch for the first chain. At the same time, the second latch needle pulls a first stitch previously formed in the second and third strands through a preceding stitch formed on that needle to form another portion of the second chain. The knitting machine feeds the strands to the latch needles and counter-reciprocates the latch needles to draw stitches through preceding stitches in each chain and cast off the preceding stitches to form the yarn.

Our knitted yarn has a number of important advantages. It is possible to vary the cross-section of the yarn by adjusting or varying the tension applied during the knitting operation, the spacing between the needles or the size of strands fed to the knitting machine. If, for example, the first and third strands are heavy and fed under greater tension than the second strand, the machine tends to knit a ribbon-like yarn. The effect is also produced by increasing the spacing between the needle and decreasing the tension to the second strand by increasing its feed rate. On the other hand, a yarn has a generally circular configuration when the tension on the second strand is increased or the needles are closely spaced, or both. This yarn has a breaking strength which has the same order of magnitude as braided yarn. It is significantly stronger than prior knitted yarn.

As neither the strand supply nor the yarn take-up operations are involved in the knitting sequence directly, the system is capable of manufacturing yarn at significantly higher rates than those available with either draw-twisting or braiding.

This invention is pointed out with particularity in the appended claims. A more thorough understanding of the above and further objects and advantages in this invention may be attained by referring to the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a machine for knitting yarn in accordance with this invention;

FIG. 1A is an enlarged detail view of a portion of the machine;

FIG. 2 schematically illustrates one operating sequence for forming knitted yarn;

FIG. 3 depicts the knitted yarn formed by the sequence shown in FIG. 2;

FIG. 4 schematically illustrates another operating sequence for forming knitted yarn;

FIG. 5 is a front view of the knitting machine shown in FIG. 1, partially broken away;

FIG. 6 is a side elevation;

FIG. 7 is a cross-sectional view taken along line 7—7 in FIG. 5;

FIG. 8 is a view from line 8—8 in FIG. 5; and

FIG. 9 is a machine timing diagram.

DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

A. General Discussion

In accordance with our invention, a yarn knitting machine 10 shown in FIG. 1 transforms three strands from a supply location 12 into knitted yarn which is stored at a yarn storage location 14. Generally, storage cones 16, 18, and 20 store the strands at the storage location 12. A feeding mechanism 22 draws strands 24, 26 and 28 from the cones 16, 18 and 20 through a conventional tensioning mechanism 30 for delivery to the knitting machine 10.

The feeding mechanism 22 supplies the strands 24, 26 and 28 to a single service bar 32 which deposits the strands as stitches about vertical latch needles 34 and 36. The service bar simultaneously oscillates about, and reciprocates along, a horizontal support axis to perform this function, as described later. At this point, it is merely necessary to understand that the strand 24 forms loops or stitches solely around the latch needle 34 and the strand 26 forms stitches only around the latch needle 36. The service bar 32 also alternately deposits stitches of the strand 28 around the two latch needles 34 and 36.

The latch needles 34 and 36, shown more clearly in FIG. 1A, reciprocates along spaced, vertical needle axes in a supporting needle slider block 38 below the service bar 32. The needle 34 includes a pivoted latch 40; the needle 36, a pivoted latch 42. Each time a needle reciprocates, it draws a new stitch through a preceding stitch disposed around needle stem (44 or 46) to form finished yarn 48.

The finished yarn 48 passes through a tensioning unit 50 and take-up drive assembly 52 driven by the knitting machine 10. At this point, the knitted yarn is completed and no further processing is necessary.

B. Yarn Structure and Method

FIG. 2 illustrates the sequence for forming a yarn shown in FIG. 3. In FIG. 2A, the latch needles 34 and 36 are centered on their respective needle axes with the needle 34 moving downwardly and the needle 36 moving upwardly. Latches 40 and 42 on the needles are open. Previously knitted stitches 54 and 56, each comprising two strands, lie around needle stems 44 and 46 below the latches 40 and 42 respectively.

The service bar 32, shown schematically in FIG. 2, comprises three cylindrical guides 58, 60 and 62 for the strands 24, 28 and 26, respectively. This service bar 32 has formed the stitches 54 and 56 and will form subsequent stitches about the needles 34 and 36 by depositing the strands in the directions indicated by the arrows on the individual strands. Service bar movement is such that the strands 24 and 28 form the stitch 54 while strands 26 and 28 form the stitch 56.

Still referring to FIG. 2A, the service bar 32 is centered between the needles 34 and 36 and disposed somewhat behind them. As it oscillates in the plane of the FIGURE, its arc is limited so that the outer guides 58 and 62 form stitches only about the needles 34 and 36, respectively, while the guide 60 forms the strand 28 into stitches around both needles alternately. In FIG. 2A, the service bar 32 is moving to the right in the FIGURE and has just deposited a stitch 64, comprising the strands 24 and 28, around the needle 34 above the latch 40. At this time, the service bar 32 does not form a stitch around the needle 36.

Next, as shown in FIG. 2B, the needle 34 reaches the lowest limit of travel while the needle 36 reaches its upper limit. At this time the service bar 32 is at a right-hand limit. Due to its axial motion, as described later, it has moved forward, or out from the FIGURE, so that the strands 26 and 28 now extend from the finished yarn 48 to the rear of the needle 36 and then forward above the latch 42 in front of the needle 36.

Concurrently, the latch 40 on the needle 34 has closed and captured the newly formed stitch 64, while the downward motion of this needle has pulled the stitch 64 through the previous stitch 54 and, at its lower limit, cast the stitch 54 off. As the stitch 54 is cast-off, it forms a portion of the finished yarn 48. The tension on the finished yarn 48, produced either by its own weight or by the tensioning unit 50 (FIG. 1), assures that the stitches clear the needles 34 and 36 as they are cast off.

In FIG. 2C, the needles 34 and 36 have returned to the position shown in FIG. 2A, but the service bar 32 is at the mid-point moving to the left. In this position, the new stitch 64 formed by strands 24 and 28 lies around the stem 44 below the open latch 40. Furthermore, the service bar 32 has completely formed the strands 26 and 28 into a new stitch 66 above the open latch 42 while the stitch 56 remains formed aroudn the stem 46 below the latch 42.

During the time interval during which the needles 34 and 36 and the service bar 32 travelled between the positions shown in FIGS. 2C and 2D, the latch 42 closed so the needle 36 pulled the new stitch 66 through the previous stitch 56 as the stitch 56 is cast-off. Simultaneously, the service bar 32 has moved to its left-hand limit and begun to form another stitch 68 with the strands 24 and 28 around the needle 34 above the latch 40.

The service bar 32 is midway between the needles and moving to the right in FIG. 2E. In this position, the needle 44 is retracting downwardly and has closed the latch 40 preparatory to drawing the next stitch 68 through the stitch 64 now formed around the stem 44.

Hence, the service bar 32 forms the strands 24 and 26 into stitches about the reciprocating axes for the needles 34 and 36. These stitches are formed alternately. As each stitch is formed, the service bar 32 also forms the strand 28 into a stitch simultaneously with one of the other strands. As a result, the strands 24 and

28 and the strands 26 and 28 form successive stitches along each of the needles with each stitch, such as the stitches 54 and 56, being pulled through preceding stitches such as the stitches 56 and 64.

The resulting yarn 48 shown in FIG. 3 comprises three strands 24, 26 and 28. THe strand 24 includes stitches 54 and 64 which are formed with the strand 28 while the strand 26 comprise stitches 56 and 66 also formed with the strand 28. Each stitch passes through a preceding stitch. As a result, the strands form two chains. Successive stitches in one chain comprise the strands 24 and 28 while successive stitches in the other chain comprise strands 26 and 28. In this manner, the strand 28 interlocks the two chains so they cannot unravel.

The yarn shown in FIG. 3 has several advantages over prior yarns. First, the configuration of the finished yarn 48 can be varied by changing the relative fineness of each strand. If the strand 28 has a significantly greater cross-sectional area than the two strands 24 and 26, a circular yarn can result. On the other hand, if the strands 24 and 26 are significantly larger than the strand 28, a thin rectangular or ribbon-like yarn results. These variations can be enhanced by changing the distance between the two needle axes, or varying the tension in the strands or both.

By virtue of this knitted configuration, the finished yarn 48 does not run or splay when it is cut. As the production rate is dependent solely upon the speed of the needles and the rate at which strands are fed, production rates equivalent to the prior knitting method are attained. In addition, the number of interruptions to the process are reduced because the supply and take-up spools form no part of the process. If the strands 24 and 26 have the predominant diameter and the feed rates are adjusted so the yarn comprises a series of tight stitches, the yarn 48 is relatively inelastic and is comparable with prior braided yarns, breaking strength approaches the breaking strength for an equivalent braided yarn.

The machine in FIG. 1 can be modified so the service bar 32 deposits the strand 28 as closed loops or bights around each needle to form closed stitches. The sequence for forming the yarn with closed stitches is shown in FIG. 4. A reference numeral followed by a prime (') indicates elements which are modified with respect to FIG. 2, identical elements being referred by the same reference numerals.

Referring specifically to FIG. 4A, the needle 34 and 36 are substantially at the mid-point of axial travel with the needle 34 moving downwardly. The latches 40 and 42 are open. Previously knitted stitches 54' and 56' lie around the needle stems 44 and 46, respectively. The stitch 54' comprises the strands 24 and 28 while the stitch 56' comprises the strands 26 and 28; and the service arm has deposited a closed stitch 64' around the needle 34. As a result, the strand 28 extends from the finished yarn 48' in front of the needle 34 around the needle and crosses itself between the needles 34 and 36 as part of the closed stitch 64'. The strand 24 merely passes around the needle 34.

In FIG. 4B, the needle 34 has moved to a bottom position with the latch 40 being closed to draw the stitch 64' through the stitch 54'. The stitch 54' has been cast-off in the FIGURE. During the interval when the needles moved between the positions in FIGS. 4A and 4B, the needle 36 has moved to its upper position with its latch 42 remaining open. The service bar 32 has travelled to a right-hand limit and has deposited the strands 27 and 28 in front of the needle 36 and above the latch 42.

During the interval when the needle moved between the positions in FIGS. 4B and 4C, the service bar 32 moved to the left to a center position and completed the new stitch 66' around the needle 36. The strand 28 again extends from the finished yarn 48' to the front and around the needle 36 above its latch 42 to a position where continued motion of the service bar 32 causes the strand 28 to cross itself between the needles 34 and 36. That is most clearly seen in FIG. 4D, where the needle 36 is at its lower limit with the latch 42 closed. The stitch 56' has also been cast over the stitch 66'. At this point, the service bar 32 is depositing the strand 28 in front of the needle 34 again so that the strand 28 forms a closed loop or stitch.

Finally, in FIG. 4E, the stitches 64' and 66' lie around the stems 44 and 46, respectively. The service bar 32 has formed the strands 24 and 28 into another closed stitch around the needle 34 above the closed latch 40 and is moving in such a direction as to lay the strand 28 in front of the needle 36 to repeat the cycle shown in FIG. 4.

It is now apparent that the yarn produced by the sequences in FIGS. 2 and 4 differs in two ways. In the sequence shown in FIG. 2, the center strand 28 circumscribes both needles 34 and 36 while in FIG. 4, it circumscribe each needle separately. Secondly, in FIG. 2, stitches formed by the strands 26 and 28 are formed by passing the threads to the rear of the needle 36 before completing the stitch whereas the reverse directions are produced in FIG. 4. The modification is made by varying the rate at which the service bar 32 reciprocates above the needles as described more fully with reference to the FIGS. 5 through 9. The yarn produced according to the sequence according to FIG. 4 is basically the same as the yarn shown in FIG. 3 with these two modifications. Its advantages are similar to those advantages described or attributed to the yarn in FIG. 3.

A seclection between the yarn produced by the sequences shown in FIGS. 2 and 4 depends upon several factors. These factors include the aesthetic characteristics of the finished yarn, its end use, its required strength and its stitch density. Still other factors include differences in sliding friction of the yarn and the material forming the strands.

The sequences shown in FIGS. 2 and 4 are both adapted to use strands which are twisted, braided or knitted in accordance with the prior art. Alternatively, any one or combination of the storage cones 16, 18 and 20 may contain yarn manufactured in accordance with this invention. Therefore, in the foregoing discussion, the term "strand" means any yarn component formed from fibers, filaments, or combinations of such fibers or filaments and made by prior methods or in accordance with this invention. Such strands may include both textile and non-textile materials. When knitted yarn is manufactured with strands manufactured in accordance with this invention, its relative bulk increases still further.

C. The yarn Knitting Machine

Our yarn can be manufactured on a knitting apparatus shown in FIGS. 1 and 5 through 8. This specific knitting machine embodiment is shown for knitting only one yarn. It will become apparent during the following discussion, however, that the knitting machine may be easily adapted to knit two yarns simultaneously.

Now referring specifically to FIGS. **5** through **8**, the yarn knitting machine is disposed in a housing **100** including a horizontal support **102**. A drive motor **104** mounted on the support **102** rotates a cam shaft **106** through a conventional belt and pulley system **107**. The motor also drives an input shaft **108** for a torque converter **110** through another belt and pulley system **112** driven by the cam shaft **106**. The torque converter **110** controls the speed of an output shaft **114**. Such torque converters are known in the art, one example being a Zero-Max^R torque converter, manufactured by the Zero-Max Co., Minneapolis, Minnesota. A secondary horizontal support **116** spaced above the support **102** carries the torque converter **110** so the output shaft **114** and the yarn feeding mechanism **22** are aligned. A third belt and pulley system **118** links the output shaft **114** and the feeding mechanism **22**.

Strands **24, 26** and **28** may differ in size and be fed to the knitting area at different rates. The yarn feeding mechanism **22** in FIGS. **5** and **6** incorporates two feeding units **120** and **122** to supply the strands. Specifically, the feeding unit **120** supplies strands **24** and **26** at one rate, while the feeding unit **122** supplies the strand **28** at a different rate. In this specific embodiment, the third belt and pulley system **118** links both the feeding units **120** and **122** so they rotate at the same angular velocity.

With specific reference to the feeding unit **122**, an idler **124** and a driving spindle **126**, both of constant diameters, are mounted in parallel on a vertical support plate **128**. The driving spindle **126** rotates with a shaft **130** driven by the belt and pulley arrangement **118** while another belt **132** couples the roller **124** and the spindle **126**.

The strand **28** is normally wrapped about the periphery of both the idler **124** and driving spindle **126** several times before being fed to the service bar **32**. As the motor **104** drives the service bar **32** and the needles **34** and **36** at constant rates, varying the angular velocity of the output shaft **114** alters the strand feed rate. That is, such a variation alters the rate at which the feeding unit **122** continuously supplies the strand **28** to the service bar **32** each time the needles **34** and **36** reciprocate.

Simultaneously, the feeding unit **120** which comprises a driving spindle **134** and idler **136** feeds the strands **24** and **26**. The belt and pulley arrangement **118** also drives a shaft **138** which supports the spindle **134** while another belt **140** turns the idler **136**. Variations in the speed in which the strands **24** and **26** are fed is obtained by varying the relative diameters of the roller spindles **126** and **134**. In this specific embodiment, the spindle **126** has about twice the diameter of the spindle **134** to deliver the strand **28** at approximately twice the rate the strands **24** and **26**.

Other types of feeding units can be incorporated in the knitting machine shown in these FIGURES. Furthermore, various guides may be interposed between the storage location **14** and the feeding mechanism **22** and between the feeding mechanism **22** and the knitting area. Sucb guides are known in the art and are not shown.

As previously indicated, the service bar **32** oscillates about and reciprocates along a horizontal axis simultaneously and in synchronism with the needles **34** and **36** which reciprocate along vertical axes to form the stitches. The service bar **32** and both needles **34** and **36** are driven by the motor **104** through a series of cams and levers shown in FIG. **7**.

The cam shaft **106** supports two eccentric cams **142** and **144** and a pinion **146** for driving an idler gear **148** mounted on a second cam shaft **150** at twice the speed of the cam shaft **106**. The shaft **150**, which is vertically aligned under the cam shaft **106**, carries another pair of spaced eccentric cams **152** and **154**. Spacers, such as a spacer **156** located directly below the cam **144**, separate the cams so each is horizontally offset from the others.

Each cam drives a lever mounted on a pivot shaft **158** parallel to and vertically aligned over the cam shafts **106** and **150**. These levers are designated as a service bar lever **160**, a first needle lever **162**, a throw-bar lever **164** and a second needle lever **166** (FIGS. **5** and **7**).

The service bar **32** is mounted on a throw-bar **168** which rides in bushings **170** and **172** located on opposite side-walls of the housing **100**. An arm **174**, rigidly affixed to the throw-bar **168**, supports the three horizontally offset cylindrical guides **58, 60** and **62** on a lower flared portion **176** of the arm **174**.

The throw bar lever **164** reciprocates the throw-bar **168** along its horizontal axis under the influences of the cam **144**. Bifurcated fingers **178** and **180** on the throw-bar lever **164** support shoes **182** which engage the cam **144** at diametrically opposed portions. As the cam **144** rotates, it oscillates the throw-bar lever **164** about the pivot shaft **158**. An integral upper arm **184** on the throw-bar lever **164** engages a yoke **186** with prarallel upper and lower journals **188** and **190**. The upper journal **188** engages the throw-bar **168** while the lower journal **190** is adapted to ride on a supporting shaft **192**. Snap rings **194** in circumferential grooves on the upper throw bar **168** capture and center the yoke **186**. As a result, the throw-bar **168** can oscillate about its axis in the yoke **186**.

A pair of offset arms **196** and **198** couple the upper arm **184** and the yoke **186**. A transverse pin **200** through the yoke **186** between the throw-bar **168** and the shaft **192**, bushings **202** formed on the arms **196** and **198** and snap rings **204** provide a conventional pivotal connection between the arms **196** and **198** and the yoke **186**. Therefore, as throw-bar lever **164** oscillates about the pivot shaft **158**, it reciprocates the throw-bar **168** and the attached service bar. It is apparent that the throw-bar **168** can support another service bar on the opposite side of the housing so the machine can knit two yarns simultaneously.

The cam **142**, the service bar lever **160** and associated linkage provide concurrent oscillating motion for the service bar **32**. Shoes **206** supported by bifurcated fingers **208** and **210** on the lever **160** tangentially engage the cam **142** so the service bar lever **160** oscillates about the pivot shaft **158**. An arm **212** on the service bar lever **160** extends horizontally from the pivot shaft when the lever **160** is at a middle position to engage a linkage mechanism and oscillate the throw-bar **168**.

Specifically, a fixed link **214** is pivotally connected to the arm **212** by a pin **216** and to a crank **218** by another pin **220**. The crank **218**, in turn, rotates the throw bar lever **168** about its axis without interfering with axial motion. Such connections are known. As the cam **142** rotates and elevates the arm **206**, the link **214** and the crank **218** rotate the throw-bar **168** clockwise when viewed from the service bar **32**.

In this configuration with the cams 142 and 144 both mounted on the cam shaft **106**, the throw bar and service bar oscillate and reciprocate at the same cyclical rate. Therefore, the service bar **32** moves substantially circularly and produces the open stitches in the yarn shown in FIG. **3**.

The knitting machine is easily adapted to knit the yarn in accordance with the sequence shown in FIG. **4**. The operator merely interchanges the cam **144** and the spacer **156** and moves the shoes **182** to a lower position on the arms **178** and **180**. With this modification, the cam **144** rotates at twice the rate of the cam **142**; and the throw-bar **168** reciprocates at twice the rate it oscillates. As a result, the service bar **32** wraps the strand **28** in a "figure **8**" as closed stitches about the needles **34** and **36**.

The remaining cams **152** and **144** move the needles **34** and **36** in the counter-reciprocal motion with separate, but identical needle levers **162** and **166**. Referring specifically to the needle lever **162**, it comprises a horizontal arm **222** which extends through an opening **224** in the housing sidewall to emerge beside the needle slider block **38** beneath the latch needle **34**. An identical arm on the needle lever **166** emerges beside the needle slider block beneath the latch needler **36**. Each arm supports a bushing **226** in an aperture **228**.

In FIG. **1**A, the needle slider block **38** comprises a body portion **230** with two spaced, vertical ways **232** and **234** for supporting the stems **44** and **46** on the needles **34** and **36**. The stems **44** and **46** terminate at elbows **236** and **238**, respectively. Bushings **226** in the needle levers **162** and **166** individually support the elbows **236** and **238**.

The needle lever **162** also comprises shoes **240** which tangentially engage the cam **152** and oscillate the needle lever **162** about the pivot shaft **158**. As the bushings **228** pivotally support the needles **32** and **34**, the oscillatory motion of the arm **222** on the needle **162** is translated into a reciprocal needle motion as the needles slide in their respective ways. Furthermore, the cams **152** and **154** are oppositely disposed on the cam shaft **150**. As a result, the needles reciprocate at a rate which is twice the oscillating rate for the throw-bar **168** and reciprocate in opposite directions; i.e., the counter-reciprocating motion.

A still more thorough understanding of the operation of the knitting machine shown in FIGS. **1** and **5** through **8** may be obtained by additionally referring to FIG. **9** which illustrates machine timing at a reference time. As shown in FIG. **9**A, the cam **152** drives the needle lever **162** starting at a mid-point with a positive-going trace of the resulting curves indicating upward displacement of the needle. Simultaneously, the cam **154** oscillates the needle lever **166** to move the needle **46** downwardly from a central reference position as represented by the dashed line. As a result, both needles reciprocate sinusoidally about a mid-point reference with respect to time at a constant rate.

FIG. **9**B represents the oscillation of the throw-bar **168** and the service bar **32** with reference to a central angular position with clockwise rotation or displacement being represented by positive-going traces. As the cam **142**, mounted on the upper cam shaft **106**, oscillates the lever **160**, the throw-bar **168** oscillates completely each time the needles reciprocate twice. As a result, the service bar **32** is centered above and between the needles when the needles are at the mid-point position.

With reference to FIG. **9**C, the cam **144** is on the cam shaft **106** to knit yarn with open stitches. Reciprocation away from the housing **100** is represented by positive-going traces. In this arrangement, the lever **164** reciprocates the throw-bar **168** at the same cylical rate it oscillates. The cam **144** is oriented to retract the throw-bar **168** from a center reference position at the reference time. As the needle **34** and service bar **32** move to a limit position and return, the throw-bar **168** moves to a maximum extension. During the time the needle **36** elevates and returns to its reference point, the guide **62** travels around the needle **36** to return to its initial position. As a result, the strand **28**, deposited by the guide **62** circumscribes both axes defined by needles **34** and **36**.

If the cam **144** is on the shaft **150**, it is oriented so the throw-bar lever **164** is at a middle position at the reference time. During the interval when the service bar **32** swings to the left and returns to the reference point, the throw-bar **168** undergoes an entire reciprocation as shown in FIG. **9**D. This operation forms a complete stitch around the needle **34**. Another complete stitch is formed around the needle **36** as the service bar **32** swings to the right and returns to the reference point.

As the machine knits yarn in accordance with the sequence in FIGS. **2** and **4**, it drops downwardly to accumulate below the support plate **116** in FIGS. **1** and **8**. A roller guide **270** pivoted on an arm **272** directs the yarn **48** to a drum **274**. Another roller **276** on an arm **278** guides the yarn **48** and holds it against the surface of the drum **274**. After the yarn **48** leaves the drum **274**, it accumulates in a final storage location **14** which may comprise a shipping cone or other storage device.

The plate **102** supports the drum **274** and the arms **272** and **278** below the upper plate **116**. A variable speed reduction unit **280**, similar to the torque converter **110** and coupled to the motor **104** drives the drum **274**. A belt-and-pulley arrangement **282** couples the reduction unit **280** and the motor **104** to thereby control the tension on the finished yarn in combination with the feeding mechanism **22**.

In summary, our invention is directed to three related aspects of yarn manufacture. Our knitted yarn, by virute of its construction, incorporates many advantages heretofore found only in different yarns. Specifically, the yarn does not unravel when it is cut and has no inherent torque. One yarn seems to have a breaking strength approaching that of an equivalent braided yarn. Another yarn may have a substantially circular cross-section. Alternately, tension, spacing, strand dimension, or all three can be controlled to provide a ribbon-like cross-section.

Both the knitting method and apparatus are flexible. A given apparatus can produce a wide range of yarn sizes with different types of strands with only minor modification to the apparatus. Both the method and apparatus enable production rates which are equivalent to prior knitted yarns; this rate greatly exceeds the rates available for draw-twisting or braiding.

While we have described a specific embodiment of a knitted yarn and a method and apparatus for manufacturing the yarn, many variations are possible. The illustrated method for manufacturing knitted yarn and apparatus describe specific elements to perform the various operations. Other elements may be substituted without significant degradation in the overall process. For example, the drive mechanisms move the needles in a continuous counter-reciprocating motion. The term "counter-reciprocating" is also intended to cover other types of needle motion. In some machines the needles may reciprocate in a mutually exclusive fashion to alternately form the two chains. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of this invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

What is claimed is:

1. A method for making yarn from three strands comprising

a. forming first and second strands into first and second stitches about first and second axes, respectively,

b. simultaneously forming the third strand into the first and second stitches whereby each stitch comprises two strands and said third strand is common to each stitch, and

c. drawing each stitch along one axis through a preceding stitch on that axis.

2. A method as recited in claim **1** additionally comprising tightening each preceding stitch after said drawing step.

3. A method as recited in claim **1** wherein the first and second stitches are formed alternately in the first and second strands, said drawing step alternately pulling each newly formed stitch on one axis to the preceding stitch on that axis.

4. A method as recited in claim **3** wherein successive stitches in the third strand circumscribe both axes to form open stitches.

5. A method as recited in claim **3** wherein the successive stitches in the third strand alternately circumscribe the first and second axes to form closed stitches.

6. A method as recited in claim **1** additionally comprising feeding first and second strands at a first controlled rate and a third strand at a second controlled rate.

7. A method of forming a yarn wherein three individual strands of material are employed, comprising the steps of arranging a first of said strands in a plurality of chain stitches that define a first chain, arranging a second of said strands in a plurality of chain stitches that define a second chain, and interknitting the third strand with said first and second strands in alternate chain stitches to unite the chains in a knitted construction.

8. A method as recited in claim **7,** comprising the further steps of arranging said first chain about a first axis, arranging said second chain about a econd axis that is spaced from said first axis, and drawing said interknitted chain stitches in alternate relation along said axes, wherein each of said interknitted chain stitches is drawn along one axis through a preceding interknitted chain stitch on that axis.

9. A method as recited in claim **8,** comprising the further step of alternately circumscribing said third strand about said first and second axes to form closed interknitted chain stitches with said first and second chains.

10. A method as recited in claim **9,** comprising the further step of feeding said first and second strands during the interknitting procedure at a first controlled rate and feeding said third strand during such procedure at a second controlled rate.

11. A machine for knitting yarn from three strands comprising:

a. support means,

b. a drive unit on said support means,

c. first and second latch needle means mounted on said support means for reciprocation along vertical axes,

d. first means connected to said drive unit for moving said first and second needle means in a counter-reciprocating motion,

e. an arm for wrapping first and second strands into stitches about first needle means and the second and third strands into stitches about the second needle means, and

f. second means connected to said drive unit for simultaneously reciprocating and oscillating said arm with reference to a horizontal axis above said needle means to form about said first and second needle means.

12. A machine as recited in claim **11** wherein said second connecting means oscillates and reciprocates said arm at the same cyclic rates.

13. A machine as recited in claim **11** wherein said second connecting means reciprocates said arm at a cyclic rate which is twice the oscillating rate.

14. A machine as recited in claim **11** additionally comprising a unit for feeding strands to said arm in proportion to the cyclic rate of said arm and needle means.

15. A machine as recited in claim **14** wherein said feeding unit comprises means for feeding the first and second strands to the arm independently of the third strand.

16. A machine as recited in claim **14** wherein

a. said drive unit comprises

1. a motor,
2. a first cam shaft responsive to said motor for rotation at a first angular velocity, and
3. a second cam shaft coupled to said motor to be driven at a second angular velocity which is twice the first angular velocity,

b. said first connecting means comprising a first and second lever means pivoted on said support means and engaging said second cam shaft and said latch needles to move said latch needles in a counter-reciprocating motion at a first cyclic rate, and

c. said second connecting means comprising

1. a horizontally disposed arm support member mounted on said support for axial and rotatable motion with respect to longitudinal axes therethrough, said arm being connected to depend from an end of said support member,
2. a third lever means coupling one of said cam shafts and said arm support member for reciprocating said arm support member,
3. fourth lever means pivoted on said support means and additionally engaging said first cam shaft, and
4. a link pivoted to said connector portion and said arm support member for oscillating said arm support member at a cylcic rate which is half the cyclic rate of said latch needles.

17. A machine as recited in claim 15 wherein said third lever means comprises

a. a lever pivoted on said support and engaging said first cam shaft, and

b. a connector for supporting said arm support member for rotation with respect thereto, but axially affixed thereto, said connector being pivotally connected to said lever to thereby reciprocate said arm support means and said connected arm at a cyclic rate which is half the cyclic rate of the latch needles.

18. A machine as recited in claim 15 wherein said third lever means comprises

a. a lever pivoted on said support means and engaging said second cam shaft, and

b. a connector for supporting said arm support members for rotation with respect thereto, but axially affixed thereto, said connector being pivotally connected to said arm support means and said connected arm at a cyclic rate which equals the cyclic rate of the latch needles.

19. A machine for knitting yarn from three individual strands of material comprising a support, a drive unit mounted on said support, a first latch needle mounted on said support for vertical reciprocating movement, a second latch needle mounted for vertical reciprocating movement on said support adjacent to said first latch needle, an arm interconnected to said drive unit and being operable to wrap first and second strands of material into chain stitches about said first latch needle and the second strand and a third strand of material into chain stitches about said second latch needle as said latch needles reciprocate, and means interconnected to said drive unit for simultaneously reciprocating and oscillating said arm to cause said latch needles to form said chain stitches during the vertical reciprocating movement thereof.

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