March 31, 1970 W. G. FARRER ET AL 3,503,232

YARN DYEING

Filed Feb. 14, 1966 3 Sheets-Sheet 1

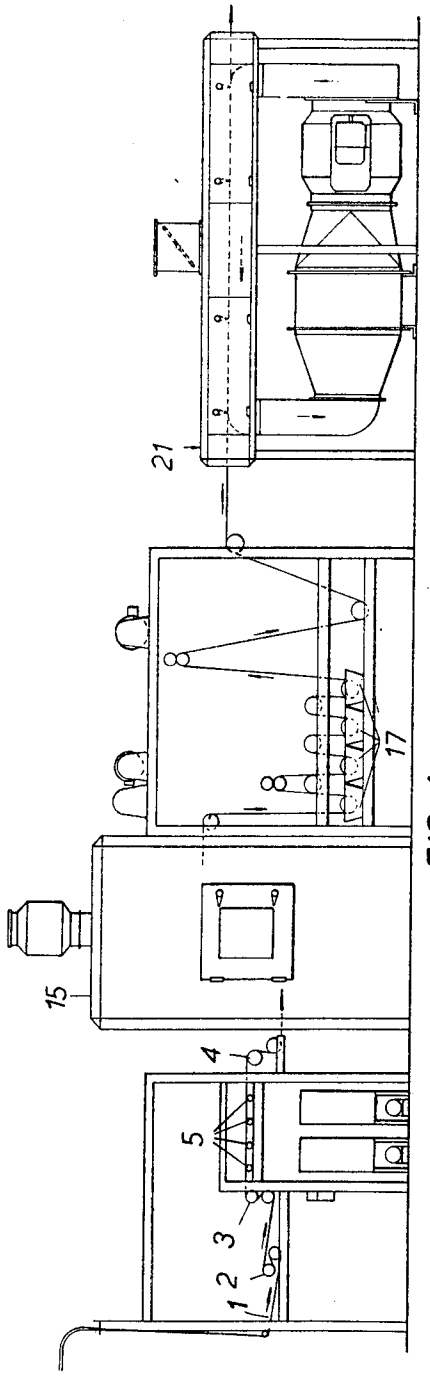

FIG. 1.

INVENTORS
WILLIAM GREENHALGH FARRER
BRIAN HARGREAVES
By Cushman, Darby & Cushman
ATTORNEYS

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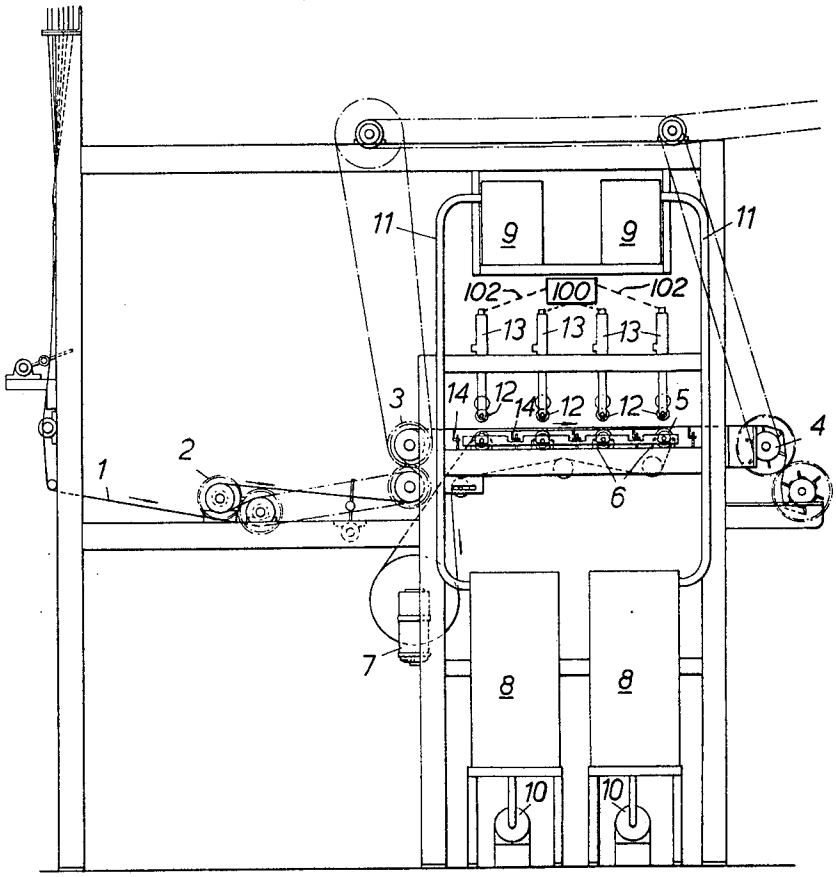
YARN DYEING

Filed Feb. 14, 1966 3 Sheets-Sheet 2



-FIG. 2.-

INVENTORS

WILLIAM GREENHALGH FARRER

BRIAN HARGREAVES

By Cushman, Darby & Cushman

ATTORNEYS

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YARN DYEING

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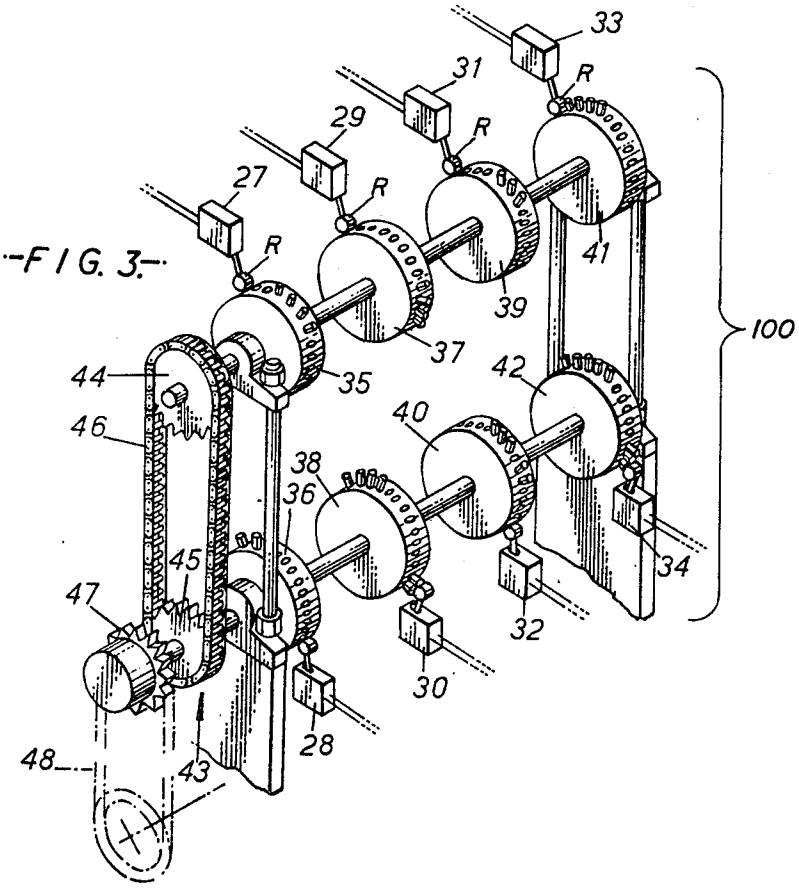
-FIG. 3-



INVENTORS
WILLIAM GREENHALGH FARRER
BRIAN HARGREAVES
By
Cushman, Darby & Cushman
ATTORNEYS

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YARN DYEING

William Greenhalgh Farrer and Brian Hargreaves, Bacup, England, assignors to Stalwart Dyeing Company Limited, Bacup, England, a corporation of Great Britain

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U.S. Cl. 68—203 1 Claim

ABSTRACT OF THE DISCLOSURE

In a space-dyeing apparatus of the type having a vertically movable presser roller which presses a moving warp against a dye applicator roller random movement of the presser roller is obtained with a pattern control mechanism which includes two series-connected switches each opened and closed by a cam rotating at a different speed. The resulting open or closed circuit electrically activates a pneumatic piston and cylinder which either raises or lowers the presser roller.

In the bulk of carpets now being manufactured, the pile consists of yarns uniformly coloured along their lengths, that is to say, the pile yarns have no longitudinal discontinuities or changes in colour. However, a small but evidently increasing proportion of carpets now being offered for sale contain pile yarns whose colours vary along their lengths, the change from one colour to another being more or less abrupt. Such yarns have come to be known as "space-dyed" yarns, and, accordingly, the processes and apparatuses used for their manufacture as space-dyeing processes and apparatuses.

Commerical interest in space-dyed yarns for carpets has been aroused only in recent years undoubtedly partly because the dictates of fashion had hitherto resisted a departure from traditional patterns involving bold and often intricate designs. In consequence, only recently have yarn producers and dyers turned their attentions away from the traditional methods of dyeing. Undoubtedly, also, some measure of rediscovery was necessary before the space-dyeing method was contemplated by yarn producers and dyers, but, once attention had been directed to it, it became clear that the space-dyeing method was potentially of value as a method of dyeing synthetic fibres since they can readily be formed into continuous filament yarns of great strength and robustness.

The space-dyeing method of colouring yarns is in fact no recent development and particular methods of space-dyeing yarns have long formed a part of the published literature on dyeing techniques, as, for example, U.S. Patents Nos. 864,312, 1,195,322 and 2,573,097 show. The methods described in British patent specifications Nos. 783,134 and 900,341 are recent contributions to the literature on space-dyeing and British patent specification No. 938,734 describes some recent developments in space-dyeing equipment and techniques.

In the space-dyeing method of colouring yarns, a large number of yarns are passed in parallel and coplanar arrangement (that is to say, as a warp) in succession over a series of dye applicators that are charged with dyes of varying colours. The warp of yarns is controlled during its passage over the dye applicators so as to maintain it normally clear of the surfaces of the dye applicators and when it is desired to colour any portion of the warp of yarns the yarns of the warp are depressed by presser members so as to cause that part of the warp to be pressed down against the surface of an appropriate dye applicator. As British patent specification No. 938,734 shows, printing

of individual yarns as well as all yarns collectively and simultaneously is possible.

After leaving the dye applicators the coloured warp of yarns passes first through a dye fixing zone, then through a number of wash tanks to remove loose dye and residual dye liquor, and thereafter through a yarn drying zone. In general, the yarns finally are wound onto suitable storage means, which may be a warp beam on which a large number of yarns may be simultaneously wound side-by-side with, say, longitudinal staggering of yarns prior to winding on the beam, or a number of individual yarn reels, cheeses, packages, cones or bobbins. It will be clear that the yarns from which the warp is formed may originate from any of these storage means. It may in particular cases be convenient to feed the dyed yarns direct to a tufting machine forming pile fabric, such as carpet. Normally, the yarn from which the warp is originally formed will be undyed yarn.

A most attractive type of space-dyed yarn is one whose colour pattern repeat length (excluding small "white" gaps between areas of applied colours) is very large despite only a few colours, say 3–5 excluding purposefully introduced white regions obtained by deliberate avoidance of dyeing, being employed and despite the length of any coloured region being short. It may be noted here that in general for a given length of pile about eight times that length of pile yarn will be required.

The yarn colour pattern repeat length can be increased either by increasing the number of applied colours or by introducing a series of invariant "white" (viz: undyed) regions. A colour pattern repeat length of say, 300 feet is readily obtainable from 4 series of colour regions and no region (whether coloured white overall or at least partly in applied colour) need be more than from 9 to 12 inches in length (equivalent to a length of pile of about 1 to 1½ inches).

Where the yarn pattern repeat length is greater than about 100 feet the yarn may be considered for many purposes as being randomly coloured and if a carpet is made from many such yarns it is relatively easy to bring about adequate longitudinal staggering of yarns to avoid transverse patterning effects in other than very small areas of the carpet pile.

Prior art space-dyeing apparatus such as that referred to above is generally capable of applying different colours to yarns with a short pattern repeat length only owing to the limitations of the pattern control mechanism which actuates the presser rollers.

It has now been found that a colour pattern having a random repeat length may be applied to yarns using a novel form of pattern control mechanism. This mechanism comprises two groups of switches, one switch from each group being in series with one switch from the other group and in the energising circuit of an electro-magnetic valve associated with a pneumatic actuator for one of the presser rollers. The two groups of switches are activated by two groups of switch-activating devices containing on the surface thereof switch-activating means to open and close switches in their associated groups. The switch activating devices in each group are rotated at the same speed and provision is made for the cams of one group to rotate at a different speed from those in the other group.

The means for rotating the dye-applicator rolls may take any suitable form, such, for example, as a chain and sprocket wheel drive system or a belt drive system coupled to the out-put shaft of a variable-speed electric motor.

The warp-advancing and -tensioning means advantageously comprises a pair of rotatably-driven winches whose blades intermesh with each other and make only line contact with the warp of coloured yarns leaving the dye-applicator rolls.

The apparatus is usable with any yarn supply means such as a warp beam on which the yarns of the entire of yarns are wound side-by-side, or creels, cheeses, packages, cones or bobbins from which individual yarns are drawn. Any of the variety of means presently employed for tensioning a warp of yarns may be employed as part of the warp-advancing and -tensioning means. Advantageously such tensioning means comprises individual devices for controlling the tensions of individual yarns.

Each warp presser roller and each dye-applicator roll are advantageously of small diameter (say up to 1½–2 inches in diameter) in order to permit short bands of colour with well-defined ends to be applied to the warp of yarns as well as, in the case of the presser roller, to reduce stresses on the pneumatic-activating means therefor to a minimum. The presser rollers are advantageously freely rotatable.

The pneumatic activating means for each presser roller advantageously comprises a piston and cylinder arrangement in which gas supply conduits lead to both ends of the cylinder permitting the piston (and hence the presser roller fixed thereto) to be positively driven under pneumatic pressure in both directions. Such arrangements are well known. If desired, the presser rollers may be acted upon by resilient means arranged to assist or cause the presser rollers to return to their inoperative positions. Each pneumatic activating means is advantageously capable of developing full applied pneumatic pressure only slowly and over the final stage of movement of its associated presser roller into its operative position. In this way, objectionable splashing of dye liquor on impact of the presser roller against the spongy dye-liquor-carrying surface of the dye-applicator roll is minimised. To achieve this, each piston and cylinder arrangement may be provided with a pressure-responsive bleed valve that controls either the rate of escape of exhaust gas from a closed chamber on the side of the piston opposite to where pneumatic pressure for printing is applied or the rate of build-up of the contained gas pressure. To cause the presser roller to move out of its operative position, full pneumatic pressure may be, and advantageously is, applied at the outset. Advantageously each presser roller is driven by two such piston and cylinder arrangements acting in consort at opposite ends of the roller.

Advantageously, the second switch group of the pattern control means includes several switches (there may be one for each switch of the first switch group) so that variations in the lengths and positions of several or all applied colours is possible. Even so, the pattern may include regularly occurring "white" regions. This situation is obtainable by arranging that, for a given lineal speed of travel of the warp or yarns, the first switch group and associated group of rotary switch-activating members could not (if they alone determined when the presser rollers were raised and lowered) colour the whole of the yarns in substantially touching bands of applied colours. Such deliberately left white regions permit very attractive contrast effects to be obtained when a bright colour (say orange or yellow) is to be used with more subdued colours (say two different shades of green) because it is readily possible to arrange for recurrent short bands ("spots") of the bright colour to be set in white ground. The short bands of bright colour may be invariant in length. It will of course be realised that there is no reason why every dye-applicator roll must apply dye in use.

The rotary switch-activating members may advantageously be rotary cams whose followers are resiliently urged against the surfaces of their respective cams and, in the course of their reciprocating motion, open and close associated switches. It has been found that a most suitable form of cam is one formed of a cylinder having a circumferential series of closely spaced holes or recesses, which are preferably internally screw-threaded, and into which are fitted, say by screwing, stub members that outstand from the curved surface of the cylinder and so provide

the raised portions of the cam track. The stub members (e.g. short screws) may also provide the lower portions of the cam track but this is ordinarily undesirable since the cylinder surface itself can conveniently provide those lower portions. It will be evident that by drilling a complete circumferential series of closely spaced holes or recesses in the cylinder practically all possibe ratios of on/off periods of each switch cycle are obtainable simply by adding and subtracting stub members. Preferably, the cylinders on which the rotary cams are formed can be fixed independently in any desired rotary position on a common drive shaft.

An alternative form of rotary switch-activating member is one formed of a cylinder of current-conducting material a desired proportion of the circumference of which is insulated and the exposed portion of which forms one contact of its associated switch; a current-conducting shoe that bears against the surface of the cylinder as it rotates provides the outer contact of the associated switch. In this case, it is convenient to form each entire group of switch-activating members of a single cylinder on side-by-side tracks of which an appropriate number of shoe contacts run and surrounding which is a sleeve of suitable pattern-controlling material that provides insulation only where desired over each shoe track.

It is clearly most convenient if the rate of rotation of each of the groups of switch-activating members is the same over all parts of every revolution but there is no requirement that it shall not differ over different parts of every revolution and it is any easy matter to arrange such variation.

The arrangement of the pattern control means may be such that each group of rotary switch activating members causes its associated switches to open and close once only per revolution thereof. Where the operation of a warp presser roller is controlled by a pair of rotary switch activating members rotating at different rates, the maximum period during any revolution of either of the members for which the warp presser roller can remain in its operative warp-printing position is determined by the particular member of the pair that maintains its associated switch for the shortest time in a position in which it permits warp printing.

Preferably, all the said particular members are in the same group, but, as described hereinafter, interesting effects are obtainable when this is not the case. When the said particular members are all in the same group, for there to be no overlap of applied colours, it is necessary for the sum of the lengths of times for which the said particular rotary switch-activating members maintain their respective associated switches in positions in which they permit warp printing to be, in theory, not greater than and, in practice, at least a little less than the period of revolution of the group of the said particular numbers.

While it is often convenient to arrange that each rotary switch-activating member opens and closes its associated switch only once per revolution thereof, in other cases, it may be preferred to arrange that each rotary switch-activating member opens and closes its associated switch say 3 to 6 times during each revolution and different switches of any group of switches may be opened and closed different numbers of times per revolution of the associated group of rotary switch-activating members; in particular cases this may be equivalent to, though simpler to arrange than, rotating different rotary switch-activating members in either group at rates that are small multiples one of another. Likewise, the switches of each pair of series-arranged switches may open and close different numbers of times per revolution of one of their rotary switch-activating members.

One form of space-dyeing apparatus containing a pattern control mechanism according to the present invention will now be described with reference to the accompanying drawings.

FIGURE 1 is a schematic side view of a space-dyeing apparatus;

FIGURE 2 is a more detailed side view of the printing station of FIGURE 1; and

FIGURE 3 is a diagrammatic representation of the pattern control mechanism of FIGURE 2.

Referring to FIGURES 1 and 2, a warp of yarn, **1**, passes around two pairs of non-contacting felt covered rolls, the pairs of rolls being coupled for rotation in the same directions at equal peripheral speeds through a suitable drive-transmission system to variable speed electric motor. From the second pair of felt-covered rolls the warp passes through the printing portion of the apparatus to a pair of winches, **4**, having blades which intermesh and which withdraw the horizontal warp of yarns from the second pair of felt covered rolls, **3**, through the printing portion of the apparatus. The winches are arranged to be driven at the same effective peripheral speed as the felt covered rolls.

The warp printing portion consists of four dye-applicator rolls, **5**, having parallel axes and spaced 6 inches apart. The rolls are 1¼ inches in daimeter and are each covered with a thick layer of dye-liquor absorbent polyurethane foam and have their lowermost portions dipping into dye-troughs, **6**. The dye-applicator rolls are severally coupled through a suitable drive-transmission system to a variable speed electric motor, **7**, for rotation at the same peripheral speed and in the same sense as the pairs of felt covered rolls.

Above each dye-applicator roll is a warp presser roll, **12**, of ¾" diameter and associated pneumatic actuation means. The warp presser roll is freely rotatable and is supported with its axis parallel to the axis of the dye-applicator roll and coupled to a pair of vertically extending thrust bars which are rigidly connected for vertical reciprocation to respective pistons of a pair of pistons and cylinder arrangements, **13** (only one of each pair of piston and cylinder arrangements being shown).

The cylinder of each such pneumatic arrangement is at a convenient fixed level, having regard to the stroke length of the piston, above the underlying dye-applicator roll and has gas-supply pipes leading to both ends so as to enable the piston to be driven under pneumatic pressure in both directions. Respective gas supply pipes of the two piston and cylinder arrangements of each pair lead via gas-flow junctions to different exit ports of the same two-way electromagnetically-actuated slide valve, a third port of which would, when in use, be placed in constant communication with a source of gas under pressure. The arrangement of the valve is such that in different positions of the valve different ones of the two exit ports communicate with the third port; when an exit port is not in communication with the third port it is open to the atmosphere. The rest position of the valve is the one in which its solenoid is unenergised and the pistons would be urged under pneumatic pressure to the tops of their strokes. The cylinders are fitted with bleed valves that, without hindering the rapid supply of gas under pressure to the undersides of the pistons, hinder the exhaust of gas from the undersides of the pistons in order to cause a more gentle lowering of each pressure roller onto the spongy dye-saturated surface of its underlying dye-applicator roll so as to avoid dye-liquor splashing.

The presser rollers reciprocate in vertical planes somewhat displaced, in the direction in which the warp of yarns would travel, from vertical planes through the dye-applicator roller axes.

Between the dye-applicator rolls of every adjacent pair of such rolls, as well as before the first and after the last dye-applicator roll, are narrow flanges, **14**, that extend with horizontal upper edges parallel to and the dye-applicator rolls. These flanges serve to reduce the length of the warp that is displaced when any presser roll moves into its operative position.

Each dye-trough, **6**, is part of a dye-liquor flow system comprising a dye-liquor reservoir, **8**, equipped with thermostatically controlled heater, a constant head dye-liquor feed tank, **9**, from whch each trough, **6**, is supplied with dye-liquor, a pump, **10**, for conveying the dye-liquor from the reservoir to the constant head feed tank, **9**, under a number of flow pipes, **11**, for transferring dye-liquor between the reservoir, feed tank and trough.

Beyond the warp advancing winches, **4**, is a steam chamber, **15**, into which the warp passes and where it is steam set and the dye fixed. The yarn then passes to a plurality of wash tanks **17** in a washing station and finally to a drying apparatus **21**. The washing station and drying apparatus form no part of this invention and may be of conventional construction.

The pattern control mechanism **100** which controls the actions of the presser rollers via the piston and cylinder arrangements, **13**, is shown diagrammatically in FIGURE 3.

The pattern control mechanism comprises a main supply current distribution channel from which energising circuits in the electro-magnetically actuated valves are laid in parallel. In each of the energising circuits are pairs of micro switches **27–28**, **29–30**, **31–32** and **33–34**, the switches of each pair being connected in series with one another, and each switch being opened and closed by a rocking switch arm. The switches are arranged in two groups **27–29–31–33** and **28–30–32–34**, each group thus containing one switch of every pair. Each switch arm carries a follower roller R that is resiliently urged against a rotary cam, these cams being arranged in two groups **35–37–39–41** and **36–38–40–42**. The two groups of cams are mounted on individual drive shafts which also carry sprockets **44** and **45** with a linking chain, **46**. The lower shaft is driven via sprocket, **47**, and coupling, **48**, by a variable speed electric motor (not shown). The sprockets, **44** and **45**, have different numbers of teeth in order that the one group of cams may be rotated faster than the other group. Each pair of series-connected switches controls the position of one of the presser rolls **12** through the respective electrically actuated piston and cylinder unit **13**, the electrical connections being shown schematically at **102** in FIGURE 2. The units **13** assume a raised position when their respective circuit **102** is open. Each switch opens upon contact of its arm with a raised portion of its cam with the result that the position of each unit depends on the position of its two cams.

The cams are each formed of a short right-circular cylindrical shell around the periphery of which are tapped a series of closely spaced holes (say 5–6 holes per inch of circumference) into which, as and where desired, are screwed stub screws (say ⅜ inch 4 B.A. Allen screws) which serve to form the raised portion or portions of the cam track. The cams are accordingly extremely versatile and afford a ready means of causing warp-patterning in any of a very wide range of patterns. It is in most cases convenient to arrange the profiles of the cams of the two groups so that one group of cams determines the basic kind of pattern to be applied to the warp of yarns and the other group of cams determines where and what proportion or proportions of the potentially warp-printing portion or portions of the periphery of each cam of the first group are to be rendered ineffectve during any revolution. The cams of the first group of cams will be referred to as the pattern cams and the cams of the second group as the randomising cams.

Three possible arrangements of pattern and randomising cams will now be described.

The first arrangement is one in which four pattern cams are employed, designated *a*, *b*, *c*, and *d*, which are in the controls of consecutive presser rollers and which could,

but for the action of the randomising cams, effect colouring of a warp of yarns travelling at a given linear speed over dye-applicator rolls at given distances apart in repeated sequences of four non-overlapping colours or colour shades. The raised portion of the pattern cams are potentially warp-printing and the angular extents and relative positions of the raised portions of the profiles of those cams are as follows. Cam *a* has a raised profile between approximately 270° and 350° of arc, cam *b* has a raised profile between approximately 90° and 160° of arc, cam *c* has a raised profile between approximately 270° and 340° of arc and cam *d* has a raised profile between approximately 90° and 96° of arc. A suitable rate of rotation of the cams is 4.48 r.p.m. when the apparatus is arranged to advance a warp of yarns at 4 yards per minute and the adjacent dye-applicator rolls are 6 inches apart.

Three randomising cams are employed and are designated *a'*, *b'*, and *c'*, associated respectively with pattern cams *a*, *b*, and *c*.

Each randomising cam has a raised portion which effects opening of its associated switch so as to open the energising circuit to the electromagnetic valve means and thereby to prevent warp-printing. The raised portions of the randomising cams extend over about 30° of arc and are suitably staggered. As already stated, the randomising cams rotate 1.27 times per revolution of the pattern cams.

The second arrangement is one in which four pattern cams, designated *a*, *b*, *c*, and *d*, are employed which are in the controls of consecutive warp presser rollers and the raised portions of the profiles of which are potentially warp-printing. The angular extents and relative positions of the cams are as follows. Cam *a* has a raised profile between about 210° and 245° of arc; cam *b* has a raised profile between about 285° and 320° of arc; cam *c* has a raised profile between 0° and 45° of arc; and cam *d* has a raised profile between about 90° and 135° of arc. The pattern cams may suitably revolve at 10 r.p.m. when the warp of yarns advances at a lineal speed of 4 yards per minute and adjacent dye applicator rolls are spaced 6 inches apart. Then the pattern cams are potentially able to effect application of colour to the entire length of the warp of yarns.

Associated with each pattern cam is a randomising cam whose raised portion extends over about 20° of arc and effects opening of its associated switch so as to prevent warp printing. The raised portions of the randomising cams are suitably staggered. As already stated, the randomising cams are arranged to revolve 1.27 times per revolution of the pattern cams.

The third arrangement is more complex.

Three pairs of cams are employed the cams of each pair opening and closing switches in series in the same energising circuit. As in the two arrangements described above one cam of each pair is arranged to revolve 1.27 times per revolution of the other cam.

The more slowly revolving cams are designated *a*, *b*, and *c*, and their associated more quickly revolving cams are designated *a'*, *b'*, and *c'*, respectively.

The raised portions of cams *a*, *b*, and *c'* (not *c*) effect closure of the switches associated with those cams so permitting warp-printing. The raised portions of cams *a'*, *b'*, and *c* effect opening of the switches associated with those cams so as to prevent warp-printing. Cams *c* and *c'* control the working of the first warp presser roller in the direction of travel of the warp of yarns.

The angular positions and extents of the raised portions of the several cams are given in the following Table 1.

TABLE 1

Cams	Degrees of arc (to nearest 5°) over which the cam profile is raised (the position of each follower roller being 0/360°)
a	105–130, 220–245, 320–350.
a'	0–10, 90–95, 110–115, 195–200, 300–305, 320–325.
b	30–60, 150–175, 290–310.
b'	15–20, 100–105, 185–190, 240–245.
c	35–65, 140–165, 180–200, 245–250, 275–295, 325–350.
c'	0–25, 50–80, 115–135, 170–190, 215–240, 280–295.

Where the cams are formed of cylinders with tapped holes in which stub screws are fixed, the above arrangement can be arrived at, say, as follows. Form cams *a*, *b*, and *c* of cylinders that are 3 inches in diameter and are each drilled with a series of 49 regularly spaced tapped holes as a complete annulus around the cylinder circumference (this implies a hole every 3/16 inch, approximately). Make the holes of such diameter as to receive 4 B.A. Allen screws. Next form cams *d'*, *b'*, and *c'* of cylinders that are 3½ inches in diameter and are each drilled with a series of 58 regularly spaces tapped as a complete annulus around the cylinder circumference. (Again this implies a hole every 3/16 inch approximately.) Again make the holes of such diameter as to receive 4 B.A. Allen screws. Secure 4 B.A. Allen screws in the holes numbered as set out in the following Table 2. The holes of the cams are all numbered from the positions of the follower rollers and in a clockwise direction.

TABLE 2

Cams	Numbering of holes, from position of follower roll in each case containing Allen screws
a	15–17, 30–32, 43–45.
b	5–7, 21–23, 39–41.
c	5–9, 20–22, 25–27, 34, 38–40, 45–47.
a'	1, 2, 16, 19, 32, 49, 52.
b'	3, 17, 31, 41.
c'	1–4, 9–13, 19–21, 28–31, 36–40, 47–50.

Cams *a*, *b*, and *c* suitably rotate at 8.13 r.p.m. for a lineal speed of travel of the warp of yarn of 4 yards per minute and a dye-applicator roll inter-spacing of 6 inches. The absolute dimensions of the cams are, of course, not important except that their dimensions in relation to the size of their associated follower rollers must not be such that the followers cause switching of their switches when moving between screws in adjacent holes and should desirably be such that switching occurs when moving between a screw in any given hole and a next-adjacent screw situated in the next hole but one or, at the furthest, the next hole but two. 3 BR MS/A Burgess microswitches have suitable dimensions for use with the above-described cams of particular dimensions.

Consideration of the lengths of the potentially warp-printing portions of the profiles of the cams of each pair (*a*, *a'*), (*b*, *b'*) and (*c*, *c'*) shows that the maximum possible lengths of application of colour by the two warp presser rollers subject to the behaviour of the cams *a*, *a'*, *b*, and *b'* are determined by cams *a* and *b* whereas the maximum possible lengths of application of colour by the warp-presser roller that is subject to the behaviour of cams *c* and *c'* are determined at most times by the cam *c'* and not by the cam *c*. The resultant pattern is one which can for practical purposes be regarded as being composed of randomly varying amounts of two colours which do not overlap superposed against a background of both white regions and randomly occurring regions of an applied colour with, as well, random overlap of the regions of applied colour in the background by each of the other two colours.

The third arrangement of pattern and randomising cams is most suitably used where cams *c* and *c'* control the application of a pale shade and the other cams control the application of darker shades.

A process for colouring a warp of yarn in accordance with the invention will now be described by way of example in greater detail.

The apparatus used was the exemplary apparatus already described and it was operated in a manner in which it has been described as being capable of operating.

396 ends of 3650 denier/204 filament nylon carpet yarn having a 20% bulk imparted to it by a stuffer box crimping process were taken off creels and led, via guide tubes terminating at a selector board, yarn separator bars, and individual yarn tensioning devices, to the initial reed of the exemplary apparatus as hereinbefore described.

From the reed the ends of yarn were formed into a tensioned horizontal warp of parallel yarns which was about 3 ft. in width and in which the yarns had the appearance of very little (at most about 5%) bulk. The warp was caused to travel at a lineal speed of 4 yards per minute over 4 dye-applicator rolls applying different colours viz: three different shades of green and a shade of yellow. The warp of yarns passed just above the level of the upper edges of the aforedescribed flanges in the warp-printing station at which level it was about ½ inch above the tops of the dye applicator rolls.

The dyes employed were standard acid dyes and the temperature of the dye liquors in the reservoirs was in all cases constant at about 55° C. The temperature of the dyestuffs in the dye troughs was not measured precisely but was believed to be between 45° C. and 50° C. and was constant as evidenced by level dyeing shades. Steady and quite rapid recirculatory rates of flow of the several dye liquors was maintained.

During passage through the dye fixing chamber, into which steam at atmospheric pressure was continuously being supplied from the open steam coils, the yarns passed as a sagging sheet at low tension. The yarns were subjected to the action of steam for 20 seconds in the dye fixing chamber and, because of the lesser tension in the yarns, their lineal speed of travel was less than 4 yards/minute and was estimated as being about 3.8 yards/minute along their curved paths.

The sheet of yarns was gently led into and out of the dye-fixing chamber by the aforedescribed winches and beyond the dye-fixing chamber was washed in the washing station already described. The rate of rotation of the pair of squeeze rolls encountered by the sheet of yarns in passing from the first to the second wash tank was carefully controlled to ensure that at no time was the sheet of yarns pulled out of the dye fixing chamber by the squeeze rolls.

Over the latter part of the movement of the sheet of yarns through the yarn-washing station the tension in the sheet of yarns was gradually increased until the lineal speed of travel of the yarns was again 4 yards per minute. After passing through the nip of the two pairs of squeeze rolls following the fourth wash tank, the sheet of yarns contained very little excess moisture and was quickly completely dried in the drying chamber. The yarns passed through the yarn drying chamber as a tensioned horizontal warp at a speed of travel of 4 yards per minute and were impinged upon over 10 feet of the length of the warp by air flowing in countercurrent thereto which had been heated by the steam battery to a temperature of about 150° F.

That the yarns were under tension in the drying chamber was not in fact in this case any hindrance to complete drying of the yarns and it was found that it is very desirable whenever the yarn ends are very close together where they are impinged upon by hot air streams for there to be substantial tension in the yarns in order to avoid intermingling of filaments of different ends.

After drying, the yarns were bunched together into 18 groups of 22 ends at compensators associated with cross-ball warping apparatus as aforedescribed in detail and the groups were wound into cross-ball warps.

The gas supply ports of the electromagnetic valves controlling the application of pneumatic pressure to the four pairs of cylinders associated with the four warp-presser rollers were placed continuously in communication with a source of gas at 60 lbs. per square inch pressure which was adequate, having regard to the lengths of the warp presser rollers and the dimensions of the four pneumatic activating means, to effect complete penetration of the warp of yarns by dye liquor during printing. Because the yarn ends were under tension, and hence temporarily of low bulk, penetration by the dye liquor was aided by capillary action.

The pattern control means included 4 pattern cams and three randomising cams as in the first arrangement aforedescribed. The lone pattern cam controlled the application of the yellow. The pattern cams revolved at 4.48 revolutions per minute.

The resultant yarn was attractively coloured, had a pattern repeat length of a little over 300 feet and gave a very attractive effect when used to form the pile of a looped pile tufted carpet, especially when the tufting machine employed had a sliding needle bar attachment and operated according to a high and low tufting sequence so giving sculptured effects.

What we claim is:

1. An apparatus for space-dyeing yarns comprising: a series of electro-pneumatic operated dye-applicators which print a moving warp of yarns with different colours over different parts of its length and containing as an integral part thereof a pattern control means including a first switch group whose switches are in the energising circuits of associated electro-magnetic valves, said switch group including rotary devices containing on the surface thereof switch activating means to open and close respective switches, means for rotating all said rotary devices at the same rate, a second switch group every switch being in series with a switch of the first switch group, said second switch group including rotary devices containing on the surface thereof switch activating means to open and close respective switches, means for rotating all the last-mentioned rotary devices at the same rate, and a common driving mechanism for rotating the two groups of switch activating devices at different speeds thereby permitting random colour pattern to be applied to the warp of yarns.

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WILLIAM I. PRICE, Primary Examiner

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