June 11, 1968 T. S. ROBERTS ET AL 3,388,261

METHOD AND APPARATUS FOR DETERMINING FABRIC STREAKINESS

Filed Sept. 24, 1965 2 Sheets-Sheet 1

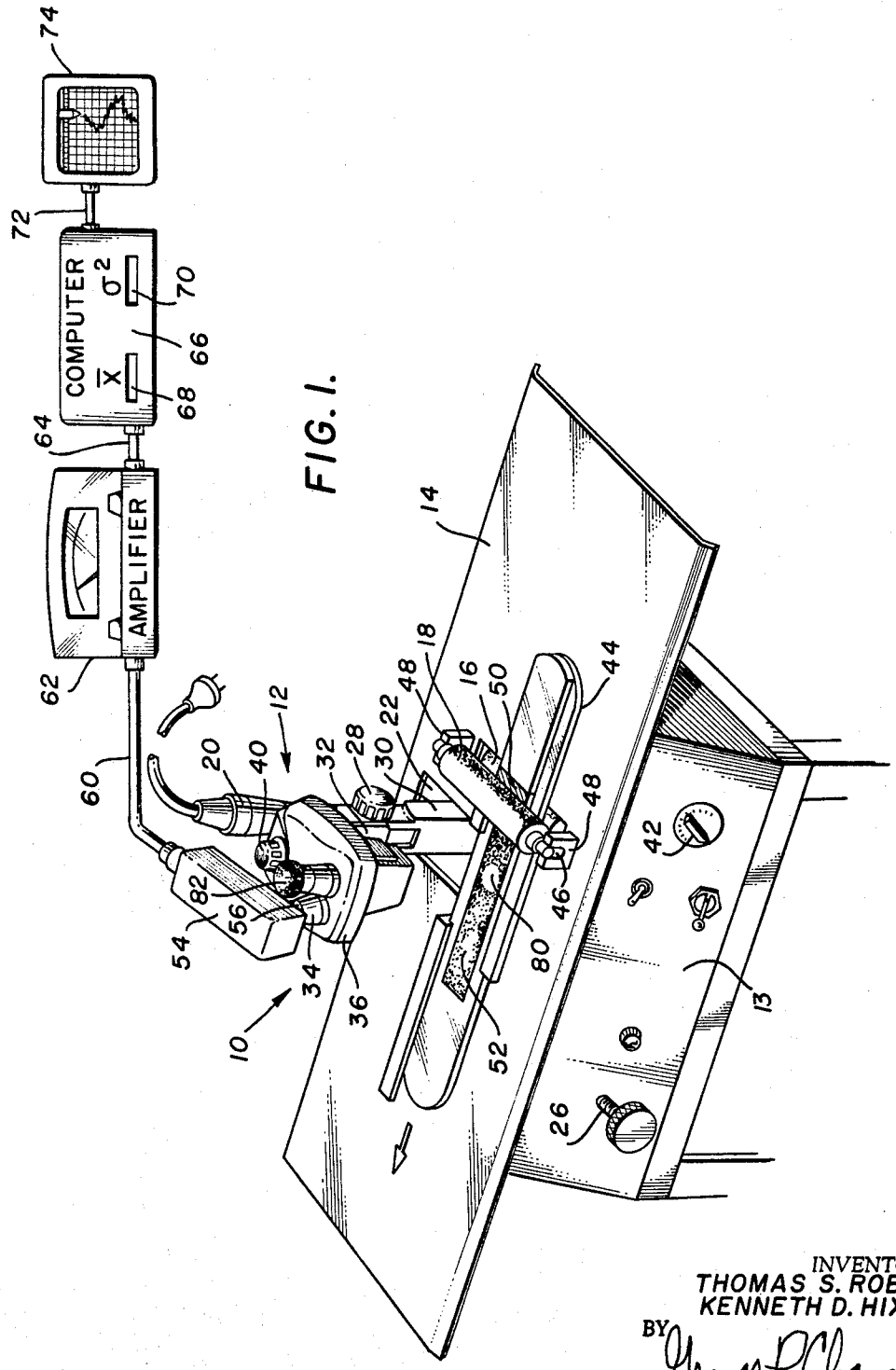


FIG. 1.

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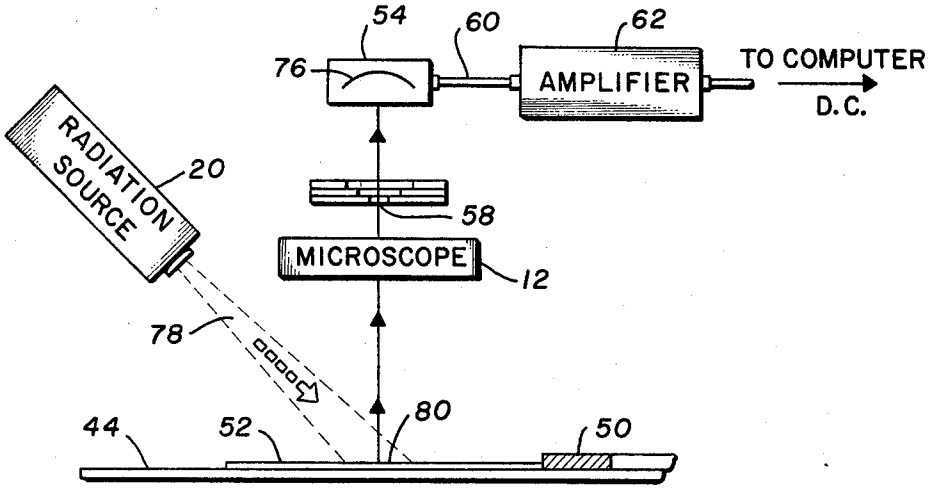


FIG. 2.

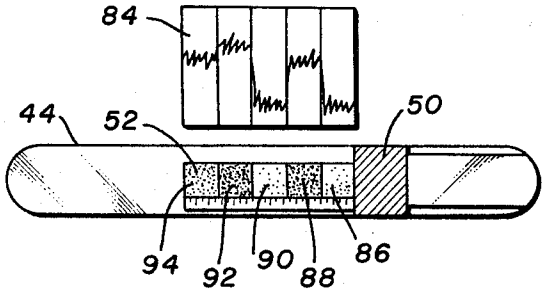


FIG. 3.

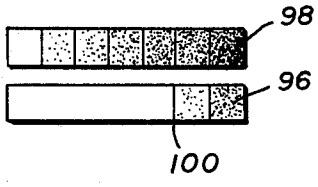


FIG. 4.

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METHOD AND APPARATUS FOR DETERMINING FABRIC STREAKINESS

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14 Claims. (Cl. 250—224)

This invention relates to a method and apparatus for determining dye depth and dye depth uniformity in a fabric. More particularly, this invention is directed to a method and apparatus for assessing dye depth and dye depth uniformity in a fabric in terms of a quantitative value.

The dyeing of a fabric is an extremly important aspect of the textile industry inasmuch as it is only by the use of such a process that cloth can be made attractive to the ultimate consumer. Obviously, it is necessary that the colors introduced to a fabric be uniformly distributed or taken-up by the various yarns from which it is constructed. If it is otherwise the dye depth is not uniform and the dyed fabric is "streaky" in appearance.

Much time and research has been expended investigating the causes of non-uniformity in dye uptake. It has been found that chemical and fine structural differences in the yarn effect its ability to unite with the molecules of the dyeing medium. For example, in nylon yarn variations in amine-end concentration and the orientation and crystallinity of the fibers result in non-uniform dyeing and thus non-uniform dye uptake.

While much effort has been directed to the problem of correcting the variations in yarn characteristics which effect dye uptake, this work is hampered by the lack of a method for uniformly assessing the effect of these variables. Until this invention, the only manner of determining the degree of non-uniformity or "streakiness" has been to utilize the subjective opinion of individual graders. This method is very often inadequate since the opinions of human beings change from day to day and a fabric which is deemed to have a certain degree of uniformity on one inspection may be assessed differently by the same grader on a subsequent inspection. Thus, the method and device which is the subject of this invention has been developed to eliminate the human error inherent in the present grading method.

The apparatus includes a source of radiations, preferably in the visible range, directed onto the surface of a fabric sample; a magnifying and focusing device which directs radiations reflected from the surface of the fabric onto a photomultiplier tube where the radiant energy is converted to electrical energy; an amplifier; and a computer for interpreting the signals received to give numerical values corresponding to the average dye depth and the variation about the average dye depth of the sample. In utilizing this device a dyed test fabric is passed through the field created by the source of radiations so that light rays reflected from the surface of the sample are directed to the photomultiplier tube by the magnifying and focusing device. The electrical signals emitted by the photomultiplier tube, which are proportional to the intensity of light rays reflected from the surface of the sample, are transmitted through an amplifier to a computer which, according to the magnitude and variations of the voltage received, produces a number proportional to the average dye depth and a second number proportional to the visual appearance of dye depth variations about the average dye depth. In this manner a quantitative value can be assigned to the non-uniformity of the fabric sample which, when the computer is adjusted to allow for supply voltage variations, will be exactly duplicated when re-evaluated at some future date.

By utilizing the apparatus and method which are the subject of this invention, it is now possible to confidently state the effect of variations in yarn characteristics on the variability of dye uptake. Thus, under controlled laboratory conditions yarn can be produced to deliberately vary in characteristics and the effect of such variations can be numerically assessed. Furthermore, samples of yarn produced for commercial usage can be inspected by assembling it into a fabric sample which is then dyed and assessed by using this novel method and apparatus. Limits within which the yarn will or will not be accepted can be established between the producer and consumer and the conformance of any particular shipment with this standard clearly and definitely determined.

Accordingly, it is an object of this invention to provide a method and apparatus for determining quantitatively the uniformity of dye depth in a fabric.

Another object of this invention is to provide a method and apparatus for determining and specifying the uniformity of dye depth in a fabric in terms of a numerical value.

Yet another object of this invention is to provide a method and apparatus for determining dye depth uniformity in terms of a numerical value independently of any human judgment error.

A further object of this invention is to provide a method and apparatus for assessing dye depth uniformity in terms of a readily usable numerical value in a manner which is extremely rapid and accurate.

These and other objects and advantages of this invention will be more apparent upon reference to the following specification, appended claims and drawing wherein:

FIGURE 1 is an overall view showing the apparatus according to the instant invention for mounting a sample, passing the sample through a field of radiation, and directing the radiations to a photometer whose output is directed through an amplifier to a computer and recording mechanism;

FIGURE 2 is a diagrammatic view showing a radiation source directed to a spot on a fabric sample and a reflected light ray passing through a magnifier and limiting slit to a photomultiplier tube whose output is coupled to an amplifier and thence to a computer;

FIGURE 3 shows a fabric sample and reference tile mounted on a sample board, the sample being compared with the trace obtained by recording the amplified output voltage of the photomultiplier tube; and

FIGURE 4 illustrates two fabric samples constructed of yarn whose characteristics were deliberately varied in the same manner, one fabric sample being colored by a dye sensitive to the variations and the other sample being colored by a dye relatively insensitive to the variations.

In order to better understand the construction and use of this novel apparatus and method it will be described in relation to the assessment of dye uniformity in fabrics constructed from yarns of synthetic material. It is to be understood, however, that various other uses may be found for this novel apparatus and method. For example, the uniformity of color in any surface can be ascertained by its usage. Examples of such are a painted surface or the surface of a section of any material which has been colored. Other uses will be readily apparent to those skilled in the art.

With continued reference to the accompanying figures wherein like numerals designate similar parts throughout the various views, and with initial attention directed to FIGURE 1, reference numeral **10** designates generally apparatus according to the instant invention for translating the dye depth of a fabric sample into an electrical signal. This apparatus includes a microscope **12** adjustably mounted in stand **13** with a portion extending above

the surface of table 14, and a variable speed driving mechanism (not shown) mounted beneath the table 14 and connected to the rollers 16 so as to provide motive force thereto. An idler roll 18 is slidably mounted above the drive roll 16 for a purpose to be hereinafter described.

In order to illuminate the field of view, the microscope 12 includes a source of radiations 20 which, in the preferred embodiment of the invention, emits at least a portion of its rays in the visible range. The base of the microscope 12 is slidably secured beneath the table 14 and adjusting knob 26 secured to the stand 13 is operatively connected therewith to provide a smooth "in and out" adjustment relative to the table 14. Vertical adjustment is provided in a conventional manner by the knob 28 cooperatively engaging a gear and rack mechanism secured to the pedestal 30 and the carriage 32 respectively.

Secured to the upper end of the carriage 32 is the optical section of the microscope 12 including a pair of eyepieces 34 and a housing 36. The magnification of the microscope 12 is adjustable and such is accomplished by rotation of the knob 40.

The microscope is not described in detail inasmuch as the particular system utilized in this regard is not an essential part of the invention. The system must, however, be capable of manipulating light rays reflected from the fabric sample to present a magnified image of a yarn or number of yarns on the surface of the photomultiplier tube. It has been found helpful to utilize a microscope having variable magnification to accommodate fabrics constructed of yarns of various deniers, spacing, and other specialized characteristics where the field surveyed must be enlarged or restricted. It is also helpful if the microscope 12 includes a pair of eyepieces so that one may be utilized to bring the sample into proper focus at the same time the other is transmitting the image onto the photomultiplier tube. While not restricted to this instrument, a Bausch and Lomb Stereo-Zoom microscope has been found to produce satisfactory results.

As stated before, the roll 16 is driven by a variable speed driving mechanism whose rate is adjustable through the use of a suitable speed adjusting device connected to the knob 42. A fabric sample mounting board 44 rides across the top of drive roll 16 and is forced into frictional engagement therewith by the weight of idler roll 18 pressing on its upper surface. As illustrated in FIGURE 1, the idler roll 18 is free to slide in slots 46 in mounting yokes 48 to facilitate removal and to accommodate variations in the thickness of the sample when mounted. In operation a reference tile 50 and fabric sample 52 are secured to the surface of the mounting board 44 in a suitable manner such as by the use of two sided adhesive tape and moved, as indicated by the arrows in FIGURES 1 and 2, with the mounting board 44 through the field of view of microscope 12 due to the action of driving roll 16.

As the sample mounting board 44 moves through the field of views, the light reflected from the fabric sample 52 is directed through the microscope 12 into a photomultiplier tube 53 in housing 54 through one of the eyepieces 34 and an adapter 56. Incorporated into the adapter 56 is a slit 58 whose width is variable as shown in FIGURE 2. By properly selecting the slit width and the degree of magnification, portions of the fabric sample as small as the width of a strand of 70 denier nylon to an area of cloth one inch in diameter may be viewed. This flexibility is very important because of the wide variety of fabric types and constructions that are encountered.

The output of the photomultiplier tube contained in housing 54 is transmitted to an amplifier 62 through cable 60. These two elements form in combination a device known as photometer which produces a direct current signal proportional to the dye depth of the fabric as it is passed through the field of view of the microscope 12. The particular type of photometer utilized should produce a signal which is linear with visual observation. One photometer which has been found satisfactory is MacBeth Model QP–10.

The DC signal output from amplifier 62 is fed through a cable 64 to a computer 66 which may be either a digital, analog, or combination type. The computer 66 is programmed in a known manner to analyze the direct current voltage input either for a preselected period of time or, if desired, continuously in terms of a mean voltage and a variance about the mean. A digital read-out device 68 is provided so that the mean voltage which is directly proportional to the average dye depth may be visually determined immediately at the termination of the preselected time period. Similarly, the variance about the mean, which figure is proportional to the visual appearance of the non-uniformity of dye depth, is presented in window 70. The read-out could as well be in the form of values printed on a sheet of paper, indications on a cathode ray oscilloscope or any of the other numerous methods of performing this task.

The unanalyzed signal is also fed through cable 72 to a recorder 74 which produces an ink tracing on a moving graph in a well known manner. The magnitude of the DC voltage output from the amplifier 62 is preserved in this manner for analysis if desired, and for visual comparison with the fabric sample tested.

In operation, the device of the instant invention is first brought to a proper operational level by placing the tile 50 which has a known, uniform depth of color into the field of view of the microscope 12. Radiations reflected from the surface of the tile 50 through the microscope 12, the slit 58 and onto the surface of the photomultiplier tube 53 create a DC signal which is transmitted through the amplifier 62 into the computer 66 wherein it is converted into a numerical indication of dye depth read-out at window 68. The amplifier 62 and/or the computer 66 are then adjusted until the value for dye depth of tile 50, which is known, appears at readout window 68.

After the apparatus has been calibrated, the fabric sample 52 is placed within the field of vision of the microscope 12 in a manner such that rays 78 are directed onto a portion 80 of its surface. Cap 82 is removed from one of the eyepieces 34 and the magnification level of the microscope is adjusted so that the desired portion of the surface of sample 52 is viewed through slit 58 by photomultiplier tube 53. Since the width of the slit 58 is dependent on the yarn size and area to be viewed, it is determined and set before assembly of photomultiplier tube to the eyepiece 34, or alternatively, provided with external adjusting means and set while in place. It is then relatively simple to adjust the magnification and focus of the microscope 12.

Many times it will be deemed desirable to view a sample yarn by yarn. "Streakiness" is, however, generally not detectable visually unless the non-uniformity extends over several yarns, usually three depending on denier. For commercial purposes, therefore, the slit width and magnification are adjusted to give the equivalent of a three yarn field of view depending on yarn denier and the compactness of the fabric.

As shown in FIGURE 2 the radiation source directs rays 78 to a forty-five degree angle to the surface of the fabric sample 52. Due to the shape of the fabric surface, some rays will be reflected normal to the surface of the sample 52 and these pass through the microscope 12 and slit 58 as described above onto the surface of the photomultiplier tube 53. There the rays are converted into direct current electrical energy and transmitted through the amplifier 62 to the computer 66.

As stated above, any type of computer properly programmed may be utilized, but great success has been obtained with a Pace 231R analog computer. This computer is programmed as hereinafter described to produce numerical values for the average dye depth and the variation about the average dye depth or as it is commonly known "streakiness."

The average dye depth is directly proportional to the arithmetic mean of the voltage over a predetermined solution time. Thus, this figure is secured by summing the direct current voltage over the selected time divided by time and is represented by the following formula. Let $X=f(t)$ be the equation of the varying DC signal; then

$$\overline{X}=\frac{\int_0^T f(t)dt}{T}$$

where

$\overline{X}$=average dye depth
T=solution time (typically 60 seconds).

Streakiness of the sample is proportional to the variance (σ^2) above the arithmetic mean of the voltage and is equal to:

$$\sigma^2=\frac{\int_0^T f(t)^2dt}{T}-\left[\frac{\int_0^T f(t)dt}{T}\right]^2$$

After the expiration of the solution time, the numerical values of the average depth, or $\overline{X}$, and "streakiness," or σ^2, are displayed in the read-out windows **68** and **70**, respectively.

The tracing **84** obtained from the recorder **74** for a particular sample **52** is shown in FIGURE 3. As described above, the sample **52** is obtained by assembling a yarn from a particular package or yarns from several different packages in a known manner to produce a fabric having good body. In this illustration the yarn or yarns have been deliberately varied in physical or chemical characteristics and dyed with a critical dye such as for example Durazol Blue 2R (C.I. Direct Blue 71). Due to the different ability of the yarn or yarns to take-up this critical dye, panels **86**, **88**, **90**, **92**, and **94** are formed showing within package variations if a single package is being utilized or package to package variations of a number of packages are used in forming a sample **52**. Thus, panels **86** and **90** are extremely light, panel **88** is somewhat darker than panels **86** and **90**, panel **92** is darker than panel **88**, and panel **94** is lighter than panel **92** but darker than panel **88**. These variations cause varying intensities of reflected radiations to reach the photomultiplier tube **53** resulting in a direct current voltage whose magnitude varies in a known manner with the radiations received and hence, with the dye depth of the various panels of the sample **52**. These changes in voltage magnitude as amplified are shown on the graph **84** with the voltage being relatively low and high where the dye depth is correspondingly less or greater. Obviously, the average dye depth would be somewhere between the highs and lows while the variance from the average would increase or decrease in accordance with the magnitude of the voltage extremes. If desired, of course, the apparatus may be utilized to examine all panels, any number of panels within the sample **52**, one panel or a portion of one panel. In any case, the apparatus will produce a tracing of the type shown at **84** and the numerical values discussed above.

As described above the variations in dye depth were deliverately caused by manipulating process variables to assess their effect on dye uptake. Thus, the novel instrument and method can be used to aid in improving the method by which yarns of synthetic fibers are produced. Furthermore, in commercial production the instrument and method can be employed as a control by assessing dye uptake and maintaining it within acceptable limits by adjusting the proper process variables.

Dyeing techniques can be improved by utilizing the instrument as described hereinbefore to assess the dye uptake of specially prepared sample fabrics containing known fiber non-uniformities that would normally produce unacceptable dyeings. Each sample is dyed in a bath in which such factors as dye combinations, dye bath additives, liquor ratio, pH adjustment, rate of temperature rise, etc. are changed. The sample produced by each treatment is then scanned to locate the combination of factors producing optimum dyeing conditions.

In commercial practice variations in physical and/or chemical characteristics may not be as decisive as in experimental useage because the dyes will usually not be as critical to these variations. The apparatus and method of the invention is still extremely useful, however, as illustrated in FIGURE 4. There, two samples are shown, one **96** of which has been colored with a commercial relatively non-critical dye and the other **98** colored by a critical dye such as Durazol Blue. Both samples have been assembled in the identical manner so that the yarn at corresponding points along their lengths have identical characteristics.

As clearly shown in FIGURE 4 the yarn characteristics have been varied from low take-up (light color) to high take-up (dark color). This variation becomes visible in sample **96** (non-critical dye) only when the variance (streakiness) is relatively great as in the last three panels of sample **98**. By expert visual inspection it is determined that the variance or streakiness is commercially unacceptable beginning at point **100** in sample **96**. By use of the method and apparatus of this invention as described above, the variance at this point on sample **98** is determined so that a specimen of a yarn produced for use with the commercial dye of sample **96** may be taken, dyed with the critical dye of sample **98**, its variance determined, and rejected if such exceeds that of sample **98**. The above process is used to provide a control for each commercial dye to be utilized.

It has been found that in order to obtain good instrumental or visual assessment of dye depth and streakiness, the fabric utilized must have considerable body. Good results have been obtained by weaving the test or commerical yarn packages into filling bands in a filling-faced weave (crowfoot). The fabrics thus produced are dyed competitively on a jig dyeing machine, and package-to-package as well as within package measurements can be made. If within package variations can be ignored, it is very convenient to place each of the test packages side by side in tricot fabric and have only one piece of fabric for instrumental measurement. The instrument then makes one scan across these individual ends, and the "streakiness" number obtained is actually the package-to-package uniformity of the particular sample in question. This latter technique is the one illustrated in both FIGURES 3 and 4.

It will be apparent that by utilizing the method and apparatus of the instant invention the need for instrumentation to assist in the evaluation of dyeing uniformity has been met. This device standardizes dyeing tests and places a number on the subsequent dyeing uniformity so that now clearly defined uniformity specifications can be set up. Thus, the subjective opinion of individual graders and the inherent error in such a method has been eliminated. Experiments have been carried out which have shown that the instrument accurately and reproducibly measures average depth and streakiness. The average depth readings are linear with percent dye on the fabric, and it has been established that the instrument will measure differences in depth as small as 0.5 percent (the eye can barely perceive only 5 percent differences).

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

We claim:

1. A method for numerically assessing visible dye non-uniformity resulting from variations in yarn characteristics both from yarn package to yarn package and within a yarn package comprising the steps of:
(a) assembling yarn to form a fabric sample;
(b) dyeing said fabric sample in a selected manner;
(c) placing said fabric sample in a field of radiations;
(d) directing the radiations reflected from a portion of said sample onto a radiation sensitive surface whereby variations in the intensity of said reflected radiations can be detected;
(e) converting said radiations received on said sensitive surface into storable energy signals the magnitude of which varies with the intensity of said reflected radiations;
(f) scanning a selected area of said fabric with said sensitive surface for a selected period of time;
(g) storing said signals produced during said scanning period;
(h) extracting from said stored signals quantities of energy equal to the mean value of said variable signal and the variance of said variable signal about said mean value, said quantities being proportional to the average dye depth and visual appearance of dye depth variations about the average of said fabric sample respectively; and
(i) converting said extracted energy into quantitative values of said average dye depth and the variation about said average.

2. A method for numerically assessing visible dye non-uniformity resulting from variations in yarn characteristics both from yarn package to yarn package and within a yarn package comprising the steps of:
(a) assembling yarn in closely spaced relationship to form a fabric sample having a compact structure;
(b) dyeing said fabric sample in a selected manner;
(c) placing said fabric sample in a field of radiations;
(d) directing the radiations reflected from a portion of said sample encompassing one or more yarn strands onto a radiation sensitive surface whereby variations in the intensity of said reflected radiations can be detected;
(e) converting said radiations received on said sensitive surface into storable energy signals the magnitude of which varies with the intensity of said reflected radiations;
(f) scanning a selected area of said fabric with said sensitive surface for a selected period of time;
(g) storing the signals produced during said scanning period;
(h) extracting from said stored signals quantities of energy equal to the mean value of said variable signal and the variance of said variable signal about said mean value, said quantities being proportional to the average dye depth and visual appearance of dye depth variations about the average of said fabric sample respectively; and
(i) converting said extracted energy into quantitative values of said average dye depth and the variation about said average.

3. A method for numerically assessing visible dye non-uniformity resulting from variations in yarn characteristics both from yarn package to yarn package and within a yarn package comprising the steps of:
(a) assembling yarn in closely spaced relationship to form a fabric sample having a compact structure;
(b) dyeing said fabric sample in a selected manner;
(c) placing said fabric sample in a field of radiations;
(d) directing radiations reflected from a portion of said sample encompassing a plurality of yarn strands onto a radiation sensitive surface whereby variations in the intensity of said reflected radiations can be detected;
(e) converting said radiations received on said sensitive surface into a signal comprised of electrical energy the magnitude of which varies with the intensity of said reflected radiations;
(f) scanning a selected area of said fabric with said sensitive surface for a selected period of time;
(g) storing the electrical signal produced during said scanning period;
(h) extracting from said stored electrical signal quantities of electrical energy equal to the mean value of said variable signal and the variance of said variable signal about said mean, said quantities being proportional to the average dye depth and visual appearance of dye depth variations about the average of said fabric sample respectively; and
(i) converting said extracted energy into quantitative values of said average dye depth and the variation about said average.

4. A method for numerically assessing visible dye non-uniformity resulting from variations in yarn characteristics both from yarn package to yarn package and within a yarn package comprising the steps of:
(a) assembling yarn in closely spaced relationship to form a fabric sample having a compact structure;
(b) subjecting said fabric to a dye sensitive to chemical and fine structural variations in said yarn;
(c) placing said fabric sample in a field of radiations;
(d) directing the radiations reflected from a portion of said sample encompassing a plurality of yarn strands onto a radiation sensitive surface whereby variations in the intensity of said reflected radiations can be detected;
(e) converting said radiations received on said sensitive surface into a signal comprised of electrical energy the magnitude of which varies with the intensity of said reflected radiation;
(f) moving a selected area of said sample relative to said sensitive surface during a selected period of time whereby said selected area is scanned by said sensitive surface;
(g) storing the electrical signal produced during said scanning period;
(h) extracting from said stored electrical signal quantities of electrical energy equal to the mean value of said variable signal and the variance of said variable signal about said mean value, said quantities being proportional to the average dye depth and visual appearance of dye depth variations about the average of said fabric sample respectively; and
(i) converting said extracted energy into quantitative values of said average dye depth and the variation about said average.

5. A method for numerically assessing visible dye non-uniformity resulting from variations in yarn characteristics both from yarn package to yarn package and within a yarn package comprising the steps of:
(a) assembling yarn into a closely knit fabric sample having a compact structure;
(b) subjecting said fabric sample to a dye sensitive to chemical and fine structural variations in said yarn;
(c) placing said fabric sample in a field of radiations;
(d) directing the radiations reflected from a portion of said sample encompassing a plurality of yarn strands onto a radiation sensitive surface whereby variations in the intensity of said reflected radiations can be detected;
(e) converting said radiations received on said sensitive surface into a signal comprised of electrical energy the magnitude of which varies with the intensity of said reflected radiations;
(f) moving a selected area of said sample relative to said sensitive surface during a selected period of time whereby said selected area is scanned by said sensitive surface;
(g) storing the electrical signal produced during said scanning period;

(h) extracting from said stored electrical signal quantities of electrical energy equal to the mean value of said variable signal and the variance of said variable signal about said mean value, said quantities being proportional to the average dye depth and visual appearance of dye depth variations about the average of said fabric sample respectively; and

(i) converting said extracted energy into quantitative values of said average dye depth and the variation about said average.

6. A method according to claim 5 wherein the dye to which the fabric sample is subjected is C. I. Direct Blue 71.

7. A method of numerically assessing visible dye non-uniformity to determine an optimum dyeing technique for a yarn having known physical and chemical characteristics comprising the steps of:

(a) producing a yarn under controlled conditions such that said yarn has known physical and chemical characteristics;

(b) assembling said yarn into fabric samples, each of which has a compact structure;

(c) subjecting each of said samples to dyeing under selected conditions and techniques which differ for individual samples;

(d) determining the average dye depth and visual appearance of dye depth variations about the average of each of said fabric samples by placing each fabric sample in a field of radiations;

(e) directing the radiations reflected from a portion of said sample encompassing a plurality of yarn strands onto a radiation sensitive surface whereby variations in the intensity of said reflected radiations can be detected;

(f) converting said radiations received on said sensitive surface into a signal comprised of electrical energy the magnitude of which varies with the intensity of said reflected radiations;

(g) scanning a selected area of said fabric with said sensitive surface for a selected period of time;

(h) storing the electrical signal produced during said scanning period;

(i) extracting from said stored electrical signal quantities of electrical energy equal to the mean value of said variable signal and the variance of said variable signal about said mean, said quantities being proportional to the average dye depth and visual appearance of dye depth variations about the average of said fabric sample respectively; and

(j) converting said extracted energy into quantitative values of said average dye depth and the variation about said average.

8. A method for numerically assessing visible dye non-uniformity to determine the effect of process variables on yarn produced from synthetic filaments comprising the steps of:

(a) producing yarns under controlled conditions in which the process variables are knowingly altered;

(b) assembling said yarn into fabric samples, each of which is compact in structure;

(c) subjecting each of said samples to a dye critical to the known variations;

(d) assessing the effect of said variations on dye uptake by first placing said fabric sample in a field of radiations;

(e) directing radiations reflected from a portion of said sample encompassing a plurality of yarn strands onto a radiation sensitive surface whereby variations in the intensity of said reflected radiations can be detected;

(f) converting said radiations received on said sensitive surface into a signal comprised of electrical energy the magnitude of which varies with the intensity of said reflected radiations;

(g) scanning a selected area of said fabric with said sensitive surface for a selected period of time;

(h) storing the electrical signal produced during said scanning period;

(i) extracting from said stored electrical signal quantities of electrical energy equal to the mean value of said variable signal and the variance of said variable signal about said mean, said quantities being proportional to the average dye depth and visual appearance of dye depth variations about the average of said fabric sample respectively; and

(j) converting said extracted energy into quantitative values of said average dye depth and the variations about said average.

9. A method according to claim 8 in which the process variables altered are physical in nature.

10. A method according to claim 8 in which the process variables altered are chemical in nature.

11. A method for assessing commercial marketability of yarn which is to be subjected to a dye relatively non-critical to yarn characteristics comprising the steps of:

(a) assembling yarn having known varying characteristics into at least two fabric samples each of which has yarn with identical characteristics at corresponding points along their respective lengths;

(b) subjecting a first of said samples to a dye which is critical to variations in yarn characteristics;

(c) subjecting a second of said samples to a relatively non-critical dye;

(d) locating the point on said second sample at which the characteristics of the yarn produce objectionable dye color non-uniformity;

(e) comparing said first sample to said second sample and locating the point and yarn on said first sample corresponding to said point and yarn on said second sample;

(f) numerically assessing the non-uniformity of said first sample in a selected area around and at said point by placing said first fabric sample in a field of radiations, directing the radiations reflected from said selected area of said first sample onto a radiation sensitive surface whereby variations in the intensity of said reflected radiations can be detected, converting said radiations received on said sensitive surface into storable energy signals the magnitude of which varies with the intensity of said reflected radiations, scanning said selected area of said first fabric sample with said sensitive surface for a selected period of time, storing the energy produced during said scanning period, extracting from said stored energy quantities of energy equal to the mean value of said variable signal and the variance of said variable signal about said mean value which values are proportional to the average dye depth and visual appearance of dye depth variations about the average of said first fabric sample respectively, and converting said extracted energy into quantitative values of said average dye depth and the variations about said average; and

(g) sampling yarn produced for commerce by assembling a specimen of said yarn into a fabric sample, subjecting said sample to said critical dye and numerically assessing dye uniformity of the entire sample by the method of step (e) to determine if the yarn is within the limit of established dye depth variation.

12. The method according to claim 11 wherein the yarns vary in physical characteristics and the critical dye used is responsive to such variations.

13. A method according to claim 11 wherein the yarns vary in chemical characteristics and the critical dye utilized is responsive to such variations.

14. A device for numerically assessing visible dye non-uniformity in a fabric comprising:

(a) a source of radiant energy;

(b) means for moving a dyed sample through the field of radiations produced by said source whereby radiant energy will be reflected from said sample

which will have an intensity proportional to the dye depth of said sample;

(c) means for converting radiant energy to direct current electrical energy;

(d) optical means for directing the radiant energy reflected from said sample to said means for converting radiant energy to electrical energy whereby the electrical energy emitted from said means for converting will vary according to the intensity of said reflected energy;

(e) means for computing the arithmetic mean of the magnitude of said direct current electrical energy produced during the period of time said dyed fabric is moving through said field of radiations, said arithmetic means being directly proportional to the average dye depth of said sample;

(f) means for computing the variance of the magnitude of said direct current electrical energy from said arithmetic mean produced during the period of time

said dyed fabric is moving through said field of radiations, said variance being proportional to the visual appearance of dye depth variations about said average dye depth of said sample;

(g) means for transmitting said electrical energy from said means for converting to said means for computing the mean and variance; and

(h) means for converting said means and variance into visually displayed quantitative values.

References Cited

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,388,261 June 11, 1968

Thomas S. Roberts et al.

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

Column 5, line 16, "above" should read -- about --.

Signed and sealed this 24th day of March 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents