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[54] **METHOD AND APPARATUS FOR CONTROLLING THE DYEING OF TEXTILE MATERIALS**

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[63] Continuation-in-part of Ser. No. 178,594, Sept. 8, 1971, abandoned.

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[51] Int. Cl. **G01j 3/46,** G01j 3/48

[58] Field of Search .... 356/173, 180, 181, 195; 250/226, 573; 8/158, 1 R, 25; 137/3

[56] **References Cited**

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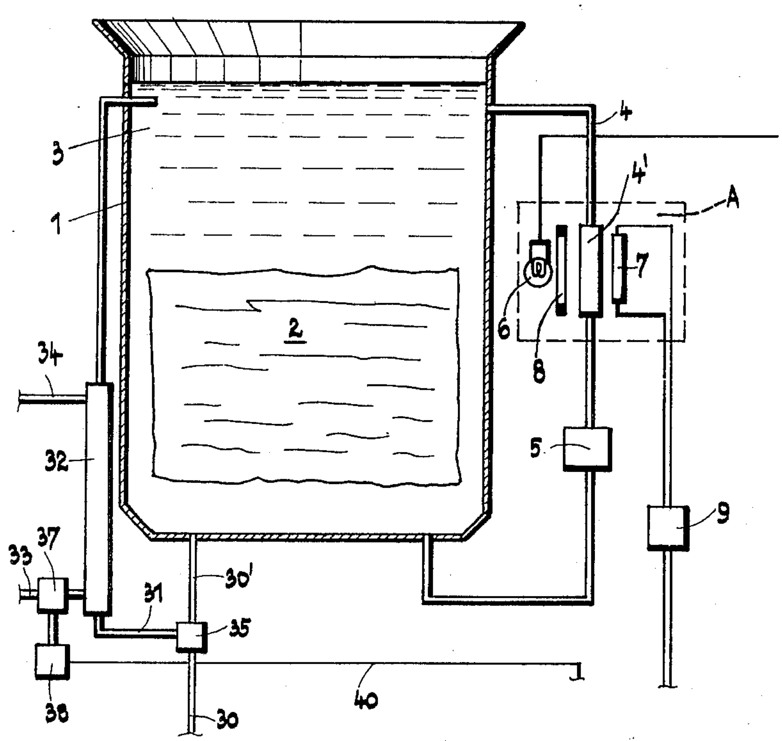
[57] **ABSTRACT**

The absorption of dye from a dye liquor by a textile material is controlled by raising the temperature of the dye liquor while its light transparency remains constant, and maintaining the temperature of the dye liquor substantially constant while its light transparency changes as dye is absorbed by the material until the dye is at least substantially absorbed.

7 Claims, 3 Drawing Figures



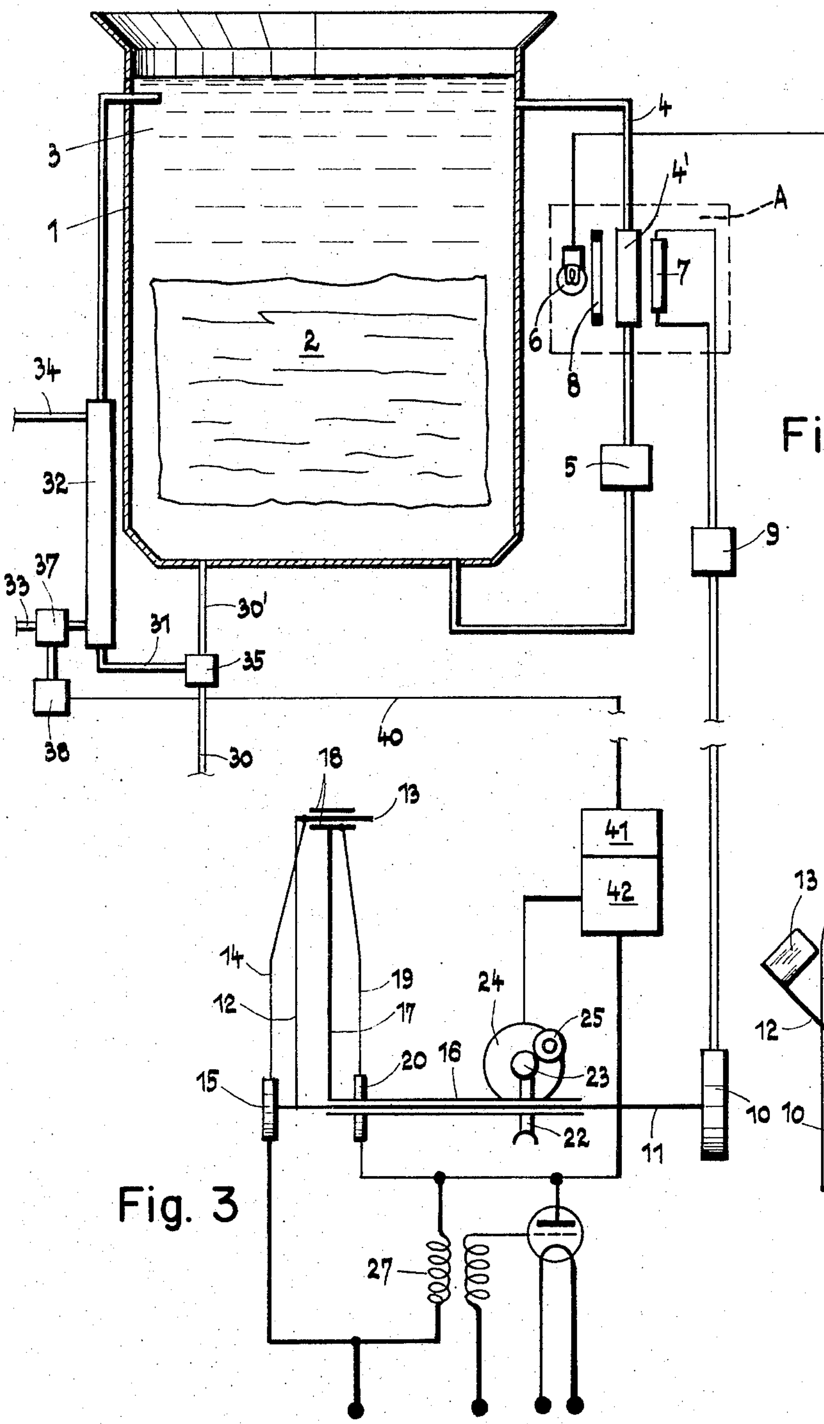


Fig. 1

Fig. 3

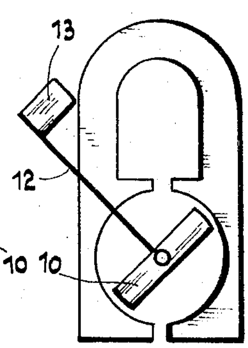


Fig. 2

METHOD AND APPARATUS FOR CONTROLLING THE DYEING OF TEXTILE MATERIALS

The present application is a continuation-in-part of our copending application Ser. No. 178,594, filed Sept. 8, 1971, now abandoned.

The present invention relates to improvements in a method of, and apparatus for, controlling the absorption of dye from a dye liquor by a textile material.

Uniform dyeing of textile materials has been difficult. When cakes of filamentary textile material are dyed, the peripheral regions of the cake are usually dyed more strongly than the interior regions of the cake. The speed with which dye is absorbed by the textile material, i.e., textile material is dyed, depends largely on the temperature of the dye liquor or bath.

The reason for these unsatisfactory results resides in the fact that the dye absorption speed exceeds the speed with which the dye liquor is pumped through the cake of filamentary material, i.e., the dye is absorbed more quickly than the dye liquor penetrates through the cake. The temperature of the dye liquor at which the cake is uniformly dyed depends primarily on the dye itself but it is also influenced by other factors, such as the denier and type or textile material, parameters of the dyeing apparatus, pressures, and speed of flow of the dye liquor.

The dyeing conditions are further complicated if the dye liquor contains more than one dye since the absorption temperature differs with each component dye in the liquor.

While the manufactures of dyes indicate absorption temperature values for their dyes for the continuous dyeing of cakes of filamentary material, these indicated values apply only to specific textile materials and assume approximately the same absorption curves for all the dye components. It is not possible to obtain fine nuances with these values. Various means have been proposed to delay the absorption of dyes but they are expensive, and are not useful under all dyeing conditions.

We have found that a very good and uniform absorption of the dye from the dye liquor by a textile material may be obtained when the temperature at which the absorption begins is maintained substantially constant as long as the dye absorption continues, i.e., until it has been completed. When the dye liquor contains more than one dye component, that temperature is first maintained at a substantially constant level at which the dye component having the lowest temperature of absorption begins to be absorbed and, after this absorption has been completed, one proceeds with the successively higher absorption temperatures of the various dye components until, finally, all the dye components have been absorbed, each at a substantially constant temperature corresponding to that at which the respective dye absorption begins. If, by some chance, the temperatures at which two of the dye components of the bath begin to be absorbed are the same, it will be this temperature which is kept constant during the entire absorption of the two dye components.

In providing an apparatus for practicing this method, it is necessary to provide means for determining that temperature at which the absorption of the "first" dye component begins. Furthermore, means must be provided for maintaining this temperature substantially constant as soon as it has been reached. Since the vat which contains the textile material to be dyed is subject to cooling, it will be necessary not simply to adjust the heat supply to the vat at the point when dye absorption begins but to see to it that any cooling will be counterbalanced without exceeding the optimal dye absorption temperature.

According to this invention, there is provided a method of controlling the absorption of dye from a dye liquor by a textile material, comprising raising the temperature of the dye liquor while its light transparency remains substantially constant, and maintaining the temperature of the dye liquor substantially constant while its light transparency changes as dye is absorbed by the material, until the dye is at least substantially absorbed.

The invention also provides apparatus for controlling the absorption of dye from a dye liquor by a textile material, comprising means for heating the dye liquor to a controlled temperature, means for measuring the light transparency of the dye liquor, and control means connected between the measuring means and the heating means for causing the heating means to raise the temperature of the dye liquor while its light transparency remains substantially constant, and maintain the temperature of the dye liquor substantially constant while its light transparency changes as dye is absorbed by the material, until the dye is at least substantially abosrbed.

The invention will now be described in more detail, by way of example, with reference to the accompanying drawing which is a simplified diagram of an apparatus embodying the invention, and

FIGS. **2** and **3** show details of the apparatus of FIG. **1.**

Vat **1** contains textile material **2** within the dye liquor or bath **3.** If desired, the textile material may be supported on a grid (not shown). A dye liquor line **4** taps the dye liquor from the vat, either through thermosiphon action or by means of a pump (not shown). Valve **5** in line **4** is operable to interrupt the dye liquor flow so that the same runs through line **4** not continuously but in intervals. Valve **5** may be a solenoid valve controlled by a timer which permits adjustment of the ratio of the flow-through (open valve) to dead (closed valve) time periods. For instance, the timer may keep the line **4** open for 10 seconds and closed for 20 seconds. The purpose of this arrangement is the provision of intermittent instead of constant measuring, the former being more readily effectuated by available technical means.

A transparent pipe section **4'** is mounted in line **4,** and light emitted from light source **6** is passed through pipe portion **4'** to a light transparency measuring device which may be a light-sensitive element, such as a photocell **7.** The amount of light reaching photocell **7** from light source **6** through pipe section **4'** depends, on the one hand, on the transparency of the dye liquor passing through pipe section **4'** and, on the other hand, from the adjustment of stop **8** mounted between light source **6** and photocell **7.** This stop may be manually adjusted.

The output signal of photocell **7** is transmitted to coil **10,** the signal being amplified by amplifier **9** arranged in the signal transmission line. The coil constitutes a pointer system whose pointer moves proportionally to the current intensity and which creates a magnetic field when a current passes therethrough, causing the coil to rotate against a spring bias within a stationary magnetic field. This corresponds to the operation of a moving coil instrument, i.e., an amperemeter, as schematically shown in FIG. 2. However, for the purposes of the present invention, the amperemeter is not used to measure current intensity but to produce an adjustment in response to a change in the current intensity.

The photocell 7 forms a control circuit with coil 10, including the amplifier 9 in the electrical transmission line connecting the photocell to the coil. The output signal of photocell 7 (or any other suitable photoelectrical device producing an output signal changing in amperage or voltage in response to a change in light) is a measure of the transparency of the dye liquor passing through pipe section 4'. A change in this transparency changes the output signal of the photocell, and this change is translated into a rotary movement of coil 10.

Arm 12 is keyed to axle 11 of coil 10, a metal lug 13 extending from the upper or outer end of the arm. The lug is insulated from arm 12 and is connected by electrical line 14 to collector 15 which is also insulatedly mounted on axle 11. A tubular shaft 16 is rotatably mounted on axle 11 and carries arm 17. A pair of plates 18 is insulatedly mounted on the upper or outer end of arm 17.

As will be noted from the side view of FIG. 3, which shows the upper end of arm 17 and the pair of plates mounted thereon, the metal lug 13 may enter between the pair of plates and thus constitute an electrical condenser of variable capacity with the plates. The pair of plates 18 are connected by electrical transmission line 19 to collector 20 which is insulatedly mounted on tubular shaft 16. Worm gear 22 is keyed to tubular shaft 16 and meshes with gear 23 to be rotated by motor 24. Furthermore, a hand wheel 25 is provided to enable the gear train to be operated manually for rotation of shaft 16. This rotation produces a movement of plates 18 in relation to lug 13.

The condenser constituted by lug 13 and plates 18 forms part of an oscillator whose oscillating circuit consists of the capacity 13, 18 and the self-induction 27. The collectors 15 and 20 constitute the transition between the movable and stationary parts of the oscillating circuit. Thus, the illustrated oscillating circuit operates with feedback but this is not essential for the purposes of the present invention.

The dye liquor is delivered to, and removed from, vat 1 by conduit 30, and a dye conduit 31 is mounted parallel thereto, with a heat exchanger 32 arranged in parallel dye conduit 31. The illustrated heat exchanger is steam operated, steam inlet line 33 and steam outlet line 34 being shown in FIG. 1. A three-way valve 35 is operable to deliver dye to the vat, to remove it therefrom, or to maintain the dye circulation conduits 30', 31 through the interior of the vat on the basis of a thermosiphon effect. A solenoid valve 37 is connected to heat exchanger 32 to control the steam supply to the heat exchanger. The valve is operated by pulse emitter 38 connected to electrical transmission line 40 which, in turn, is connected to oscillator circuit 13, 18, 27 by means of bi-stable timing switch 41 and amplifier 42 incorporating a discriminator.

As has been pointed out hereinabove, the present invention is based on the concept that for most, if not all, dyes optimum dye absorption is assured when the temperature is kept constant during the entire absorption process at that level which prevails at the beginning of the absorption of the dye by the material immersed therein.

Thus, after the textile material 2 has been placed into the vat, the dye liquor or bath is heated by operation of heat exchanger 32. The stop 8 is adjusted to produce the initial voltage signal delivered by photocell 7. The output signal value is predetermined in dependence on the coil system 10 and is chosen so that the output signal of the photocell is matched with the measuring circuit 10. Thus, the stop 8 serves to make the apparatus adaptable to the use of lighter and darker dyes. Furthermore, the hand wheel 25 is manually operated to rotate shaft 16 so as to adjust the relative position of condenser plates 18 in respect of lug 13 so that the condenser maintains the oscillator circuit at an initial frequency. This may be the resonance frequency of the circuit, which may be determined by a suitable instrument (not shown).

An auxiliary circuit 42 or discriminator is provided for detecting changes in the oscillator circuit frequency away from the initial frequency to provide an error or control signal for actuating both the motor 24 and the bistable timing switch 41 in response to such changes. The motor 24 serves to keep the arm 17 moving closely following the arm 12, and the timing switch 41 maintains the temperature constant during this movement and for a set time period thereafter.

For this purpose, timing switch 41 transmits pulses to pulse emitter 38 at intervals which do not depend on the dyeing of the material but on the cooling conditions of the apparatus. Upon receipt of these intermittent pulses, the pulse emitter 38 operates valve 37 to open or close the steam delivery to heat exchanger 32, depending on the structure of the apparatus. The time intervals selected by switch 41 depend on the nature of the apparatus, such as its heat insulation, size, location and like parameters which have nothing to do directly with the absorption temperature of the dye. These conditions of the operation of the apparatus are largely constant so that the timing switch may be suitably adjusted once and for all at the time the apparatus is installed. In this way, the cooling losses inherent in the apparatus are intermittently counteracted. If this were not done, a heat deficit would be caused in the dye bath during the continuing operation which would bring the absorption temperature below its optimal level.

The oscillator circuit includes the frequency-determining elements 13, 18, the auxiliary circuit 42 for detecting changes in the frequency of the oscillator circuit, and the motor 24. Arm 17 which carries the condenser plates 18 and is keyed to shaft 16 follows arm 12 keyed to axle 11, arm 12 carrying lug 13. The arm 17 follows arm 12 because the circuit 42 operates motor 24 when its discriminator detects a change in the oscillator frequency and continues the movement of arm 17 until the initial frequency, which may be the resonance frequency of the oscillator circuit, has been restored. As long as the circuit 42 detects a frequency deviation from the initial frequency, it will send control pulses to impulse emitter 38 so as to operate solenoid valve 37. However, this continues only as long as the increase in the dye transparency (due to continued dye absorption) produces an output from the photocell 7 so as to rotate coil 10 and thus move arm 12, i.e., as long as the respective dye component continues to be absorbed and the resultant heat loss must be compensated.

The heating means control may comprise a combination of steam (heating) and cool air (cooling) valves arranged in the heating means **32** of the dye liquor.

The apparatus illustrated operates as follows: A textile material **2** to be dyed is positioned in the vat **1** and the dye liquor **3** is introduced into the vat, whereupon the temperature of the dye liquor **3** in the vat is raised by causing steam to flow through the open steam valve **37** into the radiator **32** for heating the dye liquor. This heating step is carried out by hand, i.e., the control system is still inoperative.

While the operation is the same in principle if a single-component dye liquor is used, it will be assumed in the following that the dye liquor contains several component dyes each being absorbed by the textile material at a different temperature.

The temperature of the dye liquor or bath will be raised until a first dye component slowly begins to be absorbed by the textile material in the vat. As the first component dye begins to be absorbed by the textile material, the light transparency of the dye liquor increases, causing a corresponding increase in the output of the light-sensitive element **7** (photocell). The solenoid valve **5** is included as in practice it is usually necessary only to sample the dye liquor intermittently, e.g., for 10 seconds every 30 seconds.

Before the dyeing process is started, the arm **17** has been positioned adjacent the arm **12** by means of the setting wheel **25.** As soon as the first component dye begins to be absorbed, the arm **12** is moved from its rest position and the lug **13** on the arm **12** influences the frequency-determining elements **18** on the arm **17** to change the frequency of the oscillator circuit. This change in frequency produces an error signal which is used as a control signal for actuating the timing switch **41,** on the one hand, and the follow-up motor **24**, on the other hand. The timing switch **41** is connected to the heating means control **38** by electrical line **40** so that the control **38** will hold the temperature of the bath constant by allowing steam to be delivered into the heat exchanger **32.**

As long as arm **12** moves due to the absorption of the first component dye and the correspondingly continuing change in the transparency of the dye liquor, on the one hand, the motor **24** is operated to keep the arm **17** following the arm **12** and, on the other hand, the timing switch **41** is actuated to maintain the temperature of the bath constant. Thus, the fact that the pointer **12** is moving is used to control the heating means.

When absorption of the first component dye has been completed, i.e., the dye liquor transparency no longer changes, the arm **12** stops moving so that no further control signal is produced to actuate the timing switch **41** of the motor **24.** Therefore, after the set period of the timing switch **41,** for instance 3 minutes, has expired, the heating means control **38** is no longer operated and the temperature of the heating means will automatically rise again. Obviously, this time interval may be selected freely, i.e., it could be 2 minutes, longer or shorter.

If the arm **12** has approached or reached its end position at the beginning of the second dyeing step, i.e., when the next dye component is absorbed, it is moved back at the beginning of this step and its initial position is determined by adjustment of stop **8.** Of course, turning back arm **12** involves correspondingly returning arm **17** to its initial position. This is repeated with the absorption of each component of the dye liquor.

The rise in temperature continues until the second component dye slowly begins to be absorbed, causing the above operating cycle to be repeated since the arm **17** has been brought on top of the arm **12.** In this manner, a series of successive component dyes may be absorbed evenly by this automatic temperature control system which is responsive to the transparency of the dye liquor. When the textile material has absorbed all of the component dyes of the dye liquor, the liquor assumes a transparency corresponding to a characteristic current value. A switching element, for instance a relay, may be arranged to respond to this characteristic current value by producing an acoustic or visual signal indicating the end of the dyeing process or automatically interrupting the heating, for instance by closing the steam valves and/or opening the cool air valves.

Thus the apparatus illustrated enables the temperature of the dye liquor or bath to be controlled during dyeing in dependence on the dye absorption so as to obtain uniform dyeing and reproducible color quality of the dyed textile material.

It is possible to cause an automatic rise in the temperature immediately in response to the absorption of each component dye. This may be accomplished with circuitry of the above-described type but wherein a control signal derived from the movement of the arm **12** is used directly to actuate control **38** for maintaining the temperature constant. In this case, there is no need for the delay provided by timing switch **41.** On the other hand, when the arm movement stops, due to the end of the dye absorption, the circuit will produce a control signal actuating the control **38** for raising the temperature. This control system will reduce the total dyeing time.

It will be appreciated that any control will be useful in the illustrated embodiment wherein an actual value circuit is connected to a set value circuit so as to form a control circuit so arranged that it actuates a control whenever there is a change in a given circuit condition. In case of a multi-component dye liquor, a succession of rest conditions separates stages of increasing temperatures. A switching operation is effected successively each time one condition has been completed and another condition begins. These conditions are represented herein by the constant current values of the light-sensitive element.

As also indicated hereinabove, the apparatus may use any control circuitry which produces control signals at the end of one circuit condition as well as at the beginning of a subsequent circuit condition, the first signal causing the temperature of the dye liquor to be kept constant and the second signal interrupting this constant temperature maintenance.

What we claim is:

1. A method of controlling the absorption of dye from a dye liquor by a textile material, comprising raising the temperature of the dye liquor while its light transparency remains substantially constant, and maintaining the temperature of the dye liquor substantially constant while its light transparency changes as dye is absorbed by the material, until the dye is at least substantially absorbed.

2. The method of claim **1,** wherein the dye liquor contains more than one component dye, and the temperature of the dye liquor is maintained substantially constant while each component dye is absorbed, and is thereafter increased until the next component dye starts to be absorbed.

3. Apparatus for controlling theabsorption of dye from a dye liquor by a textile material, comprising means for heating the dye liquor to a controlled temperature, means for measuring the light transparency of the dye liquor, and control means connected between the measuring means and the heating means for causing the heating means to raise the temperature of the dye liquor while its light transparency remains substantially constant, and to maintain the temperature of the dye liquor substantially constant while its light transparency changes as dye is absorbed by material, until the dye is at least substantially absorbed.

4. The apparatus of claim **3,** wherein the measuring means comprises a source of light and a light-sensitive element arranged on opposite sides of the dye liquor.

5. The apparatus of claim **3,** wherein the control means comprises a servo loop producing an error signal, the error signal controlling the heating means.

6. The apparatus of claim **5,** further comprising a bistable switch for controlling the heating means, the error signal operating the switch.

7. The apparatus of claim **5,** wherein the servo loop comprises a first mechanical member movable in dependence upon the output of the measuring means, a second mechanical member, means for detecting relative displacement of the said members and providing the said error signal in response thereto, and means for moving the second member in response to the error signal in such a sense as to tend to reduce the displacement.

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