A non-aqueous dyeing process.

A non-aqueous process for dyeing a shaped article at an elevated temperature comprises causing a thin continuous film of a dye composition to flow over the surfaces of the shaped article at an elevated temperature. The dye composition temperature and the time of contact between the dye composition and the shaped article are sufficient to effectuate the dyeing of the shaped article. The dye composition comprises a substantially non-aqueous solvent, a dyestuff, and one or more additives, if needed.
A NON-AQUEOUS DYEING PROCESS

The present invention relates to the dyeing of shaped articles and, more particularly, it relates to a non-aqueous process for the dyeing of shaped articles at an elevated temperature by a microbath technique.

The dyeing of shaped articles, especially textile materials made of synthetic materials such as polyester, has previously been conducted with a dyestuff dispersed in an aqueous bath. The shaped article is placed in the bath for a long enough time period to allow sufficient dyestuff to be absorbed to provide the desired colouration.

Such a dyeing process poses several disadvantages and limitations. Since the temperature of the aqueous bath cannot exceed the boiling temperature of the water, the process cannot be conducted at elevated temperatures unless high pressure is used. Even then, temperatures of only 250°F to 270°F (121°C to 132°C) are reached. Consequently, relatively long dyeing cycles are needed.

Additionally, the aqueous bath is generally disposed of after each dyeing cycle because most of the dyestuff has been absorbed by the shaped article. The disposal of the used dye bath presents obvious environmental problems, as well as economic loss due to discharge of the residual dyestuff and chemicals remaining in the bath.

Dyeing at elevated temperatures with a non-aqueous system overcomes many of these problems and provides several advantages. Elevated temperatures reduce the time needed to dye the shaped article. Shorter dyeing times make the process more economical and efficient.
Various dyeing processes that use non-aqueous dye compositions have been proposed for the treatment of shaped articles. One technique involves immersing the shaped article in a bath comprising an organic dyestuff dissolved in a high boiling aromatic ester or a cycloaliphatic diester.

Whether the dye composition is aqueous or non-aqueous, it is usually brought into contact with the shaped article by spraying or showering, or by immersion. Spraying or showering is basically a pressurized operation in which the dye composition is applied to the shaped article in the form of droplets. Examples of spraying or showering processes are provided in U.S. Patent No. 3,868,835 to Todd-Reeve, U.S. Patent No. 3,557,395 to Kronsbein, U.S. Patent No. 3,181,750 to Helliwell et al., and U.S. Patent No. 3,131,840 to Berger et al.

Spraying or showering techniques have several limitations and disadvantages. Since the dye composition cools as it is sprayed or showered through the air, the dye composition cannot be maintained at a constant temperature. Such temperature fluctuations result in poor dye uniformity, especially at elevated temperatures, such as 180° to 190°C.

Since it is difficult to maintain the dye composition at an elevated temperature during the spraying or showering, longer periods of time are needed for complete dyeing to occur. If the dye cycle is shortened, uniform dyeing will not be achieved and a relatively poor quality product results.

Immersion techniques are disadvantageous, since large volumes of the dye composition are needed. Even though immersion usually provides better heat transfer properties than spraying or showering, such processes are inefficient and uneconomical.
In short, present processes are incapable of dyeing uniformly a shaped article with a non-aqueous dye composition in a sufficiently short time period at an elevated temperature and with a minimal amount of dye composition. This is particularly true with respect to some synthetic materials, such as polyester, which are difficult to dye.

The present invention enables the provision of a non-aqueous process for the dyeing of shaped articles at an elevated temperature that uses a minimal amount of dye composition, but provides excellent heat transfer properties.

The invention also enables the provision of a non-aqueous dyeing process at an elevated temperature that uniformly dyes a shaped article.

The invention also enables the provision of a non-aqueous dyeing process at an elevated temperature that rapidly colours difficult to dye synthetic materials such as polyester.

This invention further enables the provision of a method of rapidly dyeing garments composed of difficult to dye synthetic materials such as polyester.

Additional objects and advantages of the invention will be set forth in part in the description that follows and in part will be obvious from the description, or may be learned by practice of the invention.

To achieve these and other objectives, the present invention provides a non-aqueous process for the dyeing of a shaped article at an elevated temperature, the process comprising the step of causing a thin continuous film of a dye composition to flow over the surfaces of the shaped article at an elevated temperature, the dye composition temperature and the time of contact between the dye composition and the shaped
article being sufficient to effectuate dyeing of the shaped article, the dye composition comprising a substantially non-aqueous solvent and a dyestuff.

In a preferred embodiment, the process of the present invention causes the shaped article to contact the dye composition in a non-reactive environment, such as a fluorocarbon or a halogenated hydrocarbon. The preferred fluorocarbon is 1,1,2-trichloro-1,2,2-trifluoroethane. The preferred halogenated hydrocarbon is 1,1,1-trichloroethane (methyl chloroform). Preferably, the solvent of the dye composition has a boiling point greater than water. The solvent, in a preferred embodiment, is at least one aromatic ester and/or cycloaliphatic diester. The term dyestuff collectively refers to all of the individual dyestuffs that are present in the dye composition to obtain the desired colouration of the shaped article.

As used herein, the term shaped article is defined as any article having a definite form. The shaped article can be made from either textile materials or non-textile materials. Examples of shaped articles include garments, as well as components of garments and cut-up pieces that can be assembled or sewn into a garment, home furnishings, hats, seat covers, and furniture coverings.

The process of the present invention at least mitigates the problems and limitations of previous non-aqueous processes by contacting the shaped article with the dye composition in a manner that forms a thin continuous film of the dye composition over the shaped article. This technique differs significantly from spraying or showering the dye composition onto the shaped article, or immersing the material in a large volume dye bath.
For a better understanding of the present invention, and to show how it may be put into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 shows a schematic diagram depicting the apparatus of the present invention;

Figure 2 shows a plan view of the apparatus of Fig. 1;

Figure 3 shows a plan view of the interior of the apparatus of Fig. 1 showing a plurality of treatment chambers;

Figure 4 shows a more detailed schematic diagram of the loading and unloading work station of Fig. 1;

Figure 5 shows a front view of the preheating and drying work stations of Fig. 1;

Figure 6 shows a side view of the preheating and drying work stations shown in Fig. 5;

Figure 7 shows a more detailed schematic diagram of the dyeing work station of Fig. 1;

Figure 8 shows a front view of the dyeing work station of Fig. 1;

Figure 9 shows a side view of the dyeing work station shown in Fig. 8;

Figure 10 shows a schematic diagram showing the contacting of a shaped article with a thin continuous film of the dye composition in the dyeing station of the apparatus in Fig. 1;

Figure 11 shows a schematic diagram showing the passage of the non-reactive environment gas through the shaped article in any one of the preheating, cooling, and drying stations;

Figure 12 shows a more detailed schematic diagram of the rinsing work station of Fig. 1;

Figure 13 shows a plan view of an applicator head used in the assembly shown in Figs. 7, 18 and 12;
Figure 14 shows a cross section of the applicator head in Figure 13 taken along line 14-14 thereof; Figure 15 shows a top perspective view of a carrier and dye composition distribution head in the present invention; Figure 16 shows a front view of the carrier and dye composition distribution head shown in Fig. 15; and Figure 17 shows a schematic diagram of the means used to rotate the carousel unit of Fig. 1.

In a preferred embodiment of the invention, a non-aqueous process for the dyeing of a shaped article at an elevated temperature is provided. In the process, the shaped article contacts a dye composition at an elevated temperature in such a manner that a thin continuous film of the dye composition flows over the surfaces of the shaped article. The dye composition temperature and the time of contact between the dye composition and the shaped article are sufficient to effectuate the dyeing of the shaped article. The dye composition comprises a substantially non-aqueous solvent, a dyestuff, and one or more additives, if needed. Preferably, the solvent contains no water, but some water may be present.

The entire shaped article is in contact with the dye composition throughout the dyeing process. The shaped article is accordingly exposed to an environment which is substantially the same as in an immersion dyeing process. Indeed, since the film is in constant motion and flowing very rapidly, the shaped article is continuously exposed to fresh dye composition. This is a dynamic condition that cannot be easily achieved in an immersion bath. For this reason, this embodiment can be characterized as a microbath technique.
In the microbath technique, as illustrated in Figure 10, the dye composition is in constant contact with the shaped article virtually through the whole dyeing cycle. This constant contact between the dye composition of the microbath and the shaped article provides at least four significant advantages. First, it results in longer effective contact times between the article and the composition. This results in greater absorption of the composition by the article in a given period of time. Second, since the dye composition does not travel through the atmosphere surrounding the shaped article prior to contact, the temperature of the composition and of the garment can be easily maintained at the desired level. Third, only a relatively small amount of dye composition is required to perform the dyeing operation. This eliminates the necessity of heating the large volumes required in immersion dyeing. Fourth, all portions of the shaped article are in contact with the dye composition for essentially the same period of time.

The microbath technique is to be distinguished from previous processes that spray or shower the dye composition onto the material, or immerse the material in a dye bath. Spray or shower techniques apply the dye composition to the shaped article in the form of droplets or fine discrete particles which expose the largest liquid surface area to the ambient atmosphere. As a result, the entire shaped article is not in constant contact with the dye composition throughout the dyeing step. Moreover, since the droplets pass through the surrounding atmosphere before contacting the shaped article, significant heat loss occurs. This makes it difficult to maintain the dye composition at the appropriate temperature. Also, at elevated temperatures significant dye degradation occurs because of increased mixing with the ambient air.
In an immersion technique, the entire shaped article is immersed in a large volume of the dye composition. Although the material is completely covered by the dye composition as in the microbath technique, a significantly larger quantity of dye composition is required that also needs to be heated and stored. Furthermore, the dye composition in an immersion process is not in constant and rapid motion. Hence, the shaped article is not continuously exposed to fresh dye composition.

The dye composition is preferably contacted with the shaped article at atmospheric pressure. However, pressures above or below atmospheric pressure can be used.

The preferred dye composition is a substantially non-aqueous solvent having a boiling point greater than water, a dyestuff, and one or more additives, if needed. The solvents can be one of the aromatic esters and the cycloaliphatic diesters disclosed in U.S. Patent No. 4,293,305 in the name of Robert B. Wilson.

More specifically, the aromatic ester can be of the formula ArCOOR₂, ArCOO-R₁-OOCAr or (ArCOO)₂-R₃, wherein R₁ is an alkylene group of from 2 to 8 carbon atoms or a polyoxyalkylene group of the formula -C₉H₂₉(OC₉H₂₉)₉, in which r is 2 or 3 and s is an integer up to 15; R₂ is a substituted or unsubstituted alkyl or alkenyl group of from 8 to 30 carbon atoms; R₃ is the residue of a polyhydric alcohol having z hydroxyl groups; Ar is a mono- or bicyclic aryl group of up to 15 carbon atoms and z is an integer from 3 to 6.

The cycloaliphatic ester can be of the formula: \( \text{n-C₆H₁₃-} \quad \text{(CH₂)}₇ \text{COOR} \)
wherein R is a substituted or unsubstituted straight or branched chain alkyl group of from 4 to 20 carbon atoms, a polyoxyalkylene group of the formula R'(OCXH2)n or a phosphated polyoxyalkylene group of the formula

\[(\text{HO})_2\text{P(=O)OC}_x\text{H}_2\text{O}^n_\text{OC}_y\text{H}_2\text{O}^-\]

or a salt thereof, wherein \((\text{C}_x\text{H}_2\text{O})_n\) is \((\text{C}_2\text{H}_4\text{O})_n^-, (\text{C}_3\text{H}_6\text{O})_p^-(\text{C}_2\text{H}_4\text{O})_q^-; R' is H or ArCO; Ar is a mono- or bicyclic aryl group of up to 15 carbon atoms; x is 2 or 3; n is an integer from 2 to 22 and the sum of p + q is n.

Other solvents include glycerides, such as vegetable oils, of which corn oil, peanut oil, and blends thereof are examples, and fatty acids.

The dyestuffs can be those commonly found in the art, such as disperse, vat, reactive, direct, acid, basic, sulphur, and pigment. The additives can be any of those known in the art, such as levellers, dye carriers, and organic finishing agents.

Prior to applying the dye composition to the shaped article, the dye composition is heated to an elevated temperature. The temperature selected depends upon the shaped article being dyed, the particular dye composition being used, and the desired time of contact between the dye composition and the shaped article. When the shaped article is a synthetic material, such as a polyester fabric, the dye composition is heated to a temperature above the glass transition temperature, but below the melting point of the synthetic material. The temperature should, of course, be below the boiling point of the dye composition. The heated dye composition must flow over the shaped article for a time sufficient to cause the uniform dyeing of the material.
to the desired colour or shade.

One skilled in the art would select the particular dye composition depending upon the particular material being dyed. Usually, the shaped article is first selected and then the particular dye composition and the temperature range for the dyeing process are chosen.

Prior to the dyeing step, the shaped article can be preheated to allow for more rapid dyeing. By preheating the shaped article to a temperature approximately equivalent to the temperature of the heated dye composition, a more rapid and better quality of dyeing is achieved. Typically, when a synthetic material, such as polyester is used, it is preheated to a temperature above the glass transition temperature of the synthetic material, but below its melting point and the boiling point of the dye composition.

After the shaped article is dyed, the material is cooled to fix the dyestuff in the shaped material. With a synthetic material, the cooling temperature is below the glass transition temperature. This also prevents the shaped article from changing its shape, a factor that is particularly important if a garment is being treated.

After the cooling of the dyed shaped article, the present process can also include the further steps of rinsing the cooled shaped article to remove excess dye composition and drying the rinsed material.

The microbath technique can also be used in the rinse step by contacting the dyed textile material with the rinse liquid in a manner that a thin continuous film of the rinse liquid flows over the surfaces of the shaped article. In the microbath, the rinse liquid is in constant contact with the entire textile material throughout the rinse cycle.
The present process can be used in the non-aqueous dyeing at an elevated temperature of a variety of textile materials. The process is especially usable to dye synthetic material, such as polyester. Examples of other synthetic materials include polyamides, polyurethanes, polyvinyl chloride, acrylcs, halogenated polyolefins, polyolefins such as polypropylene, aramids such as Kevlar and Nomex which are trademarks of E.I. DuPont de NeMours & Co., and epoxy plastics. The process can dye natural materials including cellulosic fibres such as cotton, wool, and silk. Likewise, blends of materials, such as a polyester-cotton or a polyester-wool, can also be dyed. Other synthetic and natural materials known in the art can also be used in the present process.

The material can be in any form, for example, fibres, yarns, fabrics, garments or garment components. The fabrics can be woven, nonwoven, knitted, tufted or needle punched. Furthermore, entirely cut, sewn, and shaped garments ready for wear, such as trousers, shirts or skirts, can be dyed by the process. The textile materials to be dyed can also be fabric components that will ultimately be formed into a finished garment.

The apparatus can also be used to dye a variety of articles that are made of non-textile materials that are capable of being dyed, such as plastics. Examples of such plastic shaped articles include toys, home furnishings, utensils, and automotive accessories.

In one embodiment, the step of contacting the shaped article with the microbath of the dye composition is conducted in a non-reactive environment to prevent the degradation of the dye composition. As used herein, the
term degradation refers to the loss of colouration or colour strength of the dyestuff in the dye composition. The term non-reactive environment is defined as any composition that can be maintained as a stable gas at the dyeing temperature, without reacting with the dye composition or the shaped article, and that will displace the air and, therefore, the oxygen surrounding the shaped article.

The non-reactive environment is preferably composed of a compound that has a boiling point below the temperature of the dyeing step, but above the temperature of the rinse step. This permits use of the compound forming the non-reactive environment as a gas in the dyeing step and a liquid in the rinse step. Compounds that can be used as non-reactive environment include fluorocarbons, halogenated hydrocarbons, inert gases such as argon, neon and helium, low boiling alcohols and organic solvents, nitrogen, carbon dioxide, and combinations thereof. Fluorocarbons or halogenated hydrocarbons are the preferred compounds.

Fluorocarbon solvents are relatively easy to maintain in a vapour state, fairly safe for human exposure, and unlikely to break down into acid components. Moreover, they can be easily separated from the dye composition by distillation. This permits the recycling of both components. An especially effective fluorocarbon is 1,1,2-trichloro-1,2,2-trifluoroethane, which has the chemical formula \( \text{CCl}_2\text{FCCIF}_2 \) and is sold by E.I. DuPont de Nemours and Company under the trademark "Freon TF". Freon is a trademark of the E.I. DuPont de Nemours and Company for fluorocarbon solvents. Freon TF has a molecular weight of 187.379, a boiling point of 117.63°F (47.57°C), and a freezing point of -31°F (-35°C). It is nonflammable and has a threshold limit value (T.L.V.) of 1000 ppm.
A preferred halogenated hydrocarbon is 1,1,1-trichloroethane (methyl chloroform), which has the chemical formula CH$_3$CCl$_3$ and has a molecular weight of 133.42, a boiling range of 162°F to 190°F (72°C to 88°C), and a freezing point of -58.0°F (-50°C). It is nonflammable and has a threshold limit value (T.L.V.) of 350 ppm.

In addition, one or more of the other steps of the process, such as the preheating, cooling, rinsing, or drying steps are preferably conducted in a non-reactive environment to prevent the degradation of the dye composition in the various steps of the process. Additionally, the heating of the dye composition is conducted in a non-reactive environment to reduce significantly the degradation of the dye composition. The non-reactive environment is, preferably, the same chemical composition that is used in the dyeing step.

Reference is now made in detail to the present preferred embodiment, as illustrated in Figures 1-17.

In accordance with the invention, an apparatus 10, for the dyeing of shaped articles comprises means for surrounding a shaped article with a non-reactive environment in a treatment chamber 14 and means for causing a thin continuous film of the dye composition to flow over the surfaces of a shaped article at an elevated temperature in a non-reactive environment. The apparatus 10 is especially useful in dyeing shaped articles in the form of a shaped article, such as a garment.

The apparatus 10 also can comprise: means for transporting the shaped article within the apparatus in a treatment chamber 14; means for preheating the shaped article prior to causing the thin continuous
film to flow over the shaped article; and means for cooling the dyed shaped article. The apparatus can further include rinse means for rinsing the dyed shaped article and drying means for drying the dyed shaped article.

As shown in Figures 1 to 3, the apparatus includes a stationary cylindrical vessel 9 with a vertical axis around which is rotated a carousel unit 13, have a plurality of treatment chambers 14 for supporting and transporting simultaneously several shaped articles 12 from work station 15 to work station 15.

More particularly, the carousel unit 13 has a plurality of treatment chambers 14, each of which contains a shaped article 12 that is to be treated in the apparatus 10. The shaped article 12, contained in each treatment chamber 14, is moved from one work station to another as the carousel unit 13 rotates. A different treatment, such as loading, preheating, dyeing, cooling, rinsing, drying, and unloading is performed on the shaped article 12 at each station 15.

As shown in Figure 1, the work stations 15 include a loading and unloading station 15A, a preheating station 15B, a dyeing station 15C, a cooling station 15D, a rinsing station 15E, and a drying station 15F. In the loading and unloading station 15A, the shaped article 12 mounted on a carrier 70 (Fig. 4) is either loaded or unloaded from the treatment chamber 14, depending upon whether the treatment process is beginning or ending.

The chamber 14 has a port 16, through which the shaped article 12 is loaded and unloaded. Preferably, the port 16 is the top cover plate 11 of the apparatus 10, but it may be located elsewhere in the apparatus depending upon the compound used for the non-reactive
environment. With some compounds, the port 16 may be sealed to render the apparatus 10 airtight. Preferably, if the compound used as the non-reactive environment is heavier than air, the port 16 can be open and located in the top cover plate 11, since the non-reactive compound displaces the ambient air from the apparatus 10.

Once the first shaped article 12 to be processed is positioned on the carrier 70 and then loaded into one of the chambers 14, the carousel unit 13 is rotated so that the newly loaded chamber 14 is in the pre-heating station 15B. (Figs. 5 and 6) In the pre-heating station 15B, the shaped article is heated to a temperature approximately equal to that of the dye composition to be applied in the dyeing station 15C. As the carousel unit 13 rotates, the next empty chamber 14 is then positioned in the loading and unloading station 15A so that another shaped article can be loaded into the empty chamber 14.

After a predetermined time period, the carousel unit 13 is rotated and the preheated shaped article 12 is positioned in the dyeing station 15C. In the dyeing station 15C, the dye composition is applied to the shaped article 12. The predetermined time period depends upon the time necessary to effectuate the desired dyeing of the shaped article 12 in the dyeing station 15C. During the time needed to dye the shaped article 12, unloading and loading of the chamber 14, under the loading and unloading station 15A, takes place. The predetermined time period for rotating the carousel unit 13 is governed by the dyeing time; therefore, the shaped article 12 in each chamber 14 remains at each work stations 15 the same amount of time as determined by the dyeing cycle.
After the shaped article 12 in the dyeing work station 15C is dyed to the desired colouration the carousel unit 13 is again rotated so that the dyed shaped article is positioned in the cooling station 15D. The shaped article 12 is then cooled to a temperature sufficient to fix the dyestuff in the shaped article and to prevent the shaped article from changing its shape.

After sufficient cooling, the carousel unit 13 is then rotated to place the cooled shaped article 12 in rinsing stations 15E. (Fig. 12) The used, but non-absorbed, excess dye composition is rinsed from the shaped article and recycled for use in the dyeing station 15C.

Once the shaped article 12 is rinsed, the carousel 13 is rotated so that the dyed shaped article is positioned in the drying station 15F. The shaped article is heated to vaporize any excess liquid. After drying, the shaped article 12 on the carrier 70 is unloaded from the chamber 14 through port 16 in the unloading station 15A.

As shown in Figure 3, the plurality of treatment chambers 14 that form the carousel unit 13 are separated from each other by walls 21. The walls 21 can be constructed to seal each chamber 14 from the adjacent chamber to prevent the non-reactive environment in one chamber 14 from leaking into the other chamber 14. Preferably, the same non-reactive compound and environment is used in all of the chambers 14 so that such a tight seal between the chambers 14 need not be maintained by the walls 21.

The carousel unit 13 allows all of the stations 15 to treat simultaneously a number of shaped article 12 that are positioned on a plurality of carriers 70 within a plurality of chambers 14. Consequently, one shaped article is being dyed, while others are
simultaneously being unloaded, loaded, preheated, cooled, rinsed, and dried. Usually, the number of chambers 14 forming the carousel unit 13 corresponds to the number of work stations 15 so that a chamber 14 is positioned in each work station 15 every time the carousel unit 13 rotates.

As embodied herein, the means for transporting the shaped article 12 within the apparatus 10 in the chamber 14 between the various stations 15 includes the carousel unit 13 with the garment carriers 70 and a means for rotating the carousel unit 13. As embodied herein, the rotating means includes a motor and gear reducer 18 (Fig. 17) for rotating the carousel unit 13. A carousel position switch 20 determines the movement of the carousel unit 13. However, other known means for rotating the carousel unit 13 among the stations 15 can also be used.

As the chamber 14 rotates among the various work stations, a non-reactive environment is maintained around the shaped article 12 in the chamber 14. This prevents the degradation of the dyestuff and as a result the dye composition can be recycled and reused repeatedly for multiple dyeings. Preferably, the same non-reactive environment is present in the chamber 14 at all of the stations 15A to 15F to preserve the integrity of the non-reactive environment within the stationary cylindrical vessel 9.

As embodied herein, the means for surrounding the shaped article 12 with a non-reactive environment in the treatment chamber 14 includes a gas vapour generator 24 for producing the non-reactive environment. Preferably, as shown in Figure 4, the vapour generator 24 is stationary and located in the loading station 15A below the chamber 14.
The vapour generator 24 vaporizes the compound that is to be used as the non-reactive environment. The compound is fed into the vapour generator 24 from a tank 19 through a feed line 22. A valve 23 controls the flow of the feed. A steam source 17 with a condensate trap 25 is used as a heating source for the vapour generator 24.

As the generator 24 fills the chamber 14 with the compound of the non-reactive environment, some of the non-reactive compound escapes through the port 16 and is collected by a condenser 27 positioned on the top cover plate 11 of the apparatus 10. The condenser 27 condenses the collected compound to a liquid and returns it through conduit 26 to either the tank 19 or the vapour generator 24. A valve 34 controls the flow in the conduit 26.

The condensed compound can also be supplied to the rinse station 15E for use as a rinse liquid through conduit 28 controlled by valve 35, if the rinse station 15E uses the same non-reactive compound for rinsing as in the vapour generator 24. Similarly, reclaimed rinse liquid can be recycled to the tank 19 from a distillation unit 118 that receives its feed from the rinsing station 15E, as more fully described below.

Preferably, the chambers 14 are maintained at a temperature above the condensation temperature of the compound forming the non-reactive environment. Once the non-reactive environment is established in all of the chambers 14, the carousel unit 13 is rotated continuously among the various work stations 15, without the need of reestablishing a non-reactive environment in the chambers 14 each time.
In the preheating work station 15B shown in Figures 5 and 6, the means for preheating the shaped article 12, prior to causing the thin continuous film of the dye composition to flow over the shaped article 12, includes gas blower means for circulating a gas forming the non-reactive environment around the shaped article 12 and a heating unit 32 for heating the circulating gas. As embodied herein, the gas blower means includes a gas blower 30 and a conduit 31 leading the gas from the gas blower 30 into the chamber 14. The gas exits from the chamber 14 through a return outlet 33 to the blower 30 and the heating unit 32.

The heating unit 32 preferably contains one or more heating coils, as well as various temperature controls and dampers. The heating coils can have a steam source to heat the coils. Preferably, the gas blown on the shaped article is the compound, as defined above, that provides the non-reactive environment.

As shown in Fig. 11, in the preheating station 15B, the conduit 31 is positioned above the shaped article 12 in the chamber 14 to allow the heated gas to flow onto the shaped article 12 on the carrier 70. This positioning provides an effective and efficient heating of the garment 12.

After the dyed material is preheated, the chamber 14 is rotated to the dyeing work station 15C shown in Figures 7-9. The means for causing a thin continuous film to flow over the shaped article includes an applicator head 46 for causing a continuous thin film of the dye composition to flow over the surfaces of the shaped article 12; and means for supplying the dye composition to the applicator head 46, such as a pump 57 for pumping the dye composition from a main tank 44 through a conduit 48 to a heating unit 50. The heating unit 50 heats the
dye composition prior to supplying the dye composition to the applicator head 46.

When a shaped article 12 is not in the chamber 14, a diverter valve 41 prevents the flow of the dye composition to the applicator head 46. Rather, the dye composition is returned to the main tank 44 through a bypass line 43. This allows the dye composition to be maintained at the dyeing temperature by continued circulation and heating while the carousel unit 13 rotates.

The main tank 44 is located in the dyeing station 15C below the carousel unit 13. The main tank 44 can be relatively small, such as 5 gallons (22.8 litres), in comparison to previous apparatus, due to the efficiency of the present dyeing process. The main tank 44 is maintained in a non-reactive environment to prevent dye degradation.

A reservoir tank 51 contains a reserve supply of dye composition for use as the supply of the dye composition in the main tank 44 diminishes. The dye composition from the reservoir tank 51 is fed into the main tank 44 through a conduit 52 controlled by valve 53. A conduit 47 can also feed heated dye composition through the heating unit 50 to the reservoir tank 51 in which the dye composition is stored until it is needed. A valve 49 diverts the flow between the conduit 48 and the conduit 47.

As shown in Figures 7 and 10, the applicator head 46 is preferably positioned directly above the shaped article 12. The applicator head 46 applies the dye composition in a manner that a thin continuous film 59 of the dye composition flows over all the surfaces of the shaped article 12, as shown in Figure 10.
To provide the continuous thin film 59 of the microbath, the applicator head 46, as shown in Figures 13 and 14, includes an upper horizontally extending circuit retaining wall 58 having a circumferential ring 60 depending from the outer periphery 63 of the upper wall 58; and a lower horizontal wall 62 connected to the upper wall 58. The periphery 65 of the lower wall 62 is spaced inwardly from the circumferential ring 60 to define an annular downwardly facing discharge opening 68 for the discharge of the dye composition. A dispersion plenum 66 is formed between the upper wall 58 and the lower wall 62 for dispersing the dye composition from a coupling 56, through the plenum 66, and to the discharge opening 68.

To achieve the proper flow, the diameter of the lower wall 62 corresponds to the diameter of an inner frame 74 of the carrier 70. (Fig. 10).

As shown in Figures 7 and 10, the applicator head 46 is positioned directly above the carrier 70, when the chamber 14 is in the dyeing work station 15C. Such a positioning permits the dye composition to flow out of the applicator head 46, through the discharge opening 68, and into a circumferential inlet 72 of the carrier 70. The speed of the dye flow depends upon the dye composition, the material being dyed, the shape of the carrier 70 on which the material is positioned, and the compound used as the non-reactive environment.

As shown in Figures 10, 15 and 16, the carrier 70, preferably, has an inner frame 74 with an outwardly extending bottom wall 73 and an outer frame and support 76 connected to the bottom wall 73 to form a trough configuration. The inner frame 74 and the outer frame 76 together define a circumferential inlet 72 that lies horizontally above the bottom wall 73. The shaped
article 12, such as a pair of trousers, a skirt, or a shirt, is fitted onto the outer frame and support 76 of the carrier 70.

Preferably, the outer frame 76 is made of a porous material such as woven wire screen that allows the dye composition to flow over and through to contact all sides of the shaped article 12. The outer frame 76 is constructed to impart a smooth, dimensional shape to the desired areas of the shaped article 12.

In the particular case where the shaped article 12 is a pair of trousers, the carrier 70 includes flat blades 150 extending downwardly from the outer frame 76 (Fig. 16). The blades 150 are designed to impart creases to the leg portions of the pair of trousers; and to maintain the surface of the shaped article 12 in a smooth and unwrinkled condition during processing. The flat blades 150 may, if desired, be perforated to allow the dye composition to flow over and through or could be two narrow bands with appropriate spacing and supports coinciding with the edges of the blades 160.

During the dyeing process, the dye composition flows from the applicator head 46 into the circumferential inlet 72 of the carrier 70. Some of the dye composition then flows over the top rim 77 of the outer frame 76 onto the outside portion of shaped article 12. Some of the dye composition also flows out through holes 79 (Fig. 10) in the sieve like material of the outer frame 76 to contact the underside of the shaped article 12 held on the outer frame 76. In this manner, both sides of the shaped article 12 on the outer frame 76 are contacted by the continuous thin film 59 of the dye composition, in accordance with the microbath technique.
The carrier 70 is held in proper position within the chamber 14, as the carousel unit 13 rotates, by attaching a top lip 75 of the carrier 70 within a ring 69 formed by a flange 71 on each wall 21 of each chamber 14, as shown in Figures 10 and 11. Each carrier 70 has bars 78, as shown in Figures 10, 11 and 15, that coact with the ring 69 to hold the shaped article 12 on each carrier 70 in proper position for treatment by the work stations 15.

The outer frame 76 can also include a clip 82, along the rim 77 of the outer frame 76, to hold the shaped article 12 in place on the outer frame 76. The outer frame 76 can be constructed in a number of separate pieces to form the shaped article 12, placed on the carrier 70, into the desired shape. The size and shape of the outer frame 76 generally correspond to the size and shape of the shaped article 12 that is to be positioned on the outer frame 76. For example, if the shaped article 12 is a pair of trousers, the outer frame 76 can be constructed to provide to the trousers the final desired shape.

After the dye composition has been applied to the shaped article 12, the dyed shaped article in the chamber 14 is rotated to the cooling work station 15D. As embodied herein, the cooling means includes gas blower means for circulating a gas around the shaped article 12 and a cooling unit 104 for cooling the gas circulating around the dyed shaped article. As embodied herein and shown in Figure 2, the gas blower means includes a gas blower 102 and a blower conduit 103 leading the cool gas from the gas blower 102 into the chamber 14. The gas exits from the chamber 14 through cooling exhaust outlet 105.
The cooling unit 104 preferably contains one or more cooling coils as well as various temperature controls and dampers. The cooling coils can have a water source to cool the coils. Preferably, the cool gas blown on the dyed shaped dyeable material is one of the above identified compounds that provides a non-reactive environment. The cooling station 15D is constructed similar to the preheating station 15B shown in Figures 5, 6 and 11.

After the shaped article is cooled, the chamber 14 is rotated to the rinsing work station 15E shown in Figure 12. Preferably, as shown in Figure 12, two rinsing stations 15E-1 and 15E-2 having individual applicator heads 108 and 112, are used to apply a rinse liquid to the dyed shaped article. Fresh rinse liquid from a main tank 113 rinses shaped articles in rinse stations 15E-2 that have already been rinsed by the first rinse station 15E-1. The initial rinse of the freshly dyed and cooled, but unrinsed, shaped article 12 is carried out in rinse station 15E-1 that receives its rinse liquid from the downstream rinse station 15E-2. A pump 106 pumps the rinse liquid from a collection tank 114 through conduit 107 to the applicator head 108.

Consequently, recycled rinse liquid is used to rinse initially the shaped article 12 in rinse station 15E-1 while fresh rinse liquid is applied to the once rinsed shaped article 12 in rinse station 15E-2. This countercurrent rinse process permits the use of the cleaner or fresher rinse solvent on the shaped article 12 to remove completely the excess dye composition after it has already been rinsed once. The rinse solvent used in the first rinse station 15E-1, consequently, is very dirty and it is collected in
tank 115, prior to being pumped by pump 110 through a conduit 111 to the distillation unit 118. Various valves 109 control the rinse liquid flow between the various components of the rinse stations.

Only one rinsing station, however, is necessary for the operation of the apparatus 10. As embodied herein, the rinsing means includes the applicator head 112 flowing a continuous thin film of a rinse liquid over the surfaces of the dyed shaped article 12; a means for supplying the rinse liquid, such as a pump 122 to the applicator 112; and means for recycling the rinse liquid applied over the dyed shaped article 12. The rinse liquid is preferably one of the above identified compounds that provides a non-reactive environment.

As embodied herein, the recycling means includes a distillation unit 118 (Fig. 12) to separate the rinse liquid from the dye composition solvent; the collection tank 114 positioned beneath the chamber 14; and one or more conduits 116 for transporting the rinse liquid between the main tank 113 and the applicator head 112.

The applicator head 112, used to apply a continuous flow of the rinse liquid over the dyed shaped article 12 in the rinsing work stations 15E, is similar to the applicator head 46, used to apply the dye composition to the undyed shaped article 12 in the dyeing work station 15C. The applicator head 112 is similarly positioned over the shaped article 12 on the carrier 70 so that a thin continuous film of the rinse liquid flows over all the surfaces of the shaped article 12 to form a microbath of the rinse liquid.

After the shaped article is rinsed it is rotated to drying work station 15F as shown in Figures 1 and 2. As embodied herein, the drying means includes a gas blower means for circulating a gas around the dyed
shaped article 12 and a heating unit 90 for heating the gas circulating around the dyed article. As embodied herein, the gas blower means includes a gas blower 92, similar to the blower 30 of Figures 5 and 6 that is used to preheat the shaped article, and a blower conduit 94 leading the hot gas from the gas blower 92 into the chamber 14. The hot gas exits from the chamber 14 through the outlet 95.

The drying gas, preferably, is one of the above-described compounds that provide a non-reactive environment. Two separate drying stations 15F can be used in succession to dry effectively the shaped article. The drying station 15F is constructed similar to the preheating station 15B shown in Figures 5, 6 and 11.

The heating unit 90 preferably contains one or more heating coils, as well as various temperature controls and dampers. The heating coils can have a steam source to heat the coils.

After the shaped article 12 is dried, the chamber 14 is rotated to the unloading station 15A. The dyed and dried shaped article is removed from the chamber 14 through port 16.

Other embodiments of the invention will be apparent to one skilled in the art from a consideration of the specification or the practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with the true scope and spirit of the invention being indicated by the claims.
1. A non-aqueous process for dyeing a shaped article at an elevated temperature, the process being characterised by comprising the step of causing a thin continuous film of a dye composition to flow over the surfaces of the shaped article at an elevated temperature, the dye composition temperature and the time of contact between the dye composition and the shaped article being sufficient to effectuate the dyeing of the shaped article, the dye composition comprising a substantially non-aqueous solvent and a dyestuff.

2. A process as claimed in Claim 1, characterised in that the shaped article is a textile material.

3. A process as claimed in Claim 2, characterised in that the textile material is a synthetic material.

4. A process as claimed in Claim 3, characterised in that the dye composition is at a temperature above the glass transition temperature of the synthetic material, but below both the melting point temperature of the synthetic material and the boiling point temperature of the dye composition.

5. A process as claimed in Claim 3 or 4, characterised in that the synthetic material is a polyester.

6. A process as claimed in Claim 2, characterised in that the textile material is a synthetic material, a natural material or a combination thereof.

7. A process as claimed in Claim 6, characterised in that the synthetic material is selected from polyesters, polyamides, polyurethanes, acrylics, halogenated polyolefins, polyolefins, aramids, and epoxy plastics.
8. A process as claimed in any one of Claims 1 to 7, characterised in that the solvent of the dye composition is an aromatic ester and/or a cycloaliphatic ester.

9. A process as claimed in Claim 8, characterised in that the aromatic ester is of the formula:
\[ \text{ArCOOR}_2, \text{ArCOO}-\text{R}_1-\text{OOCAr} \text{ or } (\text{ArCOO})_z-\text{R}_3, \] wherein \( \text{R}_1 \) is an alkylene group of from 2 to 8 carbon atoms or a polyoxyalkylene group of the formula
\[ -\text{C}_r^s\text{H}_{2r}(\text{OC}_r^s\text{H}_{2r})_s, \] in which \( r \) is 2 or 3 and \( s \) is an integer up to 15; \( \text{R}_2 \) is a substituted or unsubstituted alkyl or alkenyl group of from 8 to 30 carbon atoms; \( \text{R}_3 \) is the residue of a polyhydric alcohol having \( z \) hydroxyl groups; \( \text{Ar} \) is a mono- or bicyclic aryl group of up to 15 carbon atoms and \( z \) is an integer of from 3 to 6.

10. A process as claimed in Claim 8, characterised in that the cycloaliphatic ester is of the formula:
\[ \text{n-C}_6\text{H}_{13} \]  
\[ \text{COOR} \]
\[ \text{CH}_2\text{CH} \]
wherein \( \text{R} \) is a substituted or unsubstituted straight or branched chain alkyl group of from 4 to 20 carbon atoms, a polyoxyalkylene group of the formula \( \text{R'(OC}_x\text{H}_{2x})_n \) or a phosphated polyoxyalkylene group of the formula
\[ (\text{HO})_2^p(=\text{O})(\text{OC}_x\text{H}_{2x})_n\text{OC}_x\text{H}_{2x}^- \] or a salt thereof, wherein \( (\text{C}_x\text{H}_{2x}O)_n \) is \( (\text{C}_2\text{H}_4\text{O})_n^- \), \( (\text{C}_3\text{H}_6\text{O})_q^- \) or \( (\text{C}_2\text{H}_4\text{O})_p(\text{C}_3\text{H}_6\text{O})_q^- \); \( \text{R'} \) is \( \text{H} \) or \( \text{ArCO} \); \( \text{Ar} \) is a mono- or bicyclic aryl group of up to 15 carbon atoms; \( x \) is 2 or 3; \( n \) is an integer from 2 to 22 and the sum of \( p + q \) is \( n \).
11. A process as claimed in any one of Claims 1 to 10, characterised in that the dyeing step is conducted in a non-reactive environment.

12. A process as claimed in Claim 11, characterised in that the non-reactive environment is selected fluorocarbons, halogenated hydrocarbons, inert gases, low boiling alcohols, organic solvents, nitrogen, carbon dioxide, and combinations thereof.

13. A process as claimed in Claim 12, characterised in that the fluorocarbon is 1,1,2-trichloro-1,2,2-trifluoroethane.

14. A process as claimed in Claim 12, characterised in that the halogenated hydrocarbon is 1,1,1-trichloroethane.

15. A process as claimed in any one of Claims 1 to 14 characterised in that the shaped article is a garment.

16. A process as claimed in Claim 15, characterised in that the garment is made of a polyester.

17. A process as claimed in Claim 15, characterised in that the garment is a pair of trousers, a shirt or a skirt.

18. A process as claimed in any one of Claims 1 to 17, characterised by further comprising the step of rinsing the dyed shaped article by causing a thin continuous film of a rinse liquid to flow over the surfaces of the shaped article.
19. A process as claimed in any one of Claims 1 to 18, characterised in that the solvent of the dye composition has a boiling point greater than that of water.

20. A process as claimed in any one of Claims 1 to 19, characterised in that the dyestuff is selected from disperse, vat, reactive, direct, acid, basic, sulphur, and pigment.

21. A process as claimed in any one of Claims 1 to 20, characterised by further comprising the step of preparing and heating the dye composition in a nonreactive environment.