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(54) Method and apparatus for continuously applying a liquor to an elongate material.

(57) The invention concerns a method of continuously applying a liquor to an elongate material, which comprises forming a linear assembly comprising a plurality of yarns, filaments, tow, threads or twines, hereinafter referred to as "linear assembly", continuously feeding liquor to said linear assembly whereby to impregnate said linear assembly with said liquor, characterised in that said liquor/linear assembly combination is continuously passed through an elongate treatment zone and through at least one constrictive throat located in said elongate treatment zone, the at least one said constrictive throat having a cross-sectional area smaller than that of the linear assembly immediately prior to its passage through said at least one constrictive throat such that said linear assembly is compacted on passage through said at least one constrictive throat, and wherein, after passage through said at least one constrictive throat, said liquor/linear assembly combination passes through a region in which it is maintained in a uniform, composite state. The invention also includes an apparatus for carrying out the said method.

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DESCRIPTION

METHOD AND APPARATUS FOR CONTINUOUSLY APPLYING A LIQUOR TO AN ELONGATE MATERIAL.

The present invention relates to a method and apparatus for continuously applying a liquor, e.g. a treating liquor, to an elongate material. More particularly, the present invention relates to a method and apparatus for continuously applying a treating liquor, e.g. a dye, to a linear assembly of a plurality of yarns, filaments, tows, threads or twines to thereby uniformly impregnate the linear assembly with the treating liquor.

At present yarn is normally dyed by a batch process which involves the steps of:-

(a) forming a plurality of hanks;

(b) suspending the hanks from the lid of a vat, i.e. the tank of the dyeing apparatus;

(c) supplying to the vat about 20 litres of water per kilogram of yarn, i.e. a liquor ratio of about 20:1, and adding various auxiliary chemicals to form a liquor;

(d) lowering the hanks into the liquor;

(e) heating the liquor to a temperature of 50°C whilst circulating the liquor through the hanks for a period of about 10 minutes;

(f) raising the hanks out of the liquor;

(g) adding dyestuff to the liquor, whilst circulating the liquor in the vat, to form a dyeing liquor;

(h) lowering the hanks into the dyeing liquor;

(i) increasing the temperature of the liquor to 95°C over a period of about 1 hour whilst circulating the dyeing liquor at about 10 litres per minute per kilogram of yarn;

(j) holding the temperature of the dyeing liquor at 95°C for about 1 hour whilst circulating the dyeing liquor;

(k) optionally, lowering the temperature of the dyeing liquor to 80°C with circulation of the dyeing liquor over a period of about 15 minutes (omission of this step may result in more dye being present in the effluent liquor in step 1 below);

(l) discharging the exhausted dyeing liquor as effluent;

(m) optionally, adding clean warm water to the vat at a ratio of about 20:1 (i.e. about 20 litres of water per kilogram of yarn) and circulating the warm water;

(n) if step (m) is present, discharging the water as effluent and draining the hanks;

(o) off-loading the hanks to a centrifuge and removing water;

(p) loading the hanks onto a conveyor and passing them through an oven to further dry them; and

(q) packaging the yarns.

Although satisfactory dyeing of yarn can be achieved utilizing the above batch dyeing process, the process does have the disadvantage that a number of separate steps are involved which necessitate considerable handling of the yarn.

A further disadvantage of the above-described yarn batch dyeing process is that the dyebath must be of a size sufficient to accommodate all of the yarn to be dyed in a single batch. Therefore, if at any time it is desired to dye a smaller amount of yarn, then either the dyebath has to be used at less than its optimum capacity, i.e. the dyebath is being used to dye an amount of yarn smaller than the maximum amount it is capable of accommodating, or it is necessary to have a further, smaller dyebath of a size suitable for dyeing that smaller amount of yarn and thereby avoid the inefficient situation of having to use a large amount of dyeing liquor to dye only a small amount of yarn.

A still further disadvantage of the above-described yarn batch dyeing process is that the packing of the yarns in the vat affects liquor circulation which, in turn, affects the shade and levelness of dyeing. Hence for a particular shade and degree of levelness of dyeing, there are limitations on the variation of batch size.

From the above it can, therefore, be seen that the batch system of dyeing under utilizes capital investment in apparatus except in the special case of production runs where the yarn can be divided into integral batch sizes equal to the capacity of the apparatus.

Further disadvantages of the batch dyeing of yarn are that the process utilizes large quantities of water and energy, and that the process imposes a heavy demand on the effluent system.

The main advantage of the above-described batch process for the dyeing of yarn is that satisfactory uniformity of the dyeing of the yarn, known as level dyeing, can be achieved but only at a cost. Considerable care has to be exercised in liquor circulation, in temperature change, in the use of auxiliary chemicals to adjust the rate of strike, and the equilibrium partition between liquor and the yarn. The yarn has to be presented to the liquor so that all parts have, ideally, equal liquor circulation and so equal chance of receiving dye. For economic reasons there has to be arbitration between factors such as liquor ratio, rate of change of temperatures, time at high temperature and the extent of dye exhaustion. 5% and even 10% of the dye may be left in the dye liquor.

In view of the above, it would clearly be advantageous if a continuous process could be developed which avoids the disadvantages of the batch yarn dyeing process but still achieves satisfactory uniformity of distribution of the dye on the yarn.

Continuous processes are known for the dyeing of tow in which the tow is continuously passed through a dye liquor trough and the amount of liquor applied to the tow is controlled by passing the tow, after it emerges from the trough, between two nip or pressure rollers which squeeze the excess liquor from the tow. The tow is then passed to a further treatment stage where it is heated and the dye is fixed thereon. Such continuous processes are known as "pad-mangle" processes.

Although continuous processes for dyeing tow have the advantage, over the batch dyeing technique, that they can readily accommodate differing quantities of tow being passed through the process, the existing methods of continuous dyeing have one or more of the following disadvantages:-

(i) lack of uniformity of dyeing along and across the feedstock (by feedstock is meant the material being dyed);

(ii) lack of uniformity of dyeing, surface to interior, of the feedstock;

(iii) control problems associated with the use of dye liquor troughs;

(iv) wastage of dyestuff as a result of the use of dye liquor troughs, particularly wastage occurring at changes of the dyeing programme;

(v) the dyeing apparatus holds a considerable amount of feedstock and is not self threading so that changes in programme or involuntary stoppages are extremely wasteful of feedstock;

(vi) the dyeing apparatus marks and changes the feedstock;

(vii) dye liquor in the trough may become contaminated by materials, e.g. grease or water, leaching from the feedstock into the trough; and

(viii) dye liquor in the trough may become deficient in dyestuff and acid because these transfer relatively quickly to the feedstock and also because the liquor that is recycled in such a continuous process is of a weaker dyestuff/acid strength than the initially introduced fresh dye liquor.

Because of the above disadvantages associated with the existing continuous dyeing processes, continual monitoring and control of the process is therefore necessary, particularly to maintain a constant dye concentration and a constant pH and to ensure that the level of contaminants in the trough does not reach an unacceptable level.

A pad-mangle dyeing apparatus, in which the feedstock passes vertically through nip rollers and which uses the nip rollers to form the trough, to some extent reduces the problem of weakening the dye liquor as a result of recirculation of the dye liquor. However, the use of a pad-mangle dyeing apparatus renders it difficult to maintain the conditions necessary for uniform addition of the dye liquor to the feedstock, particularly when the dye liquor addition exceeds 100% of the weight of the feedstock.

The use of the above-described continuous dyeing processes have proved unsatisfactory when applied to yarns as the uniformity of distribution of the dye on the yarn is poor. A so-called "frosting" effect occurs which is when the outermost fine fibres or filaments of the yarn are not dyed to the same extent as the main bulk of the yarn. Frosting is particularly emphasized by the use of a pad-mangle dyeing apparatus since such an apparatus raises fibres by adherence to the nip rollers at the exit from the nip. Further, the means by which the yarns are heated for the purpose of dye strike and dye fixation can affect the uniformity of the distribtion of the dye on the yarn. For example, if the yarns are heated by passing them through an electrically heated zone whilst the yarns are loosely held, the outer fibres are usually depleted of liquor which leads to more dyeing liquor, and hence more dye, migrating to these fibres, thereby resulting in these fibres being more highly dyed than the remaining fibres. If, however, the yarns are heated in steam whilst being loosely held, condensate tends to leach dye from the surface of the yarns as it wicks to the interior of the yarns, thereby enhancing the frosting effect. Increasing the amount of dyeing liquor aggravates drainage along the fibres.

There are dyeing systems which envelope the fibres during fixation of the dye but these systems are only used on fibres which are subsequently blended as staple and are unsuitable for use on yarns.

It has now been found that, by using a new method of continuously applying a liquor to an elongate material in accordance with the present invention, the above-stated disadvantages of the known batch and continuous dyeing processes may be overcome and that a dyed product may be obtained having a uniformity of dyeing which compares favourably with that of the batch dyeing techniques.

According to the present invention there is provided a method of continuously applying a liquor to an elongate material, which comprises forming a linear assembly of a plurality of yarns, filaments, tow, threads or twines, hereinafter referred to as "linear assembly", continuously feeding liquor, e.g. a dyeing liquor, to said linear assembly whereby to impregnate said linear assembly with said liquor, characterized in that said linear assembly/liquor combination is continuously passed through an elongate treatment zone and through at least one constrictive throat located in said elongate treatment zone, the or each of said constrictive throats having a cross-sectional area smaller than that of the linear assembly immediately prior to its passage through said constrictive throat(s) such that said linear assembly is compacted on passage through said constrictive throat(s), and wherein, after passage through the constrictive throat(s), said liquor/linear assembly combination passes through a region in which it is maintained in a uniform, composite state.

As used herein in connection with the present invention, the terms "compacted" and "compaction" are intended to indicate that the overall cross-sectional area of the linear assembly of yarns, filaments, tows, threads or twines is reduced.

In the method of the invention the liquor and linear assembly are held in a uniform composite state

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after they emerge from the constrictive throat(s) such that all of the yarns, filaments, tows, threads or twines of the linear assembly have uniform amounts of the liquor in their surroundings. The liquor and linear assembly are held in this uniform composite state until substantial completion of the desired interaction between the linear assembly and the liquor, e.g. in the case where the liquor is being used to treat the linear assembly the active constituent of the treating liquor, such as a dye, has transferred from the treating liquor to the linear assembly. Thereafter, the linear assembly may be further treated, for example, the active constituent, such as a dye, may be diffused into the material of the linear assembly and be fixed in the molecular structure of the material of the linear assembly, i.e. held by packing forces and/or hydrogen bonding and/or covalent chemical bonding and/or ionic bonding.

In the method of the present invention it is important that the liquor/linear assembly fills the space available in the treatment zone immediately prior to, i.e. upstream from, the constrictive throat(s) so as to form a reservoir(s) of liquor extending upstream from the restrictive throat(s). Preferably, the linear assembly has a cross-sectional area such that, on its passage through the elongate treatment zone, it is slightly compacted by the inner surface of the treatment zone upstream from the constrictive throat(s).

In a particularly preferred embodiment of the method of the present invention, the passage of the liquor/linear assembly through the elongate treatment zone is such that:

(a) the linear assembly is appreciably compacted by the constrictive throat(s) on its passage therethrough;

(b) the liquor/linear assembly fills the space available in the elongate treatment zone immediately upstream from the constrictive throat(s) and the linear assembly is slightly compacted by the inner surface of the elongate treatment zone; and

(c) in the region of the elongate treatment zone downstream from the constrictive throat(s), the liquor partially fills the space available in the elongate treatment zone and the linear assembly is slightly compacted by the inner wall of the elongate treatment zone.

The amount of liquor in this (these) "reservoir(s)" should preferably remain constant, thereby maintaining an invariant liquor flow rate.

Some or all of the liquor may, for example, be fed to the linear assembly before the "reservoir", in which case there will be part of the elongate treatment zone only partially filled with the liquor/linear assembly combination.

Preferably the greater proportion of the liquor is fed at such a rate to the linear assembly at a point within the "reservoir", so that a substantially stationary 'plug' of liquor is formed upstream of that point.

In these circumstances the rate of counterflow of liquid relative to the yarn is higher upstream of the liquor entry point to that downstream of the liquor entry point and the effective balancing pressure created per unit length of reservoir is greater upstream of the liquor entry point than downstream of the liquor entry point. This has the effect of reducing the magnitude of fluctuation in the length of the reservoir, due, for example, to variations in the linear volume of the material of the linear element (i.e. excluding voids and liquor space). Furthermore, if the cross sectional area of the treatment zone upstream of the liquor entry point is less than that downstream of the liquor entry point then since less liquor space is available, less liquor is involved in a linear variation of the reservoir and therefore the fluctuation in volume of the reservoir will also be less. The cross-sectional area of the treatment zone upstream of the said liquor entry point is therefore preferably less than that downstream of the said liquor entry point. One way of achieving this is to provide an extra constrictive throat upstream of the said liquor entry point, in which case any liquor entering before such extra restrictive throat must not be such as to create a reservoir upstream of said extra constrictive throat.

Preferably the elongate treatment zone is of circular cross-section and preferably the or each constrictive throat is in the form of a constrictive orifice of circular cross-section.

The whole of the liquor may, for example, be fed to the linear assembly by introducing it into the elongate treatment zone upstream from the constrictive throat(s) intended to produce reservoirs. However, it is also possible to feed a part of the liquor to the linear assembly before the linear assembly enters the elongate treatment zone or downstream of the constrictive throats.

At, or in the region of, the point at which the liquor is fed to the linear assembly, the linear assembly may, for example, be passed through a guide box to separate the yarns, filaments, tows, threads or twines forming the linear assembly and thereby facilitate the even distribution of the liquor throughout the linear assembly.

The liquor may, for example, be heated before it is fed to the linear assembly and such heating may, for example, be achieved by passing the liquor through a heat exchanger. Such heating would help to solubilize, in the solvent medium, e.g. water, of the liquor, other components, e.g. dye, of the liquor.

In one embodiment of the method of the present invention the linear assembly is conditioned before the liquor, e.g. a dyeing liquor, is fed thereto, the purpose of the conditioning being to aid the even distribution of the liquor throughout the plurality of yarns, filaments, tows, threads or twines forming the linear assembly. Such conditioning may, for example, comprise one or more of the steps of:

(i) washing the linear assembly, e.g. with water, preferably containing a scouring agent and removing excess washing fluid from the resulting wet linear assembly, for example, by passing the wet linear assembly between nip or pressure rollers, this treatment removing or reducing the amount of contaminants, e.g. grease, on the yarns, filaments, tow, threads or twines forming the linear assembly;

(ii) heating the linear assembly, for example by passing the linear assembly through a heat exchanger, to raise the temperature of the linear assembly to an appropriate temperature for treatment with the liquor;

(iii) directly contacting the linear assembly with steam; and

(iv) adjusting the pH of the linear assembly.

Conditioning of the linear assembly prior to it being contacted with the liquor may, for example, be advisable if the individual yarns, filaments, tows, threads or twines forming the linear assembly do not all have the same characteristics with regard to their affinity for the liquor.

The effect of passing the liquor/linear assembly through at least one constrictive throat is such that the compaction of the linear assembly as it passes through the constrictive throat(s) results in the liquor being forced, or "squirted", through the constrictive throat(s) in the same direction as the passage of the linear assembly but at a faster speed than the linear assembly is passing therethrough, and also results in the liquor being decelerated upstream from the constrictive throat(s) and relative the main direction of passage of the liquor/linear assembly. This is believed to give rise to the situation wherein the liquor and the linear assembly may both be passing at the same speed through the region of the elongate treatment zone upstream from, and remote from, the constrictive throat(s) (see aforesaid discussion of the formation of a "reservoir" of liquor and the effect of applying the liquor to the linear assembly in the region of, or before, this "reservoir"), the linear assembly is passing through the region of the elongate treatment zone immediately upstream of the constrictive throat(s) at a faster speed than the liquor is passing through the same region, and the liquor is passing through the constrictive throat(s) at a faster speed than the linear assembly is passing through such constrictive throat(s).

The overall result of the presence of the constrictive throat(s) is that the liquor is forced to move relative to the linear assembly and thereby achieves a better, and more uniform, distribution of the liquor throughout the plurality of yarns, filaments, tow, threads or twines forming the linear assembly.

The presence of at least one constrictive throat downstream from the point at which the liquor is fed to the linear assembly results in a pressure gradient in the liquor, the maximum pressure being in the region of the entrance to constrictive throat(s) and the pressure gradually decreasing on both the upstream and downstream sides of the region of maximum pressure. Further, the pressure upstream from the constrictive throat(s) balances the pressure downstream from the constrictive throat(s).

As stated above the linear assembly and the liquor, after passing through the constrictive throat(s), pass through a region wherein they are maintained in a uniform composite state such that the yarns, filaments, threads, tows or twines of the linear assembly have uniform amounts of the liquor in their surroundings. The linear assembly and liquor are maintained in such a uniform composite state until the uniform distribution of the liquor in the surroundings is no longer critical, for example, in the case of yarn dyeing, until the dye has transferred from the liquor to the yarns. The liquor/linear assembly composite may, for example, be heated in order to activate or accelerate the treatment process. The method of heating the liquor/linear assembly composite may, for example, be by an electric heater or a fluid heating jacket located around the containing outer wall of the elongate treatment zone downstream from the constrictive throat(s). Preferably, the heating is spread over the cross-section of the liquor/linear assembly composite, for example, by utilizing, as the heating source, microwave or high frequency electromagnetic radiant energy, or when convenient by passing an electric current directly through the liquor.

In a particularly preferred embodiment of the method of the present invention the liquor is heated before it is fed to the linear assembly and, after the liquor/linear assembly has passed through the constrictive throat(s), the liquor/linear assembly is passed through a hot zone in which the temperature is maintained in the downstream direction.

If the liquor is a dyeing liquor, then in the hot zone the dye transfers from the liquor onto the yarns, filaments, tows, threads or twines forming the linear assembly. However, in this case, the hot zone may not achieve sufficiently complete transfer of the dye onto the yarns, filaments, tows, threads or twines of the linear assembly and in this case a further hot zone is preferably provided. This further hot zone may, for example, comprise a continuous belt passing around a drum with the liquor/linear assembly composite passing between the belt and the drum and passing one or more times around the drum. In such an arrangement for the further hot zone, the temperature of the liquor/linear assembly composite is maintained, the composite is flattened by its passage between the belt and the drum, the intimacy of the linear assembly and liquor is maintained, and the desired interaction between the liquor and the linear assembly is permitted to be completed, e.g. the transfer of dye to the linear assembly. In the case of dyeing yarn, a still further hot zone may be provided, e.g in the form of a J-box, but in this still further hot zone it is not necessary to maintain the linear assembly and liquor as a uniform composite since the desired interaction therebetween has already been allowed to take place.

The impregnated yarns, filaments, tows, threads or twines of the linear assembly may, for example, have further liquor or a different liquor applied thereto downstream of the constrictive throat(s), e.g. to alter the pH, and/or may come into contact with steam condensate as a result of heating the yarns directly with steam, in which cases a further constrictive throat may be used to improve the uniformity of distribution of the liquor throughout each of the yarns, filaments, threads, tows or twines forming the linear assembly, this further constrictive throat being located downstream of the point of introduction of the further fluid and/or steam. The linear assembly may be further treated by passing it through a wash bath and/or through a mangle, e.g. to remove any excess fluid, and/or through a drying oven and/or through an oil applicator.

After treatment, the yarns, filaments, tows, threads or twines may, for example, be packaged on rollers, creels or bobbins suitable for further textile processing for storage or transportation, or be cut into desired lengths, or separated by guide pins into a warp sheet, and then preserved in this manner until collected.

If, in the method of the present invention, the liquor is fed to the linear assembly by introducing it into the elongate treatment zone and the linear assembly is directly contacted with steam which is introduced into the elongate treatment zone upstream from the point of introduction of the liquor, then the steam will have, in addition to its intended function of conditioning the linear assembly, the added effect of restricting the flow of the liquor and so further stabilizing the volume of the reservoir of liquor upstream of the constrictive throat(s), this restriction in flow being the result, as indicated above, of the presence of the constrictive throat(s). Restriction in the flow of the liquor is preferably achieved by the presence of a constrictive throat upstream from the point at which the liquor is fed to the linear assembly, this constrictive throat being additional to the constrictive throat(s) positioned downstream of the point at which the liquor is fed to the linear assembly.

More preferably the constrictive throat upstream of the liquor entry point has a cross-sectional area similar to that of the first constrictive throat downstream of said entry point. This will further stabilize the "reservoir" volume by stabilizing the time variation of the amount of liquor passing out of the "reservoir" by the constrictive throat downstream of the liquor entry point; said stabilization occurring due to the forces per unit length generated by liquor penetrating the constrictive throat upstream of the liquor entry point exceeding those forces per unit length required to pump the equivalent amount through the constrictive throat downstream of the liquor entry point.

If such a constrictive throat is present, upstream of the liquor entry point, the linear assembly is preferably dampened with water or steam before entering said constrictive throat, to reduce pull-through tension on the linear assembly.

According to the present invention there is also provided an apparatus for applying a liquor to an elongate material, which comprises means for continuously feeding a liquor to a linear assembly of a plurality of yarns, filaments, tows, threads or twines whereby to impregnate said linear assembly with said liquor, characterized in that said apparatus also comprises an elongate treatment zone for passage of said linear assembly therethrough, at least one constrictive throat for passage of said linear assembly therethrough and to compact said linear assembly, said at least one constrictive throat being located in said elongate treatment zone and downstream of the means for continuously feeding said liquor to said linear assembly, and means located downstream of said constrictive throat(s) for maintaining said linear assembly and liquor in a uniform composite state.

Preferably the elongate treatment zone is of circular cross-section and preferably the or each constrictive throat is in the form of a constrictive orifice of circular cross-section.

The means for continuously feeding the liquor to the linear assembly may, for example, be positioned to introduce the liquor to the linear assembly upstream from the elongate treatment zone. However, it is preferable to position the means for introducing the liquor into the elongate treatment zone upstream from the constrictive throat(s).

At, or in the region of, the means for continuously feeding the liquor to the linear assembly, there may be provided a guide box for separating the yarns, filaments, tows, threads or twines forming the linear assembly and thereby facilitate the even distribution of the liquor throughout the linear assembly.

The apparatus according to the present invention may, for example, comprise means, e.g. a heat exchanger, for heating the liquor before it is fed to the linear assembly.

Conditioning means may, for example, be provided in the apparatus according to the present invention to condition the linear assembly before the liquor is fed thereto. Such conditioning means may, for example, comprise one or more of the following:-

(1) washing means to wash the linear assembly and means, e.g. nip or pressure rollers, to remove excess washing fluid, e.g. water, preferably containing a scouring agent, from the resulting wet linear assembly;

(2) heating means, e.g. a heat exchanger, to raise the temperature of the linear assembly;

(3) steam inlet means adapted to allow steam to directly contact the linear assembly; and

(4) means for adjusting the pH of the linear assembly.

The apparatus according to the present invention preferably comprises means for activating or accelerating the treatment process, e.g. an energizing or hot zone, after the liquor has been fed to the linear assembly and after it has passed through the constrictive throat(s). The energizing or hot zone may, for example, comprise one or more of the following:-

(a) steam injection means for directly contacting the steam with the liquor/linear assembly composite and thereby raise the temperature of the composite, in which case steam condensate will increase the total liquor volume and a further constrictive throat may, for example, be utilized downstream of the point of introduction of the steam to aid in the uniform distribution of this increased total liquor volume;

(b) means for introducing further treating liquor or another fluid, e.g. for adjusting the pH, or containing a catalyst, reactive chemical or a metal complexing agent;

(c) a heater, e.g. an electric ohmic heater or a jacket for passing hot fluid therethrough, the heater being adapted to surround the fluid/linear assembly composite and heat the composite;

(d) heating means in the form of a microwave heater or a high frequency electromagnetic wave generator, such heating means avoiding the temperature gradient occurring between the heater wall and the centre of liquor/linear assembly composite when an electric ohmic heater or a fluid heated jacket is used; or

(e) a battery of cells made up of an alternating series of annular electrical insulators and conductors through which the liquor/linear assembly composite passes such that an electric current can be made to flow through the liquor.

If the apparatus according to the present invention is to be used to treat the linear assembly with a dyeing liquor and thereby dye the yarns, filaments, tows, threads or twines forming the linear assembly, then it may be desirable to include, in addition to an energizing or hot zone, a further hot zone located downstream of said energizing or hot zone and in which the linear assembly and dyeing liquor are maintained in intimate uniform contact. For example, the further hot zone may comprise a continuous hot belt passing around a hot drum such that the dyeing liquor/linear assembly composite may be passed between the belt and the drum and one or more times around the drum. A still further hot zone may, for example, be provided downstream of said energizing or hot zone and said further hot zone, e.g. in the form of a J-box, to complete the desired interaction between the linear assembly and the dyeing liquor. For example, if the linear assembly comprises a plurality of yarns, the diffusion of the dye onto the yarns and the molecular fixation of the dye within the fibres of the yarns is completed in the hot zone(s).

The apparatus may, for example, also comprise means for washing the treated linear assembly, a mangle for removing excess fluid from the linear assembly, and means for drying the linear assembly after passage through the washing means and the mangle. The apparatus according to the present invention may, for example, also comprise an additional constrictive throat or throats for improving the uniformity of distribution of the treating liquor throughout each of the yarns, filaments, tows, threads or twines forming the linear assembly and/or a wash bath and/or a mangle, e.g. to remove any excess fluid, and/or an oil applicator, these being located such that the linear assembly passes therethrough after its passage through the constrictive throat(s) in the elongate treatment zone and, if present, the energizing/hot zone and/or fixing zone.

Packaging means, e.g. rollers, bobbins or creels, for the treated yarns, filaments, tows, threads or twines, or means for cutting the treated yarns, filaments, tows, threads or twines into desired lengths, or guide pins for separating said treated yarns, filaments, tows, threads or twines into a warp sheet, may, for example, be provided in the apparatus of the present invention.

In addition to the constrictive throat(s) located downstream of the means for continuously feeding the liquor to the linear assembly, an additional constrictive throat is preferably provided upstream of the means for continuously feeding the liquor to the linear assembly.

If this further constrictive throat is present then, preferably, means for wetting or steaming the linear assembly prior to its entering said further constrictive throat is also provided.

The present invention will now be further described with reference to the accompanying drawings, in which:-

Fig.1 is a schematic representation of one embodiment of an apparatus for carrying out the method of the present invention;

Fig.2 is a schematic representation of a further embodiment of an apparatus for carrying out the present invention;

Fig.3 is a schematic representation of a still further embodiment of an apparatus for carrying out the method of the present invention;

Fig.4 is a cross-sectional view taken along line I-I of Fig.3,

Fig.5 is a side view of the device illustrated in Fig.4,

Fig.6a is a schematic view of a still further embodiment of an apparatus for carrying out the method of the present invention,

Fig.6b is a plan view of a part of the apparatus of Fig.6a, and

Fig.7 is a modified version of the treatment zone of Fig.6b.

For convenience the following description is confined to the use of a dyeing liquor as the liquor, but it is to be understood that other liquors could also be used in place of the dyeing liquor.

Referring to Fig.1 of the drawings, a plurality of yarns 1 are drawn from creel 3 (only two yarn packages illustrated) through an elongate treatment zone 5. As the yarns 1 pass through the elongate treatment zone 5 they are contacted with a dyeing liquor fed into the elongate treatment zone through a tube 7 and inlet 9. The dyeing liquor is fed to the elongate treatment zone 5 from a dyeing liquor reservoir 11 by means of a pump 13, e.g. a peristaltic pump. The pressure of the dyeing fluid fed to the elongate treatment zone 5 is continually monitored by a pressure gauge 14 positioned between the pump 13 and the inlet 9.

After being contacted with the dyeing liquor, the yarns 1 are drawn through a constrictive throat 15 having a cross-sectional area smaller than that of the elongate treatment zone immediately upstream and downstream from the constrictive throat 15. As the yarns pass through the constrictive throat 15, they are compacted and accelerate the dyeing liquor through the constrictive throat 15 at a faster speed than the yarns themselves pass through the constrictive throat 15, and also decelerate the dyeing liquor upstream against the flow of the yarn. The effect of this is to achieve a satisfactorily uniform impregnation of yarns.

The impregnated yarns 1, after passage through the constrictive throat 15, are drawn through a heating zone 17 in which the dye is transferred from the liquor to the yarn. In the embodiment illustrated in Fig.1 the heating is effected by means of an electric heater, e.g. an electric heating coil surrounding a tube through which the yarns 1 are drawn.

The yarns 1 are drawn through the apparatus illustrated in Fig.1 by means of a hot roller 19, which may be grooved to maintain the composite liquor-linear assembly so that all fibres remain in intimate contact with the liquor and wrapping belt 21, and may, for example, then be washed, dried and packaged, or be cut into desired lengths (packaging and cutting means not shown).

Fig.2 illustrates an alternative embodiment of an apparatus for carrying out the method of the present invention, in which apparatus a plurality of yarns 23 are drawn from creel 25 (only two yarn packages shown) and through an elongate treatment zone 27 wherein the yarns 23 are contacted with a dyeing liquor being fed into the elongate treatment zone 27 through inlet 29. The dyeing liquor is fed into the elongate treatment zone 27 from a dyeing liquor reservoir 31 by means of a pump 33, e.g. a peristaltic pump. Locaaed between the pump 33 and the dyeing liquor inlet 29 is a heat exchanger 35, the purpose of which is to heat the dyeing liquor to an appropriate temperature to aid in its dyeing of the yarns 23.

After being contacted with the dyeing liquor, the yarns 23 are drawn through a constrictive throat 37, the construction and function of which is the same as that of the constrictive throat 15 depicted in Fig.1.

In order to transfer the dye from the liquor onto the yarns 23, the yarns, after passage through the constricting throat 37, are drawn through a zone 39 in which they are heated by direct contact with the steam introduced through inlet 41.

The yarns 23 are then drawn through the apparatus by a mangle 43 to remove dye exhausted liquor from the yarns 23.

As in the embodiment illustrated in Fig.1, the yarns 23 are passed between a roller 45, and wrapping belt 47 and may, for example, then be washed, dried and packaged, on rollers, or cut into desired lengths (packaging rollers and cutting means, not shown).

Referring now to Fig.3 there is illustrated a further embodiment of an apparatus for carrying out the method of the present invention, in which a plurality of yarns 49 are drawn from yarn packages on a creel 51 (only three yarns on a creel are indicated) through an elongate treatment zone 53. In the elongate treatment zone 53, the yarns 49 are firstly contacted directly with steam introduced through inlet 56, the purpose of this steam treatment being to condition the yarns such that they may be subsequently impregnated and dyed satisfactorily. The yarns are then drawn through a guide box 57 which separates the yarns 49, thereby facilitating access to the yarns 49 by dyeing liquor which is introduced into the guide box 57 through inlet 59. The guide box is shown in greater detail in Figs. 4 and 5 of the drawings.

After being contacted with the dyeing liquor, the yarns 49 are drawn through two constrictive throats 61 and 63, the construction and function of which is the same as that of the constrictive throat 15 depicted in Fig.1.

In order to increase and/or maintain the temperature of the yarns 49 and the liquor pumped through inlet 59, the yarns 49, together with the liquor, are drawn through a hot zone 65, the heat in this zone being provided by passing an electric current through the liquor utilizing a battery of cells 55 made up of an alternating series of annular electrical insulators and conductors through which the yarns and dyeing liquor pass. Alternatively, the heat in zone 65 may be provided by means of microwave or high frequency radiation.

When the yarns 49 exit from zone 65 an appreciable proportion of dye will have transferred from the dyeing liquor to the yarns, with some dye having diffused into the fibres and some dye having been fixed in the fibres of the yarns.

To further transfer dye from the liquor to the yarns 49, the yarn/dyeing liquor combination emitting from hot zone 65 is directly contacted with steam introduced through inlet 67. The yarn/dyeing liquor combination is then passed through a further constrictive throat 69 to improve the uniformity of distribution of the dyeing liquor throughout the yarns 49.

In order to complete the transfer of dye to the yarns 49, the yarns are passed through a hot vessel 71 containing a hot, flexible belt 73 and a hot drum 75, the drum 75 being rotated by means of a belt 77 driven by an electric motor (not shown). The vessel 71 also contains an inclined region 79 and an exit 81. The yarns 49 are taken between the drum 75 and belt 73 and the linear assembly of yarns 49 are flattened thereby to form a tape which is passed one or more times around the drum 75 and is held in intimate contact with the dyeing liquor to substantially complete the transfer of dye to the yarns 49.

The yarns 49 and the dyeing liquor are then dispensed from belt 73 into the inclined region 79 where the yarns 49 are accumulated and stored without compaction or tension until fixation is substantially completed. Yarns 49 are then withdrawn from vessel 71 through exit 81 for rinsing, drying and repackaging (these latter three steps are not illustrated).

Figs. 6a and 6b together illustrate a further embodiment of the invention, in which a scouring apparatus is included before the elongate treatment zone and in which yarn separation means are also provided. The scouring apparatus is illustrated schematically in Fig.6a but is not shown in Fig.6b. The yarn separating means are shown in Fig.6b but for convenience are omitted from Fig.6a.

Referring to Fig.6a yarns are fed from creels 100 via a yarn feeder roll 101 into a scouring tube 103 provided with an inlet 104 for scouring solution and a tank 102 into which scouring solution drains from scouring tube 103. A constriction 105 is formed at the exit to scouring tube 103. The yarns leaving the scouring tube 103 pass over a further guide roll 106 and through a mangle 108 and thence into the elongated treatment zone 110. As shown in Fig.6b two rows 107 and 109 of pins are provided, one before and one after mangle 108 for separation of the yarns.

The elongated treatment zone 110 is provided with an inlet 111 (e.g. for steam) and a guide box 112 (similar to that illustrated in Figs. 4 and 5) having an inlet 113 for liquor. Constrictive throats 114 and 115 are provided between inlet 111 and guide box 112 and downstream of guide box 112 respectively.

A further row 116 of pins is provided for separating the yarns leaving the elongated treatment zone 110 before they pass over roll system 117 and guide roll 118 (not shown in Fig.6b). In Fig.6b constrictive throats 114 and 115 are the same dimensions and the guide box 1 is disc shaped and has two pins instead of three, and is also provided with a transparent lid for inspection purposes.

Fig.7 illustrates schematically a modified elongated treatment zone 119 having inlets 120 and 121 (for steam and liquor) and two restrictive throats 122 and 123 positioned respectively between inlets 120 and 121. Restrictive throat 123 is similar to that shown in Fig.6b at 115 but restrictive throat 122 extends the whole distance between inlets 120 and 121, and is of greater internal diameter than restrictive throat 123.

The present invention will now be further illustrated by way of the following Examples.

EXAMPLE 1.

The apparatus used in this Example comprised a glass tube having a diameter of 14 mm and a length of 10 cm, this tube having a liquor inlet at the upstream end thereof. Liquor from a reservoir was introduced into the glass tube through the liquor inlet by means of a pump located between the reservoir and the inlet. Downstream of the glass tube was located a stainless steel tube having a diameter of 4.75 mm and a length of 15 cm, and downstream of the stainless steel tube was located a winding roller.

Two yarns each of 2.2 Ktex were drawn through the glass and stainless steel tubes by means of the winding roller and water was used as the treating liquor introduced through the liquor inlet and thereby applied to the yarns.

In this Example, it was found that, when the glass and stainless steel tubes were inclined upwardly from the point of entry of the yarns into the glass tube and the water was pumped into the glass tube through the liquor inlet at a rate of 12g per minute, water dripped from the entry point of the yarns into the glass tube. However, it was also found that, if water containing 4g of a xanthate gum per litre of water was used as the treating liquor and this liquor was pumped into the glass tube at a rate of 12g per minute, all of the liquor was taken up by the yarns in approximately equal amounts in each yarn and no dripping from the entry point of the yarns into the glass tube occurred.

EXAMPLE 2

Example 1 was repeated utilizing water containing 4g of a xanthate gum per litre of water as the treating liquor. However, in this Example, one of the two yarns was pretreated, before passing it through the glass tub, by immersing it in water and then passing it through a mangle such that it contained about 40% of free water. The results of this Example indicate that all of the treating liquor was taken up by the yarns with the treating liquor being partitioned between the pretreated yarn and the un-pretreated yarn in a ratio of approximately 2:1.

EXAMPLE 3

Example 1 was repeated except that the treating liquor comprised 10g Acid Red 37 dye, 20g formic acid, 1g of wetting agent, (i.e. dodecyl benzyl sulphonate), 20g of Coacervate (i.e. Irgapadol manufactured by Ciba-Geigy) and 2g of a xanthate gum per litre of water, and a steam box was placed downstream of the stainless steel tube and before the winding roller, the steam box being open to the atmosphere, having a yarn passage length of 4 metres and having no means for maintaining the yarns and treating liquor in a uniform composite state. The yarns were drawn through the apparatus at a rate of 2 metres per minute.

By using the procedure of this Example it was observed that the dye was poorly distributed along the yarns and that projecting fibres appeared to have relatively little dye on them giving the appearance known as "frosting" to the yarns.

EXAMPLE 4

Example 3 was repeated except that the steam box was replaced by an electrically heated tube having a diameter of 4.75 mm and a length of 83.8 cms, this electrically heated tube being attached to the downstream end of the stainless steel tube. With 200 watts input to the electrically heated tube there was a noticeable issue of steam along the yarns leaving the heated tube.

After treatment in accordance with this Example, the yarns did not appear "frosted" and little dye rubbed off the yarns leaving the heated tube, thereby indicating that most of the dye had transferred from the treating liquor to the yarns within the heated tube. The yarns were, however, unevenly coloured by the dye.

EXAMPLE 5

Example 4 was repeated except that a constrictive throat having a diameter of 3.18 mm was positioned at the downstream end of the stainless steel tube and before the electrically heated tube. The winding roller was positioned close to the downstream end of the electrically heated tube.

Several samples of yarn were drawn through the apparatus. Sample 1 was a portion of yarns drawn directly from the storing package, sample 2 was a portion of yarns which had been heated in steam for 8 minutes after passage through the electrically heated tube, and sample 3 was a portion of the sample 1 yarns after passage through the apparatus and extraction and return of the dye by a levelling process.

On rinsing the treated samples, virtually no dye rinsed off sample 2 and only about 5% of the added dye rinsed off sample 1. Sample 2 was slightly deeper in colour than sample 1 and both appeared to be dyed more deeply at the surface than in the interior of the yarns. Sample 3 was lighter in colour than samples 1 and 2 and was uniform inside to outside of the yarn.

EXAMPLE 6

Sample 5 was repeated with yarn samples 1 and 2 as in Example 5 except that the treating liquor was preheated to about 80°C and with only 50 watts supplied to the electrically heated tube. Less steam was observed to be issued from the yarns as compared to Example 5.

The colour of the surface and interior of the yarns were similar to each other and similar to a "levelled sample".

The colour of the yarn surface and the colour of the cut yarn cross-section were similar to that of yarn which had been batch dyed to a level shade throughout.

EXAMPLES 7 - 12

Example 6 was repeated in each of Examples 7 - 12 except that in Example 7 the Acid Red 37 dye in the treating liquor was replaced by CI Acid Blue 80, in Example 8 the Acid Red 37 dye was replaced by CI Acid Brown 44, in Example 9 the Acid Red 37 dye was replaced by CI Acid Yellow 17, in Example 10 the Acid Red 37 dye was replaced by CI Acid Orange 10, in Example 11 the Acid Red 37 dye was replaced by a mixture of 2% CI Acid Red 114, 1.1% CI Acid Red 129 and 0.19% CI Acid Red 119 (the percentages being based on the total yarn treated and representing the amount of dyestuff containing the stated dye as the active dye component), and in Example 12 the two 2.2 Ktex yarns were replaced by 7 ends of 720 tex wool yarns.

Similar results to that of Example 6 were obtained in each of Examples 7 - 12.

EXAMPLE 13.

Twenty-two ends of 2.2 Ktex yarn were drawn at about 1.5 m/minute through an apparatus according to Fig.2 of the accompanying drawings wherein the internal diameter of the tubes through which the yarns pass is 14mm and the constrictive orifice has a diameter of 11 mm. The winding rollers were positioned about 70 cms downstream from the end of the tubing through which the yarns pass.

The treating liquor had the composition : 2g a xanthate gum, 20g Coacervate, (i.e. Irgapadol manufactured by Ciba-Geigy), and 1g wetting agent, (i.e. dodecyl benzyl sulphonate), per litre of water.

The treating liquor was pumped at ambient temperature at a rate of about 150% of the weight of the passing yarn.

No steam or heat was applied to the apparatus. A 60 cm cut length of the wet bundle of yarn taken after passing through the tubing of the apparatus and before the winding rollers was separated into individual yarns and the amount of liquor on each yarn was determined by weighing the wet yarn and weighing the yarn again after drying. The results obtained are given below in Table 1.

TABLE 1

	% Average Liquor on yarn, based on cut of yarn.							
	83-87	88-92	93-97	98-102	103-107	108-112	113-117	118-122
No. of yarns	2	3	4	4	2	3	2	2

EXAMPLE 14.

Example 13 was repeated except that 18 yarn ends were drawn through the apparatus of Fig.3 of the accompanying drawings, and only two constrictive throats (61,63) were present (i.e. constrictive throat 69 was omitted) and the hot vessel 71 was omitted. The results obtained in this Example are given below in Table 2.

TABLE 2

	% Average Liquor on yarn, based on cut of yarn.							
	83-87	88-92	93-97	98-102	103-107	108-112	113-117	118-122
No. of yarns	-	-	5	8	5	-	-	-

EXAMPLE 15

Example 14 was repeated except that 10g of Acid Red 37 and 20g of formic acid were additionally present in each litre of water and steam was supplied to the wet yarn bundle downstream of the constrictive throats 61 and 63, the steam being supplied from a small pressure boiler through a 1 mm orifice at a rate of about 25g/minute.

The bundle of yarns, after treatment, appeared slightly lighter in colour on the outside compared with the interior of the bundle.

EXAMPLE 16

Example 15 was repeated except that a constrictive throat (i.e. throat 69 of Fig.3) was positioned about 15.24 cm downstream of the steam entry point. The colour difference from the outside to inside of the yarn bundle, after treatment, appeared less than for Example 15.

Very little dye rubbed off onto absorbent paper at the winding rollers but heating for a further 8 minutes in steam slightly increased the colour depth and reduced the amount of dye rinsed off from less than 5% to almost nil.

The colour of individual yarn ends was measured using a Macbeth 2000 spectrophotometer and the results obtained are given below in Table 3.

EXAMPLE 17

Example 16 was repeated except that the dye liquor was supplied hot and steam heating was replaced by electric heating. No difference in colour could be observed between the outside and the interior of the yarn bundle. The colour of individual yarns was measured as in Example 16 and the results obtained are given below in Table 3.

TABLE 3

	Macbeth Lightness (L)	Standard Deviation of "L"	% of the L value for the 18 yarns * 95	96	97	98	99	100	101	102	103	104	105
Example 16	31	0.9	1	1	4	2	1	-	2	3	1	2	1
Example 17	31	0.6	-	-	1	2	5	3	4	-	2	1	-

* 100 represents 100% of the L value, i.e. 100% of 31 = 31 and the remaining percentages represent percentages of the L values, e.g. 95 represents 95% of L value of 31 = 29.45. The values in the columns under the percentages of the L value are the number of yarn ends having that percentage of the L value.

The colour of the yarns treated in Example 17, i.e. the outside colour and the colour of the yarn cross-section, both correspond with the colour of the same yarns treated conventionally by batch dyeing.

EXAMPLE 18

Example 17 was repeated except that the treating liquor additionally contained Acid Blue 80 dye and 20g of potassium dihydrogen phosphate per litre of water in place of the Acid Red 37 dye and formic acid. Additionally the yarns were steamed at its point of entry into the apparatus of Fig.3 and were drawn through the apparatus using a steam heated drum of 2 metres circumference enclosed in a steam box, the drum having a continuous impervious belt passing thereover. The yarns passed twice around the drum before collection (sample 1). One metre of yarn was further treated to level the dye between the yarn (sample 2). Another sample (sample 3) of about 50g of yarn was conventionally batch dyed.

Samples of the treated yarns were wound on cards such that individual yarns formed adjacent pads. Also, bundles of yarn pulled through paper tubes to form a tightly packed parallel yarn assembly and were cut to expose the yarn cross-sections.

Colour was measured on a Macbeth 2000 spectrophotometer and the results obtained are given below in Table 4.

TABLE 4

	Macbeth Lightness (L)	Standard Deviation of "L"	% of the L value for side appearance of the 18 yarns **							
			96	97	98	99	100	101	102	103
Sample 1	28	0.4	1	–	1	5	5	3	3	–
Sample 2	30	0.3	–	–	–	6	6	5	1	–
Sample 3	28	0.4	–	1	1	6	2	6	1	1

** 100 represents 100% of the "L" value, the remaining percentages represent the respective percentages of the "L" value (e.g. for sample 1, 96 represents 96% of 28 which is equal to 26.88), and the figures in the columns below the percentage values represent the number of yarns having a lightness equivalent to that percentage of the "L" value.

The colour depth of the cross-section and side of samples 1 and 2 were similar to that of the batch dyed sample (sample 3).

EXAMPLE 19

10 as formed wool yarns of about 460 tex each were treated using an apparatus shown schematically in Fig.6a excluding the scouring tube and mangle and using the modified elongated treatment zone 119 shown schematically in Fig.7. The yarns were drawn from creels 100 at 3.6 metres per minute directly into the elongated treatment zone 119 in which the constrictive throat 122 was 100 mm long and 5 mm in internal diameter, constrictive throat 123 was 20 mm long and 3.3 mm in internal diameter and the remainder of the elongated treatment zone 119 was 6 mm internal diameter. Hot dye liquor of the composition used in Example 3 was pumped into inlet 121 using the pumping system shown in Fig.2 at a rate equal to 125% of the weight of yarn passing through the elongated treatment zone 119. The separation pins 116 were not utilized in this Example. The yarn was given several minutes extra heating to complete diffusion of the dye into the yarns and then rinsed in water, dried and mounted on cards for inspection. The procedure was then repeated on a second sample of the same yarns except that the dye feed rate was increased to 150% of the weight of yarn.

At a feed rate of dye liquor of 150% the reservoir which extended upstream of constrictive throat 123 extended into constrictive throat 122 and varied in length by 111 to 118 mm. With a dye liquor input rate of 125% of the weight of yarns the reservoir was more variable and remained wholly within the region between inlet 121 and constrictive throat 123.

On inspection of the resulting dyed yarns a colour variation was visible between the yarns and the hue was affected by extraneous matter. This result is to be compared with that in the following Example 20.

EXAMPLE 20.

9 as formed yarns further soiled by arial settlement during storage were treated in the apparatus schematically shown in Fig.6a but with the elongated treatment zone 110 as shown in Fig.6b and utilizing the separation pins 107,109 and 116 of that Figure.

The scouring section was operated by injecting 250% of the weight of the yarn passing through scouring tube 103 via inlet 104 of hot water containing 5g per litre of a non-ionic detergent. The constriction 105 (3.3mm internal diameter) effectively stripped 100 of the 250% detergent solution from the yarns which flowed countercurrent to the yarn and was collected in tank 102. The detergent solution in tank 102 was found to include a considerable amount of grease and also 0.5% of solids based on the weight of yarn passed through the scouring tube 103. A further 100 of the 250% detergent solution was removed by mangle 108.

The constrictive throats 114 and 115 were both 20 mm long and 3.3 mm in internal diameter. The guide box 112 was 33 mm in diameter and 10 mm in height and had two pins dividing the yarns into three tracks. A transparent face was provided for inspection purposes.

Dye liquor was pumped into inlet 113 as in Example 19 and steam was pumped into inlet 111. The rate of input of dye liquor was 150% of the weight of yarn passing through the elongated treatment zone 110.

In contrast to the result in Example 19, the dyed yarns showed equal dyeing and the hue was unaffected.

EXAMPLE 21

10 scoured wool yarns (~460 tex each) were drawn from creels directly into elongated treatment zone 110 illustrated schematically in Fig.6b. The construction and dimensions of zone 110 were those given in Example 20. No steam was injected into inlet 111 but the application of dye liquor was the same as Example 20. 5 kg tension was required to pull the yarns through the zone 110.

EXAMPLE 22.

The procedure of Example 21 was repeated except that steam was injected into inlet 111. It was found that only 0.6 kg was required to pull the yarns through to zone 110. The change in length of the yarn finally collected was less than 3% of that leaving the creels 100 before treatment. Furthermore, the yarn texture was unaffected.

It was found that at a dye liquor input of 130% of yarn passing through zone 110 the reservoir of dye liquor formed was stable and occupied the whole space between constrictive throats 114 and 115 and a pump pressure of 5 pounds per square inch developed. Air bubbles escaped upstream of constrictive throat 114.

The resulting dyed yarns were inspected in the form of knitted panels and wound on cards and were found to have a consistency of dyeing similar to that obtained by batch dyeing.

This Example was repeated several times and showed consistent results.

EXAMPLE 23.

8 nylon/wool blend yarns and an all nylon staple yarn of similar weight 460 tex for each yarn were treated as in Example 19 but with dyestuff was a mixture of 1g per litre of nylomine blue (acid blue C.I. 62) and 5g per litre of nylomine yellow (acid

yellow 119). No nylon dye retardant was present. The nylon was found to dye to the same hue as the wool.

From the above Examples it can be seen that dripping of treating liquor from the entry point of the elongate material being treated into the treating apparatus may be avoided by utilizing a treating liquor of sufficient viscosity, e.g. by including a gum in the liquor (see Examples 1 and 2). Examples 3 and 4 illustrate that poor dyeing of yarns is achieved if the dyeing liquor is simply applied to the yarn and the yarn is then either passed through a steam box or an electrically heated tube. Examples 5 onwards illustrate that improved dyeing of yarn is achieved by the inclusion, in the dyeing apparatus, of at least one constrictive throat, the constrictive throat(s) being located downstream of the entry point of the dyeing liquor.

Also from the above Examples it can be seen that the treating liquor may, for example, contain auxiliaries, e.g. wetting agents such as dodecyl benzyl sulphonate and/or coacervates such as Irgapadol manufactured by Ciba-Geigy.

In summary, it can be seen from the above Examples that satisfactory continuous dyeing of yarn can be achieved by utilizing an apparatus and method in accordance with the present invention.

Although the present invention has been described with reference to the presence of one elongate treatment zone, it is to be understood that, if desired, two or more such elongate treatment zones may be utilized, these zones being located in series with one another.

Furthermore, whilst the method of the invention has been particularly described with reference to the treatment of a linear assembly with a liquor, i.e. a dye liquor, the invention contemplates and equally applies to situations where the linear assembly is used to effect treatment of a liquor e.g. as a carrier for a treating agent for the liquor or catalyst for reaction effected in the liquor. In such an application the elongated assembly could be recycled through a treating agent pick-up or catalyst-regeneration zone.

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CLAIMS

1. A method of continuously applying a liquor to an elongate material, which comprises forming a linear assembly comprising a plurality of yarns, filaments, tow, threads or twines, hereinafter referred to as "linear assembly", continuously feeding liquor to said linear assembly whereby to impregnate said linear assembly with said liquor, characterised in that said liquor/linear assembly combination is continuously passed through an elongate treatment zone and through at least one constrictive throat located in said elongate treatment zone, the at least one said constrictive throat having a cross-sectional area smaller than that of the linear assembly immediately prior to its passage through said at least one constrictive throat such that said linear assembly is compacted on passage through said at least one constrictive throat, and wherein, after passage through said at least one constrictive throat, said liquor/linear assembly combination passes through a region in which it is maintained in a uniform, composite state.

2. A method as claimed in claim 1, characterised in that the linear assembly is appreciably compacted by the at least one constrictive throat on its passage therethrough.

3. A method as claimed in claim 1 or 2, characterised in that the liquor/linear assembly combination fills the space available in the elongate treatment zone immediately upstream from the at least one constrictive throat and the linear assembly is slightly compacted by the inner surface of the elongate treatment zone.

4. A method as claimed in any of claims 1 to 3, characterised in that in the region of the elongate treatment zone downstream from the at least one constrictive throat, the liquor partially fills the space available in the elongate treatment zone and the linear assembly is slightly compacted by the inner wall of the elongate treatment zone.

5. A method as claimed in any of the preceding claims, characterised in that the passage of the liquor through the elongate treatment zone is such that a reservoir of treating liquor is formed upstream of the at least one constrictive throat.

6. A method as claimed in claim 5, characterised in that the amount of liquor in the said reservoir remains essentially constant, thereby maintaining an essentially invariant liquor flow rate.

7. A method as claimed in claim 5 or 6, characterised in that the liquor is fed to the linear assembly in the region of the reservoir.

8. A method as claimed in any of claims 5, 6 or 7, characterised in that the linear assembly passes successively through a first and a second constrictive throat disposed in spaced relationship in said elongated treatment zone and in which said liquor is fed to said linear assembly at a point between said first and second constrictive throats.

9. A method as claimed in claim 8, characterised in that the rate of feed of liquor to the linear assembly and the rate of passage of the linear assembly through the elongated treatment zone are such that the reservoir fills the free space available between the said consecutive constrictive throats.

10. A method as claimed in claim 9, characterised in that the reservoir extends partially along the length of the first of said consecutive constrictive throats.

11. A method as claimed in any of claims 1 to 10, in which the liquor is a dyeing liquor.

12. Apparatus for applying a liquor to an elongate material, which comprises means for continuously feeding a liquor to a linear assembly comprising a plurality of yarns, filaments, tows, threads or twines whereby to impregnate said linear assembly with said liquor, characterised in that said apparatus also comprises an elongate treatment zone for passage of said linear assembly therethrough, at

least one constrictive throat for passage of said linear assembly therethrough and to compact said linear assembly, said at least one constrictive throat being located in said elongate treatment zone and downstream of the means for continuously feeding said liquor to said linear assembly, and means located downstream of said constrictive throat(s) for maintaining said linear assembly and treating liquor in a uniform composite state.

13. Apparatus as claimed in claim 12, characterised in that said elongate treatment zone is of circular cross- section and said at least one constrictive throat is in the form of a constrictive orifice of circular cross-section.

14. Apparatus as claimed in claim 11 or 12, characterised in that said means for continuously feeding the liquor to the linear assembly is positioned to introduce the liquor into the elongate treatment zone upstream from said at least one constrictive throat.

15. Apparatus as claimed in any of claims 12 to 14, characterised in that at or in the region of the means for continuously feeding the liquor to the linear assembly, there is provided a guide box for separating the yarns, filaments, tows, threads or twines forming the linear assembly and thereby

facilitate the even distribution of the treating liquor throughout the linear assembly.

16. Apparatus as claimed in any of claims 12 to 15, characterised by also comprising a heat exchanger, for heating the liquor before it is fed to the linear assembly.

17. Apparatus as claimed in any of claims 12 to 16, characterised by including conditioning means to condition the linear assembly before the liquor is fed thereto, said conditioning means comprising at least one of the following:-

(1) washing means to wash the linear assembly and means to remove excess washing fluid from the resulting wet linear assembly;

(2) heating means to raise the temperature of the linear assembly;

(3) steam inlet means adapted to allow steam to directly contact the linear assembly; and

(4) means for adjusting the pH of the linear assembly.

18. Apparatus as claimed in any of claims 12 to 17, characterised by including activating or accelerating means for activating or accelerating the treatment process after the liquor has been fed to the linear assembly and after it has passed through the at least one constrictive throat.

19. Apparatus as claimed in claim 18, characterised in that said activating means comprises one or more of the following:-

(a) steam injection means for directly contacting the steam with the linear assembly/liquor composite and thereby raise the temperature of the composite,

(b) means for introducing further liquor or another fluid containing a catalyst, reactive chemical or a metal complexing agent;

(c) a heater adapted to surround the linear assembly/fluid composite and heat the composite;

(d) heating means in the form of a microwave heater or a high frequency electromagnetic wave generator, or

(e) a battery of cells made up of an alternating series of annular electrical insulators and conductors through which the linear assembly/liquor composite passes such that an electric current can be made to flow through the liquor.

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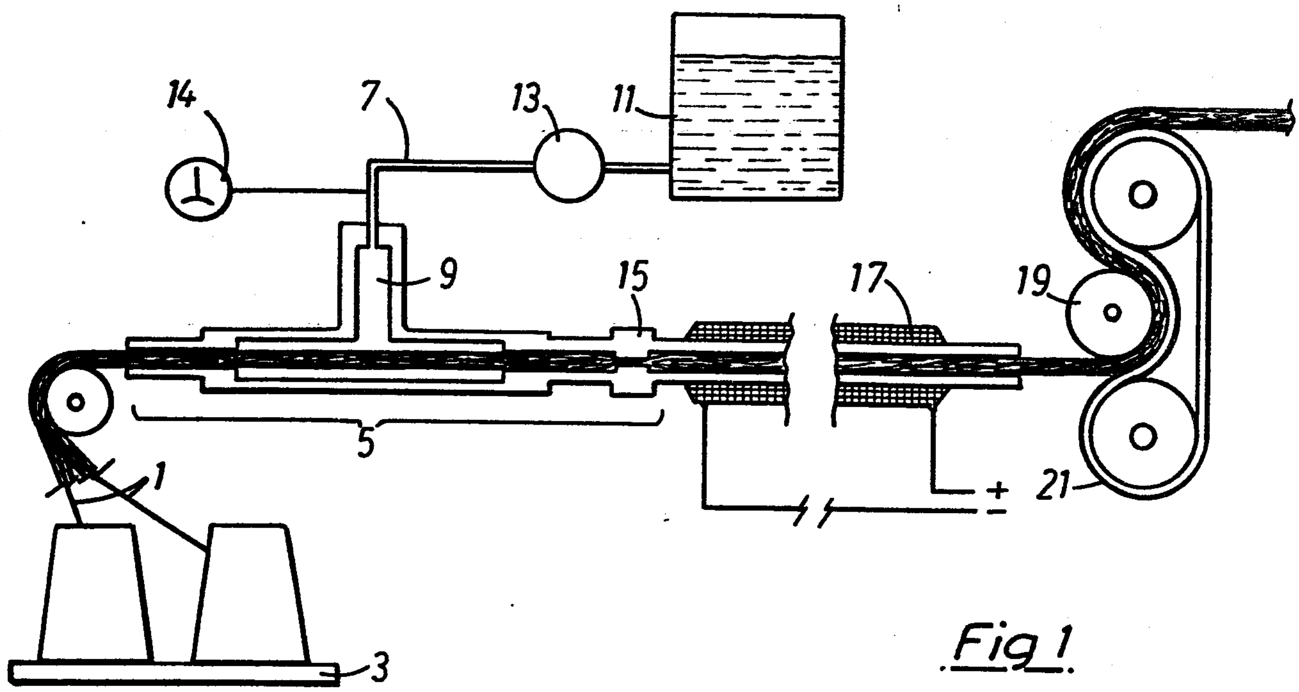

Fig 1

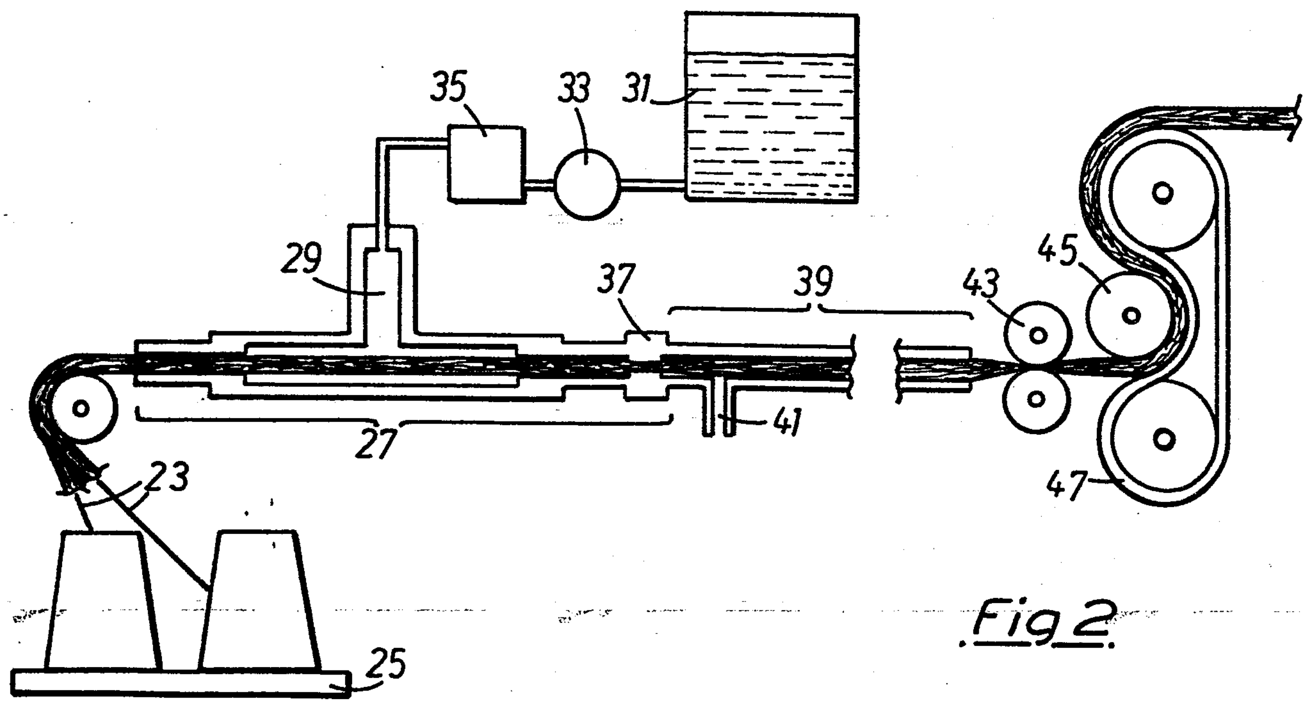

Fig 2

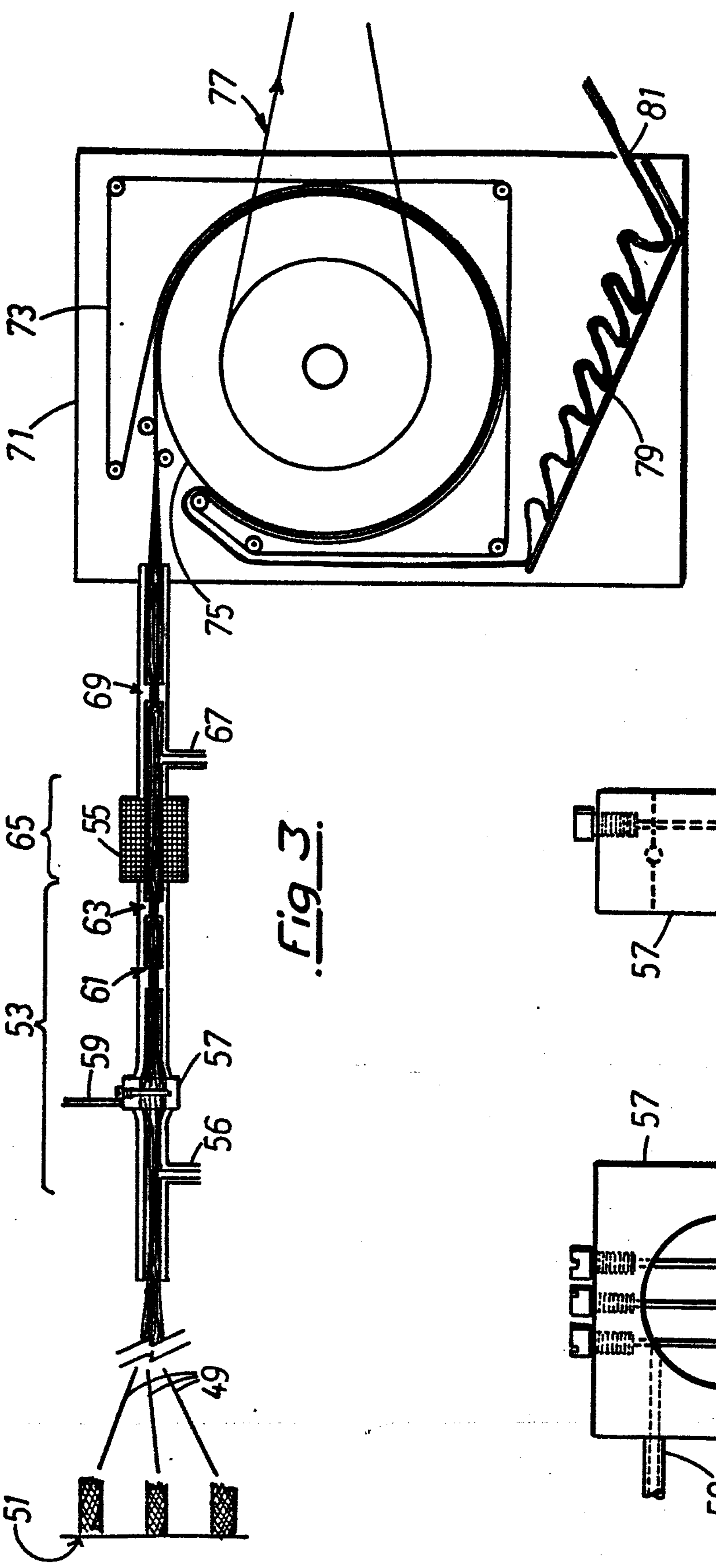

Fig 3

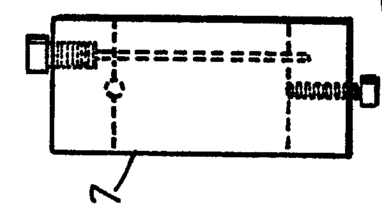

Fig 5

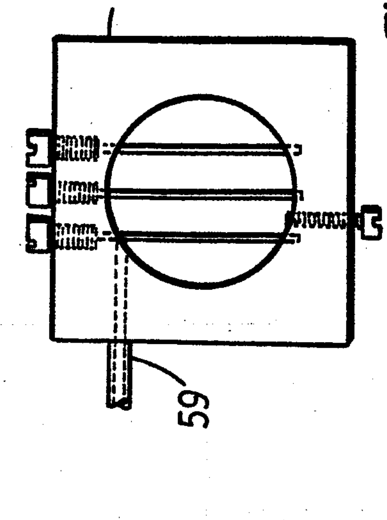

Fig 4

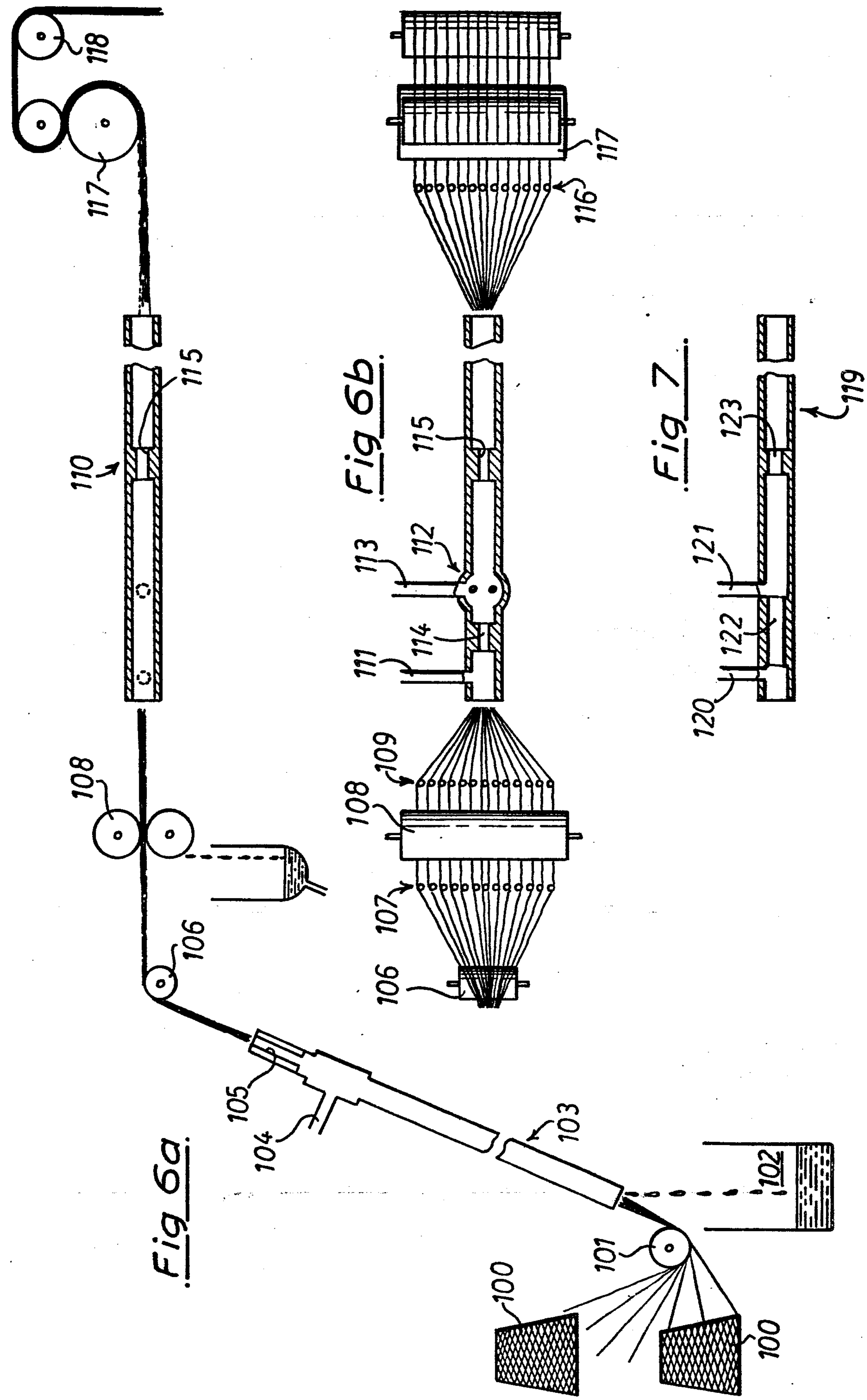

Fig 6a

Fig 6b

Fig 7