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[11] 3,724,088

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[54] **PROCESS USING SHOCK WAVES FOR THE CONTINUOUS TREATMENT OF THREADS**

[75] Inventors: **Michel S. M. Lefebvre**, Saint-Quentin; **Jean-Claude M. L. Hennion**, Arly, both of France

[73] Assignee: **Omnium De Prospective Industrielle**, Saint-Quentin, France

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Jan. 21, 1970 France 7002183

[52] **U.S. Cl.** **34/16**, 34/23, 34/61

[51] **Int. Cl.** **F26b 5/04**

[58] **Field of Search**.......34/16, 23, 61, 155, DIG. 14; 68/355, 20, DIG. 1; 28/61, 75; 117/102 L

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Primary Examiner—William F. O'Dea
Assistant Examiner—William C. Anderson
Attorney—Ward, McElhannons, Brooks & Fitzpatrick

[57] **ABSTRACT**

This invention relates to a process for squeezing and/or drying a humid thread, particularly a textile thread, in the course of a treatment, such as dyeing, effected continuously on said thread during the rectilinear displacement thereof, wherein the humid thread is passed into a zone traversed by a current of air at a pressure much lower than the pressure prevailing about the thread during the operation having provoked it humidification. The invention also relates to an apparatus for continuously treating a thread, for example a textile thread, applying the process as described hereinabove.

6 Claims, 6 Drawing Figures

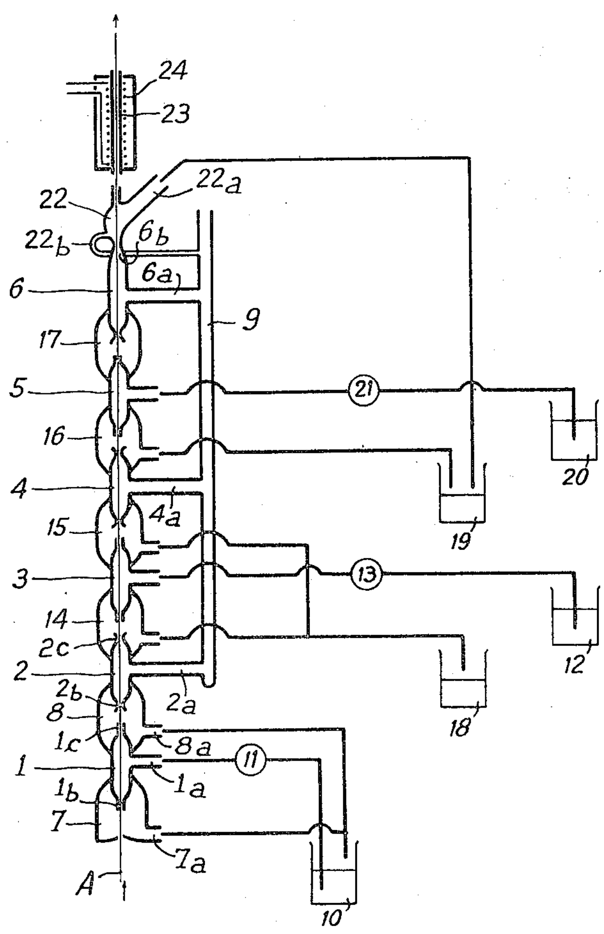

FIG. 1

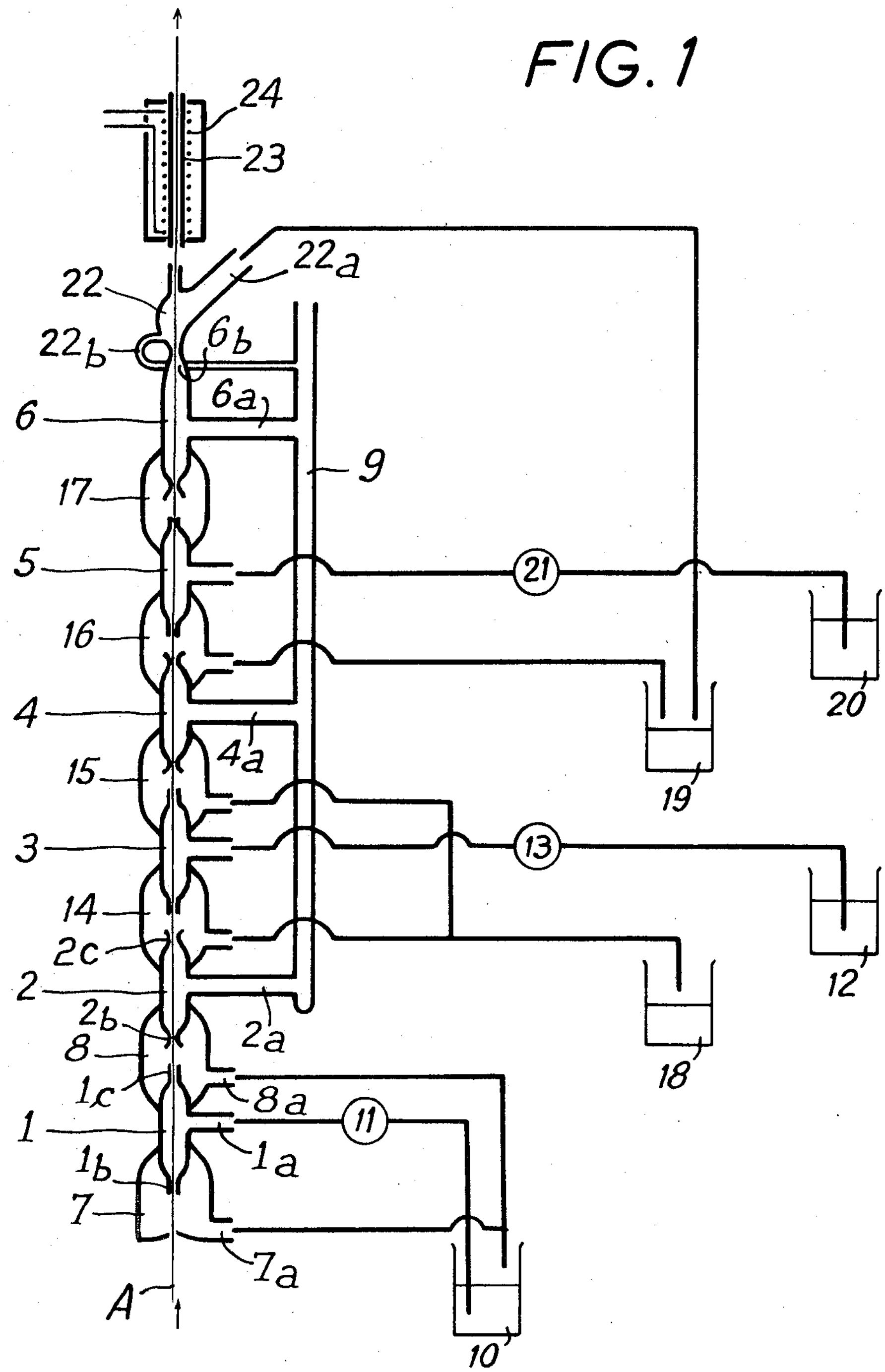
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FIG. 2

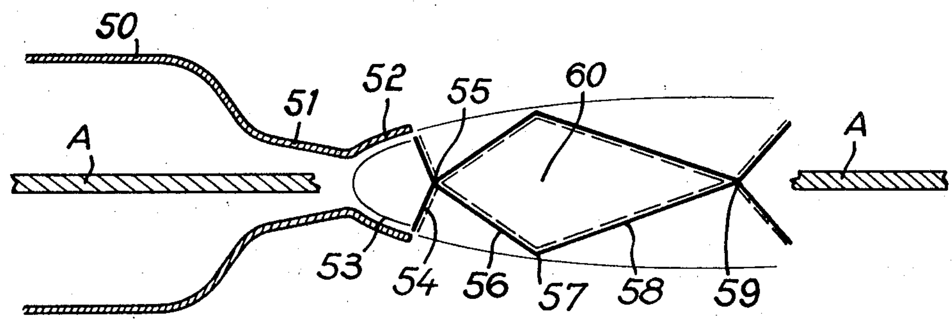


FIG. 6

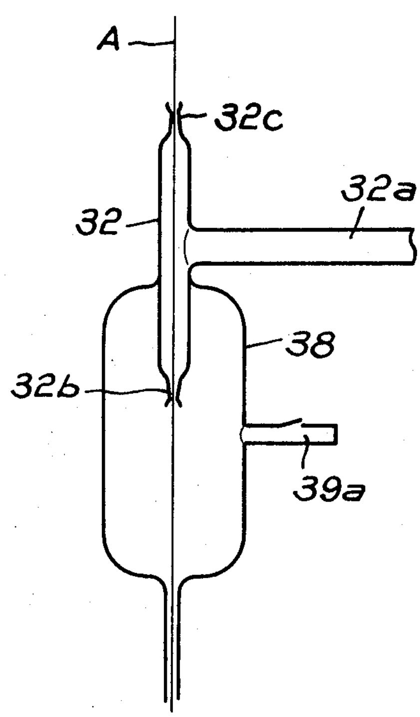
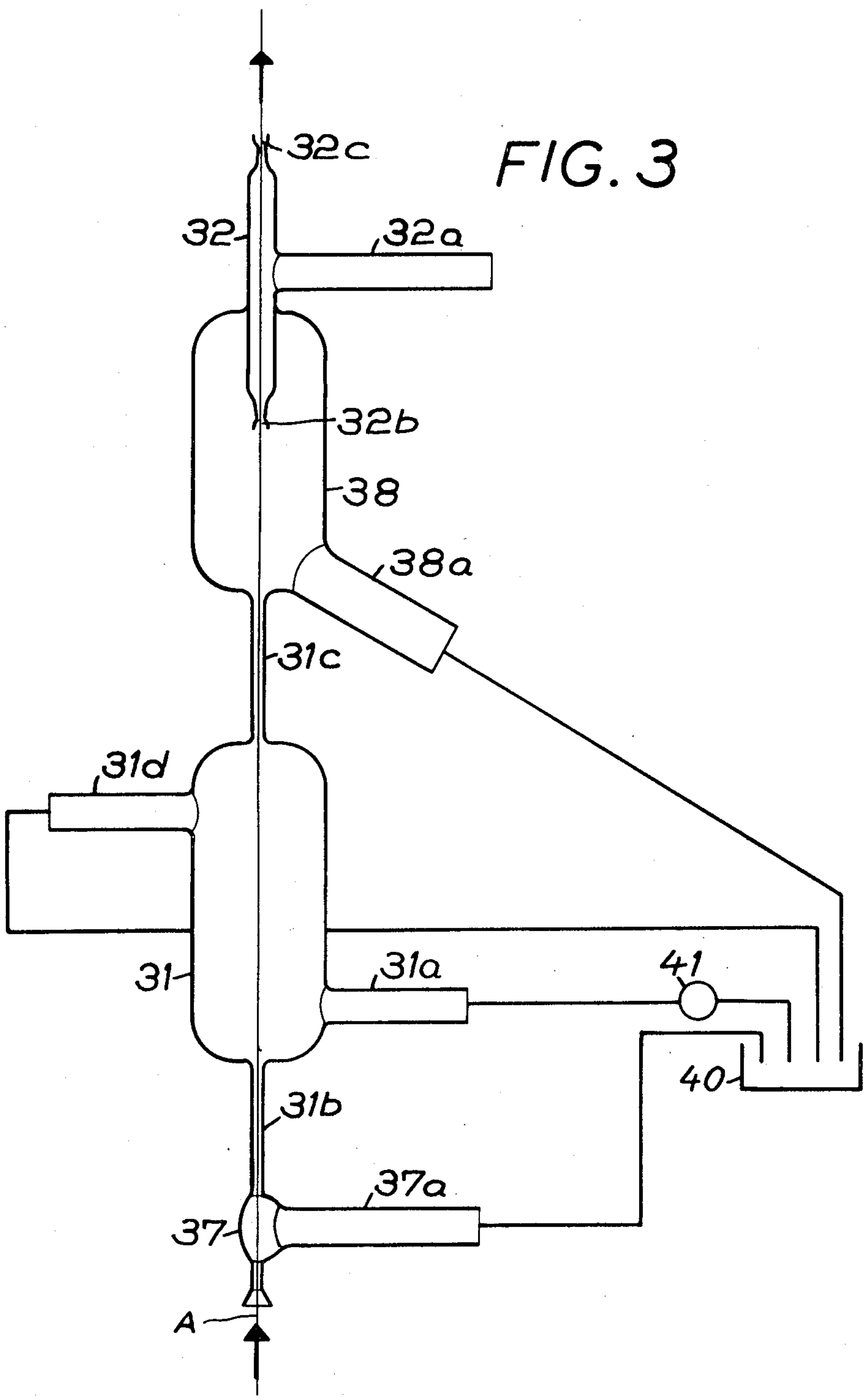


FIG. 3



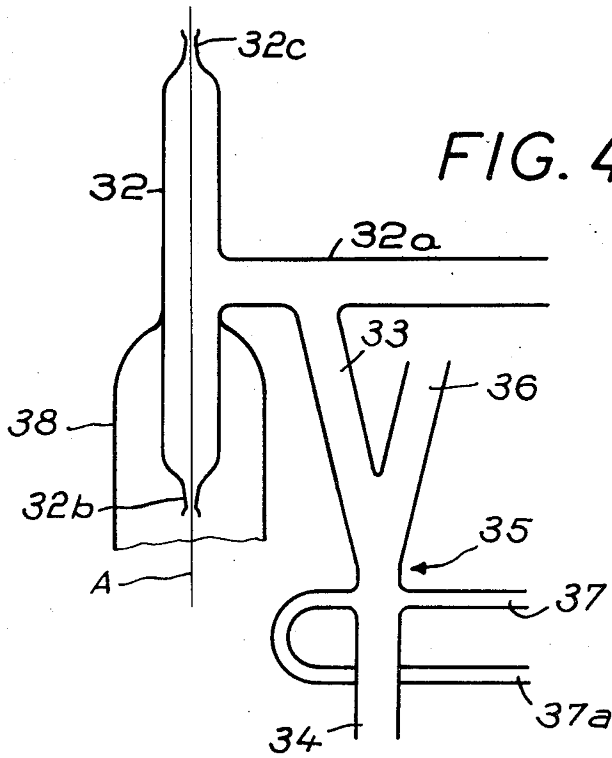


FIG. 4

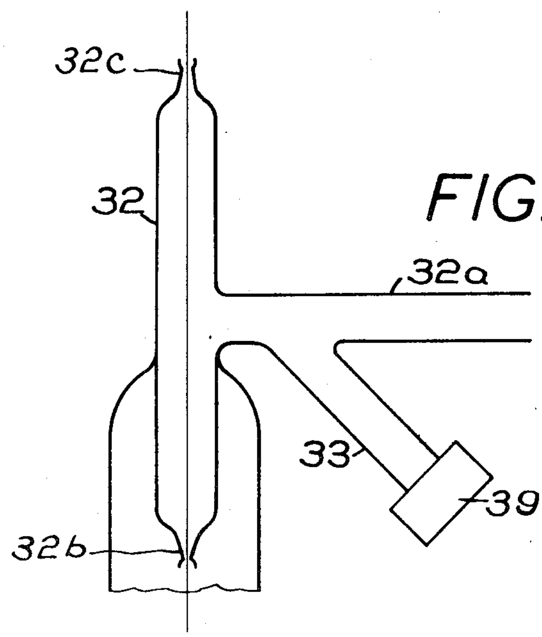


FIG. 5

PROCESS USING SHOCK WAVES FOR THE CONTINUOUS TREATMENT OF THREADS

The present invention relates to a process and apparatus for the continuous treatment of threads.

It is known that, after spinning, textile threads may undergo various treatments, for example dyeing or coating. At present, these treatments are effected on thread bobbins, and sometimes on skeins, but their efficacity does not always present the desired homogeneity.

However, different processes are known for subjecting threads to certain treatments during the continuous advance movement thereof. Such continuous treatments generally consist in depositing a product on the thread to be treated, for example by passing this thread in a bath, then in eliminating the excess of treating fluid by scraping obtained for example by means of an air current circulating near the thread.

The continuous treatments of threads known up to the present day did not permit a precise dosing of the quantity of the product deposited nor a suitable penetration of this product in the thread. This was due in particular to the fact that the squeezing and possibly the drying of the thread by the air current were insufficient.

The invention firstly has for its object to remedy the above-mentioned disadvantages and relates to a process for squeezing and/or drying a humid thread, particularly a textile thread, utilizable in particular during a treatment, such as dyeing, effected continuously on said thread. According to the invention, the humid thread is passed through a zone through which passes an air current at a pressure much lower than the pressure prevailing around the thread during the operation having provoked its humidification.

According to an advantageous embodiment of the invention, the low pressure zone is created in the supersonic flow of an air current at the outlet of a convergent-divergent nozzle through which the thread passes.

Various other characteristics of this process and its execution will appear hereinafter in the course of the detailed description.

The invention also has for its object a particular application of the above-defined process, particularly for the purpose of making dyed zones and non-dyed zones appear successively in the course of dyeing a thread.

According to this latter application, after coming from a dyeing bath, the thread is passed into two convergent-divergent nozzles, the second of said nozzles being permanently fed by an air current whose pressure upstream of said nozzle is higher than the "critical" pressure at the constriction of this nozzle, whilst the first nozzle is fed by a current of air whose pressure upstream of said first nozzle is alternately higher then lower than the "critical" pressure at the constriction of this first nozzle.

Secondary characteristics of this particular application as well as its advantages will appear hereinafter, in the course of the detailed description.

Finally, the invention has for its object an apparatus enabling the above-defined process and its particular application to be carried out, for the purpose of effecting on threads all types of treatments, particularly dyeing, which are continuously applied during a rectilinear displacement of the thread. The present invention provides both a perfect homogeneity of the treated thread as well as high speed of the treatment.

However, it should be noted that the invention may be applied to all types of natural or synthetic, textile or metallic threads. The word thread as used herein means any supple element of very small diameter with respect to its length.

The apparatus comprises at least two elementary treatment chambers, each of them corresponding to a phase of the complete treatment that a thread must undergo. These elementary treatment chambers are aligned and a recovery zone is provided therebetween for the active products used in the elementary treatment chambers, at least in the first of them.

Each treatment chamber comprises two apertures for the inlet and outlet of the thread, these two apertures being aligned with those of the other treatment chambers in the direction of the thread and having a diameter close to this latter. The shape of these apertures depends upon the nature of the treatment and will be specified later. On the other hand, there opens out into each treatment chamber a pipe connected to a source of treatment fluid.

According to the invention, the recovery zone for the treatment fluids is shaped as a chamber which surrounds, in sealed manner, the outlet aperture of one treatment chamber as well as the inlet aperture of the following treatment chamber, whilst each treatment chamber fed with a chemically active fluid is followed by a treatment chamber fed by an inert gas, such as compressed air. Of course, the recovery chamber comprises at least one pipe connected to a recovery tank for a treatment fluid.

In fact, in practice, it is frequently advisable, particularly in the case of textile threads, to repeatedly dose the thread by an active agent. This is why, as has just been indicated, at least certain of the treatment chambers ensure only squeezing and/or drying operations and are consequently fed by an inert gas and disposed after each treatment chamber fed by an active fluid: dye, acid, etc.

The invention will moreover be more readily understood and its advantages as well as various secondary characteristics will appear in the course of the following description of a few embodiments given solely by way of example. To this end, reference will be made to the accompanying drawings, in which:

FIG. 1 is a schematic view of a first apparatus according to the invention.

FIG. 2 is a schematic view of a convergent-divergent nozzle equipping at least certain of the treatment chambers fed by an inert gas.

FIG. 3 is a schematic view of a second apparatus according to the invention, applicable in particular in the case of dyeing a textile thread.

FIG. 4, 5 and 6 show variants of the apparatus of FIG. 3 utilizable in particular when it is desired to obtain threads having treated zones alternating with non-treated zones.

The embodiment described with reference to FIG. 1 corresponds to the application to a thread of a known coating treatment. In particular, it enables the weight and the resistance to abrasion of a textile thread to be increased and to be made suitable for use in a sewing machine.

Such a treatment comprises the following active elementary phases:

a. attack of the thread by an acid bath containing the coating to be deposited on the thread;

b. neutralization of the deposit in order to obtain the precipitation of the coating molecules;

c. washing;

d. squeezing and drying.

Referring now to the drawings, it is seen that the apparatus permitting application of this treatment comprises, aligned along the path followed by the thread A, elementary treatment chambers **1**, **2**, **3**, **4**, **5** and **6**.

The chamber **1**, corresponding to the attack by the acid bath comprises a pipe **1***a* connected to a tank **10** of acid solution, by means of a pump **11**. The two apertures **1***b* and **1***c* of this chamber are capillary tubes whose diameter, function of that of the thread to be treated, is determined so as to avoid, or at least limit, the leaks of liquid by gravity or by drive. The pump **11** maintains a constant level of liquid in the chamber **1**.

On either side of the treatment chamber **1** are disposed two recuperation chambers **7** and **8**. They respectively surround, in sealed manner, the apertures **1***b* and **1***c* and have pipes **7***a* and **8***a* ensuring the recovery of the leakage liquid which is returned the tank **10**.

The treatment chambers **2**, **4** and **6** correspond to intermediate squeezing and possibly drying phases. Their ends are of course also surrounded in sealed manner by the recovery chambers **8**, **14**, **15**, **16**, **17** and **22**. In this case, however, the treatment fluid is compressed air passed through a main pipe **9** and terminating at the pipes **2***a*, **4***a*, **6***a* belonging to each of said chambers. It should be emphasized that the inlet and outlet apertures of these chambers **2**, **4** and **6** are each in the shape of a convergent-divergent nozzle, referenced **2***b* and **2***c* for the chamber **2**.

The convergent-divergent nozzles of chambers **2**, **4** and **6** are fed upstream by a pressure higher than or at least equal to the "critical" pressure at the constriction of the nozzle. It will be recalled on this subject that "-critical pressure" designates the pressure prevailing at the constriction of a nozzle and from which a supersonic flow is obtained in the divergent part of the nozzle, although the flow is subsonic in the convergent part thereof.

The nozzles used in the apparatus according to the invention are preferably set out according to known methods, so that, when they exist, the shock waves provoked by the return of the air to a subsonic speed are located outside the divergent part and not, as is frequently the case, inside said latter.

FIG. **2** shows such a nozzle which may be disposed at each end of the chambers **2**, **4** and **6**, or at least at one of said ends, preferably at the outlet end for the thread A. In this Figure, **50** designates the wall of the chamber, **51** the convergent part of the nozzle and **52** the divergent part.

P_o will designate the ambient pressure outside the nozzle and P_1 the pressure inside the chamber **50**. If the ratio P_1/P_o is higher than or equal to the critical value, which depends moreover on the shape of the nozzle, there is in the divergent part **52** a supersonic flow delimited by the line **53**. As is known, the supersonic flow originates at the constriction of the nozzle.

As mentioned above, the shock waves provoked by the return of the air to a subsonic speed appear at the end of the divergent part **52**. They have been shown by a solid line and a broken line, the first shock waves **54** being of course decompression waves. They develop along the substantially conical surface **54** and reflect on themselves at the apex **55** of this surface **54**. As is known, they then become decompression waves developing along the surface **56**. When they have reached the zone where the constant pressure P_o prevails, they reflect on this zone at **57** in order then to develop along surface **58** up to its apex **59**. It is known that, when shock waves reflect on a constant pressure zone, they change nature, so that the surface **58** is delimited by compression waves. Similar phenomena continue beyond the apex **59** but it is not necessary to describe them in order to understand the invention.

It may be said that there is, outside the divergent part **52**, a zone **60** delimited by a network of shock waves. It is known that the pressure p prevailing inside this zone **60** is much lower than the ambient pressure P_o outside the nozzle.

When the humid thread A penetrates into zone **60**, part of the liquid that it carries is instantaneously evaporated. This evaporation is due to the fact that the pressure in the zone **60** is much lower than that which existed around the thread during the preceding treatment which provoked its humidification.

An effect of squeezing and/or drying of the thread is thus obtained, the efficacity of which depends upon the output of air (quantity of air per unit time) passing through the zone **60**. In fact, the quantity of residual humidity of the thread at the outlet of the zone **60** depends solely upon the partial pressure of saturation of the liquid carried by the thread in this zone. Consequently, the output of air must be regulated as a function of the desired quantity of residual humidity. In other words, the output of air must be sufficient for evacuating the humidity released in the zone **60** and thus to maintain a partial saturation pressure therein which is sufficiently low for the evaporation to continue suitably.

It should be emphasized here that the squeezing and/or drying process which has just been described is carried out in the zone **60** whatever the direction of displacement of the thread may be. Thus, in the embodiment shown in the Figure, this process may be carried out either at the inlet, or at the outlet of the chamber **2**, **4** or **6**, or at the two places simultaneously. This will be of particular interest in the case of certain embodiments described later.

However, in the case where the thread penetrates into an inlet aperture such as **2***b*, there is added to the evaporation effect described hereinbefore, a purely mechanical squeezing of the thread near the constriction of the convergent-divergent nozzle. Thus, during the passage of the thread in the inlet aperture **2***b*, the combination may be obtained of pneumatic effects which ensure both the complete penetration of the thread by the acid solution brought during the passage into the chamber **1** and the regulation of the amount of the thread in acid solution, as well as the elimination by projection of the excess of acid solution, which is then taken up by the recovery pipe **8***a*.

The treatment chamber **3** is similar to chamber **1** and is fed by a neutralizing bath coming from a tank **12** by means of a pump **13**. It is the same for the chamber **5** which is fed by a washing bath coming from a tank **20** by means of a pump **21**.

On the other hand, the treatment chambers **4** and **6** are similar to chamber **2** and ensure, if necessary, an at least partial squeezing under the conditions that were explained above.

Finally, the pairs of recovery chambers **14–15** and **16–17** have the same characteristics and operate under the same conditions as the chambers **7–8**. They return the liquid recovered to tanks **18** and **19** respectively suitable for the recovery of the excess of liquid after neutralization or after washing.

The last treatment chamber **6** may open out into the free air; however, in certain cases, it may be advantageous, as shown in the drawing, to ensure a complete recovery of the air leaving this chamber. In fact, it may be charged with solid, liquid or gaseous particles which would be dangerous to allow to escape into the atmosphere.

To this end, the outlet aperture **6*b*** is prolonged by a recovery chamber **22** whose recovery pipe **22*a*** is inclined by about 45° on the axis of the thread. A conduit **22*b*** connected to the main pipe **9** for compressed air opens out into the chamber **22** and directs the fluid leaving through the aperture **6*b*** directly into the pipe **22*a***.

It is obvious that, for certain treatments, an arrangement, similar to that of chambers **6–22** may be provided for other pairs of treatment and recovery chambers.

Finally, if it is considered necessary, a drying by heating may be provided, either as an intermediate phase or as a final phase. As shown in the drawing, the thread passes through a capillary tube **23** surrounded by an isolating means in which a heating resistor **24** is embedded.

The above-described treatment may also take the form of a pure and simple attack of a polyamide thread by hydrochloric acid, the dissolution of a part of the polyamide being outside the thread forming the dissolution, the later treatment giving the effect of coagulation and leading to a final result of the same order as before. Such a treatment no longer necessitates any addition of polyamide on the outer surface of the thread.

Referring now to FIG. 3, an embodiment of the invention is shown which is applicable more particularly to the dyeing of threads. In this case, as has already been indicated above, it is essential suitably to dose the active product, in the present case the dye, and to be sure of the reproduceability of the modes of operation. The invention enables these conditions to be easily fulfilled.

The apparatus comprises a first treatment chamber **31** provided with a feed pipe **31*a*** connected to a dye tank **40** and equipped with a pump **41**. This treatment chamber comprises inlet and outlet apertures for the thread, constituted by capillary tubes **31*b*** and **31*c*** opening out into the recovery chambers **37** and **38**, which surround, in sealed manner, the ends of said tubes. Pipes **37*a***, **38*a*** ensure the return of the excess dye to the tank **40**. Moreover, it is judicious to provide in the treatment chamber itself a pipe **31*d*** also connected to the tank **40** to maintain a substantially constant level of the dyeing liquid to be maintained in the chamber **31**.

A second treatment chamber **32** is fed with compressed air guided through a pipe **32*a***. Of course, as has already been indicated, the inlet and outlet apertures of the thread **32*b*** and **32*c*** are constituted by convergent-divergent nozzles, preferably of the type such as those described hereinabove with reference to FIG. 2. In practice, it does not seem necessary to provide a recovery chamber at the outlet of the chamber **32** but such a recovery chamber may prove useful in certain particular cases.

Similarly, a heating element similar to that described with reference to FIG. 1 may be disposed at the outlet of the chamber **32**.

It should also be emphasized that the chamber **31** may be equipped with heating means, constituted for example by electrical resistors disposed inside the chamber or surrounding this latter. Tubes may also be used through which passes a heating fluid, such as vapor, such tubes being disposable inside or outside the chamber **31**. Similarly, the chamber **31** may be disposed inside an enclosure heated by any suitable means.

Such heating means will be useful where the solubility of the dye products should be increased or if it is necessary for the thread to undergo treatments such as bleaching and the application of finishes or those which modify the tinctorial affinity.

The functioning of such an apparatus is similar to that which was described above, but it seems useful to emphasize a few particular points.

In the same way as before, P_1 will designate the pressure of the air in the pipe **32*a*** and consequently in the chamber **32**, and P_o and P_2 the air pressures at the outlet of the aperture **32*c*** and in the chamber **38** respectively.

As soon as it enters in the aperture **32*b***, the thread A which brings with it a certain quantity of active agent, for example the dye liquid contained in the chamber **31**, meets a flow of gas which, as a function of the ratio P_2/P_2, may be subsonic, sonic or supersonic. As explained hereinabove, there may also be, near the aperture $_{32}b$, a combination of pneumatic effects ensuring a squeezing, which is mechanical and/or by evaporation which is all the more considerable as the speed of the flow is high. The excess of active agent is projected into the chamber **38** and returns to the tank **40**.

When the thread A has penetrated into the chamber **32**, there remains thereon a quantity of active agent, which is perfectly determined as a function of the conditions of the treatment, particularly of the speed of the thread and the P_2/P_1 ratio. Such conditions may easily be reproduced.

When the thread A arrives near the aperture **32*c***, it is subjected outside the divergent part to a decompression provoking the evaporation of the liquid which it is carrying. This is due, as has been seen, to the formation of a network of stationary shock waves, on condition that the ratio P_1/P_o is suitable and higher than the critical value which is easily calculated as a function of the dimensions of the convergent-divergent nozzle **32*c***. After the instantaneous evaporation of the liquid, only the dye remains on the thread.

In other words, the passage of the thread in the aperture 32*b* enables the dosage of the final dye to be determined, whilst its passage in the decompression zone located at the outlet of the aperture 32 enables its quantity of humidity to be considerably reduced without modifying the quantity of dye which is applied thereto.

The thread may then be subjected to dye-fixing, drying or other treatments.

It is obvious that as a function of the more or less dark shades which it is desired to obtain, a plurality of apparatus such as that one which has just been described may be disposed one after the other.

Such an apparatus may on the other hand be slightly modified, according to a first variant embodiment (FIG. 4), in order that the treatment of a thread, for example its dyeing according to a determined color, be limited to certain zones of the thread.

To this end, the pipe 32*a* is provided with an auxiliary conduit 33 capable of being placed in communication with a source of compressed air, the pressure P_3 of which is notably higher than that of the air conveyed by the pipe 32*a*. The Figure simply shows the conduit 34 carrying this compressed air at high pressure.

Means which have generally been designated by reference 35 enable the conduits 34 and 33 to be connected or on the contrary the air carried through conduit 34 to be directed towards the atmosphere through conduit 36, whilst isolating conduit 33. Various types of valves may be used, but it seems judicious to provide a fluid controlled binary trigger circuit shown schematically in FIG. 3 and comprising two control pipes 37, 37*a*. It is known that by means of a current of gas guided through pipe 37 or through pipe 37*a*, the main flow, which must then be supersonic, may be directed either towards the conduit 33 or towards the conduit 36 from conduit 34.

The operation is then as follows:

The pressure P_1 in the pipe 32*a* is firstly regulated so that it is higher than the critical pressure in the nozzle 32*c* but lower than the critical pressure in nozzle 32*b*. This latter characteristic may be obtained by suitably adjusting, in known manner, the pressure P_2 prevailing in the chamber 38, moreover taking into account the shape of the nozzle 32*b*.

Similarly, the pressure P_3 is regulated so that it is higher than the critical pressure in the nozzle 32*b* ; this pressure P_3 is then necessarily higher than the critical pressure in the nozzle 32*c*.

When the compressed air at high pressure P_3 carried by the conduit 34 is directed towards the chamber 32 through conduit 33, the operation is identical to that which was described hereinabove with reference to FIG. 3 : the thread brings inside the chamber 32 a dosed quantity of active liquid and is squeezed at the outlet of the aperture 32*c*.

If the air coming from conduit 34 is directed towards the atmosphere, the pressure reduces sharply in the chamber 32 and becomes lower than the critical pressure in the nozzle 32*b*. The flow through this nozzle therefrom becomes of the turbulent type. There is therefore no longer any evaporation before the nozzle 32*b* but solely a mechanical squeezing similar to atomization.

However, it is ascertained that this squeezing becomes very violent for a certain duration of time when the communication is re-established between the conduit 34 and the chamber 32. During this transitory period, during which the pressure in the chamber 32 tends to become again higher than the critical pressure at 32*b*, all the liquid carried by the thread is expelled therefrom, including the dye, before the thread penetrates into the chamber 32. It seems that this phenomenon may be explained by the fact that, as the speed of the air is always sonic at the constriction of the nozzle 32*c*, the waves of turbulence which move in the chamber 32 at sonic speed reflect on the barrier constituted at the constriction of 32*c* by the front of the supersonic flow in this nozzle 32*c*. The waves reflected at 32*c* move towards 32*b* and the energy that they convey is added to the energy normally dissipated in the nozzle 32*b*. Whatever the exact explanation of the phenomenon, it is ascertained that before entering into the chamber 32, the thread is in a practically identical state to that which it had when it entered in chamber 31 (FIG. 3).

The duration of this phenomenon is however limited : it depends of course on the respective values of P_3 and P_1 as well as on the volume constituted by the chamber 32 and the conduit 33. This phenomenon disappears however as soon as the equilibrium is reached and the pressure P_3 prevails in the chamber 32 and an operation similar to that of FIG. 3 is had again.

It is easily understood that a judicious succession of the two phases of operation enables portions of treated thread to be obtained which alternate with portions of nontreated thread.

These non-treated portions may then receive a different treatment, for example another dyeing, in a consecutive apparatus similar to that which has just been described. To this end, it will be judicious to ensure a coupling between the controls of the two fluid-controlled binary trigger circuits in order to obtain the regularity of the two successive treatments.

According to a second variant embodiment which may be seen in FIG. 5, the conduit 33 may be equipped with a generator 39 of sonic or supersonic vibrations. The operation is similar to that described with reference to FIG. 4 on condition that the conditions are such that the ratio P_1/P_2 is close to the critical ratio permitting the appearance of the shock waves near the aperture 32*b*, whilst being lower than this critical ratio.

When the generator 39 is started, a concentration of energy is ascertained, as in the preceding case, near the aperture 32*b*, ensuring the complete squeezing of the thread before it enters in the chamber 32.

Of course, there again, a plurality of consecutive apparatus may be provided for effecting different treatments on consecutive portions of the thread, thanks to a suitable coupling of the vibration generators.

According to a third variant embodiment shown in FIG. 6, the conditions of flow near the nozzle 32*b* may be modified by modifying only the pressure P_2 in the chamber 38 whilst maintaining the pressure P_1 in the chamber 32 constant. As may be seen, a vibrating reed whistle 39*a* has been disposed on the wall of the chamber 38. When the vibrating reed obturates the evacuation aperture of the whistle, the pressure P_2 increases so that the ratio P_1/P_2 reduces and becomes lower than the critical value. On the contrary, when the vibrating reed uncovers said evacuation aperture of the whistle, the conditions of flow in the nozzle **32*b*** tend towards the critical conditions provoking, in a manner similar to that explained hereinabove, a concentration of energy near **32*b*** and a complete squeezing of the thread before it enters in chamber **32**.

It should be noted that in this case, the vibration frequency of the whistle will be regulated as a function of the speed of the thread in order to obtain suitable lengths of treated thread and non-treated thread.

Of course, the invention is not limited to the embodiments that have just been described, but covers on the contrary all the variants thereto. In fact, it is an easy matter to conceive that the number, succession and dimensions of the various treatment and recovery chambers will have to be adapted to the characteristics of the elementary phases of a complex treatment, as well as to the nature of the thread to be treated. In particular, the succession without interruption of treatment chambers by active fluids may be envisaged, these latter being either liquid or gaseous or even constituted by suspensions of solid particles in liquids or gases.

What we claim is:

1. Process for the continuous treatment of a thread during the rectilinear displacement thereof which comprises:
   - passing said thread through a first treatment zone to subject said thread to a treatment liquid;
   - passing said thread through a recovery zone to recover excess treatment liquid; and
   - passing said thread through at least one convergent-divergent fluid nozzle while supplying gas to said nozzle at a pressure at least as great as the critical pressure of said nozzle thereby subjecting said thread to subsonic gaseous flow in the convergent part of said nozzle, supersonic gaseous flow in the divergent part of said nozzle and a network of shock waves located outside of the divergent part of said nozzle whereby said treatment liquid is evaporated from said thread.

2. Process according to claim 1 which includes the further steps of passing said thread through an additional plurality of serially connected treatment zones, recovery zones and convergent-divergent nozzles.

3. Process according to claim 1 wherein said step of supplying gas to said nozzle is regulated as a function of the desired quantity of residual humidity in the zone following said convergent-divergent nozzle.

4. Process for the continuous treatment of a thread during the rectilinear displacement thereof to produce treated and non-treated zones which comprises:
   - passing said thread through a treatment zone to subject said thread to a treatment liquid;
   - passing said thread through a recovery zone to recover excess treatment liquid;
   - passing said thread through first and second convergent-divergent fluid nozzles;
   - supplying gas to said second nozzle at a pressure at least as great as the critical pressure of said nozzle; and
   - supplying gas to said first nozzle at pressures alternately higher and lower than the critical pressure thereof whereby said second nozzle continuously dries said thread and said first nozzle dries said thread when supplied with gas above its critical pressure but expells said treatment liquid when supplied with gas below its critical pressure.

5. Process according to claim 4 wherein said step of supplying gas to said first nozzle at pressures alternately higher and lower than the critical pressure thereof is accomplished by supplying said gas at a constant pressure and intermittently generating sonic or supersonic vibrations in said gas.

6. Process according to claim 4 wherein said step of supplying gas to said first nozzle at pressures alternately higher and lower than the critical pressure thereof is accomplished by supplying said gas at constant pressure and alternately modifying the ambient pressure outside of said nozzle.

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