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BY AUTOGENOUS BONDING OF FILAMENTS

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2 Sheets-Sheet 1

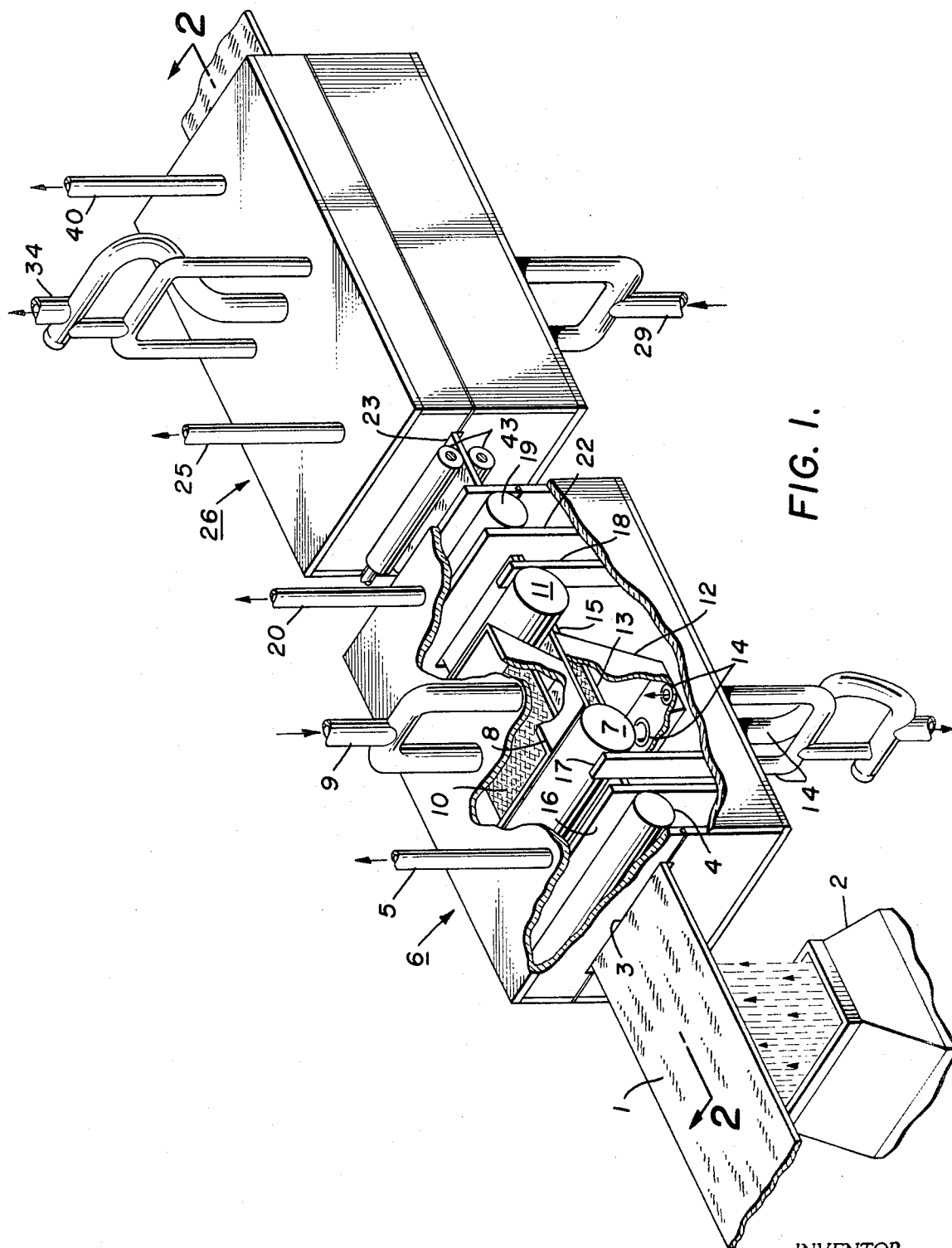


FIG. 1.

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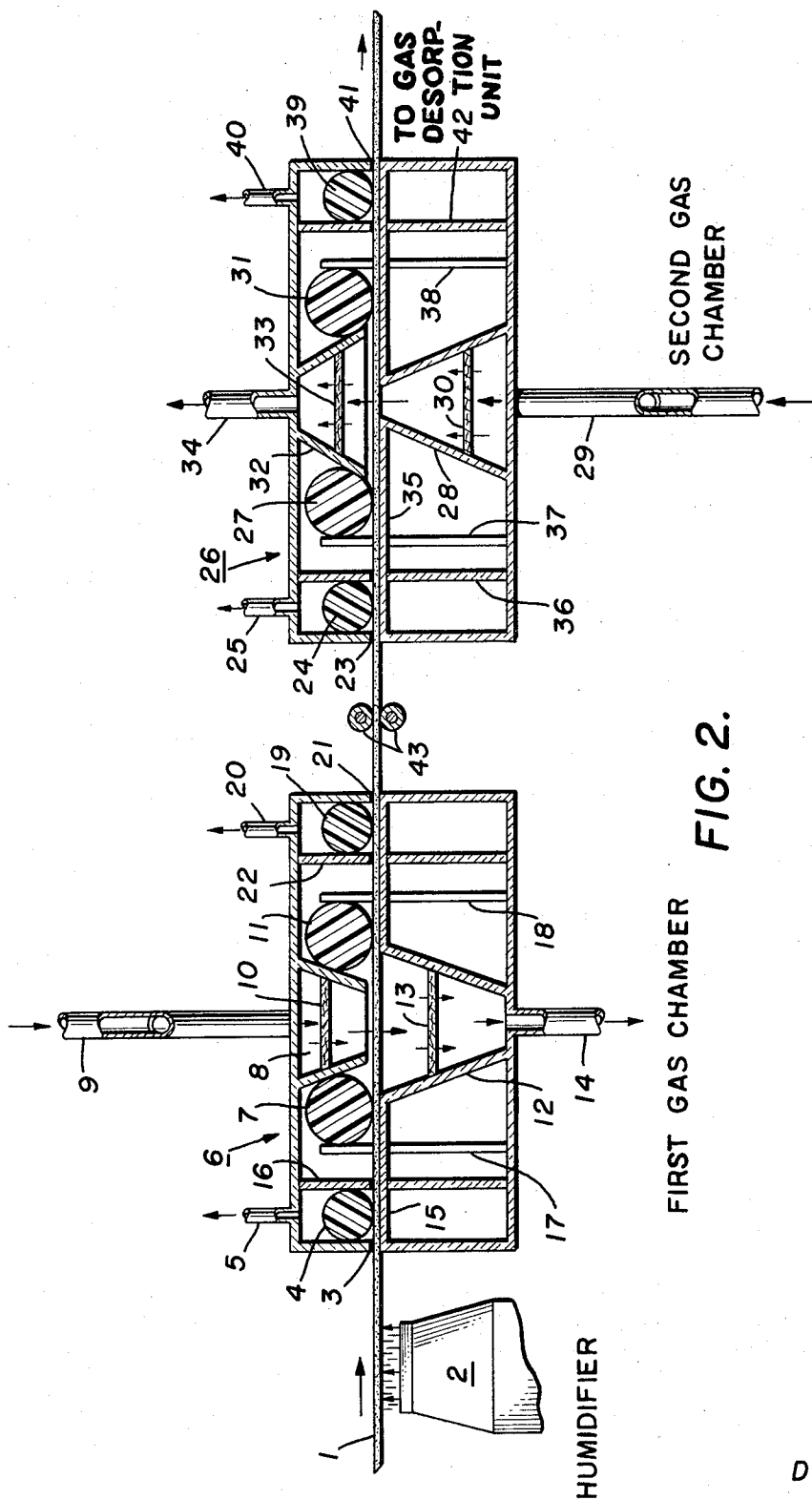
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PROCESS FOR FORMING HIGH STRENGTH SPUN-BONDED FABRIC BY AUTOGENOUS BONDING OF FILAMENTS

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6 Claims

ABSTRACT OF THE DISCLOSURE

A nonwoven web comprised of polyamide filaments which are bonded together at a substantial number of filament cross-over points by the absorption and subsequent desorption of a hydrogen halide gas is provided with increased web tenacity by elevating the moisture content of the filaments prior to bonding to at least 3% based on the filament weight.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention relates to a process for improving the tenacity of a nylon filamentary web by increasing the moisture content of the web prior to bonding with a hydrogen halide to at least 3% and to an apparatus for performing such process.

(2) Description of the prior art

The bonding of known nonwoven fabrics has been accomplished by the addition of external binders or by the softening of the fibers with heat, solvents, or plasticizers. External binders may be applied as a powder, solution, emulsion or even in the forms of other fibers. However, these methods suffer from several disadvantages. The use of an external binder presents problems in uniform application and may limit the properties of the entire web to those of the binder. Thus, if a fiber with a relatively low melting point is used as a bonding material, the temperature conditions to which the web or resulting fabric may be subjected are limited by the melting point of the binder fibers.

Autogenous bonding by known methods is difficult to control for the aesthetic properties of the web tend to be altered. For example, in solvent bonding, achieving adequate adhesion between touching fibers without dissolving the entire web or at least impairing the physical properties thereof is difficult. Furthermore, the intersections at which the fibers are bonded frequently evidence polymer migration which is the dissolving and redepositing of polymer. The bond sites which are swollen in appearance do not possess the same dye acceptance level due to a change in the crystalline structure in the polymer redeposited. The result is a web displaying a non-uniformity in dyeing.

Autogenous bonding by means of an activating gas was first disclosed in U.S. patent application, S.N. 528,699 to Henry E. Harris, now abandoned, and a method and apparatus for depositing continuous nylon filaments on a belt and bonding the filaments at their intersections by means of the absorption and desorption of an activating gas such as a hydrogen halide, and more specifically, hydrogen chloride, was disclosed in U.S. patent application, S.N. 646,720 to Emerick J. Dobo now Pat. No. 3,542,615. Basically, these applications disclose the extruding of a nylon melt to form continuous nylon filaments which are forwarded to a collection belt where they are received in the form of an unbonded nonwoven mat. The mat is then transferred to a gas cage or box which contains a particular activating gas, such as hydro-

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gen chloride, with the filaments absorbing the hydrogen chloride. Bonding between adjacent filaments occurs upon the removal or desorption of the hydrogen chloride from the nylon, desorption occurring by the application of heat or by immersion in a water bath.

It has been found that autogenous bonding of nylon filaments by the use of hydrogen halide gases to produce a nonwoven web results in webs having relatively low tenacities. Also, the resulting tenacities are unpredictable for the rate of bond formation is controlled only with difficulty. Furthermore, the rate at which the gas is absorbed by the nylon filaments is exceedingly slow.

SUMMARY OF THE INVENTION

In its broadest aspects, the present invention contemplates the formation of a nonwoven web being comprised of nylon filaments, the filaments being autogenously bonded together at a substantial number of filament cross-over points. The tensile strength of the web is increased by elevating the moisture or water content of the filaments to a range of from 3 to 6% based on the weight of the nylon filaments prior to the contact of the filaments with the activating gas.

The web may be comprised of continuous filaments or staple fibers or both and, along with nylon filaments, may include other filament systems such as polyester and polyolefins. However, this invention is best illustrated when the web is comprised of continuous nylon filaments made in accordance with the method set forth in U.S. patent application, S.N. 646,720 to Emerick J. Dobo et al.

The mat, which is the web in its unbonded state, is passed through a humidifying unit where the nylon filaments pick up at least 3% moisture based on the weight of the nylon. Alternatively, where the relative humidity is high, i.e. above about 40%, and time for absorption exist, the nylon filaments may pick up the required moisture from the ambient air. It has been found that the filaments must pick up at least 3% moisture in order to provide for rapid absorption of the hydrogen chloride gas by the filaments. In fact, the elevated moisture level, as herein taught, contributes greatly to the rate and quality of interfilament bonding, the quality being the interfilament bond strength of which web tensile strength is a direct function.

The total amount of moisture which the nylon filaments are able to absorb may slightly exceed 7½%; however, at moisture levels above 6%, bonding occurs too rapidly which results in the filaments being overbonded, overbonding being the state at which the polymer tends to migrate to the filament intersections. With the nylon filaments comprising the non-woven unbonded planar mat having absorbed a desired amount of moisture, the mat is passed through a first gas injection chamber which directs a flow of a hydrogen halide gas downwardly onto a selected mat surface. The mat is then passed through a second gas injection chamber which directs a second flow of gas onto the mat surface being opposed to the selected mat surface to achieve essentially complete contact of fibers by the gas. Bonding between adjacent and touching nylon filaments occurs by the removal of the gas from the mat. Removal or desorption is accomplished by either heating the web to approximately 150° F. or by immersing the web in a water bath. Testing of the bonded non-woven web shows that the tenacity of the web is greatly increased.

DESCRIPTION OF THE DRAWINGS

This invention can be more thoroughly understood by the following discussion, with reference to the drawings wherein;

FIG. 1 is a schematic isometric view of the apparatus for carrying out the process of this invention; and

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FIG. 2 is a section view taken along lines 2—2 of FIG. 1 which shows a nonwoven unbonded mat being carried through the apparatus of this invention (gas desorption to produce a bonded web is not shown).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The bonding apparatus of this invention is comprised of humidifying unit 2, first gas unit 6, second gas unit 26 and desorption unit (not shown). The first and second gas units are identical in structure except second gas unit 26 is inverted to allow for the mat to be treated with the hydrogen halide gas on both the top and bottom surfaces.

Humidifying unit 2 is of any convenient type wherein the rate of moisture supplied may be controlled to provide the unbonded nonwoven nylon mat with a moisture gain of from 3 to 6%. The moisture regardless of form (i.e. water vapor, relative humidity, water) may be referred to as the aqueous mass. In the following description of bonding units 6 and 26, only the first bonding unit 6 will be described, but reference will be made to each unit by using the reference numerals of both.

A continuous nylon 6, 6-filament moisture treated mat is removed from a conveyor belt (not shown) or the like and is fed to gas unit 6, 26 through opening 3, 23. The mat should have sufficient integrity to span short unsupported distances. Once in gas unit 6, 26, mat 1 travels on horizontal plate 15, 35 and under freely rotating dead weight roll 7, 27. Roll 7, 27 is supported by plate 15, 35 and resides between roll holder 17, 37 and the back side wall of gas chamber 8, 28. Roll 7, 27 serves primarily to aid in compacting any loose filaments that may have been disturbed prior to reaching hydrogen halide gas application chamber 8, 28 and provides a gas seal with the appropriate unit members.

Mat 1 is then passed across hydrogen halide treatment chamber 8, 28 and vacuum suction chamber 12, 32 and under second roll 11, 31 which rotates freely. Feed rolls 43 aid in forwarding mat 1 through the apparatus. First and second rolls 7, 27 and 11, 31 maintain the mat in a relatively taut condition during gas treatment by supporting and moving the mat at a speed which is identical to the peripheral speed of feed rolls 43. Second rolls 11, 31 also serves as an additional mechanical seal for application chamber 8, 28.

The hydrogen chloride or other activating gas which may be used for bonding is supplied to gas unit 6, 26 through gas application chamber inlet 9, 29. The flow rate under a given pressure is controlled by a rotometer (not shown) and a pressure gauge (not shown) of a known type. The gas inlet 9, 29 has orifices of the same size which are spaced apart to distribute the incoming gas uniformly across gas application chamber 8, 28. Further uniform distribution of the gas across the mat needed for uniform bonding is accomplished with 70–120 μ porous polyethylene diffusion baffles 10, 30 and 13, 33 placed in the gas application chamber 8, 28 and vacuum suction chamber 12, 32.

Gas application chamber 8, 28 is fabricated to accelerate the flow of gas as it approaches the surface of mat 1 so as to provide for gas penetration into the mat which results in uniform filament bonding throughout the thickness thereof. Gas acceleration is achieved by necking down application chamber 8, 28 as it approaches its orifice which is adjacent a selected surface of the mat to which the gas is applied. The largest penetrating force for the gas, however, is provided by the suction vacuum in vacuum suction chamber 12, 32.

Excess gas and air is exhausted through the outlet of vacuum suction chamber 12, 32 for recovery. The three outlet orifices 14, 34 are placed staggeringly with respect to the inlet orifices 9, 29 to maximize the uniform flow of gas across the mat.

Teflon rolls 7, 27 and 11, 31 provide a seal for the mat passage openings. Additional sealing of the openings

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may be provided with Teflon rolls 4, 24 and 19, 39 in conjunction with partition walls 16, 36 and 22, 42 and the exterior walls of gas units 6, 26. The provision is also made to remove the gas escaping the gas application chambers with load suction lines 5, 25 and 20, 40.

This invention provides an apparatus and method for continuously producing bonded nonwoven webs in which the activated gas penetrates the depth or thickness of the web. By varying the bonding conditions, this apparatus is capable of producing webs having properties which may adapt the ultimate nonwoven fabric for a variety of end uses. The main web properties which may be varied by altering the bonding conditions are tensile strength, extensibility, Stroll flex abrasion resistance, flexibility and appearance. For example, the amount of moisture absorbed by the web prior to bonding controls the inter-filament bond strength and, resultingly, the web tensile strength. The gas flow rate into the gas application chamber controls bending length of the web and its resistance to abrasion. The web exposure time to the gas controls the web tensile strength and appearance.

Example 1

This example serves as the control for nylon filaments comprising the mat contained only 2% water based on the weight of the nylon prior to being exposed to hydrogen chloride gas. A mat of continuous nylon 6, 6-filaments was prepared by a standard spunbonded process which includes spinning nylon filaments, attenuating the filaments and forwarding the filaments to a moving foraminous belt for collection. The mat, in its unbonded state, was subjected to the apparatus (as previously described) of this invention. The web had a fabric weight of 2.19 oz./yd.². The bonding conditions in the apparatus were as follows:

Apparatus bonding conditions	Gas unit	
	First	Second
HCl flow rate (gr./min.) at 5 p.s.i.g., 70° F.....	5.0	4.0
Exposure time (sec.).....	3.5	3.5
Suction vacuum (in. Hg).....	17.0	17.0

The resulting web, after washing in water (desorbing) at room temperature to remove the absorbed hydrogen chloride gas from the filaments to promote bonding had a tenacity of 4.4 lbs./in./oz./yd.².

Example 2

The procedure of Example 1 was followed exactly with the exception that the web was exposed to moisture and was allowed to absorb 5% water based on the weight of the web prior to being contacted with hydrogen chloride gas. The tenacity of the bonded web was 8.3 lbs./in./oz./yd.². It is to be noted that the web tenacity of this example almost doubled that of Example 1.

Example 3

In general, the procedure of Example 1 was followed with the exception that the web was allowed to absorb 4% water based on the weight of the web. The altered operating conditions were as follows:

Apparatus bonding conditions	Gas unit	
	First	Second
HCl flow rate (gr./min.) at 5 p.s.i.g., 70° F.....	3.2	4.0
Exposure time (sec.).....	3.5	3.5
Suction vacuum (in. Hg).....	27.0	3.0

The physical properties of the web were:

Fabric weight: 3.16 oz./yd.²
 Tenacity: 8.83 lbs./in./oz./yd.²
 Elongation: 63.5%
 Stroll flex abrasion resistance: 1395 cycles
 Bending length: 2.3 in.

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Example 4

The bonding procedure of Example 1 was repeated with the exception that the forced moisture regain of the web was approximately 5% based on the weight of the web. The operating conditions were as follows:

Apparatus bonding conditions	Gas unit	
	First	Second
HCl flow rate (gr./min.) at 5 p.s.i.g., 70° F.-----	4.0	5.6
Exposure time (sec.)-----	2.5	2.5
Suction vacuum (in. Hg)-----	16.0	16.0

The physical properties of the web were:

Fabric weight: 2.42 oz./yd.²
 Tenacity: 9.48 lbs./in./oz./yd.²
 Elongation: 42.0%
 Stroll flex abrasion resistance: 340 cycles
 Bending length: 2.74 in.

Example 5

The bonding procedure of Example 1 was repeated with the exception that the forced moisture regain of the web was approximately 4% based on the weight of the web.

Apparatus bonding conditions	Gas unit	
	First	Second
HCl flow rate (gr./min.) at 5 p.s.i.g., 70° F.-----	2.0	4.0
Exposure time (sec.)-----	1.0	1.0
Suction vacuum (in. Hg)-----	20.0	10.0

The physical properties of the web were:

Fabric weight: 1.25 oz./yd.²
 Tenacity: 9.18 lbs./in./oz./yd.²
 Elongation: 55.0%
 Stroll flex abrasion resistance: 250 cycles
 Bending length: 1.45 in.

Example 6

The unbonded mat was formed in accordance with Example 1 with the fabric weighing 0.6 oz./yd.². The mat was then exposed to an air atmosphere having a temperature of 70° F. and a relative humidity of 60%. The moisture content of the nylon filaments was raised to 3.19% based on the weight of the nylon filaments.

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The mat was then exposed to hydrogen chloride gas for 4 seconds after which the mat was immersed in water where the gas was removed or desorbed from the filaments and bonding between touching filaments occurred.

5 The resulting bonded web had a tenacity in the machine direction of 11.0 lbs./in./oz./yd.² and a tenacity in the transverse direction of 4.4 lbs./in./oz./yd.². The difference in strengths in the two directions results from the alignment of filaments predominately in the machine direction, such being a characteristic in the formation of light weight webs.

I claim:

1. A process for transforming an unbonded fibrous mat consisting primarily of nylon fibers into a high-
 15 strength nonwoven web comprising the steps of:

(a) associating said fibrous mat with an aqueous mass to provide said nylon fibers with a water content being at least 3% based on the weight of said nylon fibers;

20 (b) subjecting said mat to the action of a hydrogen halide gas to allow said nylon fibers to absorb a quantity of said gas; and

(c) desorbing said gas from said nylon fibers to bond said nylon fibers together at a substantial number
 25 of their touching cross-over points.

2. The process of claim 1 wherein said hydrogen halide gas is hydrogen chloride.

3. The process of claim 1 wherein the water content in said nylon fibers is from 3% to 6%.

30 4. The process of claim 1 wherein said nylon fibers are continuous nylon filaments.

5. The process of claim 4 wherein said web is comprised wholly of continuous nylon filaments.

35 6. The process of claim 5 wherein said process is continuous.

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