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PATENT

SCRIM INSERTED ELECTROSTATIC FIBROUS FILTER WEB5 Background and Field of the Invention

The present invention relates to a process for forming an electret nonwoven filter and products of such a process.

Nonwoven webs of electret fibers are
10 typically formed of loosely associated fibers. The filters can be electrostatically charged prior to, during, or after, being formed into a nonwoven web. For example, post-formation charging is described in U.S. Patent No. 4,588,537 which charges a lofty
15 nonwoven web formed by a variety of methods including carding and melt blowing. The webs are charged while under compression and then permitted to return to their original loft. This patent states that precharged fibers are preferably bipolar so that they tend to
20 resist crimping which is avoided by pre-crimping when using the charging method of this patent.

Fibers can also be charged while they are being formed, as disclosed in Kubik et al., U.S. Patent No. 4,215,682, where melt-blown fibers are bombarded by
25 ions or electrons immediately after being extruded from the melt-blowing orifices. The fibers solidify extremely rapidly in the atmosphere and are collected as a semi-coherent mass of entangled microfibers. The webs are described as preferably open to provide a low
30 pressure drop for liquid passing through the filter.

A particularly effective method of forming a nonwoven electret fiber filter is described in U.S. Reissue Patent No. 30,782 (Van Turnout et al.). The electret fibers in this patent are formed from a corona
35 charged film that is fibrillated to form the charged fibers. The charged fibers can then be formed into a nonwoven web by common methods such as carding or air

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laying. This charging method provides a particularly high density of injected charges. However, problems are encountered with forming webs from these precharged fibers. The fibers are generally quite large and
5 uncrimped. They also have a resistance to bending. Due in part to these properties, the fibers resist formation into a uniform coherent web, particularly at low basis weights. This problem is partially addressed in U.S. Patent No. 4,363,682, which proposes the use of
10 such filibrated fiber webs in face mask applications. In order to provide a more coherent web, as well as one that resists shedding fibers, this patent proposes a post-embossing treatment. This post-embossing welds the outer surface fibers together allegedly providing a
15 more coherent and comfortable web for use as a face mask. However, this treatment will also tend to result in a more condensed web, which would increase pressure loss over the filter.

20 Brief Description of the Invention

A uniform electret fiber web filter is obtained by forming a web of charged fibers, placing the charged fiber web onto an open, substantially non-extensible, scrim support material, and then needle-
25 punching the composite material to provide a highly uniform filter web.

Brief Description of the Drawing

Fig. 1 is a schematic representation of a
30 preferred process arrangement according to the invention method.

Fig. 2 is a plot of percent reduction in three properties coefficient of variability versus nominal basis weight for invention filters and
35 comparable filters without the use of scrims.

Detailed Description of the Preferred Embodiments



Fig. 1 represents an apparatus arrangement 1 for practicing the present invention. The fibrillated fibers are formed into a nonwoven web 10 by card 2. The web can then be feed to a randomizer 3 to increase 5 basis weight. The randomizer would typically be a set of intermeshing metallic wire (e.g., V-grooves) rollers. Additionally, a second web (not shown) could be taken off card 2, treated likewise, and then joined to web 10. This allows for greater flexibility in the 10 choice of basis weights. The scrim 11 is fed from a supply roll 4 onto the filter web 10. However, the scrim 11 could also be fed upstream of the card 2' so that the web 10' is laid onto the scrim 11. In a preferred arrangement, a second card 2' is used so that 15 the scrim is a center layer between two outer nonwoven filter layers. This is shown in Fig. 1 by a second card arrangement with identical numbering. Likewise, a second web could be taken off card 2' and joined to web 10'. The two webs 10 and 10' can be of differing basis 20 weights. The use of two webs provides particularly uniform filter webs of low variability.

The precharged fibers are preferably formed by the method described in U.S. Patent Reissue Nos. 30,782 and 31,285. The fibers, as such, are formed 25 from an electrostatically charged (e.g., by a corona discharge electrode) film that has been fibrillated to provide fibers with a substantially rectangular cross-section.

The web 10 and scrim 11 are then fed to a 30 needling station 5 where the web 10 is joined to the scrim by the action of the needles to form the filter web 12. The needles will preferably penetrate a web layer first to transversely displace fibers securely down into the scrim and promote the fibers to interlock 35 the scrim, and in the preferred arrangement with fibers of an underlying web 10'. The needles can be arranged to penetrate the filter web 12 composite between about



10 and 300 penetrations per cm^2 . However, higher needling densities tend to compact the filter web 12, increasing pressure loss through the filter.

Preferably, the needling is less than 75 penetrations
5 per cm^2 . The needle-punched joined composite is then collected on take-up roll 6 for subsequent converting.

Webs typically formed from carding operations are anisotropic with larger amounts of fiber orientation in the machine direction, which generally
10 allows for web-handling stability in this direction. However, lower basis weight webs are less easily handled. A practice in the past to improve nonwoven web handleability has been to needle-punch the webs to increase interfiber bonding. However, generally this
15 has been found to be disruptive to electret web uniformity. This disruption in web uniformity has been found to be particularly problematic when a randomizer is used to increase the web nominal basis weight.

Unexpectedly, it has been found that the use
20 of needle-punching treatments on an electret fibrillated nonwoven web can significantly increase the electret web uniformity when the web is needled to an underlying scrim support. Particularly good uniformity results are obtained where two webs are needled to a
25 scrim between the two webs. The coefficient of variability of these scrim supported filter webs decreases remarkably compared to similar webs prepared without the scrim support.

The scrim material can be any known
30 reinforcement scrim, woven or nonwoven. Nonwoven scrims are generally preferred in terms of cost and degree of openness. The scrim material is also preferably polymeric, and for purposes of recyclability, preferably formed of a polymer
35 compatible with the material of the electret nonwoven web. A scrim of nonwoven material will generally be



treated to increase tensile properties such as by thermoembossing, calandaring, sonic bonding, binder fibers or the like. A typical scrim material would be a spunbond polypropylene nonwoven web.

5 The precharged electret fibers are preferably formed from a dielectric film that is capable of being corona charged and then fibrillated. Suitable film forming materials include polyolefins, such as polypropylene, linear low density polyethylene, poly-1-
10 butene, polytetrafluoroethylene, polytrifluorochloroethylene; or polyvinylchloride; aromatic polyarenes; such as polystyrene; polycarbonates; polyesters; and copolymers and blends thereof. Preferred are polyolefins free of branched
15 alkyl radicals and copolymers thereof. Particularly preferred are polypropylene and polypropylene copolymers. Various functional additives known in the art can be blended with the dielectric polymers or copolymers such as poly(4-methyl-1-pentene) as taught
20 in U.S. Patent No. 4,874,399, a fatty acid metal salt, as disclosed in U.S. Patent No. 4,789,504, or particulates, as per U.S. Patent No. 4,456,648.

The disclosed process is also seen as applicable to other methods of forming charged fibers
25 into webs include air laying, electrostatic deposition, Rando webs and the like. Like problems with forming charged fibers into uniform webs are encountered with these web formation methods.

30

Examples

1-5

A fibrillated nonwoven fiber web was made according to the apparatus described in FIG. 1 using a randomizer and a scrim (Examples C1-C5). The scrim was sandwiched between two webs from cards 2 and 2'. The
35 fibers were polypropylene fibrillated electrets formed according to U.S. RE No. 30,782. These webs were compared to similar webs without an inserted scrim.



The inserted scrim was a commercially available spunbonded fleece with a basis weight of about 10 gram/m² (Lutrasil™, available from Karl Freudenberg, Kaiserslautern, Germany).

- 5 The basis weight (BW) of the webs were determined by weighing a disc with an area of 100 cm² and converted to grams/m². The penetration and the pressure drop of the media was measured on a TSI Automatic Filter Testing machine type 8110, TSI Inc.,
10 Minneapolis, MN, based on a test area of 50 cm² and an air velocity of 0.2 m/s. The air contained an NaCl aerosol where the penetration is the ratio of NaCl concentration downstream and upstream of the filter divided by 100. The Coefficient of Variation (COV),
15 defined as the ratio of the standard deviation and the basis weight, was calculated from a sampling of web properties of at least 7 locations on the web. The results are given in Tables 1 and 2.

- The Quality Factor Q is defined
20 mathematically by the expression

$$Q = \frac{-\ln(\%P/100)}{\Delta P}$$

- 25 where %P is the percent penetration, ΔP is the pressure drop in Pascal, and ln indicates the natural logarithm. This value is always positive and increases with reduced penetration. Conversely, as pressure drop increases, the Q value is reduced. Q is generally an
30 index which is independent of the basis weight. Thus, Q may be used to compare the filtration performance of webs of different basis weights.





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TABLE I

Example	Average g/m ²	Average Q l/Pa	Average ΔP	Average %P	% COV BW	% COV ΔP	% COV %P
1	60.2	0.21	5.0	17.90	5.6	9.7	8.7
2	93.6	0.19	10.0	15.80	5.1	8.2	7.0
3	153.7	0.15	23.10	3.39	2.8	6.7	13.9
4	207.9	0.14	31.5	1.39	4.1	6.7	20.9
5	260.8	0.11	45.2	0.58	3.7	6.0	13.6



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TABLE II

Type	ave. BW ¹ g/m ²	% COV BW	Ave %P	% COV %P	ΔP Pa	%COV ΔP	Avg Q, 1/Pa
6	54.63	3.15	28.76	5.1	5.2	3.2	0.24
7	94.57	3.4	12.89	7.3	8.0	6.9	0.26
8	143.00	2.8	4.00	11.2	15.1	7.9	0.21
9	191.63	3.0	1.65	12.2	25.2	5.4	0.16
10	205.79	1.8	1.28	10.9	27.5	2.9	0.16
11	244.07	3.4	0.65	17.5	36.5	6.7	0.14
C1	64.7	8.7	29.0	16.8	4.4	15.9	0.29
C2	112.63	6.7	8.97	20.1	9.1	15.7	0.27
C3	153.17	4.2	3.31	23.6	15.9	12.6	0.21
C4	191.20	4.5	1.91	33.0	24.3	10.1	0.16
C5	242.06	5.4	1.33	24.0	36.2	7.1	0.12

1. The basis weights were adjusted to exclude the nonwoven scrim.

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The COV values for comparable basis weight webs decreased significantly for the invention example webs 1-11 compared to similar webs produced without reinforcement scrims (Comparative examples C1-C5). The 5 most significant reductions in COV values were noted for lower basis weight webs (e.g., less than about 120 g/m²). This improvement is graphically summarized in Fig. 2 where the y axis represents the % reduction in COV of the scrim inserted examples compared to the non- 10 scrim examples. The x axis designates the nominal basis weights of the webs compared. The A columns represent the basis weight, the B columns the penetration, and the C columns the pressure drop.

The various modifications and alterations of 15 this invention will be apparent to those skilled in the art without departing from the scope and spirit of this invention, and this invention should not be restricted to that set forth herein for illustrative purposes.

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I claim:

1. A method for forming an electret
nonwoven filter web comprising the steps of
 - 5 a) providing electrostatically charged
dielectric fibers,
 - b) forming the electrostatically charged
fibers into at least one nonwoven filter web (10)
characterized by,
 - 10 c) joining the at least one filter web to a
reinforcement scrim (11), and
 - d) needle punching (5) the at least one
filter web (10) and reinforcement scrim (11) to
form a filter web (12) with uniform properties
15 across the web.
2. The method of claim 1 wherein the
electrostatically charged fibers are formed by
fibrillation of an electrostatically charged web.
20
3. The method of claim 2 wherein the fibers
have substantially rectangular cross-sections.
4. The method of claim 1 wherein the
25 reinforcement scrim (11) is an inner layer between two
outer filter web layers (10, 10').
5. The method of claim 1 wherein the at
least one nonwoven filter web (10) is formed by
30 carding.
6. The method of claim 5 further comprising
randomizing the carded filter web (10) prior to joining
with the scrim reinforcement (12).
35





7. The method of claim 1 wherein the fiber is a polypropylene polymer or copolymer fiber and the scrim reinforcement is a spunbond polypropylene polymer or copolymer nonwoven.

5

8. A uniform electret nonwoven filter comprising at least one nonwoven filter web (10) of electrostatically charged dielectric fibers characterized in that the web (10) is joined to a
10 reinforcement scrim (11) by needlepunching.

9. The electret nonwoven filter of claim 8 wherein the dielectric fibers are fibrillated from an electrostatically charged film of a film forming
15 polymer.

10. The electret nonwoven filter of claim 9 wherein the fibers are polypropylene polymers or copolymers.

20

11. The electret nonwoven filter of claim 8 wherein the reinforcement scrim (11) is a center layer between two outer layers (10, 10') of the nonwoven filter web.

25

12. The electret nonwoven filter of claim 8 wherein the nonwoven filter web (10) is a carded web

13. The electret nonwoven filter of claim 12
30 wherein the nonwoven filter web (10) is randomized.

14. The electret nonwoven filter of claim 8 wherein the nonwoven web material has a total basis weight of less than 120 gm/m².

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SCRIM INSERTED ELECTROSTATIC FIBROUS FILTER WEB

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Abstract of the Disclosure

Provided is a nonwoven web of electrically charged
fibers needle-punched to a scrim support. This web
provides a filter medium having increased uniformity in
10 pressure-drop, basis weight and filtration performance.

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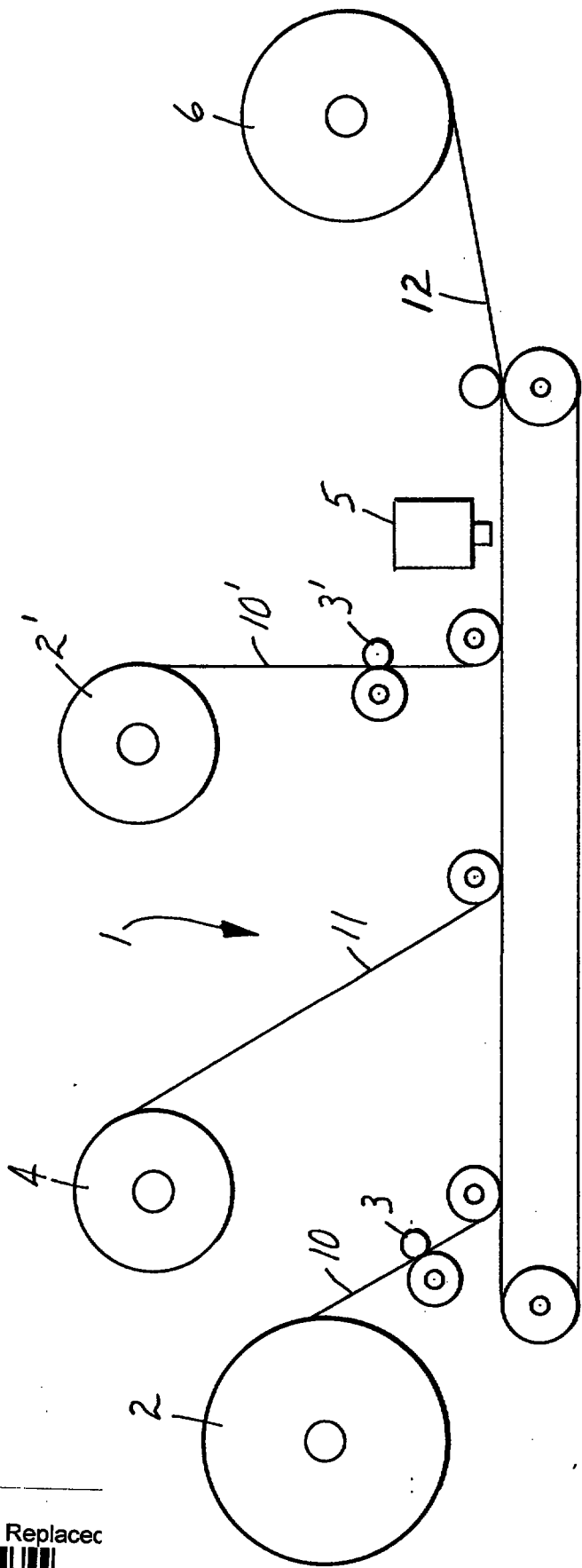


FIG.1



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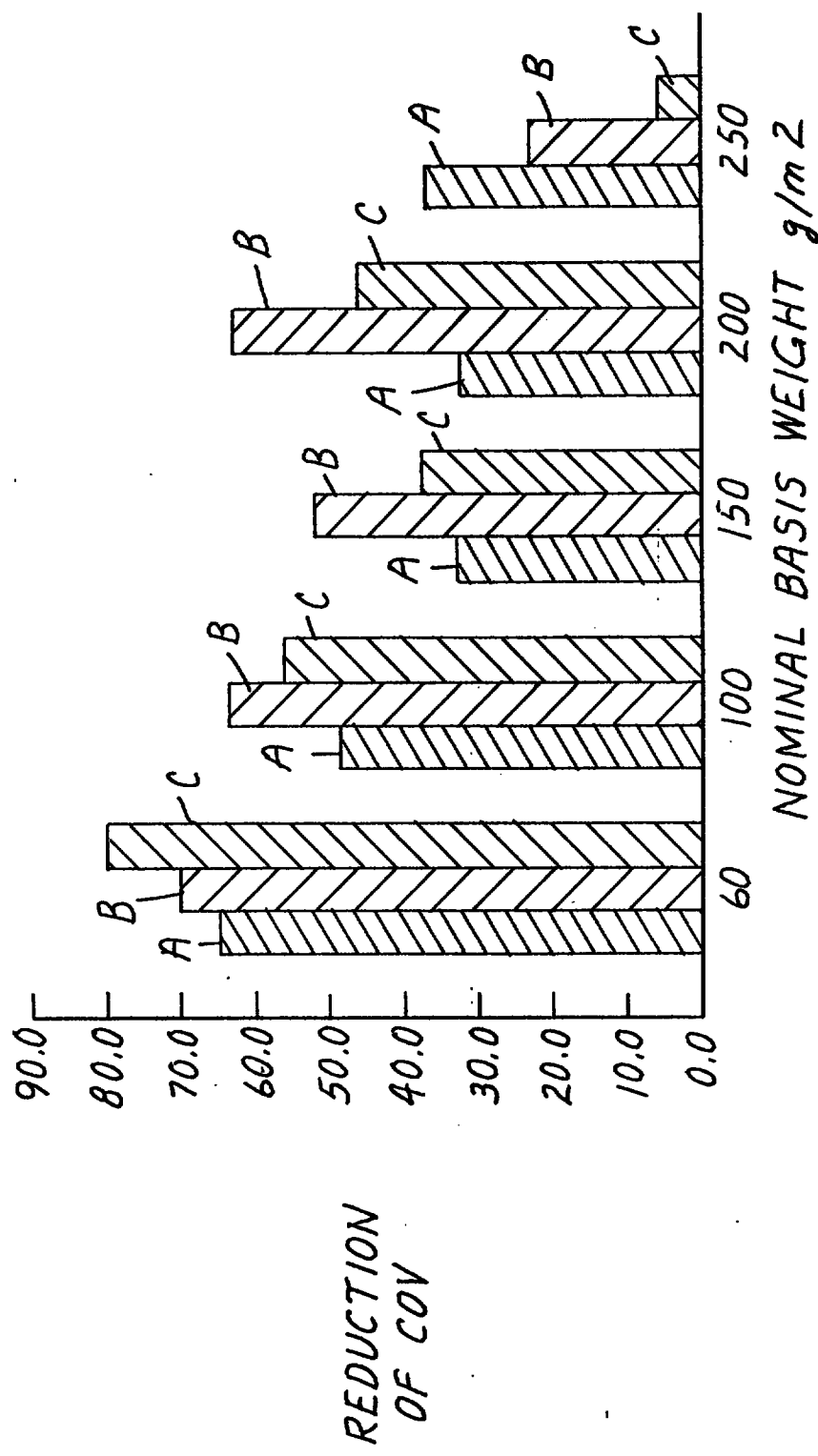


FIG. 2



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SCRIM INSERTED ELECTROSTATIC FIBROUS FILTER WEB5 Background and Field of the Invention

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Nonwoven webs of electret fibers are typically formed of loosely associated fibers. The filters can be electrostatically charged prior to, during, or after, being formed into a nonwoven web. For example, post-formation charging is described in U.S. Patent No. 4,588,537 which charges a lofty nonwoven web formed by a variety of methods including carding and melt blowing. The webs are charged while under compression and then permitted to return to their original loft. This patent states that precharged fibers are preferably bipolar so that they tend to resist crimping which is avoided by pre-crimping when using the charging method of this patent.

Fibers can also be charged while they are being formed, as disclosed in Kubik et al., U.S. Patent No. 4,215,682, where melt-blown fibers are bombarded by ions or electrons immediately after being extruded from the melt-blowing orifices. The fibers solidify extremely rapidly in the atmosphere and are collected as a semi-coherent mass of entangled microfibers. The webs are described as preferably open to provide a low pressure drop for liquid passing through the filter.

A particularly effective method of forming a nonwoven electret fiber filter is described in U.S. Reissue Patent No. 30,782 (Van Turnout et al.). The electret fibers in this patent are formed from a corona charged film that is fibrillated to form the charged fibers. The charged fibers can then be formed into a nonwoven web by common methods such as carding or air

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laying. This charging method provides a particularly high density of injected charges. However, problems are encountered with forming webs from these precharged fibers. The fibers are generally quite large and
5 uncrimped. They also have a resistance to bending. Due in part to these properties, the fibers resist formation into a uniform coherent web, particularly at low basis weights. This problem is partially addressed in U.S. Patent No. 4,363,682, which proposes the use of
10 such filibrated fiber webs in face mask applications. In order to provide a more coherent web, as well as one that resists shedding fibers, this patent proposes a post-embossing treatment. This post-embossing welds the outer surface fibers together allegedly providing a
15 more coherent and comfortable web for use as a face mask. However, this treatment will also tend to result in a more condensed web, which would increase pressure loss over the filter.

20 Brief Description of the Invention

A uniform electret fiber web filter is obtained by forming a web of charged fibers, placing the charged fiber web onto an open, substantially non-extensible, scrim support material, and then needle-
25 punching the composite material to provide a highly uniform filter web.

Brief Description of the Drawing

Fig. 1 is a schematic representation of a
30 preferred process arrangement according to the invention method.

Fig. 2 is a plot of percent reduction in three properties coefficient of variability versus nominal basis weight for invention filters and
35 comparable filters without the use of scrims.

Detailed Description of the Preferred Embodiments

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Fig. 1 represents an apparatus arrangement 1 for practicing the present invention. The fibrillated fibers are formed into a nonwoven web 10 by card 2. The web can then be feed to a randomizer 3 to increase 5 basis weight. The randomizer would typically be a set of intermeshing metallic wire (e.g., V-grooves) rollers. Additionally, a second web (not shown) could be taken off card 2, treated likewise, and then joined to web 10. This allows for greater flexibility in the 10 choice of basis weights. The scrim 11 is fed from a supply roll 4 onto the filter web 10. However, the scrim 11 could also be fed upstream of the card 2' so that the web 10' is laid onto the scrim 11. In a preferred arrangement, a second card 2' is used so that 15 the scrim is a center layer between two outer nonwoven filter layers. This is shown in Fig. 1 by a second card arrangement with identical numbering. Likewise, a second web could be taken off card 2' and joined to web 10'. The two webs 10 and 10' can be of differing basis 20 weights. The use of two webs provides particularly uniform filter webs of low variability.

The precharged fibers are preferably formed by the method described in U.S. Patent Reissue Nos. 30,782 and 31,285. The fibers, as such, are formed 25 from an electrostatically charged (e.g., by a corona discharge electrode) film that has been fibrillated to provide fibers with a substantially rectangular cross-section.

The web 10 and scrim 11 are then fed to a 30 needling station 5 where the web 10 is joined to the scrim by the action of the needles to form the filter web 12. The needles will preferably penetrate a web layer first to transversely displace fibers securely down into the scrim and promote the fibers to interlock 35 the scrim, and in the preferred arrangement with fibers of an underlying web 10'. The needles can be arranged to penetrate the filter web 12 composite between about

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10 and 300 penetrations per cm^2 . However, higher needling densities tend to compact the filter web 12, increasing pressure loss through the filter.

Preferably, the needling is less than 75 penetrations
5 per cm^2 . The needle-punched joined composite is then collected on take-up roll 6 for subsequent converting.

Webs typically formed from carding operations are anisotropic with larger amounts of fiber orientation in the machine direction, which generally
10 allows for web-handling stability in this direction. However, lower basis weight webs are less easily handled. A practice in the past to improve nonwoven web handleability has been to needle-punch the webs to increase interfiber bonding. However, generally this
15 has been found to be disruptive to electret web uniformity. This disruption in web uniformity has been found to be particularly problematic when a randomizer is used to increase the web nominal basis weight.

Unexpectedly, it has been found that the use
20 of needle-punching treatments on an electret fibrillated nonwoven web can significantly increase the electret web uniformity when the web is needled to an underlying scrim support. Particularly good uniformity results are obtained where two webs are needled to a
25 scrim between the two webs. The coefficient of variability of these scrim supported filter webs decreases remarkably compared to similar webs prepared without the scrim support.

The scrim material can be any known
30 reinforcement scrim, woven or nonwoven. Nonwoven scrims are generally preferred in terms of cost and degree of openness. The scrim material is also preferably polymeric, and for purposes of recyclability, preferably formed of a polymer
35 compatible with the material of the electret nonwoven web. A scrim of nonwoven material will generally be



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treated to increase tensile properties such as by thermoembossing, calandaring, sonic bonding, binder fibers or the like. A typical scrim material would be a spunbond polypropylene nonwoven web.

5 The precharged electret fibers are preferably formed from a dielectric film that is capable of being corona charged and then fibrillated. Suitable film forming materials include polyolefins, such as polypropylene, linear low density polyethylene, poly-1-
10 butene, polytetrafluoroethylene, polytrifluorochloroethylene; or polyvinylchloride; aromatic polyarenes; such as polystyrene; polycarbonates; polyesters; and copolymers and blends thereof. Preferred are polyolefins free of branched
15 alkyl radicals and copolymers thereof. Particularly preferred are polypropylene and polypropylene copolymers. Various functional additives known in the art can be blended with the dielectric polymers or copolymers such as poly(4-methyl-1-pentene) as taught
20 in U.S. Patent No. 4,874,399, a fatty acid metal salt, as disclosed in U.S. Patent No. 4,789,504, or particulates, as per U.S. Patent No. 4,456,648.

The disclosed process is also seen as applicable to other methods of forming charged fibers
25 into webs include air laying, electrostatic deposition, Rando webs and the like. Like problems with forming charged fibers into uniform webs are encountered with these web formation methods.

30

Examples

A fibrillated nonwoven fiber web was made according to the apparatus described in FIG. 1 using a randomizer and a scrim (Examples C1-C5). The scrim was sandwiched between two webs from cards 2 and 2'. The
35 fibers were polypropylene fibrillated electrets formed according to U.S. RE No. 30,782. These webs were compared to similar webs without an inserted scrim.



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The inserted scrim was a commercially available spunbonded fleece with a basis weight of about 10 gram/m² (Lutrasil™, available from Karl Freudenberg, Kaiserslautern, Germany).

5 The basis weight (BW) of the webs were determined by weighing a disc with an area of 100 cm² and converted to grams/m². The penetration and the pressure drop of the media was measured on a TSI Automatic Filter Testing machine type 8110, TSI Inc.,
10 Minneapolis, MN, based on a test area of 50 cm² and an air velocity of 0.2 m/s. The air contained an NaCl aerosol where the penetration is the ratio of NaCl concentration downstream and upstream of the filter divided by 100. The Coefficient of Variation (COV),
15 defined as the ratio of the standard deviation and the basis weight, was calculated from a sampling of web properties of at least 7 locations on the web. The results are given in Tables 1 and 2.

 The Quality Factor Q is defined
20 mathematically by the expression

$$Q = \frac{-\ln(\%P/100)}{\Delta P}$$

25 where %P is the percent penetration, ΔP is the pressure drop in Pascal, and ln indicates the natural logarithm. This value is always positive and increases with reduced penetration. Conversely, as pressure drop increases, the Q value is reduced. Q is generally an
30 index which is independent of the basis weight. Thus, Q may be used to compare the filtration performance of webs of different basis weights.

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TABLE I

Example	Average g/m ²	Average Q 1/Pa	Average ΔP	Average %P	% COV BW	% COV ΔP	% COV %P
1	60.2	0.21	5.0	17.90	5.6	9.7	8.7
2	93.6	0.19	10.0	15.80	5.1	8.2	7.0
3	153.7	0.15	23.10	3.39	2.8	6.7	13.9
4	207.9	0.14	31.5	1.39	4.1	6.7	20.9
5	260.8	0.11	45.2	0.58	3.7	6.0	13.6



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TABLE II

Type	ave. BW ¹ g/m ²	% COV BW	Ave %P	% COV %P	ΔP Pa	%COV ΔP	Avg Q, 1/Pa
6	54.63	3.15	28.76	5.1	5.2	3.2	0.24
7	94.57	3.4	12.89	7.3	8.0	6.9	0.26
8	143.00	2.8	4.00	11.2	15.1	7.9	0.21
9	191.63	3.0	1.65	12.2	25.2	5.4	0.16
10	205.79	1.8	1.28	10.9	27.5	2.9	0.16
11	244.07	3.4	0.65	17.5	36.5	6.7	0.14
C1	64.7	8.7	29.0	16.8	4.4	15.9	0.29
C2	112.63	6.7	8.97	20.1	9.1	15.7	0.27
C3	153.17	4.2	3.31	23.6	15.9	12.6	0.21
C4	191.20	4.5	1.91	33.0	24.3	10.1	0.16
C5	242.06	5.4	1.33	24.0	36.2	7.1	0.12

1. The basis weights were adjusted to exclude the nonwoven scrim.

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The COV values for comparable basis weight webs decreased significantly for the invention example webs 1-11 compared to similar webs produced without reinforcement scrims (Comparative examples C1-C5). The most significant reductions in COV values were noted for lower basis weight webs (e.g., less than about 120 g/m²). This improvement is graphically summarized in Fig. 2 where the y axis represents the % reduction in COV of the scrim inserted examples compared to the non-scrim examples. The x axis designates the nominal basis weights of the webs compared. The A columns represent the basis weight, the B columns the penetration, and the C columns the pressure drop.

The various modifications and alterations of this invention will be apparent to those skilled in the art without departing from the scope and spirit of this invention, and this invention should not be restricted to that set forth herein for illustrative purposes.



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I claim:

1. A method for forming an electret nonwoven filter web comprising the steps of
 - 5 a) providing electrostatically charged dielectric fibers,
 - b) forming the electrostatically charged fibers into at least one nonwoven filter web (10) characterized by,
 - 10 c) joining the at least one filter web to a reinforcement scrim (11), and
 - d) needle punching (5) the at least one filter web (10) and reinforcement scrim (11) to form a filter web (12) with uniform properties
 - 15 across the web.
2. The method of claim 1 wherein the electrostatically charged fibers are formed by fibrillation of an electrostatically charged web.
- 20 3. The method of claim 2 wherein the fibers have substantially rectangular cross-sections.
4. The method of claim 1 wherein the
- 25 reinforcement scrim (11) is an inner layer between two outer filter web layers (10, 10').
5. The method of claim 1 wherein the at least one nonwoven filter web (10) is formed by
- 30 carding.
6. The method of claim 5 further comprising randomizing the carded filter web (10) prior to joining with the scrim reinforcement (12).

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7. The method of claim 1 wherein the fiber is a polypropylene polymer or copolymer fiber and the scrim reinforcement is a spunbond polypropylene polymer or copolymer nonwoven.

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8. A uniform electret nonwoven filter comprising at least one nonwoven filter web (10) of electrostatically charged dielectric fibers characterized in that the web (10) is joined to a
10 reinforcement scrim (11) by needlepunching.

9. The electret nonwoven filter of claim 8 wherein the dielectric fibers are fibrillated from an electrostatically charged film of a film forming
15 polymer.

10. The electret nonwoven filter of claim 9 wherein the fibers are polypropylene polymers or copolymers.

20

11. The electret nonwoven filter of claim 8 wherein the reinforcement scrim (11) is a center layer between two outer layers (10, 10') of the nonwoven filter web.

25

12. The electret nonwoven filter of claim 8 wherein the nonwoven filter web (10) is a carded web

13. The electret nonwoven filter of claim 12
30 wherein the nonwoven filter web (10) is randomized.

14. The electret nonwoven filter of claim 8 wherein the nonwoven web material has a total basis weight of less than 120 gm/m².

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SCRIM INSERTED ELECTROSTATIC FIBROUS FILTER WEB

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Abstract of the Disclosure

Provided is a nonwoven web of electrically charged
fibers needle-punched to a scrim support. This web
provides a filter medium having increased uniformity in
10 pressure-drop, basis weight and filtration performance.

FIGURE 1

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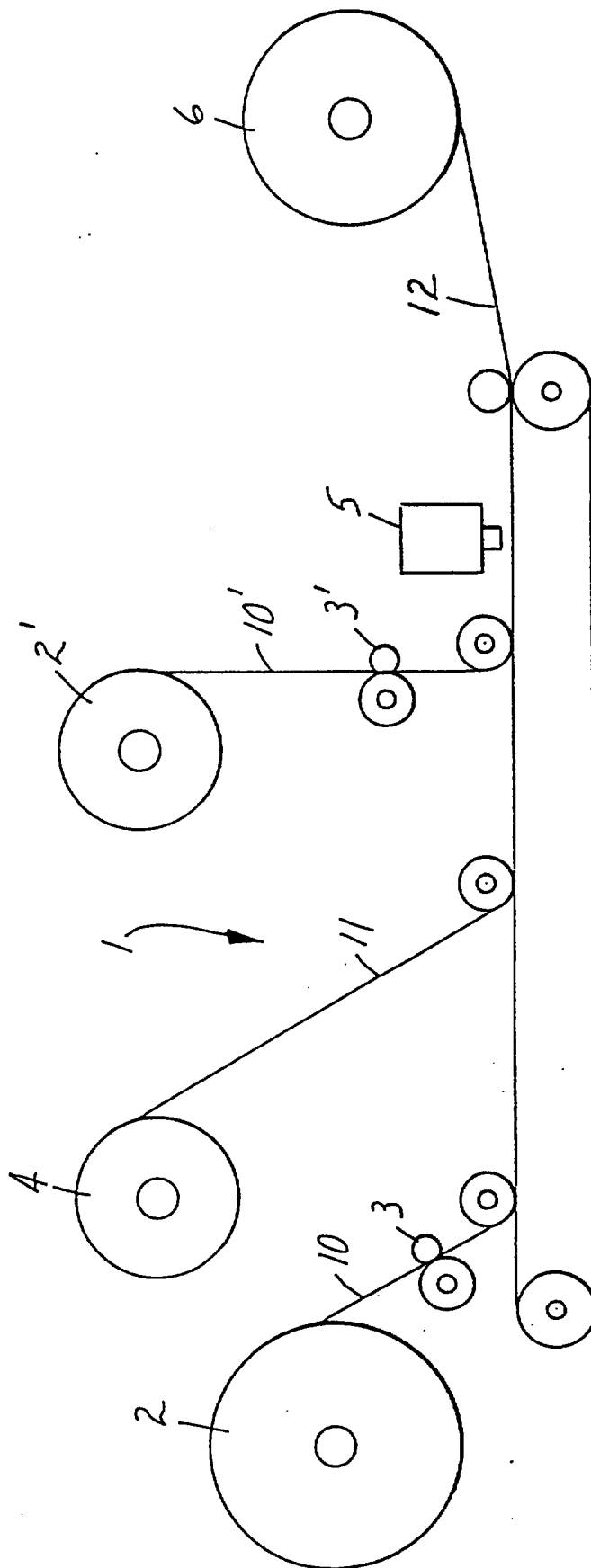


FIG. 1

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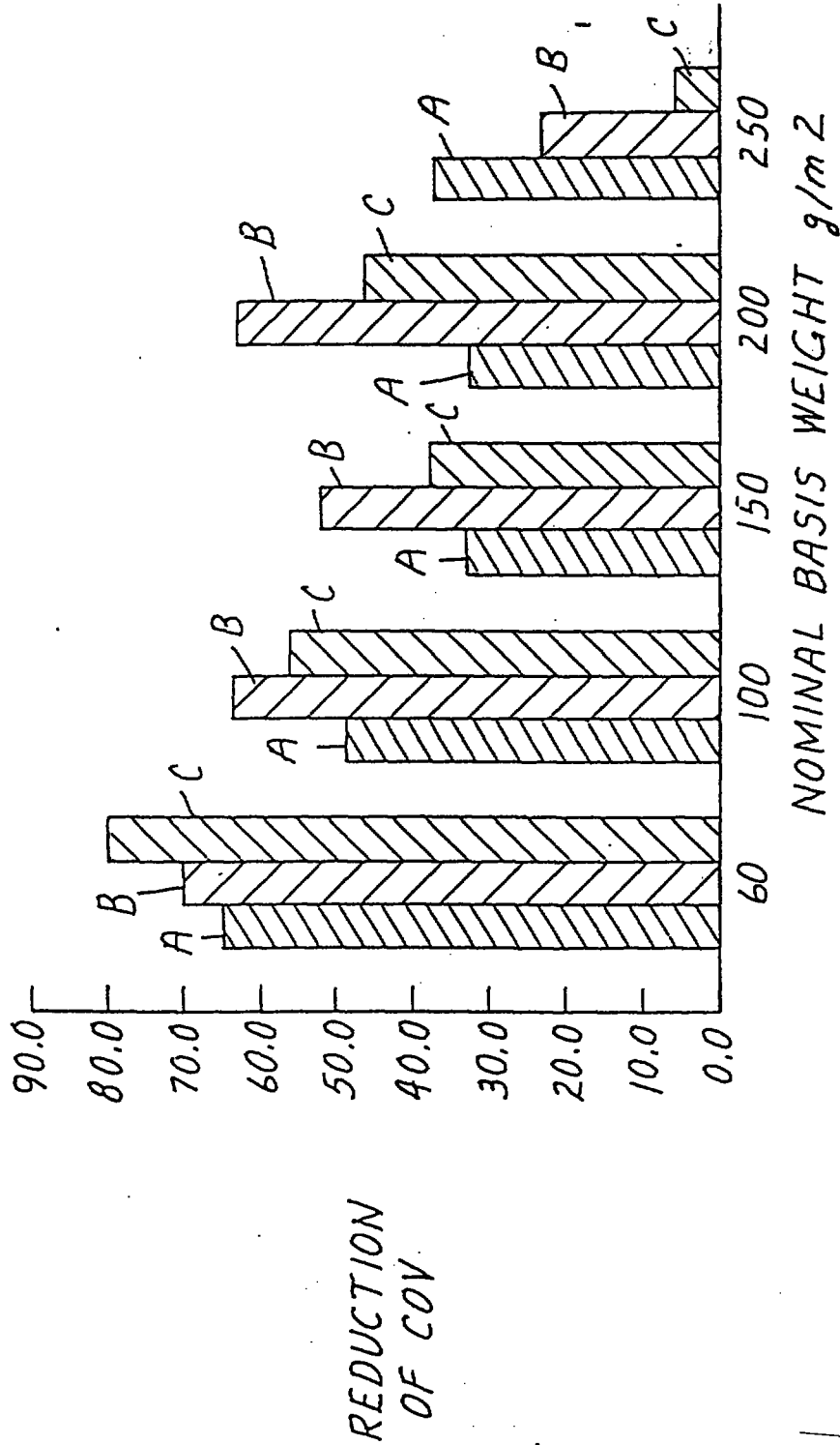


FIG. 2

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SCRIM INSERTED ELECTROSTATIC FIBROUS FILTER WEBBackground and Field of the Invention

The present invention relates to a process for forming an electret nonwoven filter and products of such a process.

Nonwoven webs of electret fibers are typically formed of loosely associated fibers. The fibers can be electrostatically charged prior to, during, or after, being formed into a nonwoven web. For example, post-formation charging is described in U.S. Patent No. 4,588,537 which charges a lofty nonwoven web formed by a variety of methods including carding and melt blowing. The webs are charged while under compression and then permitted to return to their original loft. This patent states that precharged fibers are preferably bipolar so that they tend to resist crimping which is avoided by pre-crimping when using the charging method of this patent.

Fibers can also be charged while they are being formed, as disclosed in ~~Kubik et al.~~, U.S. Patent No. 4,215,682, where melt-blown fibers are bombarded by ions or electrons immediately after being extruded from the melt-blowing orifices. The fibers solidify extremely rapidly in the atmosphere and are collected as a semi-coherent mass of entangled microfibers. The webs are described as preferably open to provide a low pressure drop for liquid passing through the filter.

A particularly effective method of forming a nonwoven electret fiber filter is described in U.S. Reissue Patent No. 30,782 (~~Van Turnhout et al.~~). The electret fibers in this patent are formed from a corona charged film that is fibrillated to form the charged fibers. The charged fibers can then be formed into a nonwoven web by common methods such as carding or air

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laying. This charging method provides a particularly high density of injected charges. However, problems are encountered with forming webs from these precharged fibers. The fibers are generally quite large and uncrimped. They also have a resistance to bending. Due in part to these properties, the fibers resist formation into a uniform coherent web, particularly at low basis weights. This problem is partially addressed in U.S. Patent No. 4,363,682, which proposes the use of such filibrated fiber webs in face mask applications. In order to provide a more coherent web, as well as one that resists shedding fibers, this patent proposes a post-embossing treatment. This post-embossing welds the outer surface fibers together allegedly providing a more coherent and comfortable web for use as a face mask. However, this treatment will also tend to result in a more condensed web, which would increase pressure loss over the filter.

It is an object of the present invention to provide an electret nonwoven filter with uniform filtration properties, and a method for forming such a filter.

This object is achieved by the method and filter according to the claims.

According to the present invention, a uniform electret fiber web filter is obtained by forming a web of charged fibers, placing the charged fiber web onto an open, substantially non-extensible, scrim support material, and then needlepunching the composite material to provide a highly uniform filter web.

Preferred embodiments of the present invention will be described in detail in connection with the drawing, in which

Fig. 1 is a schematic representation of a preferred process arrangement according to the invention method,

Fig. 2 is a plot of percent reduction in three properties coefficient of variability versus nominal basis weight for invention filters and comparable filters without the use of scrims.

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Fig. 1 represents an apparatus arrangement 1 for practicing the present invention. The fibrillated fibers are formed into a nonwoven web layer 10 by card 2. The filter web layer 10 can then be fed to a randomizer 3 to increase basis weight. The randomizer would typically be a set of intermeshing metallic wire (e.g., V-grooves) rollers. Additionally, a second filter web (not shown) could be taken off card 2, treated likewise, and then joined to web layer 10. This allows for greater flexibility in the choice of basis weights. The scrim 11 is fed from a supply roll 4 onto the filter web layer 10. However, the scrim 11 could also be fed upstream of the card 2' so that the filter web 10' is laid onto the scrim 11. In a preferred arrangement, a second card 2' is used so that the scrim is a center layer between two outer nonwoven filter layers. This is shown in Fig. 1 by a second card arrangement with identical numbering. Likewise, a second filter web could be taken off card 2' and joined to filter web 10'. The two filter web layers 10 and 10' can be of differing basis weights. The use of two filter web layers provides particularly uniform filters web of low variability.

The precharged fibers are preferably formed by the method described in U.S. Patent Reissue Nos. 30,782 and 31,285. The fibers, as such, are formed from an electrostatically charged (e.g., by a corona discharge electrode) film that has been fibrillated to provide fibers with a substantially rectangular cross-section.

The filter web layer 10 and scrim 11 are then fed to a needling station 5 where the filter web layer 10 is joined to the scrim by the action of the needles to form the filter ~~web-12~~. The needles will preferably penetrate a web layer first to transversely displace fibers securely down into the scrim and promote the fibers to interlock the scrim, and in the preferred arrangement with fibers of an underlying filter web layer 10'. The needles can be arranged to penetrate the filter ~~web-12~~ composite between about

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10 and 300 penetrations per cm^2 . However, higher needling densities tend to compact the filter-web 12, increasing pressure loss through the filter. Preferably, the needling is less than 75 penetrations per cm^2 . The needle-punched joined composite is then collected on take-up roll 6 for subsequent converting.

Webs typically formed from carding operations are anisotropic with larger amounts of fiber orientation in the machine direction, which generally allows for web-handling stability in this direction. However, lower basis weight webs are less easily handled. A practice in the past to improve nonwoven web handleability has been to needle-punch the webs to increase interfiber bonding. However, generally this has been found to be disruptive to electret web uniformity. This disruption in web uniformity has been found to be particularly problematic when a randomizer is used to increase the web nominal basis weight.

Unexpectedly, it has been found that the use of needle-punching treatments on an electret fibrillated nonwoven web can significantly increase the electret web uniformity when the web is needled to an underlying scrim support. Particularly good uniformity results are obtained where two webs are needled to a scrim between the two webs. The coefficient of variability of these scrim supported filter webs decreases remarkably compared to similar webs prepared without the scrim support.

The scrim material can be any known reinforcement scrim, woven or nonwoven. Nonwoven scrims are generally preferred in terms of cost and degree of openness. The scrim material is also preferably polymeric, and for purposes of recyclability, preferably formed of a polymer compatible with the material of the electret nonwoven web. A scrim of nonwoven material will generally be

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treated to increase tensile properties such as by thermoembossing, calandaring, sonic bonding, binder fibers or the like. A typical scrim material would be a spunbond polypropylene nonwoven web.

The precharged electret fibers are preferably formed from a dielectric film that is capable of being corona charged and then fibrillated. Suitable film forming materials include polyolefins, such as polypropylene, linear low density polyethylene, poly-1-butene, polytetrafluoroethylene, polytrifluorochloroethylene; or polyvinylchloride; aromatic polyarenes; such as polystyrene; polycarbonates; polyesters; and copolymers and blends thereof. Preferred are polyolefins free of branched alkyl radicals and copolymers thereof. Particularly preferred are polypropylene and polypropylene copolymers. Various functional additives known in the art can be blended with the dielectric polymers or copolymers such as poly(4-methyl-1-pentene) as taught in U.S. Patent No. 4,874,399, a fatty acid metal salt, as disclosed in U.S. Patent No. 4,789,504, or particulates, as per U.S. Patent No. 4,456,648.

The disclosed process is also seen as applicable to other methods of forming charged fibers into webs include air laying, electrostatic deposition, Rando webs and the like. Like problems with forming charged fibers into uniform webs are encountered with these web formation methods.

Examples

A fibrillated nonwoven fiber filter was made according to the apparatus described in FIG. 1 using a randomizer and a scrim (Examples C1-C5). The scrim was sandwiched between two filter web layers from cards 2 and 2'. The fibers were polypropylene fibrillated electrets formed according to U.S. RE No. 30,782. These filters were compared to similar filters without an inserted scrim.

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The inserted scrim was a commercially available spunbonded fleece with a basis weight of about 10 gram/m² (Lutrasil™, available from Karl Freudenberg, Kaiserslautern, Germany).

The basis weight (BW) of the filters were determined by weighing a disc with an area of 100 cm² and converted to grams/m². The penetration and the pressure drop of the media was measured on a TSI Automatic Filter Testing machine type 8110, TSI Inc., Minneapolis, MN, based on a test area of 50 cm² and an air velocity of 0.2 m/s. The air contained an NaCl aerosol where the penetration is the ratio of NaCl concentration downstream and upstream of the filter divided by 100. The Coefficient of Variation (COV), defined as the ratio of the standard deviation and the basis weight, was calculated from a sampling of filter properties of at least 7 locations on the filter. The results are given in Tables 1 and 2.

The Quality Factor Q is defined mathematically by the expression

$$Q = \frac{-\ln(\%P/100)}{\Delta P}$$

where %P is the percent penetration, ΔP is the pressure drop in Pascal, and ln indicates the natural logarithm. This value is always positive and increases with reduced penetration. Conversely, as pressure drop increases, the Q value is reduced. Q is generally an index which is independent of the basis weight. Thus, Q may be used to compare the filtration performance of filters of different basis weights.

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TABLE I

Example	Average g/m ²	Average Q 1/Pa	Average ΔP	Average %P	% COV BW	% COV ΔP	% COV %P
1	60.2	0.21	5.0	17.90	5.6	9.7	8.7
2	93.6	0.19	10.0	15.80	5.1	8.2	7.0
3	153.7	0.15	23.10	3.39	2.8	6.7	13.9
4	207.9	0.14	31.5	1.39	4.1	6.7	20.9
5	260.8	0.11	45.2	0.58	3.7	6.0	13.6

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TABLE II

Type	ave. BW ¹ g/m ²	% COV BW	Ave %P	% COV %P	ΔP Pa	%COV ΔP	Avg Q, 1/Pa
6	54.63	3.15	28.76	5.1	5.2	3.2	0.24
7	94.57	3.4	12.89	7.3	8.0	6.9	0.26
8	143.00	2.8	4.00	11.2	15.1	7.9	0.21
9	191.63	3.0	1.65	12.2	25.2	5.4	0.16
10	205.79	1.8	1.28	10.9	27.5	2.9	0.16
11	244.07	3.4	0.65	17.5	36.5	6.7	0.14
C1	64.7	8.7	29.0	16.8	4.4	15.9	0.29
C2	112.63	6.7	8.97	20.1	9.1	15.7	0.27
C3	153.17	4.2	3.31	23.6	15.9	12.6	0.21
C4	191.20	4.5	1.91	33.0	24.3	10.1	0.16
C5	242.06	5.4	1.33	24.0	36.2	7.1	0.12

1. The basis weights were adjusted to exclude the nonwoven scrim.

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The COV values for comparable basis weight webs decreased significantly for the invention example webs 1-11 compared to similar webs produced without reinforcement scrims (Comparative examples C1-C5). The most significant reductions in COV values were noted for lower basis weight webs (e.g., less than about 120 g/m²). This improvement is graphically summarized in Fig. 2 where the y axis represents the % reduction in COV of the scrim inserted examples compared to the non-scrim examples. The x axis designates the nominal basis weights of the webs compared. The A columns represent the basis weight, the B columns the penetration, and the C columns the pressure drop.

~~The various modifications and alterations of this invention will be apparent to those skilled in the art without departing from the scope and spirit of this invention, and this invention should not be restricted to that set forth herein for illustrative purposes.~~



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Claims

1. A method for forming an electret nonwoven filter comprising the steps of:
 - a) providing electrostatically charged dielectric fibers formed by fibrillation of web or film in at least one nonwoven filter web layer (10 or 10') characterized by,
 - b) joining at least one nonwoven filter web layer to a reinforcement scrim (11), and
 - c) needle punching (5) the at least one nonwoven filter web layer (10 or 10') and reinforcement scrim (11) to form a filter with uniform basis weight, pressure drop and percent penetration across the filter.
2. The method of claim 1 wherein the electrostatically charged fibers have substantially rectangular cross-sections.
3. The method of any claims 1 to 2 wherein the reinforcement scrim (11) is an inner layer between two outer nonwoven filter web layers (10, 10').
4. The method of any claims 1 to 3 wherein the at least one nonwoven filter web layer (10 or 10') is formed by carding.
5. The method of any claims 1 to 4 further comprising randomizing the carded filter web layer (10 or 10') prior to joining with the scrim reinforcement (11).
6. The method of any of claims 1 to 5 wherein the electrostatically charged fiber is a polypropylene polymer or copolymer fiber and the scrim reinforcement is a spunbound polypropylene polymer or copolymer nonwoven.
7. The method of any claims 1 to 6 wherein the fibrillated web or film is electrostatically charged.



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8. A uniform electret nonwoven filter or filter web comprising at least one nonwoven filter web layer (10 or 10') of electrostatically charged dielectric fibers characterized in that the nonwoven filter web layer (10 or 10') is joined to a reinforcement scrim (11) by needlepunching wherein the electrostatically charged dielectric fibers are fibrillated from a film of a film forming polymer wherein the needlepunching provides uniformity in the nonwoven filter web layer basis weight, pressure drop and percent penetration.

9. The electret nonwoven filter or filter web of claim 8 wherein the electrostatically charged fibers are polypropylene polymers or copolymers.

10. The electret nonwoven filter or filter web of any of claims 8 or 9 wherein the reinforcement scrim (11) is a center layer between two outer nonwoven filter web layers (10 or 10').

11. The electret nonwoven filter or filter web of any of claims 8 to 10 wherein the nonwoven filter layer (10 or 10') is a carded web.

12. The electret nonwoven filter or filter web of any of claims 8 to 11 wherein the nonwoven filter web layer (10 or 10') is randomized.

13. The electret nonwoven filter or filter web of any of claims 8 to 12 wherein the at least one nonwoven filter web layer has a total basis weight of less than 120 g/m².

14. The electret nonwoven filter or filter web of any of claims 8 to 13 wherein the fibrillated film is electrostatically charged.

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SCRIM INSERTED ELECTROSTATIC FIBROUS FILTER WEB**Abstract of the Disclosure**

Provided is a nonwoven web of electrically charged fibers needle-punched to a scrim support. This web provides a filter medium having increased uniformity in pressure-drop, basis weight and filtration performance.

FIGURE 1

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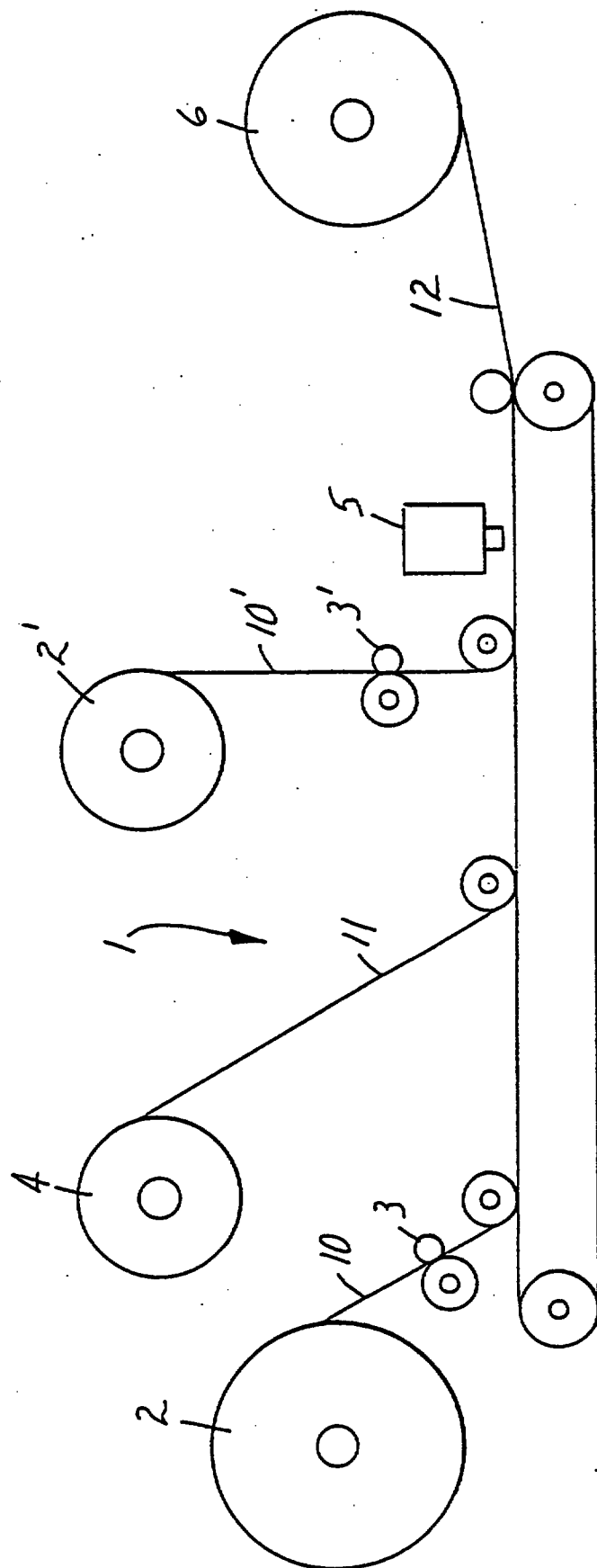


FIG.1

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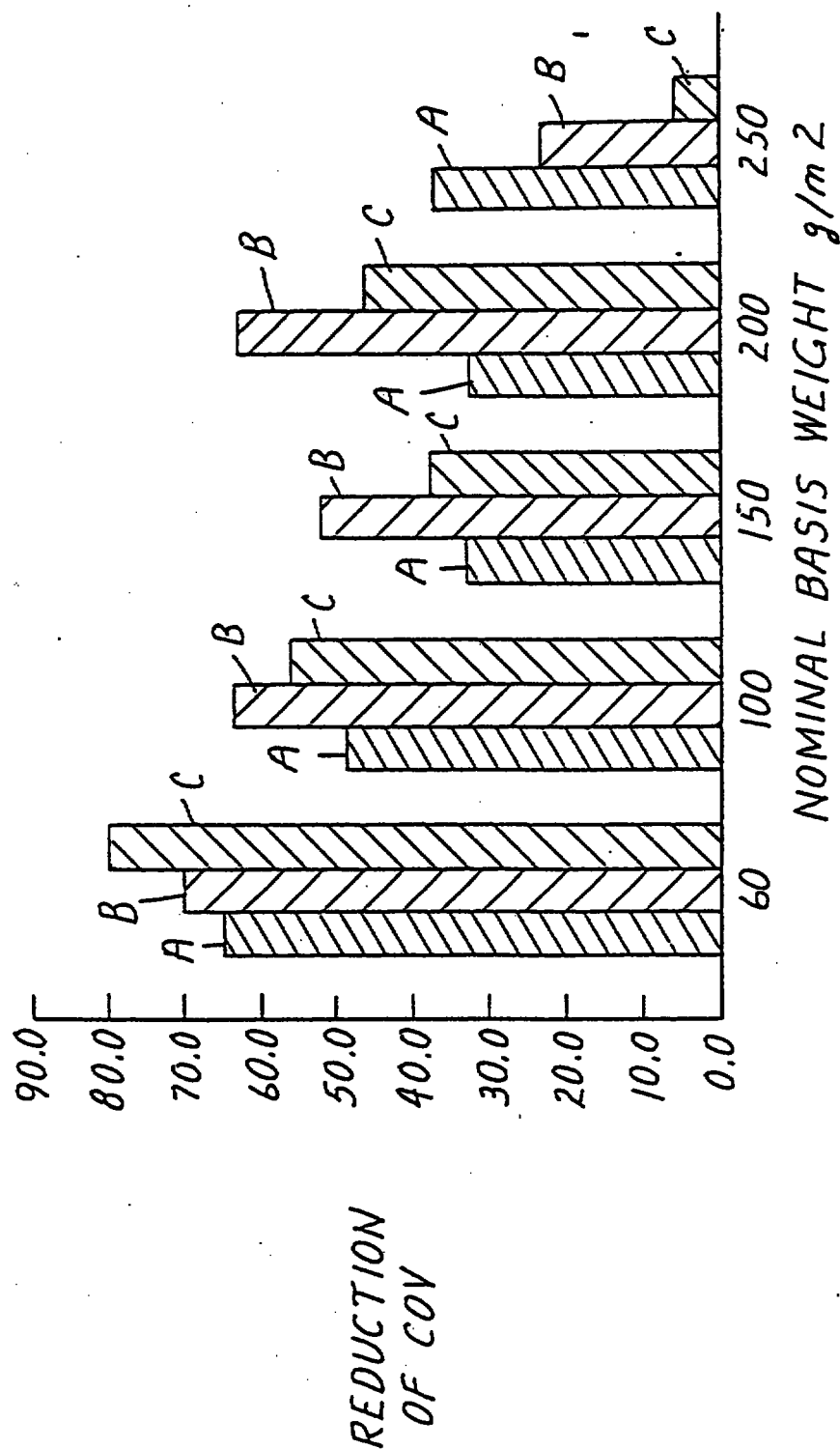


FIG. 2