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54 Clean room garments and method of making same.

57 Substantially nonshedding clean room garments are provided which have a reduced tendency to shed surface particles while retaining good water vapor transmission properties. The garments are comprised of a nonwoven fabric of synthetic fibers which has been coated with from about 2 to

about 26 percent of a coating, based on the weight of the uncoated fabric, said amount being sufficient to substantially coat the individual fibers of said fabric on at least one side thereof, without forming a continuous film on the surface of said fabric.



FIG. 4



FIG. 5

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## CLEAN ROOM GARMENTS AND METHOD OF MAKING SAME

### FIELD OF THE INVENTION

The present invention relates generally to the field of clean rooms. Specifically, this invention relates to garments which are particularly adapted for use in clean rooms, a method of making such garments, and the use of such garments to reduce airborne particulate contamination in a clean room.

### BACKGROUND OF THE INVENTION

Various industries such as microelectronics, aerospace, pharmaceuticals, food processing, and the like, have manufacturing processes which require an environment which is substantially free of airborne particulates. Various clean room designs have thus been developed to provide such a manufacturing environment. The most rigorous design is potentially capable of reducing the number of airborne particles having a size of 0.5 micron or larger, to 100 particles per cubic foot, or less. Such a design typically employs a horizontal laminar flow design and has been found in fact to be capable of providing such a low level of airborne particulates at a first line of work positions. However, in view of the fact that the people and the equipment contained therein continually release particles, the actual environment at the most remote work station contained in such a clean room may in fact be no better than about 10,000 particles per cubic foot. Such a result is not surprising, especially in view of the fact that at rest a person is said to shed at least 100 particles a minute, which is increased to 500,000 particles per minute with only slight head motion and up to 30 million particles per minute while exercising.

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In order to reduce the contamination in clean rooms emanating from the human body itself, various clean room garments have been developed. However, such garments typically suffer from any one or more of a number of problems. For example, in order to reduce the particles emanating from a person, the garment needs to be capable of filtering out a majority of such particles. As the lower particle size which is of a determinative factor in a clean room is on the order of 0.5 microns, the fabric used in such a clean room garment must have a relatively "tight" porous structure. However, when the porosity of a fabric is reduced, the ability of such a fabric to allow air and water vapor to pass there through is substantially reduced. Under such circumstances, worker comfort may degenerate below an acceptable level.

Perhaps of most concern with respect to the design of a clean room garment is the tendency of the fabric used in the construction thereof to shed particles itself. As is readily apparent, it is certainly of little utility to substantially reduce the amount of particles emanating from a human, through use of a clean room garment, if the garment itself is a substantial source of airborne particulates, due, for example, to shedding from the garment.

To date, no successful clean room garment structure has been developed to meet the needs of all industries, especially the microelectronics industry. As the "chip density", that is the number of transistors located on a single chip, increases, the problem of airborne particle contamination becomes more severe. As can be appreciated, as more transistors are located on a single chip, there

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becomes less room for error on that chip, due to the presence, for example, of a flaw caused by a speck of dust or other particulate.

In view of the need for improved clean room garments, numerous designs have appeared. For example, in "Microcontamination," February 1985, pages 46-52, the results of the testing of several different types of clean room garments is shown. The garments discussed therein include those made of spun-bonded Olefin, polyester herringbone, and expanded PTFE laminate fabrics. Similarly, Hirakawa et al., in an article entitled "Influence of Fabric Construction on the Performance of Clean Room Garments," discusses various aspects related to the material of construction of clean room garments. In particular, various woven cloths of polyester filaments are discussed, including two such fabrics which are indicated to be "coated" and "laminated", respectively. No further description of the nature of such coating and lamination appears in said article. However, when discussing the dust protection performance of the various garments, the number of particles resulting from the use of the coated and laminated fabrics was found to be higher than for similar fabrics without such coating or lamination.

In an article entitled "Generation of Dust from Various Kinds of Garments for Clean Rooms," by Minamino et al., various aseptic uniforms of various materials of construction were compared to certain polyester non-linting uniforms. It was concluded that substantial quantities of dust were generated by the aseptic uniforms made from cotton materials, with nonwoven cloth ranking second. It was also determined that the amount of dust generated by the

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polyester aseptic uniform was on the same level with that of the non-linting uniforms.

In "Evaluation of the Elements of Clean Room Garments for Particle Protection and Comfort," by Brinton et al., appearing in "Proceedings - Institute of Environmental Sciences," at pages 163-165, clean room garments made of polyester herringbone, spun-bonded Olefin nonwoven material, and expanded PTFE membrane/polyester knit laminate were compared. The conclusion reached was that both the polyester herringbone and the expanded PTFE laminate were low in releasable particles with the spun-bonded Olefin being somewhat higher. It was also concluded that the polyester herringbone was quite permeable to 0.5 micron particles with the spun-bonded Olefin being much less permeable. The expanded PTFE/polyester knit material could not be penetrated by particles of that size. Although such expanded PTFE/polyester knit material is useful in the construction of clean room garments, most have found the extremely high cost of such material to be prohibitive.

Heretofore, spun-bonded polyethylene, such as that sold under the trademark Tyvek, has been used in the manufacture of clean room garments but has suffered due to the fact that as supplied said material has a pronounced tendency to shed particles. One method of overcoming the propensity of said material to shed particles has been to wash the material after forming the same into clean room garments. However, because the antistatic treatment which is present on said Tyvek® polyethylene is water soluble, the wash water used must also contain a fairly high level of antistatic agent in order for the polyethylene material to retain its antistatic properties. Washing such material is costly both due

to the processing costs associated with such washing and the need to reincorporate antistatic agent in the fabric.

It has been known to apply various types of coatings to different substrates to achieve certain desired results, none of which relate to reduction of particulate contamination in a clean room. For example, U.S. Patent No. 4,499,139, discloses a nonwoven fibrous fabric which has incorporated beneath the surface thereof a layer derived from a froth of acrylic-type latex and clay. In accordance with the examples of said patent, the latex material amounted to from about 30% to about 50%, by weight, based upon the weight of the nonwoven fibrous fabric itself. The fabric is stated to be useful for hospital operating room surgical gowns, hospital draperies, upholstery, and rain wear.

In accordance with the teachings of U.S. Patent No. 4,319,956, a nonwoven fibrous web material made by a wet paper making process is saturated with an inherently hydrophobic latex binder containing up to 2% by weight of a surfactant, the latex binder being a crosslinkable acrylic and being applied at a level from about 5% to 50%, based upon the weight of the nonwoven web. The product disclosed in said patent is indicated to be usable as a disposable medical towel and the like.

A method for preventing surface exiting of piles from a nonwoven fabric is disclosed in U.S. Patent No. 4,276,345, which first impregnates a nonwoven fabric with emulsion destabilizers and then contacts the same with an acrylic resin in an emulsion. The purpose of employing such a process is to assure that the emulsion upon contact with the nonwoven fabric would remain above the surface of the fabric,

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covering the piles and increasing the fabric thickness. It is stated in said patent that such a coated product is useful in cleaning cloths.

U.S. Patent Nos. 2,773,050; 3,438,829; 3,669,792; and 3,510,344 all relate to various coating compositions which are applied to nonwoven web materials, generally. Also of general interest is U.S. Patent 3,613,678 which relates to a face mask made from a filtering web composed entirely of synthetic organic fibers having a non-fuzzy base contacting layer formed from a porous, smooth-surfaced thermoplastic film which is manufactured, for example, by heating a nonwoven layer of randomly oriented thermoplastic fibers and pressing the same against a smooth, heated surface such as that of a heated drum or roller.

DuPont, in a brochure entitled Tyvek® Spunbonded Olefin - Properties and End Uses, has suggested that the Tyvek® nonwoven material is particularly useful for clean room garments because of its low-linting properties. However, as discussed above, the amount of particle shedding from the Tyvek® material as supplied from the manufacturer is too great to be used directly for clean room garments. Also, in the same brochure, it is indicated that the Tyvek® material is available coated with polyethylene or laminated with Saranex®, also a product of DuPont. Such coated or laminated Tyvek material is indicated to be used to manufacture garments for hazardous or toxic material. Thus, it is believed that the coating or lamination on the Tyvek material is quite heavy and acts to form an essentially impervious barrier, to protect the worker from exposure to any toxic material.

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In another brochure by DuPont, entitled Tyvek® Spunbonded Olefin - A Guide to Printing, details are supplied concerning the techniques to be employed to print onto Tyvek material, as by using flexographic and gravure processes. Polyamide/alcohol inks are indicated to be preferred inks for such printing processes and the addition of nitrocellulose is mentioned. However, nothing is mentioned in said brochure about the use of the Tyvek material after printing except with respect to printed items such as tags, signs, maps, floppy disk sleeves and other items requiring good quality color and appearance.

In view of the foregoing, it is quite apparent that there continues to exist a need for suitable clean room garments which can filter out substantially all particles which are 0.5 micron or larger, emanating from a person, while having adequate water vapor permeability, and most importantly without the garment being a substantial source of particle contamination. A further desired feature is that the garment have good surface electrostatic decay properties.

#### SUMMARY OF THE INVENTION

In accordance with the present invention, there are now provided substantially non-shedding garments particularly adapted for use in a clean room wherein the material of construction of said garments comprises a nonwoven fabric of coated, synthetic fibers, said coated fabric having a water vapor transmission rate of from at least about 250 to at least about 500 grams per square meter per day, and said coating being present in an amount from about 2 to about 26 percent, based on the weight of uncoated fabric, said amount being sufficient to substantially

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coat the individual fibers of said fabric on at least one side thereof, without forming a continuous film on the surface of said fabric, said fabric being further characterized by having a particle filtration efficiency of at least about 70%. The coated fabrics used in the garments will typically have a releasable surface particulate test value of less than 100 particles per minute.

In another aspect of the present invention there is provided a method of making a garment particularly adapted for use in a clean room having a substantially reduced tendency to shed surface particles comprising obtaining a nonwoven fabric of synthetic fibers, having a water vapor transmission rate from at least about 250 to at least about 500 grams per square meter per day, and a particle filtration efficiency of at least about 70 percent, uniformly coating said fabric with an amount of coating from about 2 to about 26 percent based on the weight of uncoated fabric, said amount being sufficient to substantially cover the individual fibers of said fabric on at least one side thereof without forming a continuous film on the surface of said fabric; and subsequently forming said coated fabric into a garment suitable for use in reducing airborne particulate contamination emanating from a person in said clean room. The coated fabrics used in the garments again will typically have a releasable surface particulate test value of less than 100 particles per minute.

An additional aspect of the present invention is a method of reducing airborne particulate contamination emanating from a person in a clean room comprising surrounding at least a portion of said person prior to entry into or during at least a

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portion of said person's residence in the clean room, with a garment characterized in that it is particularly adapted for use in a clean room and its material of construction comprises a nonwoven fabric of coated, synthetic fibers, said fabric having a water vapor transmission rate from at least about 250 to at least about 500 grams per square meter per day, and a particle filtration efficiency of at least about 70 percent, said coating being present in an amount from about 2 to about 26 percent based on the weight of uncoated fabric, said amount being sufficient to substantially coat the individual fibers of said fabric on at least one side thereof without forming a continuous film on the surface of said fabric. The resultant fabric will generally have a releasable surface particulate test value of less than 100 particles per minute.

A particularly surprising aspect of the present invention is the discovery that the relatively small amount of coating when placed uniformly on the nonwoven fabric of synthetic fibers can produce a material which is particularly suited for use in clean room garments due to its retention of good water vapor permeation and particle filtration properties, and its extremely low release or shedding of surface particles. This latter aspect is especially surprising when comparing the particle shedding properties of the nonwoven fabric as received from the manufacturer, unwashed, to the same material which has been coated and also not washed. The number of particles released on the face side of the coated fabric is less than ten percent of that released from the uncoated material. An almost equally dramatic difference exists when comparing the washed, coated material to the washed uncoated

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fabric. In this instance, the number of particles released on the face side of the coated fabric is less than twenty percent of that released from the uncoated fabric. Such a particle shedding reduction heretofore was completely unappreciated.

#### DESCRIPTION OF THE FIGURES

FIGS. 1 and 2 are end and side sectional views of a chamber used in performing the modified Gelbo Flex Test.

FIG. 3 is a graph of the water vapor transmission rate for the products of Examples IV and V in comparison with the products of Controls A and B.

FIGS. 4 and 5 are photomicrographs at 500X of the backside and the faceside, respectively, of the product of Example III.

FIG. 6 is a graph of the weight percent of coating added to a substrate, versus the viscosity of the coating formulation, in accordance with Examples XVI-XX.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As indicated, the present invention is especially concerned with garments particularly adapted for use in a clean room. As used in this application, the various garments of concern include, but are not limited to, coveralls, hoods, foot coverings (booties), bunny suits, masks, smocks, and gowns.

The nonwoven fabric used in the present invention may be comprised of synthetic fibers of any composition, such as polyethylene, polypropylene, and the like. Preferably, the fabric is comprised of polyethylene and is spun-bonded. U.S. Patent No.

3,169,899 relates to a method for preparing a preferred form of polyethylene. U.S. Patent Nos. 3,169,899; 3,478,141; and 3,442,740 all relate to various means of cold consolidating, point embossing, and surface bonding, respectively, such a polyethylene.

It is preferred that garments used in a clean room possess substantial antistatic activity to prevent airborne particles from accumulating on the surface of said garments and subsequently becoming dislodged in the clean room environment. U.S. Patent No. 3,821,021 relates to a particularly useful method of rendering a nonwoven polyolefin antistatic by treatment with a finish as disclosed therein. It is believed that the material supplied by DuPont under the trademark Tyvek® is manufactured in accordance with the teachings of U.S. Patent No. 3,169,899 and treated with an antistatic agent in accordance with U.S. Patent No. 3,821,021. Such Tyvek® spun-bonded polyethylene is of particular use in the practice of the present invention.

In accordance with the present invention, when the coating material is applied to a fabric such as Tyvek® spun-bonded polyethylene, not only is the propensity of the fabric to shed particles reduced, but also no further treatment with antistatic agent is necessary. It is certainly surprising that even after the application of the coating material in accordance with the present invention to the Tyvek® polyethylene, no substantial difference in antistatic properties are observed over the uncoated material.

Of greatest surprise, of course, is the finding that the coated fabrics used in the present invention exhibit substantially nonshedding properties, meaning that the fabric itself contributes to the environment

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very few particles having a particle size of 0.5 microns or larger. Generally, when analyzing the particle shedding characteristics by use of the Releasable Surface Particulate Test (0.5 micron or larger), values of less than 100 particles per minute will be achieved. Typically, the coated fabrics used in the present invention will have Releasable Surface Particulate Test values of less than 50, more typically less than 25, and preferably less than 10 particles per minute. In all instances, reference to such test values is with respect to the face of the fabric, that is the side which would be exposed to the clean room environment, as opposed to the back of the fabric which would be the side placed in contact with a worker, when the fabric is shaped into a clean room garment.

In general, with respect to the nonwoven fabric, the same should have a water vapor transmission rate of from at least about 500 to at least about 1000 grams per square meter per day, preferably from at least about 500 to above 1000 grams per square meter per day, and most preferably from at least about 600 to above 1000 grams per square meter per day. It is particularly important that the final coated fabric should have a vapor transmission rate which is sufficiently high to preserve some degree of worker comfort. It should be noted that the application of the coating to the nonwoven fabric will slightly decrease the water vapor transmission rate when compared to the original noncoated fabric.

The coated fabric should thus have a water vapor transmission rate of at least about 250 to at least about 500 grams per square meter per day, preferably from at least about 300 to at least about 500, and most preferably from at least about 350 to at least about 500 grams per square meter per day.

Another consideration with respect to the nonwoven fabric is that it should have a particle filtration efficiency of at least about 70 percent, preferably at least about 90 percent, and most preferably at least about 97 percent. Particle filtration efficiency is used herein to mean the percentage of particles having a size of 0.5 micron, or larger, which are rejected by said fabric when tested in accordance with the analytical procedure therefor, which is discussed below.

With respect to the coating material which is used in accordance with the present invention, essentially any polymeric coating may be placed on the surface of said fabric by essentially any suitable means. Particularly useful polymeric materials which may be employed in the practice of the present invention include polyamides, polyacrylates, polyesters, copolymers of the foregoing, polyurethanes, polysiloxanes and the like.

The polymeric coating may be applied by any suitable method. Typically, the easiest method for applying the coating to the surface of the fabric is to apply a solution of the coating in a suitable solvent which does not substantially dissolve the nonwoven fabric and to evaporate or otherwise remove the solvent therefrom. Coating materials which are useful in the practice of the present invention thus include formulations such as Rohm and Haas Acrylic E-1179N which is comprised of aqueous emulsions of non-formaldehyde substitute copolymerized acrylic acid and short chain esters of acrylic acid, Union Carbide Silicone RE28 which is comprised of polysiloxane resins and crosslinking components, and Conico Varnish A99550 which is a polyamide dissolved in alcohol. The polyamide is believed to be formed

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by the reaction of dimerized short chain fatty acids, such as oleic and stearic acid, with ethylene diamine or hexamethylene diamine. The chains are terminated with fatty acid groups. As the polyamides are relatively short-chain and as they are chain terminated with acid functions, they possess good solubility in alcohols. The solvent is usually n-propyl alcohol.

It may also be useful, from an aesthetic viewpoint, to incorporate a dye or other coloring agent, along with the coating material. This can be readily accomplished when the coating material is applied in the form of a liquid solution by including, as by dissolving or emulsifying in such a solution, a suitable dye or other coloring agent. There may also be included in such a solution or emulsion any other useful additives such as emulsifying agents, surfactants, wetting agents, and the like.

The method of applying the coating material to the fabric, as stated above, is not critical, so long as the amount applied results in an appropriate coating, substantially covering the individual fibers of the fabric on at least one side without forming a continuous film on the surface of the fabric. When a solution of the coating material in a suitable solvent is employed, a printing method of application is especially suitable, such as flexographic and gravure techniques. Other suitable approaches may include spraying, knife coating, and the like.

To achieve the desired level of coating, it is a relatively simple matter to adjust the viscosity of the ink or coating and to thus control the amount of coating deposited on the desired substrate. A preferred coating material is sold by Converters Ink

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Co., Dallas, Texas, under the designation B.B. Versaflex, HiScuff and contains the polyamide resin discussed above with respect to Conico Varnish A99550, dissolved in normal propyl alcohol. The coating also contains polyethylene wax, cyan (thiol) blue, nitrocellulose resin, ethyl alcohol and n-propyl acetate. It is preferred to use such an ink which has been adjusted with n-propyl alcohol and n-propyl acetate as a solvent, to achieve a viscosity from about 15 to about 60 centipoise, more preferably from about 20 to about 40 centipoise, which will result in appropriate coating levels of about 6 to about 8 percent, by weight.

Prior to application of the coating it may be desirable to treat the fabric by any known manner to increase the tendency of the fabric to form a surface bond. Thus, treatment with a chemical agent which will etch the surface of the fabric may be desirable. Another known means of etching the surface is through the use of corona discharge. The applicability or desirability of using this technique will depend in large part upon the nature of the fabric, the nature of the coating material, the tendency of the two to interbond, and the method of applying the coating to the fabric.

The amount of coating as discussed should be sufficient to substantially coat the individual fibers of the nonwoven fabric without forming a continuous film on the surface of the fabric. The latter feature is important in maintaining a suitable water vapor transmission rate. Preferably, the amount of coating on the fabric should not reduce the water vapor transmission rate below about 60 percent of the water vapor transmission rate of the untreated fabric. Most preferably, the reduction in the water

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vapor transmission rate should not be more than about 30 percent of the water vapor transmission rate of the uncoated fabric. Typically, the amount of coating applied will be from about 2 to about 26 percent based upon the weight of the uncoated fabric, preferably from about 2 to about 10 percent, and most preferably from about 4 to about 8 percent. It should be noted that it is not absolutely necessary to coat both sides of the fabric. Thus, if only one side of the fabric is coated, that side should form the exterior of the garment. Thus, at least one side of the fabric should have coating substantially uniform on the fibers which comprise that side of the fabric.

When the coating is applied to the nonwoven fabric in accordance with the present invention, there should be no substantial stiffening of the fabric. Thus, the typical fabric coated in accordance with the present invention will not be significantly stiffer when compared to the original uncoated fabric.

The coated fabric may be formed into a garment suitable for use in reducing airborne particulate contamination emanating from a person in said clean room, using any known applicable technique. Most often a piece of fabric will be shaped, as by cutting in accordance with a predetermined pattern, into a desired form and then joined together with itself or other pieces of fabric to yield a garment of the desired configuration. Appropriate attachments may be added to complete the garment, such as zippers, retaining strings, fasteners, elastic bands, and the like, all by techniques well known and established in the art.

An added advantage of the fabric which is coated in accordance with the present invention is that the surface abrasion resistance thereof is increased when compared to the corresponding uncoated fabric. The surface abrasion resistance is typically increased by about 50 percent, more typically by about 60 percent, and most typically by about 80 percent.

The coated fabrics used in the present invention, especially those having the preferred level of coating, exhibit a surface resistivity in the  $10^{11}$  ohm per square range, which renders them static dissipative, a desirable feature as will be discussed below.

Another surprising finding of the present invention is that the surface resistivity of the coated fabric used in the present invention, after washing is dramatically lower than the uncoated fabric after washing, although well above the desired range of  $1 \times 10^{11}$  ohm per square. The resistivity in ohms of the coated, washed fabric is less than two percent of the resistivity of the uncoated, washed fabric. The ability to retain good surface conductivity was also heretofore not appreciated. Its importance is quite apparent in that as surface resistivity increases, so does the tendency of the fabric to attract particles on the surface thereof which may be later shed in the clean room environment, as by physical motion or otherwise. The ability to retain good surface resistivity through a washing is important to the ability to reuse a garment made of such a fabric.

The present invention will be further illustrated by the following examples which are presented for purposes of further description of the invention and are not meant to be a limitation thereon.

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In the following examples, the analytical procedures employed were as follows:

#### Particle Filtration Efficiency

This method is used to measure the number of particulates filtered by a media as a percent of the total particulates available.

#### Apparatus

A membrane filter holder, Gelman Magnetic, open type No. 4202 or equivalent, Gelman Sciences, Inc., Ann Arbor, Michigan.

Airborne Particle Analyzer, Climet Model CI-208C or equivalent, Climet Instruments, Redland, California.

#### Specimens

Five circular specimens measuring 1-7/8" (47 mm) in diameter are cut from the fabric.

All test samples should be handled by clean technique, i.e., cutting should be done in a clean area, avoid contamination. May use a laminar flow hood when cutting, may also wear clean attire such as a lab coat, washed latex gloves, cap, etc.

#### Procedure

1. Select a low traffic area of the laboratory to set up the apparatus. This area should provide a relatively constant source of particulates from the air.
2. Mount the filter holder on a support stand.
3. Connect exit port of the filter holder to the inlet tubing attached to the particle counter.
4. Calibrate the particle analyzer.

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## 5. Adjust as follows.

a. Depress the POWER switch to energize the apparatus (allow 5 minutes for warm-up).b. Calibrate as follows: Adjust the flow knob on the flow meter to the proper altitude setting for your geographic location. This setting provides a flow rate of 0.25 CFM. Depress the ONE MINUTE switch to select a 1.0 minute counting interval. Depress COUNT AND DELAY switch. Depress appropriate RANGE SELECT and CHANNEL SELECT switches; when properly set the particle size indicator will be lit (0.3, 0.5, 0.7, 1.0, 3.0, 5.0, 7.0 or 10.0 microns). Select a range size of 0.5 microns and above. Depress the CALIB switch to initiate internal calibration. Calibration will be complete in one minute.

Testing of Specimens

1. Place a test specimen on the filter holder platform and secure it in place with the magnetic seal.
2. Select a particulate size range of 0.5 microns and above.
3. Obtain a test specimen count. In order to do this, adjust the air flow knob on the flow meter to achieve a maximum flow rate, this is called the TEST FLOW RATE. Note, as accurately as possible, the position of the flow meter indicator. This information will be needed for subsequent control testing.
4. Depress the RESET switch on the particle analyzer to initiate a 1.0 minute particulate count. Record the particulate count from the digital display.
5. Obtain a control count. In order to do this, remove the test specimen from the filter holder. Now adjust the air flow knob on the flow

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meter to the TEST FLOW RATE; immediately depress the RESET switch on the particle analyzer to initiate a 1.0 minute count. Record this one minute particulate count. This number represents a corresponding control count for the test specimen previously evaluated.

6. Repeat steps 1 through 5 above for the remaining test specimens. (Note: The TEST FLOW RATE may vary from test specimen to test specimen. Record each individual test specimen count and then record each corresponding individual control count.)

#### Calculations

Using the first set of individual data points, determine the percent Particle Filtration Efficiency (% PFE) as follows:

$$\% \text{ PFE} = A - B / A \times 100\% \text{ where}$$

A = Individual Control Count  
B = Individual Test Specimen

Record this value.

Repeat the calculation using data sets obtained from each specimen tested.

Determine the average percent Particle Filtration Efficiency. Record this value.

#### Releasable Surface Particulate Test

This method is used to measure the number of lint particles removed from a fabric surface by means of rubbing abrasion.

#### Apparatus

Surface Particulate Tester. A sample chamber consisting of 5.6" x 7.0" specimen platform with a 4.4" x 6.5" clear plastic cover which also serves as a specimen clamp. The cover is raised and lowered by means of a pneumatic cylinder. The chamber is

inclined 45 degrees to facilitate particle extraction.

A smooth stainless steel block measuring 1.0" x 1.0" x 3.6" is mounted within the sample chamber with its long dimension perpendicular to the direction of movement. The block is driven in a reciprocating motion by means of an electric motor with eccentric cam and monofilament cable. The length of each stroke is 4.7 inches and the motor turns at 60 rpm.

The upper edge of the sample chamber is perforated to allow free passage of clean air over the specimen during testing. A plastic hose is fitted to the lower edge of the sample chamber for connection to an automatic particle counter.

Particle Analyzer, Model CI-208C or equivalent, Climet Instruments Co., Redlands, California.

Horizontal Laminar Flow Hood, Model EG-4320 or equivalent, The Baker Co., Inc., Sanford, Maine.

### Specimens

Five specimens measuring 6" x 8" are cut in a diagonal pattern across the width of the sample material with the long dimension parallel to the machine direction.

Care should be taken to protect the cut specimens from exposure to airborne particulates (dust) or contaminated work surfaces.

### Procedure

#### Standardization.

1. Place the Surface Particulate Tester in the Horizontal Laminar Flow Hood so that the plastic hose on the output side of the sample chamber faces forward. Connect the pneumatic valve to a compressed air supply.

2. Place the Particle Analyzer close to the Surface Particulate Tester, and just outside of the Horizontal Laminar Flow Hood.

3. Connect the plastic hose from the output of the Surface Particulate Tester to the input of the Particle Analyzer.

4. Turn on the Horizontal Laminar Flow Hood.

5. Adjust the Particle Analyzer as follows:

6. Depress the POWER switch to turn on the instrument.

7. Adjust the FLOW control to set the FLOW METER to the proper altitude setting.

8. Depress the CALIBRATE switch to field calibrate the instrument.

9. Depress the 1 MINUTE switch to select a one minute counting interval.

10. Depress the HOLD switch.

11. Depress the CHANNEL SELECT switch to select a particle size range of  $\geq 0.5$  microns.

Testing:

1. Place a test specimen on the specimen platform so that the long dimension is parallel to the direction of motion of the stainless steel block.

2. Rotate the drive motor by hand to raise the stainless steel block to its highest position.

3. Lower the sample chamber cover by moving the pneumatic valve to the DOWN position. Make certain that the stainless steel block lies flat on top of the fabric specimen.

4. Depress the RESET switch to initiate a background count.

5. Repeat step 4 above at one minute intervals until a consistent background count is obtained.

6. Start the drive motor on the Surface Particulate Tester, and immediately press the RESET

switch to initiate a one minute count.

7. Stop the drive motor after the count has been completed, and record the number of particles counted from the Particle Analyzer display.

8. Raise the sample chamber cover by moving the pneumatic valve to the UP position. Remove the test specimen.

### Calculations

Determine the net particle count for each specimen by subtracting the background count from the recorded particle count.

Calculate the average total particle count for the five machine direction samples.

### Modified Gelbo Flex Test

This method is used to measure the number of lint particles removed from a fabric sample during continuous twisting flexure.

### Apparatus

Modified Gelbo Flex Tester, Model 5000 or equivalent, United States Testing Co., Inc., Hoboken, New Jersey, which is a motor driven device consisting of a stationary 3.5" diameter head, and a movable 3.5" diameter head spaced 7.5" apart face to face. The movable head is attached to a reciprocating shaft which is grooved to provide a 440° twisting motion during the first 3.5" of its 6-inch stroke.

An electric motor drives the reciprocating shaft at 45 cycles/min., and a counter is provided to record the total number of cycles completed. (One cycle consists of one forward and one return stroke.)

The basic apparatus is modified by extending the metal base 12 inches, and lengthening the

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reciprocating shaft by 7.5 inches. The reciprocating and stationary heads are enclosed in a clear plastic chamber measuring 10" x 8.5" x 8.0" (see Figures 1 and 2).

This chamber is provided with a circulating fan, inlet and outlet ports, and a clear plastic lid which may be removed to allow access to the test specimen.

The chamber is provided with filtered air by a laminar flow hood, HEPA filtered to class 100 at 0.5 microns, Westinghouse Environmental Systems or equivalent, Grand Rapids, Michigan.

An Airborne Particle Analyzer, Climet Model CI-208C or equivalent, Climet Instruments Co., Redlands, California, is used to measure the particle level.

### Specimens

Five specimens measuring 8.5" x 11.0" are cut in diagonal pattern across the width of the sample material with the long dimension parallel to the machine direction.

Care should be taken to protect the cut specimens from exposure to airborne particulates (dust) or contaminated work surfaces.

### Procedure

1. Laminar Flow Hood - Place the Gelbo Flex Tester within the laminar flow hood and turn on the hood blower motor.
2. Connect the outlet port of the plastic chamber to the inlet of the particle analyzer using a short length of clean, flexible tubing.
3. Secure the lid on the plastic chamber so that the chamber is sealed.
4. Adjust the particle analyzer as follows.

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5. Depress the POWER switch to energize the apparatus. (Allow 5 minutes for warm-up.)
6. Adjust the FLOW knob to set the ball float to the proper altitude setting. This setting provides a flow rate of 0.25 CFM.
7. Depress the CALIB switch to initiate internal calibration.
8. Depress the COUNT AND DELAY switch.
9. Depress the 1 MIN switch to select a 1.0 minute counting interval.
10. Depress the RANGE SELECT and CHANNEL SELECT switches as needed to set the required minimum particle size (lower counting threshold). When properly set, the appropriate indicator light will be lit (i.e., 0.5, 0.7, 1.0, 3.0, 5.0, 7.0 or 10.0 microns).
11. Turn on the fan in the plastic chamber.
12. Depress the RESET switch on the particle analyzer to initiate 1.0 minute particle counts.
13. Continue to run 1.0 minute counts on the empty plastic chamber until consecutive counts agree to within  $\pm 20\%$ . If the particle count for the empty plastic chamber exceeds 500, check all connections and seals for possible leakage.
14. Turn off the fan in the plastic chamber.
15. Remove the lid from the plastic chamber.
16. Turn the hand knob on the Gelbo Flex Tester drive motor to position the reciprocating shaft so that the circular heads are at the extreme open position (i.e., 7.5" separation face to face).
17. Wrap a test specimen around the circular heads so that the specimen forms a cylindrical shape. The long dimension of the specimen should correspond to the circumference of the cylinder, with the specimen face to the outside.

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18. Clamp the ends of the test specimen to the circular heads with the worm clamps provided.
19. Set the counter to zero.
20. Secure the lid on the plastic chamber.
21. Turn on the circulating fan.
22. Depress the RESET switch on the particle analyzer to initiate 1.0 minute particle counts.
23. Continue to run 1.0 minute counts until consecutive counts agree to within  $\pm 20\%$ . Record the final two counts as background readings.
24. Start the drive motor on the Gelbo Flex Tester, and immediately depress the RESET switch on the particle analyzer to initiate 1.0 minute (particle) counts.
25. Record the particle count for each 1.0 minute interval from the digital display.
26. Stop the drive motor after the total number of desired counting intervals has been completed.
27. Turn off the circulating fan.
28. Remove the lid from the plastic chamber.
29. Remove the test specimen.
30. Repeat steps 16 through 29 for the remaining test specimens.

#### Calculations

Determine the background particle count for each specimen by averaging the final two background readings taken prior to flexing the specimen.

For each 1.0 minute counting interval, determine the average particle count for the five specimens tested.

Plot a graph of the average particle count for each 1.0 minute interval versus total elapsed time in minutes.

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Optional: Calculate the total number of particles emitted from the sample by summing the average particle counts for each 1.0 minute interval.

#### Water Vapor Transmission Rate

This method is used to determine the rate of water vapor transmission through plane, sheet material measuring 1/8 inch in thickness, or less.

#### Apparatus

Test Cup: Vapometer, Model 68-1 or equivalent, Thwing-Albert Instrument Co., Philadelphia, Pennsylvania.

A cylindrical aluminum cup measuring 2" x 2½" diameter with a scribe line to indicate liquid water level.

The top of the cup is fitted with a flange and rubber gasket which is used to secure the test specimen and make a vapor tight seal.

The gasketed flange is held in place with six thumb screws located around the outer edge.

Test Chamber: A room or cabinet where the test cups may be stored at a controlled temperature and relative humidity, commonly 23° ±1°C and 50% ±2% R.H. Continuous air circulation should be provided to maintain uniform conditions throughout the chamber.

Analytical Balance: Mettler PC 440 electronic balance or equivalent, Mettler Instrument Corp., Highstown, New Jersey.

#### Deionized Water

Weighing Covers: Weighing covers should be placed over test cups which are removed from the conditioning room or cabinet for weighing.

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Specimens

Five circular specimens measuring 3 inches in diameter are cut in a diagonal pattern across the width of the sample material.

ProceduresVertical Cup

1. Add deionized water to the test cup up to the level of the internal scribe line.
2. Position a test specimen in the recess in the top of the cup, taking care to eliminate folds or wrinkles.
3. Secure the test specimen in place with the rubber gasketed top flange. Tighten the six thumb screws evenly to provide a vapor proof seal around the outer edges of the specimen.
4. Weigh the assembly on the analytical balance, and record its weight to the nearest  $\pm 1$  mg.
5. Place the assembly in the test chamber in an upright position, and maintain a constant external temperature and relative humidity for a period of at least 24 hours. (Recommended conditions are  $23^{\circ} \pm 1^{\circ}\text{C}$  and  $50\% \pm 2\%$  R.H.)
6. Remove the assembly from the test chamber after 24 hours, and immediately reweigh to the nearest  $\pm 1$  mg.
7. (Optional) Remove the assembly from the test chamber at one hour intervals, weight to the nearest  $\pm 1$  mg, and return the assembly to the chamber. Make successive weighings at one hour intervals until a constant rate of loss is observed.
8. Test the remaining specimens in a similar fashion using steps 1 through 6.

### Calculations

Calculate the water vapor transmission rate of each specimen as follows:

$$\text{WVTR (g.m.}^{-2}\text{day}^{-1}) = \frac{W_1 - W_2}{(1.32 \times 10^{-4}) T}$$

Where:

WVTR = water vapor transmission rate.

$W_1$  = initial weight of test assembly in grams.

$W_2$  = final weight of test assembly in grams.

T = time interval between weighings in hours.

Determining the average water vapor transmission rate for the five specimens tested to the nearest  $\pm 1 \text{ g.m.}^{-2}\text{day}^{-1}$ .

### Electrostatic Decay

This method is used to measure the time required to dissipate an induced electrostatic charge on a material surface to 10% of its initial value.

### Apparatus

Static Decay Meter: Model SDM406B or equivalent, Electro-Tech Systems, Inc., Glenside, Pennsylvania.

Faraday Test Cage: A protective enclosure containing a sensor mounted in an adjustable frame, and a specimen holder with magnetic and screw clamps.

Meter Console: Consisting of a electrometer, variable high voltage power supply, precision timer, and meter display.

Calibration Module (Model CM-1): A device which may be clamped in the specimen holder and used to simulate a test specimen with a nominal decay time of 0.5 seconds.

Specimens

Five specimens measuring  $3\frac{1}{2}$ " x 5" are cut in a diagonal pattern across the width of the sample fabric with the long dimension parallel to the machine direction.

The specimens are conditioned at 50%  $\pm$ 2% R.H. and 70°  $\pm$ 3.5°F for a minimum of 25 hours prior to testing.

ProcedureCalibration:

1. Set the shutter control to operate, the high voltage adjust to zero, and the Charge/Test switch to the charge position.
2. Push the power switch to on and allow the instrument to warm-up for at least 5 minutes.
3. Set the range switch to X1, push the shutter control to the close position, and zero the electrostatic voltmeter.
4. Return the shutter control to the operate position.
5. Open the Faraday cage cover, and clamp the CM-1 calibration module in the specimen holder.  
(Note: Do not connect the banana plug to its receptacle.)
6. Close the cage cover and place the high voltage select switch to either the positive or negative position.
7. Adjust the high voltage control to 5KV on the high voltage meter.
8. Adjust the sensor position with the knob located at the rear of the Faraday cage so that a full scale reading of 1.0 is read on the electrostatic voltmeter.
9. Allow the electrostatic voltmeter to complete two cycles, and when a full charge is read,

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depress the test switch and record the time from the decay rate display to the nearest 0.01 second.

(Note: The time should read 0.03 seconds or less.)

10. Return the Charge/Test switch to the charge position.

11. Repeat steps 6 through 10 with the high voltage select in both the positive and negative positions.

Testing:

1. Test all conditioned specimens at 50%  $\pm 2\%$  R.H. and 70°  $\pm 3.5^\circ\text{F}$ .

2. Open the cover to the Faraday cage and clamp a specimen vertically in the specimen holder.

Tighten the specimen to remove any slack or creases.

3. Close the cover to the Faraday cage and place the high voltage select switch in either the positive or negative position.

4. Adjust the high voltage control to 5KV on the high voltage meter, and allow the electrostatic voltmeter to cycle for 60 seconds or until a full charge is accepted.

5. Depress the test switch as soon as the electrostatic voltmeter completes an automatic zero cycle, and record the elapsed time on the decay rate display to the nearest 0.01 second. (Note: This reading represents the time required to dissipate the induced charge to 10% of its original value.) Allow the specimen to remain grounded until all residual charge is removed from the specimen. Return the Charge/Test switch to the charge position.

6. Repeat steps 3 through 5 three times for positive and negative voltages on each specimen.

7. Test the remaining specimens in a similar manner.

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Calculations

Determine the average decay time for each specimen for positive and negative charges.

If the electrostatic voltmeter did not indicate at least 1250 volts (positive and negative) for a particular specimen, then that specimen failed to accept a charge, and no decay time can be reported.

Surface Resistivity

This method is used to measure the surface resistivity of materials having resistances greater than  $10^6$  and less than  $10^{16}$  ohms per square as outlined in ASTM Method D 257-66.

Apparatus

Keithley #247 high voltage supply, El Paso #248 and Keithley #6105 resistivity chamber.

Specimen

Three inch diameter circle sample cut from material.

Procedure

1. Turn high voltage supply on. Allow at least 10 minutes to warm-up.
2. The short circuit plug inside the 6105 resistivity chamber should be over the lower two jacks, leaving "SURFACE" clearly visible. Insert the test weight banana plug into top jack.
3. Place the test sample under the test weight, making sure the sample is centered over the electrodes.
4. Close the chamber cover.

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5. Set the electrometer front panel control as follows:

Zero check switch: LockRange check  
switch:  $10^1$  Amperes  
Multiplier switch: 1  
Feedback switch: Normal  
Meter switch: +

6. Set the polarity switch on the voltage supply to POS and the output voltage switch to 500. The voltage dial should remain fully counterclockwise, set at 000.

7. Unlock the zero check switch on the electrometer. Increase the sensitivity using the range switch. Use the smallest multiplier setting to obtain the best accuracy.

8. Allow sample to charge for 60 seconds, then take the current reading. The full scale current is determined by multiplying the top scale reading times the multiplier setting times the range setting.

9. The surface resistivity is found by calculating:

$$\text{Surface Resistivity} = \frac{(53.4) (500 \text{ volts}) \text{ ohms}}{\text{Current}}$$

Where the current is the reading taken from the electrometer.

#### Surface Abrasion Resistance

This method is used to determine the resistance of fabric surfaces to abrasion.

#### Apparatus

Abrasion Tester, Model No. 8675 or equivalent,  
U.S. Testing Co., Hoboken, New Jersey.

Abradant head with clamps: Two abradant heads,

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with an abrasive area of 4" x 0.44" each, are independently mounted on hinged arms which may be weighted as desired. Each head is fitted with two clamps for securing a 4" x 4" piece of abradant.

Reciprocating table with clamps: The table is divided into two sections, each fitted with a pair of clamps for securing a 4-5/8" x 7" fabric specimen. The table reciprocates horizontally at 90 cycles per minute, producing a 3.5" stroke in each direction. A counter is provided for recording number of cycles completed.

Lamp: Luxo, color-correct, fluorescent and incandescent, with 22 and 60 watt bulbs, Luxo Lamp Corp., Port Chester, New York.

Abradant: Sandpaper, 3M Wet or dry Tri-M-ite Paper A wt. 600 or equivalent.

### Specimens

Five specimens measuring 4-5/8" x 7" are cut in a diagonal pattern across the width of the sample material with the long dimension parallel to the cross direction.

Five pieces of abradant measuring 4" x 4" are cut from sandpaper.

### Procedure

1. Clamp a fabric specimen face up on the reciprocating table with the long dimension (cross direction) parallel to the direction of the stroke.
2. Clamp an abradant piece to the abradant head.
3. Rotate the abradant head so that it comes to rest on the surface of the fabric specimen positioned on the reciprocating table. (Note: The abradant head should apply a force of 33 oz. to the fabric specimen.)

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4. Turn on the lamp and position it to provide maximum visibility of the test area.
5. Reset the counter to zero.
6. Turn on the motor to start the reciprocating table.
7. Turn off the motor after 50 cycles have been completed.
8. Raise the abradant head and visually examine the fabric specimen for evidence of abrasion. Rate the degree of surface degradation using the following scale: 0-None visible; 1-slight; 3-moderate; 5-severe.
9. Remove the accumulated particulate from the abrading surface of the sandpaper with a strip of 3M Scotch brand adhesive tape #681 or equivalent. (optional) Attach the tape strip to a sheet of clear plastic for later visual evaluation of quantity and/or size of particulate.
10. Lower the abradant head and continue testing the same specimen using steps 6-9 until a rating of 5 is obtained, or 200 cycles have been completed.
11. Test the remaining fabric specimens in a similar manner using steps 1-10. Use a new piece of abradant for each fabric specimen.
12. The average rating for the five fabric specimens at each 50 cycle increment is calculated and reported.

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Examples I-III

Tyvek® spun-bonded polyethylene, type 1422R, which had been treated with Zelec TY antistat by the manufacturer and subsequently corona processed by the manufacturer to increase coating adhesion was used. The material was 56 inches wide and weighed 1.13 ounces per square yard. The coatings discussed below were applied with a flexographic printing machine under the following conditions:

|                            |                                  |        |      |
|----------------------------|----------------------------------|--------|------|
| Printing Roll              | Anilox Roll - 200 lines per inch |        |      |
| Fountain Roll              | Front                            | Center | Back |
| Durometer                  | 72                               | 75     | 72   |
| Coating Roll               | No gear (not driven)             |        |      |
| Durometer                  | 60                               | 60     | 62   |
| Roll Travel                | 65 RPM                           |        |      |
| Fabric Speed               | 300 FPM                          |        |      |
| Infrared Dryer             |                                  |        |      |
| Thermostat Setting         | 170° F                           |        |      |
| Fabric Surface Temperature | 150° F                           |        |      |

The coating formulations employed were as follows:

| <u>Example I</u>       | <u>Dry Chem<br/>add-on %</u> | <u>Example II</u>     | <u>Dry Chem<br/>add-on %</u> |
|------------------------|------------------------------|-----------------------|------------------------------|
| Conico A-99550 varnish | 17.0%                        | UCC Silicone RE28     | 2.59%                        |
| Blue Toner P 92487     |                              | Zinc Octoate (18% fn) | 0.51%                        |
|                        |                              | Tyzov LA              | 0.51%                        |
|                        |                              | Milstat N20           | 0.65%                        |
|                        |                              | Artilene Blue 6825    | 0.13%                        |
| Total                  | 17.0%                        | Total                 | 4.39%                        |

Example III

|                     |   |       |
|---------------------|---|-------|
| Rohm & Haas Acrylic | } |       |
| Rhoplex E-1179N     |   | 3.94% |
| Sherex DP-5C55-185  |   | 0.39% |
| Artilene Blue 6825  |   | 0.11% |
| Total               |   | 4.44% |

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It was determined that, based on the weight of the uncoated Tyvek® polyethylene, the weight percent of solids deposited on the fabric was 17.0%, 4.4% and 4.4%, for Examples I, II and III, respectively.

Samples of the products of Examples I, II and III were subjected to various analytical procedures, the results of which are shown in Table 1, along with results for the uncoated Tyvek® polyethylene. The samples were tested both before and after washing.

Figs. 4 and 5 are photomicrographs at 500x of the backside and the faceside, respectively, of the product of Example III. The photomicrographs clearly show that the fibers are uniformly coated but that the coating did not form a continuous layer itself. Thus, the coating did not and would not be expected to significantly reduce pore volume or size.

#### Examples IV-V

Using the same techniques as in Examples I-III, two different rolls of Tyvek® polyethylene (A and B) were coated with a polyamide formulation to yield a coating, based on the weight of the uncoated polyethylene, of 2 percent (Example IV) and 10 percent (Example V), respectively.

The water vapor transmission rate of the controls (A and B) and the coated products (Examples IV and V) was measured and the results are shown in Figure 3.

Table 1

|                                                                       | Uncoated     |        | Example I    |        | Example II   |        | Example III  |        |
|-----------------------------------------------------------------------|--------------|--------|--------------|--------|--------------|--------|--------------|--------|
|                                                                       | Unwashed     | Washed | Unwashed     | Washed | Unwashed     | Washed | Unwashed     | Washed |
| Electrostatic Decay (sec)<br>positive<br>negative                     | 0.04<br>0.04 | --*    | 0.89<br>0.95 | --*    | 0.67<br>0.71 | --*    | 0.20<br>0.22 | —<br>* |
| Initial Cleanliness (Flex/Climet)**<br>particles $\geq 0.5$ )microns) | 1853         | 356    | 263          | 61     | 646          | 276    | 78           | 30     |
| Surface Abrasion Resistance (rating)                                  | 5.0          | 3.3    | 1.0          | 0.0    | 5.0          | 1.0    | 2.3          | 0.7    |
| In-Use Abrasion Resistance (RSPT/Climet)** <sup>1</sup>               |              |        |              |        |              |        |              |        |

\* Did not accept full charge

\*\* 84 sec. cycle at 0.25 CFM flow rate; 6"x6" sample

<sup>1</sup> A prototype garment consisting of one half (right side or left side) being made from uncoated washed material, the other half being made from coated washed material, for each of the three coatings listed was constructed and worn in the lab for a period of five days. Specimens were then cut from both sides of each garment and evaluated by the Releasable Surface Particulate Test as a means of assessing the amount of abrasion that had occurred. Material of both Example I and Example III showed a significant improvement over the uncoated material. The face of material of Example I (outside of garment) released only 7 particles  $\geq 0.3$  microns compared to 343 particles released by the uncoated material. The back of material of Example I (inside of garment:) released 88 particles compared to 263 particles released by the uncoated material. Similarly, the back of material of Example III released 21 particles compared to 268 particles released by the uncoated material.

Examples VI-XV

To determine the effect of the amount of coating on the physical properties of the coated fabric, products were made having a final coating level, based on the weight of the uncoated fabric, of 2% (Example VI), 4% (Example VII), 6% (Example VIII), 8% (Example IX), 10% (Example X), 12% (Example XI), 15% (Example XII), 17% (Example XIII), 20% (Example XIV), and 26% (Example XV). The results of the various tests are shown in Table 2 and are contrasted with the results of the uncoated fabric. Also the effect of washing on the fabric was compared between the uncoated fabric and the product of Example VIII having a 6% coating.

The formulations used to prepare the products of Examples VI-XV were comprised of an alcohol soluble polyamide.

All samples were coated on both sides with approximately equal amounts of coating, to a tolerance of about  $\pm 30$  percent.

Table 2

| TEST                     | UNCOATED | UNWASHED COATED (% by weight of uncoated fabric) |      |      |      |      |      |       |      |      |          | WASHED   |           |
|--------------------------|----------|--------------------------------------------------|------|------|------|------|------|-------|------|------|----------|----------|-----------|
|                          |          | 2%                                               | 4%   | 6%   | 8%   | 10%  | 12%  | **15% | 17%  | 20%  | 26%      | UNCOATED | COATED 6% |
| ISPT <sup>1</sup> , Face | 250      | 5                                                | 4    | 1    | 3    | 0    | 21   | 10    | 7    | -    | -        | 155      | 23        |
| ISPT <sup>1</sup> , Back | 4,800    | 113                                              | 48   | 30   | 71   | 2    | 44   | 29    | 88   | -    | -        | 238      | 98        |
| WIF <sup>2</sup>         | 34,000   | 3116                                             | -    | 746  | 1287 | 461  | -    | 606   | 263  | -    | -        | 2251     | 465       |
| WVIR <sup>3</sup>        | 570      | 488                                              | -    | -    | -    | 368  | -    | -     | -    | 251  | 186-281* | 598      | -         |
| Static Decay (sec.)      | 0.04     | 0.04                                             | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.28  | 0.92 | 0.20 | 0.25     | 0.04     | 0.05      |
| SR <sup>4</sup>          | 0.03     | 2.5                                              | -    | 9.4  | 21.8 | 10.9 | -    | 22.0  | -    | -    | -        | 81,600   | 1,570     |

Legend: 1 - Releasable Surface Particulate Test (>0.5 microns particles/minute)

2 - Modified Gelbo Flex (>0.5 microns particles/minute)

3 - Water Vapor Transmission Rate (g/m<sup>2</sup>/day)

4 - Surface Resistivity (X10<sup>9</sup> ohm per square)

\* Variation due to non-uniform coating

\*\* 0.5% of an antimicrobial agent was included in the coating formulation

NOTE: The uncoated material and Example VIII (6%) were both evaluated for Particle Filtration Efficiency and found to be 98.7% and 98.9% respectively.

From the data in Table 2 it is apparent that when the fabric has from about 2 to about 26 percent coating, by weight, the particle counts were significantly reduced when compared to the uncoated material. As noted in discussing the background to the present invention, washing the uncoated fabric produced a significant reduction in particle count as compared with the unwashed material. It is also clear from the data that as the preferred range of coating is exceeded, the static decay values are increased appreciably over the values obtained at lower levels of coating.

With respect to the water vapor transmission rate, there is a relatively smooth increase from the 2% to the 26% coating level, the rate diminishing to about 200 grams per square meter per day at the 26 percent level, which rate of water vapor transmission is about the minimum which a worker wearing a garment made of such material would still feel comfortable.

#### Examples XVI-XXII

To demonstrate the relationship between the viscosity of the coating and the amount of coating which is deposited on the substrate, several different coating formulations were made by diluting BB Versaflex, HiScuff ink. Thus Examples XVI-XXII had viscosities from 15 to 60 centipoise, as indicated in Table 3. Correspondingly, the amount of coating which was deposited onto Tyvek 1422R spun-bonded polyolefin ranged from 2.0 to 12.5 percent by weight, also as shown in said Table. For reference purposes, the viscosity of the pure solvent is also indicated in said Table 3. From the data contained therein, it is apparent that for the viscosity level investigated, there is a nearly linear relationship

between viscosity of the coating and the weight percent of coating which is deposited on the substrate, as illustrated by FIG. 6 which is a graph of the weight percent of coating added to the substrate, versus the viscosity of the coating formulation.

Table 3

| <u>Example</u> | <u>Viscosity<br/>Centipoise</u> | <u>Average<br/>Coating (wt.%)</u> |
|----------------|---------------------------------|-----------------------------------|
| Control        | .3                              | 0                                 |
| XVI            | 15                              | 2.0                               |
| XVII           | 20                              | 6.1                               |
| XVIII          | 30                              | 7.3                               |
| XIX            | 35                              | 8.0                               |
| XX             | 40                              | 8.8                               |
| XXI            | 50                              | 11.6                              |
| XXII           | 60                              | 12.5                              |

CLAIMS

1. A substantially nonshedding garment particularly adapted for use in a clean room, wherein said garment comprises, a nonwoven fabric of coated, synthetic fibers, said coated fabric having a water vapor transmission rate of from at least about 250 to at least about 500 grams per square meter per day, and said coating being present in an amount from about 2 to about 26 percent, based on the weight of uncoated fabric, said amount being sufficient to substantially coat the individual fibers of said fabric on at least one side thereof, without forming a continuous film on the surface of said fabric, said fabric being further characterized by having a particle filtration efficiency of at least about 70%.

2. The garment of claim 1 wherein the nonwoven fabric is a spun-bonded olefin which when coated has a releasable surface particulate test value of less than 100 particles per minute.

3. The garment of claim 2 wherein the coating is present in an amount from about 4 to about 8 percent, based on the weight of the uncoated fabric and the coated fabric has a releasable surface particulate test value of less than 50 particles per minute.

4. The garment of claim 3 wherein the coating comprises an alcohol soluble polyamide.

5. The garment of claim 4 wherein the coated fabric has a water vapor transmission rate of at least about 350 grams per square meter per day and a particle filtration efficiency of at least about 97 percent.

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6. The garment of claim 5 wherein the coated fabric has a surface resistivity of  $10^{11}$  ohms per square or less and a releasable surface particulate test value of less than 10 particles per minute.

7. A method of making a garment particularly adapted for use in a clean room having a substantially reduced tendency to shed surface particles comprising obtaining a nonwoven fabric of synthetic fibers, having a water vapor transmission rate from at least about 250 to at least about 500 grams per square meter per day, and a particle filtration efficiency of at least about 70 percent, uniformly coating said fabric with an amount of coating from about 2 to about 26 percent based on the weight of uncoated fabric, said amount being sufficient to substantially cover the individual fibers of said fabric on at least one side thereof without forming a continuous film on the surface of said fabric; and subsequently forming said coated fabric into a garment suitable for use in reducing airborne particulate contamination emanating from a person in said clean room.

8. The method of claim 7 wherein the nonwoven fabric is a spun-bonded olefin which when coated has a releasable surface particulate test value of less than 100 particles per minute.

9. The method of claim 8 wherein the coating is present in an amount from about 4 to about 8 percent, based on the weight of the uncoated fabric and is sufficient to produce a fabric having a releasable surface particulate test value of less than 50 particles per minute.

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10. The method of claim 9 wherein the coating comprises an alcohol soluble polyamide.

11. The method of claim 9 wherein the coated fabric has a water vapor transmission rate of at least about 350 grams per square meter per day, a particulate filtration efficiency of at least about 97 percent, and a surface resistivity of  $10^{11}$  ohms per square or less.

12. A method of reducing airborne particulate contamination emanating from a person in a clean room comprising surrounding at least a portion of said person prior to entry into or during at least a portion of said person's residence in the clean room, with a garment characterized in that it is particularly adapted for use in a clean room and its material of construction comprises a nonwoven fabric of coated, synthetic fibers, said fabric having a water vapor transmission rate from at least about 250 to at least about 500 grams per square meter per day, and a particle filtration efficiency of at least about 70 percent, said coating being present in an amount from about 2 to about 26 percent based on the weight of uncoated fabric, said amount being sufficient to substantially coat the individual fibers of said fabric on at least one side thereof without forming a continuous film on the surface of said fabric.

13. The method of claim 12 wherein the coated nonwoven fabric is spun-bonded polyethylene, having a sufficient amount of a coating to reduce the releasable surface particulate test value for the coated fabric to less than 100 particles per minute.

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14. The method of claim 13 wherein the coating is a polyamide and is present in an amount from about 4 to about 8 percent based on the weight of the uncoated fabric.

15. The method of claim 14 wherein the coated fabric has a water vapor transmission rate of at least about 350 grams per square meter per day and a particle filtration efficiency of at least about 97 percent.

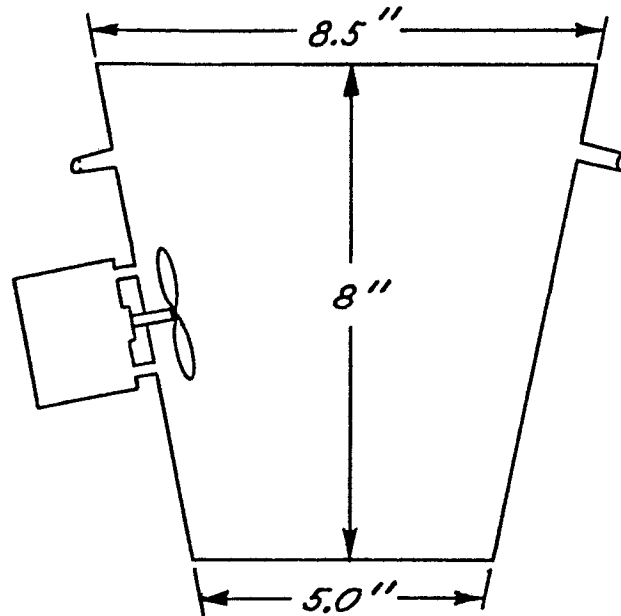


FIG. 1

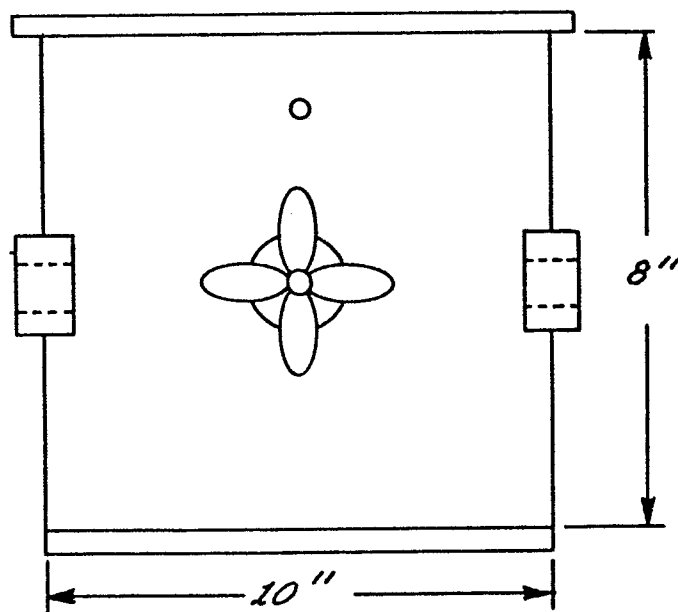


FIG. 2

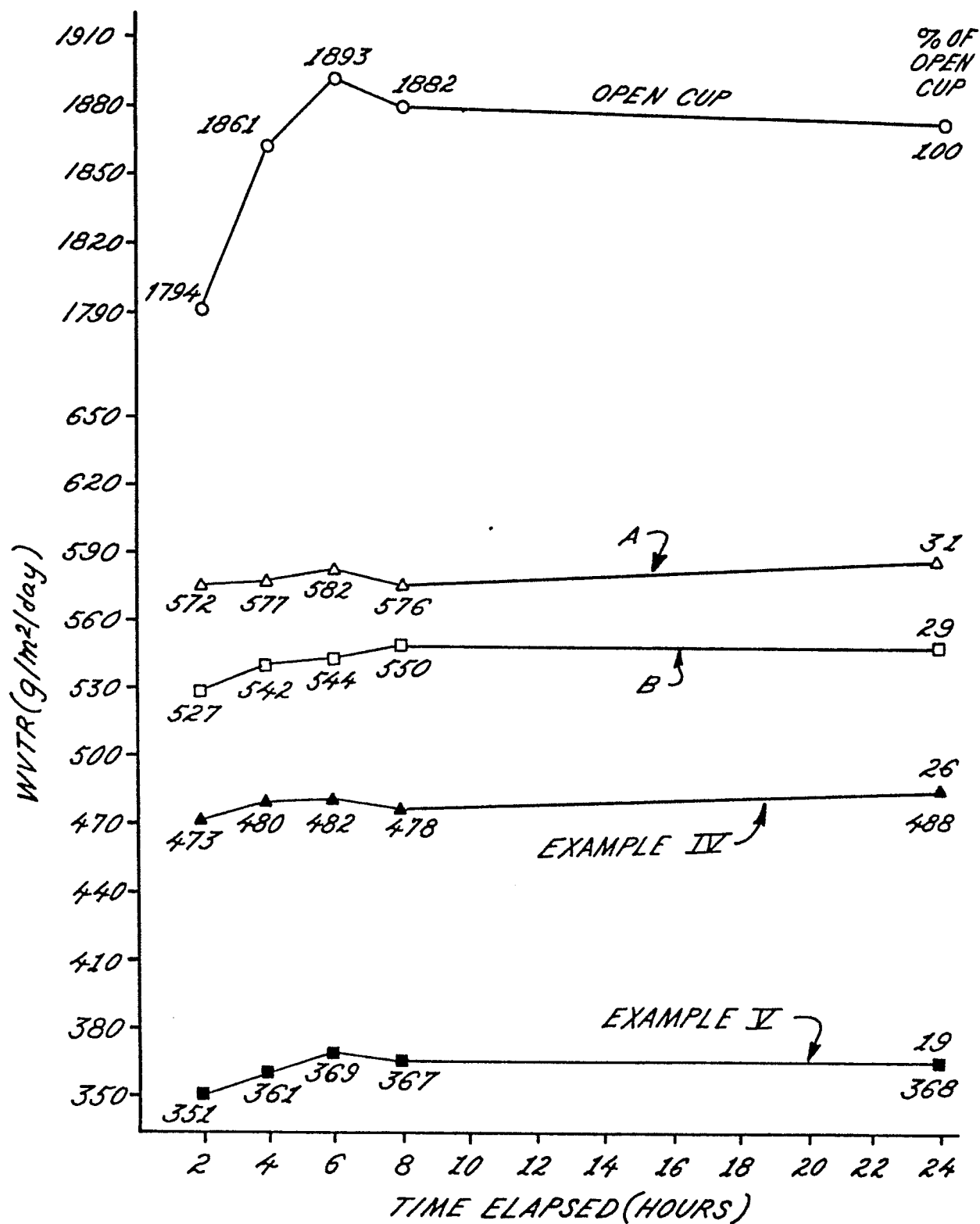
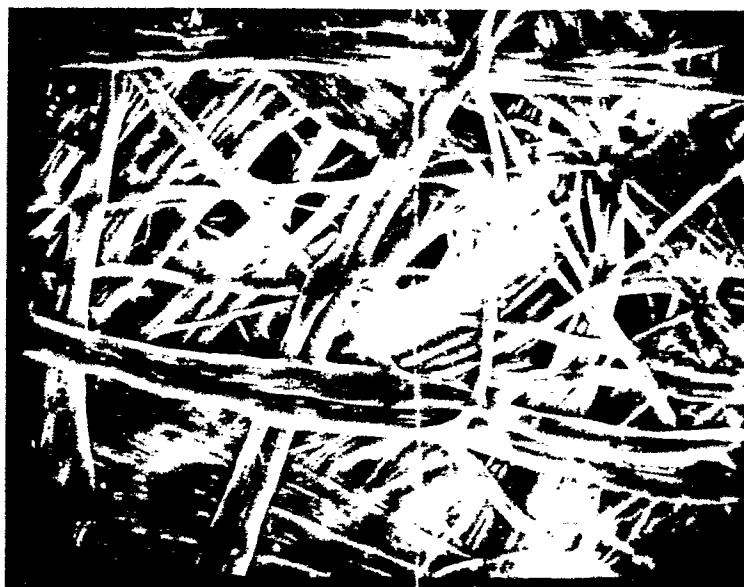


FIG. 3

*FIG. 4**FIG. 5*

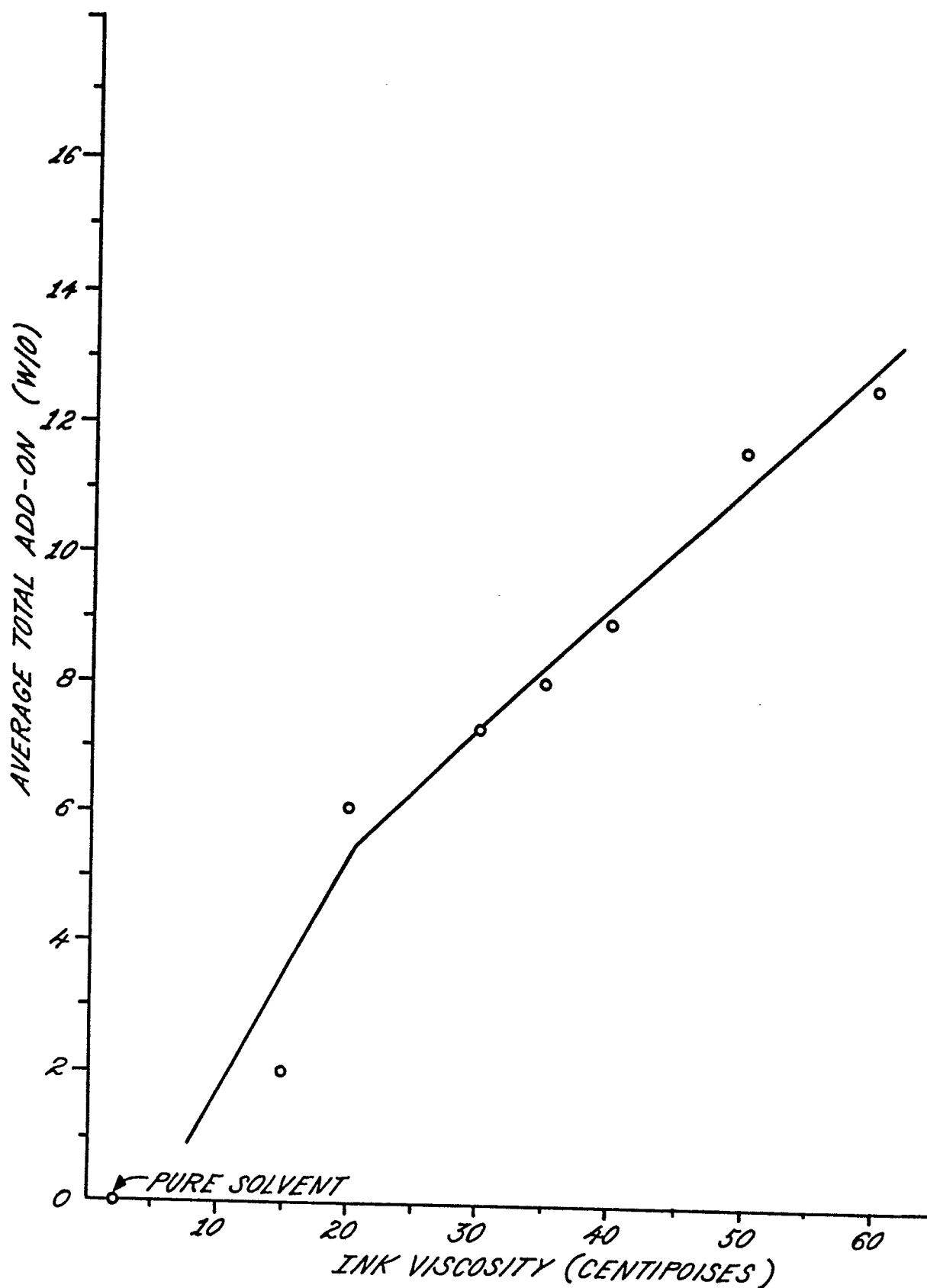


FIG. 6