Dec. 16, 1969 W. J. LEWICKI, JR 3,484,275

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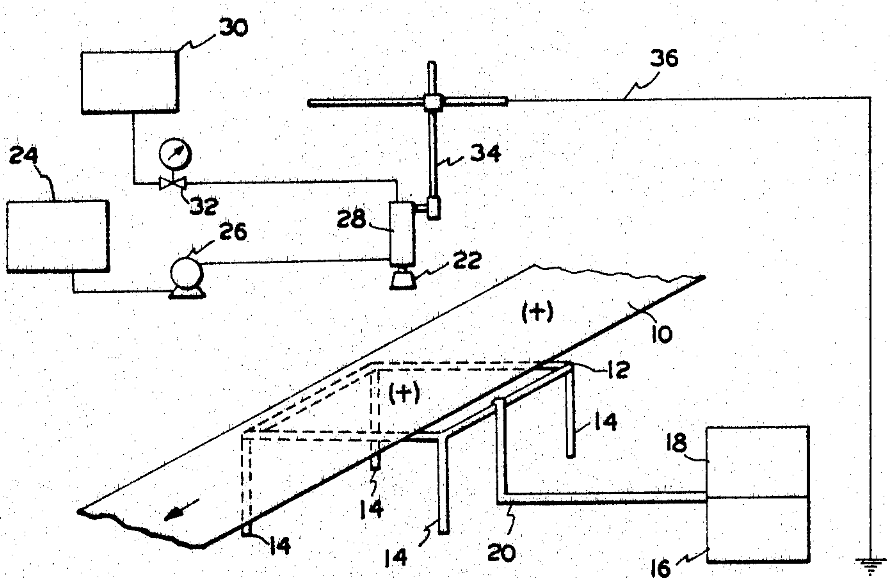
Filed May 17, 1965



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United States Patent Office

3,484,275

Patented Dec. 16, 1969

3,484,275

ELECTROSTATIC DEPOSITION OF COMPOSITIONS ON SHEET MATERIALS UTILIZING PRE-EXISTING FRICTION INDUCED ELECTROSTATIC CHARGES ON SAID SHEET MATERIALS

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Filed May 17, 1965, Ser. No. 456,244
Int. Cl. B05b *5/00;* D21h *1/10*
U.S. Cl. 117—93.4 29 Claims

ABSTRACT OF THE DISCLOSURE

A method of depositing various coating materials on a traveling paper web by electrostatic deposition. The paper web in traveling through processing or handling machinery prior to being coated attains an electrostatic charge with respect to ground. This charge is monitored as to magnitude and polarity and an additional charge is applied between a grounded spraying device and an electrode on the side of the paper opposite the sprayer. The added charge is of the same polarity as the original charge on the paper and of such magnitude as to maintain a constant predetermined total charge.

The present invention relates to a method and apparatus for depositing various liquid, semiliquid and liquefiable coating materials on a web of material. More specifically, the present invention relates to a method and apparatus for depositing various liquid, semiliquid and liquefiable coating materials on a moving web of material. In a still more specific aspect, the present invention relates to a method and apparatus for depositing nonconductive, chemical coating materials, such as, surfactants, lubricants, oil emulsions, and other organic coatings, to a web of paper.

It has heretofore been the practice to spray a coating material, such as surfactants, lubricants and the like, on moving webs of paper and like materials by the utilization of pneumatic or hydraulic spraying devices. In this type of application, a plurality of nozzles or spray heads are generally spaced across the web of material and pressure is utilized to force a fine spray or mist of the coating material onto the moving web of material. There are a number of difficulties inherent in such pressurized coating operations. For example, such spray equipment requires rather critical environmental control. Obviously, a fine mist or spray of a liquid or semiliquid material can be carried away from the web being treated by normal air currents, thereby producing uneven coating and resulting in a substantial waste of coating material. Specifically, it has been found that with the best of present-day pressurized spray equipment as much as 40% of the coating material is lost to the atmosphere. If one attempts to overcome the problem of loss of coating material by enlarging the size of the sprayed particles or droplets, the loss to the atmosphere is cut down at the expense of uneven coverage of the web of material. Under such circumstances the coating material is deposited in droplets form and a spotted or mottled spray pattern is also formed on the web. Obviously, another alternative is to increase the

pressure on the sprayed coating or to increase the amount of coating material which is deposited. Increasing the spray pressure also leads to a substantial waste of coating material, since increasing the pressure behind the sprayed material only serves to cause the material to be absorbed in the interior pores of the web of material as opposed to forming a film on the surface; and increasing the amount of coating material results in complete coverage but such coverage is uneven or excessive in spots. In addition, irrespective of the spray technique, uneven coverage is experienced when more than one spray head is utilized, since a certain degree of overlap is necessary or there is a possibility of completely missing strips. Another factor which has been found to interfere seriously with the deposition of a coating material on a moving web is that there is an air layer or barrier built up on either side of a moving web by the movement of the web. Thus, a spray pattern adjusted for coverage some distance above the web will assume an entirely different pattern immediately adjacent the web, and additional spray pressure is necessary to overcome the resistance of this air layer. The air layer will, of course, change in character and thickness depending upon the speed of movement of the web. Accordingly, the speed of movement of the web is also a critical factor in spray coating operations. Another disadvantage of pressurized spray coating, particularly of an absorbent material such as paper, is the fact that highly viscous or semiliquid materials cannot be conveniently sprayed without clogging of the spray unit. Accordingly, many paper coating materials, such as, surfactants, lubricants, and the like, must be highly diluted with solvents or water in order to make the material sprayable. Such dilution also interferes with even coverage of the web, but more importantly, requires that the web be passed through a heating unit of some type in order to evaporate the excess water or solvent.

Another and even less desirable technique for applying coating materials to paper and the like is to dip the web material in the coating solution or apply it by means of saturated rollers. This operation is often used where sizing materials, such as starch, polyethylene emulsions and the like, are applied to various types of paper. The many disadvantages of these techniques; including, waste of material, oversaturation, unevenness of coating, the necessity of drying to remove excess coating material and carrier, etc., are almost too obvious to require comment. In addition, in a dip coating process, many of the coating materials have a tendency to foam. The only way in which such foaming can be reduced to any major extent is to drastically reduce the speed at which the web is carried through the bath. This, of course, results in undue delay and oversaturation when only a surface film is generally desired to be deposited.

It is, therefore, an object of the present invention to provide an improved method and apparatus for applying a coating material to a web of material.

Another and further object of the present invention is to provide an improved method and apparatus for applying a coating material to a moving web of material.

A further object of the present invention is to provide an improved method and apparatus for applying nonconductive coating materials to a web of material.

Still another object of the present invention is to provide an improved method and apparatus for applying a coating material having a dielectric constant substantially lower than water to a web of material.

Yet another object of the present invention is to provide an improved method and apparatus for applying a coating material to a web of paper.

Still another object of the present invention is to provide an improved method and apparatus for applying a coating material to a moving web of paper.

Another object of the present invention is to provide an improved method and apparatus for applying a nonconductive coating material to a web of paper.

Yet another object of the present invention is to provide an improved method and apparatus for applying a coating material having a dielectric constant substantially below that of water to a web of paper.

A further object of the present invention is to provide an improved method and apparatus for applying a coating material to a web of material whereby substantially all of the coating material is applied to the web and waste of coating material is virtually eliminated.

Another object of the present invention is to provide an improved method and apparatus for applying a coating material to a web of material whereby surprisingly even coverage of the web is obtained.

A further object of the present invention is to provide an improved method and apparatus for applying a coating material to a moving web of material which is essentially independent of the speed of movement of the web.

Another object of the present invention is to provide an improved method and apparatus for applying a coating material of high viscosity to a web of material.

Another and further object of the present invention is to provide an improved method and apparatus for applying a softening and lubricity agent to paper.

A further object of the present invention is to provide an improved method and apparatus for applying rewettting agents to nonabsorbent paper.

A still further object of the present invention is to provide an improved method and apparatus for applying a detergent to paper.

Yet another object is to provide an improved method and apparatus for applying a sizing agent to paper.

Yet another object of the present invention is to provide an improved method and apparatus for applying a wet-strength chemical to paper.

A further object of the present invention is to provide an improved method and apparatus for applying a wet-strength-rewetting agent mixture to paper.

These and other objects and advantages of the present invention wil be apparent from the following detailed description when read in conjunction with the drawing wherein:

The drawing is a schematic diagram of apparatus useful in the practice of the present invention.

As previously indicated, the present invention is directed to the deposition of various types of chemicals in a liquid or semiliquid form onto a web of material. In a specific and primary application, the present invention will be described with particular reference to the deposition of such chemicals on a moving web of paper.

It has been pointed out above that a moving web of paper generates a layer of air along the surface of the paper which seriously interferes with the application of coating materials to the web of paper. For example, numerous spray-type techniques for depositing chemicals on a moving web of paper have been tried without a great deal of success. Airless spraying and controlled pneumatic spraying, including pressure, siphon and gravity feeds, have been tried. Utilizing the best of these prior art spray systems, a pneumatic spray setup, it was found that even under ideal conditions only about 40% of the spray material was actually deposited on the moving web and the remainder was lost to the air. In addition, in all except the best of the pneumatic systems, the deposited material was found to exhibit substantial spottiness and overlap. It is, therefore, highly desirable to provide a method and apparatus for depositing chemicals on a moving web of paper in a manner such that the loss of material is substantially reduced and the deposited material is evenly distributed on the web of paper. It is additionally desirable, in most cases where a chemical is to be deposited on a web of paper, that the chemical be deposited as a film on the surface of the paper rather than to saturate the entire thickness of paper or deposit the material in the interior pores of the paper also.

The present invention therefore provides such an efficient and effective method and apparatus for depositing chemicals in a liquid or semiliquid form onto a moving web of paper. In accordance with the present invention these objectives are accomplished by passing an atomized chemical through the field of force created when the distributing or atomizing device and an electrode on the opposite side of the moving web of paper form the plates of an electrical capacitor. It has been surprisingly discovered, in accordance with one aspect of the present invention, that a characteristic electrical charge, either positive or negative, depending upon the nature of the machine, is created in a machine supplying a moving web of material. An electrical charge of the same sense, that is, either positive or negative, has also been found to be present on the moving web of paper even though the paper is actually a nonconducting or insulating material. While the magnitude of the charge is affected by atmospheric conditions, the sense of the charge never changes. Specifically, this static charge on the moving web of paper changes from a maximum on dry days to a minimum approaching zero on humid days. However, the charge has been found to exist in most cases and is taken advantage of in the practice of the present invention. specifically, the device used to atomize the chemical which is being deposited on the moving web is grounded to form one plate of an electrical capacitor and the other plate is formed on the other side of the web of paper by providing a conductive electrode adjacent the web which is electrically isolated or completely insulated from the machine and surrounding equipment. When a charge is present on the moving web of paper, it has been found that this charge induces a like charge in the conductive electrode. When a chemical material is atomized and directed toward the web of paper, passing between the two plates of the capacitor, the atomized material will follow the lines of force of the capacitor. These lines of force serve to draw the atomized chemical material toward the charged plate and, hence, deposit the material on the web of paper. It is believed that this direction or attraction of atomized particles is due to the fact that the atomized particles assume a surface charge opposite to the charge on the charge plate and, thus, are attracted to the charge plate. Accordingly, the present technique has been found highly effective in the deposition of nonconductive materials having a dielectric constant substantially lower than that of water, thus forming a nonconductive essentially true dielectric between the two plates of the capacitor which is not substantially different from the dielectric formed by the air between the plates. By contrast, it has been found that highly conductive materials or materials having dielectric constants in the neighborhood of water or higher are not evenly and efficiently deposited on the web of paper even though exactly the same equipment is employed, under the same conditions and in the same manner. In fact, it has been found that highly conductive aqueous solutions of various chemicals cannot be deposited any more effectively than by conventional spray techniques, and, accordingly, that it is necessary to add materials which radically change or lower the dielectric constant of the solution.

While the charge induced on the charged plate by the charge on the moving web of paper can often be as high as 100,000 volts and is in many cases effective in the deposition of chemicals on the paper web, this charge is generally too variable to be depended upon under normal production conditions. While conditions can be maintained substantially constant in a laboratory-type environment and effective deposition can be obtained under the conditions previously set forth, this is not true in a plant where the humidity varies over rather wide ranges, and, consequently, where the charge on the moving web of paper varies radically in magnitude. Accordingly, it is a further feature of the present invention that charge existent on the moving web of paper and induced in an insulated plate mounted adjacent the web can be aided or maintained at a minimum magniture sufficient for effective deposition of chemicals on the moving web of paper by applying a direct current charge of like sense to the insulated plate. In this form of the invention it is, therefore, necessary to first determine the sense of the charge on the paper. As previously indicated, this charge may differ in different paper supply machines, but, for a given machine, its sense does not change. Accordingly, one should first determine whether the charge on the paper is positive or negative and then apply a like charge, which will be additive rather than subtractive, from an external source of DC energy. Obviously, if a charge of opposite polarity were applied, it would simply cancel the charge induced in the plate by the charge of the paper and serve no useful purpose.

The drawing schematically illustrates an apparatus, in accordance with the present invention, for depositing a chemical material on a moving web of paper. Paper web **10** is shown moving in the direction of the arrow from a paper supply machine (not shown). Paper web **10** is assumed to have a positive static charge thereon. Mounted below and adjacent paper web **10** is electrically conductive metal plate or electrode **12**. Metal plate **12** is preferably about ⅛" in thickness and has a length of from about 6" to about 20" in the direction of movement of the web. The width of the plate is equal to the width of the web or, if less than the full width of the web is to be coated, to the width to be coated. While a flat metal plate is illustrated, other types of electrodes may be substituted, for example, a flat screen mesh, a metal roll, an arched piece of sheet metal or screen and other such conductive devices could be utilized. Conductive plate **12** is electrically isolated or insulated from the surrounding sections of the machine or any other items which may be grounded or conductive by insulating legs **14**. Legs **14** may be solid or hollow and made of a material such as steatite. Since paper web **10** has a positive electrical charge thereon, a charge of the same sense will be induced in conductive plate **12** as web **10** passes over the plate. Where the charge on web **10** is inadequate in magnitude to supply the necessary minimal charge on plate **12**, a charge of like sense may be supplied from an external source of DC energy, such as transformer **16**. Transformer **16** is electrically coupled to control unit **18** which is adapted to vary the voltage output of transformer **16** from about 150,000 volts or more down to about 0 volt. The output of the transformer is fed to conductive plate **12** by means of high voltage electrical transmission line **20**. Thus, a variable and controllable minimum voltage, which is necessary for good chemical deposition, can be maintained on plate **12** by appropriate adjustment of control unit **18**. With no voltage present on the moving web, a minimum of about 10,000 volts per linear inch between the point of atomization and the charged plate is necessary for good deposition under normal conditions of operation. Mounted above plate **12** and paper web **10** is a spinning disc atomizer **22**. Spinning disc atomizer **22** is of conventional design and is adapted to atomize the chemical material being deposited on web **10**. The chemical material which is to be deposited on web **10** is stored in reservoir **24** and is pumped from reservoir **24** through a flow meter (not shown) to atomizer **22** by pump **26**. The chemical to be deposited on web **10**, and which is stored in reservoir **24**, may be heated when it is desired to deposit a material which is solid at ambient temperatures but which is deposited in a liquid or semiliquid form. Atomizer **22** is operated by an air turbine **28**. Air turbine **28** is supplied with air under pressure from an appropriate air source **30** through metering valve **32**. Atomizer **22** is suspended above web **10** by an adjustable rod **34** which is adapted to lower or raise the atomizer head for reasons which will be pointed out hereinafter. The entire atomizing mechanism is maintained at ground potential by means of electrical conductor **36** which ties the atomizing device to ground. Thus, atomizer **22** and charged plate **12** form the two plates of an electrical capacitor having the air between the two plates as a dielectric. The magnitude of the lines of force between atomizer **22** and plate **12** can, of course, be varied as dictated by the particular situation by varying the distance between atomizer **22** and plate **12** and/or varying the charge on plate **12**. In any event, however, the distance between head **22** and plate **12** should be from about 2" to 11" for a disc atomizer 1.75" in diameter. It should also be recognized that in order to prevent arcing and direct transmission of electrical energy between atomizer **22** and plate **12**, the voltage on plate **12** should not be too high. In addition, the distance of plate **12** from conductive or grounded items other then the atomizer **22** should be at least twice the distance between atomizer **22** and plate **12**. If the plate **12** and/or grounded machinery is insulated in some manner with materials, such as a fibrous web impregnated with a resin polymer manufactured by Westinghouse Electric Company, Pittsburgh, Pa., under the trade name Micarta, nonconductive polytetrafluoroethylene manufactured by E. I. du Pont de Nemours & Co., Wilmington, Del., under the trade name Teflon, etc., the allowable operating distance from grounded objects and machinery can be reduced considerably.

As shown in the drawing the preferred operation of the apparatus takes advantage of the gravitational forces on the atomized particles. However, it has been found that these gravitational forces have only a small influence on finely atomized particles and, therefore, the positions of the web **10**, the plate **12**, and the atomizer **22** may be varied in any desired manner to fit the particular operational situation. For example, plate **12** and atomizer **22** could be reversed in position, they could be placed at an angle to the web or arranged in any number of other possible configurations, the only criterion being that the web of paper **10** be between the atomizer **22** and the plate **12**. The relative position of paper **10** between plate **12** and atomizer **22** can be varied to a considerable extent from a position in actual contact with plate **12** to a position about 1" from spinning disc atomizer **22**.

It should be reiterated and emphasized at this point that in the operation of the present apparatus there is actually no flow of current from the atomizing mechanism to the charged plate or vice versa and the atomized coating material appears to have only a surface charge as opposed to the entire particle being conductive as is the case when highly conductive fluids are utilized. Accordingly, the system acts as a true electrical capacitor with the air between the atomizer and the electrode and also the atomized coating material between these two items serving as a dielectric. Therefore, there is also no conduction of current through the stream of atomized particles of coating material moving from the atomizing means to the charged plate. Another factor of significance is the observation that the degree of atomization is not affected by the chrage on the plate but is controlled almost exclusively by the operational conditions of the atomizing mechanism. As a result the charge on the plate affects only the directivity of the atomized material.

As previously indicated, the present technique is applicable to any web material. These materials can include textiles, metal foils, plastics, papers, etc., so long as sufficient flexibility to be classifiable as a web. Such web material may be porous or nonporous, provided only that the porosity is not so great as to pass excessive amounts of chemicals therethrough. The technique has been found particularly effective in depositing a wide variey of chemicals on fibrous web materials, such as papers. In the application to papers, materials having basis weights as low as tissue and as high as card stock can be treated. Based on reams of 2880 square feet, basis weights of about 3 lbs./ream to about 120 lbs./ream or higher are exemplary. Papers having basis weights of about 9.0 to 34.6 lbs./ream have been quite effectively treated.

Coating can be accomplished in accordance with the present invention with the web moving at speeds anywhere from 0 to about 6000 feet per minute or more, but excellent results are obtained at lower speeds below about 3000 feet per minute. The speed or fluid flow rate can, of course, be preselected and easily changed to vary the amount of coating material deposited on the web. Therefore, the material can be deposited either as a surface film on the web of material, as is the desired result in most paper coating processes, or sufficient material can be deposited to saturate the web material or deposit the coating material into the structure of the web material.

As set forth above, the coating material may be fed to the atomizing means either as a hot or cold liquid or semiliquid. It has been found in accordance with the present invention that coating materials, which are normally solid at ambient temperature, can be liquefied by applying heat to the storage reservoir or the storage reservoir and the liquid supply line. The fluid coating material, when fed to the disc-type atomizer, is broken up against the rotating vanes of the disc and is subjected to a high degree of atomization, depending upon the rotational speed or the centrifugal force of the disc. The centrifugal force of the disc disperses the fluid with a sufficient fluid velocity that atomization occurs by friction with the surrounding air. The air turbine operating the atomizing disc can be supplied with compressed air at pressures anywhere from about 1 to about 100 p.s.i.g. It should again be reiterated that the atomizing device accomplishes substantially all of the atomization of the fluid and the degree of atomization is substantially independent of the charge on the electrode.

The rotating disc atomizer is also capable of handling both high and low fluid flow rates. It has also been found, in accordance with hte present invention, that the atomizing device herein described when utilized in the apparatus of the present application can handle liquid and semiliquid materials of extremely high viscosity. Accordingly, most coating materials utilized in the coating of paper need not be diluated, and there is, therefore, no requirement that the web be passed through a heating apparatus to remove excess water or solvent. The necessity of diluting the coating materials, when conventional spray systems are used, not only added the time-consuming and costly drying step but deleteriously affects many papers. In addition, where the coating material is a solid at ambient conditions, the operating conditions set forth herein are normally such that the material is essentially a semisolid or solid as it strikes the web. This condition of the coating material, as it strikes the web, is apparently also partially responsible for the fact that a film or surface coating is applied as opposed to saturation or deposition into the interior pores of the web material.

The novel coating processes and the products thereof, which are made possible by the generic technique of the present application, are discussed in detail below.

By way of example, the method and apparatus of the present application have been used to apply softening and lubricating agents to lightweight paper materials, such as toilet paper and facial tissues. The characteristics of softness and lubricity are formed in the paper by

application, to a moving web of the paper, of a thin layer of a surfactant. The surfactant is delivered to the atomizing disc as a liquid, and because of the distance between the atomizing unit and the paper, the material is essentially semisolid when it strikes the web. Thus, the very fine particles of surfactant appear to adhere only to the outermost portions of the surface fibers and there is little or no migration of the material into the web and to the inner fibers. Since the interfibers bonding of web materials of this character is completed before deposition of the softener-lubricant and since water or other liquids capable of dissolving the interfiber bonding are not present in the coating material applied in accordance with the present invention, there is no deterioration of the interfiber bonds and the original strength of the sheet is maintained.

The rate of water absorbency of the surfactant treated paper is also increased to a great extent by this treatment when the product is compared with standard lightweight grades of facial and toilet tissue presently marketed.

The amount of softener-lubricant deposited on the web may vary anywhere from about 1% to about 4% by weight based on the basis weight of each ream of paper or about 0.20 to about 1.5% by weight per ply. For example, facial tissue having a basis weight of about 10 pounds per ream requires a surface addition of about 0.075 pound of material per ream of paper to produce a softener application of about 0.75% by weight per ply.

Under controlled low humidity conditions, the deposition of a mixture of about 80% by weight polyethylene glycol distearate and about 20% by weight polyethylene glycol dilaurate can be carried out as follows:

The temperature of the fluid in the storage reservoir, the fluid line and the atomizing device should be maintained at a maximum temperature of about 200° F. The web speed may vary between about 0 and about 3000 feet per minute. Since the web speed determines the period the web is unrolled, the temperature of the coating should be varied to permit good solidification when the speed is changed. The voltage on the charge plate should be maintained at a minimum of about 40,000 volts with a paper to charging plate distance of about ¼" or greater. An atomizing disc of about 1" diameter or greater can be operated by a turbine supplied with air at a pressure in excess of about 30 p.s.i.g. while pumping coating material thereto at a desired rate to apply about 0.75% by weight of chemical, based on web speed, basis weight of the sheet and coating width. The atomizer to charging plate distance can be maintained between about 2" and about 9".

In one specific test, under controlled, low humidity conditions, a negative charge of about 40,000 volts was maintained on the charging plate while applying the previously mentioned ester mixture to a 2-ply facial tissue. Voltages above this value appeared unnecessary for adequate, uniform coverage. The coating material was maintained at about 170° F. while being pumped at a rate not exceeding about 0.5 gallon per hour. The turbine operating the disc was in turn rotated by air at a pressure not exceeding about 90 p.s.i.g. Paper speed was maintained at about 2,000 feet per minute. In this fashion, two runs of 10,000 feet of paper were coated.

Under the above conditions, the subject coating material was applied to the paper in a surprisingly even manner, being greater than 90% consistent in its coverage, and it was found that 95% or more of the coating material was actually deposited on the paper. This compares with a 60% deposition of coating material accomplished with hydraulic spraying equipment previously used for the same purpose.

In another specific test, for the production of facial tissue coated with the previously mentioned softener-lubricant mixture of polyethylene glycol distearate and dilaurate, this coating material was utilized to coat the outermost surfaces of a 2-ply web of 800,000 feet of paper at a paper speed of about 2,000 feet per minute. The basis weight of the 2-ply paper was about 20 pounds per ream and, therefore, the facial tissue contained about 0.15 pound of the softener-lubricant on the surface of the 2-ply facial web. A perfume was also incorporated in the softener-lubricant material. Both texturized and untexturized products of the character specified were treated.

During the course of the treatment the following conditions were maintained: the voltage applied to the charging plate was about 60,000 volts for the 2,000 feet per minute web speed; the web width and, therefore, the charging plate width was about 8½"; the softener-lubricant was maintained at a temperature of about 200° F. as it was supplied to an atomizing disc about 1.75" in diameter; the atomizing disc was operated by a turbine supplied with air at about 60 p.s.i.g.; paper to atomizing disc distance was about 7"; and, the paper to charging plate distance was about ¼".

The above treatment produced a product which was vastly superior to an untreated or "control" product of the same character and to comparable treated and untreated competitive products.

One outstanding property of the product manufactured in accordance with the present invention was the absorbency rate of water by the tissue. The following chart compares the rate of absorbency of the treated product with untreated product and competitive products.

TABLE I

Brand:	Initial absorbency, sec./.1 ml. H_2O
Treated texturized	Instantaneous
Treated untexturized	Instantaneous
Competitive A	0.50
Competitive B	0.50
Competitive C	0.78
Competitive D	0.84
Control	1.90
Competitive E	47.00

A second outstanding property of the product produced in this test was the surface friction or lubricity of the product. The following table summarizes surface friction measurements of the treated product and untreated product and competitive products.

TABLE II

Brand:	Surface friction [1]
Treated untexturized	0.61
Competitive A untexturized	1.38
Treated texturized	1.54
Control	1.58
Competitive E	1.69
Competitive B	1.91
Competitive D	2.08
Competitive C	2.61

[1] Increase in number indicates an increase in surface friction between test sample and test surface.

The product treated in accordance with the present invention was also found to have many other desirable properties, such as, a minimum tendency to migrate, resistance to oxidation and other deterioration with age, and a cooling effect.

Other materials suitable for use as softener-lubricants include zinc stearate, aluminum stearate, sodium stearate, calcium stearate, magnesium stearate, spermaceti, steryl alcohol, "Carbowax," palmitic acid, oleic acid, mineral oil, tallow glyceride, di-stearyl methyl amine, primary and secondary fatty amines, petrolatums, lanolin derivatives, glycerin, etc.

Other chemicals such as perfumes, antiseptics, bacteriostats, germicides, and optical brighteners may also be incorporated in the softener-lubricant and deposited on the web.

The present invention has also been utilized to deposit rewetting agents to nonabsorbent papers having a wide range of basis weights from about 9.5 pounds per ream to about 35 pounds per ream and to nonwoven web materials having essentially the same basis weights.

Such rewetting or change of the interfacial surface tensions of nonabsorbent web materials can be accomplished by the application of nonionic, cationic and anionic surfactants. An example of a nonionic surfactant is Igepal CO–630 (an alkyl phelol+ethylene oxide), a suitable anionic surfactant is Gafac RS–710 (a complex organic phosphate ester-free acid), and a cationic surfactant is exemplified by cetyltrimethyl ammonium bromide.

The previously mentioned fluids are atomized as a liquid but are in an essentially dry state at the conditions of use of the products.

A few of the other surfactants which may be used in this process for improving the rate of absorbency are: Emulsan A–67, nonionic, polyethylene oxide adduct with long chain fatty acids; Larosol 2–8, nonionic; Napco DE–115, nonionic, ethoxylated fatty acid; Piotron K–31–S, nonionic, polyoxyethylene ethers of nonphenol and polyoxypropylene-polyoxyethylene glycols; Sandrol 200 CG, nonionic, coconut oil alkanol-amide; Sterox CD, nonionic, polyoxyethylene ester of tall oil; Sulfonic LF–5, nonionic, fatty alcohol and ethylene oxide adduct; Synthrapol RWP, nonionic; Triton X–100, nonionic, alkyl alcohol aryl polyether; and Estranol FTS, amphoteric, sodium sulfonic acid salts of carboxylic acid esters.

Materials similar to the rewetting agents may also be applied to heavy absorbent grades of paper having basis weights ranging from about 17 to about 35 pounds per ream. In this instance a detergent, such as, an alkyl sulfonate, is applied to the paper to produce what is commonly known as a soap-impregnaed, disposable paper dishcloth. The concentration of detergent is generally in the range of about 30% to 95% by weight of the ream of paper.

Previously, in the application of detergents to disposable paper dishcloths, the product was produced by either dip coating or applying the material in a size press. In both of these techniques serious problems of foaming occur. This foaming problem is completely eliminated when practicing the present invention since at no point in the process does the web pass through a large concentration of the impregnating material.

Operating conditions for the application of rewetting agents to nonabsorbent papers and of detergents to absorbent papers may be as follows:

The voltage on the charging plate can be maintained at a minimum of about 40,000 volts with a paper to charging plate distance of about ¼" to about 1". The atomizer may be a disc-type atomizer about 1" or more in diameter operated by an air turbine supplied with air at about 30 p.s.i.g. or more. An atomizer to paper distance of about 2" to about 9" may be used and a web speed anywhere from 0 to 3,000 feet per minute can be employed. The fluid reservoir, the fluid flow line, and the atomizer should be maintained between about 70° and about 140° F. for detergent application. The temperature, however, is primarily selected so as to suitably control flow. Rewetting agents can be applied economically at rates up to about 0.22% by weight per ream while detergent application preferably averages about 48% by weight per ream.

A series of runs were made in which five different surfactants were utilized in the rewetting of production roll towel paper of both fresh run and stored variety. The basis weights of the towel paper were about 33.7 pounds per ream for the stored paper. Both of these papers initially exhibited poor absorbency characteristics. Varying amounts of the wetting agents from about 0.05% to about 1.25% by weight were deposited on the papers. The absorbency of the papers was measured both immediately after deposition of the rewetting agent and after toasting at about 300° F. for about five minutes. The following operation conditions were utilized: a charging plate voltage of about 60,000 volts; a web speed of about 2,000 feet per minute; turbine air pressure about 35 p.s.i.g.; a disc size of about 1¾", a fluid temperature of about 68° to about 77° F.; a plate to paper distance of about ¼"; and a disc to paper distance of about 7". The results of the absorbency tests are shown in the following table:

TABLE III

Rewetting Agent	Amount (percent on paper) delivered to atomizer	Absorbency, sec./0.1 ml. H_2O			
		Fresh Paper		Old Paper	
		Initial	Toasted	Initial	Toasted
Synthrapol RWP	0	14.4	42.0	74.4	258.1
	0.05	15.6	22.1	61.6	136.9
	0.10	9.0	14.5	35.5	95.6
	0.15	7.0	8.3	16.2	32.7
	0.20	7.5	9.6	12.8	14.8
	0.30	7.3	11.6	9.4	24.5
	0.50	7.0	9.1	12.2	13.5
Igepal CO-630	0	15.7	32.4	91.2	270.8
	0.05	9.1	16.8	69.9	239.4
	0.10	6.5	8.3	33.5	56.6
	0.15	8.4	8.0	20.4	31.6
	0.20	6.6	8.9	19.5	26.7
	0.30	6.9	6.6	17.1	21.3
	0.50	6.3	6.8	11.7	15.8
Larosol 2-8	0	16.9	73.9	40.2	166.9
	0.05	15.2	30.7	55.5	140.8
	0.10	12.3	26.6	65.7	144.0
	0.15	11.6	15.7	33.0	56.6
	0.20	7.5	11.5	23.7	47.1
	0.30	6.9	10.8	33.3	39.6
	0.50	6.0	10.4	11.2	28.1
Gafac RS-710	0	15.8	31.9	71.5	308.5
	0.05	13.1	33.7	72.3	260.8
	0.10	10.4	22.8	33.9	61.6
	0.15	6.1	10.5	26.8	40.0
	0.20	6.4	9.1	20.8	31.4
	0.30	5.7	7.0	16.8	28.1
	0.50	5.9	6.2	15.8	25.9
Estranol	0	14.9	34.3	42.8	223.4
	0.5	8.0	11.8	19.9	29.3
	0.75	8.2	11.1	20.2	24.9
	1.0	7.4	9.7	16.2	20.5
	1.25	7.9	9.6	16.7	15.4

In the above-mentioned tests the rewetting agents were utilized in their concentrated form as received. Accordingly, it was not necessary to pass the web to a drying stage after application of the rewetting agent to remove excess water or diluent. These concentrated solution of rewetting agents varied in viscosity from about 85 to 350 centipoises at 77° F. Such high viscosity materials cannot be conveniently and effectively applied by hydraulic spray equipment; however, the present apparatus readily handled even the most viscous material.

Measurements of the physical properties of the paper before and after treatment showed that the treatment had little or no effect on physical properties, such as tensile strength, stretch, etc., of the paper.

It was found in the series of tests set forth above that the amount of material applied to the web was very easily controlled by varying the rate at which the material was pumped to the atomizer.

It is to be observed by an inspection of the data of Table III that, in almost every case, the greatest gain in absorbency occurred after the application of the first 0.1% of rewetting agent and that no appreciable change occurs after the application of about 0.2% by weight of rewetting agent. It is, of course, quite obvious from the data that rather dramatic improvements in the absorbency of the papers were obtained.

Similar tests were also run on commercial units with like results.

A series of tests were also conducted on pilot equipment with and without a voltage applied to the plate by depositing Igepal CO-630 containing 3% of an ultraviolet responsive additive on the new towel stock at a rate of 0.6 gallon per hour. In these tests the web speed was 2,000 feet per minute, the turbine air pressure 35 p.s.i.g.; the fluid temperature 68° F.; the disc size 1¾"; the paper to plate distance 7"; and, where the plate was charged, a voltage of 60,000 volts.

Visual inspections and ultraviolet photography of the treated paper were carried out. It was found in all instances that the degree of atomization, the web coverage, the uniformity of coverage, and the lack of signs of overlap or streaking were quite outstanding when the plate was charged as compared with the operation in which no charge was applied to the plate.

Runs were also made utilizing the mixture of Igepal CO-630 plus 3% optical brightener to treat the fresh paper stock while varying the operating conditions of an apparatus having two atomizers. The basic conditions were: a voltage of about 60,000 volts; a turbine air pressure of about 40 p.s.i.g.; a web speed of about 2,000 feet per minute; a fluid flow rate of about 0.6 gallon per hour; a fluid temperature of about 77° F.; a disc size of about 1¾"; a paper to plate distance of about ¼"; a paper to disc distance of about 7"; and an edge to edge distance between heads of about 2".

First, the air pressure to the atomizer turbine was varied from about 0 to 70 p.s.i.g. It was found in this series of tests that the degree or fineness of atomization of the coating material depended almost exclusively upon the speed at which the atomizing disc was operated. Accordingly, close control of the degree of atomization can be accomplished simply by varying the air pressure to the turbine. Excellent coverage and deposition was obtained at air pressures of about 30 to about 50 p.s.i.g.

Next, the flow rate of liquid to the atomizer was varied between about 0.01 and about 2.75 gallons per hour. Over the range investigated, no undesirable streaking or overlapping was observed. Varying the flow rate simply varied the amount of material deposited, and, irrespective of flow rate, the material was distributed evenly.

Voltage applied to the charging plate was varied between about 20,000 and about 80,000 volts. It was found that a voltage range of about 30,000 to about 60,000 volts is necessary at web speeds up to about 2,000 feet per minute. It was also concluded that voltages above this range such as 70,000 volts and 80,000 volts, could be conveniently utilized but are not necessary for effective operation of the equipment.

The paper to charging plate distance was also varied from about ¼" to about 2". This was found to be a suitable range for operation of the process while distances outside this range gave less desirable results.

The paper to atomizer disc distance was also varied from about 2" to about 9". It was found that at a minimum distance of about 2", a lower voltage was required to obtain even distribution and efficient deposition of the coating material. The higher distances required a higher voltage. Preferably, a distance of about 4" to about 9" is used.

Tests were made while varying the speed of the web from about 250 to about 2,000 feet per minute. All speeds in this range were found to produce products having a small particle size coating. Speeds above this range are also acceptable and efficient.

Finally in evaluating the center to center distance between the two atomizing discs, distances between about 2" and about 12" were investigated. It was found that at the operating conditions listed, a center to center distance of about 10" was optimum. At a distance greater than 10", a portion of the center of the web was untreated. This, of course, could be corrected by increasing the speed of the atomizing disc or increasing the disc to paper distance. However, with an increased disc to paper distance, a slight increase in the voltage would be required.

In order to determine the efficiency of application of rewetting agents to the fresh towel paper, an extended run was made. During this run the following conditions were maintained: a voltage of about 60,000 volts; a turbine air pressure of about 35 p.s.i.g.; a web speed of about 250 feet per minute; a disc size of about 1¾" utilized; a paper to charging plate distance of about ¼"; a paper to atomizing disc distance of about 7"; and a flow rate of 1.0 gallon per hour (about 5.05% by weight).

In this investigation of a large roll of towel paper, the roll was first weighed, rewetting agent was then added at a known flow rate for a specified time and the roll was again weighed to determine the amount of atomized material actually deposited. The amount of material that was actually deposited for a specific period of time was then compared to the amount of material which was theoretically applied. After running this test for 50 minutes, a deposition efficiency in excess of about 94% was obtained.

The present technique was also compared with a conventional hydraulic spray system, presently in use on a commercial basis, under essentially parallel conditions. In this comparison, Synthrapol RWP plus about 3% by weight of an optical brightener was applied to the previously-mentioned fresh towel stock. The rewetting agent application rate was about 0.219% by weight, the temperature of the coating material was maintained at about 77° F., and the paper to distributor distance at about 7". The web speed was about 2,000 feet per minute when utilizing a charged plate (about 60,000 volts), and about 1,500 feet per minute when using a hydraulic spray. The disc-type atomizer was operated by a turbine utilizing an air pressure of about 35 p.s.i.g., and the hydraulic spray system utilized a fluid pressure of about 35 p.s.i.g. In this side-by-side comparison, the superiority of the present technique was evident. The hydraulic spray showed clear evidence of nonuniform coverage, streaking, pattern overlap, and partial atomization. By contrast, the present technique resulted in uniform distribution, a high degree of atomization and no pattern overlap or streaking. Of even greater significance, however, was that the present technique deposited about 95% of the coating material while the hydraulic system deposited about 50%. The hydraulic system also requires that the coating material be diluted by about 50% and, therefore, also requries drying after deposition.

Comparative tests were also run under mill conditions, in which towel stock having a basis weight between about 30 and 32.8 pounds per ream was treated with varying amounts of Larosol 2–8 by utilizing a hydraulic spray system, which had been in commercial use in the plant for this purpose, along with the apparatus of the present invention.

In the first of these tests about 0.219% by weight of rewetting agent was utilized in all of the hydraulic spray operations, while from about 0.219 to about 0.05% by weight of rewetting agent was used in evaluating the present invention in a designated area on the same commercial machine. A fluorescent dye was added to the rewetting agent in an amount of about 0.5% by weight. The dye was then Soxhlet extracted from the towel using methanol as a solvent; and the extracted dye was analyzed in a photoelectric colorimeter to determine the optical density. From these determinations, the deposition efficiency was obtained.

The following conditions were maintained when operating the present apparatus: three discs about 1.75" in diameter were utilized to deposit material across a 48" web of paper. Voltage on the charging plate was maintained at about 50,000 volts. A plate to atomizing disc distance of about 5¾" and a distance of about 14" between atomizing discs were utilized. Air turbines supplied with air at pressures between about 40 and 50 p.s.i.g. operated the atomizers. The web speed was between about 1440 and 1520 feet per minute. Since the rewetting agent had a viscosity of about 350 cps. at 77° F., it was necessary to dilute the material with water in order to permit spraying by the hydraulic spray system. However, no dilution was necessary for the present invention. With about a 4 gallons per hour rate of rewetting agent supply, it was necessary to utilize about 178 gallons per hour of water to dilute the material sufficiently.

The average amount of rewetting agent deposited in the hydraulic spray test was about 59.4%, while that obtained in accordance with the present invention was at least about 90% in all tests, and averaged 94.5%.

A second set of comparative tests was made utilizing the previously mentioned hydraulic spray system and the system of the present invention to apply rewetting agent in amounts ranging from about 0.05% to 0.219% by weight, to a paper having a basis weight between about 31.6 and 32.4 pounds per ream. The web speed was approximately 1480 to 1530 feet per minute. Fluid temperature was between about 83° F. and 91° F. The distance between the distributing head and the paper was about 5½". The flow rate when utilizing the atomizer system of this invention varied between about 4.73 and 18.3 cc. per minute per disc, while the flow rate for the hydraulic system varied from about 0.84 to about 3.79 gallons per hour. The air turbine operating the spinning disc atomizer, of the present invention, utilized air pressures between about 40 and 50 p.s.i.g. Plate voltage in the present system was maintained at about 60,000 volts.

During this comparative set of tests, the efficiency of application was again measured as described above, and it was found that the hydraulic spray system deposited about 59.6% of the rewetting agent, while the present system deposited about 96.05%.

Various tests were also conducted to compare a 3" diameter atomizing disc with the previously employed 1.75" disc. It was found in this comparison that the disc size made little difference at the low flow rates except that the larger disc required a slightly higher turbine pressure and permitted a greater disc to paper distance. Specifically, the larger disc required an air pressure of about 50 p.s.i.g. to obtain atomization equivalent to that produced with an air pressure of about 40 p.s.i.g. when using the smaller disc; and the equivalent minimum disc to charged plate distances are about 4½" and about 5½".

During the first set of mill tests, web voltage was measured with a vacuum tube voltmeter and the efficiency at various web voltages determined. The deposition efficiencies and web voltages were about 89.7% at about 13,646 volts, about 93.3% at about 18,020 volts, about 96.3% at about 19,600 volts, and about 98.4% at about 22,546 volts. In all cases the charge plate voltage was 500,000 volts. When the web voltage was essentially 0 and no voltage was applied to the plate, the efficiency was about 41.5% and streaking and nonuniformity were present.

The present invention has also been utilized in the application of functional organic coatings, such as starch solutions, polyethylene emulsions and the like, to converting grades of paper having a basis weight in the range of 34 pounds per ream to 100 pounds per ream. These materials are applied as a sizing agent and are generally applied by size presses or dip coaters, as previously discussed in connection with the application of detergents. Consequently, the same problems exist in the prior art. In addition, the web was normally completely saturated with the size material when only a thin surface coating is desired. To apply a thin surface coating, in the present instance, it is desirable to maintain the speed above about 250 feet per minute. Here again, substantial savings are effected since the conventional size press and dip coating operations have highly restricted speeds because of the tendency to foam. In applying the sizing material to paper, voltages in excess of about 80,000 volts should be maintained while the disc is rapidly rotated by a turbine air pressure of about 90 p.s.i.g. As in the previous examples, the disc size was at least about 1" in diameter. The paper to charging plate distance should be about 1/4" to about 1" and the disc to paper distance between about 2" and 4". The sizing fluid is maintained at a temperature of about 77° F. Under these conditions, applications of sizing material between about 5 and 25% by weight can be obtained.

Comparative tests of aqueous solutions and nonaqueous solutions of sizing materials showed rather dramatically that the present invention is substantially superior when used in the deposition of nonaqueous materials. It was found that a loss of about 50% occurred with aqueous solutions and the usual loss of about 5% with nonaqueous solutions. Theoretically, it is believed that a nonaqueous droplet receives a surface charge from friction when it is atomized while an aqueous droplet does not. In any event a very real difference is apparent in the present method.

The present invention was also found quite effective in the deposition of latex on 2-ply facial tissue. Amounts of latex in the range of about 1 to 20% were applied with no plugging of the atomizer. Good atomization of the coating material was obtained with no significant loss of material and a very uniform web coverage resulted. Because of the nature of latex, some drying is also needed.

A water-dispersible lecithin material was applied to the dull side of a web of aluminum foil. In this instance, about 0.5 pound per ream of coating material was applied, and good results were obtained so long as the aluminum did not contact the charging plate. Since the coating material was an aqueous solution, the efficiency of deposition was poor. This, of course, could be significantly improved by the addition of a nonaqueous or insulating liquid. As in the previous instance, drying of the coated product is necessary.

I claim:

1. In the method of applying a coating to a paper web under the influence of an electrostatic field by atomizing the coating in a field established between atomizing means and a backup electrode placed on a side of the paper web opposite the atomizing means, the steps of

monitoring the paper web to determine the presence, magnitude and polarity of any machine friction induced electrical charges, and

applying between said coating device and said backup electrode an electric field having the same polarity as said machine friction induced electrical charges and of sufficient magnitude to maintain constant the resultant of the applied and the machine induced charges.

2. A method for applying a surface coating to a web of material as said web travels past the point of application, said web in its travel having an electrical charge induced on it by machine friction, comprising:

(a) determining the polarity with respect to ground of the electrical charge present on the traveling web;

(b) applying a charge of the same polarity as said determined polarity to the side of the web opposite the side to be coated;

(c) atomizing a coating material;

(d) directing said atomized material toward the side of said web to be coated; and

(e) simultaneously with the atomization of said coating material, maintaining said atomized coating material at ground potential.

3. A method in accordance with claim **2** wherein the magnitude of the charge on the web is monitored and the charge applied is adjusted to maintain a predetermined minimum charge.

4. A method in accordance with claim **3** wherein the minimum charge is the voltage necessary to achieve efficient deposition of coating material on the web.

5. A method in accordance with claim **3** wherein the minimum charge is about 10,000 volts per linear inch of distance between the point of atomization of the coating material and the point at which the charge is applied.

6. A method in accordance with claim **2** wherein the charge is less than about 150,000 volts.

7. A method in accordance with claim **2** wherein the coating material is maintained in a fluid form.

8. A method in accordance with claim **2** wherein the coating material has a dielectric constant substantially less than water.

9. A method in accordance with claim **2** wherein the coating material contains a nonconductive additive adapted to reduce the dielectric constant of the coating material to a value substantially lower than that of water.

10. A method in accordance with claim **2** wherein the coating material is atomized by passing it through a disc rotating at a high speed.

11. A method in accordance with claim **9** wherein the atomizing disc is operated by compressed air at a pressure between about 1 and 100 p.s.i.g.

12. A method in accordance with claim **2** wherein the charge is applied to a flat metal plate.

13. A method in accordance with claim **2** wherein the charge is applied to a flat metal mesh.

14. A method in accordance with claim **2** wherein the charge is applied to a curved metal plate.

15. A method in accordance with claim **2** wherein the charge is applied to a curved metal mesh.

16. A method in accordance with claim **2** wherein the charge is applied to a metal roll.

17. A method in accordance with claim **2** wherein the charge is applied to a flat metal plate between about 6 and 20 inches long and substantially the same width as the web.

18. A method in accordance with claim **2** wherein the discharge of atomized coating material is carried out a distance of about 2 to 11 inches above the point of charge application.

19. A method in accordance with claim **2** wherein the web material is a web of paper.

20. A method in accordance with claim **19** wherein the coating material is a surfactant.

21. A method in accordance with claim **19** wherein the coating material is a softening agent.

22. A method in accordance with claim **19** wherein the coating material is a lubricating agent.

23. A method in accordance with claim **19** wherein the coating material is a rewetting agent.

24. A method in accordance with claim **19** wherein the coating material is a detergent.

25. A method in accordance with claim **2** wherein the coating material is a wet-strength chemical.

26. A method in accordance with claim **2** wherein the coating material is a wet-strength chemical-rewetting agent mixture.

27. A method in accordance with claim **19** wherein the coating material is an organic sizing agent.

28. A method in accordance with claim **2** wherein the coating material is applied to paper of about 9.5 to 35 pounds per ream (based on a ream of paper having 2880 square feet).

29. A method in accordance with claim **2** wherein the web is traveling at a speed up to about 3,000 feet per minute.

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U.S. Cl. X.R.

117—154, 155, 156; 162—135, 192