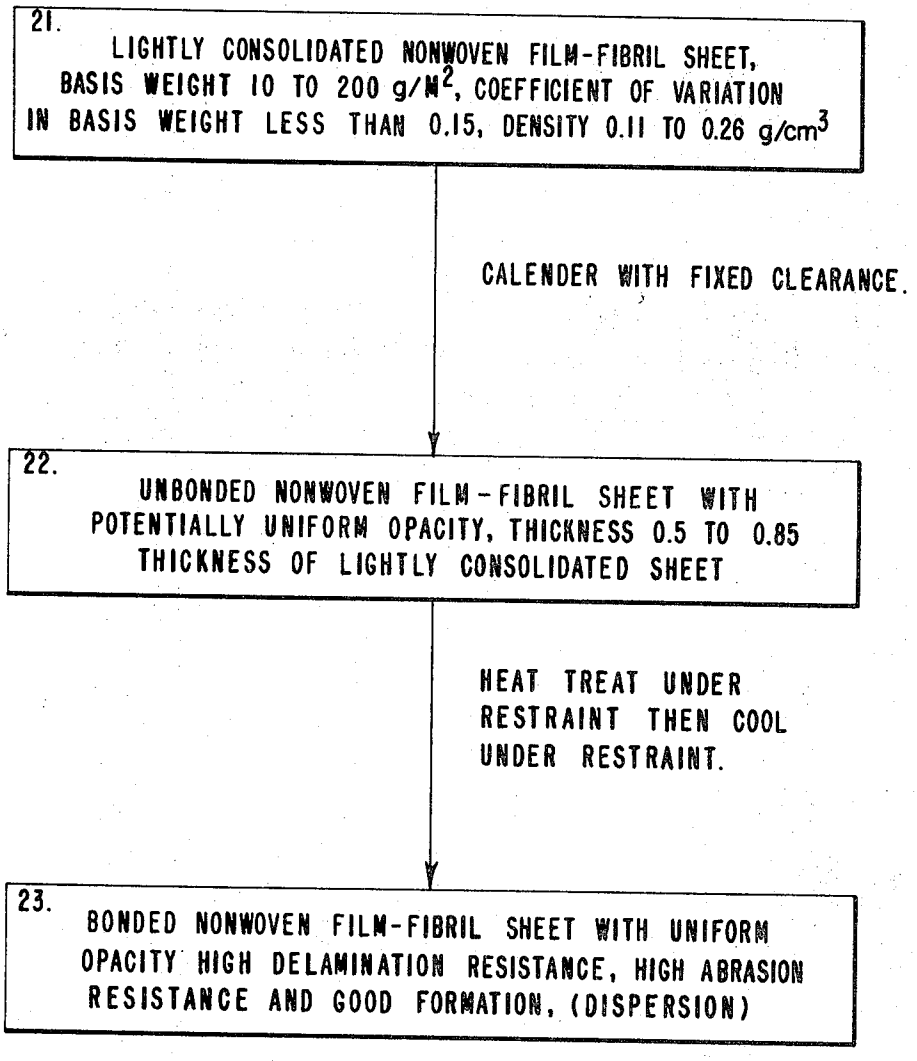
Oct. 27, 1970 CHI-CHANG LEE 3,536,552

FINISHING PROCESS FOR NON-WOVEN SHEETS OF STRAND MATERIAL

Filed Dec. 19, 1966 3 Sheets-Sheet 1

FIG. 1



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Oct. 27, 1970 CHI-CHANG LEE 3,536,552

FINISHING PROCESS FOR NON-WOVEN SHEETS OF STRAND MATERIAL

Filed Dec. 19, 1966 3 Sheets-Sheet 2

FIG. 2

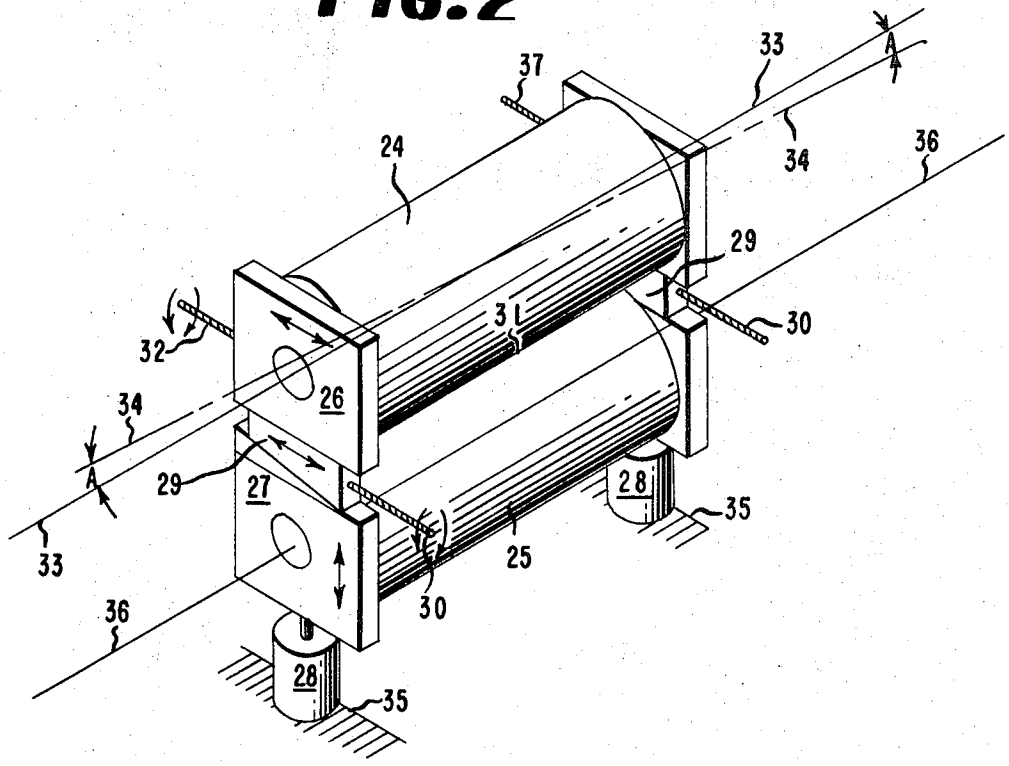
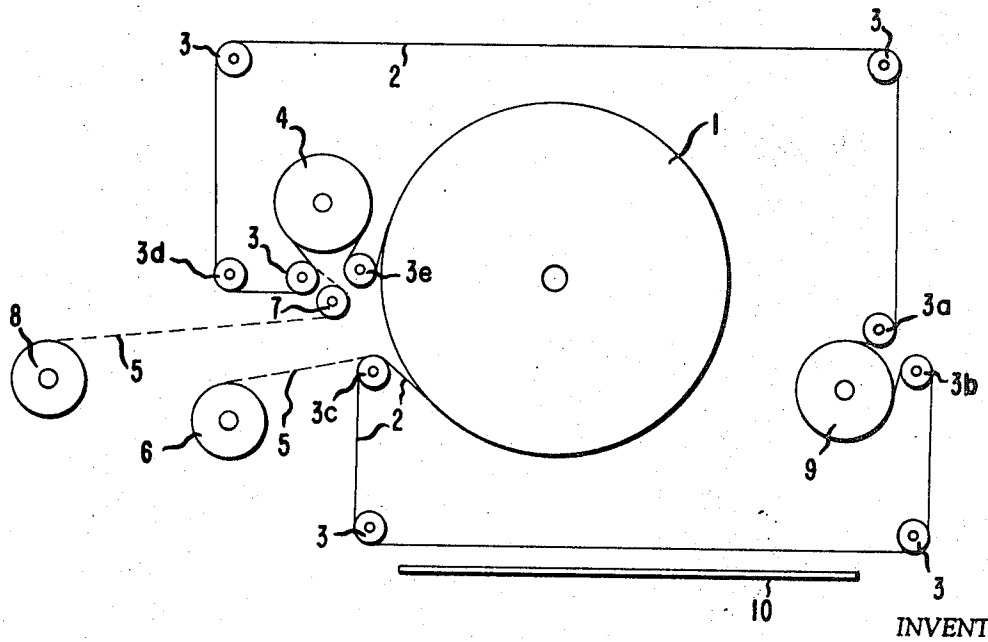


FIG. 3



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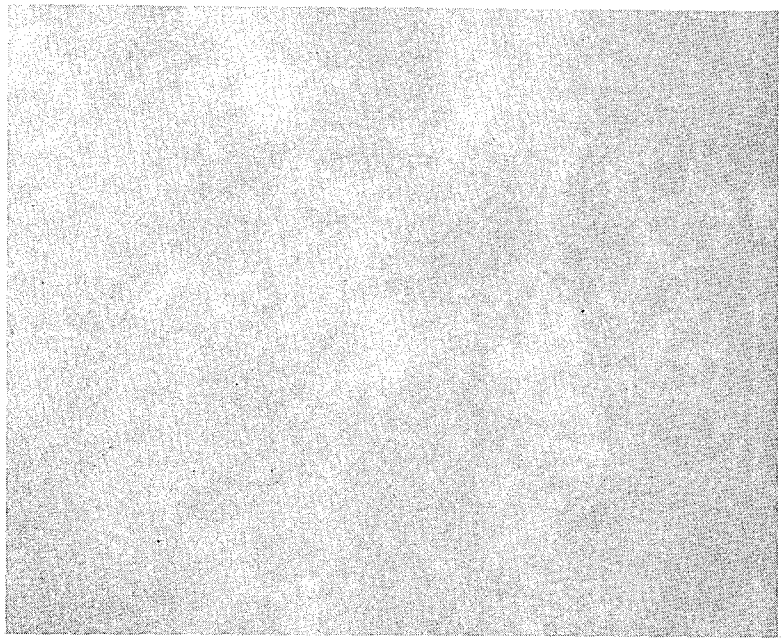


FIG. 4

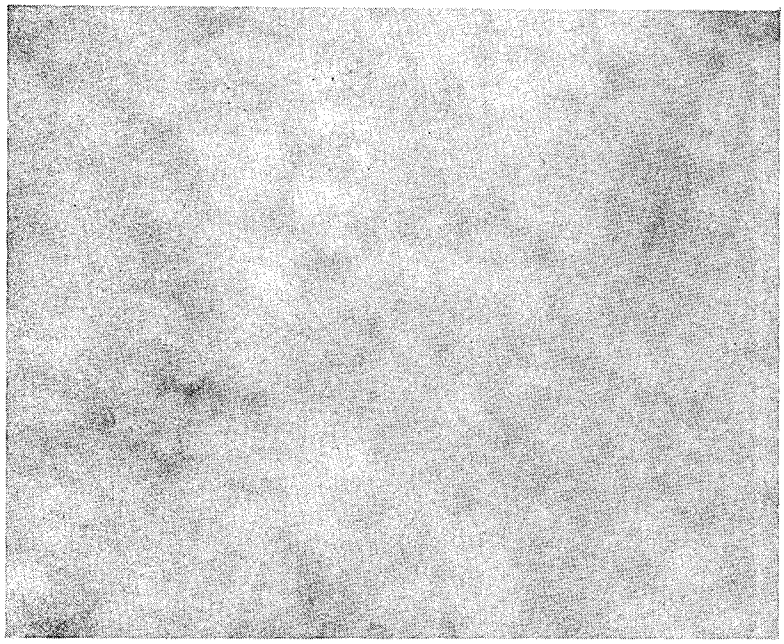


FIG. 5

United States Patent Office 3,536,552 Patented Oct. 27, 1970

3,536,552

FINISHING PROCESS FOR NON-WOVEN SHEETS OF STRAND MATERIAL

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Filed Dec. 19, 1966, Ser. No. 602,673
Int. Cl. B32b 27/00
U.S. Cl. 156—166 1 Claim

This invention concerns an improved finishing process for nonwoven sheets of self-bonding film-fibril strand material. The invention relates particularly to a process for preparing a nonwoven sheet material which has a high level of opacity uniformity and uniform dispersion (as in paper formation) and which at the same time is sufficiently well bonded to have high delamination resistance and high abrasion resistance.

BACKGROUND

U.S. Pat. No. 3,169,899 to Steuber describes the formation of "film-fibril" sheets by the random, overlapping, deposition of continuous fibrillated strands. These strands, described in Blades et al. U.S. Pat. No. 3,081,519, are each characterized as a three-dimensional network of film-fibrils which are interconnected at random intervals along and across the strand. The individual film-fibrils are composed of molecularly oriented crystalline organic polymer, the average polymer thickness in the film-fibrils being less than 4 microns. The initially deposited film-fibril sheets may be compressed and/or fused, e.g. by calendering or by hot air treatments, to further develop certain desired qualities. However, a sheet treated in such a manner tends to have non-uniform translucent areas. For certain applications such as book binding, a film-fibril sheet should exhibit constant opacity throughout its area, good flatness, and, on one surface at least, high abrasion resistance or surface stability. Similar properties are needed in a sheet for wall covering. Such materials should have high resistance to delamination so that the well covering may later be removed from the wall without leaving fibers behind.

The tendency for the film-fibril sheets to become transparent when exposed to excessive pressure or heat has created problems in the utilization of film-fibril sheets as substitutes for coating materials or as printing paper for books or other such uses. When the sheet is consolidated under a constant pressure such as by exposure to a soft roll calendar, sheet basis weight nonuniformities are transformed to thickness nonuniformities. Since rate of heat transferred to the sheet is inversely proportional to its thickness, the relatively thin spots in the sheet become even more highly bonded than the relatively thick spots, and a nonuniform appearance results. As the degree of bonding increases, sheet opacity is decreased and resistance to coating or ink strike-through is decreased in these portions of the sheet. The ink or coating material then shows through the sheet on the opposite side at the overly bonded relatively thin spots creating a mottled undesirable appearance.

In Belgian Pat. 662,353, issued Apr. 30, 1965, a method is described for bonding film-fibril sheets to obtain products with good surface stability and high resistance to delamination. While the process described in this application provides sheets with good uniform opacity, this quality seems to be dependent upon the history of the sheet prior to the bonding operation. The reasons for this are not precisely understood. However, sheets which have been prepared by depositing on a moving belt in air or in the presence of low velocity gases or by use of certain types of deflectors are easily bonded by the method described in the Belgian Pat. No. 662,353 to obtain a product of uniform opacity. On the other hand, sheets which have been deposited in an atmosphere of trichlorofluoromethane (Freon® 11) tend to have non-uniform opacity after the bonding operation. In addition the type of deflector and the laydown pattern affect the ability to obtain uniform opacity. The improved process of the present invention substantially reduces this tendency for nonuniformity.

According to this invention there is provided an improved process for obtaining a bonded nonwoven film-fibril sheet having uniform opacity throughout its area, having a high degree of abrasion resistance, a high resistance to delamination, and good formation (dispersion).

SUMMARY OF INVENTION

The process of this invention utilizes a lightly consolidated film-fibril sheet having a density of 0.11 to 0.26 g./cm.^{3} (7 to 16 lbs./ft.^{3}), basis weight of 10 to 200 g./M.^{2} (0.3 to 6.0 oz./yd.^{2}) and a coefficient of variation in basis weight of less than 0.15. This sheet is passed through a constant clearance nip between a pair of hard calender rolls at substantially room temperature. The clearance between the rolls is adjusted to give a new thickness which is between 0.5 and 0.85 of the thickness of the lightly consolidated film-fibril sheet. The sheet from the constant clearance calender is then passed through a heating zone while under restraint to prevent shrinkage and is given sufficient exposure to heat to raise the temperature of either face of the sheet to within 7° C. of the upper limit of the melting range of the film fibrils, but not substantially above said upper limit. The sheet is then cooled while still under restraint to a temperature below that at which the sheet distorts or shrinks.

The invention is more fully described by reference to the figures:

FIG. 1 is a flow diagram showing the process of the invention wherein a lightly consolidated film-fibril sheet is passed through a fixed nip calender at room temperature and then bonded by heating to near the melting point while under restraint.

FIG. 2 is a perspective view of a calender with an adjustable clearance between rolls.

FIG. 3 is a diagram showing an apparatus for bonding the sheets after fixed nip calendering.

FIG. 4 is a picture of a nonwoven film-fibril sheet produced by the process of this invention.

FIG. 5 is a picture of a nonwoven film-fibril sheet produced in a similar manner, but without calendering with a fixed clearance prior to bonding.

DESCRIPTION OF THE BASIC PROCESS

As shown in FIG. 1, the process of the invention is applied to a lightly consolidated nonwoven sheet of film-fibril material with a density of 0.11 to 0.26 g./cm.^{3} (7 to 16 lbs./cu. foot) and a basis weight of 10 to 200 g./M.^{2} (0.3 to 6 oz./yd.^{2}). In order to obtain a satisfactory result, the film-fibril sheet should have reasonably uniform basis weight throughout its area. A sheet having a coefficient of variation in basis weight of 0.15 or less is satisfactory. The lightly consolidated sheet is prepared by the method of Steuber U.S. 3,169,899 using one or more spinnerets. A solution is flash-spun from the spinneret(s) and directed by means of a rotating or oscillating baffle to a collecting belt. The amount of spreading which is accomplished by each deflector and the degree of overlap is carefully controlled to give a uniform distribution of fibers on the collecting belt. The collected sheet is lightly consolidated by passage on the belt under a roll which applies a pressure less than 10 lbs./linear inch (1.8 kg./cm.). The sheet which is obtained after cold consolidation is represented in FIG. 1 by the block **21**.

The lightly consolidated sheet is passed through a calender of the type commonly described as "a fixed nip calender." This type of calender is readily available on the market and will be further described in subsequent paragraphs. The clearance between the rolls of the calender can be accurately controlled so that variations along the length of the nip are less than .0005 inch (0.00127 cm.). The cold consolidated sheet as it passes through the fixed nip calender is reduced in thickness to form a still unbonded sheet represented in FIG. 1 by the block **22**. The new thickness is between 0.5 and 0.85 of the thickness of the lightly consolidated film-fibril sheet.

It should be understood that the actual nip in the calender compresses the sheet more than is indicated by the final thickness of the sheet. There is considerable springback after calendering. Nip clearance is between 90% and 40% of the final sheet thickness.

As shown in FIG. 1 the sheet **22** which is obtained after fixed nip calendering is particularly susceptible to uniform bonding. While this sheet before bonding has good formation and high opacity, it does not have sufficient abrasion resistance for use as a printing paper and its delamination resistance is not satisfactory for wall covering use. There are, of course, numerous other uses to which this sheet would be satisfactory without further processing. However, in order to improve the delamination resistance and the surface stability the sheet is passed next through a heat treatment while under restraint to prevent shrinkage. The heat treatment raises the temperature of the sheet to near the melting point of the film-fibril elements. For operation to obtain well bonded sheets the temperature of at least one surface of the sheet must be within 7 degrees of the upper limit of melting range of the film-fibril elements. As will be explained with reference to FIG. 4, the temperature of the surface layers of the sheet during heat treatment may be determined by a measurement of surface area per gram after treatment.

The resulting bonded nonwoven film-fibril sheet indicated in FIG. 1 by block **23** has high delamination resistance, i.e. greater than 0.35 lb./inch (63 g./cm.) and has high abrasion resistance, i.e. greater than 2 cycles. The opacity of this product is preferably greater than 90% when measured by means of the Bausch and Lomb contrast ratio apparatus. The opacity uniformity is such that the coefficient of variation is less than 0.01. The various methods for measuring these properties are disclosed in the specification in later paragraphs.

A fixed calender suitable for use in the process of this invention is shown in FIG. 2. This type of machine is available from Holyoke Machine Company, Holyoke, Mass. The calender consists primarily of two hard steel rolls. The upper roll **24** is aligned approximately parallel to lower roll **25**. In use, the sheet to be consolidated passes through nip **31** between rolls **24** and **25**. The angle A between the two roll axes is adjustable. The upper roll is supported by massive bearings **26**, which in turn, are mounted in a heavy framework not shown. The bearings **26** are supported on horizontal tracks which permit a small movement horizontally, but which permit no vertical movement of the bearings. The lower roll **25** is likewise supported on massive bearings **27**. These bearings are supported in rigid framework in such a manner that vertical adjustment is possible. On the other hand, these bearings are not movable in the horizontal direction. The lower bearings **27** are supported by means of hydraulic cylinders **28**, which in turn, are rigidly mounted on base structure **35**. The upper roll bearings are supported on the same base by massive framework.

A safety escape valve is provided in the hydraulic system to prevent overloading at any point in the nip. However, in normal operation of the rolls, this escape mechanism is not actuated and a fixed clearance is maintained. Generally, the escape pressure in the hydraulic system is sufficient to apply 40 lbs./linear inch (7.1 kg./cm.) of nip length of roll axis for a roll having a diameter of 14 inches. The usual running pressures are about 10 lbs./linear inch (1.8 kg./cm.).

The gap between the upper and lower rolls is adjusted by the lateral movement of gap adjustment wedges **29**. The movement is effected by turning gap adjustment screw **30**, the screw being engaged with threads in the wedges. The opposite end of the screw is rigidly but rotatably retained in place in a supporting structure not shown. In operation the distance between the two rolls is carefully adjusted so that the gap is constant so far as possible throughout the length of the nip. However, because of bowing which occurs in the two rolls when sheet is passed through, this is not precisely possible. For this reason, fixed nip calenders are commonly fitted with a cross axis adjustment screw such as **32** and **37** at each end. The adjustment screws **32** and **37** are threaded into the bearings **26** at one end and are rigidly but rotatably supported by the framework of the machine at the other end. By tightening one screw and loosening the other, the axis of the top roll may be caused to rotate within a horizontal plane.

In the figure, reference axis **33** of the top roll **24** is parallel to the actual axis **36** of the lower roll **25**. In operation of the calender the nip clearance at the end of the roll may be increased without changing the clearance of the center of the roll. This is done rotating the actual axis **34** of the upper roll by use of adjustment screws **32** and **37**. For example, the clearance at each end may be increased by unscrewing adjustment screw **37** and by tightening adjustment screw **32**. As a result, the axis of the roll will be rotated through an angle A as shown in FIG. 2, the new axis being **34**. After such adjustment the axis of the upper roll is no longer parallel to the axis of the lower roll.

The apparatus of Belgian Patent No. 662,353, is especially preferred for the second step in the process of this invention. One form of the apparatus is shown in FIG. 3. Essentially it is a modification of the palmer apparatus commonly used in textile finishing. In textile dictionaries it is sometimes referred to as a palmer finisher or a palmer dryer. The apparatus is ordinarily used for drying or heat-setting of woven fabrics at relatively mild temperature. The process of the present invention requires certain modifications to be made to the palmer apparatus as customarily used, for instance to enable cooling of the fabric while under compressional restraint. A modification which accomplishes this is shown in FIG. 3.

The principal source of heat in the system is a rotating heated drum **1**. A heavy endless belt **2** of felt or other material and which is driven by the drum passes around the drum and by means of numerous idler rolls **3**, **3***a*, **3***b*, **3***c*, **3***d* and **3***e* is continuously fed back to the heated drum. Certain of the idler rolls may be adjusted with means to enable control of the belt tension. The belt after passing around the drum, goes around idler roll **3***e* and then passes around cooling roll **4**.

In operation of the process, the film-fibril sheet **5** passes around idler roll **3***c* and is carried into the nip between the heated drum and the endless belt. It is carried from the heated drum around idler roll **3***e* to a cooling roll **4**, and is separated from the moving belt by idler roll **7**. The treated film-fibril sheet is wound up on roll **8**.

For certain operations it may be desirable to preheat the heavy endless belt by means of preheat roll **9**. The belt is guided into the preheat roll by idler rolls **3***a* and **3***b*. Any loss in heat may be compensated by heated plate **10** underneath the belt. However, it has been found that the most critical heat control must be imposed at the main drum **1**. One side of the sheet is heated by the main drum to a temperature substantially equal to or slightly less than the upper limit of the melting range of the film-fibrils of the sheet.

While the face of the sheet is heated to a temperature at or near the upper limit of the melting range of the film fibrils, the back side of the sheet (facing the belt) must be

kept somewhat lower. Preferably the temperature of the back side should be within the melting range of the film fibrils to give appreciable bonding of the film fibrils throughout the sheet thickness. It has been established that the desired temperature for the backside is 0.8 to 10° C. less than the temperature of the other face of the sheet. By maintaining a temperature differential during bonding, a sheet is obtained having greater density and greater abrasion resistance on the side nearest the hot roll. But on both sides of the sheet the abrasion resistance is superior to that of unfinished sheet. The side of the sheet facing the belt tends to accept many surface coatings more readily than the other face, because the belt side is less severely bonded. The other side of the sheet has a hard surface which is particularly useful for the open surface of book binding wherein superior abrasion resistance is necessary. The hard surface also is an asset in wall covering material, since, when used next to the wall, it permits easy removal of the covering from the wall.

The temperature differential of 0.8 to 10° C. can be established by varying the drum temperature, the belt temperature, and the speed or exposure time of the sheet between the two surfaces. The minimum heating period need only be sufficient for the sheet side adjacent the heat-conducting surface to attain the upper limit of the melting range of the film fibrils. Accordingly heating periods of as little as one second may be used. The heating period may be as long as one minute or more although for operating efficiency exposure times of less than 10 seconds are most advantageous. It will be understood that in general shorter time periods can be used with higher temperatures and vice-versa.

The light compression which is obtained by tensioning the belt against the drum roll need only be sufficient to prevent shrinkage of the sheet. It is estimated that this pressure is about 1 lb./in.^{2}. Excessive pressures should be avoided as they will tend to cause losses in opacity and bulk.

The drum roll may have any type of surface finish, it being possible to develop a variety of textures or patterns on the sheet by using these various textures. It is necessary that the roll surface be a good heat conductor such as steel. The belt on the other hand should be a relatively poor heat conductor and should provide firm support for the film-fibril sheet during treatment over its entire surface. It has been found that a felt belt approximately 6 mm. thick composed of wool fibers is quite satisfactory for this purpose. It conducts heat very poorly, which is desirable. The insulating properties of this material are indicated by the fact that the back surface of the belt during operation will normally have a temperature 50 to 70° C. lower than the surface which faces the main drum.

Once the sheet has been heated to the required temperature and a temperature differential established from one surface of the sheet to the other, the necessary bonding has been accomplished and subsequent cooling of the sheet may then be effected. At least the initial portion of the cooling must be conducted while the sheet is under restraint or otherwise distortion and shrinkage will occur. The temperature at which this will happen can readily be ascertained by experimentation, but will normally be at least 30° C. below the upper limit of melting range of the film-fibrils. In this regard, it will be noted in FIG. 3 that cooling roll **4** and idler roll **3***e* as positioned as close as practicable to the heated drum **1** so that the sheet is essentially under a restraining force at all times. It will be apparent that various cooling techniques could be devised to accomplish this objective.

CHARACTERIZATION METHODS

Special methods have been developed for measuring the actual surface temperature of the sheet on the face side (next to the roll) and on the back (next to the belt) during heat treatment. The necessity for keeping the sheet under compression in the machine wherever exposed to heat makes direct temperature measurements difficult. In addition with a dynamic situation, i.e., with high heat flow across the thickness of the sheet, errors in measurement are easily made. Even the mass and geometry of the thermocouple under these circumstances can affect the temperature recorded, especially when thin film-fibril sheets are used. For these reasons the properties of layers of the sheet after treatment have been adopted as the best indication of temperature experienced in treatment.

Several analytical procedures have been developed for determining the temperature history or degree of fusion for layers of the treated film-fibril sheet. One such method involves measuring the surface area of the treated sheet. The sheet must first be dissected by manually starting a tear across the sheet and then splitting the sheet into three layers of approximately equal weight and thickness. Circular samples of 2 to 3 inch in diameter are sufficient. The samples are visually inspected and weighed to determine if approximately equal layers are achieved.

The surface area method for determining the degree of fusion and therefore the temperature history of layers within the sheet is based upon nitrogen adsorption techniques. The surface area/g. is determined by exposure to liquid nitrogen as described by P. A. Faeth and C. B. Willingham in "Technical Bulletin on the Assembly, Calibration, and Operation of a Gas Adsorption Apparatus for the Measurement of Surface Area, Pore Volume Distribution, and Density of Finely Divided Solids," Mellon Institute of Industrial Research, September 1955. In this procedure, the surface area is calculated from the amount of nitrogen adsorbed by the sample at liquid nitrogen temperature by means of the Brunauer-Emmet-Teller equation using a value of 16.2 square angstroms for the cross-sectional area of the adsorbed nitrogen molecule.

The surface area per gram in the layers of the bonded film-fibril sheet is inversely related to the temperature of the sheet during heat treatment. It has been experimentally determined that if the surface area as determined by nitrogen adsorption in each of the three layers is less than 5.0 m.^{2}/g. but greater than 0.5 m.^{2}/g., then the sheet must have been exposed to a temperature sufficient to raise at least one surface to within 7° C. of the upper limit of the melting range of the film-fibrils but not substantially above said upper limit. Further, it has been found that if the surface area as determined by nitrogen adsorption of the center layer is at least 0.3 m.^{2}/g. higher than the surface area of one of the outer layers, the temperature of the surface of the sheet facing the belt must have been within the desired range of 0.8 to 10° C. lower than the temperature of the surface of the sheet facing the drum. The differential fusion provided by the heat treatment method disclosed in Belgian Pat. 662,353 is advantageous because the unfused film-fibril elements in the center of the sheet form a reflective layer and increase the opacity of the sheet.

Abrasion resistance for sheets made by the process of this invention is determined by means of the Crockmeter tester of Atlas Electric Device Company, Chicago, Ill., S.N. CM–598. A 5" x 5" piece of silicon carbide paper is taped to the base of the Crockmeter directly under the full movement of the rubber foot. The carbide paper serves to prevent the sample from moving. A rubber finger stall (finger tip) is fastened to the circular plastic foot on the swing bar. The finger stall is Size 12 obtained from Swingline Incorporated, Long Island City, N.Y. The swing bar handle is turned so that the rubber foot traverses back and forth across the surface of the sample. When the first surface fiber is disturbed (i.e., pops up), the number of cycles is determined from the counter on the instrument. The average number of cycles of 5 tests is reported for each sample. In the above test a sheet that withstands 2 full cycles is considered to be very good. If the back or felt side of a sheet fails to withstand at least one stroke (0.5 cycle), the sheet will generally lack adequate de-

lamination resistance for uses in wall coverings, book bindings and the like.

The Elmendorf tear strength for film-fibril sheets made by this invention is determined by TAPPI test T–414 M–49.

The film-fibrils are characterized by a melting range that may extend over several degrees C. The upper limit of the melting range of the film-fibrils, as referred to herein, is the temperature at which the highest peak occurs in a differential thermal analysis. The analysis is performed using a Du Pont 900 Differential Thermal Analyzer and a standard heating block for 2 mm. capillary tubes. A 1–2 mg. sample of polymer is placed in one tube and an equal weight of finely ground glass particles in the other. The block containing the tubes is heated at a rate of 5° C./min. The difference in temperature recorded between the tubes is plotted against the temperature of the polymer sample. The maximum peak of the resultant thermogram is taken as the polymer melting temperature or upper limit of the melting range.

The delamination resistance of the products made by this invention is outstanding, being above 0.35 lb./in., preferably above 0.45 lb./in. The 0.45 lb./in. limit is particularly important in sheet materials to be used for wall covering since the material can be easily removed from the wall without leaving fragments of the sheet behind.

Delamination resistance is measured using an Instron Tester, 1 inch x 3 inch line contact clamps, and an Instron Integrator, all manufactured by Instron Engineering Inc., Canton, Mass. Delamination of a 1 inch x 7 inch specimen is manually started across a 1 inch x 1 inch edge area (so that the remaining 1 inch x 6 inch portion remains unseparated) by splitting the sheet with a pin. With a "C" load cell, the following settings are used: gauge length of 4.0 inch, crosshead speed of 5.0 inch/minute chart speed of 2.0 inch/minute and full scale load of 2 lbs. A sample is placed in each of line clamps and the force is measured which is required to pull the sheet apart. Delamination resistance (lbs./in.) equals the integrator reading divided by 2500.

As stated above, opacity values are obtained by use of a Bausch and Lomb Opacimeter, model 1602 R 788. Percent opacity is expressed as

$$\frac{B}{W}\times 100$$

where B is the instrument reading taken with the sample on a black back-up and W is the instrument reading taken with the sample against a white back-up.

A large number of measurements are made in this manner over the sheet area, and the standard deviation (σ) in opacity is calculated as

$$\sigma=\sqrt{\frac{\sum_{i}^{n}=1(x-\bar{x})}{n-1}}$$

where

x_i=the individual measurements

$\bar{x}$=the average of the measurements=$\sum_{i=1}^{n} x_i/n$

n=the total number of measurements.

The coefficient of variation (cv) in opacity is then calculated as

$$cv=\sigma/\bar{x}$$

The same statistical expressions are of course used in calculating standard deviation and coefficient of variation in basis weight for the lightly consolidated sheet represented by block **21** in FIG. 1.

EXAMPLE I

This example illustrates the preparation of a bonded non-woven film-fibril sheet by a process not including the step of calendering with a fixed clearance as required by this invention.

A film-fibril sheet is made from linear polyethylene having a density of 0.95 g./cm.^{3}, a melt index of 0.9 (ASTM method D 1238–57T, condition E), and an upper limit of melting range of about 131° C. The polymer is first slurried with trichlorofluoromethane, then the slurry is raised to a temperature of 184° C. and a pressure of about 1900 p.s.i.g. to form a solution; the polymer is 12.5% by weight of the solution.

The polymer solution is then flash spun in a closed cell (an atmosphere of trichlorofluoromethane) to form a continuous plexifilamentary strand. As the strand is formed at the spinneret orifice it is spread into a web and deflected downward by a rotating baffle onto an electrostatically charged moving belt to form a sheet. The web itself is electrostatically charged as it passes between an ion gun and target below the rotating baffle. The spinneret used is similar to the spinneret shown in FIG. 2 of Anderson et al. U.S. Pat. 3,227,794, issued Jan. 4, 1966, in that it has a letdown zone for lowering the pressure of the solution to below the two-liquid-phase boundary prior to discharging it through the terminal orifice. The terminal orifice is 30 mils in diameter and 25 mils in length. The end of the spinneret is covered by a shroud which forms a tunnel 3/16" in diameter and 3/16" in length on the exit side of the orifice.

Flow rate through the spinneret is 35 lbs. of polymer per hour. Pressure and temperature in the pressure letdown zone of the spinneret are 900 p.s.i.g. and 182° C., respectively. Temperature in the closed cell is approximately 50° C. The current to the ion gun is 380 microamperes. The baffle rotates at 60 cycles per second. The laydown belt is a metal screen charged to 50 kv. The distance from the discharge orifice of the spinneret to the lay-down belt is 12 inches.

The loose material on the belt is then carried by the belt under a 9" diameter rubber roll with a hardness of 70 which exerts a pressure of about 10 lb. per linear inch across the width of the sheet. This is referred to hereafter as the primary consolidation step. The resulting lightly consolidated film-fibril sheet is about 20" wide and 10 mils thick and has a basis weight of about 2.0 oz./yd.^{2}. The coefficient of variation in basis weight of the lightly consolidated sheet is less than 0.15.

The lightly consolidated sheet is then heat treated with the device shown in FIG. 3. The drum is heated with 37.5 p.s.i.g. steam (140° C.). Linear speed of the sheet through the apparatus is 50 y.p.m. Contact time of the sheet with the heated drum is about 6 seconds. Water at about 15° C. is used in the cooling drum. Contact time with the cooling drum is about 2 seconds.

The sheet is passed twice through the heat treatment apparatus, first with one surface then the other facing the heated drum. Hereafter, the surface facing the drum on the second pass is referred to as the smooth side, and the surface facing the belt on the second pass is referred to as the rough side.

Properties of the finished sheet are shown in Tables I and II below.

EXAMPLES II–V

These examples illustrate the procedure of the invention.

Example I is repeated for each of these examples, except that the pressure exerted on the loose material on the belt in the primary consolidation step is lower, so that the thickness of the lightly consolidated sheets is about 12.9 mils.

Thereafter, the sheets are calendered with a fixed nip calender of the type illustrated in FIG. 2 having 14" di-

ameter steel rolls. The extent of the calendering for each example is shown below:

Example	Sheet thickness after calendering
II	10.1
III	10
IV	9.8
V	9.1

Each sheet is then subjected to heat treatment and cooled as in Example I. Properties of the sheets of these examples are also summarized in Tables I and II below.

TABLE I.—PHYSICAL PROPERTIES

	Tear strength, lb.		Delamination Resistance, lb./in.		Abrasion Resistance, cycles	
	MD [a]	CD [b]	MD [a]	CD [b]	S [c]	R [d]
Example:						
I	1.31	1.16	0.55	0.73	3	12
II	1.34	1.66	0.59	0.60	7	4
III	1.13	1.34	0.44	0.80	4	13
IV	1.20	1.16	0.55	0.67	3	2
V	1.45	1.06	0.43	0.68	5	6

[a] Machine direction.
[b] Cross direction.
[c] Smooth side of sheet.
[d] Rough side of sheet.

TABLE II.—OPACITY AND THICKNESS

	Opacity			Thickness		
	Av. [a] percent	σ [b] percent	CV [c]	Av. [a] (mils)	σ [b] (mils)	CV [c]
Example:						
I	94.8	1.2	0.0127	8.51	0.73	0.086
II	96.0	0.7	0.0073	8.31	0.40	0.048
III	95.8	0.5	0.0052	8.32	0.49	0.059
IV	95.9	0.8	0.0084	8.09	0.43	0.053
V	95.3	0.7	0.0074	8.09	0.45	0.056

[a] Average of 180 measurements, 60 measurements ½" apart in machine direction in each of three lanes, one in center, one 2" to left of center, and one 2" to right of center.
[b] Standard deviation calculated for measurements in each of the three lanes then averaged to obtain this value.
[c] Dimensionless.

FIG. 4 is a photograph of the finished sheet of Example II and FIG. 5 is a photograph of the finished sheet of Example I. The improvement in visual aesthetics owing to the step of calendering with a fixed clearance is apparent from these photographs.

I claim:

1. A process for preparing a bonded nonwoven sheet of organic polymer film-fibrils, said sheet having uniform opacity, high delamination resistance, high abrasion resistance, and good formation, which comprises: providing a lightly consolidated nonwoven film-fibril sheet having a basis weight of 10 to 200 g./m.^{2}, a coefficient of variation in basis weight less than 0.15, and a density of 0.11 to 0.26 g./cm.^{3}; passing said lightly consolidated film-fibril sheet through a constant clearance nip between a pair of hard calender rolls at substantially room temperature, said clearance being adjusted to provide a new sheet thickness between 0.5 and 0.85 of the thickness of the lightly consolidated film-fibril sheet; passing said sheet through a heating zone, while under restraint to prevent shrinkage, and raising the temperature of either face of the sheet to within 7° C. of the upper limit of the melting range of the film-fibrils but not substantially above said upper limit; then cooling the sheet while under restraint to a temperature below that at which the sheet distorts or shrinks.

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U.S. Cl. X.R.

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