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METHOD OF DIMENSIONALLY STABILIZING
A PAPER-PLASTIC LAMINATE
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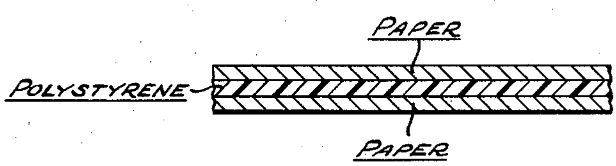

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METHOD OF DIMENSIONALLY STABILIZING A PAPER-PLASTIC LAMINATE

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This invention relates in general to commercial papers such as bond, graph, index, chart and map papers and the like, and particularly to a new and useful dimensionally stable laminate formed from two outer layers of paper and an intermediate layer of a heat-sealable rigid plastic. This application is a continuation-in-part of copending application, Serial No. 502,496, filed April 19, 1955, now abandoned.

Ordinary paper expands and contracts with changes in humidity of the surrounding atmosphere. It expands upon absorption of moisture from the atmosphere as humidity increases and contracts when moisture is given up to the atmosphere as humidity decreases. Since paper as formed on a Fourdrinier machine comprises fibres which are aligned in the machine direction more than in the cross-machine direction, expansion and contraction of the finished sheet is usually greatest in the cross-machine direction.

Many end uses of paper require dimensional stability of the paper or characteristics of the paper which insure little or no change in dimensions due to changes in temperature or humidity. As an example, business tabulating cards are punched out at precise positions to record information which is later picked up by machine sensing devices. Any change in position of the punched out portions which may result from changes in the dimensions of the cards due to humidity or other changes will cause the registry of inaccurate information. Therefore, when paper is to be used for any such end uses where the dimensions must remain constant, such as for scale maps, graphs, charts, etc., it is necessary to have a paper with excellent dimensional stability.

Heretofore in the manufacturing and drying of paper requiring excellent dimensional stability attempts have been made to achieve a paper which would not expand or contract to an excessive extent, but the results have not been satisfactory. Attempts have been made to laminate paper in which the direction of the fibres on various laminae were disposed angularly to one another, but this was costly due to the necessity of using sheeted paper instead of rolls of paper, and the decreased expansion and contraction is relatively small. Many other means for reducing dimensional changes have been tried, including increased beating of the stock, addition of materials at the beater, and impregnation of the paper with materials such as wax or other materials. All have the disadvantage of changing the characteristics of the paper and adding to the cost of its manufacture without materially changing dimensional characteristics.

In some instances the paper has been stored and used only in locations having controlled temperatures and humidity kept within a range which will not result in the expansion or contraction of the paper. But the control of temperature and humidity is costly and unsatisfactory.

Paper and card stock manufactured in accordance with this invention, however, overcomes all the deficiencies mentioned above. The invention is based on the discovery that by sandwiching or interposing a heat-sealable plastic having qualities of resistance to water absorption and elongation, such as polystyrene, between two sheets of any suitable type of paper, which itself may be of poor dimensional stability, it is possible to achieve a paper laminate product which is very stable dimensionally and which will not be affected by change of temperature and/or humidity to any great extent.

Accordingly, it is an object of this invention to provide a paper laminate product which has a high degree of dimensional stability.

It is a further object of this invention to provide a laminated paper product comprising outside laminae of paper having only good or moderate natural dimensional stability, bonded by a core of heat-sealable plastic which acts to prevent expansion or contraction of the bonded product during changes of temperature or humidity.

It is a still further object to provide as an article of manufacture an inexpensive, dimensionally stable paper comprising a polystyrene, acrylic resin, methacrylate or other relatively rigid non-moisture-absorbent plastic, heat-sealed between paper sheets.

The various features of novelty which characterize the invention are pointed out with particularly in the claims annexed to and forming a part of this specification. For a better understanding of this invention, its operating advantages and the specific objects attained by its use, reference should be had to the accompanying drawing and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

The sole figure of the drawing is a cross-section of a laminated paper product constructed in accordance with this invention.

The paper shown in the drawings comprises two sheets of ordinary, generally lightweight paper and an inner core of a commercial polystyrene plastic or other similar non-water absorbent plastic heat-sealed together to form a laminated paper product having all the good characteristics of ordinary paper and being substantially dimensionally stable when exposed to changes in humidity.

Paper made in accordance with this invention is easily fabricated by feeding the two laminae of paper on the outside of a preformed plastic web between pressure rolls or by extruding hot plastic between two paper webs as they approach the nip of two pressure rolls.

The outside laminae of paper comprise any ordinary paper sheets chosen for the paper characteristics desired in an end product. For such uses as for charts, map and machine-sorted classification cards papers are chosen which will give the desired ink receptiveness and then are made to the desired rigidity, caliper and basis weight by varying the quantities of plastic and/or the caliper and weight of the paper laminae.

It has been found that a paper laminate made in any of the weights or calipers desired when compared with ordinary papers used for the same purposes is far more dimensionally stable than any papers heretofore known. For example, the following table indicates the machine-direction and cross-direction expansion and contraction of ordinary commercial circular flat chart paper as compared to two variations of paper laminates constructed in accordance with this invention. All paper weights are on a 24" x 36"—500 sheet ream basis.

All Papers 6 Mils Caliper

EXPANSION DUE TO CHANGE OF RELATIVE HUMIDITY FROM 20% TO 75% AT 73° F.

	Fibre direction	
	Cross	Machin
	Percent	*Percent*
Ordinary commercial chart Paper 95# basis weight	0.75	0.30
No. 1 paper laminate Paper 29# basis weight Polystyrene 37# basis weight	0.149	0.034
No. 2 paper laminate Paper 13# basis weight Polystyrene 69# basis weight	0.076	0.058

CONTRACTION DUE TO CHANGE OF RELATIVE HUMIDITY FROM 75% TO 20% AT 73° F.

Ordinary commercial chart Paper 95# basis weight	0.75	0.30
No. 1 paper laminate Paper 29# basis weight Polystyrene 37# basis weight	0.303	0.231
No. 2 paper laminate Paper 13# basis weight Polystyrene 69# basis weight	0.094	0.089

From the above it can be seen that a paper laminate made in accordance with this invention expands and contracts substantially less than a similar type of ordinary commercial paper of the same caliper and basis weight. In fact, even though each of the paper laminates compared is in every way suitable for the same use as the commercial chart paper insofar as the other normal paper characteristics are concerned, it is as much as nine times better, percentagewise, in the cross direction and six times in the machine direction, as far as expansion and contraction due to humidity change are concerned.

Referring to the above table it can be seen that expansion and contraction of the paper laminate can be reduced much further by the addition of more polystyrene while reducing the basis weight of paper laminae proportionately in order to arrive at a 6 mil caliper paper of the same combined basis weight. Paper laminate No. 1 is a 95# material made up of approximately 37# basis weight of polystyrene and 29# basis weight of each paper lamina. Laminate No. 2 is also a 95# material, but has an increased amount of polystyrene in the core (69#) and a proportionately lighter paper (13#). Since the same type of paper is used in each laminate, each possesses similar paper characteristics. However, sheet No. 2 is more stable dimensionally due to the increased polystyrene.

As the heat-sealable lamina core the polystyrene holds the outer paper laminae against dimensional change due to moisture. The thermal coefficient of expansion of Dow Styron 475, a commercially available polystyrene, is, for instance, 4 to 4.5×10^{-5} in./in./° F. according to the ASTM test method and its water absorption in 24 hours is 0.12% by weight, dry. Other plastics such as acrylic resin and methacrylate which are also moisture-resistant are satisfactory for use as a core.

Experiments have shown that, when making a card paper suitable for use as machine-sorted classification and information registry cards, laminating with a polystyrene core has reduced expansion and contraction of the card due to humidity change by as much as three times in the machine direction and nine times in the cross direction. This can be even bettered by using a greater amount of polystyrene as a core and proportionately reducing the amount of outer paper laminae.

Experiments have also shown that when polystyrene is heated, as for extrusion, it is normally molten. When it is then deposited as a thin film to be sealed between two

webs of paper, it cools to a solid, i.e., plastic, film after contacting and becoming somewhat imbedded in the paper. In changing from a hot liquid to a hot solid, polystyrene normally tends to shrink about 0.6%. But, when such a film cools between, in contact with, and imbedded in two paper webs, this tendency is resisted and/or prevented by the paper and the polystyrene is or remains under tension. Evidence of this opposition of forces can be gleaned, from the fact that, when only one of the outer paper laminae of the product of the invention is moistened, a curl therein results which places the wet lamina inside or on the concave side of the curl, instead of outside or on the convex side of the curl where it would be found if a simple piece of paper were substituted for the laminated product. The direction of the curl indicates that the wetting of the outer paper lamina, while it may cause the individual paper fibres to expand, ultimately serves only to weaken the structural resistance of the lamina to the compressing forces exerted by the polystyrene center.

Thus, an internal stress and strain is constructed or built-into the laminated products of the invention and, so long as this dynamic balance of forces favors the tendency of the polystyrene to contract, dimensional changes in the outer paper laminae, e.g., expansions caused by their absorption of moisture and later contractions caused by their loss of moisture, are held to a surprisingly low minimum, since polystyrene is a rigid plastic and does not absorb moisture.

The following table shows a comparison of the expansion and contraction of a relatively thin 3½ mil roll meter type of paper presently used commercially as compared with the same caliper paper laminate suitable for the same use:

Both Papers 3½ Mils Caliper

EXPANSION DUE TO CHANGE OF RELATIVE HUMIDITY FROM 20% TO 75% AT 73° F.

	Fibre direction	
	Cross	Machine
	Percent	*Percent*
40# roll-meter paper	0.70	0.32
40# roll-meter paper laminate Paper 13# basis weight Polystyrene 22# basis weight	0.30	0.20

CONTRACTION DUE TO CHANGE OF RELATIVE HUMIDITY FROM 75% to 20% AT 73° F.

40# roll-meter paper	0.68	0.30
40# roll-meter paper laminate Paper 13# basis weight Polystyrene 22# basis weight	0.31	0.20

The above table shows that the paper laminate using only a moderate amount of polystyrene as a core will be much less susceptible to dimensional changes than ordinary roll-meter paper. For uses such as meter paper where registry of information must be precise it is imperative to have a paper which will not register inaccurate information due to changes in dimension.

An experiment to determine the characteristics of the paper laminate when exposed to large quantities of water showed that when the laminate is immersed in a water bath and then blotted dry the paper actually shrinks slightly instead of expanding, as is the case with ordinary paper. However, aside from the unusualness of the phenomenon, it is clear that such a characteristic can have its disadvantages and that it would be preferable, if possible, to shrink the laminate beforehand wherever its contemplated use entails a highly humid atmosphere and nevertheless requires a high degree of dimensional stability.

Accordingly, it has been found that the dimensionally stable paper laminate of the present invention can be given a future resistance, i.e., a relative immunity, to shrinkage due to moisture absorption by means of the steps of immersing the entire laminate in water for a short time, of allowing the thus wet laminate to stand for a longer period, and of uniformly drying it at a relatively slow rate. The resulting sheet or web is flat and exhibits a minor amount of expansion or contraction with changing humidity. The magnitude of this expansion or contraction is dependent, as it was prior to the pre-shrinking or post treating series of steps, on the ratio of the physical strength of the two paper surfaces as compared to the polystyrene center. The type of cellulose fibre in the paper is a small factor, but, as before, the ratio of the total weight of paper to the total weight of polystyrene is an important factor. Such ratio is, preferably, about 60% by weight of paper and 40% by weight of the resin.

Just how the pre-shrinking or the post treating of the dimensionally stable paper laminate of the invention is effected is not conclusively known, but it is believed that, when the entire laminate is soaked in water and allowed to stand in a wet condition for a period of time, the stresses originally created in the polystyrene upon its contacting of and imbedding in the two paper webs with which it is laminated are released. The polystyrene is then no longer under tension and it assumes its normal dimensions. And, thereafter, if the entire lamination is dried uniformly, at not too fast a rate, and, preferably, under a slight tension, the paper on each side of the polystyrene will, because of its water-weakened structural strength and despite the expansion of its individual fibres due to water absorption, conform to the normal dimensions of the polystyrene center without creating new stresses or strains.

Preferably, the immersion bath of the post treating series of steps has a temperature of not higher than about 65° F. or lower than room temperature, the time of immersion is from about 3 to 10 seconds, the standing period is in the range of about 15 minutes to 24 hours, and the time of drying, if it is done in a tunnel dryer having a temperature in the range of from 100° F. to 225° F., is from about 20 to 50 seconds. Thus, for example, in a recent trial, polystyrene (Dow Styron 475) was extruded at 570° F. through a 20 mil die opening and drawn down to 2 mils, so that, when making contact simultaneously with two 30 lb. per ream chart paper webs that were feeding from each side of the die into the nip of pressure rolls, a 95 lb. per ream laminated product containing 35 lb. per ream of the polystyrene and having a caliper of 6.0 mils resulted. The lamination from the nip proceeded straight down to the bottom of the machine before contacting a turning roll, so that the polystyrene could set in a flat plane before being trimmed and wound on the winder. Next, the laminated roll was run through a bath of water at a speed assuring an approximately 3 second immersion of the laminate and the excess of water was squeezed off between a rubber pressure roll and a chrome chill roll, so that the laminated paper on the roll had, when rewound, an approximately 17% moisture content. Immediately after rewinding, the laminated roll was wrapped in a polyethylene bag and waterproof paper and stored for about 4 hours. Next, the laminated roll was run through a tunnel dryer at slow speed countercurrently to forced hot air supplied to both outer paper laminae. The temperature in the tunnel was held below 180° F.

Next, test specimens of the laminated roll were preconditioned in the 20 leveling tubes of a Neenah expansimeter at 75% relative humidity for 2¾ hours before initial measurements were made, in order to eliminate errors in the first cycle. The instrument contains 20 leveling tube holders through which air of controlled humidity and temperature can be passed. In each holder a strip of paper can be suspended and measured for length with a micrometer adjustment. Thus, the 20 samples could be run through the various humidity cycles at one time and changes in humidity could be measured without moving the instrument or disturbing the samples. The results of these tests are set forth below in Table I and the results of similar tests made on a variety of laminated products made in accordance with the invention, some of which were and some of which were not post treated, i.e., water-immersed and dried, in accordance with the invention are set forth below in Table II. In such tables, "Con." means the percent contraction in the samples due to a change of the relative humidity from 80% to 25% each sample experienced during the tests, "Ex." means the percent expansion in the samples due to a change of the relative humidity from 25% to 85% each experienced during the tests, "M.D." means that the measurement of expansion or contraction was measured in the machine direction of the paper fibres, and "C.D." means that the measurement of expansion or contraction was measured in the cross-machine direction of the paper fibres.

TABLE I

	Test Cycle No.													
	1		2		3		4		5		6		7	
	Con.	Ex.	Con.	Ex.	Con.	Ex.	Con.	Ex.	Con.	Ex.	Con.	Ex.	Con.	Ex.
M.D.	.21	.20	.21	.19	.20	.20	.20	.20	.20	.21	.20	.20	.20	.20
C.D.	.35	.37	.35	.33	.34	.35	.34	.33	.34	.33	.33	.32	.32	.32

TABLE II

Sample		Test Cycle No.									
		1		2		3		4		5	
		Ex.	Con.	Ex.	Con.	Ex.	Con.	Ex.	Con.	Ex.	Con.
A	M.D.	.07	.11	.11	.12	.12	.14	.11	.11	.12	.13
	C.D.	.13	.28	.25	.28	.28	.29	.28	.27	.27	.29
A-T	M.D.	.17	.21	.20	.20	.20	.21	.20	.20	.20	.20
	C.D.	.25	.30	.28	.28	.28	.29	.29	.29	.29	.29
B	M.D.	.15	.15	.15	.16	.16	.17	.15	.16	.16	.16
	C.D.	.24	.25	.23	.24	.25	.26	.24	.24	.24	.25
B-T	M.D.	.16	.19	.17	.17	.17	.19	.17	.17	.17	.19
	C.D.	.23	.25	.23	.24	.24	.24	.24	.24	.24	.24
C	M.D.	.09	.17	.15	.16	.15	.17	.15	.15	.15	.16
	C.D.	.15	.28	.27	.29	.29	.29	.28	.27	.29	.30
C-T	M.D.	.16	.19	.19	.19	.19	.19	.17	.17	.17	.17
	C.D.	.27	.31	.30	.30	.30	.31	.31	.31	.31	.31
D	M.D.	.09	.21	.19	.20	.20	.21	.19-	.20	.20	.20
	C.D.	.20	.36	.32	.36	.36	.36	.34	.34	.35	.37
D-T	M.D.	.16	.21	.20	.20	.20	.21	.20	.20	.20	.20
	C.D.	.31	.35	.34	.34	.34	.35	.35	.35	.35	.35

In Table II, Samples A and A–T were made from 30 lb. per ream bleached kraft paper and Dow Styron 475 and had a caliper of 7.3 mils; Samples B and B–T were made from 28 lb. per ream register paper and Dow Styron 475 and had a caliper of 6.9 mils; Samples C and C–T were made from 29 lb. per ream chart paper and Dow Styron 475 and had a caliper in the range of 5.8 to 6.4 mils; and, Samples D and D–T were made from 27 lb. per ream chart paper and Dow Styron 475 and had a caliper of 5.9 mils. The letter "T" symbolizes the fact that the sample in question was given the water immersion and drying post treatment before the tests were made on the Neenah Expansimeter.

What is claimed is:

1. In the production of dimensionally stable paper having ink receptiveness and adapted for use in the form of tabulating cards, maps, charts, and graphs, a first step of immersing in water a paper laminate consisting of two outer sheets of paper heat-sealed to a polystyrene core under tension, the core being from about 37% to 73% by weight of the laminate, at from about room temperature to 65° F. for from about 3 to 10 seconds; a second step of allowing the wet paper laminate to stand for from about 15 minutes to 24 hours; and, a third step of drying the resulting paper laminate in a tunnel dryer at from about 100° F. to 225° F. for from about 20 to 50 seconds.

2. A process in accordance with claim 1 in which the weight of the polystyrene core is about 40% of the weight of the laminate.

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