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PROCESS FOR MAKING CRUSH RESISTANT BOXBOARD

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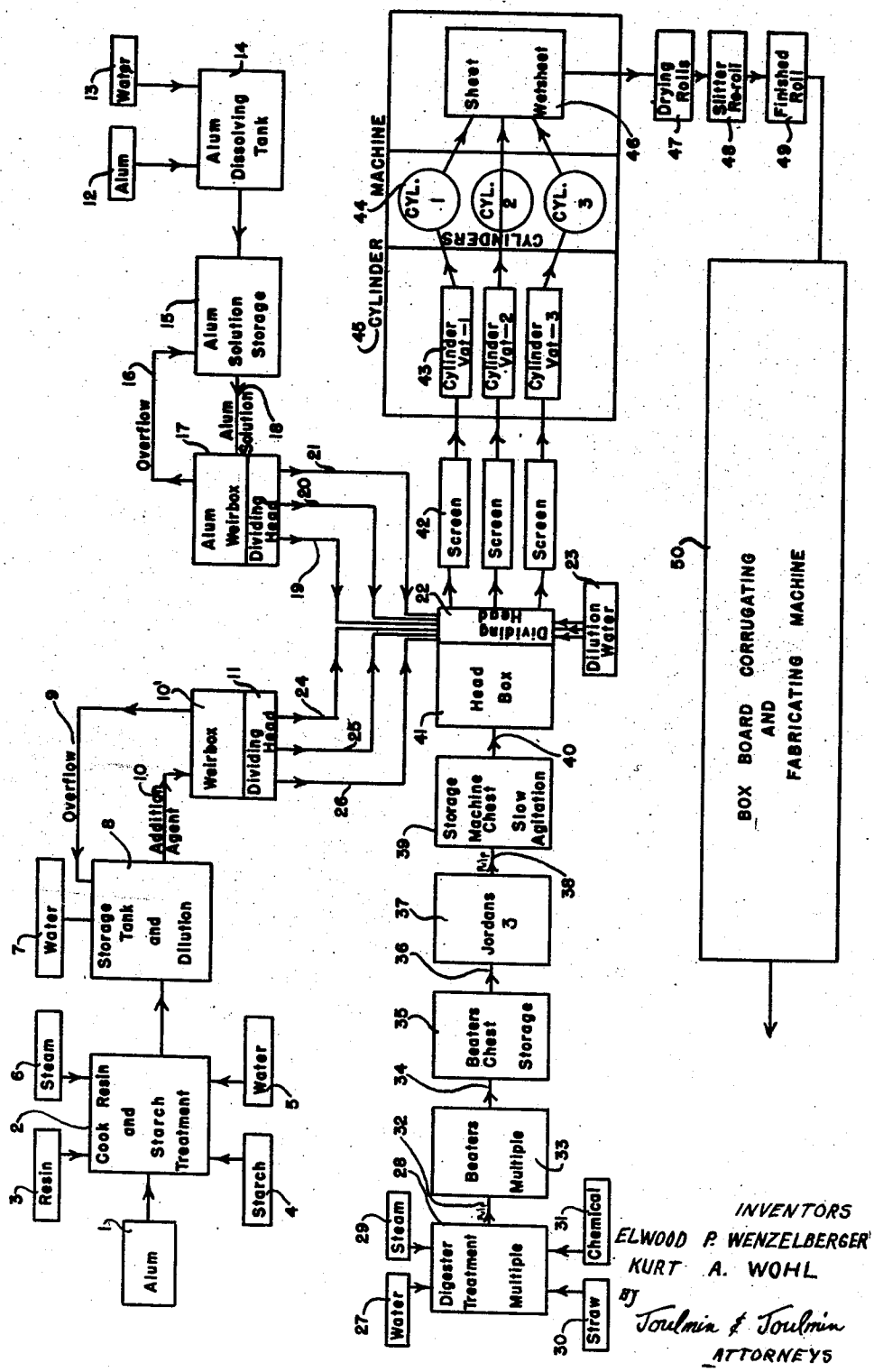

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PROCESS FOR MAKING CRUSH RESISTANT BOXBOARD

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Our invention relates to the process of manufacturing paper and particularly boxboard; and relates to the process, product and apparatus for practicing the process and producing the product to secure decreased weight or increased strength, or both decreased weight and increased strength.

Our invention relates primarily to fiber treatment and conversion into a substantially standardized product for producing dry paper of uniform strength characteristics.

This invention deals with dry strength paper.

In this art the problem competitively is to produce boxboard of decreased weight or increased strength, referring to strength as resistance to crush, or both. The variations due to the variety of raw materials used in manufacture necessarily present an unusually difficult problem in the control of the weight and strength and particularly in the effective reduction of weight and increase of crush strength economically on existing paper making and corrugated boxboard making machines and in connection with the mechanisms used for preparing the stock prior to delivery to the machines. Due to the nature of manufacture of boxboard in which the paper sheets are first manufactured on one machine and then corrugated in part and the corrugated sheet is assembled between two flat sheets on still other machines and heat is applied on both machines to the paper stock, an additional set of variables is introduced into the problem.

It is an object of this invention to be able to meet these varying conditions and at the same time to so modify the crush strength and weight of the paper as to produce an improved product and one that is more economical as the sales price and cost vary in proportion to the weight and strength.

It is a further object to provide a product that can be so manufactured, while at the same time retaining most of the desired characteristics of ink absorption for the printing on the boxboard and other characteristics required by the trade.

It is an object of this invention to provide an additive compound and method of making; and to provide a method of introducing this compound into the paper stock, to treat the fibers, control the stock pH value, control its absorption and adsorption on the stock so as to regulate the resulting strength and weight of the paper; and further to provide for polymerization of the compound on or in the fibers, preferably by stages on the paper machine and the later treatment on the corrugating machine, so

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that the ultimate polymerization will be accomplished for producing the ultimate in increase of strength and saving in the weight with the approximate conclusion of the manufacture of the completed boxboard.

It is a further object to provide for a mechanism for adequately introducing and incorporating the compound so as to bring about the maximum saving in weight and increase in crush strength of the dry paper.

It is particularly an object of this invention to provide for a new combination which is precooked and is introduced as a pre-cooked combination constituting a new composition of matter introduced into the fiber stock under controlled pH condition. We bring about the combination of this composition of matter with the paper stock itself and chemical means to control alkalinity and acidity.

The unexpected result is that the new composition effects the desired results of increased strength resistance to crush and reduced weight although the components from which the new composition is manufactured in themselves do not produce the same result.

The particular object of this invention is to provide for the combination of water soluble urea formaldehyde resins and starch pre-cooked sufficiently to pre-polymerize this composition of matter into a new form, preferably in the presence of papermaker's alum, aluminum sulphate ($Al_2(SO_4)_3$), or its equivalent, for acidifying the resin and starch polymerization composition, to facilitate the polymerization prior to introduction into the fiber stock by controlling the pH.

It is a further specific object to likewise control the acidity upon the introduction of this prepolymerized composition into the stock.

It is an additional object to utilize the heat on the paper machine for further polymerization of the composition of matter in the presence of alum in the stock to bring about, not only further polymerization of the composition, but to do so on the stock so as to control and secure adsorption in or absorption on or into the fibers.

It is an object to control absorption and adsorption of the composition with the fiber and to provide a controlled balance between absorption and adsorption. The pre-polymerization of the composition prior to the introduction into the paper fiber is for the purpose of providing a molecular structure that permits entry of the molecules into the fibers as well as coat the fibers thereby effecting a controlled balance if desired between absorption and adsorption.

It is still a further object to provide for the completion of this polymerization in the completed sheet by the application of the heat in connection with the corrugation of the sheet and final assembly of the corrugated sheet with the liners as a part of the boxboard manufacture.

It is an object of this invention to control the pH value at each stage to regulate the polymerization rate and to regulate the incorporation of this composition of matter into and upon the fiber stock to form the resulting paper and boxboard.

It is a particular object to accomplish this result for dry strength, particularly crush strength, of the finished paper.

It is an object to provide a method involving time, temperature, and viscosity control, plus control of the chemical reactions indicated above, and the control of the pH values for regulating and accelerating the reaction and the polymerization and unity of the composition with the paper fibers into a new composition.

Due to the fact that heat is applied to the paper in both the making of it originally and later during the corrugation and assembly into boxboard, this new composition is particularly adaptable to progressive polymerization until the final result is achieved in the completed boxboard, but it will be understood that the invention is equally applicable to conditions in which polymerization is completed in one stage when used with a product where a single heating takes place. In both instances it is an object of this invention to be able to utilize the existing heat employed in paper making and boxboard making to conclude and complete the polymerization which has been initially started in the step of combining starch and resin in the initial pre-polymerization operation to produce the composition of matter which is introduced later into the stock to treat the fibers. At this stage, the composition is readily combined with the stock fibers. Later, the stage polymerization completes the incorporation into the fibers while completing the boxboard.

It is a further object to provide a method of introduction of this composition into the paper making line for its maximum incorporation and to insure the ease of control of the pH values.

It is a further object of this invention to provide for proportions of this new composition of matter which have a low ratio compared to the resulting dry paper stock.

It is a further object to provide a highly cationic resin of water soluble urea formaldehyde composition in combination with starch and alum (the latter optionally) under an elevated temperature sufficient to bring about pre-polymerization and the formation of a new composition of matter; and to combine such partially polymerized composition with paper fibers; and then to complete the polymerization of the composition on or in the fibers as the boxboard is made.

The drawing shows a flow sheet indicating the various steps in connection with the practice of these inventions.

Referring to the accompanying flow sheet, the following examples indicate variations of the basic features of our invention. It will be understood that our objective is to improve the dry strength and primarily the crush strength properties of boxboard by increasing crush strength and reducing weight; and, in doing so, to adapt this process and its composition of matter to the specific operating conditions of producing

the paper and resulting boxboard while at the same time providing a process and composition of matter that can be equally effectively employed on other types of paper where increased dry strength is desirable.

Statement of introduction steps

The process is as follows: 1 designates a source of papermakers' alum which is introduced into the cooker 2 containing a suitable amount of water 5 and into which the water soluble formaldehyde condensation resin is introduced as at 3 together with starch as at 4. The mixture is heated at elevated temperatures supplied by the steam 6. A typical cook comprises introducing 140 gallons of water to the mixer tank 2; adding 125 pounds of 50% resin and mixing thoroughly. Then there is added 62.5 pounds of starch slowly which again is mixed thoroughly. Alum is then added to the mixture as required to the desired pH. The exact amount however varies and the amount to be added should be sufficient to give the desired pH of 5.5 to 6.5. The mixture while agitated is heated to gelation (166 to 180° F.). When the gelation starts a temperature of approximately 175° F. is maintained for approximately 25 minutes. It is understood that a longer or shorter time may be chosen depending on character of paper to be treated and the degree of molecular size desired of the resin starch mix; we may use from 5 minutes to 50 minutes. On the completion of the heating, the steam is shut off and the mixture is diluted to 300 gallons with cold water. For convenience we cook at approximately 10% total solids and then dilute to 5% solids for use. We emphasize this is a typical cook: the procedure and proportions can be varied considerably. The solution diluted with the water 7 is stored in the tank 8. A certain amount of overflow 9 may be added from the weir box 10' to which the composition is added through the line 10 and then sent to the dividing head 11. This pre-cooked, pre-polymerized starch-resin composition prepared in the presence of alum is added on a one to one solids ratio to provide a 2% total solids based on dry paper weight. In practice, this composition is metered into the stock as it flows from the weir box or head box into the dividing head 11.

The second alum solution is prepared and added as follows: Turning to the right hand side of the flow sheet there is added alum 12 and water 13 to the alum dissolving tank 14. The mixture then passes to the alum storage tank 15 which is supplied with overflow water through the line 16 from the alum weir box 17. The alum solution from the storage tank 15 is introduced by the line 18 into the alum weir box 17 to produce a pH of 5.5 to 7.0, preferably not above 6.9. This alum solution is introduced by the lines 19, 20 and 21 into the dividing head 22 which is provided with dilution water 23. The dividing head 22 receives the starch-resin composition which has been pre-cooked and pre-polymerized in the presence of alum through the lines 24, 25 and 26.

Turning to the left of the flow sheet, we now describe the preparation and supply of the paper fibers. Water 27 is delivered to the digester 28 which is supplied with steam 29. In this digester is introduced straw 30 as an example, it being understood that other materials may be used; and the digesting chemicals 31 of conventional type. The pulp passes through the line 32 to the multiple beater 35 and thence through the line 34 into the beater chest 35 where it is stored.

It is withdrawn through the line 36 into one or more Jordans 37 from whence the pulp passes through the line 38 into the storage machine chest 39 where it is slowly agitated. It thence passes through into the dividing head 22 where it is mixed with water and the pre-polymerized, pre-cooked composition and with the additional alum for the maintenance of the pH value in the cylinder vats of from 6.7 to 6.95 pH (preferably 6.9). Thence the impregnated and coated fiber passes to the screens 42 and to the cylinder vats 43 with their cylinders 44 diagrammatically shown under the general title of cylinder machine 45. It will be realized that this diagram is merely our outline to indicate the several steps. In practice the cylinder is mounted in the vat. From this point the treated stock from each cylinder is laminated and the 3-ply sheet passes out as wet sheet at 46 and thence to the drying rolls 47, slitter reroll 48 and finish roll 49. The temperature to which the combined stock and composition are subjected on the machine varies according to the machine but generally the temperature is as follows: normal process water temperatures on the wet end of the machine of 60 to 70° F. The drier temperature ranges between 235° F. to 285° F. from the wet end to the calenders. The time the paper is exposed to these temperatures is dependent on the speed of running but usually the total time is about 1 minute. The higher temperature could be used satisfactorily. In the making of boxboard this temperature and time may not be sufficient to complete the polymerization of the composition absorbed and adsorbed in the fiber. This polymerization can be completed on the boxboard, corrugating and fabricating machine indicated at 50 in which the temperature of the heater is carried at approximately 340° F. at 300 ft. per minute or faster. This temperature and speed will vary with the corrugating machine. The sheet corrugated in the usual manner is then treated with adhesive and a liner sheet applied to one or both sides of the corrugation depending upon the type of boxboard to be produced. This final heat treatment completes the polymerization far enough to provide the reduced weight of the completed board and the high crush strength which constitute the desired results from this process. We wish to emphasize that the details of this process will vary greatly from machine to machine but with the foregoing teaching to one skilled in the art the adaptation of this invention to varying conditions can be effected with the minimum difficulty.

It will be noted that the unexpected and unusual results of dry paper with crush strength increase and of reduced weight is effected by a very low ratio of resin and starch based upon the relative solids of the composition and the paper itself. This not only effects great economies in these expensive materials but it has been found that such preparation produces a result that is satisfactory, that is usually not possible with increased proportions of the materials.

The function of the papermaker's alum, which we prefer to use as a convenient concentrated solution of 100 pounds and 36 gallons of water is to secure, control and maintain a suitable acid pH in either the pre-treatment or the stock system of the machine or both. There are various materials which are suitable substitutes for alum such as acids and acid salts. Specific examples are acetic acid, hydrochloric acid, sulphuric acid, ammonium chloride or sulphate, ammonium nitrate or phosphate, diammonium phosphate, sodium bisulphate or bisulphite.

We find that a water soluble urea formaldehyde or melamine formaldehyde condensation resin will be useful. Any film forming cooking starch is useful.

The pH values given are those we find particularly adaptable to conditions where wheat and oat straw predominate. On the machines the lower pH could possibly be used advantageously on other types of pulp and may vary depending on the type of pulp and chemical used for digesting the paper. We realize that pre-cooking and pre-polymerizing the starch and resin in the presence of alum not only hastens the formation of a balanced colloidal solution between the starch-resin and water but it forms a means of adjusting the molecular composition of the product as polymerization takes place so as to facilitate the absorption and adsorption of the composition onto or into the paper fiber to produce the desired result.

We wish to emphasize that the problem solved by this invention has nothing to do with wet strength paper where the problem is to improve tensile strength when wet as compared with the same kind of paper when wet which has had no treatment. The problem here is to provide increased crush strength and reduced weight of dry paper. It is well known that treatments for improved wet strength paper by increasing tensile strength frequency and usually do result in influencing the dry strength, but in any event the strength there in question is tensile and not crush.

To secure the result of this invention it is preferred to have a fiber characteristic of wheat and oat straw which should at least predominate, but this invention is adaptable to a variety of papermaking fibers. It need only be adjusted to such conditions to secure the desired result. For instance, if soya bean straw is utilized as a source of fiber for the pulp, foaming may occur which interferes with machine operation and if a defoaming agent such as kerosene is used, it is injurious to the product of this invention because it apparently "lubricates" the fibers and softens the sheet and retards polymerization of the resin-starch additive. Other defoaming agents may or may not affect the operation depending on what is used.

Basically our objective is to produce a molecular resin starch combination with a carefully controlled pH, precooked and pre-polymerized to a controlled degree and then combined with the fiber stock so as to have a controllable balance of absorption and adsorption in or on the fiber due to the range of molecule size controllable by the pre-polymerization: and after incorporation of this composition has been effected, the fiber and this composition are so treated by heat of the machines in the formation of the paper and boxboard that the crush strength is progressively increased until the paper is finished and polymerization is simultaneously completed. One reason for this progressive polymerization in boxboard manufacture according to this invention is that premature setting of the resin to the ultimate completely polymerized condition before the laminate reached the corrugation machine would be undesirable as it would defeat satisfactory corrugation and would result in breaking of the fibers in the sheet. It is therefore desirable, and indeed in many instances essential, that the timing of the progress of polymerization must match the timing and progress of the formation of the sheet

and its completion by corrugation into boxboard. It should be kept in mind that the greater the molecular size, the greater the dry crush strength and probable reduction in weight, but this rule is modified by the fact that if the molecular size progresses to such an extent that only the fiber is coated on the outside by adsorption and there are not sufficient smaller molecular sizes there will be no desirable absorption to carry the molecules of the composition into the fiber to add that internal strength as well as the coating producing external strength so desirable in a balanced fiber treatment. It will be understood that the foregoing is our theory and we do not wish to be bound to such a theory but state it for the purpose of making the best and most complete disclosure within the realm of our knowledge.

Place of introduction of the pre-polymerized composition

Keeping in mind that thoroughly mixing of this composition of matter is important to incorporate it with the stock, we have employed its introduction into the open trough leading to the Jordan after the flow regulating dam; into the stock stream from the Jordan to the machine chest; into the machine head box after the gate regulating overflow back to the machine chest; and into the dilution box at the end of the machine head box.

It is found that the preferable point for addition of chemicals is at the dividing head of the machine head box where dilution with water takes place. This head box is located between the machine chest and cylinder vats. The dilution water creates sufficient agitation to mix the chemicals into the pulp.

While the pre-cooked partially polymerized starch and resin combination can be introduced into any one of the vats it has been found preferable to introduce the composition into all of the vats equally.

pH values

The question of pH values is an important one both in the initial reaction of the starch and the water soluble urea formaldehyde resin, and in the stock to which the starch-resin product is added. In the pre-cooked mixture it is desired to have a pH range of 5.3 to 6.5. While this varies according to the type of resin used, and paper stock to treat, as elsewhere indicated, yet the foregoing range is typical and will prove an effective guide.

The preferred optimum pH in the stock due to the addition of an additional amount of controlling alum or its equivalent at the time of mixing the foregoing composition of matter with the fiber stock is in the range of 6.5 to 6.95, although under some conditions an even lower pH may be suitable.

Temperature control

Temperature control is important in connection with the pre-cooking. A satisfactory cook of starch, alum and resin is effected at 175° for five minutes after gelation and then held for 20 minutes at that temperature. This period may vary and the temperature may vary with the type of resin employed. With such a combination the proportions of resin and starch are 1% resin and 1% starch making a 2% mixture of solids based on the dry paper weight.

The word "cook" used herein indicates heating and holding of the components to temperature as required and does not indicate a boiling temperature. This holds true throughout the process.

EXAMPLE I

The following is a typical composition and method of preparation of a pre-cooked starch and water soluble urea formaldehyde resin:

Cook the starch and water and a water soluble urea formaldehyde resin and bring the composition to boiling point and thereafter cook at 175° F. for five minutes and then hold for twenty minutes at that temperature. The composition of matter so formed is then cooled and used as an additive as indicated as follows:

The pH value of the composition is maintained at 5.7 by the addition of alum or its equivalent such as any acid salt or any material which gives excess of hydrogen ions such as sodium, bisulphate, hydrochloric acid, acetic acid, phosphoric acid, nitric acid, oxalic acid or any mineral acid or any of the strongly organic acids or any acid salt.

The alum added or its equivalent depends upon the pH value to be maintained.

This composition is then added as indicated to the stock where the pH value ranges from 6.5 to 6.95, although an even lower pH may be used under some circumstances. This pH value is controlled by the second addition of alum or its equivalent.

The stock is then passed through the paper machine and is manufactured into finished sheets. The heat of such manufacture brings about further polymerization of the starch resin composition. Thereafter the corrugation of the sheets and the assembly with the front and back liner sheets involve the application of heat which completes the polymerization and the reaction between this composition of matter and the paper fibers to form a boxboard of high crush strength and reduced weight.

Principles of cooking

In principle the shorter the foregoing cook, the longer the period necessary for the final cure to bring about complete polymerization. The longer the cooking time or the longer the heating of this composition of matter prior to combination with the paper pulp the larger the resin molecules and the higher the viscosity, whereas the shorter the cook, the smaller the resin molecule, giving greater ability to effect penetration into the paper fiber to bring about absorption. In this way one can control the formation of average molecular size thus governing the degree of absorption and adsorption in or on the fiber.

For instance if a short cook composition is introduced into the machine chest with slow agitation and mixing is conducted for an hour we find that greater absorption is secured, but if it is added at the head box which holds a much smaller amount and there is movement continuously in and out of the head box, creating shorter time of contact we find that greater adsorption or surface coating and lesser penetration result. The resulting strength and characteristics of the paper can be accordingly modified. If there is a short cook, the paper will be more flexible because of greater absorption, while, with the longer cook, the composition of matter stays more on the surface of the stock and provides a stiffening effect on the fiber.

In the making of the paper sheet the temperature of the drying rolls ranges from 235 to 300° F. as the stock moves through the machine. Depending on the length of the driers and their

capacity for drying from 100 to 500 feet of sheet per minute the temperature of the sheet ranges from 70–280° F. On the corrugating machine the temperature runs approximately 300–340° F. in the drying ovens with the paper travelling at 300 to 500 feet per minute, again depending on the particular machine.

EXAMPLE II

The steps of a typical example of our invention are as follows:

A

Starch	gms.	10
Water soluble urea formaldehyde resin	gms.	20
Water	gms.	170

Heat to 167° F., hold 5 minutes, cool.
This is a 5% solution of each component in water.

B

Prepare straw pulp:

Strawboard pulp (15 gms. solids in 1350 gms. water)	gms.	1365
Solution A	gms.	6

Stir and add:
Alum (25% sol.) to pH of 5.7.
The final mixture contains 1% starch and 1% resin on finished paper weight.

EXAMPLE III

The steps of a typical example of our invention are as follows:

A

Starch	gms.	10.0
Water soluble urea formaldehyde resin 45% solids	gms.	22.2
Water	gms.	170.0

Heat the above mixture 167° F., hold five minutes and cool. (5% of each component in solution.)

B

Straw pulp (15 gms. solids in 1350 gms. water)	gms.	1365
Solution A	gms.	6

Stir and stand 3 minutes, add alum (25% sol.) to pH 5.6.

EXAMPLE IV

The steps of a typical example of our invention are as follows:

A

Water soluble urea formaldehyde resin (45% solids	gms.	11.1
Water	gms.	83.9

Mix.

Add cornstarch	gms.	5.0

Reduce to pH 5.0 with papermaker's alum and heat ten minutes at 175° F.

B

Straw pulp (15 gms. solids in 1350 gms. water)	gms.	1365
Solution A	gms.	6

The final mixture contains 2% starch and 2% starch resin on finished paper weight.

EXAMPLE V

The steps of a typical example of our invention are as follows:

A

Corn pearl starch	lbs.	73
Water	gal.	135

Mix well and add:

Water soluble urea-formaldehyde resin (50% solids)	lbs.	146

Mix well and while mixing add dry alum (papermaker's grade) to a pH of 5.3.
Heat with agitation to approx. 175° F. and hold at this temperature for twenty minutes.

Dilute with water	gal.	350

This is a 2.5% solution of each (resin and starch) in solution (total 5%).

This solution is fed into the pulp at the dividing head of the paper machine at the head box at a rate to add 1% of each component based on the air dry paper being made on the machine. Alum is added continuously here (25% solution) simultaneously to hold the pH at about 6.7 to 6.95.

On a paper machine producing 55 tons per day the additions as above would amount to 30.56 lbs. per minute of the resin-starch solution.

Above resin-starch solutions have also been used by adding to straight bogus stock (scrap paper) with equally improved results over the results obtained on a straight untreated paper.

Curing of the resin

The cooking period of the starch and resin is the first step in controlling the extent to which there will be obtained absorption or adsorption in or on the fiber. As a rule slow agitation for a considerable period, approximately an hour, of the starch resin composition with the pulp as in the machine chest will bring about the predomination of absorption, whereas by adding at the head box where shorter time of contact results will give greater adsorption. As a rule the shorter the cook, the smaller the molecular structure and the greater the ability to penetrate the fiber by the starch resin pre-cooked combination to bring about greater absorption, whereas the longer the cook, the larger the molecule size which will bring about greater adsorption.

Also, it is the rule that the shorter the cook the longer the final cure at equal temperatures. A short cook may result in a more flexible product while a longer cook brings about more of a surface deposit of the starch resin composition tending to give a stiffer fiber after curing.

We have found that a longer or shorter duration of time of contact of the resin starch solution with the fibers will also govern the degree of relative absorption or adsorption even after the average molecular sizes have been controlled and established in the pre-cook of the resin and starch.

The heat used in manufacture of paper is largely consumed in the drying of the paper so that the heat is effective to a lesser degree for further polymerization and curing of the resin as compared with the corrugating operation where the paper runs over corrugating rolls and over steam heated driers to dry the glue applied to the corrugations. In a typical machine these driers normally run about 340° F. The paper travels about 450' per minute and the driers are about 40' long. The temperature of the paper

is such that the paper is too hot to touch, but being in rapid motion it is not possible to determine the actual temperature of the paper.

Between the paper machine and the corrugating machine the paper is rolled while warm and this residual temperature continues the slow curing of the resin.

After the delivery of the boxboard from the boxboard making machine there is sufficient residual heat in the boxboard so that the cure of the resin in some instances will continue (even at room temperature) to bring about the final cure.

Generally speaking temperatures above 250° F. will bring about the final and accelerated cure of the resin. The speed of cure is a function of and is governed by the pH values as a high pH (alkaline) gives more stability and less tendency for rapid cure than a low pH (acid condition). These conditions are controlled by using the proper amount of papermakers' alum or other similar chemicals.

In the instant case when straw is the basis of the stock it is essential that the acidity be controlled as indicated, in order to prevent any destruction of the strength of the stock itself which would negative the strengthening effect of the additive composition.

However, in the event that the composition is employed with stock other than straw we have found it possible to increase the amount of alum and thereby accordingly modify the pH values because the effect of alum in some cases is not deleterious per se on the strength of the stock.

Thus in the event that bogus (any scrap paper and mixed boxboard) or other paper making fibers were utilized as the basis of the stock on the run then the pH values would be accordingly adjusted as indicated because the destructive effect of incorporating alum would not be as marked as in the case of using virgin straw.

It is understood that the use of alum under these circumstances for the primary purpose of effecting the polymerization of the resin and setting it up in combination with the starch and its combination with the paper fibers is (aside from) its well known function of acting as a size precipitant for rosin size and other sizing materials.

In various places throughout the text the phrase "to increase strength and lower weight" is used. It must be understood that this is proportional, that is if we lower the weight, strength changes proportionally to the reduction in weight. In other words we lower the weight to a point where strength remains the same as it was without any treatment. By the same token if we maintain constant weight then strength (crush resistance) increases to its maximum. This resolves itself into an economic feature. By maintaining uniform crush resistance (strength), we can reduce weight and save costs. If we maintain uniform weight compared with untreated sheets then at the same cost or very slightly additional due to chemical costs, we attain increased quality of crush resistance.

In increasing strength we do not refer to tensile strength, but mean resistance to crush force. The term "crush resistance" can be employed instead of "strength" as we have no reference to tensile, burst or tear strength when we speak of this property called crush resistance, although increased crush resistance will influence these properties of tensile and burst to some extent. This differentiates this result from "wet strength" which is essentially a tensile strength when wet. The property of crush resistance is essentially a stiffening of the fibers by applying treatment to fibers as well as some stiffening of the matrix which cements these fibers together.

Again referring to our description of the flow sheet of paper making this is merely typical. Although this procedure is used in a number of mills, others use one or more Fourdrinier machines instead of cylinder machines.

The urea resin starch is applicable to either type of sheet forming.

There are, also, variations as to preliminary preparation of the cooking, the pulp treatment, etc. before reaching the paper sheeting stage. Some plants use spherical steam heated digesters, others use chemical pulpers and various other types of digesters.

In the case of "bogus" paper it may be pulped in the beater or it may be treated in a "hydraulic" pulper or by other mechanisms.

Also, in a cylinder machine, the number of cylinders may vary from one cylinder up to four or even five cylinders or more.

In our flow sheet and description thereof, there are shown two weir boxes for controlling the rate of addition of the chemicals to the paper pulp. This again is a typical set up. Instead of weir boxes we may use proportioning pumps or flow regulating meters or any other devices suitable to control and regulate a constant flow.

This also is true of the dividing head of the boxes. Any other method may be used to furnish three or more (or less) uniformly controlled feeds such as three separate pumps, three meters or any other suitable method.

The chemical addition agents, besides being suitable for straw stock and "bogus" can also be applied to any other type of stock including jutes, kraft, rag, wood, chestnut or any other grade of pulp.

It will be understood that we desire to comprehend within our invention those modifications and substitutions of materials that are found necessary in adapting these inventions to various conditions of use and particularly where the claims specify a particular resin or other material it will be understood that equivalent substitutes of material may be employed some of which are indicated herein as typical substitutes. The specification and the claims therefore of a specific material is meant in the generic sense of any materials of that class having those similar characteristics.

We claim:

1. The method of making a water-dilutable potentially thermosettable starch-resin reaction product which comprises adding from about 62.5 to about 73.0 pounds of raw starch to an aqueous solution of about 125 to 146 pounds of a 50% solids water-soluble urea-formaldehyde resin precondensate in about 135 to 140 gallons of water at room temperature, adding sufficient alum to adjust the pH of the mass to about 5.3 to 6.5, heating the mass at said pH and with agitation to a temperature in the range of 166° F. to 180° F. and maintaining the mass at said elevated temperature for from about 20 to 25 minutes.

2. A water-dilutable potentially thermosettable raw starch-urea formaldehyde resin reaction product made by the method of claim 1.

3. The method of making boxboard having controlled crush resistance and weight which comprises (1) incorporating an aqueous dilution of a water-dilutable potentially thermosetting

raw starch-urea formaldehyde reaction product in the paper stock in an amount to provide the stock with a total solids content of 2% of the raw starch modified-resin based on the dry weight of the paper, said 2% being made up of 1% of raw starch and 1% of the urea-formaldehyde resin, (2) adjusting the pH of the mixture of paper stock and diluted starch-modified resin to 6.7 to 6.95, (3) sheeting the mixture, (4) laminating a plurality of sheets to obtain a multilayer product, (5) passing the laminate through a drying zone, (6) passing the dried laminate through a corrugating zone, (7) and then passing the corrugated laminate through a finishing zone in which an adhesive is applied to at least one surface of the corrugated laminate and a liner sheet is applied to the adhesive-coated surface, the temperature to which the mixed fibers and heat-curable starch-modified resin are subjected from the wet end of the sheeting machine to the exit end of the finishing zone being increased progressively and being correlated with the rate at which the mixture, in the sheeted form and then in the laminated form, is passed to the exit end of the finishing zone so that conversion of the resin to thermoset condition is effected progressively but is not completed before the boxboard is ready for removal from the finishing zone, said aqueous dilution of the starch-resin reaction product being obtained by adding from about 62.5 to about 73 pounds of raw starch to an aqueous solution of about 125 to 146 pounds of a 50% solids water-soluble urea-formaldehyde resin precondensate in about 135 to 140 gallons of water at room temperature, adding sufficient

alum to adjust the pH of the mass to about 5.3 to 6.5, heating the mass at said pH and with agitation to a temperature in the range of 166° F. to 180° F., maintaining the mass at the elevated temperature for from about 20 to 25 minutes, and diluting the mass with 300 to 350 gallons of water.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
109,621	Hutchins	Nov. 29, 1870
1,582,841	Lorenz	Apr. 27, 1926
2,121,076	Ellis	June 21, 1938
2,221,200	Perry	Nov. 12, 1940
2,275,314	Pierson	Mar. 3, 1942
2,302,309	Glarum	Nov. 17, 1942
2,302,310	Glarum	Nov. 17, 1942
2,338,602	Schur	Jan. 4, 1944
2,400,820	Glarum	May 21, 1946
2,407,071	Gill	Sept. 3, 1946
2,450,377	Kesler et al.	Sept. 28, 1948
2,544,714	Moore	Mar. 13, 1951
2,555,057	Porter	May 29, 1951
2,590,013	Huntzicker	Mar. 18, 1952
2,601,671	Wilson et al.	June 24, 1952
2,629,699	Moore	Feb. 24, 1953

OTHER REFERENCES

Collins, Paper Ind. & Paper World, June 1943, pp. 263–269.

Maxwell, Paper Trade Journal, May 13, 1943, page 41.