Dec. 6, 1966 A. GOLDSTEIN ETAL 3,290,205

METHOD OF MAKING CORRUGATED FIBRE BOARD AND PRODUCTS OBTAINED THEREBY

Filed April 18, 1962 4 Sheets-Sheet 1

Fig. 1.

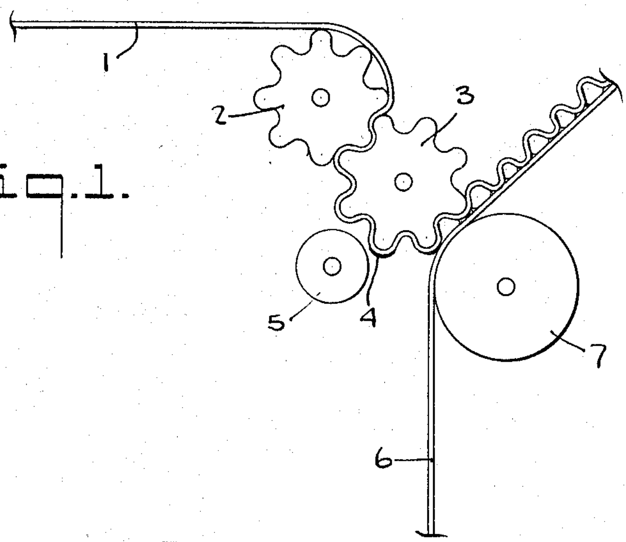

Fig. 2.

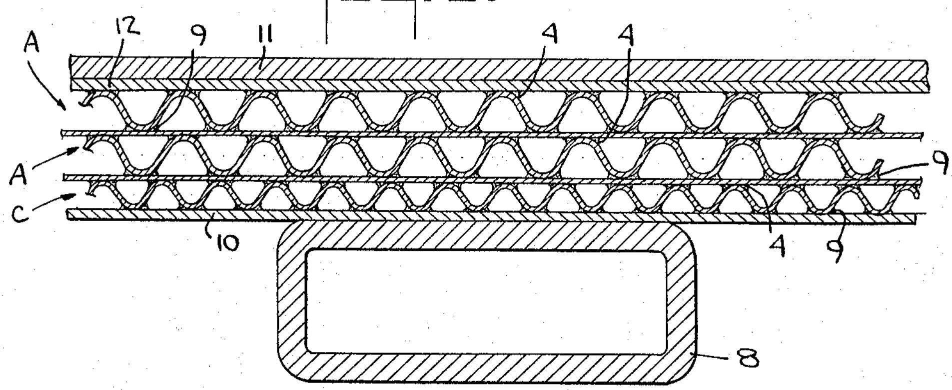

Fig. 3.

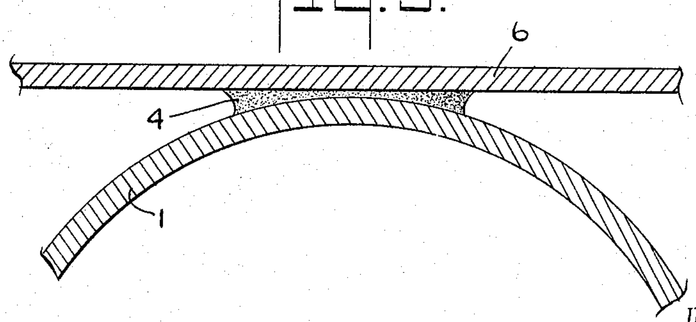

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Fig. 5.

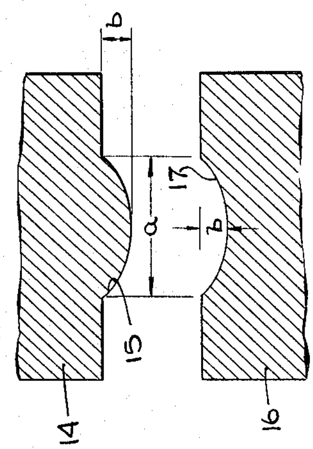

Fig. 4.

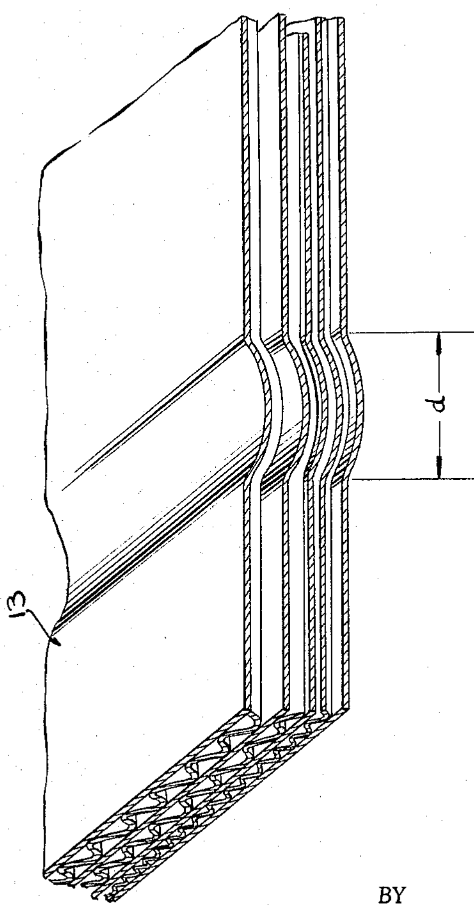

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Fig. 7.

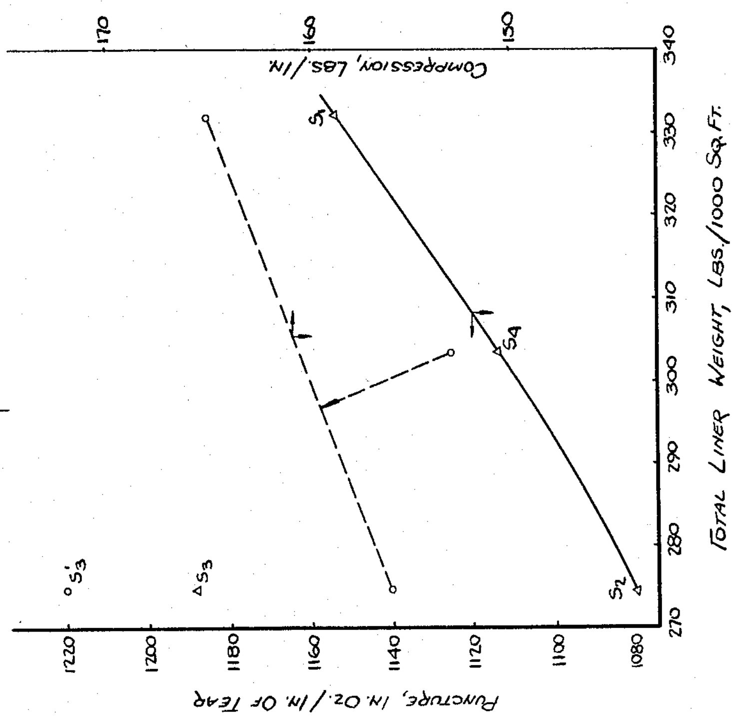
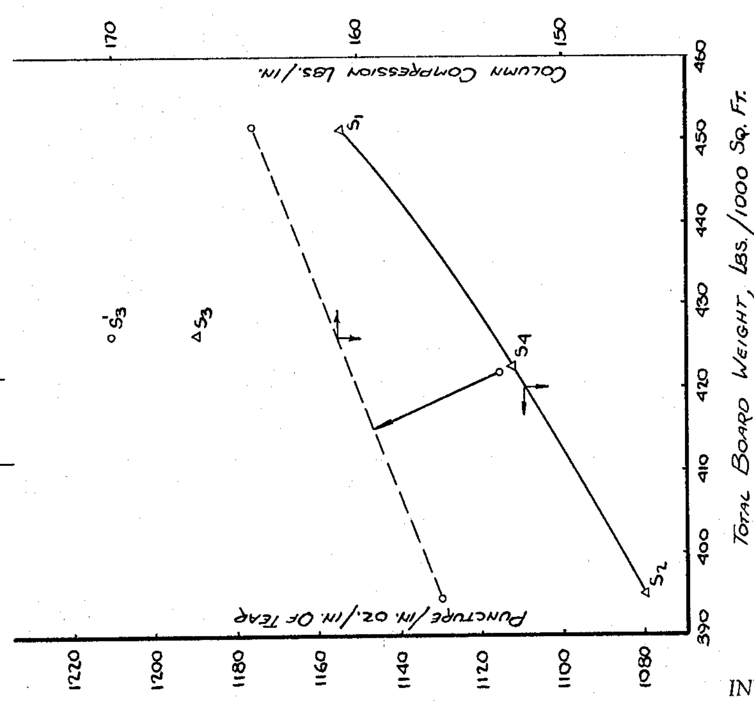


Fig. 6.



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METHOD OF MAKING CORRUGATED FIBRE BOARD
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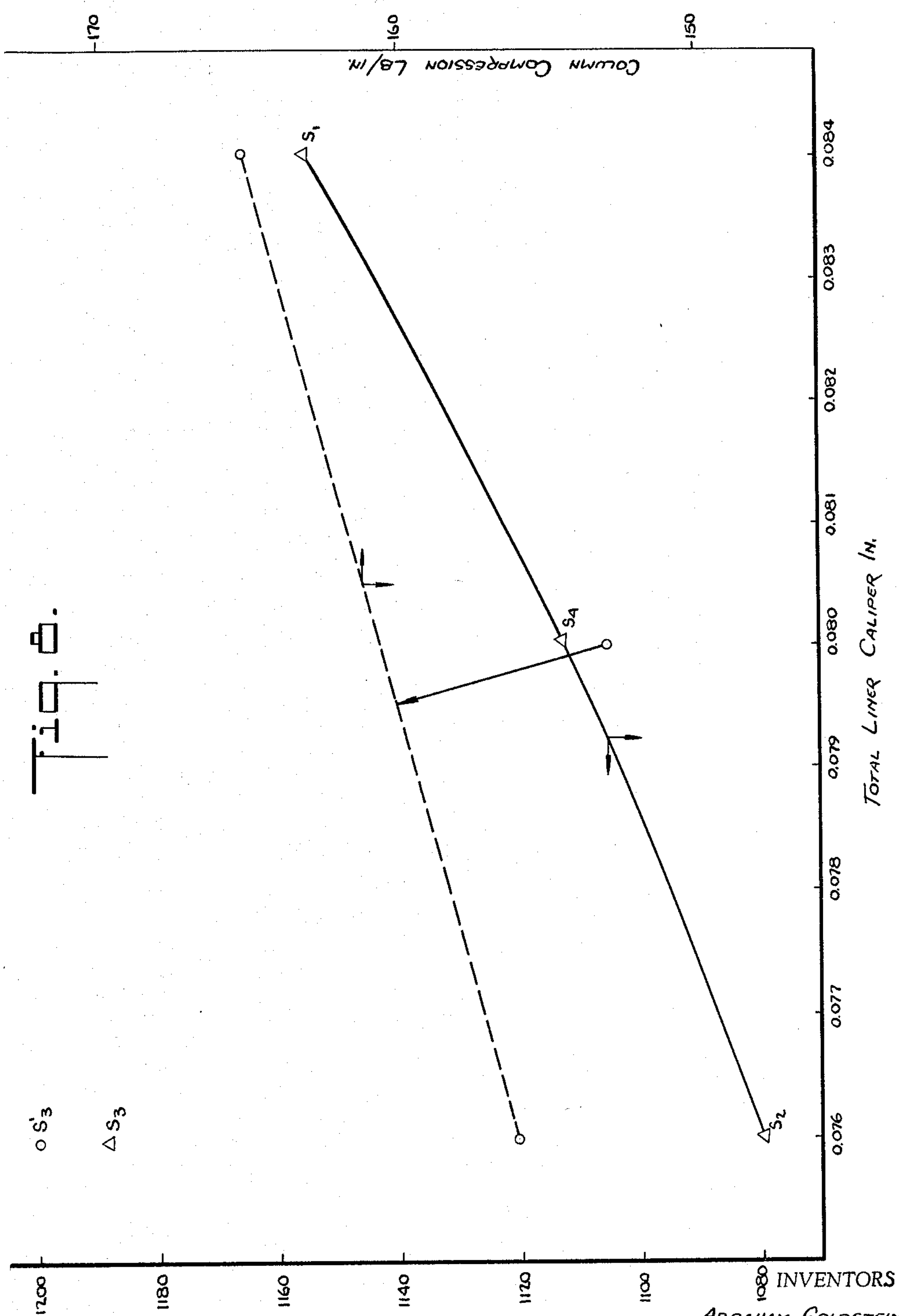

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METHOD OF MAKING CORRUGATED FIBRE BOARD AND PRODUCTS OBTAINED THEREBY

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5 Claims. (Cl. 161—137)

This invention essentially relates to a method of making multiple wall corrugated fibre (or paper) board of the thick and very thick kind comprising at least two and preferably three layers or plies of corrugated mediums and three of four liners and to the products obtained thereby. The corrugated mediums are thus interposed or sandwiched between, these spaced liners which are flat sheets adhesively secured to the tips of the corrugated medium to form an integrated product.

Particularly the triple wall product has the advantage over other fibre board materials when made into boxes, of having great column strength and therefore permitting a number of the boxes to be piled one on top of another when containing heavy objects, without causing excessive buckling or complete collapse of the vertical walls of the boxes near the bottom. Another advantage is that this product has great resistance against the tearing penetration occasioned by sharp objects striking against it, such as might occur when boxes are transported and subjected to careless treatment.

The great column strength is obtained because the liners or flat sheets are spread very widely apart away from the neutral axis and the tear resistance is obtained because of the multiple layers of material. However, these properties are obtained to a high degree only after the tips of the corrugations of the corrugated medium are adhesively secured firmly to the liners or flat sheets throughout the construction of the product.

In order to manufacture the product one flat liner sheet is adhesively bonded to one web of corrugated medium by adhesive or glue applied to the tips or crests of the corrugations or flutes across the entire width of the latter which are parallel to each other, so as to form a layer known as a single face corrugated board. This is done twice or three times according as a double wall or a triple wall corrugated board is contemplated. Then the single face boards are preheated to condition the sheets for the reception of adhesive and the exposed ridges of the corrugations on the unlined side of the corrugated medium of each of the two or three layers have adhesive applied to them across their entire width and the two or three layers are superimposed and pressed together with a third or fourth outermost liner whereby said ridges of said corrugations are adhesively secured to the liner of an adjacent ply and to said outer third or fourth liner. While pressure is continuously applied to the composite board thus obtained, the latter is heated to partially dry it for bonding the several sheets together whereby the sheets are incompletely set. For triple wall corrugated board this heating may be effected preferably at a temperature within the range of approximately 300 to 350° F. The composite board is then cooled to allow handling thereof and possibly subsequently scored or creased transversely to the corrugations to permit folding or bending the material to a packaging shape and possibly crushed locally and trimmed and cut to finished size. All of said operations may be effected manually but they are generally more conveniently carried out while the material is continuously moving with the corrugations transverse to the path of travel in a single pass through an automatic corrugated fibre board machine comprising two or three corrugating and single facer sections followed by a combining double backer device incorporating a laminating, heating and cooling section and a scoring and shearing section. The temperature-speed relationship is varied with the humidity, the thickness, and porosity of the sheets to provide a residence time in the heating section to set or harden said adhesive. Thus for example the web of triple wall corrugated board may be heated for not less than 14 seconds and not more than 24 seconds (otherwise the product is scorched).

The medium which is relatively cheap may have any furnish and may even be glassine paper. However, in the manufacture of shipping containers this sheet is generally composed of paper made by the kraft pulping process, paper made by the semi-chemical pulping process, paper made from waste papers or paper made from the pulping of straw. The liner which is relatively expensive can again have any furnish but is generally a sheet of all kraft furnish or a sheet with waste paper furnish.

The purpose of the adhesive is to adhere the mediums to the liners. Since the machines used to produce corrugated board operate at relatively high speed, the adhesive must bond or at least set immediately. When an adhesive is set, it has undergone either a physical or chemical change to an extent such that the materials between which it lies are sufficiently adhered so that they cannot be separated easily. Further physical or chemical changes only serve to help develop maximum bond strength in the adhesive. This latter period is a curing or a bonding period.

It is an object of the present invention to provide an improved method of making multiple wall corrugated fibre board having increased rigidity and strength and preferably pertaining to the triple wall type. This method is remarkable notably in that among other operations known per se it comprises the step of tensioning said liners end to end by stretching same to positively maintain their flatness throughout the manufacturing process, the step of assembling the component layers in their freshly made and slightly damp state with all of the adhesive incompletely set by simultaneously and continuously pressing them firmly together while the liners are held taut and the component parts are prevented from any slippage relative to each other, the moisture but not all of it then being progressively driven off substantially uniformly by heating, the step of cooling the resulting composite board while still tensioned and immediately thereafter possibly scoring said board as required by folding, while some moisture still remains therein, and possibly the step of stacking the finished product cut to size for a curing time to allow the remaining moisture to evaporate and the board components to eventually acquire a stabilized moisture content with respect to the humidity of the surrounding atmosphere.

It is surprising that when the triple wall product is made as described with an overall weight practically the same as that of the prior art double and triple wall products, the former exhibits so much greater strength this prevailing whether it is manually made or made in a corrugated paper board machine. Concerning the time and temperature values, both of these vary over wide limits. The great strength of the new triple wall product thus obtained is for instance due to maintaining the liners tensioned to keep them absolutely flat during the whole process without any relative slippage between any of the parts such as might smear the glue freshly applied or rupture the glue of the previously glued parts. Furthermore, if the finished product is to be scored to permit the folding of flaps and the like, this should be done immediately after the cooling step because at that time the product still retains some of its moisture and although its glue is set, it is still slightly flexible, thereby facilitating the crushing which forms the score lines or strips without substantial harm to any of the layers or to the glue connections. The result is a product that is structurally balanced and firmly interconnected.

Instead of using the relatively heavy weight paper liners used to make single wall and double wall prior art products, the triple wall product resulting from the above procedure is tremendously stronger in every way than is the double wall product even though the weight of the liners of both is substantially the same. In other words, the triple wall product may be made with relatively thinner or lighter weight paper liners.

The adhesives used comprise essentially starch and water which must be heated to a high enough temperature to cause the starch to gel, or a silicate type adhesive such as sodium silicate and water which must be heated to evaporate the water to set the adhesive. Thus heat is required in both instances.

It is not very difficult to get heat to the adhesive at the time the single layer of corrugated medium is applied to the single layer of liner or flat sheet. However, serious problems occur when attempting to get the proper amount of heat to the adhesive after the various layers have been combined to form the three layers of corrugated medium and four layers of liner or flat sheet materials.

Such problems are increased if the liner is made thicker to provide the finished product with greater column strength and tear resistance, or if the corrugated medium is shaped with large or high corrugations to spread liners farther apart as is indicated to increase the column strength by placing the liners farther from the neutral axis. Preferably, both outermost liners are of greater weight than the inner liners to attain the greatest possible moment of inertia. Thicker liners soak up more water when the adhesive is applied and their very thickness reduces their ability to conduct heat. Higher corrugations contain more air which reduces the flow of heat and in addition spaces the liners and adhesive farther from the heat which can only be applied to one side of the combined pieces when any convenient manufacturing method is used.

If excessive heat is applied to one side of the combined layers to try to get enough heat to the far side, then there is the possibility of over-heating the adhesive close to the source of heat. Both kinds of adhesive when over-heated become brittle and tend to break away from their desired locations and from the normally desired form or shape of the adhesive material as it is located between the parts it must hold together.

Now it can be appreciated that normal ways for attempting to make this triple wall corrugated fibre board with greater strength, are self defeating.

According to the present invention, the production of multiple wall corrugated fibre board especially of the triple wall type whose minimum strength is better than similar known board made with the same overall weight of liners or flat sheets incorporated in only three flat sheets or liners and only two webs of corrugated medium between them and whose maximum strength is considerably greater than this is made possible in a practical way. This is done by making the outermost liners or flat sheets of paper not only of greater weight but according to another feature of the invention also by employing liners of very great density obtained by using highly calendered paper.

In addition, according to a further feature of this invention the manufacturing of the separate single face layers comprises the step of gluing the ridges of the flutes of the corrugated medium which are to be adhered to the liner with an adhesive compounded to set at relatively high temperatures; thus when securing the single layers of liner an adhesive is used, whether of the starch or silicate kind, which requires a large amount of heat to set it properly and which therefore can later withstand satisfactorily higher temperatures. The use of this kind of adhesive is practical because at this time there is no great problem in getting heat to the adhesive.

Then at the later time according to still another feature of the invention, when the several for example three single face layers of corrugated medium and liner are juxtaposed or brought together with an extra for example fourth outermost liner required to produce the final product, an adhesive is used, and again it may be either of the starch or silicate type, which is compounded to set at lower temperatures.

The advantages are that although the liner is of heavy weight and great strength, being highly calendered, its high density and relative thinness permits the heat to pass through it more readily. Furthermore, when the final combining step is carried out a large amount of heat can be passed through the product to set the adhesive requiring the lower temperature to set this adhesive satisfactorily without hurting the previously applied adhesive having the higher temperature setting characteristic.

A well-established principle of mechanical engineering is that the greatest strength and rigidity in a structural member having a given amount of material is realized by disposing the surfaces subjected to stress so that they are as far apart as possible to provide the greatest moment of inertia. Therefore it is known to spread the liners or flat sheets as far apart as possible, and in the case of triple wall board for example to use corrugated mediums two of which are made with corrugations that are quite high while the third is made with a corrugation of lesser height. Then according to a further feature of the invention, the parts are combined so that the corrugations of lesser height are closest to the heat source used to set the adhesive required to inter-connect the various layers of the final product. Therefore, the heat does not have to travel a great distance before reaching the first zone of adhesive used in the second or overall combining step. At the same time all of the layers are spread rather widely apart from the neutral axis of the material of the product. Furthermore, cartons made from the board described are easier to fabricate and use.

As a further and preferred elaboration of the invention, the adhesives applied during the combining step also differ from each other in characteristics. Those applied to the corrugation tips closest to the heat source may be compounded to set at somewhat higher temperatures than the adhesive used to affix the latter furthest from the heat source. Thus the greater heat that reaches the adhesive closest to the heat source has even less tendency to hurt that adhesive while the heat reaching the farthest adhesive is adequate to set this adhesive.

Preferably, as already set forth hereinabove, the liners are made from highly calendered pure kraft paper which are of high density but which are of different weights for the various layers. Thus according to prior art practice the outermost two layers may be made of very heavy weight while the two liners in between may be made of lighter weight paper. This has the great advantage that the one thicker layer closest to the heat receives its heat directly, the adhesive on the inside of the liner farthest from the heat receives heat without it passing through this liner, and the two liners in between are both of the lighter and therefore thinner paper that does not resist the passage of heat to so great a degree.

A further feature of the invention is to use an adhesive of a type that may be heated to high temperatures before it is applied to the tips of the corrugations of the corrugated medium in the case of the combining of all of the parts to produce the triple wall construction. Such adhesive may be a formula consisting largely of silicate of soda, starch, clay, water and other additive. The starch acts as a sort of desiccating or dehydrating agent, in that in conversion or gelatinization with heat it absorbs the water available from the silicate of soda. The silicate of soda of course sets when a certain percentage of water (e.g. between 13.5% and 15%) is removed from it.

As a matter of fact all of the adhesive is located between the tips and the flat liners and none of the adhesive has the characteristic of adhesive that has been first hardened and then rewet such as would occur if previously made single wall or double wall components were later on combined by manual methods using new glue, the water of which necessarily resoftened the previously hardened glue.

The present invention permits the rapid and effective production of triple wall corrugated paper board of great strength even when the outer liners or flat sheets are made of so called water-proof or moisture-proof pure kraft paper, and even though the corrugated medium is made of heavier than usual paper for the purpose of even further increasing the strength of the final product as will be ascertained hereinafter.

Another object of the present invention is to provide a scoring device for multiple wall corrugated fibre board. Scoring devices are known which comprise at least one pair of registering rotatable score wheels between which the finished board is pulled and constituting the one a male die having in cross-section a projecting forming part and the other a female die having in cross-section a corresponding depression. The scoring device according to the invention is remarkable notably in that said male die overlies said female die so as to engage from above the top surface of said board, said male die projecting part forming a raised arcuate portion around its periphery and about three-quarters of an inch wide and about three-sixteenths of an inch high whereas said depression around the periphery of said female die which is substantially exact mate of the male has dimensions corresponding to those of the male.

This invention also relates to the multiple wall corrugated fibre board product manufactured according to the method broadly set forth hereinabove and comprising a plurality of layers of corrugated medium interspersed between flat liners which are of heavier weight on the two outermost layers than those forming the inner layers which thus are relatively thinner. This product is remarkable notably in that said liners are all of equally very high density and preferably made of highly calendered pure kraft paper and are joined together with said corrugations on one side of the corrugated medium by at least one type of adhesive and on the other side by at least another type of adhesive, the adhesive being confined to the interconnecting parts and being firm and free from overheating effects throughout the entire product.

According to another very important feature of the present invention, said multiple wall fibre board product comprises corrugated medium of relatively very heavy weight combined with liners at least some of which are of possibly relatively reduced weight and caliper.

In effect, this invention advocates the use of heavier corrugating mediums for the purpose of increasing not only the column compression load which the finished fibre board may withstand but also its resistance to puncture by sharp objects during transit. It has frequently and emphatically been stated in prior art and present trade practice that the strength of combined corrugated fibre board except as concerns flat crush is entirely dependent of the strength of the liners or flat sheets and that the sole purpose of the corrugating medium is that of spacing the liners sufficiently from the neutral axis of the board for the development of maximum strength by the fibre board. The weight and thickness of the corrugating medium have thus far been considered unimportant in their contribution to strength.

It was found, to the contrary, that the weight and thickness of the corrugating medium contribute markedly to an increase in strength especially in resistance to puncture. The increase is so marked that increases in strength due to small increases in the weight and caliper of the medium are more than sufficient to overcome potential losses due to a large decrease in the weight and caliper of the liner sheets. Typical test results as concerns column compression and puncture are shown in the following Table I for different constructions of triple wall corrugated fibre board. It is evident from the examination of this table that an increase in the weight of the liners results in an increase in the strength of the board, a result which is in accord with past experience. Examination of sample No. 1 fibre board shows that an increase in the weight and caliper of the liner sheets of 21% and 10.5% respectively over those of sample No. 2 produces a 7% increase in the puncture resistance of the board and a 5.75% increase in the compression resistance of the board. The total paper weight change is 14.5%.

While previous experience indicates that the increase of weight and caliper of the medium contributes little to column compression strength and nothing to puncture resistance, examination of samples 2 and 3 shows that increasing the weight and caliper of only the medium in sample No. 3 by 27% and 20% respectively over those of sample No. 2 produces an increase of 17.5% in puncture resistance and 10% in compression resistance. The total paper weight change is 8.2%. Furthermore, comparison of samples 1 and 3 shows that despite the decrease of 17.3% and 9.5% in liner weight and caliper respectively of sample No. 2, a decrease which is considered to be large, an actual increase of 3% in puncture resistance and 4% in compression resistance was obtained. It is important to note at this point that the increase in corrugating medium weight and caliper between these samples of 27% and 20% respectively, not only offset the loss in strength due to the decrease in liner weight and caliper, but in actual fact raised the strength of the board. The overall weight change of the board is a decrease of less than 6%.

Sample 4 is included in Table I to indicate that intermediate weight and caliper of liners will produce intermediate strength results. This would be expected from the foregoing paragraphs.

In normal plant production, where board is made using adhesives exactly like the adhesives used in making the fibre board described in Table I and where similar grades of paper are used, but obviously not from the exact same rolls, we have found that grades of board exactly like those shown as sample 2 of Table I may have a puncture value which ranges from a low of 1000 to a high of 1124, while the compression may vary from a low of 130 to a high of 160. Production board exactly like that shown as sample 3 of Table I may have puncture values ranging from a low of 1140 to a high which exceeds 1300 while the compression strength may vary from a low of 140 to a high of 200.

TABLE I.—PROPERTIES AND TEST RESULTS OF TYPICAL TRIPLE WALL CORRUGATED FIBRE BOARDS (C-A-A TYPE FLUTE CONFIGURATION)

Sample No.	Fibre Board construction		Total Liner Properties		Total Medium Properties		Puncture, in.-oz./in. of tear	Compression, lbs./in.	Total Fibre Board Properties	
	Liner Arrangement	Mediums	Weight,[1] lbs./1,000 sq.ft.	Caliper,[1] in.	Weight,[1] lbs./1,000 sq.ft.	Caliper,[1] in.			Weight,[1] lbs./1,000 sq.ft.	Caliper,[1] in.
1	90-64-64-90	26	331.6	0.084	[2] 119.6	0.030	1,155 (1,137)	165	451.2	0.114
2	90-42-42-90	26	274.2	0.076	119.6	0.030	1,080	156	393.8	0.106
3	90-42-42-90	33	274.2	0.076	152.0	0.036	1,189	172	426.2	0.112
4	90-64-42-90	26	302.9	0.080	119.6	0.030	1,112	153	422.5	0.110

[1] Weights and calipers of individual liners and mediums used in the above boards:

Grade	Weight, lbs./1,000 sq.ft.	Caliper (thickness), in.
90	93.5	0.024
64	72.3	0.018
42	43.6	0.014
33	34.3	0.012
26	27.0	0.010

[2] Take-up factor of 1.5 used for A-flute and 1.43 for C-flute $=\frac{\text{lineal length of medium}}{\text{lineal length of single face liner}}$

The increase in puncture resistance wrought by the inclusion of heavier and thicker corrugating mediums in triple wall corrugated fibre board is all the more remarkable when examined in the light of past practice in meeting minimum standards for corrugated fibre boards. The minimum standards for corrugated fibre boards is set forth for example in the U.S. Uniform Freight Classification under Rule 41. This rule specifies that each grade of board must meet a minimum burst or puncture strength. In the case of some boards, the burst strength measured by the Mullen or Cady test is beyond the capacity of the testing machine used to test it. Under these circumstances, a puncture test (Beach test) is used. While the two tests are not the same, the results are comparable since the unit of puncture, inch-ounces per inch of tear, were chosen so that it would correspond to a burst reading. .

In an attempt to meet the specifications under Rule 41, it is common practice to determine the burst strengths of the liners only and place in the finished board liners whose total burst strength is equivalent to the burst strength desired in the finished board. The corrugating medium is ignored completely. For example, if a double wall board of 600 test were desired, the liners would be chosen such that the sum of their individual burst values would be 600. No account is taken of the medium.

This practice when used with triple wall board, would produce errors of considerable magnitude. In the case of sample 2 in Table I a burst or puncture strength of only 570 could be predicted. Certainly, this method can never predict that with a net decrease of 21% in liner weight could any increase in burst or puncture be obtained.

The inclusion of heavier mediums in triple wall corrugated fibre board while at the same time reducing the weight of the flat sheets or liners has a second important advantage in the overall manufacture of the board. As has been previously indicated, the transfer of heat to the uppermost adhesive line during the combining operations of FIGURE 2 is both difficult and critical. Any arrangement of liners, mediums or air space between them which would facilitate the movement of heat to the upper adhesive line is desirable to facilitate the process of fabricating the combined board.

The movement of heat through the corrugated fibre board is indeed facilitated by the simultaneous use of thinner liners and heavier mediums. The heat travels through the fibre board principally by two methods, conduction and the thermal bath offered by rising steam. The steam, of course, emanates not only from the adhesive which is being dried but also from excess moisture which is contained in the sheet due to the combination of liner and medium in the single facer.

The amount of heat which travels through the board by conduction is governed by the relationship

$$Q=\frac{\Delta t}{R} \tag{1}$$

where Q is the amount of heat transferred, Δt is the temperature difference across the sample and R is the resistance to the flow of heat. The resistance R is in turn determined by means of the relationship

$$R=\frac{L}{kA} \tag{2}$$

where k is the thermal conductivity of the material, L is the thickness of the material, and A is the area exposed to the heat source. In any multi-layer material, the total resistance to heat flow is the sum of the individual resistances. Therefore the heat transferred through a multi-layer material such as corrugated fibre board is given by the equation

$$Q=\frac{\Delta t}{R_1+R_2+R_3+\ldots} \tag{3}$$

or

$$Q=\frac{A\Delta t}{\frac{L_1}{k_1}+\frac{L_2}{k_2}+\frac{L_3}{k_3}+\ldots} \tag{4}$$

In reducing the thickness of the liners, the quantity L in Equation 2 is lowered, leading in turn, to a reduction in the resistance R. In accordance with Equation 1 the amount of heat transferred through the board is greater. It must be remembered that increasing the thickness of the corrugating medium has the opposite effect. However, the total change due to reducing the liner thickness and increasing the medium thickness is a net reduction in overall paper board thickness through which the heat must travel.

The use of thicker mediums also causes the gas or vapor layer between the liner and the medium to be reduced. This occurs since the single facer produces a flute of definite height which will be only slightly affected by the corrugating medium. If the cross sectional area, and thus the volume between the inner faces of the liners thus remains constant, it is obvious that the thicker corrugating mediums will occupy a greater amount of volume thus reducing the vapor volume and consequently its effective thickness. This reduction in thickness of the air layer again results in greater conductive heat transfer. The total increase in the amount of heat transfer by conduction is between 3 and 4%.

The steam and air stream rising through the board is the second major means by which heat is transferred through the fibre board. The heated air portion of the stream transfers heat to the adhesive and the board components which are furthest from the heat source through loss of sensible heat. The steam transfers heat not only through loss of sensible heat but also through repeated condensations and evaporations. However, the effect of the latter is small. The percentage of air in the mixed stream increases as the stream moves up through the board with a resulting decrease in the partial pressure of water vapor. Thus the steam is held mainly in the vapor form and transfers heat through loss of sensible heat or superheat.

Since it is essentially a vapor stream that is responsible for heat transfer, the amount of heat transferred is a function of the amount of vapor which is capable of passing up through the interstices of the components. The passage of a fluid through any opening is given by a formula of the Poiseuille type

$$\frac{dF}{dL}=\frac{32\mu V}{gcD^2\rho} \qquad (5)$$

It can be seen, that all other things being equal, the volume of fluid "V" capable of passing through an opening of diameter "D" is inversely proportional to the length "L" of the opening.

In the present invention, the use of thicker medium while at the same time using thinner liners results in a net decrease in thickness of paper contained in the final combined board (see Table I). Thus there is a net decrease in the length of the openings resulting in a greater flow of vapor and a greater amount of heat transfer.

One must also take into account the factor "D," the diameter of the opening, in Equation 5 which shows that the amount of vapor is directly proportioned to the square of the opening. In the present invention dense liners are used having small interstices. By comparison, the corrugating medium is porous having larger interstices. Thus even for the same thickness of total board, the flow of vapor would be greatest where the medium thickness is a larger percentage of the total thickness.

Examination of Table I reveals that the medium constitutes 26% of the total paper thickness in sample 1 as compared to 32% in sample 3. The total effect, therefore, of caliper and porosity gives an increase in heat transfer from 5 to 6 percent, or a grand total including conduction of 8 to 10 percent.

A further advantage of the present invention relates to the cost of the finished triple wall corrugated fibre board. Comparison of samples 1 and 3 of Table I shows that board of greater strength can be obtained by using thicker corrugating mediums and thinner liners despite the fact that there is a net reduction in the total weight of paper board in the product. Since paperboard is purchased on a weight basis, there is obviously a net saving involved in using a lower weight of paper. This saving is amplified when it is remembered that the cost of corrugating mediums is lower than the cost of liner. Thus, in the present invention low cost medium is substituted for high cost liner with an overall reduction in total weight resulting in significant savings.

In summary it has been ascertained that significant increase in strength and heat transfer and significant savings can be obtained where the medium weight and caliper are 33 lbs./1000 ft.^{2} and 0.012" respectively and where the medium weight and caliper ranges from 30 lbs./1000 ft.^{2} and 0.011 inch respectively to the heaviest and thickest medium which it is practical to corrugate. This discovery is directly contradictory to the prior literature and art relating to normal corrugated fibre board and to heavier corrugated fibre board structures.

Other objects, features and advantages of the present invention will become apparent as the following description proceeds with reference to the accompanying diagrammatic drawings given by way of example only for illustrating a form of embodiment of the invention and in which:

FIG. 1 is a partial elevational side view of one single facer section of a corrugated fibre board machine showing the step wherein the corrugated medium is applied to one liner;

FIG. 2 is an enlarged partial side view of the double backer section of said machine showing the combining step wherein all three single face components and the fourth liner are put together;

FIG. 3 is an enlarged vertical section parallel to the direction of travel of the paper showing the effective adhesive bond obtained between all of the tips of the corrugation and the adjacent liner;

FIG. 4 is a perspective partial view of a scored board showing the possibility of creasing or scoring the new product so it may be folded as required to make a rectangular box for example;

FIG. 5 is a fragmentary cross-section of the score dies;

FIGS. 6, 7 and 8 are graphs based upon test data included in Table I given hereinabove and wherein puncture and column compression strengths are plotted against total board weight, total liner weight and total liner caliper respectively.

Referring now to the embodiment in FIG. 1, the corrugating medium denoted by the reference numeral **1**, is first formed in the nip between corrugating rolls **2** and **3** after first conditioning the medium with moisture as by steaming and with both corrugating rolls being properly heated. While on roll **3**, the medium **1** has lines of adhesive **4**, applied to each tip of each corrugation by means of adhesive applicator roll **5**. The usual starch or silicate adhesive may be used provided it is compounded to set at higher temperatures. In the case of sodium silicate, a normal 38° Bé. solution having a silica (SiO_2) to soda (Na_2O) ratio in the range of 3.2 to 3.33 may be used directly. In the case of starch a mix containing 20% solids and having 33 pounds of caustic in a 666 gallon batch will be satisfactory. In addition, the previously described type of silicate adhesive containing starch protein and other ingredients besides water may be used.

In all cases enough water is used to provide a fluid consistency (with a viscosity of 50 to 120 Saybolt seconds for example for silicate type glue). The exact corrugating material used may be any of those customarily used in making the older kinds of corrugated paper board. The material that is considered to be best is medium weighing 33 to 36 pounds per 1000 square feet as stated hereinabove.

The liner **6** after being suitably heated is fed over a heated roll **7** which presses the liner **6** against the tips of the corrugations of medium **1**, the heat causing the adhesive to set enough to hold the two components together thereafter.

This liner may be for example very dense highly calendered pure kraft paper. It may weigh 90 pounds per 1000 square feet but due to its density it is not very thick. It is directly in contact with the heated roll **7**. The corrugated medium **1** is of course hot from the corrugating step and therefore the adhesive may be set easily during this phase of the manufacture.

On the other hand the liner **6** may be of relatively light paper when intended for the mid portions of the final product. In these instances although still a more dense heavily calendered pure kraft paper, the liner may weigh only 42 pounds per 1000 square feet.

The liner material of the desired kind is only about .023" to .030" thick in the case of the 90 pound material and is only .013" to .016" thick in the case of the 42 pound material.

In FIG. 2 the three layers of the material shown being made in FIG. 1, are placed together with a fourth liner, this beneath the corrugations that would otherwise be exposed. Before being thus combined the tip of each exposed corrugation has the second adhesive **9** applied to it again in the form of a line running along the tip of the corrugation. In this case the adhesive is of the lower temperature setting formula.

As shown by FIG. 2 all corrugations were made during the steps shown by FIG. 1 with the top two relatively high or deep corrugations while the bottommost corrugations were made shallower or less high. The liner **6** and the liner of the top component are made of the heavier but dense paper while the other two liners were made of the lighter liner material. If desired, the adhesive **9** applied to the exposed corrugations of the top layer has a formulation permitting the lowest temperature setting of all.

During the step of FIG. 2 all of the liners or flat sheets are held flat and straight and free from curvature insofar as is possible. The layers are all pressed together because the liner **10** is resting on a heated plate **8** while a belt **11** at the uppermost liner **12** presses all of the layers together against the hot plate **8**. Continuous production is possible by causing the various layers to move while under the conditions noted but in such an event care must be taken as to permit the layers to have no movement relative to each other.

It is considered best to heat the plate **8** to temperatures ranging about 300° F. to some thirty or more degrees higher. The exposure time of the layers being put together at such heat may vary from a minimum where there is danger of destroying the integrity or strength of the layer up to maximum, such as might be desired for high speed manufacture, that is just sufficient to set the adhesive **9** enough to hold the product firmly together. Moisture from the adhesive and from other causes should of course be driven off to a considerable degree.

As previously explained the density of the liner **10** promotes heat conduction through this layer. The small size of the first set of corrugations permits this heat to get quickly to the liner or flat sheet to which the first set of corrugations were previously attached. The only barriers then in the way of heat transfer are the two substantially thinner next upwardly flat liners and the air space produced by the corrugating medium between them. Radiation plus the thermal bath provided by rising steam gets the heat to the most difficult to set locations, namely the lines of adhesive **9** located on the bottoms of the corrugations of the upper most layer of previously put together corrugated medium and heavier liner sheet.

During this necessarily high temperature working, the previously applied lines of adhesive **4** are not damaged because they consist of the adhesive having the higher temperature setting characteristic and therefore relatively unaffected by the temperatures used during this overall combining step. Specific usable compositions of adhesive are as follows:

For the first step, 38° Bé. silicate may be used where a silicate formula is desired. Where a starch formula is desired an adhesive containing 33 pounds of caustic in a 666 gallon batch may be used giving a caustic content of about 2.7%.

For the second step, about 12% clay is added to the silicate where a silicate formula is desired. The caustic content is raised to 40 pounds in a 666 gallon batch giving a caustic content of about 3.3% where a starch formula is desired. For the uppermost last applied adhesive a formula containing 70% silicate, 6% starch, 18% clay and 6% borax is used where a silicate formula is required. Where a starch formula is desired, the formula given under the second step may be modified to contain about 20% of a polyvinyl acetate emulsion. All percentages specified are on a dry adhesive weight basis.

In all cases the adhesive **9** must be set firmly enough to permit the relatively thick product to be handled. As to thickness, the upper two layers of corrugated medium may be of the so-called A-type defined by a flute depth in the neighborhood of $\frac{6}{32}$ of an inch with about thirty-six corrugations per lineal foot, whereas the lowermost corrugated medium having reference to FIG. 2, may be made with so-called C-type corrugations having a depth or height of about $\frac{5}{32}$ of an inch with about 42 corrugations per lineal foot. The whole finished product may have a thickness of about $\frac{9}{16}$ inch. In FIG. 3 the general contour of the finished bond of adhesive **9** is shown as having the usually desired but not always attained restriction close to the tip of the corrugation, which applies to all instances, and as having lateral edges which are concave because they form the meniscus of the liquid adhesive prior to setting. This type of bond is recognized as being highly desirable and can be attained in the case of thin corrugated paper products. It is not ordinarily obtainable throughout the length of the adhesive line in the case of triple wall material such as has been described.

Overheating causes the embrittlement of the adhesive so that the adhesive cracks or breaks when the board is handled resulting in the separation of the previously combined layers. Relative slippage between layers before the adhesive is properly set causes the corrugated tips to wipe the adhesive in a wide band along the width of the board leaving an inadequate amount of adhesive in the correct position between the corrugated tip and the liner for a proper bond between the components. This wiping also causes the board to lose its proper configuration. The present invention provides for the most desirable bond throughout the desired product.

With all of the adhesive set satisfactorily there arises the problem of creasing or scoring this very thick product without breaking or cracking any of the layers such as would destroy strength at the bend required for right angular parts. In the case of the present invention this can be done immediately following the step shown in FIG. 2 preferably before the combined board has been cut and while some moisture still remains in the fibre board. All of this moisture need not be driven out during the FIG. 2 step because of the effectiveness of the new features previously described.

Such creasing or scoring is shown by FIG. 4. The corrugations of board 13 are of course crushed but throughout a relatively wide zone, indicated at *d* and the various liners move towards each other. This zone *d* should be much wider than that ordinarily used for thinner corrugated materials.

The particular score line that is considered most effective is the one that would be made by the set of score wheels shown in FIG. 5. The male score wheel **14** has a raised portion **15** around its periphery at the point where the board is to be scored. The dimension *a*, the width of the raised portion, is about three-quarters of an inch while dimension *b*, which is the height of the raised portion, is about three-sixteenths of an inch. The female score wheel **16** is an exact mate of the male and has around its periphery a depression **17** whose dimensions correspond to those of the male.

In operation, the male score is pressed into the board perpendicular to the axis of the corrugations. The corrugations are crushed in a band along the length of the board. The upper liner conforms exactly to the contour of the raised portion of the male score wheel. The bottom liner is not pushed completely into the depression of the female score wheel because of the crushing of the corrugations. However, in the finished score the liner in contact with the female score wheel does extend below the surface of the board.

This type of score offers the advantage that it stresses the board in the direction in which this portion must eventually be stressed after a carton is produced from the board. The score herein described is a flap score which is to say that it produces a line of bend in the board which separates the flaps used in forming the top and bottom of the box from the sides of the box.

When a carton is made from the fibre board described, the flaps are bent inwards towards the center of the carton. Under these circumstances, the liner which had previously been in contact with the male score is greatly depressed while the liner which had previously been in contact with the female score, is greatly elongated. The score described tends to stress the liners in just this manner so that the bend is made easily and the liners will suffer no damage during the bending operation.

The scoring or creasing need not be followed by bending or folding of the product. The product in convenient lengths is preferably stacked and given time for what might be called a cure. During this time any remaining moisture evaporates and the fibre board components acquire a moisture content that is stabilized with respect to the humidity of the surrounding atmosphere. In some cases further setting of the adhesive may occur during this period.

The foregoing produces a new product in the form of three layers of corrugated medium, two of which have deep corrugations, and one of which, on the outside of the central one, has less deep corrugations. These three components are interleaved between the four layers or flat sheets of which the outermost ones of the latter are of the relatively heavy but very dense pure kraft paper while the inner two are of equally dense but somewhat thinner pure kraft paper.

The adhesive bond is in all cases of the type as shown in FIG. 3. The use of the two types of adhesive is made evident by this bond and its characteristics because otherwise the lowermost bond points would not have the desired characteristics but would be brittle, out of shape and weak.

Furthermore, by crushing the score or crease lines as shown by FIG. 4 so that the bottommost layer will form the outside of any parts creased to rectangular shape, breaking of the liners is prevented during such creasing, particularly the bottommost or outermost liner. The relatively shallow lowermost or outermost layer of corrugated medium also helps prevent breaking of the outer liner since there is less paper in the shallow corrugation which will bear on the outer liner. Also, external crushing such as may be occasioned by placing concentrated loads on the surface of the board is to a large extent eliminated because the shallower corrugations provide a greater rigidity in the direction of such pressure. Referring now to the graphs of FIGS. 5–7 based upon the data included in Table I:

Graph of FIG. 6 shows the puncture and compression properties of the board plotted against total board weight. The curves connect test points S_1, S_2, S_4 representing samples 1, 2 and 4 respectively which include the light weight medium with varying thicknesses of intermediate liners. Thus, the variable for the curves is the liner weight. These curves demonstrate and support the prior art concept that increases in the liner weight increase the puncture and compression properties of the board. The points S_3 and S_3' on this graph represent the heavy medium triple wall board and demonstrate the marked increase in puncture and compression properties. Curves are not shown for the heavy medium triple wall since the data only includes sample No. 3.

It is presumed that if additional data was available for the heavy medium triple wall, curves could be drawn through the points S_3 which would lie above the curves for the light weight medium. In probability curves for the heavy medium triple wall would extend to the left of the graph towards a common origin with the curves of the light weight medium. Thus, the slope of the heavy medium curves would be appreciably greater than that of the light weight medium curves. The increased slope, which represents the ratio of the properties to the total board weight, is a measurement of the efficiency of the board and thus the heavy medium triple wall is shown to have greater efficiency as well as absolute values for the puncture and compression properties.

The graphs of FIGS. 7 and 8 show curves for the light weight medium against total liner weight and total liner caliper, respectively. As discussed with respect to the curves in FIG. 6, the graphs of FIGS. 7 and 8 also demonstrate the prior art concept that the properties of the board are dependent upon liner weight and liner caliper. Again as in FIG. 6, the points S_3, S_3' representing the heavier medium triple wall point out the marked improvement achieved by this arrangement.

It is felt that the graphs demonstrate why the prior art practice has been to vary liner weight and caliper alone in order to obtain increased puncture and compression properties but not to vary the medium weight and caliper.

The available data is limited to that of Table I and therefore it is impossible at the present time to provide any further graphical presentation of the heavy medium triple wall against the light weight medium triple wall.

The scope of the present invention should not be construed to be limited to the forms of embodiment herein described and shown which have been given by way of example only.

What is clamed is:

1. A method of making triple wall corrugated paper board having four liners and three corrugated paper mediums individually interposed between two liners in each instance, the corrugations of said mediums being parallel to each other throughout said board, said method comprising the steps of bonding each of the corrugated mediums at one side thereof to a different one of the liners with a first adhesive having a first predetermined setting temperature to form a single face corrugated paper board sheet, heating each of said single face sheets to raise the temperature of said first adhesive at least to said first setting temperature to initially set said first adhesive, applying a second adhesive to the ridges at the opposite side of said single face sheets, said second adhesive having a second setting temperature which is lower than said first setting temperature of said first adhesive, combining at least three of said single face sheets with mediums bonded thereto in juxtaposition with an additional liner, the medium of two of said single face sheets during said combining being placed contiguous with the liner of the single face sheet adjacent thereto and the medium of the other one of said single face sheets during said combining being placed contiguous to said additional liner, and additionally heating the combined single face sheets and the additional liner to raise the temperature of said second adhesive to at least said second setting temperature to set said second adhesive and to set further said first adhesive, the lower setting temperature of said second adhesive enabling said second adhesive to be set by said additional heating at a temperature which safeguards said first adhesive from overheating.

2. A method in accordance with claim 1 in which the step of bonding a corrugated medium to a liner with said first adhesive having a first predetermined setting temperature to form a single face corrugated paper board sheet further comprises using for said first adhesive an adhesive which may be heated to high temperatures before it is applied to the tips of the flutes of the corrugated medium, said first adhesive including sodium silicate, starch, clay, water, and additional additives.

3. A method in accordance with claim 1 in which the step of bonding a corrugated medium to a liner with said

first adhesive having a first predetermined setting temperature to form a single face corrugated paper board sheet further comprises the using for said first adhesive one of the high temperature setting adhesive of a normal 38° Bé. gravity sodium silicate solution having a silica to soda ratio in the range of 3.2 to 3.33 and the high temperature setting adhesive of a starch mixture containing 20% solids and having 33 pounds of caustic in a 666 gallon batch, said starch mixture having a caustic content of about 2.7%.

4. Triple wall corrugated paper board which is flat and adapted for scoring and bending to form a shipping container comprising four paper liners, the outermost liners weighing about 90 pounds per 1000 square feet and being from about .023 to about .030 of an inch thick, two intermediate liners weighing about 42 pounds per 1000 square feet and being from about .013 to about .016 of an inch thick, three corrugated paper mediums, the mediums being interposed between the liners in each instance with the corrugations of the medium being parallel to each other throughout said board, two of said mediums being made with deep corrugations of the A-type having a flute depth of about 3/16 of an inch with about 36 flutes per lineal foot, and a third of said mediums on the outside of the central one being made with less deep corrugations of the C-type having a flute depth of about 5/32 of an inch with about 42 flutes per lineal foot, the weight and caliper of the mediums being in a range from 30 pounds to about 52 pounds per 1000 square feet and from about .011 to about .018 of an inch, respectively, first and second adhesives applied to the ridges of the mediums' corrugations for intimately and rigidly bonding the mediums and liners together, said first adhesive bonding each of the corrugated mediums at one side thereof to a different one of the liners, to form a single face corrugated paper board sheet, said first adhesive having a first predetermined setting temperature and being one of a sodium silicate mix added with about 12% clay and a starch mixture containing 40 pounds in a 666 gallon batch and giving a caustic content of about 3.3%, said second adhesive being applied to the ridges at the opposite side of the medium of each of said single face sheets and having a second setting temperature which is lower than said first setting temperature of said first adhesive, said second adhesive being of a sodium silicate formula containing about 70% sodium silicate, 6% starch, 18% clay, and 6% borax on a dry weight basis and a starch formula modified to contain about 20% of a polyvinyl acetate emulsion, the lower setting temperature of said second adhesive enabling said second adhesive to be set by said additional heating at a temperature which safeguards said first adhesive from overheating.

5. A method for making triple wall corrugated paper board having four liners and three corrugated paper mediums individually interposed between two liners in each instance, the corrugations of said mediums being parallel to each other throughout said board, said method comprising the steps of bonding each of the corrugated mediums at one side thereof to a different one of the liners with a first adhesive having a first predetermined setting temperature to form a single face corrugated paper board sheet, said first adhesive being one of a sodium silicate mix added with about 12% clay and a starch mixture containing 40 pounds in a 666 gallon batch and giving a caustic content of about 3.3%, heating each of said single face sheets to raise the temperature of said first adhesive at least to said first setting temperature to initially set said first adhesive, applying a second adhesive to the ridges at the opposite side of the medium of each of said single face sheets, said second adhesive having a second setting temperature which is lower than said first setting temperature of said first adhesive, said second adhesive being one of a sodium silicate formula containing about 70% sodium silicate, 6% starch, 18% clay, and 6% borax on a dry weight basis and a starch formula modified to contain about 20% of a polyvinyl acetate emulsion, combining at least three of said single face sheets in juxtaposition with an additional liner, the medium of two of said single face sheets during said combining being placed contiguous with the liner of the single face sheet adjacent thereto and the medium of the other one of said single face sheets during said combining being placed contiguous to said additional liner, and additionally heating the combined single face sheets and the additional liner to raise the temperature of said second adhesive to at least said second setting temperature to set said second adhesive and to set further said first adhesive, the lower setting temperature of said second adhesive enabling said second adhesive to be set by said additional heating at a temperature which safeguards said first adhesive from overheating.

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