This invention relates to container board, and relates particularly to that type of board which has a particular use in the manufacture of shipping containers.

There are some types of merchandise which supply their own structural strength when packaged, for example canned goods. On the other hand, there are many kinds of merchandise which in themselves have no structural strength, for example breakfast food, and other types of merchandise which although possessing some structural strength may be seriously damaged by being subjected to excessive pressure, for example certain fruits. Such merchandise must be shipped in a type of container which itself furnishes the necessary stability and structural strength to be self-supporting or self-sustaining without any significant assistance from the contents of the container.

This invention relates particularly to a type of sheet material called corrugated board which is especially adapted for the construction of self-sustaining shipping containers. Corrugated board is usually constructed of an intermediate layer which is corrugated and two outer layers which are adhesively united to the interior corrugated layer. The interior layer before corrugating is usually called a corrugating medium, and after corrugating it is called a corrugated medium. The two outer layers are ordinarily described as liners.

The principal objects of the present invention are to provide a type of corrugated board or container board which has improved qualities in respect of its ability to resist crushing as well as tearing, and particularly when subjected to severe atmospheric conditions such as storage for long periods in a damp atmosphere, while at the same time satisfactorily retaining the property of being scored and then bent, or folded and such other properties as are desirable in a board for use in making boxes or shipping containers.

A further object of the invention is to provide a type of container board having the desirable properties indicated above, and an improved of making same, which can be efficiently and economically manufactured upon, or utilized by, equipment generally available, without the need for the design and construction of new and expensive machinery.

In the drawings accompanying this application,

Fig. 1 is a schematic drawing showing the various steps in the manufacture of the board from its component parts, in accordance with a selected embodiment of the invention;

Figs. 2A and 2B are schematic drawings of a selected embodiment of equipment which may be used to manufacture container board according to the method diagrammatically shown in Fig. 1; and

Fig. 3 is an enlargement of a portion of Fig. 2B.

I am aware that, because of the cheapness of sulphur (pound for pound it costs, at the present time, only about one-third as much as good quality paper fiber), attempts have been made to use it for improving the strength of paper. I am informed that these attempts have been unsuccessful, and that before my invention it was the opinion of persons skilled in the manufacture of paper and of products manufactured therefrom, that sulphur, because of its extreme brittleness or lack of cohesion when in its elemental form, was not suitable for impregnating corrugated board or any of the components thereof.

I have discovered that a container board having the improved properties above described can be produced by incorporating in the center layer of the corrugated board a certain percentage of elemental sulphur, i.e., essentially the element sulphur which is uncombined with other elements to form different chemical compounds. I have further discovered how to incorporate the sulphur into the body of the corrugating medium in such manner that the liners can be adequately and efficiently united with the sulphur-impregnated corrugated medium without making too great changes in the adhesive employed in the equipment for applying the adhesive or attaching the liners.

According to the preferred embodiment of my invention as set forth in Fig. 1, to the corrugating medium there is applied in any suitable manner a supply of elemental sulphur, preferably in molten form and in an amount not exceeding the weight of fiber in the sheet. At the time of such application or thereafter, the sulphurized sheet, while at a temperature above the melting point of sulphur, is rolled or ironed, the effect of which is to drive into the body of the sheet the sulphur which has been applied to the sheet and some of which sulphur may be carried on the surface of the sheet prior to the ironing operation. Depending upon the condition of the sulphur when it is applied to the sheet, the speed of travel of the sheet, and upon other conditions, it may be advisable to raise the temperature of the sheet.
considerably above that of the atmosphere before the sulphur is applied thereto.

When the sulphur is driven into the body of the sheet by the ironing operation serves to condition the fibers on the outer surface of the corrugating medium, perhaps by stripping them of sulphur, so that there will be restored to said fibers the property of compatibility with the adhesive, preferably an aqueous dispersion, which is later used in attaching the liner to the corrugating medium after the latter has been corrugated. Said property of compatibility may not be completely restored, but it is restored in sufficient degree so that an efficient bond can be obtained between the corrugating medium and the liner. By this method, I have succeeded in incorporating into the sheet an amount of sulphur equal to the weight of the fiber in the corrugating medium while still retaining the compatibility characteristics sufficiently.

If desired, sulphur may be applied to both sides of the sheet by immersion or otherwise before the ironing operation. However, in view of the compatibility requirement, there may be a disadvantage in applying the sulphur to both sides of the sheet. If applied to only one side of the sheet, and if the quantity of sulphur is limited and the conditions are otherwise adjusted so that the sulphur does not penetrate completely through the body of the sheet to the opposite surface, the said other surface of the sheet will obviously retain substantially its original compatibility characteristics.

The sheet is then corrugated by means of a set of corrugating rolls of conventional construction. During the corrugating operation, it appears to be advisable, if not necessary, to have the corrugating medium at a relatively high temperature. The obtaining of this temperature may be facilitated by effecting the corrugating operation promptly after the ironing operation or, if this is not feasible, by reheating the sheet before it enters the nip between the corrugating rolls. Also, it appears to be advantageous to apply moisture to one or both sides of the sheet before it enters the corrugating nip. This may be done by the use of conventional steam jets or sprays.

In any sheet-corrugating operation, the sheet, if too brittle because of dryness or any other reason, will tend to develop surface cracks or may be otherwise damaged due to the mechanical distortion. It would be expected that the presence of sulphur in the sheet would render the sheet so brittle that it could not be successfully corrugated. However, I have found that by properly distributing the sulphur in the sheet, by limiting the amount thereof which is contained in the sheet, and by effecting the corrugating operation at a sufficiently high temperature so that a considerable part of the sulphur is plasticized or liquefied, the sulphur content of the sheet instead of interfering with the corrugating operation, may serve as a lubricant for the fibers as the latter are distorted or forced to move relatively to each other during the corrugating step. Therefore, if I am correct in my analysis of what occurs in my improved process, it is advantageous that the temperature of the sheet during the corrugating step should be above the melting point of the sulphur.

After the sheet has been corrugated and preferably while it is still heated, liquid adhesive is applied to the outer surfaces of the crests of the corrugations which are exposed on one side of the sheet and one of the liners is then applied to and pressed against the corrugated medium for a sufficient length of time to enable the adhesive on the crests of the corrugations to effect an adequate bond between the liner and the corrugated medium.

The next step in the operation is to apply adhesive to the crests of the corrugations on the other side of the sheet and then apply the other liner to that side of the corrugated medium, sufficient pressure and time being used to effect a proper bond. The three-element, composite structure is then complete and ready for use as a finished container board.

It will be understood that, although the aforesaid steps of the process have been described as a continuous operation, it will be manifest that, if desired for any reason, the various steps above described may be conducted as separate operations. For example, the impregnating of the sheet with sulphur may be effected entirely separately or, if desired, in connection with the production of the paper on the paper-making machine. Also, the application of the liners to the corrugated medium may be effected as independent operations. However, there are some advantages in effecting the corrugation and the application of the liners as a continuous sequence of operations.

In Fig. 2A and 2B I have illustrated in somewhat more detail a preferred embodiment of the above-described process which has been successfully employed in producing container board in accordance with the invention. In Fig. 2A of the drawings, it will be seen that the corrugating medium, which in the present instance is a good quality of 9 point (.009 inch thick) kraft paper made from kraft pulp on a Fourdriner machine and weighing about 26 pounds per 1000 square feet, is preferably heated by conducting the same around a set of three steam-heated metal rolls 14, 15, and 16. The corrugating medium, heated preferably to a temperature of about 240°F. is then conducted around an idler roll 18 and a wrappor roll 19 which may be adjusted or moved down or by means not shown. The illustrated roll 19b is movable along the line 19c indicated in the drawings. The heated corrugating medium is then passed through the nip of a pair of metal rolls 17 and 18 about 10 inches in diameter.

The roll 17 is hollow and is heated by steam at sufficient pressure to maintain the surface of the roll at about 280°F., which is the temperature of a bath of sulphur 19 contained in a steam-heated tank 20 into which the lower surface of the roll 17 dips. As the applicator roll rotates it carries a supply of molten sulphur into the nip or crevice between the paper 10 and roll 17. For convenience, the roll 18 is also supplied with steam, although it does not appear necessary or perhaps even desirable to maintain the surface of the roll 18 at as high a temperature as the surface of the roll 17.

One at least of the metal rolls 17 and 18 is driven positively at a speed of about 320 feet per minute, and the roll 18 is preferably of such weight that the pressure in the nip between the rolls 17 and 18 is of the order of about 50 pounds per linear inch of web width. In some instances, it may be desirable to have a still higher pressure in order to reduce the amount of waste which is incorporated in the sheet, and, in such case, the nip pressure may be augmented by any conventional means such as adjustable springs.
of or hydraulic cylinders. One of the rolls preferably is suitably crowned in accordance with the
amount of pressure found most desirable.

It will be observed that the ironing rolls also serve as metering rolls so that the amount of
sulphur applied can be controlled by adjusting the pressure between said rolls. The position of
roll 18b can also be varied to regulate the amount of sulphur which is picked up by the sheet. As
has been pointed out, the weight of sulphur in the sheet should be so regulated that it amounts
to less than the weight of fiber in the sheet. Preferably, the amount of sulphur is not more
than 80 per cent of the weight of the fiber in the sheet. Small amounts of sulphur have a bene-
ficial effect but with the equipment which has been used it has not been possible to apply less
than about 5 pounds of sulphur per 1000 square feet of paper (one side). On the basis of a
paper base sheet weighing 26 pounds per 1000 square feet, 5 pounds of sulphur will amount to
about 20 per cent of the weight of the fiber. In order to facilitate the impregnating operation, it
may be found advantageous to add to the bath of molten sulphur a small percentage of suitable
fluidizing agent. The addition of about one per cent of terpene hydrate has been advantageously
used for this purpose under some conditions to increase the range of temperature in which the
sulphur is fluid.

The impregnated corrugating medium 10a is then conducted around an idler roll 21, and is either
directly fed into the corrugating equipment, or may be wound up into a roll for later use.

The sulphurized corrugating medium 10a is fed into the corrugating machine around a pair
of rolls 22 and 23 and led to the rolls between a set of steam sprays indicated at 24 for treat-
ing the upper side of the web, and another set of steam sprays 25 for treating the under side of
the web. Preferably, these steam sprays are obtained from a series of nozzles extending across
the sheet in conventional manner, and are sup-
plied with live steam at 5 to 15 pounds per square inch pressure. When the sheet leaves the
steam sprays, it may have a temperature of any-
where from 190° to 210° F. It first passes around
the upper corrugating roll 26 and then into the
corrugating nip between the said upper roll 26
and the lower driven corrugating roll 27.

In order to heat the sheet to the proper tem-
perature so that when the corrugating teeth do
their work, sufficient sulphur will be in a fluent
condition to enable the corrugations to be prop-
erly formed without damage to the sheet, the
rolls 26 and 27 are hollow and are heated by
live steam. Ordinarily, with corrugating rolls
having a diameter of from 9 to 12 inches, and
with a web speed of 300 feet per minute, a roll
temperature of about 300° F. to 355° F. will be
found to be adequate. A nip pressure of the
order of 50 pounds per linear inch of web width is
satisfactory.

After the corrugated medium comes out of the
nip between the corrugating rolls 26 and 27, it
continues to travel around the lower corrugat-
ing roll 27, and during the first part of such
additional travel the adhesive is applied to the
crests of the exposed corrugations by means of a
starch-hydraulic cylinder arrangement which includes a trough 28 for containing the adhesive, a pickup roll 29 which dips into the adhesive in the trough, and an applicator roll
30 which contacts the pickup roll 29 and trans-
ers the required amount of adhesive to the cor-
gruations. The adhesive may be any conven-
tional type of adhesive which ordinarily is an
aqueous dispersion of starch modified to the de-
sired extent in accordance with the usual prac-
tice, an aqueous dispersion of sodium silicate,
or other compatible adhesive.

The corrugated medium continues its travel around the lower corrugating roll 27, and, while
still supported thereby is applied to the outer face of the corrugating medium the top
liner 11. The top liner 11 may preferably be
heated in the usual manner by conducting it
around a set of three heated rolls 31, 32, and
33, and thence to a steel pressure roll 34 which
presses the liner tightly against the crests of
the outer face of the corrugating medium, which is
still supported on the corrugated roll 27. Be-
cause of such support considerable pressure may
be used in applying the top liner which, if it will
be observed, is applied to the sulphurized top
side of the corrugated medium. A pressure of
50 pounds per linear inch, or such pressure as is
customary in the industry for applying top
liners, may be employed. Any desired type or
weight of top liner may be employed. I have
successfully used a conventional top liner of
kraft-Fourdriner paper, having a weight of 47
pounds per 1000 square feet.

The web 10b, which includes the corrugated
medium and the top liner thereto applied, is
then conducted to equipment for applying the
bottom liner. This comprises a conventional
paste-applying mechanism consisting of the
usual paste trough 36, pickup roll 37, and ap-
pli-cator roll 38 which applies the usual adhe-
sive to the crests of the downwardly presented
corrugations on the bottom stretch of the web
10b. The web 10b is then passed through the
nip of a pair of smooth, low-pressure rolls 39
and 40 together with the bottom liner 12 which
is first heated by passing same around a set of
suitably heated rolls 41, 42, and 43. The roll
40 also may be heated, if desired, according to
conventional practice. After the composite board
10c, consisting of the three elements 10, 11, and
12 is delivered by the applicator rolls 39 and
40, it may be cut up into the proper sizes for
shipment or use.

It will be understood that in applying the bot-
tom liner 12 it may not be possible to use the
same amount of pressure as in applying the top
liner 11 for the reason that the corrugated me-
dium has no outside support to help it resist
the compressing force applied by the rolls, where-
as when applying the top liner the corrugations
may be supported by the lower corrugating roll.

A typical, commercially satisfactory container
board made in accordance with the above-de-
scribed process was of the following construction:

<table>
<thead>
<tr>
<th>Corrugating medium:</th>
<th>Base sheet:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fourdriner-kraft paper weighing 26 lbs. per 1000 square feet (uncorrugated)</td>
</tr>
<tr>
<td>Impregnation:</td>
<td>Sulphur, 50 per cent of the weight of the fiber or 15.6 lbs. per 1000 square feet (uncorrugated)</td>
</tr>
<tr>
<td>Corrugations:</td>
<td>Cuts in with a corrugating ratio of 1.4 (weight per 1000 square feet equal)</td>
</tr>
<tr>
<td></td>
<td>28+ (5.6) X 1.4 = 40.2 lbs.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top liner of Fourdriner-kraft paper</th>
<th>Bottom liner of Fourdriner-kraft paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>67 lbs. per 1000 sq. ft</td>
<td>78 lbs. per 1000 sq. ft</td>
</tr>
</tbody>
</table>

| Adhesive—starch (dry basis) | 5 do. |

Total weight of the finished contain-
ner board on the dry basis: 178 lbs. per 1000 sq. ft

A board made to the above specifications in
accordance with my improved process tested as follows:

Average of 5 tests:
Pop or Millen test—279
Flat crush test—50.48 lbs. per square inch
Caliper—174 inch

Weight of this board under test conditions was 155 pounds per 1000 square feet.

Container board made according to my invention has satisfactory shock resistance and maintains practically all of its mechanical strength under humid atmosphere tests, whereas under the same conditions ordinary container board was found to lose more than one-half of its mechanical strength.

This application is a continuation-in-part of my prior application Serial No. 81,183, filed on March 12, 1949, now abandoned.

I claim:
1. A bendable sheet which is usable as a material of which to construct self-supporting containers to the sulphur-free of merchandise, and which comprises an intermediate corrugated paper-fiber base sheet impregnated with elemental sulphur which serves to unite the fibers of the sheet, said sulphur being present in an amount not less than 5 pounds per 1000 square feet of the paper-fiber base sheet prior to corrugation but less than the weight of the fiber in said base sheet, the sulphur being located principally within the body of the sheet so that the exterior surfaces of the sheet are substantially free from sulphur, a paper face sheet positioned on each side of the corrugated base sheet, the inner surfaces of said face sheets being substantially free from sulphur, and a water dispersible adhesive uniting the inner surfaces of said face sheets to the sulphur-free fibers at the outer surfaces of the corrugated sheet.

2. A bendable sheet which is usable as a material of which to construct self-supporting containers for the shipment of merchandise, and which comprises an intermediate corrugated paper-fiber base sheet impregnated with elemental sulphur which serves to unite the fibers of the sheet, said sulphur being present in an amount not less than 5 pounds per 1000 square feet of the paper-fiber base sheet prior to corrugation but less than about 80 per cent of the weight of the fiber in said base sheet, the sulphur being located principally within the body of the sheet so that the exterior surfaces of the paper fibers on the outer surfaces of the sheet are substantially free from sulphur, a paper face sheet positioned on each side of the corrugated base sheet, the inner surfaces of said face sheets being substantially free from sulphur, and a water dispersible adhesive uniting the inner surfaces of said face sheets to the fibers at the outer surfaces of the corrugated sheet.

3. The improved process of making a bendable sheet usable as a material of which to construct self-supporting containers for the shipment of merchandise and having an intermediate corrugated sheet secured between two spaced face sheets, which process comprises contacting a paper fiber web with a supply of fluid elemental sulphur and thereby causing said sheet to pick up a limited amount of sulphur, ironing the sulphur into the sheet while the sulphur is in a heated fluid condition so that the exterior surfaces of the sheet to which the sulphur was applied is rendered substantially free from sulphur, then corrugating the sheet at an elevated temperature so that at least a part of the sulphur in the body of the sheet is in a liquid condition and serves as a lubricant for the fibers of the sheet during the formation of the corrugations therein, then subsequently applying a water-dispersible adhesive to the outer crests of the corrugations on each side of the corrugated sheet and applying face sheets having surfaces which are substantially sulphur free to the opposite sides of said corrugated sheet.

4. The improved process of making a bendable sheet usable as a material of which to construct self-supporting containers for the shipment of merchandise and having an intermediate corrugated sheet secured between two spaced face sheets, which process comprises contacting only one side of a paper fiber web with a supply of fluid, molten sulphur and thereby causing said sheet to pick up an amount of molten sulphur not greater than the weight of the fiber in the sheet, applying heat and pressure maintained at a temperature above the melting point of sulphur and corrugating the sheet at a high enough temperature so that at least a part of the sulphur in the body of the sheet is in a liquid condition and serves as a lubricant for the fibers of the sheet during the formation of the corrugations therein, then subsequently applying a water-dispersible adhesive to the outer surfaces of the crests of the corrugations on each side of the corrugated sheet and applying face sheets having surfaces which are substantially sulphur free to the opposite sides of said corrugated sheet.

5. A sheet which comprises a corrugated paper-fiber base sheet coated with elemental sulphur which serves to unite the fibers of the sheet, said sulphur being present in the amount of not less than 5 pounds per thousand square feet of the paper-fiber base sheet prior to corrugation but less than the weight of the fiber in said base sheet, the sulphur being located principally within the body of the sheet so that the exterior surfaces of the paper-fibers on the outer surfaces of the sheet are substantially free from sulphur, a paper face sheet positioned on the coated side of the corrugated base, the inner surface of said face sheet being substantially free from sulphur, and an adhesive uniting the fibers at the inner surface of said face-sheet to the fibers at the outer surface of the corrugated sheet.

6. The improved process of making sheet material which includes a corrugated sheet which is secured at least one face sheet, which process comprises contacting at least one side of a paper fiber web with a supply of fluid elemental sulphur and thereby causing said sheet to pick up a limited amount of sulphur, ironing the sulphur into the sheet while the sulphur is in a heated fluid condition so that the exterior surfaces of the sheet to which the sulphur was applied is rendered substantially free from sulphur, then corrugating the sheet at an elevated temperature so that at least a part of the sulphur in the body of the sheet is in a liquid condition and serves as a lubricant for the fibers of the sheet during the formation of the corrugations therein, then subsequently applying a water-dispersible adhesive to the outer
crests of the corrugations on a side of the cor-
rugated sheet to which sulphur has been applied
and applying a face sheet having a surface
which is substantially sulphur-free to the side
of said corrugated sheet to which the water-dis-
persible adhesive has been applied.

ROBERT C. McKEE.

REFERENCES CITED
The following references are of record in the
file of this patent:

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,497,809</td>
<td>Sutherland</td>
<td>June 17, 1924</td>
</tr>
<tr>
<td>1,512,729</td>
<td>Webb</td>
<td>Oct. 21, 1924</td>
</tr>
<tr>
<td>1,519,281</td>
<td>Wandel</td>
<td>Dec. 16, 1924</td>
</tr>
<tr>
<td>1,639,680</td>
<td>Ellis</td>
<td>Jan. 5, 1932</td>
</tr>
<tr>
<td>2,331,951</td>
<td>Wright et al.</td>
<td>Oct. 19, 1943</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>374,298</td>
<td>Great Britain</td>
<td>June 9, 1932</td>
</tr>
<tr>
<td>373,786</td>
<td>Italy</td>
<td>Aug. 3, 1939</td>
</tr>
</tbody>
</table>