The design of a plant for the production of insulation board from agricultural wastes and cost data on this process

Charles Earl Hartford

Iowa State College

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THE DESIGN OF A PLANT FOR THE PRODUCTION
OF INSULATION BOARD FROM AGRICULTURAL WASTES
AND COST DATA ON THIS PROCESS

By

Charles Earl Hartford

A Thesis Submitted to the Graduate Faculty
for the Degree
of
DOCTOR OF PHILOSOPHY
Major Subject Chemical Engineering

Approved:

Signature was redacted for privacy.

In Charge of Major

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

1931
ACKNOWLEDGMENT

The writer wishes to gratefully acknowledge the help of Dr. O. R. Sweeney. Dr. Sweeney's counsel and guidance were equally invaluable on the small scale work at Ames and later when the process was applied commercially at Dubuque.

The writer also wishes to acknowledge his indebtedness to Dr. R. W. Richardson, fellow worker on the small scale process, Mr. Laurin Sabatke, Mr. George Seidel, all the staff members and research workers of the Chemical Engineering Department, and to his associates in the Maizewood Products Corporation, all of whom contributed a great deal to this work.
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A. Development of Insulation Board Industry.

Synthetic lumber in the form of various types of wall board has been on the market for many years. Examples of this class of material are, Upson Board, Beaver Board, and Rocklath, the latter consisting of a gypsum plaster core covered on both sides by paper. However, about fifteen years ago a new type of board, known as "insulation board" made its appearance. This board was made 1/2 inch thick instead of the usual 3/16 or 1/4 inch of the wall boards. The new type of board claimed as its advantages, insulating value as well as sufficient structural strength to give rigidity and strength to structures where it was used. It was early found to be an excellent material for a plaster base, the plaster adhering firmly and showing less tendency to crack than when applied to wood lath. The greater ease of application was also an important factor in its favor. The uses of the board as a plaster base and in the place of wood sheathing grew rapidly and many new uses were found such as for factory roofs to prevent moisture in the air from condensing and dripping from the ceilings, refrigerator lining, and for the building of many small, lightly built structures.

The increasing popularity of the board is attested to by the fact that since 1915 the number of factories making it has increased from one, having a daily output of 100,000 square feet, to twelve, having a combined daily output of 2,750,000 square feet.
B. Use of Agricultural Wastes in Manufacture of Insulation Board.

Work done in the Chemical Engineering Department at Iowa State College under the direction of Dr. O. R. Sweeney indicated that a satisfactory insulation board could be made from cornstalks, straw, milkweeds, artichoke tops, tobacco stems, and other agricultural waste products.

Straw is now being successfully used as a raw material in the manufacture of an insulation board made at St. Joseph, Missouri, while cornstalks are used at Dubuque, Iowa.
HISTORICAL

A. Review of Literature on Wall Board and Insulation Board.

Probably the first use of a wall board was made by the Japanese in 600 A.D. (1) This wall board was simply a heavy paper and was used in the walls of houses. In 1772 a process was patented in England for making a wall board by gluing a number of sheets of paper together, drying in an oven, and then dipping in oil. (2) This process is typical of the early processes used to make wall board, that is, individual sheets of paper were cemented together with various materials such as glue, sodium silicate, asphalt, and tar, until the desired thickness was attained. The board was then dried, and sometimes treated with oil.

In 1890 the process of forming boards by means of several cylinders was introduced. Each cylinder formed one thickness of the board and added it to the layer formed by the preceding cylinder. In this way it was possible to build up a board of two to seven layers thickness without introducing a binding material between the layers. Numerous boards of this type were put on the market, of which "Upson Board", "Beaver Board", and "Cornell Board" are examples.

A variation of this type of board is one made by applying a sheet of heavy paper to each side of a core of a gypsum mixture containing an adhesive material. The advantages of this board are greater strength and a higher degree of fire proofing. (3)

Boards of the class of those named above are made in thicknesses ranging from 1/4 inch to 3/8 inch. They are used principally in building
partitions, for lining attics, and as a plaster base.

About 1910 architects began to stress the advantages of insulating homes against heat and cold, and several materials came on the market for this purpose. An example of these is "Insulex", a gypsum mixture which is poured into the space between the sheathing and lath of a house, and which has the property of setting into a light, porous highly insulating material. (4) Flax-Linum is a soft felted mat made from refined flax straw quilted between sheets of heavy paper. This material is placed between the studding of a house. There are other materials of this class on the market, such as Lin-o-Felt and Balsam Wool. (5) All of these materials are excellent insulators, their chief drawback being the fact that since they do not take the place of any material ordinarily used in the construction of the house, they add an extra item of cost.

In 1916 a board was introduced which combined high insulation value with sufficient structural strength so that it could replace wood sheathing or lath and thus not add another item of cost to the structure. The new type of insulating material met with such great success that in sixteen years its total daily production increased to 2,750,000 square feet. The more important boards on the market now are Celotex (6), made from bagasse; Insulite, made from newsprint pulp screenings and spruce; Masonite (7), which utilizes pine edgings and waste; Nu-Wood (8), from saw mill waste; Maftex (9), from spent licorice root; Maizewood (10), from cornstalks; Insoboard (11), from straw; Vascane (12), from sugar cane; Firtex (13), Arborite (14), Weatherwood (15), and Temlock (16), from wood waste. The process used in making all of these boards consists roughly of grinding the raw material with water; adding water proofing
material; forming into a sheet; drying; and trimming. In some of the processes the pulp is cooked before the final refining treatment; in others the cooking treatment is omitted. Forming machines are usually specially designed for the particular process, and vary from cylinder type machines to machines in which an endless wire belt moves over a suction box. Pressing in some cases is accomplished by rolls, in others by platens. Large enclosed dryers through which the boards are conveyed by rollers are used in a majority of processes, but some use hydraulic presses with heated platens.

B. Resume of Work Done by Iowa State College - Bureau of Standards.

About twelve years ago Dr. O. R. Sweeney, Head of the Chemical Engineering Department of Iowa State College, started a line of systematic research to discover commercial uses for agricultural wastes, especially cornstalks and corn cobs. The work was principally carried on as research problems for senior undergraduate and for graduate students. Most of the work done was reported in theses which are available at the Iowa State College at Ames. Early in the work it was found that a good grade board could be made from cornstalks. John Mudge (17) reported work on a board made from corn cobs. Mina (18) investigated various chemical cooks of corn stalks in the production of a board. Kozak (19) experimented with mixtures of flax, cottonwood fibres and peat with cornstalks. Schneider (20) worked on producing a board from uncooked pulp, the use of the rod mill as a refining agent, and the effect of different cooking agents. Seidel (21) worked on uncooked pulp insulating boards, gypsum-cornstalk boards, on fireproofing, and on water proofing.
After nine years of small scale laboratory work it became advisable to do some experimental work with the process of cornstalk insulation board manufacture on a larger scale. Accordingly, with funds secured through the cooperation of the Iowa Engineering Experiment Station and the United States Bureau of Standards, a semi-commercial factory for the manufacture of cornstalk insulation board was built in the Iowa State College Chemical Engineering laboratory. Work in this plant was carried on by a staff employed by the Bureau of Standards, and by men hired by the Iowa Engineering Experiment Station. Work was first done on uncooked pulp, then on various kinds of cooked pulp. A great variety of refining machines was tried. A new type of forming machine was developed. The work done in this plant is reported in detail by a bulletin of the Iowa Engineering Experiment Station. (22)

At the time of the beginning of the commercial scale work at Dubuque, which is reported in this thesis, the process as worked out in the semi-commercial plant was as follows: Bales of cornstalks were broken open and the stalks fed into a stationary vertical digester where they were cooked for two hours at forty pounds pressure with eight times their weight of water. The capacity of the digester was about two bales, weighing about sixty pounds apiece, and 960 pounds of water. The cooked stalks were then run through a rod mill, then to a tank where rosin size was added. The stock in the chest was circulated for about fifteen minutes through a small Claflin refiner. Alum solution was added until a pH of 4.6 was reached. The pulp was then formed into a mat on a special type forming machine, pressed in a Downingtown roll press, dried in a Coe drier, and trimmed by means of a circular saw.
C. Commercial Scale Work.

On November 12, 1929 the Maizewood Products Corporation factory at Dubuque, Iowa, started continuous operation on the manufacture of insulation board from cornstalks. Continuous production on a commercial scale has been carried on from this date until the present time with the exception of two or three short periods. Although a regular production schedule has been maintained, a great deal of experimental work has been carried on with a view to reducing production costs and improving the product. The experimental work, which will be reported in detail in this thesis, was undertaken in close cooperation with small scale work continually being carried on in the laboratory at Iowa State College. When a change in process was contemplated it was first tried out in the semi-commercial plant at Iowa State College and then, if the results warranted, it was given a thorough trial in the Dubuque factory. The cooked pulp process as finally developed at Dubuque for the production of structural insulation board is as follows: Baling wire is removed from the bales of stalks which are then put through a bale breaking machine which tears them apart sufficiently so that any tramp iron in the bales may be removed by a magnetic separator. From the magnetic separator the stalks pass through a cutting machine which reduces the stalks to particles ranging from fine chaff to pieces two inches long. This material is then blown into a storage bin by means of a fan. The storage bins discharge the cut material into rotary digesters where it is cooked for about 1-1/2 hours at a temperature of 316 degrees Fahrenheit. The cooked material is dumped into a pit from whence it is washed to a plunger pump by means
of drain water from the second washer. The pump delivers the pulp to a revolving cylinder type washer which discharges the pulp to a Smalley ensilage cutter. From this point the pulp goes through a second washer into a stock chest where rosin size is added. It is then pumped through a Claflin/refiner and Jordan refiner. As the stock discharges from the Jordan, alum is added and the pulp goes to a stock chest and then to the forming machine, a continuous type platen press, Coe continuous dryer, and then through the cutting and trimming saws.
A great deal of related work is being carried on which has a direct bearing on the process of producing insulation board from agricultural wastes.

A. Harvesting of Stalks.

1. Work has been carried on for a period of years in the Agricultural Engineering Department at Iowa State College to improve methods of harvesting stalks and to design machines to do this work. The best machine worked out thus far consists of a cutter bar, modified hay rake, and hay baler all built into one machine and pulled through the field by a tractor. The cutter bar cuts two rows of stalks at a time. The rake rakes the stalks up into a hay baler. The bales are dropped off onto the ground to be collected later. Experimental work indicated that stalks could be harvested with this machine at a cost of $2.40 per ton. (23)

2. L. W. Flager (24) who has charge of raw material purchasing for the Maizewood Products Corporation reports that harvesting costs were about $4.40 per ton for the 1930-31 season. Most of the stalks harvested under Flager's supervision were gathered in the following manner: Stalks were broken down by dragging rails across the rows by means of teams of horses. The broken stalks were then raked to a central point by means of a "bull rake" and baled. When the field is soft and muddy the method of breaking the stalks down with the rail is not satisfactory because the stalks are apt to be pulled out by the roots, bringing large quantities of dirt with them. In the spring of 1930 modified "corn shavers" were used successfully by Flager for cutting the stalks. A new cornstalk harvesting machine
designed by the John Deere Company with the cooperation of Mr. Plager was given its first trial during May of 1931. The harvesting cost with the new machine was $3.37 per ton. The new machine cuts two rows at a time, puts the stalks through a threshing machine cylinder and discharges the roughly broken stalks into a wagon. This results in cleaner stalks and better baling.

B. Chemical Work

A great deal of work is being continually carried on at Iowa State College on problems of a chemical nature dealing with the utilization of various parts of the cornstalk. Certain of this work has a direct bearing on the insulation board process because of the possibility of its leading to the development of valuable by-products. Work done by Naffziger (25) indicates that the recovery of an adhesive from the cook liquors is feasible. Bruins (26) and others have worked on furfural. Naffziger (27) has utilized the pith of the cornstalk to make an extremely light weight, highly insulating material. Reese (28) reports work on the production of a hard, dense, pressed board suitable for paneling desk tops and similar work. Hartford (29) has produced a material having properties similar to those of vulcanized fibre, from cornstalks, corncobs, and various parts of cornstalks.
INVESTIGATIONAL WORK

A. Development of Process.

1. Raw Materials.

Large scale work with various kinds of cornstalks, straw, and paper has been carried on at Dubuque. Richardson [30] reports semi-commercial work on milkweeds, artichoke tops, and flax straw.

a. Cornstalks.

1'. Field Corn Cornstalks.

Field corn cornstalks have proven in factory operation to be the most satisfactory raw material from the standpoint of ease of processing. This material gives a satisfactory board using a cooking time of one hour and fifty-five minutes. Table I shows the yield obtained using one hundred percent field corn cornstalks over a period of two weeks. In this table "yield per digester" refers to the quantity of finished board obtained per digester load of field dry raw material.

2'. Broom Corn Cornstalks.

Broom corn cornstalks require more drastic cooking than the field corn cornstalks to give a board of equal strength, and when this strength is reached the board is heavier than the board from field corn cornstalks. It is also apt to contain more coarse particles of tough brittle outer fibres which have not been properly refined. It was found that it was necessary to cook one hundred percent broom corn cornstalks three and one-half hours as compared to one hour and fifty-five minutes for field corn cornstalks. Table II shows yields obtained over a period of twelve weeks with various mixtures of broom corn cornstalks and field corn cornstalks. The average yield of 2,697 square feet per digester compares to an average yield of
TABLE I
Yield Using Field Corn Cornstalks
as Raw Material

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Finished Board Produced - Square Feet</th>
<th>Weight of Board Pounds Per Square Feet</th>
<th>Yield Per Digester Square Feet</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>144,163</td>
<td>0.562</td>
<td>4,650</td>
<td>2,520</td>
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<tr>
<td>2</td>
<td>143,000</td>
<td>0.608</td>
<td>4,760</td>
<td>2,690</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>4,705</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,755</td>
</tr>
</tbody>
</table>

TABLE II
Yield Using Various Mixtures of Field and Broom Corn Cornstalks as Raw Material

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Finished Board Produced - Square Feet</th>
<th>Weight of Board Pounds Per Square Feet</th>
<th>Percent Broom Corn Cornstalks</th>
<th>Yield Per Digester Square Feet</th>
<th>Pounds</th>
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<tr>
<td>1</td>
<td>96,964</td>
<td>0.656</td>
<td>7</td>
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<td>2</td>
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<tr>
<td>3</td>
<td>90,868</td>
<td>0.612</td>
<td>28</td>
<td>4,540</td>
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<td>26</td>
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<td>11</td>
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<td>0.708</td>
<td>15</td>
<td>3,040</td>
<td>2,150</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>4,135</td>
<td>2,697</td>
</tr>
</tbody>
</table>
2,755 square feet per digester for the one hundred percent field corn cornstalks. The average weight for a 7/16 inch thick one hundred percent broom corn cornstalk board having a modulus of rupture of 400 - 475 lbs. per square inch is 0.687 lbs. per square foot, which compares to 0.630 lbs. per square foot for a one hundred percent field corn cornstalk board.

3'. Sweet Corn Cornstalks.

Tests at Ames have shown that sweet corn cornstalks also require a longer cooking period than field corn cornstalks. After being given the proper cooking, however, they process practically the same way.

4'. Pop Corn Cornstalks.

A test run of 4,000 square feet of board using one hundred percent pop corn cornstalks was made in the spring of 1930. It was found that giving the pulp the same treatment as that given field corn cornstalks yielded a board which was satisfactory but not quite as strong for a given weight as the field corn cornstalk board.

b. Straw.

Straw has not been used alone as a raw material in the Dubuque factory. Richardson (30) reports that on small scale runs at Ames it acted almost exactly like cornstalks both as to kind of treatment required and quality of board obtained. Mixtures of straw with field corn cornstalks up to fifty percent have been run on a commercial scale at Dubuque. The process was not changed from that used for field corn cornstalks. The board obtained showed practically identical tests with the field corn cornstalk board. It was a trifle lighter in color and had just a few more coarse particles on
the surface. No difference could be detected in the behavior of oat and wheat straw. The yield obtained with the straw-stalk mixture as shown by Table III was about ten percent higher than that obtained with one hundred percent field cornstalks.

c. Other Raw Materials.

1'. Paper

a'. Newsprint

Richardson (30) reports that the addition of newsprint in amounts ranging from four to twenty-five percent improves the appearance and strength of the board somewhat, but tends to make the pulp somewhat "slower". The terms "slow" and "free" are used to indicate the manner in which water drains out of pulp. A "slow" pulp retains its water, while water drains rapidly from a "free" pulp. Work at Dubuque on the use of newsprint is reported later in this thesis.

b'. Sweeney (31) reports that corrugated paper gave satisfactory results when blended with cornstalk pulp up to twenty-five percent paper. The corrugated paper produced a slightly darker colored board than the same percentage of newspaper.

c'. Richardson (30) reports that satisfactory boards have been produced from milkweeds, artichoke tops, and flax straw as well as from cornstalks and straw.

2. Processing Operations.

a. Material Handling.

1'. Raw Material.

a'. Tractor (or Team) and Wagon.

A team and wagons are used at Dubuque for unloading and
<table>
<thead>
<tr>
<th>Run No.</th>
<th>Finished Board Produced - Square Feet</th>
<th>Weight of Board Pounds Per Square Feet</th>
<th>Yield Per Digester Square Feet</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>225,271</td>
<td>0.669</td>
<td>4.800</td>
<td>3,210</td>
</tr>
<tr>
<td>2</td>
<td>135,784</td>
<td>0.662</td>
<td>4.610</td>
<td>2,960</td>
</tr>
<tr>
<td>3</td>
<td>194,148</td>
<td>0.630</td>
<td>4.740</td>
<td>2,985</td>
</tr>
<tr>
<td>4</td>
<td>126,342</td>
<td>0.640</td>
<td>4.670</td>
<td>3,000</td>
</tr>
<tr>
<td>5</td>
<td>154,136</td>
<td>0.665</td>
<td>4.170</td>
<td>2,780</td>
</tr>
<tr>
<td>6</td>
<td>80,884</td>
<td>0.717</td>
<td>4.250</td>
<td>3,050</td>
</tr>
<tr>
<td>7</td>
<td>171,296</td>
<td>0.737</td>
<td>4.280</td>
<td>3,160</td>
</tr>
<tr>
<td>8</td>
<td>172,220</td>
<td>0.774</td>
<td>4.100</td>
<td>3,170</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td></td>
<td><strong>4.452</strong></td>
<td><strong>3,039</strong></td>
</tr>
</tbody>
</table>
storing raw materials and for transporting it from the storage piles to the shredder house. During the time when stalks are being brought in one car is always "spotted" in front of the shredder house and unloaded directly onto the shredder conveyor belt. When stalks are being brought in, as many teams are used as are needed to unload the cars promptly.

For hauling from the storage piles to the shredder house during the remainder of the year, one team and two wagons are used. Two men and the teamster load one wagon at the pile. As soon as it is loaded the teamster drives to the shredder house while the two men at the pile load the second wagon. At the shredder house the teamster leaves his wagon and returns to the pile for the next one. This system has the advantage of flexibility which is important, as the point from which raw material is being transferred is continually changing as the storage piles are torn down. Also its initial cost is low.

b'. Conveyor System.

A conveyor system such as shown in Fig. I might be used for handling the raw material. Bales are removed from the face of the row of cornstalk piles and dropped onto any section "a", "b", "c" of the conveyor system. These sections which are mounted on wheels and run forward on tracks as the piles are torn down, feed the conveyor "d", which feeds the bale breaker. The initial cost of this system would be much higher than that of the team and wagon system, but it reduces the labor required by about 0.72 man hours per thousand square feet of board produced.

c'. Stacking Machine.

The bale stacker used at Dubuque is simply a chain slat
conveyor running in a trough which may be raised and lowered. The trough and conveyor are mounted on a heavy truck. It has capacity to elevate six bales per minute to any height up to thirty feet, and is operated by a five horse power gasoline engine.

2'. Material in Process.

a'. Belt Conveyor.

Belt conveyors are used at Dubuque for conveying the raw material into the first cutting machine and for carrying the material from the machine into a fan.

b'. Fans.

A Clarke Type SR No. 70 exhaust fan is used to blow material from the first cutter to storage bins above the cookers. The material which the fan handles is dry particles of stalks and straw ranging in length from fine chaff to pieces eight or nine inches long. As long as the material is dry and not too dirty, the fan handles it satisfactorily. Damp material is apt to plug the fan or the pipe line. A small amount of the fine particles is lost through the vent which it is necessary to leave in the top of each bin. The fan requires twelve K.W.H. per ton of board made.

c'. Pumps.

Fluever type pumps having a twelve inch inlet, an eighteen inch outlet, and an eighteen inch stroke are used to pump pulp from pits under the cookers to the first washer. The pulp contains pieces up to two or three inches long. The pumps lift this pulp fifty feet at a rate as high as 4,000 lbs. of bone dry pulp per hour, and requires nine K.W.H. per ton of board made. They give very little trouble in operation.

Centrifugal trash pumps are used to pump pulp which has been through
the wet cutter, to the first Claflin, and from the last refining machine to the forming machine. Care must be taken to see that the pump parts fit closely so pulp cannot leak in back of the impeller and thus plug the pump. The pump should be thoroughly flushed out at regular intervals. If these precautions are taken, this type of pump will give satisfactory service. The power requirements are nine K.W.H. per ton of board for the pump handling the coarser stock, and four and one-half K.W.H. for the pump handling the stock for the forming machine.

3'. Finished Board.

Finished boards are piled on skid platforms, which are then wheeled to storage space or cars for shipment by means of a manually operated lift truck. One man can handle 5,000 lbs. of board by means of the skid and lift truck.

It is a good policy to always have a small quantity of eight feet by twenty feet boards on hand which may be used for cutting into odd sized pieces on orders which are too small to warrant a special run. These large boards can be piled four or five feet high alongside the conveyor table which feeds the saws. Since the quantity to be handled is small, they can be removed from and replaced on the conveyor manually with the aid of an inclined roller table.

b. Cutting, Shredding, and Refining Operations.

1'. Williams Dry Shredder.

This machine is simply a swing hammer mill with a grate of iron bars through which the stalks and straw are beaten by the hammers. A belt conveyor feeds the machine. It is necessary to break the bales into pieces six or eight inches thick to secure satisfactory operation. The fineness
of the product secured is regulated by the number of bars left in the grate under the hammers. When delivering a product ranging from chaff to pieces eight or nine inches long the machine has a capacity of about four tons of field dry material per hour. This is equivalent to a little less than two tons of board per hour. The power consumption is twenty six K.W.H. per ton of board when used alone, and sixteen K.W.H. when used following a bale breaker and cutter. Because of the rapid wear of the hammers, the upkeep cost on this machine is high. One set of hammers costing $272.00 are serviceable for the production of only six hundred tons of board. It is important to replace dull hammers as they decrease the capacity of the machine greatly and give an unsatisfactory material. Except for the hammers, the machine is reasonably free from wear, being quite rugged and sturdy.

2'. Smalley Dry Cutter.

The Smalley cutter cuts the material in much the same way as a lawn mower. It is a low priced machine, costing only $350.00 compared to $2,000.00 for the Williams shredder. It can be adjusted to give either a 1/4, 1/2, 3/4, or 1-1/2 inch cut. When set to give a 1/2 inch cut it has a capacity for about three and three-quarter tons of field dry stalks, or one and three-quarter tons of board per hour. Its power consumption is fifteen K.W.H. per ton of board. It is necessary with this machine, as with the Williams shredder, to break the bales into six or eight inch thicknesses before feeding them. Stalks which are fed into the machine directly at right angles to the axis of the cutting knives are cut quite accurately to the length for which the machine is set. However, the pieces which go into the knives parallel to the axis will be split but not cut into short lengths. The quality of the finished board is the same as that secured with the
shredder. The Smalley cutter, being a farm machine, is not especially sturdy. Work with it at Dubuque indicated that it is not strong enough to stand up in continuous operation as a cornstalk cutter.

iv. Taylor-Stiles Rag Cutter.

This machine consists of a heavy cast steel cylinder in which are set three straight knives. A belt conveyor feeds the cutting cylinder, with the help of a top feed apron which rides on the material being fed. Experience at Dubuque indicates that the rag cutter does not do as good a cutting job as the Smalley. It is, however, a very strong, sturdy machine and would be entirely satisfactory for fairly coarse cutting. The principal objection to it at Dubuque has been that many of the stalks are left only partially cut through. It does not seem to give a uniform, clean, short cut. The knives should be sharpened every twelve hours. The power consumption on material which has first been through the bale breaker is about twenty-eight K.H.P. per ton of board. Its capacity is about one and one-half tons of board per hour.

iv. Fox Bale Breaker and Cutter.

The Fox bale breaker consists of a heavy threshing machine cylinder fed by a chain conveyor. The conveyor is fitted with steel prongs which retard the bale after it reaches the cylinder and prevent its being carried through too rapidly and thus not being thoroughly broken open. The machine handles whole bales satisfactorily. The Fox cutter consists of a heavy rotating cutter head which carries four knives curved like lawn mower knives. These knives shear against three successive bed knives in making a revolution. The entire discharge side of the cutter head is enclosed by a perforated
screen. This feature does away with the large pieces which go through most cutters by passing through parallel to the bed knives and being split rather than cut in short lengths. A trial run on a carload of stalks indicated that the Fox bale breaker and cutter had a capacity for about three tons of field dry stalks, or 3,700 lbs. of board per hour with a two inch screen on the cutter. The power consumption is about sixteen K.W. per ton of board for both machines. The cost of the bale breaker is $800.00, and the cutter is $750.00. The fly knives should be sharpened every eight hours, and the bed knives every forty-eight hours.

5'. Smalley Wet Cutter.

The Smalley which is used for cutting pulp as it comes from the washer following the digester is the same kind of machine as the dry cutter. A smaller machine is required, however, and the power consumption is much lower, being only three K.W. per ton of board produced. The cutter does not do a great deal of work on the pulp, just cutting enough of the long pieces which passed through the first cutter to let the pulp go through the Claflin and Jordan without trouble. A twenty-six inch wide cutter will handle forty-eight tons of board per twenty-four hours easily. It is necessary to sharpen the knives of the wet cutter once every two days.

6'. Williams Wet Shredder.

This machine is a swing hammer mill. The pulp is fed in at the top of the hammers and is beaten through a perforated plate at the bottom. In the process for making structural insulation board it was found that the Smalley cutter did the work required at this point with a power consumption of three K.W. per ton of board compared to one hundred and twenty-seven K.W. for the shredder. Moreover the capacity of the shredder was only
42,000 lbs. of board per twenty-four hours, or about 67,700 square feet of structural insulation board. This capacity was attained with a plate having two inch perforations. With larger perforations the capacity could be increased, but difficulty was experienced in getting the pulp through the following refining machines. Swing hammer mill hammers require replacement about once a year at a cost of $454.00. The rods on which the hammers are swung must be replaced about once every six months at a cost of $17.00.

In the process of making a light weight refrigerator board at Dubuque it was found that the swing hammer mill gave the uncooked pulp the hydration needed to make it handle successfully in the Claflin and Jordan. The use of the Smalley cutter on this pulp left it so free that it would float on the surface in the stock chests, making pumping difficult, and lodge in elbows and corners of pipe lines, causing plugging. However, in designing a plant to produce this class of board a rod mill would be used which would do away with any need for a swing hammer mill. It seems, therefore, from the work done thus far that the swing hammer mill has no place in the process of manufacturing insulation board from cornstalks.

7'. Claflin.

The Claflin refiner consists of a conical shaped plug on which are mounted dull knives, spaced about an inch apart, which rotate inside a shell carrying knives similar to those in the plug. The clearance between the shell and plug is adjusted by means of a hand wheel. Pulp is fed into the small end of the shell and is forced by centrifugal force to travel between the shell and plug, discharging at the large end of the shell. It serves to cut the pulp to short fibres and to separate the bundles into individual fibres,
but does not hydrate the pulp to any great extent. Pulp prepared with no refinement after that given it by the Claflin is "free" and produces a board of low strength. Table IV shows results obtained in a series of experiments at Dubuque which were run to determine whether or not a second Claflin could be substituted for the Jordan as a final refining engine. It will be noticed that most of the trials gave boards having a modulus of rupture below 400, the lower limit which is arbitrarily set for standard building board.

Increasing the speed of the second Claflin from 443 to 486 r.p.m. did not affect the results materially. The capacity of the Claflin depends on the nature of the pulp fed to it and on the closeness of the plug setting. A No. 1 Claflin has a capacity of about 48,000 lbs. of board per twenty-four hours when set to reduce steam digested pulp, which has been cut to pieces four inches and less in length, to fibres two inches and less in length. Unless the pulp fed to the Claflin is fairly well hydrated, trouble will be experienced with backing at the inlet. This machine uses fifty-seven K.W.H. per ton of board produced. For classes of board in which strength is not important, the Claflin is entirely satisfactory. It produces a pulp short enough and free enough to form nicely on the machine, and its power consumption is low, compared with that of the Jordan. It is necessary to replace Claflin shell and plug linings about once a year at a cost of approximately $230.00.

8" Jordan.

The Jordan refiner is very similar to the Claflin just described. The principal difference is that the Jordan plug and shell slope at a much more gradual angle than do the Claflin shell and plug. This has the effect of passing the pulp through the machine at a slower rate, permitting more work to be done on the fibres. It accomplishes most of the hydration of the
<table>
<thead>
<tr>
<th>Run No.</th>
<th>Preparation of Pulp</th>
<th>Board Tests</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Strength</td>
<td>Weight</td>
</tr>
<tr>
<td>1</td>
<td>Swing hammer mill; 1 hr. 50 min. cook; first Claflin speed 443 r.p.m., second Claflin speed 443 r.p.m.</td>
<td>403</td>
<td>716</td>
</tr>
<tr>
<td>2</td>
<td>Swing hammer mill; 1 hr. 55 min. cook; Claflin speeds, 443-443 r.p.m.</td>
<td>328</td>
<td>680</td>
</tr>
<tr>
<td>3</td>
<td>Swing hammer mill; 2 hr. cook; Claflin speeds, 443-443 r.p.m.</td>
<td>253</td>
<td>620</td>
</tr>
<tr>
<td>4</td>
<td>Swing hammer mill; 2 hr. 10 min. cook; Claflin speeds, 443-443 r.p.m.</td>
<td>302</td>
<td>640</td>
</tr>
<tr>
<td>5</td>
<td>Swing hammer mill; 2 hr. 10 min. cook; Claflin speeds, 443-443 r.p.m.</td>
<td>362</td>
<td>680</td>
</tr>
<tr>
<td>6</td>
<td>Swing hammer mill; 2 hr. 20 min. cook; Claflin speeds, 443-443 r.p.m.</td>
<td>412</td>
<td>810</td>
</tr>
<tr>
<td>7</td>
<td>Swing hammer mill; 2 hr. 15 min. cook; Claflin speeds, 443-443 r.p.m.</td>
<td>323</td>
<td>750</td>
</tr>
</tbody>
</table>
### Table IV Con't.

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Preparation of Pulp</th>
<th>Strength</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Swing hammer mill; 2 hr. 15 min. cook; Claflin speeds, 443-486 r.p.m.</td>
<td>447</td>
<td>653</td>
</tr>
<tr>
<td>9</td>
<td>Swing hammer mill; 3 hr. 40 min. cook in #2 cooker (supposed to correspond to 2 hr. 5 min. at 100 lbs.) Claflin speeds, 443-486 r.p.m.</td>
<td>225</td>
<td>730</td>
</tr>
<tr>
<td>10</td>
<td>Swing hammer mill; 2 hr. 5 min. cook; Claflin speeds, 443-486 r.p.m.</td>
<td>324</td>
<td>748</td>
</tr>
<tr>
<td>11</td>
<td>Smalley 3/4&quot; cut; 1 hr. 55 min. cook; Claflin-Jordan. Last 15% through Claflin-Claflin, speeds 443-486 r.p.m.</td>
<td>483</td>
<td>890</td>
</tr>
<tr>
<td>12</td>
<td>Smalley 3/4&quot; cut; 1 hr. 55 min. cook; Claflin speeds, 443-443 r.p.m.</td>
<td>363</td>
<td>820</td>
</tr>
<tr>
<td>13</td>
<td>Smalley 3/4&quot; cut; 1 hr. 50 min. cook; Claflin speeds, 443-486 r.p.m.</td>
<td>285</td>
<td>730</td>
</tr>
</tbody>
</table>
pulp in the process used at Dubuque. It takes stock up to two inches long from the Claflin, reduces it to fibres practically all under one inch in length, removes coarse chunks and bundles of fibres, and gives the stock the hydration necessary to make a strong board. Its power consumption is one hundred and sixty-five K.W.H. per ton of board. Its capacity under the conditions outlined above is about twenty-four tons of board per twenty-four hours. It is necessary to replace shell and plug liners once a year at a cost of about $260.00.


The Bauer mill consists of two disks, on the surfaces of which can be fastened knife plates of any desired design. The disks are directly connected to motors which turn them in opposite directions at a speed of 1,800 r.p.m. Provision is made for feeding stock in at the axis of one of the disks. From the center of the machine the pulp is thrown outward between the knives of the two disks by centrifugal force against the casing which encloses the disks. It then drops down through the discharge opening in the base of the machine. The clearance between the disks can be adjusted by means of a hand screw from nothing to four inches. This machine has not been used on cooked pulp at Dubuque. Gibson (11) reports that it has been used on wheat straw which has been steam digested and then put through a swing hammer mill shredder. Gibson reports that high silica iron plates last about four weeks.

At Dubuque the Bauer has been used in the mechanical pulp process following the swing hammer mill wet shredder, Claflin-Jordan combination. Its use has been to brush out coarse outer fibre particles and chunks of pith.
It does this satisfactorily at a capacity of nineteen tons of board per twenty-four hours and a power consumption of about one hundred and thirty-nine K.W.H. per ton of board. A set of ordinary steel plates costing $50.00 produces about one hundred and ninety tons of board.

10. Rod Mill.

The rod mill consists of a heavy steel cylinder revolving on trunnions. The mill is about one-third filled with steel rods ranging from 1-1/2 to 3 inches in diameter and the length of the inside of the mill. As the mill revolves the rods tumble about on one another and grind the pulp between them and between them and the mill lining. The pulp is introduced at one end of the mill, works through it by gravity, and discharges at the other end. Work done with this machine at Ames over a period of eighteen months is reported by Richardson (30). This work has shown that a satisfactory cooked pulp board can be made with the rod mill as the sole refining machine. The capacity of the rod mill is increased if the pulp is first put through a cutting machine, and is still further increased if a Claflin or Jordan is used following the rod mill, thus making it possible to put the pulp through the mill at a faster rate, doing less work on it in this machine. The rod mill in the laboratory at Ames, which is three feet in diameter by six feet long, shows a capacity of 2.18 tons of board per twenty-four hours when used on whole stalks and followed with a Claflin; 3.45 tons per twenty-four hours on material which had first been put through an ensilage cutter.

Data published by the Denver Mine and Smelting Company indicate that on refining chestnut chips a six foot by fourteen feet mill has a capacity thirty-eight times as great as that of the three feet by six foot
machine. Assuming that the capacity of this machine would increase on cornstalk pulp in the same ratio it does on chestnut pulp, a six feet by fourteen feet rod mill would have a capacity for eighty-two tons of board per twenty-four hours when used on whole stalks, one-hundred-and seventeen tons on cut material. Figuring the power consumption of the machine in the same way, the six feet by fourteen feet mill would use thirty-three K.W.H. per ton of board produced by the first method, twenty-three K.W.H. by the second. The cost of rod replacement is estimated at about $240.00 per year.

The rod mill produces a fine, well-hydrated fibre which makes a good appearing board with fewer coarse particles than board made with other refining machines. The amount of work which the rod mill does on the pulp depends upon the pulp consistency and rate of feed. Low consistency tends to produce cutting action rather than hydration. The higher the rate of feed, the less work the mill does, and consequently the coarser and less hydrated the product. The rod mill with the cutter and Claflin produces a good grade mechanical pulp board. Calculations indicate that a six feet by fourteen feet machine would have a capacity of fifty-seven tons of mechanical pulp board per twenty-four hours at a power consumption of forty-seven K.W.H. per ton of board. One of the good features of the rod mill is its freedom from injury due to tramp iron, and its general ruggedness and consequent lack of operating troubles.

c. Cooking.

1'. General Processes.

In the cooked pulp process, the cooking of the stalks is probably the most important step in the process. The cooker charge used at Dubuque
at the present time is 2,450 lbs. of field cornstalks on a bone dry basis, 2,450 lbs. of wheat straw on the same basis, 750 lbs. of finished board trim, and 2,200 gallons of water. It is necessary to use two fills to get this charge into the digester. As much as possible is loaded into the cooker and it is then rotated two or three times, after which it is possible to add more material. About five-sixths of the charge is added at the first fill. Steam is blown into the digester for about ten minutes, at the end of which time a blow-off valve is opened to allow air, steam, and gasses to escape. The valve is again closed and the cooking proper started. When a temperature of 280 degrees Fahrenheit is attained, the time is noted and the cooking is continued for one hour and thirty minutes. The temperature is brought up to 316 degrees Fahrenheit, but is not allowed to exceed this. About forty-five minutes are required to reach 280 degrees Fahrenheit, and sixty minutes to reach 316 degrees Fahrenheit. At the end of the cooking period the blow-off valve is opened and the steam blown into the charge of another cooker to pre-heat this charge. The blow-off time is forty-five minutes. As soon as the blow-off is completed, the cooker charge is dumped.

The cooking process dissolves the pentosan materials from the cornstalks and straw, and softens and hydrates the fibres. The more cooking the charge receives, the "slower" the pulp which it produces, and the heavier and stronger the board. Undercooked pulp is "free" and tough, is more difficult to refine, and produces a weak, light weight board.

2'. Effect of Degree of Shredding Given Cooker Charge.

Little difference can be noted between the quality of board produced from material which was shredded before cooking and that which was
not shredded. Table V shows the yield per digester of whole stalks and straw, and also the yield from material which had been put through the swing hammer mill shredder before cooking. There is evidently little difference in yield. Runs recently made on material which has been put through both a Smalle; cutter and a swing hammer mill shredder before cooking indicate that it is possible to put about ten percent more of the finely cut material in the cooker, and that this material requires about ten minutes less cooking.

3'. Effect of Temperature.

As the cooking temperature is increased, the length of time required for the cook is shortened. One hour and thirty minutes are required when cooking at 100 lbs. gauge pressure (327 degrees Fahrenheit), two hours at 85 lbs. (316 degrees Fahrenheit), three hours at 4) lbs. (267 degrees Fahrenheit).

4'. Ratio Water to Fibre.

The amount of water used with the 5,650 lbs. of bone dry fibre has been decreased from 3,600 gallons to 2,200 gallons at Dubuque, with no appreciable change in the quality of the board. The use of as little water as possible is desirable because of the saving in steam and the shorter time required to reach the cooking temperature of 327 degrees Fahrenheit. The time required to reach this temperature was twenty minutes less with 2,200 gallons than it was with 3,600 gallons.

5'. Spray Lines in Cooker.

At the start of operations at Dubuque, three of the cookers were equipped with internal perforated pipes which led the cooking steam directly down into the mass of pulp, while in the fourth the steam was simply blown
## TABLE V

**Yield Per Digestor Shredded Stalks Versus Whole Stalks**

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Preparation of Cornstalks and Straw</th>
<th>Finished Board Produced Square Feet</th>
<th>Number of Cooks</th>
<th>Yield Per Digestor Square Feet</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Shredded</td>
<td>144,163</td>
<td>31</td>
<td>4,650</td>
<td>2,620</td>
</tr>
<tr>
<td>2.</td>
<td>Shredded</td>
<td>143,000</td>
<td>30</td>
<td>4,760</td>
<td>2,890</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>4,705</td>
</tr>
<tr>
<td>3.</td>
<td>Not Shredded</td>
<td>3,680</td>
<td>1</td>
<td>3,680</td>
<td>2,650</td>
</tr>
<tr>
<td>4.</td>
<td>Not Shredded</td>
<td>3,448</td>
<td>1</td>
<td>3,448</td>
<td>2,880</td>
</tr>
<tr>
<td>5.</td>
<td>Not Shredded</td>
<td>3,585</td>
<td>1</td>
<td>3,585</td>
<td>2,579</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>3,571</td>
</tr>
</tbody>
</table>
in through the digester trunion and dispersed throughout the cooker. By equipping the fourth cooker with the spray pipes the cooking time was reduced from three hours and forty minutes to two hours and fifteen minutes.

d. Washing.

Washing at Dubuque is carried out by passing the pulp through two revolving screen-covered cylinders.

1'. Diamond Iron Works Washer.

The first of these washers which receives the pulp as it comes from the cookers is twenty-six feet long by forty-two inches in diameter. Iron tires fastened to the washer at four points rest on driven wheels. The friction between the tires and wheels serves to turn the washer. There are water sprays on both the inside and outside of the washer running its entire length. A twenty mesh brass wire cloth covers the cylinder, and this is reinforced by a one-inch mesh, 1/8 inch diameter brass wire backing cloth. The twenty-mesh wire costs $140.00, and lasts about six months, while the backing wire costs $235.00 and lasts nine months. A forty-mesh wire was tried on this washer, but it went to pieces in a few days. Little trouble has been experienced with this washer.

2'. Allis-Chalmers Washer.

A second washing is given the stalks as they discharge from the Smalley wet cutter. The second washer is fourteen feet long and forty-two inches in diameter. It consists of a cylinder supported at intervals by spider arms radiating from a central shaft. This washer is covered by the same kind of wire as the first. The presence of the spider arms makes it impossible to have a water spray inside of this washer, so all the washing
at this point is done by a spray from the outside. A great deal of trouble has been experienced with this washer due to breakage of the spider arms, finally necessitating replacing the old arms with larger ones.

Table VI shows a number of dirt determinations made on wash water from the two washers, and on pulp discharging from the washers.

e. Sizing.

1'. Rosin Addition.

Work at Ames (32) has shown the best sizing practice, considering the economics as well as the results obtained, calls for the addition of about two percent rosin size on the basis of bone dry weight of board, and five percent alum. The rosin size is an emulsion of sixty percent wood resin in soda ash. Rosin is introduced at Dubuque at the discharge of the Number two washer. The stream of rosin is introduced in such a way that it strikes and mixes with the pulp as it discharges from the washer, and the mixing is completed by agitation in the stock chest. The rosin size is purchased in tank cars, from which it is blown into the storage tanks by compressed air. It is withdrawn from the storage tanks as needed, sucked by a steam jet through an emulsifier which mixes seventeen parts of water per part of rosin size, and ejected into another storage tank. It is fed from this tank by a steam eductor.

2'. Alum Addition.

Alum is purchased in ground form in 200 lb. bags. It has been found that the unpurified alum gives just as good sizing and goes just as far as the more refined grade, and can be purchased for seven and a half cents per hundred weight less. The alum is put into solution in the ratio of one pound of alum per gallon of water. It is fed to the pulp at the
<table>
<thead>
<tr>
<th>Run No.</th>
<th>No. 1 Washer</th>
<th>No. 2 Washer</th>
<th>No. 1 Washer</th>
<th>No. 2 Washer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0.28</td>
<td>0.10</td>
<td>0.70</td>
<td>0.07</td>
</tr>
<tr>
<td>2.</td>
<td>0.21</td>
<td>--</td>
<td>0.99</td>
<td>--</td>
</tr>
<tr>
<td>3.</td>
<td>--</td>
<td>0.12</td>
<td>--</td>
<td>0.16</td>
</tr>
<tr>
<td>4.</td>
<td>0.15</td>
<td>--</td>
<td>0.47</td>
<td>--</td>
</tr>
<tr>
<td>5.</td>
<td>--</td>
<td>0.13</td>
<td>--</td>
<td>0.46</td>
</tr>
<tr>
<td>6.</td>
<td>0.64</td>
<td>0.06</td>
<td>1.22</td>
<td>0.56</td>
</tr>
<tr>
<td>7.</td>
<td>--</td>
<td>0.09</td>
<td>--</td>
<td>0.21</td>
</tr>
<tr>
<td>8.</td>
<td>0.19</td>
<td>--</td>
<td>0.50</td>
<td>--</td>
</tr>
</tbody>
</table>
Jordan discharge by means of a steam eductor. The alum flows over a riffle board arranged so that a sheet of alum solution flows continuously into the sheet of pulp, giving thorough mixing, which is completed by agitation in a stock chest. When the proportion of alum and rosin is right, and the consistency of the pulp is adjusted to three percent, it should show a pH of 4.3. This gives a check on the sizing operation.

Richardson (32) reports that sulfuric acid can be substituted for one-quarter of the alum. This would affect an economy, since sulfuric acid is cheaper than alum. The acid is apt to give a board of slightly darker color.

Calculations indicate that a grade of alum sufficiently pure for this use could be made at the insulation board factory from bauxite and sulfuric acid at a cost of about one cent per pound. This is one-half cent per pound cheaper than commercial alum, and would save fifteen cents per thousand square feet of board.

3'. Other Sizing Agents.

Although the work at Ames indicates that rosin and alum are probably the best and cheapest sizing agents, other materials can be used satisfactorily. A compound prepared from alginic acid from seaweeds can be used either incorporated into the board or as a surface size. Animal glue also makes a good surface size.

f. Forming.

An Oliver Continuous Filter was first used in the Ames laboratory as a forming machine, and was also the first forming machine to be used at Dubuque. It was found that the Oliver would not handle pulps of any very great range of freeness. Only quite free pulp like that used for
mechanical pulp board would work satisfactorily.

Accordingly the machine shown in figure 2 was worked out, a two feet wide machine being built first for the laboratory and later an eight feet wide machine for the Dubuque factory. This machine consists of a wire cloth, "A" running over a breast roll, "B", draining area, "C", suction box, "D", through the press, and back to the breast roll. The pulp may be brought onto the forming machine through any suitable kind of headbox, figure 2 showing the box used at Dubuque. It is important, however, that the pulp have an even, uniform flow onto the machine, and the fewer the pulp, the more important this becomes, as the free pulp begins to form as soon as it strikes the wire, while the slower pulp tends to level itself out on the machine before it reaches the suction box. Deckles, consisting of two inch cypress boards, confine the pulp on the forming machine. The deckle boards have a one-half inch thick piece of pure gum rubber fastened along their bottom edges, and this rubber makes a seal with the moving forming machine wire and prevents pulp leakage. They should be set so they are slightly farther apart at the dry end of the machine than they are at the wet end, as this prevents the edge of the wet mat from dragging against the edge of the board as the mat emerges from the pool of pulp. The inside edge of the deckle must be perfectly smooth in order to get a sharp, square edged board. A "vibrator" is used to smooth the top surface of the board. This consists of a light wood bar supported from a cross beam by a rubber flap, and resting on the pulp. The cross beam is given an oscillatory motion by a pitman and eccentric driven by a small motor. This machine must have horizontal adjustment so that it can be accommodated to changing pulp levels caused by changes in the freeness of the stock.
Figure II - Board Forming Mach
The weight with which the vibrator presses on the pulp should also be adjustable by means of a counterweight, and the length of stroke and speed should be adjustable. All of these adjustments are desirable to suit the vibrator to changes in the freeness of the stock.

Table VII gives the strength of brass and of phosphor bronze screens of various meshes. The finer the mesh used, the finer textured, better appearing, is the surface obtained on the board. However, since the type forming machine used at Dubuque requires a strong wire, a fourteen mesh 0.020 gauge phosphor bronze wire has been used. Table VIII shows service obtained from several wires in operation. It is important to run the wire no tighter than necessary, and to see that the speed of all rolls are synchronized as closely as possible. Cracks in the edges of the wire should be sewed as soon as they appear. It has been found that the life of the wire is increased by graphiting the suction plate before putting on a new wire, and by lubricating the bottom side of the wire occasionally. When the shute wires are worn half way through their diameters, the wire should be taken off and turned over. This exposes to the surface of the suction box the parts of the shute wires which, because of their crimp, did not touch the box before, and thus almost doubles the life of the wire.

Figure III shows the method of joining the ends of a new wire. When it is necessary to sew the wire ends together, a lap joint should be used and the stitching done with a fine, close, stitch. The greater the vacuum used, the greater the strain on the wire. Experience at Dubuque indicates that vacuum in excess of three inches harms the wire more than it helps the board formation.
### TABLE VII

**Strength of Fourdriner Wire of Various Mesh**

**Average Values**

<table>
<thead>
<tr>
<th>Mesh</th>
<th>Nominal</th>
<th>Actual</th>
<th>Material</th>
<th>Diameter</th>
<th>Section</th>
<th>Approx. Yield Point</th>
<th>Approx. Ultimate Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>in.</td>
<td>sq.in.</td>
<td>lbs. per in. width</td>
<td>lbs. per in. width</td>
</tr>
<tr>
<td>14</td>
<td>14x14</td>
<td></td>
<td>Brass</td>
<td>0.0210</td>
<td>0.00486</td>
<td>126</td>
<td>252</td>
</tr>
<tr>
<td>20</td>
<td>20x18</td>
<td></td>
<td>Bronze</td>
<td>0.0170</td>
<td>0.00454</td>
<td>118</td>
<td>240</td>
</tr>
<tr>
<td>30</td>
<td>30x23</td>
<td></td>
<td>Bronze</td>
<td>0.0125</td>
<td>0.00368</td>
<td>96</td>
<td>195</td>
</tr>
<tr>
<td>40</td>
<td>40x32</td>
<td></td>
<td>Bronze</td>
<td>0.0110</td>
<td>0.00380</td>
<td>99</td>
<td>201</td>
</tr>
<tr>
<td>50</td>
<td>48x36</td>
<td></td>
<td>Bronze</td>
<td>0.0100</td>
<td>0.00377</td>
<td>98</td>
<td>200</td>
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<tr>
<td>60</td>
<td>50x40</td>
<td></td>
<td>Bronze</td>
<td>0.0092</td>
<td>0.00392</td>
<td>102</td>
<td>208</td>
</tr>
<tr>
<td>65</td>
<td>65x46</td>
<td></td>
<td>Bronze</td>
<td>0.0086</td>
<td>0.00369</td>
<td>96</td>
<td>195</td>
</tr>
<tr>
<td>65</td>
<td>65xC</td>
<td></td>
<td>Bronze</td>
<td>0.0082</td>
<td>0.00347</td>
<td>90</td>
<td>184</td>
</tr>
<tr>
<td>70</td>
<td>70x50</td>
<td></td>
<td>Bronze</td>
<td>0.0075</td>
<td>0.00309</td>
<td>80</td>
<td>164</td>
</tr>
<tr>
<td>72</td>
<td>72x52</td>
<td></td>
<td>Bronze</td>
<td>0.0072</td>
<td>0.00318</td>
<td>83</td>
<td>169</td>
</tr>
<tr>
<td>75</td>
<td>75x54</td>
<td></td>
<td>Bronze</td>
<td>0.0072</td>
<td>0.00309</td>
<td>80</td>
<td>164</td>
</tr>
<tr>
<td>80</td>
<td>78x60</td>
<td></td>
<td>Bronze</td>
<td>0.0065</td>
<td>0.00259</td>
<td>67</td>
<td>137</td>
</tr>
<tr>
<td>90</td>
<td>88x72</td>
<td></td>
<td>Bronze</td>
<td>0.0055</td>
<td>0.00209</td>
<td>54</td>
<td>111</td>
</tr>
<tr>
<td>100</td>
<td>98x84</td>
<td></td>
<td>Bronze</td>
<td>0.0045</td>
<td>0.00156</td>
<td>41</td>
<td>83</td>
</tr>
</tbody>
</table>

14  14x14  Thaenbor  0.0210  0.00486  195  316
20  20x18  Bronze    0.0170  0.00454  181  295
30  30x23  Bronze    0.0125  0.00368  147  239
40  40x32  Bronze    0.0110  0.00380  152  247
50  48x36  Bronze    0.0100  0.00377  151  245
60  50x40  Bronze    0.0092  0.00392  157  255
65  65x46  Bronze    0.0086  0.00369  147  240
65  65xC    Bronze   0.0082  0.00347  139  225
70  70x50  Bronze    0.0075  0.00309  124  201
72  72x52  Bronze    0.0072  0.00318  127  207
75  75x54  Bronze    0.0072  0.00309  124  201
80  78x60  Bronze    0.0065  0.00259  104  168
90  88x72  Bronze    0.0055  0.00209  84   136
100 98x84  Bronze    0.0045  0.00156  62   101

Note: The above values were reported by the Lindsay Wire Weaving Company of Cleveland, Ohio. The specimens were tested for strength in the machine direction.
TABLE VIII

LIFE OF FORMING MACHINE WIRES

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 4, 1929</td>
<td>Jan. 25, 1930</td>
<td>797,961</td>
<td>$0.287</td>
</tr>
<tr>
<td>Jan. 27, 1930</td>
<td>Feb. 25, 1930</td>
<td>484,640</td>
<td>0.498</td>
</tr>
<tr>
<td>* Feb. 26, 1930</td>
<td>May 3, 1930</td>
<td>1,545,272</td>
<td>0.151</td>
</tr>
</tbody>
</table>

* This wire was fit for further service when removed on May 3rd. It was removed to make way for a wider wire to change from a seven feet wide sheet to one eight feet wide.
Figure III - Method of Joining Forming Machine Wires
A spiral weave wire manufactured by the Wickwire Spencer Steel Company is being tried out in the Dubuque plant at the present time. The advantages of this type wire over the ordinary square mesh are much greater tensile strength - about 800 lbs. per linear inch compared to 312 for fourteen-mesh phosphor bronze - greater flexibility, and ability to be made into an endless belt without connecting rods or seams which leave marks on the board. The construction of the wire is such that it can be used in heavy gauge and mesh without sacrificing the flexibility which is necessary to allow the wire to pass around the machine rolls without cracking. Its initial cost is high, $2.35 per square foot for ten-mesh twenty-two gauge stainless steel wire compared to $0.48 for fourteen-mesh phosphor bronze in ordinary square mesh. The Dubuque wire has made 2,500,000 square feet of board thus far, and shows very little wear. One of the most important advantages of this type wire is that it does not twist and narrow as the ordinary square mesh wire does.

g. Pressing.

The Kutztown press, shown in Figure IV, consists of upper and lower belts made up of three-quarter inch thick steel platens four inches wide. These platens are supported and carried through the press by three heavy chains. The lower platens pass over a series of rolls fastened to a fixed bed plate. The upper platens pass beneath a movable girder to which varying pressure may be applied by means of heavy springs. The distance between the platens in the pressure zone is determined by steel liners inserted beneath the outer edges of the top girder. Holes are drilled through the platens to allow the water which is pressed out of the pulp to escape. It is important to remove the water which is pressed through the top platens
Figure IV - Kutztov
before it has a chance to flow back through the press and wet the top surface of the board. "Crushed" and weakened spots result in the board if it is too wet when pressed. The removal of the water from the top platen is accomplished by means of a suction device. One of the difficulties experienced with the Kutztown press was that of properly removing water from the inaccessible pressure zone. A great deal of trouble was encountered because of the tendency of the press to twist and narrow the wire. After two years of intermittent use, breakdowns on the Kutztown press became so frequent it was necessary to replace it. Difficulty was experienced at Dubuque for a time in that the press pressed the edges of the board thinner than the center. This trouble was overcome by putting a one-eighth inch thick liner between the two center roller boxes and the upper girder, and one-sixteenth inch thick liners between the next set of roller boxes and the girder. This had the effect of exerting greater pressure at the center of the press than at the edges.

A top press wire at Dubuque made 1,500,000 square feet of board and was still good for further service. On the basis of two million feet production, the top wire cost would be about $0.05 per thousand square feet.

Several runs have been made at Dubuque without a top screen on the press, that is, running with the platens bare. Sticking of the pulp to the platens was overcome by keeping the platens oiled with kerosene. However, when running with slow pulp which is apt to be somewhat wet and mushy in the press, the pulp tends to squeeze up between the platens. This pulp builds up between the platens, prevents their coming together as they should, and puts the connections by means of which the platens are held to the chain
under dangerous strain. The board made without the top screen was
"crushed" to the extent that it was not satisfactory.

A felt gives satisfactory results in place of a wire, but must be
washed frequently to prevent crushing. The felt cost is about $0.06 per
thousand square feet. Generally speaking, a wire is more satisfactory
than a felt.

2'. Roll Type Press.

The press used in the laboratory at Ames is manufactured by the
Downingtown Company. It consists of three sets of rolls between which the
pulp is carried by wire screens. Clearance between the rolls is adjusted by
means of a hand wheel, and a heavy spring determines the pressure exerted on
the mat. It is important with this machine, as with the Kutztown press, to
remove the water as it is pressed out of the mat. This is done by suction
devices which fit closely behind the pressure rolls. The construction of the
press makes it easier to effectively remove the water than with the Kutztown
press. Figure 7 shows a five roll press which is being installed at Dubuque
to replace the Kutztown press. This press is made by the Beloit Iron Works,
and sells for about $11,000.00, compared to about $20,000.00 for the Kutztown.

h. Drying.

From the press the board may be fed either continuously into a single
dock dryer running at the same speed as the forming machine, or it may be cut
into convenient lengths as is done at Dubuque by means of an automatic cut-off
saw, and fed by an automatic tipple into successive decks of a multiple deck
dryer. The more decks the dryer has, the slower it runs and the shorter the
length of dryer required. The continuous dryer does away with the necessity
for the more or less complicated automatic cut-off saw and tipple, but requires
a very long building. Figures supplied by the Coe Manufacturing Company of Painesville, Ohio indicate that an eight deck dryer requires eighteen percent less heat to dry an equivalent amount of board than a single deck dryer. For dryers of equal capacity an eight deck machine costs $10,000.00 less than a single deck. Drying may be accomplished either by steam heated coils or by the direct heat of the products of combustion of coal or fuel oil. The cost of a twelve foot, eight deck dryer is $123,000.00 installed. The cost is the same whether the dryer is steam heated or oil heated. Since by using an oil heated dryer a considerably smaller steam plant is sufficient, it is obviously the more economical installation, providing fuel oil is available at prices competitive with steam costs.

Figure VI shows a diagramatic layout of the Coe dryer. The moisture which is evaporated from the board flashes into steam at 320 degrees Fahrenheit and is circulated continuously in the path indicated by the arrows. The excess gas is continually vented out to the atmosphere at "A", while the circulated gas is reheated by being blown through the steam coils "M" and "N". Nets of coils above and below each deck of rolls maintain the temperature of the gases at 320 degrees Fahrenheit as they circulate through the dryer.

The time required to dry boards at a given dryer temperature depends upon the thickness of the board, "freeness" of the pulp, and the moisture content of the board as it goes into the dryer. This latter factor depends upon the pressure given the board in the press. A standard board pulp having a freeness of twenty-five seconds and a thickness of 9/16 inch requires 163 minutes to dry, whereas a low density board pulp having a freeness of seventeen seconds and the same moisture content and thickness as the standard
Figure VI - Coe
pulp, requires only 144 minutes to dry. Mechanical pulp pressed to a moisture content of sixty-eight percent as it enters the dryer, and one-half inch thick, dries in 144 minutes, whereas lighter pressed mechanical pulp having a moisture content of seventy-five percent requires 162 minutes. Standard pulp 7/16 inch thick dries in 168 minutes, while pulp of the same freeness and moisture content, but 7/8 inch thick requires 224 minutes to dry.

A seventy-five horsepower motor is required to circulate the gases through the dryer and a five horsepower motor to drive the dryer. At Dubuque a twenty horsepower motor is used to exhaust the excess gases, but by placing the exhaust vent on the discharge side of the circulating fan instead of the intake side, the excess gases would escape under their own pressure and do away with the need of an exhaust fan.

The dryer rollers and steam coils should be thoroughly cleaned off once a week by blowing with compressed air to remove small pieces of board which break off the boards as they pass through the dryer. It is necessary to remove this material to guard against fire in the dryer. Each deck of rolls should be grounded by means of a short piece of chain fastened to the deck framework and dragging on the board beneath to prevent static sparks caused by the movement of the hot gases over the warm, dry board.

It is important that the moisture content of the board as it leaves the dryer be uniformly the same so that a constant amount of expansion can be figured on as the boards absorb their equilibrium moisture content. It is necessary to know what this expansion will be so that allowance for it can be made in sawing.

1. Sawing.

The arrangement of saws and the extent of the equipment in this
department depends largely upon the trade which the insulation board factory is supplying. If board is being supplied for building purposes only, the saw equipment is comparatively simple. Figure VII shows a saw arrangement which will take boards four feet, eight feet or twelve feet wide from the dryer, and of any length up to twenty feet, and saw them into any standard building size such as four feet wide by six feet, seven feet, eight feet, nine feet, ten feet, or twelve feet lengths for wall insulation, or two feet by five feet, two feet by three feet, or three feet by four feet for roof insulation. There should also be a band saw for filling orders for pieces of irregular shape, and ordinary box maker's cut-off saw for cutting odd size pieces, and a machine for cutting ship lap edges on the insulation board lath.

If the insulation board factory is to supply board cut to sizes for refrigerator cars or household refrigerators, the sawing equipment must be more elaborate, since the sizes required for this work range from pieces seven inches by nine inches to four feet seven and three-eighth inches by nine feet eleven and fifteen-sixteenths inches, and from one-quarter inch thick to four inches thick. Also some of the pieces must have beveled edges and some must be wedge-shaped. A tilt saw is required to cut the beveled edges. A wood veneer re-saw should be supplied for splitting one-half inch boards to one-quarter and for splitting thicker blocks to wedge-shaped pieces.

Sanding equipment and gluing or stapling equipment which will also be required for refrigerator work will be discussed under separate headings.

To facilitate changing saws and changing positions of saws, the mandrels should be above the table.

An ordinary steel saw cuts about 3,500 linear feet of standard Maizewood before requiring filing, and about 7,000 feet of low density Maizewood.
Hard Trim and Cross-Cut Saws
Stellite, carbaloy, and tungsten carbide inserted tooth saws cut from 5,000 feet to 15,000 feet, but because of their high initial cost are not as economical to use as ordinary steel saws. The steel saws cost $.02 each compared to $25.00 to $240.00 for the special alloy saws.

j. Sanding.

An accurate and uniform thickness and a fine smooth surface may be given the insulation boards by running them through a drum sander. An endless bed sander with sanding drums overhead must be used to correct variations in thickness across the width of the board. The roll feed type sander which has the sanding rollers underneath will smooth the board surface but will not correct thickness variations. The sander should be fitted with flexible finger platen plates rather than solid plates ahead of the first sander roll in order to take care of variations in thickness of the board.

A belt driven No. 431, 57" Yates-American three drum endless bed sander is used at Lubuque. The maximum cut which this machine will take satisfactorily is one-eighth inch. Number 2-1/2 garnet paper is used on the first two drums, and number 0 paper on the third. The capacity of this machine on four feet wide board, taking into consideration the time out required for changing sand paper, oiling machine, etc., is about 50,000 square feet per twenty-four hours. Number 2-1/2 paper will sand about 22,000 square feet before requiring changing. The cost of sanding board, exclusive of overhead, is about $0.63 per thousand square feet, and is made up as follows: sand paper, $0.16, power, $0.19, labor, $0.28. The following data indicate that sanding has slight effect on the properties of the board:
The boards show a tendency to warp in the direction of the sanded surface as they come from the sander, but this may be overcome by reversing the boards as they are piled and leaving them in piles for a few days before shipping.

k. Cluing.

Thick blocks of insulation are often made up by cluing a number of one-half inch thick boards together. Stapling is also sometimes used in making up thick pieces. For blocks which must be sawed after being made up, cluing is more satisfactory than stapling because of the interference of the staples with the saws.

Figure VIII shows a layout for cluing boards. The boards are fed through the glue spreaders, piled together to the desired thickness, placed in an hydraulic press for about thirty minutes, and then dried for thirty minutes in a warm room.

The cost of cluing depends largely upon the kind of adhesive used, and this is usually specified by the customer. With glue at seven and a half cents per pound, the cost of cluing per thousand square feet of glued surface is as follows: labor, $0.70, plus, $0.91. Thus the cost of cluing a thousand square feet of board two inches thick made up of four one-half inch boards would be $4.63, since this board would have three glued surfaces.

1. Stapling.

Stapling machines may be secured to fasten boards together by driving
wire staples through them up to four inches thick. The stapling machine may be fitted with as many as four heads, thus driving four staples at a time. The boards may be fed through the machine by hand or a conveyor may be supplied which feeds the boards through with stops at the desired intervals while the staples are being driven. The stapled board is not as firmly held together as the glued board, but on the other hand is a slightly better insulator because of the air films between the boards. The cost of stapling depends upon the size piece being worked with and the number of staples used per unit. On a two feet by three feet by one inch thick slab made up from two half-inch boards stapled together with three rows of staples running parallel with the long edge, the staples spaced five inches apart, that is, twenty-one staples in the six square feet area, the cost is, stapling wire, $.152, labor, $.420, power, $.01, making a total of $.583 per thousand square feet one-half inch thick.

m. Wrapping.

It is necessary to wrap less than carload shipments and carload shipments to dealers who re-sell the material in small lots. The lightest paper which it has been found feasible to use is one hundred and ten pound Kraft paper. The standard size boards are wrapped six pieces in a package, the lath sixteen pieces. It is advisable to protect the corners of the pile of boards with chipboard caps before wrapping, and if the board is to be shipped far it is well to place strips of insulation board along the edges of the pile before wrapping.

A canvas of manufacturers of wrapping machines indicates that a machine to handle the large insulation board sizes would have to be built specially. The cost of wrapping by hand depends upon the size of board being wrapped,
the cost being higher on the smaller sizes than on the larger boards.

Wrapping four feet by eight feet boards six in a bundle, protecting the
corners with chipboard caps, and using one hundred and ten pound Kraft
paper, the cost per thousand square feet is, paper, $0.55, labor, $0.15,
corners, $0.12, gummed tape, $0.06, making a total of $0.88 per thousand
square feet one-half inch thick.


a. Raw Material.

The cornstalks and straw are tested for moisture and dirt in the
following manner. As the car is unloaded, a sample through the center of
every twentieth bale is removed by means of a four inch diameter auger. The
samples for the entire carload are then reduced in a laboratory shredding
machine and the shredded sample is reduced to approximately 300 grams by
quartering. This material is divided into three samples for the moisture
test. The moisture test is made by drying the samples to constant weight
in covered aluminum pans at one hundred and five degrees Fahrenheit, and
noting the loss in weight. Dirt is determined by taking a five gram sample
from each of the dried one hundred gram samples and heating in a crucible
with a cover until the sample is reduced to a flaky, white ash. From the
percent residue subtract 3.5 (the percent ash in clean, washed, cornstalks
(23), and the remainder represents the percent dirt.

b. Pulp in Process.

It is important to have regular checks on the pulp in process to deter-
mine (1) amount of pulp being lost at washers, (2) dirt content of pulp
coming from washers, (3) consistency of pulp on forming machine, (4) freeness
of pulp on forming machine, (5) null of pulp at forming machine, (6) moisture
content of pulp entering and leaving the press.

The amount of fibre being lost at the washers can be determined by measuring the amount of water drained from the washer and determining the percent of fibre in the water. This latter factor is determined by evaporating a sample from the washer drain to dryness, and then ashing the dry sample to determine its percentage of volatile matter.

The dirt content of the pulp as it comes from the washer should be determined by the same method as that described for the raw material.

The consistency and freeness of the pulp are determined as follows: A one liter representative sample is placed in a Buchner funnel and suction applied. When drainage has slowed to three drops per minute, the mat of pulp is weighed, and the weight recorded. Twenty grams of this pulp is then diluted to one liter with water at twenty-three degrees Centigrade and thoroughly agitated. This pulp suspension is poured into the freeness testing machine. The number of cubic centimeters overflowing through the side arm is a measure of the freeness. By considering the freeness and weight of pulp mat together, the consistency may be read from a chart. The consistency should be kept at three percent and the freeness seventeen to twenty-three.

The pH value of the pulp should be kept at 4.5 for best sizing, according to Richardson (30). The pH of the pulp is determined by draining the water off the pulp and determining the pH of the liquor by means of a LaMotte colorimetric set.

The moisture content of the pulp entering and leaving the press is determined by simply breaking a representative sample out of the pulp mat just as it enters the press and again just as it emerges, drying these
samples at one hundred and five degrees Centigrade to constant weight, and from their loss in weight computing their moisture contents.

c. Finished Product.

The finished board should be tested for (1) strength, (2) weight, (3) moisture absorption, (4) insulating value, (5) resistance to impact, (6) moisture content.

The modulus of rupture is determined as indicative of the strength of the board. The machine shown in figure IX is used in making this test. A test sample six inches long by three inches wide is placed across the two supports and the breaker block is then exactly centered on the test specimen. Shot is poured into the bucket at the end of the lever arm until the sample breaks. The weight of the shot and bucket is then determined in grams, the thickness of the board is measured at the breaking point, and the modulus of rupture in pounds per square inch is read from the graph shown in figure XIV.

The weight of the board in terms of an equivalent weight of 1,000 square feet of board one-half inch thick is read from the graph shown in figure XV after determining the weight in grams of a sample eight inches by eight inches.

The moisture absorption is determined by immersing a three inch by three inch sample in water at twenty degrees Centigrade for thirty minutes, removing the sample, standing it on edge to drain for one minute, weighing, and computing the percentage gain in weight.

The apparatus shown in figure XVI is used to determine the insulation value. This apparatus was designed by Prof. H. Stiles of the Physics Department at Iowa State College (34). The container "A" is filled with ice water and crushed ice and a pipet which extends into the container is filled
Fig. IX TRANSVERSE STRENGTH TESTER
Figure XIV - Modulus of Rupture Chart

Breaking Load in Grams

$d = \text{thickness of sample}$
with ice water. Heat from boiling water in the boiler passes through a
definite area and thickness of the test specimen "M", melts ice in the
container "A" and causes the level of water in the pipet to fall. The time
required for the water level to fall a given distance is a measure of the
rate at which heat is transmitted through the test specimen, and thus is a
measure of its insulating value. With this apparatus an insulating value
determination can be made in about two hours.

The impact testing machine shown in figure XVII was designed at the
Iowa State College. A five kilogram weight can be dropped from any definite
height indicated by the calibrated slide rod "B" onto a round pointed pin
"C" which rests on the test specimen "M" which in turn is supported by the
hollow cylinder "D". Graduations on the pin indicate the depth of the im-
pression made in the specimen, and thus its resistance to shock or impact.

It is important to make regular tests of the moisture content of the
finished board since this must be held constant if the board is to expand
a constant amount in absorbing its equilibrium moisture content. This ex-
pansion must be a constant amount in order to make the correct allowance
in sawing.

The Forest Products Laboratory (35) has recently announced a test
method to determine the "Coarseness modulus" of the fibre of the finished
board by means of sieve analyses. This test determines the ratio of fines
to long fibre, and is suggested as an aid to process control.

The strength, weight, and moisture tests should be made from six to ten
times per twenty-four hours, while the other tests should be made daily.

4. By-Products.

a. Furfural.
SWEENEY IMPACT TESTER

Zero Setting:

With zero mark at top face of fixed arm, catch pin is adjusted to bring lower edge of adjustable arm clamp exactly on zero of the inches scale.

Test Adjustment and Reading:

Set adjustable arm at desired height. Raise weight till caught by trigger. Place sample on test cup with peen resting on sample. Release knurled lock nut, and turn test cup to raise or lower peen to zero graduation, and tighten lock washer. Pull out on trigger to drop weight. Then read deflection from graduations on peen that project below lower face of fixed arm. NOTE Do not test within 3" of an edge or a former test mark.

S. R. Whittemore - J. E. Baker
Ames Laboratory, Bur. of Stds.

May 19, 1930
Work carried on by La Forge and Maina (36) indicates that ten percent of the field dry weight of corn cobs can be recovered under optimum conditions by steam digestion. The assumption that similar results should be obtained with cornstalks seems justified because of the chemical similarity of the two materials. Curves worked out by La Forge indicate that under the cooking conditions used in the manufacture of insulation board, six percent of furfural should be recoverable from the blow-off steam of the digesters. Work done by Naffziger (37) at Iowa State College, however, indicated less than one percent of furfural in the blow-off steam. No work has been done on this problem at Dubuque. Granting that the furfural content of the blow-off steam is as low as Naffziger's work indicates, it might be built up to the point where it could be recovered efficiently by the following means:

Blow-off steam from one digester is introduced into the next digester to preheat the charge in that digester, as is done now at Dubuque. All furfural is thus retained in the system. The cook liquor from each charge is drawn off into a triple effect evaporator. The concentrated liquor is a valuable adhesive. The condensate from the second effect would be relatively high in furfural content and would be sent to a column still for fractionating.

b. Adhesive.

The process of manufacturing adhesive from the cook liquors has been described above. This adhesive has properties which make it suitable for use as core binder, coal briquette binder, etc. Adhesive has been made at Dubuque by evaporating the cook liquors in an open steam kettle. This work indicates a yield of about 350 lbs. of twenty-four degrees Bo' adhesive per ton of finished board. Assuming a board weight of 0.7 lb. per square foot and a value
of two cents per pound for the adhesive, this would indicate a recovery of
$2.44 worth of adhesive per 1,000 square feet of finished board produced.

b. Saw and Sander Dust.

About six pounds of saw dust are produced per thousand square
feet of finished board. If all the board is sanded about forty-three
pounds per thousand square feet of sander dust is produced. Work at
Dubuque indicates that this dust may be satisfactorily returned to the
pulp in the stock chest just ahead of the forming machine.

Other possible uses for the dust are (1) sweeping compound,
(2) filler for plastics, (3) manufacture of Maizolith. (29)
A. Location of Plant.

In deciding upon the location of a plant for the production of insulation board from cornstalks, the following factors are of prime importance: (a) supply of raw material available; (b) supply of water, electric power, and fuel, and the cost of these three items.

For every thousand square feet of board produced, about 955 pounds of cornstalks on the bone dry basis will be required. This figure is based on a weight of 635 pounds per thousand square feet of finished board and a yield of sixty eight percent of the weight of bone dry stalks. A plant producing 100,000 square feet per day would require 14,325 tons of bone dry stalks per year. L. K. Arnold (38) of the Chemical Engineering Department at Iowa State College summarizes the results of investigations of a number of Experiment Stations and concludes that a yield of two tons of bone dry stalks per acre may be expected in the corn belt. Experience in the Agricultural Engineering Department at Iowa State College, and of L. W. Plaeger, in charge of cornstalk buying for the Maineemood Corporation, shows that in actual harvesting of the stalks the yield is about one to one and three-quarters tons per acre when stalks are harvested early, and one-half to one ton after stalks are pastured and wind blown. Since these figures will undoubtedly be improved as better harvesting methods are developed, three-quarter ton per acre will be a conservative figure to use in computing the area required to supply stalks for an insulation board plant. Using this figure, 37,600 acres, or about fifty nine square miles, would be required for a plant producing 133,000 square feet per day. An
Iowa Engineering Experiment Station bulletin (23) states that in a considerable part of Iowa more than one-third of the farm land is in corn. On this basis the insulation board plant would draw its raw material from an area of 177 square miles. Assuming the factory to be located in the center of a circular area of this size, the average haul would be about four miles. The cost of hauling baled stalks by truck is about fifteen cents per ton-mile. Thus, for the optimum condition outlined above, i.e., a haul of four miles, the cost per ton of finished board produced is $1.54. The increase in cost per ton of board as the length of raw material haul increases is shown in table No. IX.

The necessity for locating the factory at a point where the corn production is sufficiently great to insure a short haul for cornstalks is evident from the table.

The location for the plant should be chosen with the thought in mind that about 1,000,000 gallons of water will be required per day. Excessive dirt and hardness should be avoided. Too much dirt in the water would give trouble in the process, while the hardness causes boiler tube trouble.

About 315 K.W.H. of electricity are consumed for every ton of board produced. Thus, it will be seen that power rates should be given careful consideration in selecting the plant location. Because of the steady nature of the load and the continuous twenty four hour per day use of power, the insulation board plant is entitled to good power rates. At the present time plants located in the corn belt should be able to purchase power at from one cent to one and one-quarter cents per K.W.H.

Cheap coal is important since a large amount will be used in producing steam for the digesters. Fuel oil will be used to supply heat for drying.
### TABLE IX

**Cost of Hauling Cornstalks**

<table>
<thead>
<tr>
<th>Length of Haul</th>
<th>Method of Haul</th>
<th>Per Ton of Raw Material</th>
<th>Per Ton of Finished Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 miles</td>
<td>Truck and Trailer</td>
<td>$0.60</td>
<td>$1.54</td>
</tr>
<tr>
<td>5 miles</td>
<td>&quot;</td>
<td>0.75</td>
<td>1.93</td>
</tr>
<tr>
<td>6 miles</td>
<td>&quot;</td>
<td>0.90</td>
<td>2.32</td>
</tr>
<tr>
<td>7 miles</td>
<td>&quot;</td>
<td>1.05</td>
<td>2.70</td>
</tr>
<tr>
<td>8 miles</td>
<td>&quot;</td>
<td>1.20</td>
<td>3.09</td>
</tr>
<tr>
<td>9 miles</td>
<td>&quot;</td>
<td>1.35</td>
<td>3.48</td>
</tr>
<tr>
<td>10 miles</td>
<td>&quot;</td>
<td>1.50</td>
<td>3.86</td>
</tr>
<tr>
<td>24 miles or less</td>
<td>Rail</td>
<td>1.20</td>
<td>3.08</td>
</tr>
<tr>
<td>25 to 50 miles</td>
<td>&quot;</td>
<td>1.30</td>
<td>3.34</td>
</tr>
<tr>
<td>50 to 75 miles</td>
<td>&quot;</td>
<td>1.50</td>
<td>3.86</td>
</tr>
<tr>
<td>75 to 100 miles</td>
<td>&quot;</td>
<td>1.60</td>
<td>4.12</td>
</tr>
<tr>
<td>100 to 125 miles</td>
<td>&quot;</td>
<td>1.80</td>
<td>4.64</td>
</tr>
<tr>
<td>125 to 150 miles</td>
<td>&quot;</td>
<td>1.90</td>
<td>4.89</td>
</tr>
<tr>
<td>150 to 175 miles</td>
<td>&quot;</td>
<td>2.10</td>
<td>5.40</td>
</tr>
<tr>
<td>175 to 200 miles</td>
<td>&quot;</td>
<td>2.20</td>
<td>5.66</td>
</tr>
<tr>
<td>200 to 225 miles</td>
<td>&quot;</td>
<td>2.40</td>
<td>6.18</td>
</tr>
<tr>
<td>225 to 250 miles</td>
<td>&quot;</td>
<td>2.60</td>
<td>6.70</td>
</tr>
</tbody>
</table>
Aside from the three main points just discussed, the following factors should be considered in choosing the plant's location: transportation facilities, nearness to market for finished product, and labor market.

B. Size of Factory.

The most economical size factory will be brought out by cost figures which will be discussed later.

C. General Layout.

The plant layout shown in Fig. 1 is that dictated by semi-commercial scale work done thus far and by experience gained in the operation of the commercial plant at Dubuque Iowa.

The layout indicated by Fig. 1 shows four railroad sidings; one for delivering coal to the boiler room, alum and rosin to the size room, and making shipment of finished board; two for bringing in cornstalks; and one for making shipment of finished board from the other side of the warehouse. The sidings for bringing in stalks run between rows of piles and on through to the main line. This makes it possible to spot a line of cars and keep moving them on ahead as they are unloaded. In order to minimize the fire hazard, the piles of stalks should not be larger than seventy feet by forty feet by thirty feet high. A pile of this size contains about 840,000 pounds of bone dry fibre. Assuming a weight of 635 pounds per thousand square feet of board, a production of 140,000 square feet per twenty four hours, and a yield of sixty eight percent of the weight of bone dry fibre, \( \frac{140,000 \times 635}{6} = 130,500 \) lbs. of bone dry fibre.
will be required per day. As a general thing cornstalk harvesting would begin during the latter part of November and would not last past the latter part of March. Therefore, the storage space would have to accommodate an eight months, or on the basis of three hundred working days in the year, two hundred days supply of stalks, i.e. $200 \times 130,500 = 26,100,000$ pounds of bone dry fibre. Thus thirty two piles seventy feet by forty feet by thirty feet high would be required. These would be arranged on each side of the railroad sidings. A good road would be provided between the piles in addition to the railroad siding so stalks might be brought in by truck as well as by rail. During the harvesting season as many stalks as are needed to operate the factory are unloaded directly from the cars onto the bale breaker conveyor, the balance are stacked directly from the cars or trucks by means of the stacking machine previously described.

Stalks are brought from the piles to the shredder house by means of the conveyor system described earlier in this thesis. The baling wire is removed by hand and the bales fed to a Fox bale breaker. The bale breaker discharges onto a belt which passes over a magnetic separator and then delivers the stalks to the feed of a Fox cutter, set to cut about one and one-half inch lengths. The cutter is located on a balcony above a row of digesters. As the material discharges from the cutter it falls upon a slat conveyor which may be made to feed any one of the six digesters by opening trap doors.

The average capacity of the digesters, as shown in tables 2 and 3, is about 2,850 lbs. of board, or, on the basis of a board weighing 0.635 lb. per square foot, 4,500 square feet. The cooking cycle is four hours and twenty minutes, made up in the following way: sixty minutes for filling,
forty-five minutes to bring up to temperature, ninety minutes to cook, forty-five minutes to blow off, and twenty minutes to dump. This makes five and a half charges possible per twenty-four hours per digester, giving the six digesters a theoretical capacity of 148,000 square feet of finished board weighing 0.335 lb. per square foot per twenty-four hours. Each digester is driven by an individual 7-1/2 horsepower motor, 1,800 r.p.m., driving through a one to ten speed reducer. Steam and water valves for each digester are located at convenient points on the balcony above the digesters, and a panel carries gauges indicating the steam pressure in each digester. In addition to the steam gauges, each digester carries a thermometer, the well of which extends through the digester wall into the mass of pulp. Blow-off steam from one digester is blown into the next to preheat the charge. The system used is shown in figure XVIII. The flexible steel hose "A" is connected to the digester blow-off and to the header "B" which discharges into another steel flexible hose "C" which leads steam into the bottom of the fresh digester charge. The digesters dump into a long pit. In the bottom of the pit is a conveyor onto which the pulp is forked at a steady rate. The conveyor discharges the pulp into the rod mill hopper.

As explained earlier in this thesis, calculations based on experimental work at Ames with a three feet by six feet rod mill, and statements of the Denver Mine and Smelter Company regarding the capacity of various size mills on paper stock, indicate that a six feet by fourteen feet rod mill would have a capacity for 117 tons of finished board per twenty-four hours. However, in view of the lack of actual production data with the large mills, the six feet by fourteen feet mill is specified for producing 140,000 square
Diagram of proposed blowdown pipe.

Figure XVIII - System for Utilizing Blow-Off Steam
feet per twenty-four hours. The same kind of calculations indicate that the power consumption would be about twenty-three K.W.H. per ton of board. The mill is driven at twenty-four r.p.m. through a ten to one speed reducer by a one hundred and fifty horsepower motor. A screw conveyor running in the bottom of the feed hopper feeds the pulp to the mill. The pulp discharging from the rod mill feeds through a cylindrical washer by gravity.

As the pulp discharges from the washer it meets a small stream of rosin, the first step in the waterproofing process. The pulp from the washer passes to a small pump, from which it is pumped through the Jordans to give it the final refining treatment. Alum is added to the pulp as it discharges from the Jordans, completing the waterproofing. The stock then passes to a large stock chest where "white water" from the forming machine is added to maintain the proper consistency. This chest is twelve feet deep by twenty feet long by ten feet wide to give it enough size to equalize slight irregularities in the pulp and to provide a reserve stock to keep the forming machine running in the event of minor breakdowns at some point in the refining line.

D. Rosin and Alum.

Rosin size is purchased in tank cars and is blown into a large storage tank by means of compressed air. From this tank small quantities are bled off as needed into a small tank which is equipped with heating coils to lower the viscosity of the rosin size emulsion. The thick rosin is drawn from the tank by means of a steam eductor through an emulsifier which intimately mixes the rosin size with the right proportion of water.
This diluted solution then passes to two storage tanks, from which it is 
drawn by a steam eductor to a measuring tank which feeds it to the pulp 
stream coming from the rod mill.

The machine for adding the alum is shown in figure XIX. Ground "B" 
grade alum is purchased in 200 lb. bags. "B" grade alum contains slightly 
higher iron content than "A" grade, but is lower in price and has been 
found to be equally good in this process. The bags of alum are opened 
and dumped into the hopper of the dosimeter shown in figure XIX, which 
feeds any predetermined amount of alum into the pulp stream coming from 
the Jordan.

E. Forming, Pressing, and Drying.

The forming machine and press which have been previously described 
are driven by a twenty horsepower, 870 r.p.m. motor. The suction for 
the forming machine and for removing water from the press is supplied 
by a Nash Nytor pump, driven by a seventy-five horsepower, 870 r.p.m. 
motor.

A twelve feet width is specified for the forming machine and press 
because cost figures indicate more economical operation on this width 
board than on the four feet or eight feet widths.

A continuous eight deck dryer is specified, having an enclosed drying 
length of two hundred feet. As the boards come from the press, they are 
automatically cut into any desired length up to twenty feet by means of 
a traveling rotary knife. This knife moves forward at the same time it 
moves across the board, so as to give a square cut.

As the twelve feet wide board comes from the dryer, it is trimmed
The Improved Gauntt Dry Feeder fits the Standard Cast Iron Base, the foundation bolt being located the same.

The Hopper can be furnished with Agitator, the same being driven from the Feed Conveyor shaft; therefore the two shafts run the same speed and work in unison.

HORSE POWER REQUIRED FOR GAUNTt DRY FEEDERS

<table>
<thead>
<tr>
<th>No. 2 &amp; 3</th>
<th>No. 4</th>
<th>No. 6</th>
<th>No. 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 H.P.</td>
<td>1/4 H.P.</td>
<td>1/8 H.P.</td>
<td>1/8 H.P.</td>
</tr>
</tbody>
</table>

*Figure XIX - Alum Feeding Machine*
into three four feet wide sheets by circular saws and then automatically
carried through a set of saws placed at right angles to the trim saws.
These saws reduce the long, four feet wide boards to shorter standard
lengths.

Immediately after passing through the saws the boards are given a
light water spray to bring their moisture content up to about ten percent
in order to minimize expansion. Boards which are to be sanded are not
sprayed until after the sanding operation.

The boards from the saws are either piled on skid platforms and put
in storage, or are put through further operations, such as sanding or
cutting to special sizes, and are then placed on skids and put into the
warehouse. The skids are arranged so they may be pulled directly into
cars spotted along both sides of the warehouse for loading. Warehouse
space is provided for four million feet of board, or forty days production.

A ship lap machine is provided for making lath, and a tilt saw,
router, stapling machine, and gluing equipment for making special size
refrigerator and acoustical material.
COST DATA

Table X gives the cost of building and equipment for factories for making board in four feet, eight feet, and twelve feet widths. The capacities for these three factories, based on a forming machine speed of eight feet per minute and twenty-four hours per day operation, are, for the four feet board factory, 45,000 square feet per twenty-four hours; for the eight feet board, 92,160 square feet; and for the twelve feet board, 155,340 square feet.

The prices listed for the various machines include the cost of the motor or motors for driving, and the cost of installing the machine.

Table XI gives the cost per thousand square feet of producing cornstalk insulation board in the four feet, eight feet, and twelve feet plants. These costs are based on the best experience at Dubuque, and assuming productions of 46,000, 92,000, and 158,000 square feet of finished board per twenty-four hours. A weight of 635 lbs. per thousand square feet of board is assumed.

The raw material cost is based on a figure of $7.00 per ton for baled cornstalks at the shipping point. Assuming the factory to be located in a good corn producing country, the average hauls for the three size plants would be three miles for the four feet plant, three and a half miles for the eight feet plant, and four miles for the twelve feet plant. This would make the raw material cost per ton for the three plants, $7.45, $7.53, and $7.60.

The cost figures indicate a decided advantage in cost for the larger plants despite the slightly higher raw material costs entailed by the
TABLE X
Cost of building and equipment (including motors and installation) for factories for four feet, eight feet, and twelve feet wide board.

<table>
<thead>
<tr>
<th>Item</th>
<th>For 4' Board</th>
<th>For 8' Board</th>
<th>For 12' Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building * and grounds</td>
<td>$35,000.00</td>
<td>$50,000.00</td>
<td>$66,000.00</td>
</tr>
<tr>
<td>Stacking Machine (1 for 4', 2 for 8', 2 for 12')</td>
<td>600.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
</tr>
<tr>
<td>Bale Handling Equipment</td>
<td>4,000.00</td>
<td>7,000.00</td>
<td>10,000.00</td>
</tr>
<tr>
<td>Bale Breaker</td>
<td>800.00</td>
<td>800.00</td>
<td>800.00</td>
</tr>
<tr>
<td>Magnetic Separator</td>
<td>1,000.00</td>
<td>1,000.00</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Cutting Machine</td>
<td>1,200.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
</tr>
<tr>
<td>Dry Stalk Conveyor, at $4.50/ft.</td>
<td>200.00</td>
<td>300.00</td>
<td>500.00</td>
</tr>
<tr>
<td>Digesters (2 for 4', 4 for 8', 6 for 12')</td>
<td>8,000.00</td>
<td>16,000.00</td>
<td>24,000.00</td>
</tr>
<tr>
<td>Cooked Pulp Conveyor, at $11.50/ft.</td>
<td>600.00</td>
<td>1,000.00</td>
<td>1,200.00</td>
</tr>
<tr>
<td>Rod Mill (4'x10' for 4', 5'x12' for 8', 6'x 14' for 12')</td>
<td>8,600.00</td>
<td>12,800.00</td>
<td>18,600.00</td>
</tr>
<tr>
<td>Rod Mill Sump and Agitator</td>
<td>1,000.00</td>
<td>1,000.00</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Jordan (1 for 4', 1 for 8', 2 for 12')</td>
<td>5,000.00</td>
<td>5,000.00</td>
<td>10,000.00</td>
</tr>
<tr>
<td>Jordan Stock Chest and Agitators</td>
<td>1,000.00</td>
<td>1,000.00</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Forming Machine</td>
<td>2,000.00</td>
<td>2,500.00</td>
<td>3,000.00</td>
</tr>
<tr>
<td>Press</td>
<td>10,000.00</td>
<td>15,000.00</td>
<td>21,000.00</td>
</tr>
<tr>
<td>Dryer</td>
<td>74,000.00</td>
<td>98,000.00</td>
<td>128,000.00</td>
</tr>
</tbody>
</table>
TABLE X Continued

<table>
<thead>
<tr>
<th>Item</th>
<th>For 4' Board</th>
<th>For 8' Board</th>
<th>For 12' Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skid Platforms</td>
<td>$0</td>
<td>$2,700.00</td>
<td>$8,000.00</td>
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<tr>
<td>Automatic Trim and Cut-off Saws</td>
<td>$10,000.00</td>
<td>$12,000.00</td>
<td>$14,000.00</td>
</tr>
<tr>
<td>Router</td>
<td>$600.00</td>
<td>$600.00</td>
<td>$600.00</td>
</tr>
<tr>
<td>Gluing Equipment</td>
<td>$6,700.00</td>
<td>$6,700.00</td>
<td>$6,700.00</td>
</tr>
<tr>
<td>Sander</td>
<td>$5,000.00</td>
<td>$5,000.00</td>
<td>$5,000.00</td>
</tr>
<tr>
<td>Tilt Saw</td>
<td>$500.00</td>
<td>$500.00</td>
<td>$500.00</td>
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<tr>
<td>Stapling Machine</td>
<td>$2,800.00</td>
<td>$2,800.00</td>
<td>$2,800.00</td>
</tr>
<tr>
<td>Boiler and Boiler House Equipment</td>
<td>$4,550.00</td>
<td>$9,100.00</td>
<td>$13,650.00</td>
</tr>
<tr>
<td>Steam Piping</td>
<td>$2,000.00</td>
<td>$3,000.00</td>
<td>$4,000.00</td>
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<tr>
<td>Water and Pulp Piping</td>
<td>$5,000.00</td>
<td>$6,000.00</td>
<td>$7,000.00</td>
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<tr>
<td>Electric Wiring</td>
<td>$6,000.00</td>
<td>$8,000.00</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Resin Equipment</td>
<td>$1,000.00</td>
<td>$1,000.00</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Alum Equipment</td>
<td>$500.00</td>
<td>$500.00</td>
<td>$500.00</td>
</tr>
<tr>
<td>Delivery Truck</td>
<td>$1,000.00</td>
<td>$1,000.00</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Office Equipment</td>
<td>$1,000.00</td>
<td>$1,000.00</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Well and Pump</td>
<td>$8,000.00</td>
<td>$10,000.00</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Washer</td>
<td>$1,000.00</td>
<td>$1,500.00</td>
<td>$1,500.00</td>
</tr>
<tr>
<td>Vacuum Pump</td>
<td>$1,600.00</td>
<td>$2,000.00</td>
<td>$2,500.00</td>
</tr>
<tr>
<td>Two Stock Pumps</td>
<td>$1,000.00</td>
<td>$1,200.00</td>
<td>$1,200.00</td>
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<tr>
<td>Dust Fan, Cyclone, and Collecting System</td>
<td>$1,600.00</td>
<td>$1,800.00</td>
<td>$2,000.00</td>
</tr>
</tbody>
</table>

$215,550.00 $292,900.00 $381,750.00

* Building cost is figured at $1.25 per square foot of floor space.
## TABLE XI

Cost Per Thousand Square Feet of Producing Cornstalk Insulation In Four Feet, Eight Feet, and Twelve Feet Plants.

(Cost of board in standard sizes, unsanded.)

<table>
<thead>
<tr>
<th>Plant</th>
<th>46,000 sq.ft. capacity per 24 hours</th>
<th>92,000 sq.ft. capacity per 24 hours</th>
<th>138,000 sq.ft. capacity per 24 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>4' Plant</td>
<td>8' Plant</td>
<td>12' Plant</td>
<td></td>
</tr>
</tbody>
</table>

### Raw Material: (780 lbs. board per ton of raw materials)

- **Cornstalks**: $7.45, $7.53, and $7.60 per ton delivered
  - 4' Plant: $6.06
  - 8' Plant: $6.12
  - 12' Plant: $6.19
- **Alum**: $0.01185/lb. delivered
  - 4' Plant: 0.49
  - 8' Plant: 0.49
  - 12' Plant: 0.49
- **Rosin**: $0.03245/lb. delivered
  - 4' Plant: 0.66
  - 8' Plant: 0.66
  - 12' Plant: 0.66

### Management:

- **Manager**: $5,000 per year for 4' and 8' plants, $5,000 per year for 12' plant
  - 4' Plant: $0.76
  - 8' Plant: $0.18
  - 12' Plant: $0.15
- **Asst. Mgr.**: $2,400 per year
  - 4' Plant: $0.09
  - 8' Plant: $0.09
  - 12' Plant: $0.06
- **Night Superintendent**: $2,400 per year
  - 4' Plant: $0.17
  - 8' Plant: $0.09
  - 12' Plant: $0.06
- **Maintenance Superintendent**:
  - 4' Plant: $2,400 per year
    - 4' Plant: $0.70
    - 8' Plant: $0.45
    - 12' Plant: $0.33

### Labor: (Operating and maintenance)

- **Yard**: 2 men $0.35 for 4', 8', 4 men for 12' plant
  - 4' Plant: $0.37
  - 8' Plant: $0.19
  - 12' Plant: $0.25
- **Shredding**: 1 foreman $0.50 (for yard and shredding)
  - 4' Plant: 0.26
  - 8' Plant: 0.13
  - 12' Plant: 0.09
  - 1 man $0.35 for 4', 2 men for 8' and 12' plants
  - 4' Plant: 0.18
  - 8' Plant: 0.18
  - 12' Plant: 0.12
Labor: (continued)

<table>
<thead>
<tr>
<th>Activity</th>
<th>1st week</th>
<th>2nd week</th>
<th>3rd week</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cooking</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 foreman</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 men</td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.26</td>
<td>0.13</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td><strong>Refining</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 man</td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 men</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.19</td>
<td>0.10</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td><strong>Forming and Pressing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 man</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.24</td>
<td>0.12</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td><strong>Drying</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 man</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.24</td>
<td>0.12</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td><strong>Sawing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 foreman for sawing and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shipping</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.26</td>
<td>0.13</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>3 men</td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.55</td>
<td>0.28</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td><strong>Warehousing and Shipping</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 men</td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td><strong>Boiler House</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 fireman</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 helper</td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.26</td>
<td>0.13</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 electrician</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 electrician's helper</td>
<td>0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 mechanic</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 mechanic's helper</td>
<td>0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.30</td>
<td>0.15</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>1 carpenter</td>
<td>8.00/24 hrs.</td>
<td>0.17</td>
<td>0.09</td>
</tr>
<tr>
<td>1 janitor</td>
<td>0.35 for 8' and 4' plants, 2 for 12'</td>
<td>0.19</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Clerical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$30.00 per week for 4'</td>
<td>0.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$50.00 per week for 8' and 12'</td>
<td>0.09</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td><strong>Coal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$3.85 per ton delivered</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td><strong>Fuel Oil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.06 per gallon delivered</td>
<td>1.05</td>
<td>0.92</td>
<td>0.88</td>
</tr>
<tr>
<td><strong>Depreciation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>1.56</td>
<td>1.06</td>
<td>0.92</td>
</tr>
</tbody>
</table>
### TABLE XI Con't.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maintenance Material</strong></td>
<td>$0.36</td>
<td>$0.36</td>
<td>$0.36</td>
</tr>
<tr>
<td><strong>Power</strong> (based on assumption of 80% load factor and 1.25 per K.W.H. rate)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bale Breaker - 20 HP</td>
<td>$0.08</td>
<td>$0.04</td>
<td>$0.03</td>
</tr>
<tr>
<td>Cutter - 60 HP</td>
<td>0.24</td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td>Hod Mill - 50, 100, 150 HP</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Jordan - 150, 250, 2 - 200 HP</td>
<td>0.60</td>
<td>0.49</td>
<td>0.52</td>
</tr>
<tr>
<td>Vacuum Pump - 30, 50, 75 HP</td>
<td>0.12</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Dryer - 50, 75, 100 HP</td>
<td>0.20</td>
<td>0.16</td>
<td>0.13</td>
</tr>
<tr>
<td>Saws - 20, 30, 40 HP</td>
<td>0.08</td>
<td>0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>Other Motors - 90, 105, 125 HP</td>
<td>0.37</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Miscellaneous: (Insurance, Taxes, Postage, etc.)</strong></td>
<td>$0.07</td>
<td>$0.07</td>
<td>$0.07</td>
</tr>
</tbody>
</table>

#### RECAPITULATION

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Material</td>
<td>$7.21</td>
<td>$7.27</td>
<td>$7.34</td>
</tr>
<tr>
<td>Management</td>
<td>0.70</td>
<td>0.45</td>
<td>0.33</td>
</tr>
<tr>
<td>Labor</td>
<td>4.69</td>
<td>2.96</td>
<td>2.43</td>
</tr>
<tr>
<td>Clerical</td>
<td>0.11</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>Coal</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>1.05</td>
<td>0.92</td>
<td>0.88</td>
</tr>
<tr>
<td>Depreciation</td>
<td>1.56</td>
<td>1.06</td>
<td>0.92</td>
</tr>
<tr>
<td>Maintenance Material</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>Power</td>
<td>1.89</td>
<td>1.36</td>
<td>1.30</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$18.84</td>
<td>$15.74</td>
<td>$14.89</td>
</tr>
</tbody>
</table>
longer hauls. There are certain conditions, however, which might make the smaller plants the more economical. For example, a plant might be built in the same locality as a refrigerator manufacturing plant, and of the right capacity to supply its requirements for refrigerator insulation. The freight saving on shipment of finished board in such a case might materially offset the advantages of more economical operation in the larger plants. Also, a small plant would have better opportunities to work out shipping schedules with the farmers from whom the stalks are bought which would make it possible to do away with the necessity for storing huge piles of stalks at the factory. This would result in a considerable saving in the cost of raw material handling.
MODIFIED PROCESS

The process now in use at Dubuque is a modification of the above outlined process. The chief changes are, (1) the cooking process is modified to a two hour period of soaking the shredded stalks in water at one hundred and fifty degrees Fahrenheit; (2) old newspapers are soaked in water, put through a Smalley cutter, and are added to the pulp in No. 1 stock chest to the extent of twenty percent of the weight of finished board; (3) a Bauer refiner is added following the Jordaning treatment to insure removal of all coarse pieces of fibre.

The board produced by this process has a light gray color compared to the brown color of the board produced by the more drastic cooking process. The two boards are very similar from the standpoint of strength, weight, and thermal conductivity. By varying the paper content and press pressure, boards may be produced ranging from very weak, light, highly insulating boards, suitable for refrigerator construction, to strong, dense boards for building purposes. Boards have been made ranging in modulus of rupture from 100 to 700 pounds per square inch, and from 0.375 to 0.900 lbs. per square foot of one-half inch thick material, in weight. The yield of board by the new process is about 2,000 square feet per ton of raw material to 1,230 square feet for the old process. The power requirements are slightly higher. Less steam is used because of the less drastic cooking. The plant cost is lower because of the substitution of low priced digestion tanks for the rotary pressure cookers, and because of the smaller steam plant required. The cost of a twelve feet plant for producing the
new process board would be about $352,000.00, and the cost of producing
the board would be about $12.00 per thousand square feet.
SUMMARY AND CONCLUSIONS

Semi-commercial scale work carried out in the Chemical Engineering Department at Iowa State College, and operations of the Malwood Products Corporation factory at Dubuque, Iowa, have demonstrated conclusively that insulation board of a wide range of qualities and meeting the requirements of the market may be produced from cornstalks. The best process as worked out at Dubuque, is, roughly, the bales are put through a bale breaking machine to roughly break them apart; the roughly shredded material is passed over a magnetic separator to remove tramp iron; it is then put through a cutter; given a cooking treatment; washed; shredded; washed again; paper (which has been soaked and put through a Smalley cutter) is added, or not, according to the type board desired; the mixed cornstalks and paper pulp is put through a Claflin; Jordan; and through a Bauer if additional refining is desired. It is then formed, pressed, dried, sawed, and sprayed with water to give it its equilibrium moisture content. Work at Ames has indicated that a rod mill can be substituted for the shredder, Claflin, and Bauer. This machine has not been tried at Dubuque, however.

Cost figures indicate that board may be produced more economically in a plant having a capacity for 138,000 square feet per twenty-four hours than in a smaller plant. The cost of a plant of this size for producing cooked pulp board is about $351,750.00, and the cost of producing the board is about $14.89 per thousand square feet. The cost of a plant for the new process board containing newspring, and the cost of producing the board, is $352,000.00 and $12.00 respectively.

At prevailing market prices these cost figures would allow cornstalk insulation board to compete on a favorable basis with other similar products.
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The process of making Masonite Insulation board is described
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22:223. 1930.
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A description of the properties and uses of "Weatherwood", a wood fibre insulation board.


A board having a density ranging from two to four pounds per cubic foot was made from cornstalk pith.


An account of experimental work to determine the optimum conditions for the production of a hard pressed dense board from cornstalks.


