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APPROPRIATE TECHNOLOGY FOR THE MANUFACTURE OF PULP AND PAPER PRODUCTS

APPROPRIATE TECHNOLOGY FOR A LOW-COST PAPER PROJECT TO BOOST THE RURAL ECONOMY

Background Paper

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APPROPRIATE TECHNOLOGY FOR A LOW-COST PAPER PROJECT TO BOOST THE RURAL ECONOMY

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ABSTRACT

A project to manufacture liner board and corrugating medium to produce corrugated box containers has been identified as essential to boost the rural economy of developing countries. The appropriate technology for this industry is based on the use of agricultural residues for pulp production, the use of less steam, water and energy for processing, simple process techniques suitable for ease of operation and maintenance, flexibility of operational systems and reduction of pollution load. Since this project is based on agricultural residues, it will have far reaching socio-economic benefits to the rural communities of developing countries.

INTRODUCTION

Developing countries largely depend on the import of paper from countries that produce pulp from coniferous woods. In view of the increasing demand for paper and paper products on a world wide scale and constraints placed on these paper exporting countries due to ecology restrictions, high cost of labor for wood extraction and high transport costs, this source of supply of pulp, paper, and paper products cannot be fully relied upon as a long term measure. In other words, developing countries have to do some rethinking and explore possibilities of using indigenous fibre resources to meet a greater portion of their own requirements. Developing countries are mostly agriculture oriented and it is possible for them to use some of the agricultural residues, various annual crop plants, etc., to develop the paper industry in their own countries.

It is also noted that developing countries, on the other hand, have certain limitations and there is a need for the use of appropriate technology to meet these limitations.

This paper, therefore, outlines a pulp and paper project that could be developed taking into account the general limitations of developing countries and the need to boost their rural economy. The guidelines followed by the writer for this project is basically as follows:

1. Input of raw materials in the form of agricultural residues and annual crop plants for the manufacture of paper, so as to provide an income to the rural communities.
2. Gainful employment of a large proportion of agricultural labor, both directly and indirectly, in the industry, so that their income could be either supplemented or improved.
3. Use of less capital intensive equipment and methods so that there could be more labor employed, wherever possible, thereby reducing capital cost.
4. Selective use of technology so that it fits into the socio-economic aspirations of the country but would not fall short of the standards in producing a product to match today's society.
5. Selective technology that would require comparatively less fuel and less electric energy to produce a ton of paper as most developing countries are relatively short of these resources.
6. Selective technology that would require less water per ton of paper and would also employ such methods that would result in the effluent water becoming suitable for irrigation purposes, since developing

countries, more often than not, suffer from a shortage of water.

GRADES OF PAPER MOST ESSENTIAL TO BOOST RURAL ECONOMY

According to the Lima Declaration and Plan of Action, at least 25% of the world's industrial production should originate in developing countries by the year 2000. In implementing this plan of industrialization, the pulp and paper industry is expected to play a major role in providing packaging grades of paper for various industries. In a developing country, where the industries would be more agriculture-oriented, the manufacture of liner board and corrugating medium would receive priority over other grades of paper. The rural economy, which is mainly dependent on various types of farming and have products such as vegetables, fruits, dairy products, eggs, poultry, meat products, fish, shrimps, etc., requires corrugated containers for the packing and transport of these agricultural goods either to the domestic or export market. Although developing countries have traditionally used wood and containers made with leafy material, modern technology for the preservation, storage and transport of food and the marketing of these products would call for the use of corrugated containers. This paper, therefore, examines the appropriate technology that has to be applied in a developing country to manufacture these two grades of paper i.e., liner board and corrugating medium.

RAW MATERIALS

Agricultural Residues

The raw materials available for pulp production in the form of agricultural residues and agricultural crop plants are as per Table 1. It will also be seen from Column 4, these materials are most suited only for certain particular grades of paper. The choice of raw materials for manufacturing different grades of paper depend largely on three factors:

1. Suitability for quality, based mostly on the fibre characteristics of the raw material.
2. Availability in quantity to make it feasible for collection and usage on a commercial scale.
3. Production cost factors such as yield of pulp per ton of raw material, cost of processing, such as chemicals, input of energy, etc.

Based on all these techno-economic factors, bagasse and straw have found wide acceptance commercially as agricultural residues suitable for a number of cultural and industrial grades of paper. However, agricultural residue pulp would need a blending with other types of pulp for quality as well as economic reasons. Coniferous wood pulp or other long fibre pulp is blended with straw or baggasse pulp to improve the runnability, and obtain the required strength properties while manufacturing light weight printings, writings, kraft paper grades, etc. Secondary fibre produced from waste paper, on the other hand, is used as part of the fibrous furnish in almost all grades of paper board as well as some grades of paper, to

TABLE 1

Agricultural Residues and Crops Considered

Suitable for Paper Manufacture

Type	Technological Feasibility	Economic Feasibility	Suitable Paper Grades
Baggasse	Feasible (C)	Feasible to most developing countries.	Newsprint, Writings, Printings, Kraft grades, Brown board and other types of board.
Straw (wheat, rice, barley, oats)	Feasible (C)	Feasible to most developing countries.	Writings, Printings, Liner board, Corrugating medium and other types of board.
Maize Stalk	Feasible (C)	Feasible to most developing countries. Some limitations due to storage.	Liner board, Corrugating medium and other types of board.
Sisal	Feasible (L)	Feasible to certain developing countries.	Hard tissues, Cigarette tissue.

Cont'd - Table 1

Sun Flower Stalk	Feasible (L)	Feasible for certain developing countries. Some limitations due to high pith content.	Liner board grades and Corrugating medium.
Cotton Stalk	Feasible (L)	Feasible for certain developing countries.	Corrugating medium.
Date Palm Leaves	Feasible (L)	Feasible for only certain developing countries. Some limitations due to poor yield.	Brown board, Bag paper.
Banana Stems	Feasible (L)	Feasible for certain developing countries.	Hard tissues, Specialty grades.
Pineapple Leaves	Feasible (L)	Feasible for certain developing countries.	Liner board and Corrugating medium.
Common Hemp (Cannabis Sativa)	Feasible (C)	Feasible for certain developing countries.	Hard tissues, Cigarette paper, Specialty grades, etc.

Cont'd - Table 1

Sorghum (Sorghum-Vulgare)	Feasible (L)	Feasible for certain developing countries.	Liner board and Corrugating medium and other types of board.
Sunn Hemp (Crotalaria-Junicea)	Feasible (C)	Feasible for certain developing countries.	Hard tissue, Cigarette paper, Specialty grades.

C - Commercially operated basis.

L - Laboratory work basis.

reduce the cost of fibrous furnish.

Waste Paper

As referred above, the use of waste paper is emphasized for economic reasons. By increasing the use of waste paper it would be possible to reduce the capacity of the pulp mill and thereby reduce the capital cost on pulp mill equipment. The operating cost too, would be reduced due to the replacement of virgin fibre with secondary fibre resulting in savings on account of chemicals, less use of steam and electric energy.

A further economy is possible in the manufacture of corrugating medium since all type of trimmings and common waste could be used along with agricultural residue pulp.

Collection and Usage Also a Social Benefit

From the socio-economic angle the collection of waste paper could generate employment at the unskilled level and is of particular interest to the disabled and aged who need light work. Developing countries with no positive social security measures could use the collection and sorting of waste paper as a means to provide gainful employment and income to the handicapped and the underprivileged.

Raw Materials for Long Fibre Pulp

The use of agricultural residues requires a blending of long fibre pulp to give the required strength characteristics to the paper produced. The percentage blended would depend on the end use of the particular grade of paper. Sack kraft for

packing cement may require as much as 50% of long fibre pulp for blending with agricultural residue pulp, liner board may require only about 20%, and corrugating medium could be made with no blending of long fibre pulp. Developing countries are usually deficient in coniferous species such as spruce, pine, fir, hemlock, etc., to produce the commercially developed long fibre pulp. There are a few agricultural crops that could provide the long fibre pulp for developing countries, such as Sunn Hemp, Sisal, Common Hemp, Abaca Stem, Banana Stem, Jute, etc., but economic factors such as limited availability in terms of quantity, low yield of fibre per acre, and the high cost of preparing the raw material (prior to cooking such as retting) limit the use of these materials to only speciality grades of paper such as cigarette tissues, carbonizing tissues, bible paper, etc.

Kenaf:- In recent years, work done on kenaf (HIBISCUS CANNABINUS) indicates the possibility of substituting this pulp in place of long fibre wood pulp. This is of particular interest to such developing countries where kenaf could be grown easily and are at present facing problems in the import of wood pulp due to unfavourable foreign exchange or high cost of imported wood pulp.

Plantation Wood:- Besides kenaf as a substitute for imported long fibre pulp, it is also possible to develop man-made forests in the growing of poplar, pinus species, etc. Experimental plantations in the growing of these coniferous species have shown encouraging results in tropical countries.

Boosting of Rural Economy through Wood Plantation:- In order to boost the rural economy, the growing of kenaf and the creation of man-made wood plantations using high yield forestry techniques have to be introduced. Wood plantations in particular are emphasized as this will not only help the pulp and paper industry, but would improve the overall economy of the country in providing lumber for a number of wood based industries.

SELECTION OF PULPING PROCESS

There are five well-known processes for the production of pulp from agricultural residues:

- Lime Process
- Pomilio Process
- Neutral Sulphite (semi-chemical)
- Kraft
- Soda

Besides these processes there are several other less known processes available. They are not being discussed here due to the limted value they have in the application of appropriate technology to developing countries.

Lime Process:- This is an old process based on the use of lime as the sole cooking agent. Some mills have used this process for manufacturing corrugating medium. This process has become obsolete as modern technology is replacing equipment such as spherical digesters, drainers, and beaters which are used for this process. This process could be, however, considered for the manufacture of yellow straw board on a small scale to improve rural economy in developing countries, but

will not be suited for the manufacture of liner board and corrugating medium to make corrugated containers to meet present day packaging standards.

Pomilio Process:- This process was mainly developed for use with agricultural residues. It is now considered uneconomic due to high consumption of chemicals and high maintenance costs on account of corrosion problems in the use of chlorine.

Neutral Sulphite Semi-chemical process is also a well-known process particularly for producing corrugated medium from both hardwoods as well as softwoods. Neutral sulphite is being used by some mills as a chemical process for agricultural residues to produce bleached pulp. Although neutral sulphite could be considered for making brown board, an evaluation of this process with the soda process does not merit its choice as this would increase the capital requirements for the preparation of sulphite liquor through the use of sulphur burner. One other reason for omitting neutral sulphite cooking would be to reduce pollution problems through sulphur free cooking.

Kraft Process, although widely used in wood pulping to produce kraft liner board, has marginal advantages when used on agricultural residues. When comparing the capital cost of a pulp mill, the soda process has advantages over the kraft process due to simplicity and low capital requirements. Another key point to support soda pulping would be the advantages on pollution control due to sulphur free cooking.

Soda Process has been found to have advantages over all the other processes mentioned above for the production of both

liner board and corrugating medium due to the simplicity of the process, sulphur free cooking, and economic advantages, and is, therefore, more appropriate to developing countries.

YIELD AND ECONOMY

The higher the yield of pulp, the better the economy both from the point of capital investments as well as operation costs. In the manufacture of paper grades to produce corrugated board and corrugated containers, two types of pulp have to be produced with different yields. Corrugating medium is produced from agricultural residues with a yield of about 70%-75% and linor board is produced with a yield of 55%-60%. Although an improvement in the above specified yields could be made that could improve the economy, it is found this results in lowering the physical strength properties of the paper.

BATCH vs CONTINUOUS COOKING

For the cooking of agricultural residues both batch digesters as well as continuous digesters are used. Mills that use the batch digesters claim better flexibility of operation particularly if different types of raw materials are planned to be used. In addition, batch digesters are claimed to reduce time if maintenance work has to be done on the different digesters.

The continuous digesters normally available for agricultural residues are both the horizontal multi-tube type as well as the vertical tower type, but the horizontal type has been widely accepted. The advantage of using the continuous digesters would be savings in equipment cost and operating

economy through less use of steam and energy. Besides economy, continuous cooking gives a better process control and quality control of the pulp produced compared to batch digesters.

Further Application of Appropriate Technology by Cooking at Atmospheric Pressure

The conventional type of digesters described above, both batch as well as continuous, are pressure digesters. Generally, agricultural residues are cooked in pressure type of digesters using steam at 6 to 7 kg/cm^2. Pulp suitable for the manufacture of packaging grades such as liner board, corrugating medium, etc., could be cooked at nearly atmospheric pressure with a temperature of about 85° to 100° C. The digester used for cooking agricultural residues at low temperatures is somewhat similar to the multi-tube horizontal digester. The digester has five functional zones:

1. Impregnation Vessel-For mixing of both white liquor and black liquor with the raw material.
2. Pre-cooking Tube-For the intimate mixing of chemicals. (Steam could be admitted, if needed.)
3. Cooking Tube-Material is heated up to 100° C and a double screw working counter-clockwise, gives mechanical action to the material while being cooked. (Heating is indirect.)
4. After Cooking Tube-Continued agitation to the raw material but reduced to one screw action.
5. Extractor Press-Partial separation of warm black liquor for recycling back into the impregnator vessel.

Since the digester is designed to work at very low temperature/pressure, the capital cost is relatively low. The digester is compact and requires less building space. There is operating economy through less usage of steam. A high percentage of black liquor gets recycled, reducing the pollution load.

BROWN STOCK REFINING AND HIGH YIELD

In producing high yield pulp from agricultural residues, the cooking action has to be followed up almost immediately with a gnetle fiberizing treatment to obtain a yield of about 70% to 75%. Since the inter-fibre bonds of agricultural residues are not so strong as in the case of woody materials, this fiberizing action could be done with less energy and with light conical refiners. The use of agricultural residue pulp, therefore, results in savings, in terms of both capital as well as operational costs. For example, the power requirements for agricultural residues is approximately 30 to 40 KWH/ton compared with 150 to 300 KWH required for some of the woody materials widely used in the developing countries.

WASHING AND SCREENING

Washing of brown pulp to remove the spent chemicals and the dissolved non-cellulosic substances is mostly done in mills by using vacuum washers. Agricultural residues have poor drainage properties and in consequence the vacuum washers, which work on the filteration principle, have to be relatively large requiring more capital investment. The appropriate processing method for this function would be the use of a two

screw system which works on the principle of press washing. The advantages of using the press washing system, in preference to filter washing, for agricultural residues to produce brown board would be:

1. Less capital needed for equipment.
2. Reduction in floor space.
3. Possibility to operate at high consistency.
   (i.e., inlet consistency to press 10% to 12% and outlet consistency 38%.)
4. Higher washing efficiency.
   (Press washing gives better results on agricultural residue pulp.)
5. Foaming problems are avoided.

The pulping system considered for the manufacture of brown board (i.e., liner board and corrugating medium) would not require the use of centrifugal screens, pressure screens, centricleaners, thickeners, etc., at this stage, resulting in considerable savings in capital cost. The brown pulp, therefore, is ready at the end of the two stage press washing to be pumped to the paper mill for the manufacture of brown board.

CHEMICAL RECOVERY SYSTEM

The scale of operation considered for a project of this nature in a developing country would be a maximum of about 80 to 100 tons of paper per day to effectively support the rural economy. This scale of operation would keep pace with the limits that are usually encountered in the collection and transportation of agricultural residue. The estimated capacity of a pulp mill to produce 80 to 100 tons of paper board

as part of the fibre furnish along with waste paper and imported long fibre pulp would be approximately 50 tons per day.

The recovery of chemicals for a production capacity of 50 tons per day of pulp, based on agricultural residues, have both technical and economic limitations and is, therefore, not normally considered for a project of this nature. The black liquor chemicals, as discussed earlier, is recycled for cooking because it has relatively less organic substances and a high inorganic chemical content.

The handling of the effluent from such a type of pulp mill without a chemical recovery system would be discussed under effluent treatment.

STOCK PREPARATION SYSTEM

Agricultural residues such as bagasse and straw produce a type of pulp that could be called "energy savers" since they require very little mechanical treatment to produce the paper. For example, the energy requirement for wood pulp could average between 300 to 400 KWH per ton, whereas straw pulp would require about 75 to 100 KWH per ton. The capital cost necessary for equipping the stock preparation section would, therefore, be relatively low.

Treatment of Agricultural Residue Pulp

The fibres, as discussed earlier, are short and would need a gentle brushing action which is generally done in conical refiners. It may be possible at times to skip the refining needed for agricultural residues entirely, and give a brushing action at the finishing stages of the blended pulp ahead of

the machine.

Treatment of Waste Paper

The pulper for the treatment of waste paper would be equipped with a junk remover and ragger since mixed waste paper would be used along with agricultural residue pulp, for manufacturing corrugating medium. The waste paper used for liner board would be sorted and would mainly contain kraft grades, container waste, envelope trimmings, etc., to give the required strength characteristics. Besides the pulper for slushing the waste paper, the treatment plant would be equipped with a high density cleaner and a vibration screen. High cost and high energy consuming low density cleaners, centrifugal screens, etc., would not be necessary at this stage of the processing for the manufacture of both corrugating medium and liner board.

Treatment of Long Fibre Pulp

Disc refiners have the advantages of high efficiency and versatility for the treatment of long fibre pulp produced from wood. The free atmospheric discharge type of refiners have been largely replaced by the totally enclosed pressurized type. On account of the high skill needed in the maintenance of this equipment and the complexity of spares needed, it will be advantageous to use conical refiners instead of disc refiners for a project of this nature. The tackles have to be carefully chosen so as to avoid a cutting action to the fibre and to give a suitable treatment so that the short fibred agricultural residues blended with long fibre pulp would give the necessary strength characteristics to the brown board.

Blending of Fibrous Stock and Paper Making Additives

In the manufacture of liner board, stock would be prepared for delivery, both through the primary head box and through the secondary head box.

The blending of stock varies from mill to mill and changes are often made depending on operating conditions. However, a typical furnish could be as follows:

Primary Stock:- 40% Secondary fibre (Waste paper).
35% Agricultural residue pulp.
10% Long fibre pulp.

Secondary Stock:- 15% Long fibre pulp.

By using the secondary head box arrangement (which is described later under 'paper machine'), flexibility could be obtained to make bleached liner, jute liner, or kraft liner board depending on the nature of the end use of the corrugated containers.

The corrugating medium would be made as one single layer with the entire stock being supplied through the primary stock. The typical furnish would be:

60% Agricultural Residue Pulp.
30% Waste Paper.
10% Long Fibre Pulp.

Due to the charecteristics of agricultural residues, they require very little sizing. Alum requirements are generally high to maintain low pH, to prevent picking on the press rolls.

PAPER MACHINE

The continuous sheet formation of paper could be done in different ways depending largely on drainage conditions such as speed, basis weight, characteristics of the paper-stock, etc. The different forming methods could be briefly summarized as follows:

- Open wire forming -fourdrinier type.
- Cylinder machine forming.
- Suction breast roll forming.
- Twin wire forming.

The manufacture of liner board and corrugating medium could be done on all formers referred to above, except the suction breast roll former which has a short forming length and was specially developed to produce tissue grades at high speed.

The fourdrinier type of formation has wide flexibility and the control of operation is much simpler. Another major advantage is the large drainage capacity it has compared with the other forming methods in practice today.

The cylinder type of formation is largely applied to the manufacture of paper board, requiring multilayer board formation. These machines have limitations on speed due to centrifugal forces acting on the cylinder former. Another operation problem is the disturbance caused to the mat formed on the cylinder by the washing action. These problems have been largely overcome by the use of suction forming cylinders. Although the flexibility to make different grades with different furnish components is available on a cylinder machine for

various types of paper board, the large drainage capacity required for agricultural residue pulp and the simple operational adjustments that could be made to alter the drainage capacity is not available on the cylinder machine. Another disadvantage on the cylinder machine is the "pick-up felt" system which gets fouled up easily when using agricultural residue pulp.

The twin wire formers have gained importance in recent years over the fourdrinier due to advantages such as:

- High speed.
- Better uniformity (less two sidedness).
- Better formation compared to fourdrinier.
- Less space requirements.
- Less energy requirements.

In the search for an ideal former to replace the fourdrinier, different machine builders have different twin wire forming arrangements and there are pros and cons for each of these arrangements. Twin wire formers are successfully used in the well developed countries, mainly for high speed and high production. However, the appropriate technology for a developing country would emphasize the use of a fourdrinier due to the simplicity of its operation and maintenance, flexibility to make different grades with different types of furnishes, and its high dreinage capability, which is an essential element for producing paper from agricutltural residue pulp.

SPECIAL FEATURES NEEDED ON THE FOURDRINIER MACHINE

The fourdrinier machine in a developing country has to be flexible to a greater extent than in a developed country mainly due to market conditions. For example, a developed country would make liner board and corrugating medium on separate machines and in the making of liner board flexibility may not be required to make different grades of liner board. Developing countries, on the other hand, will have to make the corrugating medium as well as all the different grades of liner board on one machine such as kraft liner, jute liner (cylinder liner) and bleached kraft liner. The machine features required, therefore, have to cover a wide range of grades and a wide range of basis weights (i.e., 60 to 130 g/m^2 for corrugating medium and 100 to 300 g/m^2 for liner board). Besides all these design features, there are other important aspects needed to be considered while using agricultural residue pulp. This section of the paper will, therefore, concentrate on such special features.

Stock Approach Systems

The stock approach from the machine chest to the head box, the back water, and the broke systems, requires a careful design arrangement considering two problems:

- Susceptibility to heavy slime build ups.
- High tendency for air entrainment in stock.

Although the above problems are generally common to all types of stock, it could be said agricultural residues have more serious problems compared with other types of stock and

a concentrated effort is needed in the designing of the stock approach system to avoid problems such as channelling, settling, excessive turbulence, air pockets, dead stock, etc.

Head Box

The machine has to be provided with two head boxes (i.e., primary and secondary) for the following reasons:

1. To manufacture different grades of liner board.
2. To produce the required strength properties using minimum long fibre pulp as top liner.
3. To provide better appearance by effectively hiding the specks that result from high yield agricultural residue pulp.
4. To provide a better printing surface.

Secondary Head Box or "Strata Flow" Head Box

Technology is presently available to replace the function of a secondary head box by the use of a single head box employing the "strata flow" system. This type of head box could provide a three channel flow to the paper machine with capability to deliver three different type of stocks to the machine. By using such head box, it is possible to make a two ply or three ply liner board. The adoption of such technology could be only recommended to such developing countries that are fairly well advanced in technology as the operating of such a system requires higher skill.

Wire Part

Agricultural residue pulps are characterized by slow

drainage and would require at least 25% more forming length compared to conventional machines designed for working on wood pulp. Operating experience also indicates wires made out of synthetic fabrics have less tendency to get filled up and have therefore, better drainage capability than phosphor bronze wires. Based on experience it could be said "foils" provide a better removal of water. The wire part also requires additional suction boxes compared to a conventional machine.

Press Part

Problems often experienced with agricultural residue pulp is "felt crushing" particularly at the first press where the moisture content in the web is higher than the other presses following it. Synthetic felts with more open structure have been helpful in providing better removal of water at the presses, with reduced felt crushing. On machines where plain rolls were used for the first press, replacement with a suction roll at the bottom position was found to be helpful.

Another problem associated with agricultural residue pulp is "press sticking" and web breaks. The use of "granite" rolls resulted in better results than "stonite" rolls in the top position. Still better results were obtained by using "self skinning" rolls in place of "granite" rolls.

The provision of a "crumb" doctor for the first and second press doctors was also found to be helpful.

Most of the web breaks take place in the press section (i.e., between the couch and the first drying cylinder) due to the poor wet strength of the web made with agricultural residue pulp. Although the number of breaks would be

relatively low in corrugating medium and liner board due to high basis weights, consideration should be given while designing the press section to avoid long stretches of unsupported wet web length. Another important factor would be the degree of the "take-off angle" to prevent strain on the web.

A multinip press arrangement for the first and second presses, with pick-up transfer from the couch, are considered advantageous to the manufacture of paper from agricultural residue pulp.

Felts on the press section tend to get filled up and dirty due to a high content of "fines" present in the agricultural residue pulp. The press section therefore, has to be provided with adequate felt cleaning equipment. Better results were obtained by using a "wringer press" along with felt cleaning equipment such as "Uhle" boxes and "Vickery" shoe cleaners.

Agricultural residue pulp, due to fines and silica matter, tends to fill up the suction rolls more easily than wood-pulp. These rolls have to be provided with high pressure showers that could give a periodic wash on the "run."

Dryer Section

For the manufacture of paper and paper board from agricultural residue pulp, the dryer section has to be divided into more groups. This gives better operation control in relation to draws and shrinkage. The dryer section also requires separate controls for the top and bottom cylinders in the last group, after the size press, to control curl.

On account of the "fuzz" problem normally experienced with agricultural residue pulp, it is advantageous to operate the machine without a felt for the first group (bottom cylinders).

The dryer section could be designed to eliminate the use of "felt dryers" since conventional type felts could be replaced with high permeable dryer screens. The use of dryer screens results in better drying efficiency and profile. The dryer section too would require the use of pocket ventilators. This results in about a 35% increase in drying capacity and will also give a more even profile. Obtaining a more even profile is essential to reduce breaks and this is all the more important while using agricultural residues which have a higher tendency for paper breaks.

Size Press

The use of a size press enhances the possibility of giving different characteristics to the liner board produced on the machine. This is an important feature to a developing country where diversification in quality required is great but the market is small.

Another important value of the size press is the possibility to improve certain strength characteristics. Liner boards made with agricultural residue pulp could be reinforced in strength properties by giving appropriate surface treatment.

Machine Drive

The prime mover needed to drive the machine could be either electric or steam. If the overall economy and the

steam balance of the specific mill are favorable, it would be advisable for a mill in a developing country to choose steam instead of electricity for the paper machine drive. The electric supply in a developing country, which is dependent on an outside source of supply, has several drawbacks, such as frequent outages and voltage fluctuations, that interfere heavily with the operation of the paper machine.

INSTRUMENTATION

Paper making was largely manually controlled, where the operator made use of his senses (i.e., hearing, sight, smell, and touch) for process control work. This system has undergone a rapid change and now digital computers are being used in some mills to control a number of important paper making variables.

For the application of process control through instruments in a developing country, a careful evaluation is necessary to determine how much instrumentation is actually necessary to suit the local conditions. The extreme point of working on human senses is not feasible to meet present day quality standards and efficiency, whereas excessive instrumentation for developing countries has problems related to the displacement of employment possibilities as well as lack of skill to maintain and operate some of the sophisticated control equipment.

Developing countries should generally concentrate on applying process control instruments to some basic functions such as consistency, flow rate, temperature, and pressure controls

in selected areas.

WATER SUPPLY FOR THE MILL

Availability of water in large quantities is an important factor for the production of pulp and paper. A pulp and paper mill in a developing country based on agricultural residues, would be dependent on a source of water supply common to both the farmer and the paper mill. This could be a small river, or lake, or an irrigation facility. Due to the competitive nature of water usage for both agriculture and industry (particularly in tropical countries), the farmer normally expects an economy in the use of water by the paper industry as he always makes the claim, "I was here first."

Besides the economy exercised due to the competitive use of water by the farmer and the industry, there are other reasons for controlling the use of water such as:

- Reduction in fibre loss.
- Reduction in size and cost of external treatment plant.

This section will therefore, examine the methods that could be adopted to reduce the consumption of water.

Pulp Mill

The pulping technology described earlier is provided with features that could result in water economy such as:

- Counter current and high consistency washing (press washing).
- Recycling of black liquor for cooking.
- Usage of paper mill water for washing and dilution of stock. (clarified water from the save all)

The water requirements of the pulp mill based on this system would be 4.6 m^3/ton compared to 120 m^3/ton in a conventional type of mill.

Paper Mill (Closing the Water System)

Some of the measures that could be adopted on the paper machine to close up the system and economize on the use of fresh water would be as follows:

1. Proper allowance for "white water" storage capacity to meet the high and low swing demands and prevent overflow.
2. Reuse of cooling water from cooling cylinder, calenders, lubrication oil cooler, etc.
3. Control of sealing water to pumps and agitators, wherever it is possible, by using a reducing washer and a flow indicator.
4. Recirculation of sealing water from vacuum pumps, using a cooling tower for temperature control.
5. Examine possibility of using clarified water for low pressure showers on pres felts.
6. Use of clarified water for wire showers (except the high pressure wire, cleaning shower and breast roll shower).

A closing up of the system as suggested above could reduce the fresh water usage to about 35 m^3/ton compared with 90 m^3/ton to 120 m^3/ton for a conventional mill.

EFFLUENT WATER FOR IRRIGATION AND SUSPENDED SOLIDS FOR THE PRODUCTION OF SOLID BOARD

As discussed earlier, a paper mill project based on agricultural residues, has to generally compete with the farmer for water supply. The effluent, therefore, has a value to the farmer if properly treated and supplied to him for irrigation purposes. Land requirements are about 40 to 50 acres per m.g.d.* of effluent, or 4.3 to 5.3 ha** per 1000 m^3/day. Experimental work conducted in this respect seems to indicate the possibility of such a use and an existing mill is reported to be successfully irrigating rice fields with the mill effluent.

The combined effluent of the pulp mill and paper mill would be given a primary treatment to remove the suspended solids. This is generally done by sedimentation. Generally, for irrigation purposes, a secondary biological treatment may not be necessary. The waste water after removal of suspended solids could be, therefore, used for irrigation purposes during the dry season when there is a high demand for water from the farmer. During the heavy rainy season when there is no demand from the farmer, the effluent could be effectively mixed with the storm water and discharged with no ill effects to the environment.

The suspended solids and sludge in most mills is either used as a land fill or incinerated after a process of thickening. But in the case of developing countries where there is a

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* m.g.d. - million gallons per day

** ha - hectares

need to boost the rural economy, this sludge, (without going into the expense of thickening by centrifugation or vacuum filtering), could be mixed with screen rejects and waste paper to produce solid board on a single cylinder wet board machine. The sheet thus formed could be pressed on a hydraulic press and sun dried or air dried to produce a heavy weight board that could be used for book binding, suitcase boards, and for the manufacture of rigid boxes.

INTEGRATED CONVERTING OPERATION

The type of integration needed for a project of this nature, in a developing country, would go beyond just the manufacture of pulp and paper, to include the making of corrugated board and the making of corrugated containers.

The advantages would be both technical and economic and could be summarized as follows:

1. Ready availability of containers to the farming community to pack agricultural products.
2. Economy in the direct use of waste from the corrugated container operation as part of the fibre furnish, with no need for separate baling and handling.
3. Common usage of service facilities such as steam, water, compressed air, workshop, and laboratory facilities, thereby reducing capital cost and also improving operating economy.

AFFILIATED OPERATIONS

Agricultural Residues

The farming community in a developing country is not

generally geared to meet the disciplines of an industry. There is a great deal of preliminary work needed in organizing, providing the know-how and even supplying the capital to purchase equipment such as balers, tractors, trucks, etc., for the handling, transport and storage of agricultural residues. The best approach for providing these services in a developing country is to first organize and form farmer cooperative societies so that the collection of raw material would be much simpler and convenient.

Waste Paper Collection

The mill may also have to take the lead to organize and provide facilities for the collection and handling of waste paper. Here again it would be convenient, in the case of developing countries, to provide such services through co-operative societies, or voluntary organizations formed to help the handicapped.

Man-made Forests

A project of this nature in a developing country has to make long term targets for further expansion in the production of similar grades or diversification in the production of other grades of paper to maintain growth. In planning growth in the paper industry, an important factor would be the creation of man-made forests on the basis of selected species for the production of long fibre pulp. The mill has to, therefore, get involved in the planning and promotion of wood plantations either directly with the farming communities, or indirectly through government agencies such as the forest department.

Research and Development

The operation of a project of this nature should be coupled with research and development facilities. The mill should work closely with research institutions and universities for a continuous improvement of technology to bring about an efficient use of resources. The research and development work should also go beyond the technological problems in the mills to look into the methods of improving agricultural crops, forest yields, development of correct hybrid species for man-made plantations, etc., in order to bring an overall improvement in production efficiency and quality by using better raw materials. Other than man-made forests, research work should also cover the growing of annual plants such as kenaf, Sunn Hemp, etc., in uneconomic land not suitable for agriculture.

CONCLUSION

An integrated pulp, paper, and corrugated container project, as envisaged in this paper, has many socio-economic benefits to a developing country whose rural population far exceeds that of its urban counterpart. Some of these socio-economic benefits are:

- Greater employment opportunities for the rural community.
- Acceleration of food production.
- Alternative use for uneconomic land.
- Improvement in the quality of life due to greater income generation in the community.

The technology suggested in this paper has carefully examined various factors, i.e., raw materials, costs, environmental concerns, employment factors, maintainence needs, energy consumption, etc. The most appropriate technology has been suggested, highlighting the following factors:

- Agricultural waste as raw material.
- Selective technology that would require less energy, less fuel, and less water per ton of paper.
- Labor intensive technology in place of capital intensive technology, wherever possible.
- Flexibility of technology to make a wide range of grades using diversified raw materials.
- Supplementary nature of industry to foster the food processing and wood-based industries.
- Recycling and use of waste materials from the industry.
- Research and development work to improve technology, environment, development of man-made forests, and development of annual crops resulting in benefits to the rural economy.

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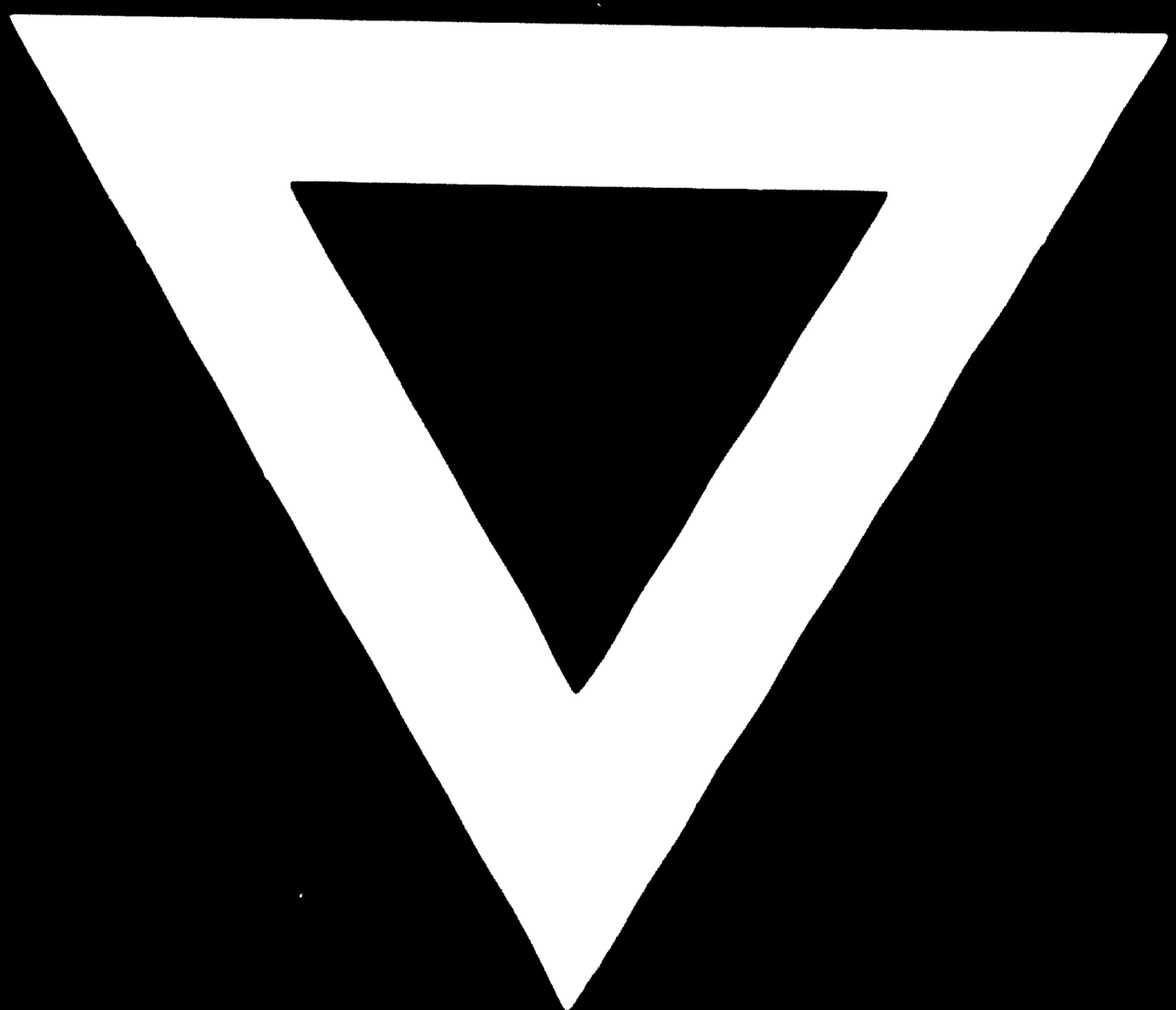

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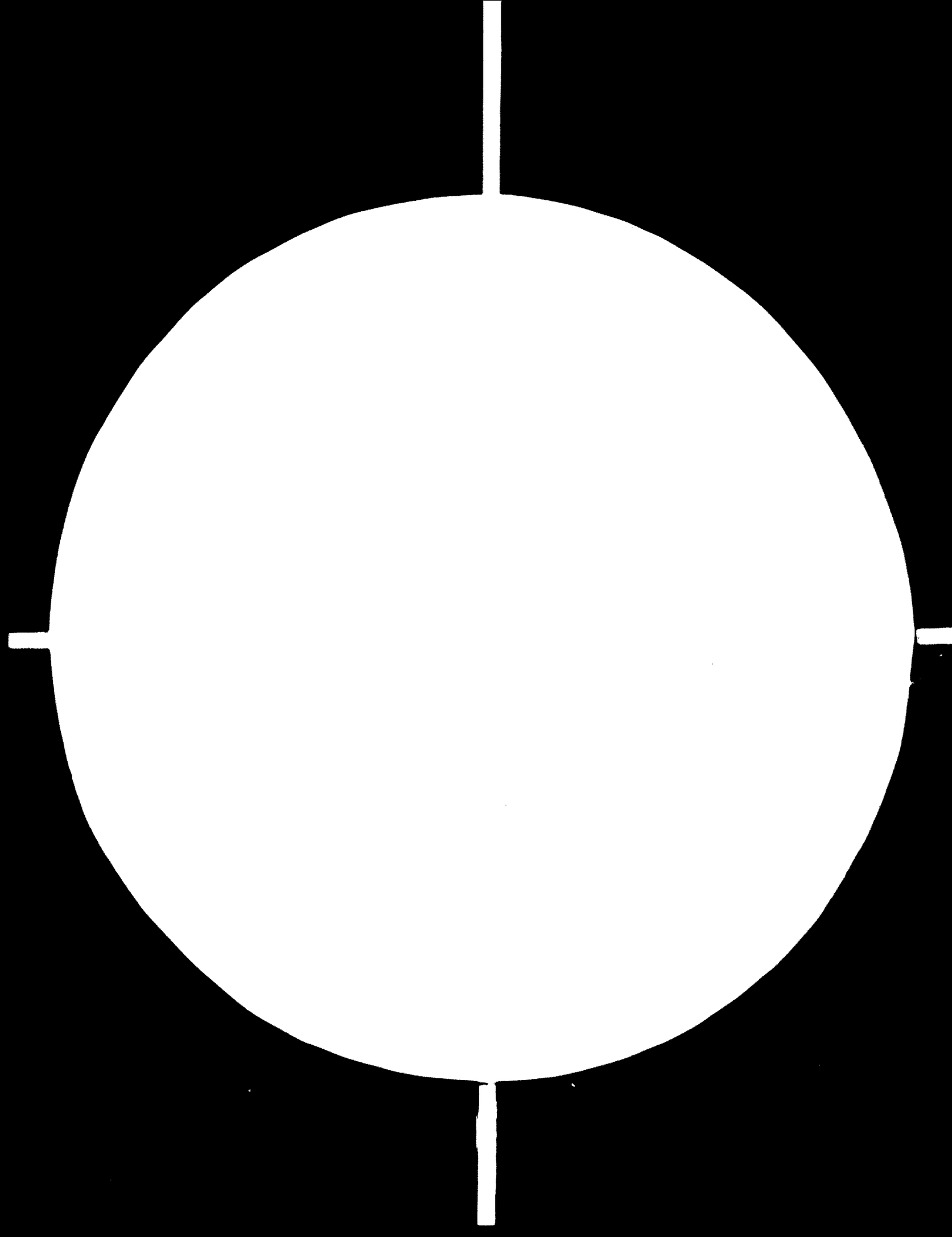

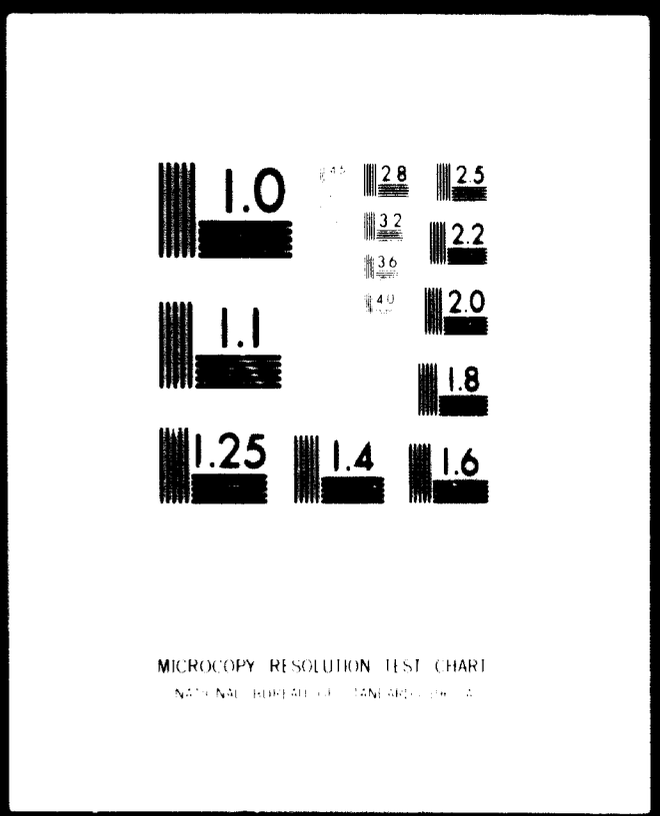

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APPROPRIATE TECHNOLOGY FOR THE MANUFACTURE OF PULP AND PAPER PRODUCTS

APPROPRIATE TECHNOLOGY FOR A LOW-COST PAPER PROJECT TO BOOST THE RURAL ECONOMY

Background Paper

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APPROPRIATE TECHNOLOGY FOR A LOW-COST PAPER PROJECT TO BOOST THE RURAL ECONOMY

by

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ABSTRACT

A project to manufacture liner board and corrugating medium to produce corrugated box containers has been identified as essential to boost the rural economy of developing countries. The appropriate technology for this industry is based on the use of agricultural residues for pulp production, the use of less steam, water and energy for processing, simple process techniques suitable for ease of operation and maintenance, flexibility of operational systems and reduction of pollution load. Since this project is based on agricultural residues, it will have far reaching socio-economic benefits to the rural communities of developing countries.

INTRODUCTION

Developing countries largely depend on the import of paper from countries that produce pulp from coniferous woods. In view of the increasing demand for paper and paper products on a world wide scale and constraints placed on these paper exporting countries due to ecology restrictions, high cost of labor for wood extraction and high transport costs, this source of supply of pulp, paper, and paper products cannot be fully relied upon as a long term measure. In other words, developing countries have to do some rethinking and explore possibilities of using indigenous fibre resources to meet a greater portion of their own requirements. Developing countries are mostly agriculture oriented and it is possible for them to use some of the agricultural residues, various annual crop plants, etc., to develop the paper industry in their own countries.

It is also noted that developing countries, on the other hand, have certain limitations and there is a need for the use of appropriate technology to meet these limitations.

This paper, therefore, outlines a pulp and paper project that could be developed taking into account the general limitations of developing countries and the need to boost their rural economy. The guidelines followed by the writer for this project is basically as follows:

1. Input of raw materials in the form of agricultural residues and annual crop plants for the manufacture of paper, so as to provide an income to the rural communities.
2. Gainful employment of a large proportion of agricultural labor, both directly and indirectly, in the industry, so that their income could be either supplemented or improved.
3. Use of less capital intensive equipment and methods so that there could be more labor employed, wherever possible, thereby reducing capital cost.
4. Selective use of technology so that it fits into the socio-economic aspirations of the country but would not fall short of the standards in producing a product to match today's society.
5. Selective technology that would require comparatively less fuel and less electric energy to produce a ton of paper as most developing countries are relatively short of these resources.
6. Selective technology that would require less water per ton of paper and would also employ such methods that would result in the effluent water becoming suitable for irrigation purposes, since developing

countries, more often than not, suffer from a shortage of water.

GRADES OF PAPER MOST ESSENTIAL TO BOOST RURAL ECONOMY

According to the Lima Declaration and Plan of Action, at least 25% of the world's industrial production should originate in developing countries by the year 2000. In implementing this plan of industrialization, the pulp and paper industry is expected to play a major role in providing packaging grades of paper for various industries. In a developing country, where the industries would be more agriculture-oriented, the manufacture of liner board and corrugating medium would receive priority over other grades of paper. The rural economy, which is mainly dependent on various types of farming and have products such as vegetables, fruits, dairy products, eggs, poultry, meat products, fish, shrimps, etc., requires corrugated containers for the packing and transport of these agricultural goods either to the domestic or export market. Although developing countries have traditionally used wood and containers made with leafy material, modern technology for the preservation, storage and transport of food and the marketing of these products would call for the use of corrugated containers. This paper, therefore, examines the appropriate technology that has to be applied in a developing country to manufacture these two grades of paper i.e., liner board and corrugating medium.

RAW MATERIALS

Agricultural Residues

The raw materials available for pulp production in the form of agricultural residues and agricultural crop plants are as per Table 1. It will also be seen from Column 4, these materials are most suited only for certain particular grades of paper. The choice of raw materials for manufacturing different grades of paper depend largely on three factors:

1. Suitability for quality, based mostly on the fibre characteristics of the raw material.
2. Availability in quantity to make it feasible for collection and usage on a commercial scale.
3. Production cost factors such as yield of pulp per ton of raw material, cost of processing, such as chemicals, input of energy, etc.

Based on all these techno-economic factors, bagasse and straw have found wide acceptance commercially as agricultural residues suitable for a number of cultural and industrial grades of paper. However, agricultural residue pulp would need a blending with other types of pulp for quality as well as economic reasons. Coniferous wood pulp or other long fibre pulp is blended with straw or baggasse pulp to improve the runnebility, and obtain the required strength properties while manufacturing light weight printings, writings, kraft paper grades, etc. Secondary fibre produced from waste paper, on the other hand, is used as part of the fibrous furnish in almost all grades of paper board as well as some grades of paper, to

TABLE 1

Agricultural Residues and Crops Considered

Suitable for Paper Manufacture

Type	Technological Feasibility	Economic Feasibility	Suitable Paper Grades
Baggasse	Feasible (C)	Feasible to most developing countries.	Newsprint, Writings, Printings, Kraft grades, Brown board and other types of board.
Straw (wheat, rice, barley, oats)	Feasible (C)	Feasible to most developing countries.	Writings, Printings, Liner board, Corrugating medium and other types of board.
Maize Stalk	Feasible (C)	Feasible to most developing countries. Some limitations due to storage.	Liner board, Corrugating medium and other types of board.
Sisal	Feasible (L)	Feasible to certain developing countries.	Hard tissues, Cigarette tissue.

Cont'd - Table 1

Sun Flower Stalk	Feasible (L)	Feasible for certain developing countries. Some limitations due to high pith content.	Liner board grades and Corrugating medium.
Cotton Stalk	Feasible (L)	Feasible for certain developing countries.	Corrugating medium.
Date Palm Leaves	Feasible (L)	Feasible for only certain developing countries. Some limitations due to poor yield.	Brown board, Bag paper.
Banana Stems	Feasible (L)	Feasible for certain developing countries.	Hard tissues, Specialty grades.
Pineapple Leaves	Feasible (L)	Feasible for certain developing countries.	Liner board and Corrugating medium.
Common Hemp (Cannabis Sativa)	Feasible (C)	Feasible for certain developing countries.	Hard tissues, Cigarette paper, Specialty grades, etc.

Cont'd - Table 1

Sorghum (Sorghum-Vulgare)	Feasible (L)	Feasible for certain developing countries.	Liner board and Corrugating medium and other types of board.
Sunn Hemp (Crotalaria-Junicea)	Feasible (C)	Feasible for certain developing countries.	Hard tissue, Cigarette paper, Specialty grades.

C - Commercially operated basis.

L - Laboratory work basis.

reduce the cost of fibrous furnish.

Waste Paper

As referred above, the use of waste paper is emphasized for economic reasons. By increasing the use of waste paper it would be possible to reduce the capacity of the pulp mill and thereby reduce the capital cost on pulp mill equipment. The operating cost too, would be reduced due to the replacement of virgin fibre with secondary fibre resulting in savings on account of chemicals, less use of steam and electric energy.

A further economy is possible in the manufacture of corrugating medium since all type of trimmings and common waste could be used along with agricultural residue pulp.

Collection and Usage Also a Social Benefit

From the socio-economic angle the collection of waste paper could generate employment at the unskilled level and is of particular interest to the disabled and aged who need light work. Developing countries with no positive social security measures could use the collection and sorting of waste paper as a means to provide gainful employment and income to the handicapped and the underprivileged.

Raw Materials for Long Fibre Pulp

The use of agricultural residues requires a blending of long fibre pulp to give the required strength characteristics to the paper produced. The percentage blended would depend on the end use of the particular grade of paper. Sack kraft for

packing cement may require as much as 50% of long fibre pulp for blending with agricultural residue pulp, liner board may require only about 20%, and corrugating medium could be made with no blending of long fibre pulp. Developing countries are usually deficient in coniferous species such as spruce, pine, fir, hemlock, etc., to produce the commercially developed long fibre pulp. There are a few agricultural crops that could provide the long fibre pulp for developing countries, such as Sunn Hemp, Sisal, Common Hemp, Abaca Stem, Banana Stem, Jute, etc., but economic factors such as limited availability in terms of quantity, low yield of fibre per acre, and the high cost of preparing the raw material (prior to cooking such as retting) limit the use of these materials to only speciality grades of paper such as cigarette tissues, carbonizing tissues, bible paper, etc.

Kenaf:- In recent years, work done on kenaf (HIBISCUS CANNABINUS) indicates the possibility of substituting this pulp in place of long fibre wood pulp. This is of particular interest to such developing countries where kenaf could be grown easily and are at present facing problems in the import of wood pulp due to unfavourable foreign exchange or high cost of imported wood pulp.

Plantation Wood:- Besides kenaf as a substitute for imported long fibre pulp, it is also possible to develop man-made forests in the growing of poplar, pinus species, etc. Experimental plantations in the growing of these coniferous species have shown encouraging results in tropical countries.

Boosting of Rural Economy through Wood Plantation:- In order to boost the rural economy, the growing of kenaf and the creation of man-made wood plantations using high yield forestry techniques have to be introduced. Wood plantations in particular are emphasized as this will not only help the pulp and paper industry, but would improve the overall economy of the country in providing lumber for a number of wood based industries.

SELECTION OF PULPING PROCESS

There are five well-known processes for the production of pulp from agricultural residues:

- Lime Process
- Pomilio Process
- Neutral Sulphite (semi-chemical)
- Kraft
- Soda

Besides these processes there are several other less known processes available. They are not being discussed here due to the limted value they have in the application of appropriate technology to developing countries.

Lime Process:- This is an old process based on the use of lime as the sole cooking agent. Some mills have used this process for manufacturing corrugating medium. This process has become obsolete as modern technology is replacing equipment such as spherical digesters, drainers, and beaters which are used for this process. This process could be, however, considered for the manufacture of yellow straw board on a small scale to improve rural economy in developing countries, but

will not be suited for the manufacture of liner board and corrugating medium to make corrugated containers to meet present day packaging standards.

Pomilio Process:- This process was mainly developed for use with agricultural residues. It is now considered uneconomic due to high consumption of chemicals and high maintenance costs on account of corrosion problems in the use of chlorine.

Neutral Sulphite Semi-chemical process is also a well-known process particularly for producing corrugated medium from both hardwoods as well as softwoods. Neutral sulphite is being used by some mills as a chemical process for agricultural residues to produce bleached pulp. Although neutral sulphite could be considered for making brown board, an evaluation of this process with the soda process does not merit its choice as this would increase the capital requirements for the preparation of sulphite liquor through the use of sulphur burner. One other reason for omitting neutral sulphite cooking would be to reduce pollution problems through sulphur free cooking.

Kraft Process, although widely used in wood pulping to produce kraft liner board, has marginal advantages when used on agricultural residues. When comparing the capital cost of a pulp mill, the soda process has advantages over the kraft process due to simplicity and low capital requirements. Another key point to support soda pulping would be the advantages on pollution control due to sulphur free cooking.

Soda Process has been found to have advantages over all the other processes mentioned above for the production of both

liner board and corrugating medium due to the simplicity of the process, sulphur free cooking, and economic advantages, and is, therefore, more appropriate to developing countries.

YIELD AND ECONOMY

The higher the yield of pulp, the better the economy both from the point of capital investments as well as operation costs. In the manufacture of paper grades to produce corrugated board and corrugated containers, two types of pulp have to be produced with different yields. Corrugating medium is produced from agricultural residues with a yield of about 70%-75% and linor board is produced with a yield of 55%-60%. Although an improvement in the above specified yields could be made that could improve the economy, it is found this results in lowering the physical strength properties of the paper.

BATCH vs CONTINUOUS COOKING

For the cooking of agricultural residues both batch digesters as well as continuous digesters are used. Mills that use the batch digesters claim better flexibility of operation particularly if different types of raw materials are planned to be used. In addition, batch digesters are claimed to reduce time if maintenance work has to be done on the different digesters.

The continuous digesters normally available for agricultural residues are both the horizontal multi-tube type as well as the vertical tower type, but the horizontal type has been widely accepted. The advantage of using the continuous digesters would be savings in equipment cost and operating

economy through less use of steam and energy. Besides economy, continuous cooking gives a better process control and quality control of the pulp produced compared to batch digesters.

Further Application of Appropriate Technology by Cooking at Atmospheric Pressure

The conventional type of digesters described above, both batch as well as continuous, are pressure digesters. Generally, agricultural residues are cooked in pressure type of digesters using steam at 6 to 7 kg/cm^2. Pulp suitable for the manufacture of packaging grades such as liner board, corrugating medium, etc., could be cooked at nearly atmospheric pressure with a temperature of about 85° to 100° C. The digester used for cooking agricultural residues at low temperatures is somewhat similar to the multi-tube horizontal digester. The digester has five functional zones:

1. Impregnation Vessel-For mixing of both white liquor and black liquor with the raw material.
2. Pre-cooking Tube-For the intimate mixing of chemicals. (Steam could be admitted, if needed.)
3. Cooking Tube-Material is heated up to 100° C and a double screw working counter-clockwise, gives mechanical action to the material while being cooked. (Heating is indirect.)
4. After Cooking Tube-Continued agitation to the raw material but reduced to one screw action.
5. Extractor Press-Partial separation of warm black liquor for recycling back into the impregnator vessel.

Since the digester is designed to work at very low temperature/pressure, the capital cost is relatively low. The digester is compact and requires less building space. There is operating economy through less usage of steam. A high percentage of black liquor gets recycled, reducing the pollution load.

BROWN STOCK REFINING AND HIGH YIELD

In producing high yield pulp from agricultural residues, the cooking action has to be followed up almost immediately with a gnetle fiberizing treatment to obtain a yield of about 70% to 75%. Since the inter-fibre bonds of agricultural residues are not so strong as in the case of woody materials, this fiberizing action could be done with less energy and with light conical refiners. The use of agricultural residue pulp, therefore, results in savings, in terms of both capital as well as operational costs. For example, the power requirements for agricultural residues is approximately 30 to 40 KWH/ton compared with 150 to 300 KWH required for some of the woody materials widely used in the developing countries.

WASHING AND SCREENING

Washing of brown pulp to remove the spent chemicals and the dissolved non-cellulosic substances is mostly done in mills by using vacuum washers. Agricultural residues have poor drainage properties and in consequence the vacuum washers, which work on the filteration principle, have to be relatively large requiring more capital investment. The appropriate processing method for this function would be the use of a two

screw system which works on the principle of press washing. The advantages of using the press washing system, in preference to filter washing, for agricultural residues to produce brown board would be:

1. Less capital needed for equipment.
2. Reduction in floor space.
3. Possibility to operate at high consistency.
   (i.e., inlet consistency to press 10% to 12% and outlet consistency 38%.)
4. Higher washing efficiency.
   (Press washing gives better results on agricultural residue pulp.)
5. Foaming problems are avoided.

The pulping system considered for the manufacture of brown board (i.e., liner board and corrugating medium) would not require the use of centrifugal screens, pressure screens, centricleaners, thickeners, etc., at this stage, resulting in considerable savings in capital cost. The brown pulp, therefore, is ready at the end of the two stage press washing to be pumped to the paper mill for the manufacture of brown board.

CHEMICAL RECOVERY SYSTEM

The scale of operation considered for a project of this nature in a developing country would be a maximum of about 80 to 100 tons of paper per day to effectively support the rural economy. This scale of operation would keep pace with the limits that are usually encountered in the collection and transportation of agricultural residue. The estimated capacity of a pulp mill to produce 80 to 100 tons of paper board

as part of the fibre furnish along with waste paper and imported long fibre pulp would be approximately 50 tons per day.

The recovery of chemicals for a production capacity of 50 tons per day of pulp, based on agricultural residues, have both technical and economic limitations and is, therefore, not normally considered for a project of this nature. The black liquor chemicals, as discussed earlier, is recycled for cooking because it has relatively less organic substances and a high inorganic chemical content.

The handling of the effluent from such a type of pulp mill without a chemical recovery system would be discussed under effluent treatment.

STOCK PREPARATION SYSTEM

Agricultural residues such as bagasse and straw produce a type of pulp that could be called "energy savers" since they require very little mechanical treatment to produce the paper. For example, the energy requirement for wood pulp could average between 300 to 400 KWH per ton, whereas straw pulp would require about 75 to 100 KWH per ton. The capital cost necessary for equipping the stock preparation section would, therefore, be relatively low.

Treatment of Agricultural Residue Pulp

The fibres, as discussed earlier, are short and would need a gentle brushing action which is generally done in conical refiners. It may be possible at times to skip the refining needed for agricultural residues entirely, and give a brushing action at the finishing stages of the blended pulp ahead of

the machine.

Treatment of Waste Paper

The pulper for the treatment of waste paper would be equipped with a junk remover and ragger since mixed waste paper would be used along with agricultural residue pulp, for manufacturing corrugating medium. The waste paper used for liner board would be sorted and would mainly contain kraft grades, container waste, envelope trimmings, etc., to give the required strength characteristics. Besides the pulper for slushing the waste paper, the treatment plant would be equipped with a high density cleaner and a vibration screen. High cost and high energy consuming low density cleaners, centrifugal screens, etc., would not be necessary at this stage of the processing for the manufacture of both corrugating medium and liner board.

Treatment of Long Fibre Pulp

Disc refiners have the advantages of high efficiency and versatility for the treatment of long fibre pulp produced from wood. The free atmospheric discharge type of refiners have been largely replaced by the totally enclosed pressurized type. On account of the high skill needed in the maintenance of this equipment and the complexity of spares needed, it will be advantageous to use conical refiners instead of disc refiners for a project of this nature. The tackles have to be carefully chosen so as to avoid a cutting action to the fibre and to give a suitable treatment so that the short fibred agricultural residues blended with long fibre pulp would give the necessary strength characteristics to the brown board.

Blending of Fibrous Stock and Paper Making Additives

In the manufacture of liner board, stock would be prepared for delivery, both through the primary head box and through the secondary head box.

The blending of stock varies from mill to mill and changes are often made depending on operating conditions. However, a typical furnish could be as follows:

Primary Stock:- 40% Secondary fibre (Waste paper).
35% Agricultural residue pulp.
10% Long fibre pulp.

Secondary Stock:- 15% Long fibre pulp.

By using the secondary head box arrangement (which is described later under 'paper machine'), flexibility could be obtained to make bleached liner, jute liner, or kraft liner board depending on the nature of the end use of the corrugated containers.

The corrugating medium would be made as one single layer with the entire stock being supplied through the primary stock. The typical furnish would be:

60% Agricultural Residue Pulp.
30% Waste Paper.
10% Long Fibre Pulp.

Due to the charecteristics of agricultural residues, they require very little sizing. Alum requirements are generally high to maintain low pH, to prevent picking on the press rolls.

PAPER MACHINE

The continuous sheet formation of paper could be done in different ways depending largely on drainage conditions such as speed, basis weight, characteristics of the paper-stock, etc. The different forming methods could be briefly summarized as follows:

- Open wire forming -fourdrinier type.
- Cylinder machine forming.
- Suction breast roll forming.
- Twin wire forming.

The manufacture of liner board and corrugating medium could be done on all formers referred to above, except the suction breast roll former which has a short forming length and was specially developed to produce tissue grades at high speed.

The fourdrinier type of formation has wide flexibility and the control of operation is much simpler. Another major advantage is the large drainage capacity it has compared with the other forming methods in practice today.

The cylinder type of formation is largely applied to the manufacture of paper board, requiring multilayer board formation. These machines have limitations on speed due to centrifugal forces acting on the cylinder former. Another operation problem is the disturbance caused to the mat formed on the cylinder by the washing action. These problems have been largely overcome by the use of suction forming cylinders. Although the flexibility to make different grades with different furnish components is available on a cylinder machine for

various types of paper board, the large drainage capacity required for agricultural residue pulp and the simple operational adjustments that could be made to alter the drainage capacity is not available on the cylinder machine. Another disadvantage on the cylinder machine is the "pick-up felt" system which gets fouled up easily when using agricultural residue pulp.

The twin wire formers have gained importance in recent years over the fourdrinier due to advantages such as:

- High speed.
- Better uniformity (less two sidedness).
- Better formation compared to fourdrinier.
- Less space requirements.
- Less energy requirements.

In the search for an ideal former to replace the fourdrinier, different machine builders have different twin wire forming arrangements and there are pros and cons for each of these arrangements. Twin wire formers are successfully used in the well developed countries, mainly for high speed and high production. However, the appropriate technology for a developing country would emphasize the use of a fourdrinier due to the simplicity of its operation and maintenance, flexibility to make different grades with different types of furnishes, and its high dreinage capability, which is an essential element for producing paper from agricutltural residue pulp.

SPECIAL FEATURES NEEDED ON THE FOURDRINIER MACHINE

The fourdrinier machine in a developing country has to be flexible to a greater extent than in a developed country mainly due to market conditions. For example, a developed country would make liner board and corrugating medium on separate machines and in the making of liner board flexibility may not be required to make different grades of liner board. Developing countries, on the other hand, will have to make the corrugating medium as well as all the different grades of liner board on one machine such as kraft liner, jute liner (cylinder liner) and bleached kraft liner. The machine features required, therefore, have to cover a wide range of grades and a wide range of basis weights (i.e., 60 to 130 g/m^2 for corrugating medium and 100 to 300 g/m^2 for liner board). Besides all these design features, there are other important aspects needed to be considered while using agricultural residue pulp. This section of the paper will, therefore, concentrate on such special features.

Stock Approach Systems

The stock approach from the machine chest to the head box, the back water, and the broke systems, requires a careful design arrangement considering two problems:

- Susceptibility to heavy slime build ups.
- High tendency for air entrainment in stock.

Although the above problems are generally common to all types of stock, it could be said agricultural residues have more serious problems compared with other types of stock and

a concentrated effort is needed in the designing of the stock approach system to avoid problems such as channelling, settling, excessive turbulence, air pockets, dead stock, etc.

Head Box

The machine has to be provided with two head boxes (i.e., primary and secondary) for the following reasons:

1. To manufacture different grades of liner board.
2. To produce the required strength properties using minimum long fibre pulp as top liner.
3. To provide better appearance by effectively hiding the specks that result from high yield agricultural residue pulp.
4. To provide a better printing surface.

Secondary Head Box or "Strata Flow" Head Box

Technology is presently available to replace the function of a secondary head box by the use of a single head box employing the "strata flow" system. This type of head box could provide a three channel flow to the paper machine with capability to deliver three different type of stocks to the machine. By using such head box, it is possible to make a two ply or three ply liner board. The adoption of such technology could be only recommended to such developing countries that are fairly well advanced in technology as the operating of such a system requires higher skill.

Wire Part

Agricultural residue pulps are characterized by slow

drainage and would require at least 25% more forming length compared to conventional machines designed for working on wood pulp. Operating experience also indicates wires made out of synthetic fabrics have less tendency to get filled up and have therefore, better drainage capability than phosphor bronze wires. Based on experience it could be said "foils" provide a better removal of water. The wire part also requires additional suction boxes compared to a conventional machine.

Press Part

Problems often experienced with agricultural residue pulp is "felt crushing" particularly at the first press where the moisture content in the web is higher than the other presses following it. Synthetic felts with more open structure have been helpful in providing better removal of water at the presses, with reduced felt crushing. On machines where plain rolls were used for the first press, replacement with a suction roll at the bottom position was found to be helpful.

Another problem associated with agricultural residue pulp is "press sticking" and web breaks. The use of "granite" rolls resulted in better results than "stonite" rolls in the top position. Still better results were obtained by using "self skinning" rolls in place of "granite" rolls.

The provision of a "crumb" doctor for the first and second press doctors was also found to be helpful.

Most of the web breaks take place in the press section (i.e., between the couch and the first drying cylinder) due to the poor wet strength of the web made with agricultural residue pulp. Although the number of breaks would be

relatively low in corrugating medium and liner board due to high basis weights, consideration should be given while designing the press section to avoid long stretches of unsupported wet web length. Another important factor would be the degree of the "take-off angle" to prevent strain on the web.

A multinip press arrangement for the first and second presses, with pick-up transfer from the couch, are considered advantageous to the manufacture of paper from agricultural residue pulp.

Felts on the press section tend to get filled up and dirty due to a high content of "fines" present in the agricultural residue pulp. The press section therefore, has to be provided with adequate felt cleaning equipment. Better results were obtained by using a "wringer press" along with felt cleaning equipment such as "Uhle" boxes and "Vickery" shoe cleaners.

Agricultural residue pulp, due to fines and silica matter, tends to fill up the suction rolls more easily than wood-pulp. These rolls have to be provided with high pressure showers that could give a periodic wash on the "run."

Dryer Section

For the manufacture of paper and paper board from agricultural residue pulp, the dryer section has to be divided into more groups. This gives better operation control in relation to draws and shrinkage. The dryer section also requires separate controls for the top and bottom cylinders in the last group, after the size press, to control curl.

On account of the "fuzz" problem normally experienced with agricultural residue pulp, it is advantageous to operate the machine without a felt for the first group (bottom cylinders).

The dryer section could be designed to eliminate the use of "felt dryers" since conventional type felts could be replaced with high permeable dryer screens. The use of dryer screens results in better drying efficiency and profile. The dryer section too would require the use of pocket ventilators. This results in about a 35% increase in drying capacity and will also give a more even profile. Obtaining a more even profile is essential to reduce breaks and this is all the more important while using agricultural residues which have a higher tendency for paper breaks.

Size Press

The use of a size press enhances the possibility of giving different characteristics to the liner board produced on the machine. This is an important feature to a developing country where diversification in quality required is great but the market is small.

Another important value of the size press is the possibility to improve certain strength characteristics. Liner boards made with agricultural residue pulp could be reinforced in strength properties by giving appropriate surface treatment.

Machine Drive

The prime mover needed to drive the machine could be either electric or steam. If the overall economy and the

steam balance of the specific mill are favorable, it would be advisable for a mill in a developing country to choose steam instead of electricity for the paper machine drive. The electric supply in a developing country, which is dependent on an outside source of supply, has several drawbacks, such as frequent outages and voltage fluctuations, that interfere heavily with the operation of the paper machine.

INSTRUMENTATION

Paper making was largely manually controlled, where the operator made use of his senses (i.e., hearing, sight, smell, and touch) for process control work. This system has undergone a rapid change and now digital computers are being used in some mills to control a number of important paper making variables.

For the application of process control through instruments in a developing country, a careful evaluation is necessary to determine how much instrumentation is actually necessary to suit the local conditions. The extreme point of working on human senses is not feasible to meet present day quality standards and efficiency, whereas excessive instrumentation for developing countries has problems related to the displacement of employment possibilities as well as lack of skill to maintain and operate some of the sophisticated control equipment.

Developing countries should generally concentrate on applying process control instruments to some basic functions such as consistency, flow rate, temperature, and pressure controls

in selected areas.

WATER SUPPLY FOR THE MILL

Availability of water in large quantities is an important factor for the production of pulp and paper. A pulp and paper mill in a developing country based on agricultural residues, would be dependent on a source of water supply common to both the farmer and the paper mill. This could be a small river, or lake, or an irrigation facility. Due to the competitive nature of water usage for both agriculture and industry (particularly in tropical countries), the farmer normally expects an economy in the use of water by the paper industry as he always makes the claim, "I was here first."

Besides the economy exercised due to the competitive use of water by the farmer and the industry, there are other reasons for controlling the use of water such as:

- Reduction in fibre loss.
- Reduction in size and cost of external treatment plant.

This section will therefore, examine the methods that could be adopted to reduce the consumption of water.

Pulp Mill

The pulping technology described earlier is provided with features that could result in water economy such as:

- Counter current and high consistency washing (press washing).
- Recycling of black liquor for cooking.
- Usage of paper mill water for washing and dilution of stock. (clarified water from the save all)

The water requirements of the pulp mill based on this system would be 4.6 m^3/ton compared to 120 m^3/ton in a conventional type of mill.

Paper Mill (Closing the Water System)

Some of the measures that could be adopted on the paper machine to close up the system and economize on the use of fresh water would be as follows:

1. Proper allowance for "white water" storage capacity to meet the high and low swing demands and prevent overflow.
2. Reuse of cooling water from cooling cylinder, calenders, lubrication oil cooler, etc.
3. Control of sealing water to pumps and agitators, wherever it is possible, by using a reducing washer and a flow indicator.
4. Recirculation of sealing water from vacuum pumps, using a cooling tower for temperature control.
5. Examine possibility of using clarified water for low pressure showers on pres felts.
6. Use of clarified water for wire showers (except the high pressure wire, cleaning shower and breast roll shower).

A closing up of the system as suggested above could reduce the fresh water usage to about 35 m^3/ton compared with 90 m^3/ton to 120 m^3/ton for a conventional mill.

EFFLUENT WATER FOR IRRIGATION AND SUSPENDED SOLIDS FOR THE PRODUCTION OF SOLID BOARD

As discussed earlier, a paper mill project based on agricultural residues, has to generally compete with the farmer for water supply. The effluent, therefore, has a value to the farmer if properly treated and supplied to him for irrigation purposes. Land requirements are about 40 to 50 acres per m.g.d.* of effluent, or 4.3 to 5.3 ha** per 1000 m^3/day. Experimental work conducted in this respect seems to indicate the possibility of such a use and an existing mill is reported to be successfully irrigating rice fields with the mill effluent.

The combined effluent of the pulp mill and paper mill would be given a primary treatment to remove the suspended solids. This is generally done by sedimentation. Generally, for irrigation purposes, a secondary biological treatment may not be necessary. The waste water after removal of suspended solids could be, therefore, used for irrigation purposes during the dry season when there is a high demand for water from the farmer. During the heavy rainy season when there is no demand from the farmer, the effluent could be effectively mixed with the storm water and discharged with no ill effects to the environment.

The suspended solids and sludge in most mills is either used as a land fill or incinerated after a process of thickening. But in the case of developing countries where there is a

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* m.g.d. - million gallons per day

** ha - hectares

need to boost the rural economy, this sludge, (without going into the expense of thickening by centrifugation or vacuum filtering), could be mixed with screen rejects and waste paper to produce solid board on a single cylinder wet board machine. The sheet thus formed could be pressed on a hydraulic press and sun dried or air dried to produce a heavy weight board that could be used for book binding, suitcase boards, and for the manufacture of rigid boxes.

INTEGRATED CONVERTING OPERATION

The type of integration needed for a project of this nature, in a developing country, would go beyond just the manufacture of pulp and paper, to include the making of corrugated board and the making of corrugated containers.

The advantages would be both technical and economic and could be summarized as follows:

1. Ready availability of containers to the farming community to pack agricultural products.
2. Economy in the direct use of waste from the corrugated container operation as part of the fibre furnish, with no need for separate baling and handling.
3. Common usage of service facilities such as steam, water, compressed air, workshop, and laboratory facilities, thereby reducing capital cost and also improving operating economy.

AFFILIATED OPERATIONS

Agricultural Residues

The farming community in a developing country is not

generally geared to meet the disciplines of an industry. There is a great deal of preliminary work needed in organizing, providing the know-how and even supplying the capital to purchase equipment such as balers, tractors, trucks, etc., for the handling, transport and storage of agricultural residues. The best approach for providing these services in a developing country is to first organize and form farmer cooperative societies so that the collection of raw material would be much simpler and convenient.

Waste Paper Collection

The mill may also have to take the lead to organize and provide facilities for the collection and handling of waste paper. Here again it would be convenient, in the case of developing countries, to provide such services through co-operative societies, or voluntary organizations formed to help the handicapped.

Man-made Forests

A project of this nature in a developing country has to make long term targets for further expansion in the production of similar grades or diversification in the production of other grades of paper to maintain growth. In planning growth in the paper industry, an important factor would be the creation of man-made forests on the basis of selected species for the production of long fibre pulp. The mill has to, therefore, get involved in the planning and promotion of wood plantations either directly with the farming communities, or indirectly through government agencies such as the forest department.

Research and Development

The operation of a project of this nature should be coupled with research and development facilities. The mill should work closely with research institutions and universities for a continuous improvement of technology to bring about an efficient use of resources. The research and development work should also go beyond the technological problems in the mills to look into the methods of improving agricultural crops, forest yields, development of correct hybrid species for man-made plantations, etc., in order to bring an overall improvement in production efficiency and quality by using better raw materials. Other than man-made forests, research work should also cover the growing of annual plants such as kenaf, Sunn Hemp, etc., in uneconomic land not suitable for agriculture.

CONCLUSION

An integrated pulp, paper, and corrugated container project, as envisaged in this paper, has many socio-economic benefits to a developing country whose rural population far exceeds that of its urban counterpart. Some of these socio-economic benefits are:

- Greater employment opportunities for the rural community.
- Acceleration of food production.
- Alternative use for uneconomic land.
- Improvement in the quality of life due to greater income generation in the community.

The technology suggested in this paper has carefully examined various factors, i.e., raw materials, costs, environmental concerns, employment factors, maintainence needs, energy consumption, etc. The most appropriate technology has been suggested, highlighting the following factors:

- Agricultural waste as raw material.
- Selective technology that would require less energy, less fuel, and less water per ton of paper.
- Labor intensive technology in place of capital intensive technology, wherever possible.
- Flexibility of technology to make a wide range of grades using diversified raw materials.
- Supplementary nature of industry to foster the food processing and wood-based industries.
- Recycling and use of waste materials from the industry.
- Research and development work to improve technology, environment, development of man-made forests, and development of annual crops resulting in benefits to the rural economy.

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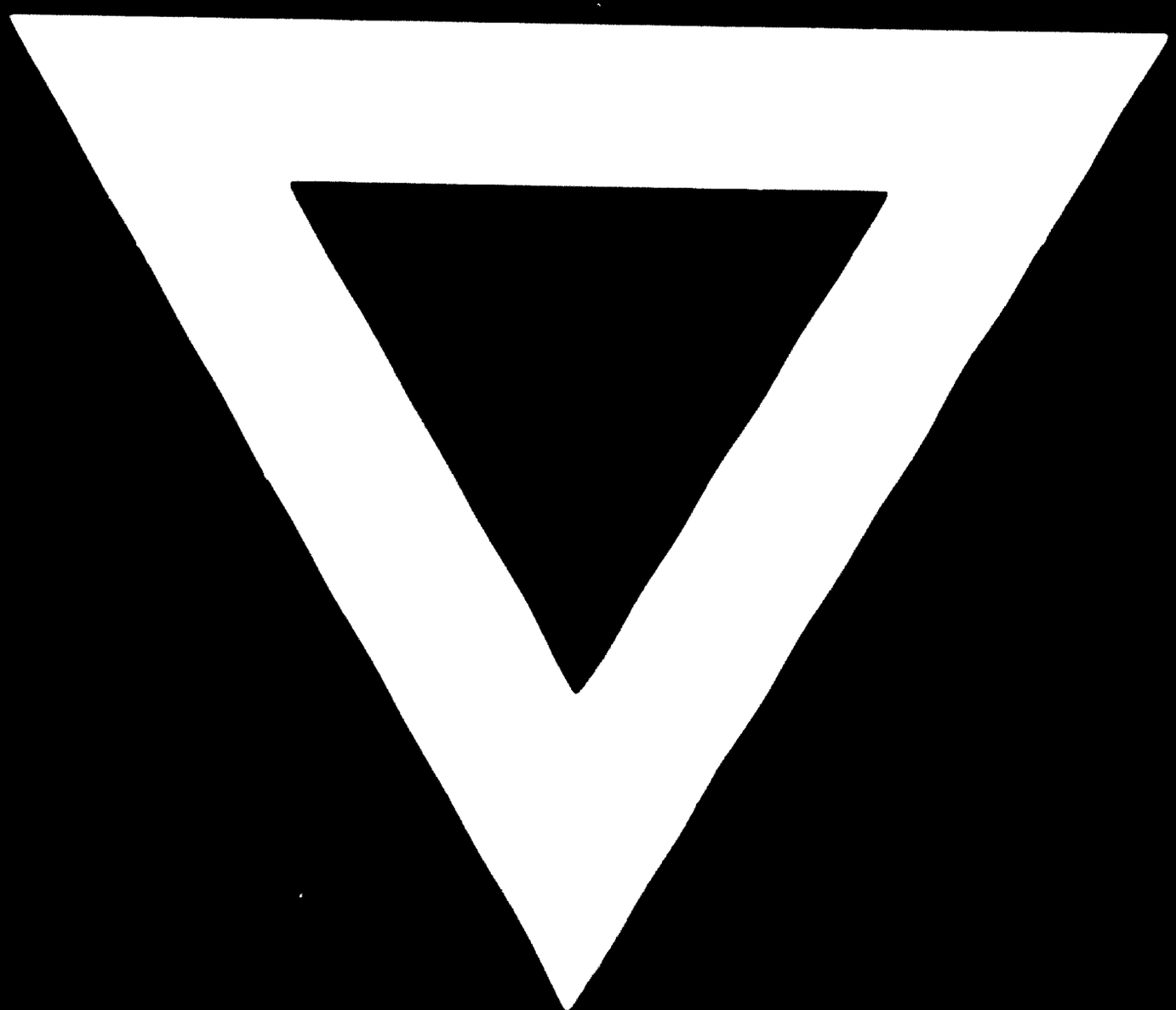

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