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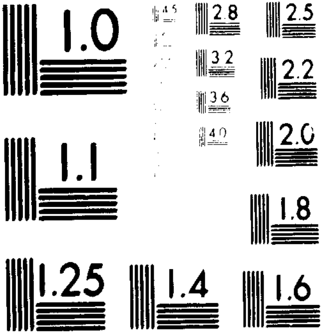

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963 A

KOJESS DEVELOPMENT LTD

P O Box 190 - Georgetown - Island of Grand Cayman

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UTILIZATION OF COTTON STALKS

BY

APPLICATION OF

THE "UNIVERSAL PULPING" PROCESS

A Prefeasibility Study

Eric S. Prior
June 25, 1980

RESTRICTED

June 25, 1980

PREFEASIBILITY STUDY
OF THE
APPLICATION OF "UNIVERSAL PULPING"
IN THE
UTILIZATION OF COTTON STALKS

EL SALVADOR

Assignment DP/ELS/78/001 - Contract 80/30/DG

Project Findings and Recommendations

Terminal Report prepared for

the Government of El Salvador

by

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Expert of the United Nations Industrial Development Organization

acting as Executive Agency for

the United Nations Development Programme

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A. SUMMARY

Cotton stalks offer a relatively low cost fibrous structure that within the limits of its characteristics and competitive position with other agricultural wastes could be converted economically into a variety of useful products such as animal feed, pulp and paper, panel board and fuel, using the principles of the "Universal Pulping" process.

Potentially large export and national markets could be developed in particular for panel board as partial or whole substitute for plywood and in packaging especially for bananas, permitting the downgrading of imported linerboard in corrugated boxes while upgrading the physical strength of the box.

Further application as fuel briquettes could find a rising market as could molded wood products where the needed binder, as in the panel board, can be wholly or substantially derived from the cooking process.

Certainly, the potential exists for converting the stalks into basic cattle fodder for local consumption where grazing possibilities are marginal. Similarly, a paper making operation could be established where other better fibrous materials such as cane or straw are not readily available.

The findings of this prefeasibility study merit further work with larger quantities in the areas that offer substantial economic potential, i.e. panel board, fuel and feed, which involve much lower investment for the tonnage handled than pulp and paper production.

B. INTRODUCTION

Throughout the world, wherever cotton is grown, total production of which can be reckoned in millions of tons, an agricultural residue in the form of cotton stalks is available in at least equal quantity to that of the commercial yarn cotton fiber produced.

Like straw, another agricultural residue, it forms one of the greatest underutilized natural fibrous materials. Straw finds a limited use as cattle feed and bedding, strawboard, and a great deal of development work is currently in progress to improve the factor of utilization in animal feed and as a source of sugars and proteins. The use of straw for paper or board making purposes has declined sharply and in some countries, as in the U.S.A. and West Germany, disappeared completely - mostly due to water pollution problems, poor fiber characteristics, harvesting and storage problems. Nevertheless, developing countries such as Turkey and Egypt look to straw as a prime source of indigenous fiber, unfortunately at the expense of increased pollution.

Cotton stalks as a source of fiber has most of the disadvantages of straw and some additional peculiar to itself.

Firstly, the stalk must be considered as a woody material rather than a grass derivative such as straw and reaches, in its annual growth, diameters over 3 cm. As wood it is more resistant to chemical action and its relative non-uniformity in size from growing tips to woody stem presents an additional problem. Further, cotton is subject to high rates of insecticides' application which are highly poisonous, even when burned, possibly long lifed and accumulative in animal tissue. Although the stalks would be normally harvested under rather dry conditions, it would still be a growing plant, and when subject to chopping and crushing, it can be expected that a high rate of fungus growth and deterioration would result under natural storage conditions. Finally, as an annual woody fibrous structure, the stalk contains a substantial percentage of pith cells which together with the outer, dark colored bark create problems in paper making processes and uses excess chemicals.

Normal disposal of the stalks after harvesting the cotton and possible eating of the leaves by cattle is to either burn in place or after hand collection thus creating high air pollution. Returning to the ground as litter where it becomes usable humus can take several years. In Russia, some use is made of the stalks to make a very acceptable fiber board, but a considerable problem remains in disposing of waste materials.

It has been reported that a study by an American consulting company recommended for El Salvador a 250 ton per day pulp mill to utilize cotton stalks at a cost of $ 250,000,000. The infrastructure of such an immense project and the problems of financing and the marketing of the low strength pulp produced would be, to say the least, very considerable.

In summary, it would appear that like many agricultural residues as straw, coffee pulp, banana stalks, bagasse, etc., cotton stalks need a very different approach to utilization if it is to be economic.

With the rather dismal background pictured above, a pre-feasibility study was proposed by Dr. Konrad F. Schultz, stationed in Central America, to determine if the advantages of the "Universal Pulping" system had any applicability toward dispersing the inherent problems of cotton stalk utilization.

"Universal Pulping" is a fast process designed to make practical a non-polluting, small or large pulp mill, using low quantities of inexpensive common chemicals, non-pressure equipment and low temperatures with a flexibility of operation that can produce products ranging from dissolving pulp to animal feed.

A 30 kilo sample of stalks was shipped from El Salvador for laboratory investigation at Düren, West Germany, which was followed, based on preliminary favorable findings, by a field survey in El Salvador and additional laboratory work.

The following findings are based on processing this small sample for a rather wide variety of end uses and in themselves must be considered as indicative rather than conclusive.

It has been possible to find certain attributes that can be turned to economic advantage and, of most importance, lead to market acceptance in quantities relative to the huge potential reservoir of this unused fibrous material.

Market acceptance must of course be based on competition with other potential sources of fibrous material and for this reason, although certain end products producible from cotton stalks are indeed possible, they would not be economically viable and recommendations for further study is based on this factor among others.

C. FINDINGS

1. Characteristics of Cotton Stalks

The stalk segments as received were sawn, two inches or more in length, varying in diameter from 0.5 cm to 3 cm, with some residual dried foliage and in an air dry condition (10% moisture). Field observation indicated this sample was representative, although field harvested stalks would be expected to have a moisture content over 35% making processing much easier.

It is a principle of "Universal Pulping" that any fibrous material processed must be first prepared in a uniform size. This is important not only to provide equal chemical action but to provide the basic form for ease in handling after cooking - washing - bleaching - defibering and refining.

Each individual segment was crushed by hand with a hammer and followed by fifteen minutes steam (2.5 atu) impregnation to bring up the moisture content and achieve some element of elasticity and reduction of hardness of the stalk. The stalks were then passed through a double disk defibrator to achieve a uniformly sized fibrous segment. An important factor emerged at this point of process as it appeared possible, though starting with very dry material, to bring the stalk to a fine fibrous condition rather than the conventional wood particles made by processing wood from tree sources. This feature should produce advantages in all phases of pulping, handling and strength characteristics.

An additional advantage of the stalks vs. straw, bagasse and some other grasses is that the bark, while of no value, does replace the usual waxy dermis of these other plants which make adhesion and pulping more difficult.

Although the sum production of stalks is large, the yield - as in the case of straw - is spread over a large area and the problem and cost of transport to a central processing mill could be sufficient to limit the viability of any project. It would be proposed therefore to create individual field storage piles of reasonable size of cut and crushed stalks as harvested by a machine, similar to a combine. To avoid degradation of the woody structure it would probably be necessary to cover such piles with plastic and treat with SO_2 gas. Transport of the stalks even in this cut and crushed condition, with a high volume to weight ratio, would be economically impossible. A portable defibrating unit could provide a field unit to rapidly process the piles and with trucks using a compactor provide a high density load at least twice as high as straw bales for shipment to the central processing mill.

The cotton syndicate in El Salvador has quoted a price of U.S. $ 30 / metric ton for stalks chopped and piled as being satisfactory. This would equate to about $ 40 / ton bone dry material and $ 50 delivered mill. This figure compares to approximately $ 85 per B.D. metric ton of delivered mill wood chips in West Germany and $ 90 for export chips in the U.S.A.

This apparent price advantage however will only be real if the end products are such that the element of fiber yield is considered in the comparison since it appears to be well below 40% paper pulp yield for stalks as opposed to 50 - 55% for wood. The low yield results from the high percentage of non woody material, i.e. bark, pith and leaves which mostly dissolve in any cooking process.

The fiber characteristics of pulped cotton stalks severely limit its use as a paper making fiber since it is very short - being thin and under 0.50 mm, compared to bagasse at 1.7 mm and pine at 3.0 - 3.5 mm. Consequently, it has little strength and could only be used in combination with long fiber from other sources. Further, bark and dirt content, which would be difficult to clean out, limit its practical use to unbleached or possibly colored papers and to packaging board.

2. Pulping

"Universal Pulping" is a one or two step method, the one step being made with an alkali solution and the two step being first an acid impregnation followed by an alkali extraction.

In this case the two step method was used on the defibered cotton stalk, using a range of acid concentrations 0.5% - 2.0% - 3.0% for thirty minutes at 95°C in a non-pressure vessel. This stage was followed by washing and then with alkali at pH 12 for 15 minutes.

Pulp yields were respectively 66% - 47.3% and 34.4%.

The high yield pulp was designed for use as a basic fiber constituent for animal feed. Digestibility was rated at 75% by "in vitro" tests - this relates to 32% for uncooked straw. We can assume that under normal feed lot conditions cotton stalks as harvested are essentially inedible except for the tips which could be consumed in limited quantities, thus the cooking essentially brings the digestibility from zero to 75%. The question of tolerance by the animal of any residual insecticide remains, although it can be assumed that the major part had been washed away and/or destroyed by the chemical cooking action. Only an extensive "in vivo" test will prove definitely the relative safety of this fiber as a feed material and the quantity that could be absorbed in the ruminant's diet.

The 2% cook was designed for use as a basic fiber for production of corrugating medium. By itself the fiber bonding is too weak to carry across the paper machine in wet form (i.e. low wet tensile strength), so it is necessary to add long fiber. Since long fiber sources are not indigenous to El Salvador, excepting the kenaf bark fiber which is presently used in the manufacture of sacks, an attempt was made to use No. 2 cotton linters which are essentially a low priced waste product available in large quantity. Cotton fiber unfortunately has a bad habit of twisting on itself forming knots and although the linter fiber is relatively short (1 - 3 mm), this habit persists. By the addition of resin it was shown possible to work with this fiber in conjunction with the short stalk fiber. Unfortunately, not enough of this fiber mix was available to make an experimental paper machine run, but hand sheets are included in this report which also include a 5 - 10% proportion of black liquor solids derived from the cooking process. The use of cotton linters in paper making - specifically for use in the production of corrugating medium, since they are dirty and cannot be cleaned - in conjunction with the short fiber from the stalks should be further examined.

A short paper machine run was made with 80% cotton stalk pulp cooked with 3.0% acid together with 15% long fiber (spruce pulp) and 5% black liquor solids. Sheets from this run were run over the corrugator (samples attached) satisfactorily and produced a CMT 30 (Concora Medium Test) index per 100 grams of basis weight of 150 which is a reasonable level. Waste from corrugated boxes could be substituted for the long fibered pulp used.

I believe, however, we can rule out the manufacture of paper board from cotton stalks, at least in El Salvador, as the market would be extremely limited - 3,000 tons annually. The total market for medium in Central America is approximately 100,000 tons of which 60,000 tons are imported and used for banana boxes. If cotton production were in the adjacent vicinity of that of bananas, a paper industry to supply the corrugating medium could be envisaged, but a strong competitor of known and superior qualities would be bagasse fiber or even more so, the fiber derived from the new cane separation process.

In the above discourse I have mentioned the use of the black liquor (lignin) solids in the manufacture of the board. Such use is a feature of "Universal Pulping" and unique in the pulp and paper making process. Specifically, its use as a binder is a natural replacement of nature's glue (i.e. lignin), eliminates a water pollutant and adds strength and yield to the pulp.

This particular attribute of the process will be shown as a vital part of further recommendations.

Comparative Data - Pulping Cotton Stalks

Liquor Ratio to B.D. Sample 5 : 1

Acid Stage	Water Solubility	Feed	Semi Chemical	Paper Pulp
Acid Concentration	-	0.25%	2.0%	3.0%
Cooking Time - Minutes	30	30	30	30
Temperature °C	90 - 95	90 - 95	90 - 95	90 - 95
Alkali Stage				
Alkali pH	-	11 - 12	11 - 12	11 - 12
Cooking Time - Minutes	-	15	15	15
Temperature °C	-	95 - 100	95 - 100	95 - 100
Yield				
B.D. Pulp %	-	62.7	44.9	36.5
Solubles incl. Lignin %	-	25.2	42.8	52.0
Total %	91.7	88.9	87.7	89.5

3. Solid Board

As previously mentioned, the ability of the cotton stalk to defiber into relatively long, thin fibers when subjected to the mechanical action of a double disk defibrator, offers a unique strength potential in the manufacture of solid fiber board as opposed to the weak and friable panels made from ground wood, i.e. particle board.

There exist several systems of making panel boards - conventional wet and dry for heavy boards - and of particular interest in this case - the continuous process for making thin boards, 2.0 - 6.5 mm in thickness, which is used currently using grassy materials which have been defibered.

It is this thin board which, in addition to the present limited uses of similar materials such as "Masonite", offers entirely new and vast markets for an inexpensive product as this can be when made from low cost defibered cotton stalks and especially so when the natural binder - lignin - could be substituted for synthetic bonding resins.

These new markets are:

A. The center panel of plywood
As the supply of plywood sized logs continues to diminish the need for conservation and substitution will grow.

B. The side panels of plywood
Since the fibrous structure of defibered cotton stalks gives the directional strength which characterizes plywood, a three-ply-board of 100% cotton stalks can be envisaged. Alternatively, two panels could be cotton stalk and the face decorative wood. Furthermore, fabrication of the board invites many strengthening modifications of interior treatment to meet special needs.

C. **Packaging board**

The great need in the packaging industry in the form of corrugated boxes is reliable compression strength. Today it is necessary to overpackage by five to six times theoretical compression resistence strengths to achieve required carrying strengths for agricultural products and even higher for iced or cooled products where the high cost so called "rigid when wet box" provides temporary protection. The alternative to the above and often the only satisfactory way is the wooden or wire bound box, both unsanitary and expensive in many ways.

What is proposed is to use thin or ribbon board made from cotton stalk as a low cost insert to a conventional corrugated box to provide the needed rigidity and high compression factors. The banana box, made in the millions in Central America, is an ideal target as the thin board can be substituted for kraft linerboard which in a few decades will be in short supply. The simple cost factors are that linerboard costs $ 500.00/ metric ton - one eighth inch thick ribbon board will cost an estimated $ 140.00/ ton or $ 100.00 / m3. This thin board will have ten times the compressive strength of 90 lbs/MSF linerboard. There is therefore a total factor of x 34 in evaluating substitution of linerboard. The ribbon board will weigh approximately 490 lbs/MSF.

Normally, the manufacture of this type of board requires 12% solid resin, wax and hardner as binder. It is proposed to use the lignin solids generated by the "Universal Pulping" process as binder either in total or in part substitution for the urea formaldehyde normally used.

In the course of this project good quality board has been made (in spite of minimum material at hand) using untreated shredded cotton stalks, intermixed with lignin solids derived from the cooking of the cotton stalks as sole binder. Pressures of 60 kg/cm2 and 200°C were used. It is felt the temperature used was excessive in effecting the necessary cure since 100 - 130°C is all that is normally used on a paper machine. Additionally, it was not possible with the limited quantity on hand to control the pH which affects initial hardness and water vapor permeability.

Normally, for paper making purposes, the "Universal Pulping" process used is a wet one to fully dissolve out the lignin binder from the fiber interstices, but in this case it is necessary to release only the lignin on the surface of the fiber for binding purposes, thus retaining the natural rigidity and directional strength of the defibrated cotton stalk. To do this, a semi-dry process can be used in which the chemicals are sprayed or foamed in concentrated form on the fiber and the mixture subjected to heat and probably some pressure releasing the lignin which can then be hardened and the board compressed with the necessary temperature and pressure. Pulping trials using this method have been made where a drier process was used instead of the intended semi-dry process outlined above which would make the release of lignin easier and effect a better bonding.

Representative data for the board machine is as follows:

Technical Data

Thin Ribbon Particleboard Plant

thicknesses	2.0-6.5 mm/ 5/64" - 1/4"
thickness tolerance	+ 0.20 mm/0.008"

widths mm	feet	daily capacity m3	sq.ft.at 1/8"
1300	4	80	269,000
1600	5	100	336,000
1850	6	110	370,000
2100	7	130	437,000
2500	8	150	504,000

electrical energy requirement	205-150 kWh/m3
heating energy requirement	600,000-800,000 kcal/m3
personnel requirement	2.9-1.5 h/m3
heavy oil requirement	90 kg/m3
cooling water requirement	4.5 m3/m3
compressed air requirement	17-30 Nm3/m3

At a proportion of about 12% solid resin, wax and hardener, following statistic values can be obtained:

spec. weight	44-47 lbs/cu.ft.	700-750/m3
bending strength	3550-4250 lbs/sq.inch	250-300 kp/cm2
internal bond	115-140 lbs/sq.inch	8-10 kp/cm2
swelling		2 hrs. 6 % 24 hrs. 15 %

Labor requirements for the entire plant would approximate five man hours per ton, so that a 60 TPD or 18,000 tons per year ribbon board plant would require personnel complement of approximately 40 in number.

Linerboard consumption for banana boxes in Central America for 1978 is indicated as 180,000 tons and medium as 60,000 tons which leaves ample opportunity for substitution with solid board. Alternatively, there would appear to be a large market for building board. Cotton stalk production in El Salvador alone is estimated at 500,000 tons.

Quoted costs for a 60 TPD complete plant F.O.B. Germany are DM 7,000,000 plus another DM 2,000,000 for the auxilliary equipment essential to the plant but not including buildings, land, wiring and piping.

4. Fuel / Molded Products

A corollary of the proposed treatment of cotton stalks for the production of solid fiber board is the alternative production of fuel briquettes.

The procurement of fuel is a growing problem as urban centers grow and power, oil and gasoline become ever more expensive for the general use of the population.

The use of the shredded cotton stalks at the board plant as fuel would reduce cost and make the utilization of available cotton stalk tonnage more efficient and complete.

Carrying the pulping process beyond that necessary for either panel board or fuel briquettes could produce, with a semi-dry cooking process, a fine grained material suitable for manufacture of molded wood products. The market for such would probably be limited but would be labor intensive.

5. Animal Feed

The processing of cotton stalks by the "Universal Pulping" method to provide animal fodder as a minimum would find a substantial market during the dry season in El Salvador. As previously noted, a 75% digestibility factor can be reached by processing the fiber.

A feed lot, in conjunction with the mill, would avoid the necessity of drying, compounding and pelletizing the feed.

To produce complete feed compounding it is necessary to include minerals, carbohydrate and protein. Carbohydrate would normally come from available molasses leaving protein availability as the chief problem but from observation derivation of protein from available plants appears possible on a commercial scale.

Trials are being made in France with both synthetic enzimes and bacteria to produce glucose from cellulose and ultimately, by fermentation, protein or ethanol. One of the problems is the accessibility of the cellulose molecule to action of either enzyme or bacteria due to the shielding action of the lignin chain which is in intimate relation with the cellulose fibrile molecular structure. The "Universal Pulping" process provides a simple way to break this lignin association as evidenced by the increase in digestibility to 75 - 85% of straw, coppice willow and cotton stalks. Whether or not this treatment is adequate to speed up and make the action of enzymes and bacteria economic must be determined. Straw pulp samples have been sent to the French laboratories together with the lignin extract for analysis. A favorable response would open up another phase for the utilization of cotton stalks. If necessary, the lignin could be used in manufacture of solid fiber board.

Other sources of protein are locally available in the form of plant extracts - some of these are agricultural residues but most would have to be separately cultivated. An activated study would be necessary to formulate a complete feed program.

D. Recommendations

Of necessity, this prefeasibility, or rather, possibility study touched on a wide variety of potential uses of cotton stalks in widely dispersed fields of technology. Actual investigation was somewhat limited by the sample available but the positive indications gained were impressive and should be followed up.

The world production of cotton stalks as an agricultural residue is of too great a volume and too widespread geographically to be ignored in the present wave of more intense study and utilization of the available global biomass.

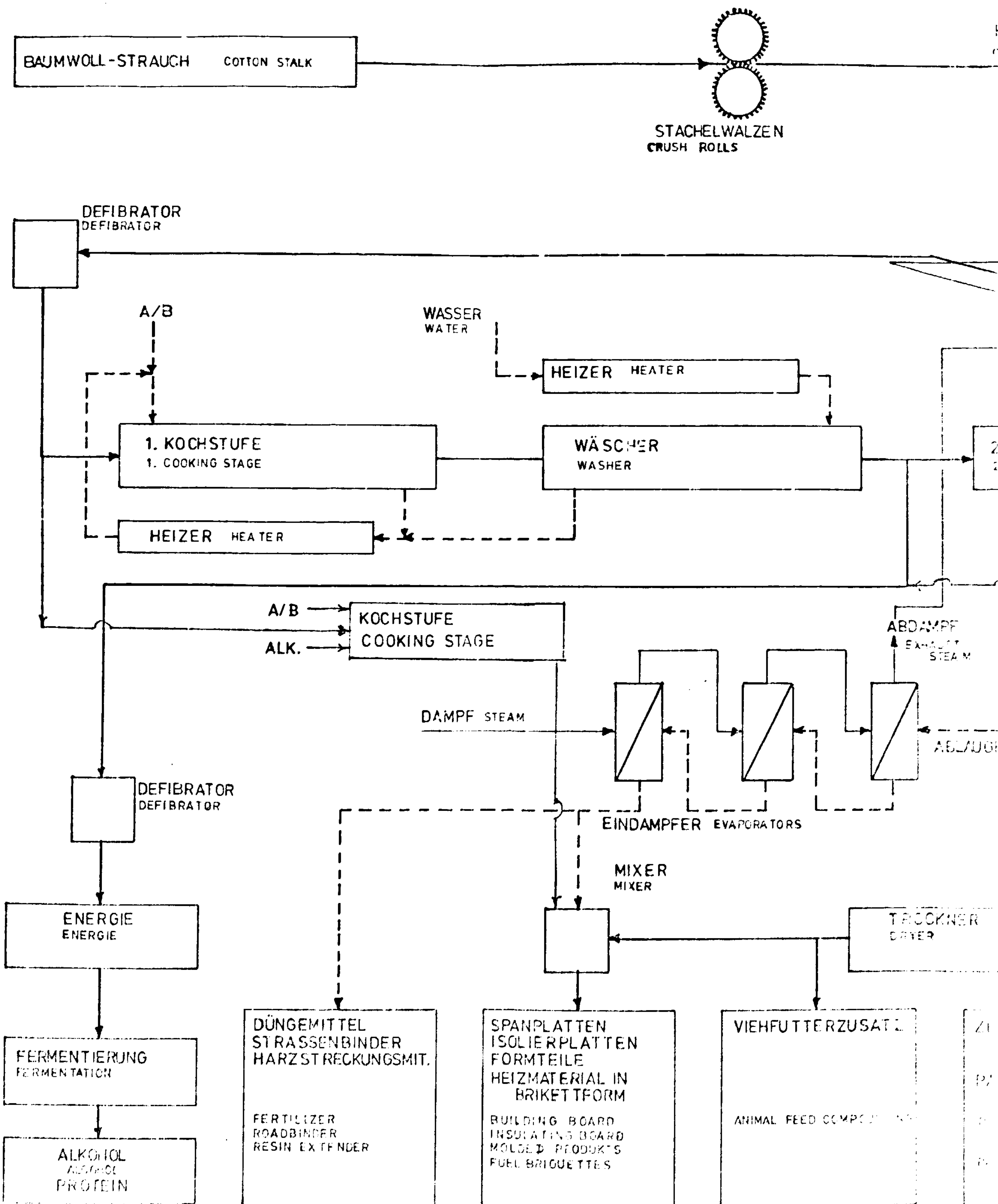
It is premature to recommend installation of even a modest commercial operation and the present disturbed situation in El Salvador would make the required investment and operation by private sources difficult. Additionally, the agrarian policy is in a state of flux and it would be difficult to predict now the feasibility of a collective effort which a cotton stalk industrial complex would require. Finally, the state of the Central American concept of a Common Market indicates caution in a project which could require export of production.

I therefore recommend the continuation and enlargement of this study in all its indicated areas of potential - panel board, feed, fuel, pulp and paper. For particular need and purposes, I would suggest the main effort be centered at the Instituto Centro Americano de Investigacion y Tecnologia Industrial (I.C.A.I.T.I.) in Guatemala City with the assistance and guidance of Kojess Development Ltd. as consultants and utilization of their specialized pulping facilities in West Germany.

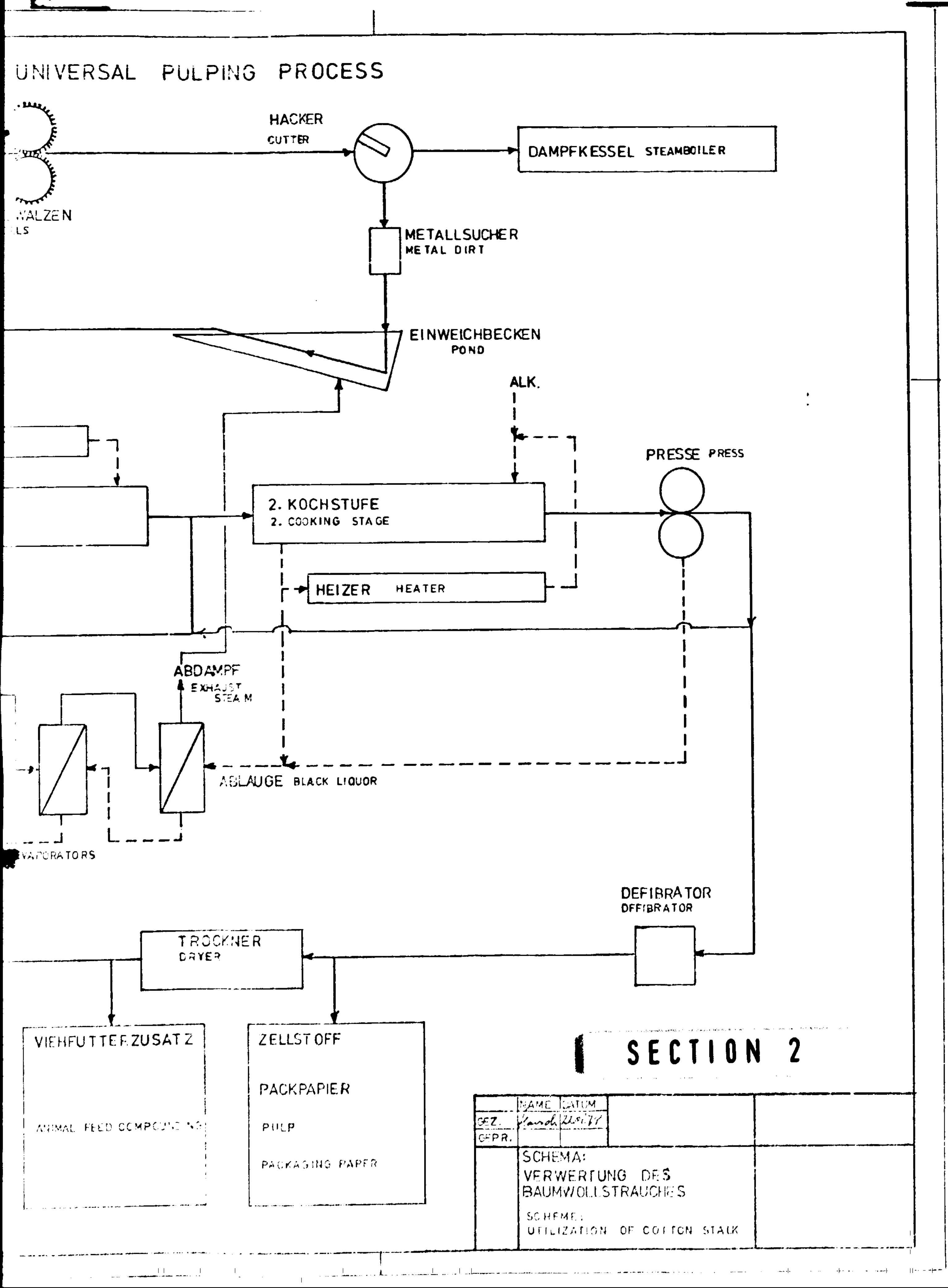
It can be anticipated that some experimental equipment would be necessary, some of which would itself need development to meet process needs. Mostly, however, I would expect any needed equipment to be scaled down commercial units or acceptable substitutes which could lead directly into a future commercial project.

It would be expected to utilize the interest, knowhow and facilities available, particularly in European commercial firms to expedite the development work and especially to check out the economics involved.

UTILIZATION OF COTTON STALKS BY APPLIKATION OF THE UNIVERSAL PULPING

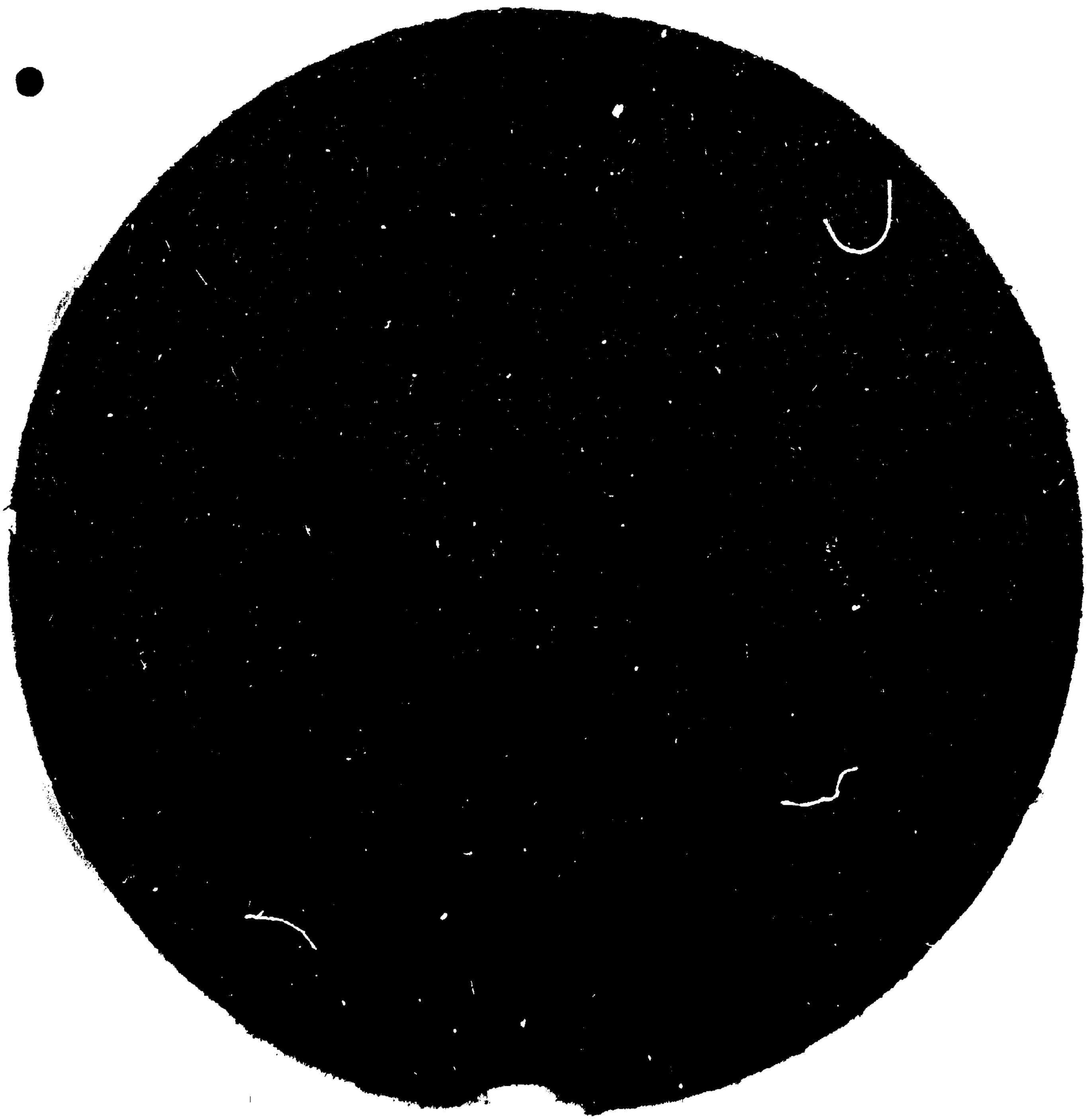


SECTION 1



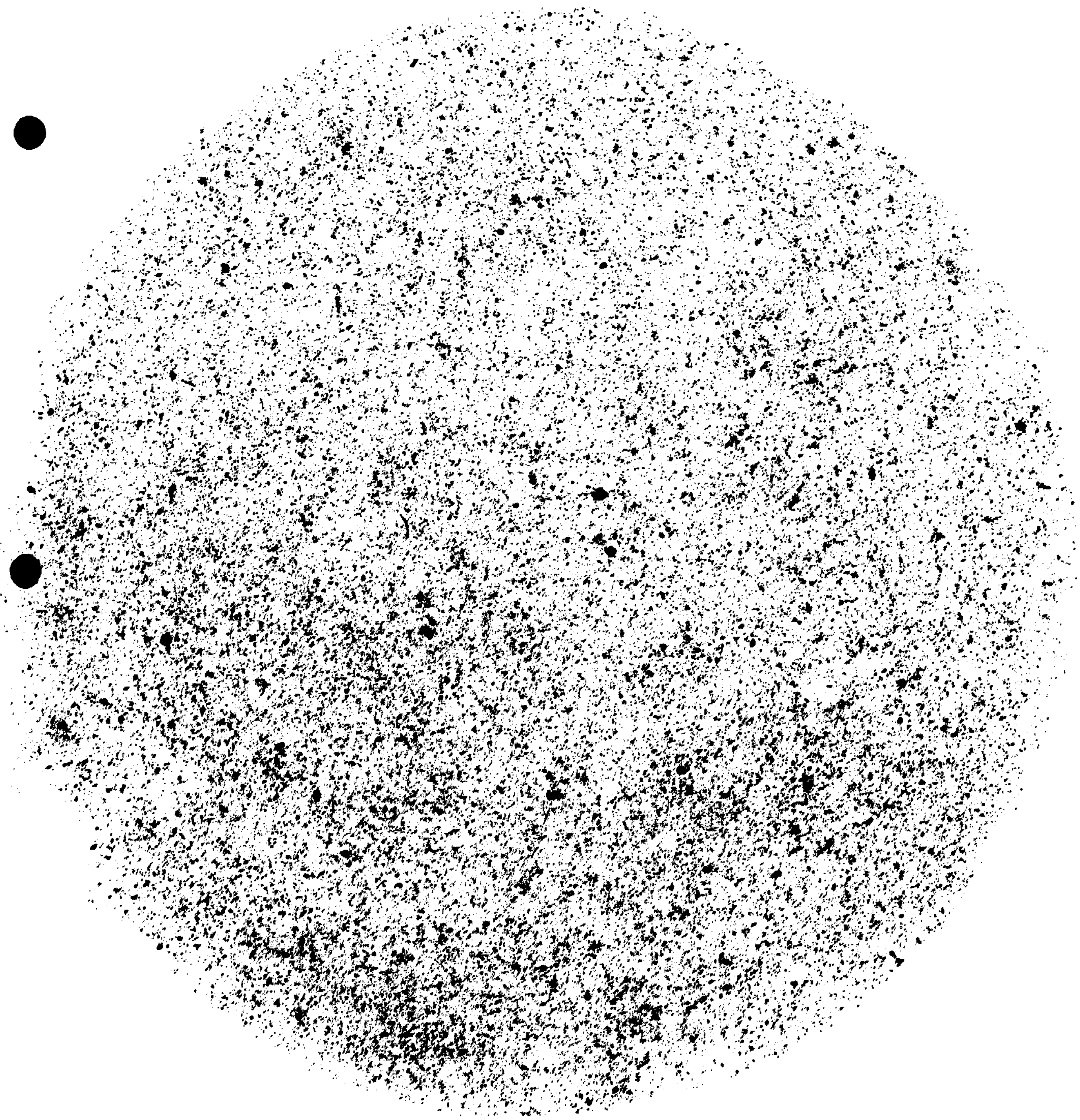
UNIVERSAL PULPING PROCESS
HACKER
CUTTER
DAMPFKESSEL STEAMBOILER
WALZEN
METALLSUCHER
METAL DIRT
EINWEICHBECKEN
POND
ALK.
PRESSE PRESS
2. KOCHSTUFE
2. COOKING STAGE
HEIZER HEATER
ABDAMPF
EXHAUST STEAM
ABLAUGE BLACK LIQUOR
VAPORATORS
DEFIBRATOR
DEFIBRATOR
TROCKNER
DRYER
VIEHFUTTERZUSATZ
ANIMAL FEED COMPOUND
ZELLSTOFF
PACKPAPIER
PULP
PACKAGING PAPER
SECTION 2
NAME
DATUM
GEZ.
GEPR.
SCHEMA:
VERWERTUNG DES
BAUMWOLLSTRAUCHES
SCHEME:
UTILIZATION OF COTTON STALK

84% COTTON STALK PULP
(2% Acid Stage)
16% No.2 Cotton Linters



84% COTTON STALK PULP
(3% Acid Stage)
16% Long Fiber

No. 2 COTTON LINTERS
Processed
with
Polyethylene Oxide Resin



Mcchine Made Board
CORRUGATING MEDIUM

80% Cotton Stalk Pulp
(2% Acid Stage)
15% Long Fiber (Spruce)
5% Black Liquor Solids
CMT 30 - 150 Index
Schopper Regler 67°