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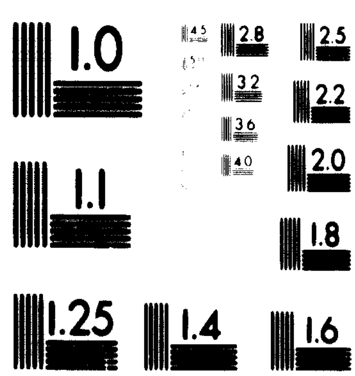

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United Nations Industrial Development Organization

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FINAL REPORT

Trinidad and Tobago.

REPORT ON

FEASIBILITY AND MARKET STUDY FOR PRODUCTION OF FURFURAL

PORT OF SPAIN, TRINIDAD

FEBRUARY/MARCH 1967

1967

The UNIDO/SIS Mission to Trinidad & Tobago included the following:

Dr. R. C. Desai Team Leader

Dr. J. M. Smuk

Mr. B. Thiagarajan

LETTER OF TRANSMITTAL

To: Mr. I. H. Abdel-Rahman
Executive Director
UNIDO

Sir,

1. At the request of the Government of Trinidad and Tobago a United Nations Mission was organized to explore the possibilities of producing furfural in Trinidad and Tobago primarily from the bagasse available from the operations of the sugar industry. The Mission consisted of:

Dr. R. C. Desai, Industrial Economist
Dr. J. Smuk, Chemical Engineer and Furfural Specialist
Mr. B. Thiagarajan, Chemical Engineer

The Mission was in Trinidad and Tobago for three weeks from 21 February to 13 March 1967.

2. Prior to the Mission's departure for Trinidad and Tobago, the UNIDO Secretariat had undertaken to study the market conditions for furfural. On the basis of information published in the trade and professional literature, supplemented by two reports prepared by Messrs. Cargill and Company and conversations with the DuPont Company, it appeared that the price of furfural was the key to the market. The main consumer, namely the DuPont Company, was switching to an alternative raw material for the production of tetrahydrofuran, and then some high cost producers might go out of production. It emerged that the main efforts should be toward cost reduction. If furfural could be produced in Trinidad at an ex-factory cost of US 8 cents per lb. of furfural, it was reasonable to believe that the production could be marketed without difficulties. If, on the other hand, the costs were above 10 cents per lb., it would be extremely difficult for Trinidad to market any significant quantities. The local consumption in Trinidad for the oil refining processes of the Texaco plant is small.

3. The crux of locating furfural production lies in the raw material situation. Bagasse in Trinidad is produced in two large sugar mills and two small ones. The two large sugar mills release respectively 135,000 and 120,000 long tons of bagasse, dry weight. The two factories are situated 1¼ miles apart, and are connected by a narrow asphalt road in poor condition. Of the quantities of bagasse available, all but 50,000 tons (dry weight) are used up as fuel in the two plants. The relatively small quantities produced in the other two plants are fully burnt up as fuel. The pith content of dry bagasse, as reported by independent laboratories in the United Kingdom to whom the bagasse specimens were sent, is 25%. The pentosan content of the dry bagasse is given as an average of 22%.

4. Two alternative methods of manufacturing furfural were considered. The first method was depithing the bagasse (into fibre and pith) and producing furfural from the pith. The second alternative was to use the total bagasse. In each case two different techniques were considered:

(a) the conventional Quaker Oats batch technique and

(b) pre-hydrolysis, followed by continuous production of furfural, as in the previous case.

5. Based on the local raw material situation and the technologies of production as described above, the Mission was given terms of reference by the Government of Trinidad and Tobago as below. The Mission was to investigate and report on the following:

1. World market situation for furfural

2. Alternatives for local production of furfural, utilizing the bagasse, including.

   (a) economics of production;

(b) applicable technology;

(c) stages of project implementation;

This study to include:

(i) The feasibility of separating bagasse into pith and fibre from all available supplies of bagasse and using pith as the basis for furfural production.

The following alternatives utilizing all the resulting fibre should be considered:

(a) As a fuel for the manufacture of sugar; and

(b) As a feed stock for pulp and paper and other industries.

(ii) The feasibility of immediate commercial production of furfural using the quantity of raw material over and above the normal fuel requirements of the sugar industry.

(iii) The feasibility of commercial production of furfural in Trinidad and Tobago using all available bagasse and other pentosaniferous materials (e.g. coconut bass), and to advise on:

(a) The ceiling price of raw materials which would render such maximum production economically viable; and

(b) The need for the establishment and operation of a pilot project or scheme to handle some proportion of the planned final capacity.

3. Recommendations for further action by:

(i) United Nations

(ii) Trinidad and Tobago.

6. The Mission considered all these alternatives in detail, on the basis of its evaluation of data assembled by visits, consultations

and correspondence with Ministries of the Trinidad and Tobago Government, with sugar companies, and with oil and electricity companies which were to be concerned with supplying alternative fuel and energy, and has the honour to present its Report herewith.

7. The Report begins with a general description of the technology of furfural production. It then proceeds to examine the raw material situation in some detail. Various alternatives of furfural production by depithing and from total utilization of bagasse are then considered. The results are then evaluated.

8. The main conclusion is that the best alternativa is to produce furfural at the largest sugar factory, using total bagassa from the two large sugar mills, together with the available coconut bass. This is a relatively large venture, involving conversion of sugar mills to alternative fuels, and transportation and storage of begasse (and bass) in large quantities. Even so, the project comes out marginal on paper. Any practical difficulty or error in calculation could easily upset the economics of the project.

9. On the other hand, some favorable facts needs to be taken into account:-

(a) The project seems so close to marginal that any favorable developments (such as a long-term contract for the sale of pulp or fibra) may make it extremely attractive;

(b) The project may just pay for itself; however, the incomes generated in producing furfural (which are chargeable as costs to the project) would make a sizeable addition to the gross domestic product of Trinidad and Tobago.

There is retrenchment in the petrolaum industry and the wages paid to labor employed can be taken as involving no net cost to the economy. Incomes earned in transporting bagasse and in selling natural gas which is surplus at the moment would also be additions to the benefits derived by the economy of the Islands. A case can be made out that the project is economic from the national standpoint, even if it is not so from the standpoint of its independent commercial viability in a market economy.

10. As the Report was being submitted the Mission received information that the tests carried out recently at the University of West Indies resulted in higher percentages of pentosan content of samples of Trinidad bagasse. The pentosan content in these tests averaged 25.7 percent. It may be worth investigating the reasons for the discrepancy between the results obtained by the British Laboratory and those by the University of West Indies. If the results obtained by the University are confirmed the statistics in Tables 3, 6 and 9 will alter as below.

EFFECT OF INCREASE IN PENTOSAN FROM 22 to 25.7% ON REPORTED EXPENSES IN TABLES 3, 6, & 9. VALUES INCLUDE INCREASES IN PREHYDROLYSIS COSTS

	Table 3	Table 6	Table 9
Total Additional Steam Cost + Fuel Value Water + Elect. + Acid	$ 137,600	$ 254,200	$ 257,500
Furfural Produced	30,400,000	58,400,000	60,800,000
New Manufacturing Expense	2,444,700	4,440,800	4,427,600
New Product Value at 8¢/Lb.	2,432,000	4,672,000	4,864,000
Net Increase	(12,700)	231,200	436,400
% Return on Investment	-	3.4	6.3
Cash Flow	-	888,200	1,093,400
Cash Flow/Capital Investment (%)	-	12.8	15.8

11. The evidence thus is variable, and even with the latest results the prospects remain marginal. The project requires, therefore, to be further evaluated before any firm decision can be reached on its economic viability.

12. We recommend that the Government and the sugar and the fuel industries of Trinidad and Tobago take all steps to effectively establish the technical and economic data on (a) the pentosan content of the Trinidad bagasse (b) the true replacement costs of converting the sugar factories to alternative fuels (and not what the interested parties would each like to charge for bagasse or for alternative fuels), and (c) the practical aspects of transportation and storage of bagasse (and baaa) in large quantities.

13. We recommend that the United Nations keep the project under review and help the Government of Trinidad and Tobago in two stages. Stage one may consist of the assistance it may need in establishing the above technical and economic data. If these data result in a more optimistic view of the project, stage 2 may consist of assistance leading to the establishment and operation of a viable furfural plant in Trinidad.

14. We also recommend that this Report be submitted to the Government of Trinidad and Tobago.

15. So many persons were helpful that it would be somewhat invidious to mention only a few by name. Nevertheless, we would like specifically to acknowledge the strong support, guidance and helpfulness of Sir Alan Reece, Chairman, Dr. Max Richards, Director and Mr. Eldon Warner, General Manager of the Industrial Development Corporation. That this Mission was able to accomplish what it did in the short time it had is a tribute to the organization and quickness of decision of the IDC. Our Liaison Officer, Mr. Henry Chee Hung was able, conscientious and thorough. His assistance saved us many hours of work. Mrs. Theresa Nurse, our secretary, carried a heavy stenographic load with aplomb and skill. Much of our work had to do with Messers Caroni Ltd. whose representatives were cordial, helpful and kind. To have spared so many hours of so many

officials for us during the height of the cane grinding season was indeed a consideration which we much appreciated. To all the many others who were of service to us we can wish to offer a collective thanks, especially to Messers Cargill Inc. of Minneapolis, Minnesota. This firm had spent several thousands of dollars on a pre-investment study of furfural, and very generously turned over the study to the United Nations free of cost. We found the material to be valuable in our work.

ORIGINAL SIGNED

R. C. Dessi
Leader of Mission

John M. Smuk

J. M. Smuk
Member

ORIGINAL SIGNED

B. Thiagarajan
Member

Partial List of Persons Interviewed

Alcantara, Miss Joyce, Ministry of Planning and Development, Port-of-Spain

Alexander, Simeon, Director, Industrial Development Corporation, Tobago.

Bassotti, Frank - Economic Adviser to Ministry of Agriculture, Port-of-Spain.

Blackburn, F.H.B. - Managing Director, Caroni Ltd., Usine Ste. Madeline.

Bowell, George Director, Industrial Development Corporation.

Brijmohan, G. - Asst. Manager, Coir Factory, Icacos.

Brotherton, Mrs. Daphne - Chief of Industrial Surveys, Dept. of Statistics, Port-of-Spain.

Campbell, Alexander - Permanent Represnetative, United Nations Development Programme, Port-of-Spain.

Chandler, M.D. - General Manager, Shell (Trinidad) Ltd. Port-of-Spain.

Chinnia, Irving W. - Act. Director of Statistics, Port-of-Spain.

Collins, R.W. - Reed Paper Co. (of Scotland), Port-of-Spain.

Curlet, A.S. - Manager, Technical Division, Texaco, Point-a-Pierre.

Down, A.L. - Resident Director, Texaco, Point-a-Pierre.

Dookhie, C. - Chief Planning Engineer, Trinidad & Tobago Electricity Commission, Port-of-Spain.

Easton, M.E.G. - Factories Superintendent, Caroni Ltd., Usine Ste. Madeline.

Edwards, George - Asst. Manager, British Petroleum (Trinidad) Ltd., Port-of-Spain.

Fitzwilliam, A.G.M. - Petrochemicals Manager, Texaco, Point-a-Pierre.

Frazer, Harold - Permanent Secretary to Ministry of Agriculture, Port-of-Spain.

Green, H.E. - Secretary, Caroni Ltd., Brechin Castle.

Guevera, C. - Planning Engineer Trinidad & Tobago Electricity Commission, Port-of-Spain.

Haring, C.J. - General Manager, Shell Petroleum Refinery, Point Fortin.

Julien, K.J. - Dean of the Faculty of Engineering, University of West Indies, St. Augustine.

Keech, A.F. - Technical Superintendent, Shell Petroleum Refinery, Point Fortin.

Macintyre, Alistair - Director, Industrial Development Corporation, Port-of-Spain.

Macmeechan, W. - General Manager, General Paper Corporation (Caribbean) Ltd., Guanapo.

Mathurin, Miss Rose - Ministry of Planning and Development, Port-of-Spain.

Merry, Charles, Director, Industrial Development Corporation, Port-of-Spain.

Mitchell, A.D. - General Manager, Caroni Ltd., Usine Ste. Madeline.

O'Halloran, Hon. John H. - Minister of Commerce, Industry, Petroleum and Mining, Port-of-Spain.

Pearse, M.G. - Planning and Development Engineer, Caroni Ltd., Usine Ste Madeline.

Prevatt, F.C. - Parliamentary Secretary to Minister of Finance, Port-of-Spain.

Rampersad, Frank - Permanent Secretary to Ministry of Planning and Development, Port-of-Spain.

Reece, Sir Alan - Chairman, Industrial Development Corporation, Port-of-Spain.

Richards, Max - Director, Industrial Development Corporation, University of West Indies, St. Augustine.

Robinson, Hon. Lionel - Minister of Agriculture, Port-of-Spain.

Robinson, Hon. Ray - Minister of Finance, Port-of-Spain.

Satcunanandan, T. - Professor of Mechanical Engineering, University of West Indies, St. Augustine.

Schuelt, - General Manager, Trinidad and Tobago Electricity Commission, Port-of-Spain.

Sisnett, W.H. - Factory Manager, Brechin Castle Sugar Factory, Brechin Castle.

Stevens, H.S. - Feneral Manager, British Petroleum (Trinidad) Ltd., Port-of-Spain.

Syrdal, A. - Deputy Resident Representative, United Nations Development Programme, Port-of-Spain.

Werner, Eldon - General Manager, Industrial Development Corporation, Port-of-Spain.

Williams, Victor - Asst. Permanent Secretary, Ministry of Planning and Development, Port-of-Spain.

Wilson, T. - Act. General Manager, Texaco, Point-a-Pierre.

ON THE POSSIBILITY
OF
FURFURAL PRODUCTION IN TRINIDAD

April 1967

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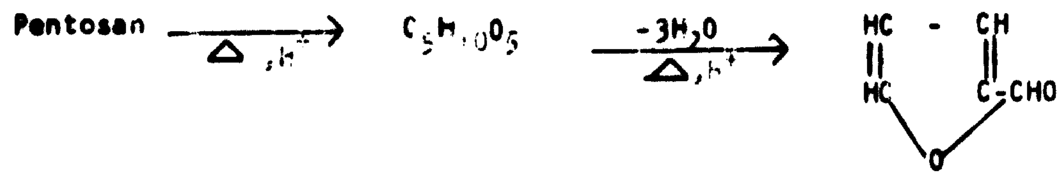
TECHNOLOGICAL

General Process

The formation of furfural occurs when a pentosan (polymeric five-carbon sugar) is first hydrolyzed to the monosaccharide which subsequently loses three molecules of water to yield one molecule of furfural. The overall reaction can be written as follows:



Several side reactions occur simultaneously with the main reaction shown above which detract from the furfural yield. To a small extent furfural is destroyed by the high temperature and acidic media, but a more important reason for not attaining quantitative yields is the reaction of furfural with some precursor. If, however, the furfural is removed as rapidly as it is formed, essentially all of the pentosan is converted to furfural. This important fact provided the basis for the well known Quaker Oats Process which has been responsible for nearly all of the commercial furfural.

In the Quaker Oats Process, which is a semi-batch operation, corn cobs or other agriculture residue, along with sulfuric acid are fed into large spherical digesters. While the digesters rotate slowly, steam at about 100 psi is introduced until the desired reaction temperature is reached. During the cooking period furfural and other volatile products are stripped from the reaction mass using additional steam. The furfural-laden vapors are led into fractionating and dehydrating columns where approximately 99% furfural is finally obtained. The solid residue from the digesters is primarily burned as fuel. By removing the furfural as it is formed through the stripping action of the steam, destruction losses can be minimized. Of course, it is evident that an optimum operating point axists where the gain in yield can no longer compensate for the increased steam consumption. Yields of 33-38% based on pentosen content are commonly obtained in industrial plants. Each digaster in itself operates as a batch reactor and the required continuous feed to the distilletion unit is achieved by operation of many digesters on a prescribed timing cycle. Because of the relativaly low cooking temperatures the reaction times are very long, resulting in a necessarily large number of digesters in order to simulete a continuous system. These digesters represent a very high capital invastment per ton of product and ara by far the most expensive equipment item in the entire plant. A schematic flowsheet of the Quaker Oats type of process is shown in Figure 1.

The inefficiencies of the single stage system have stimulated investigations into other methods of furfural production. A large shara of this work has concentrated on a two staga type of process. That is, prehydrolyzing the raw material to extract the pentosens into solution followed by a conversion of the solubilized sugar to furfural. The basis for this type of scheme lies in the fact that conversion of the pentosan to monosaccharide (or soluble oligosaccharides) proceeds much mora rapidly than the subsequent dehydration step. Thus, by properly staging the temperatures and acid concentration it is possible to effectivaly stop any degradation of the monosaccharide while obtaining a high yield (about 90%) of the available five-carbon sugars. Such a reaction is commonly carried out in the manufacture of dissolving type pulps by the Kraft process where the prasence of pentosans in the product is undesirabla. Due to the nature of the pulping process, however, the equipment would not be directly suitable for use in furfural production. There are no other existing industrial examples of prehydrolysis (except perhaps in Russia), but it is a technically feasible and relatively straightforward process. Commercial equipment is available today for carrying out any of the necessary steps (material preparation, reaction, concentration) involved in making a separation of the pentosan fraction. The process economics, of course, are directly tied to the utilization of the total material.

Because of the extraction step the final dehydration to furfural can be quite simply effected. With due attention to fouling problems the homogeneous reaction can take place at 500°F with yields approaching 65% of theoretical. The high temperature and presence of acid (effectively 0.1 normal) produce very rapid reaction rates so that the residence time is reduced to approximately 10 seconds. If the prehydrolysis step is carried out at 120°C, total hold up time in the two stage process is of the order of 30 minutes. The short residence time allows the use of a tubular reactor with very high flow rates and correspondingly large shear forces at the wall to help prevent fouling. The simplicity of the system and continuous operation result in the advantageous combination of high throughput capacity at very low investment. In contrast to the single stage process where as much as 3/4 of the equipment investment is due to reactors, the tube type reactor is practically expendable, amounting to about 5% of the equipment cost. Figure 2 shows the schematic flowsheet for a two stage process.

Raw Material

The item of major expense in the manufacture of furfural is the cost of the carbohydrate raw material. This is due to the low yields (generally less than 12%) that can be practically obtained and the handling costs associated with the necessity for moving large quantities of low bulk density material. With conventional processing techniques the raw material accounts for about 45% of the total manufacturing expense. Consequently, a strong position in the raw material supply is a fundamental requirement for economic furfural production. This implies a high degree of control over supply so as to remove as much as possible the uncertainties in availability and fluctuations in price. The sugar mill is therefore a very important partner in any furfural producing scheme based on bagasse.

In the past, corn cobs have been the primary carbohydrate material used for furfural production. This has been due to the high pentosan content, large quantities available in rather concentrated locations, and the essentially zero value which the farmers put on them. The cost to the furfural plant is incurred primarily in the collection and storage operations, which until the present time has amounted to $5-6 per ton of wet cobs. Recently the availability and projected availability of cobs has become restricted due to the introduction of mechanized corn pickers. As a result the price of cobs is rising with estimated cost in the early 1970's of $10/ton. Because of this, other carbohydrate materials have become more attractive and have been the subject of recent investigation. The changing raw material situation is clearly reflected in the decision of the major producer of furfural to construct a new plant adjacent to a sugar mill utilizing bagasse.

The total sugar produced in Trinidad amounts to about 230,000 tons annually, corresponding to nearly 300,000 short tons of bagasse. The relative distribution of this production is indicated by the following mill capacities:

Location	Daily Sugar Production (Tons)
Orange Grove	150
Forres Park	120
Reform	90
Woodford Lodge	240
Brechin Castle	700
Ste. Madeleine	700

The raw cane supply comes from 83,000 acres along the coast between the Port of Spain and San Fernando. The sugar estates cultivate about 1/2 of the total acreage but account for two thirds of the cane production. This is due to more fertilization, closer pest control and better cultivation practices. In view of the past trend and the continued efforts at improvement through agricultural research the proportion of sugar produced by the estates (Caroni Ltd.) will probably increase. This could be an important consideration in choosing a furfural plant site. Whereas the centroid of production is currently in the neighborhood of Brechin Castle, the greatest future increases in cane production will probably be in the South. To some degree the recent plant modernization at Ste. Madeleine substantiates this potential shift in cane production. The capacity now is very nearly equal that of Brechin Castle, with the distinct possibility that within a few years it will exceed the Brechin Castle sugar production by 30,000 tons. Another advantage of the Ste. Madeleine location is the possibility of a working arrangement with Federation Chemical for bulk loading at their dock.

The future of the total sugar production for the country is not clear. The low yields per acre, relatively low sugar content and substantial lack of mechanized harvesting techniques result in the highest sugar production costs in the [illegible] almost 3/4 of the total production has been sold on a [illegible] basis at a guaranteed price to the British Commonwealth. This agreement extends for seven years and is negotiated each year for the eighth year. Obviously, these factors mitigate against any significant increases in sugar production. On the other hand, as mentioned above, Caroni Ltd has modernized their Ste. Madeleine sugarhouse (to the extent of nearly 3.8 million dollars). In addition they have projected about $100,000 will be spent for incineration equipment. This seeming anamoly of facts tends to indicate that whereas the total production of the country may change very little, the more efficient producers will progressively increase their share of the market. The largest future sources of raw material for a furfural plant therefore will probably come from the two main Caroni mills.

A summary of the current and near future supplies of bagasse and the distances between the Caroni mills is given below. Since the largest available supply is at Brechin Castle, all distances are given to Brechin Castle assuming this location as the furfural plant site, and transport charges for the bagasse are given on this basis. The local cost for bagasse haulage is 7.5¢ U.S./gross ton mile.* This rate does not show any seasonal variation.

	Brechin Castle	Woodford Lodge	Reform	Ste. Madeleine
Distance to Brechin Castle (Miles)		10	13	14
Haulage Charge per ton dry bagasse		$1.40	$1.82	$2.10
Total available dry bagasse (long tons)	135,000	32,000	16,000	120,000
Surplus dry bagasse (long tons)	27,000	-	-	23,000

*Rate of exchange assumed as:
60¢ U.S. = $1.00 T.T.

Surplus bagasse refers to that which must be hauled away (about one mile) because of inadequate burning facilities.

Bagasse as it comes from the last extraction unit in the mill contains about 50% moisture. An analysis of the bagasse from Trinidad has shown it to contain 24-26% pith by wet screening methods. Roughly 2/3 of the pith can be removed by simple mechanical means. There is very little difference between the chemical composition of the pith and that for the remaining fiber with the pith perhaps containing slightly more gums or xylans. The principal chemical constituents of the whole dry bagessa are:

Lignin	17%
Cellulose	57%
Pentosans	22%
Ash	4%

The two constituents of primary concern in furfural production are, of course, the pentosans and the ash. Ash is important from the standpoint of acid requirements and the affect of silica content on high pressure steam generation equipment. In lieu of a detailed analysis of the ash the buffering capacity has been taken as zero. This assumption minimizes the acid cost. As an indication of the possible increase due to ash alkalinity, the buffering capacity of wood can result in a doubling of the theoretical acid requirement.

The pentosan fraction is the furfural precursor, the quantity of furfural derived being dependent upon the particular process employed. Under carefully controlled laboratory conditions the conversion is essentially quantitative with the measurement of furfural actually used as a method for pentosan determination. However, in the conventional manufacture of furfural yields do not exceed 38% based on pentosan content. It has been demonstrated on a small scale that a solubilized pentosan media can yield 40-43% furfural. For the construction of a new plant it is not unreasonable to assume that a yield of 40% can be realized. Based on this, the yield of furfural from the various sources in Trinidad can be summarized as follows:

POTENTIAL ANNUAL FURFURAL PRODUCTION (POUNDS)

	Source		
Location	Total Bagasse	Surplus Bagasse	Pith
Woodford Lodge	6,240,000		1,560,000
Reform	3,120,000		780,000
Ste. Madeleine	23,400,000	4,[illegible]	5,850,000
Brechin Castle	26,600,000	5,4[illegible]	6,650,000

PROCESS ALTERNATIVES

Depithing

Under this alternative the whole bagasse is separated into a pith fraction and a fiber fraction. The pith is utilized for furfural production and the fiber is either burned as fuel or up-graded to another product. Since the pith does not substantially differ in composition from the rest of the stalk, the potential furfural amounts to one quarter of that obtainable from the whole bagasse. Therefore, the plant scale is relatively small - 6,650,000 pounds of furfural at the Brechin Castle mill and 5,850,000 pounds at Ste. Madeleine. In addition to this disadvantage of smaller scale of production there is the cost of pith separation. There are, however, several factors which tend to counterbalance these unfavorable aspects.

The current surplus bagasse at both Brechin Castle and Ste. Madeleine is between 20-23% of the total available quantity. Since there is no reason to suspect large differences between the heat of combustion of the pith and whole bagasse, it is apparent that utilizing the pith for furfural practically removes the problem of excess bagasse disposal. Indeed, a financial credit can be taken based on the estimates for additional incineration capacity made by the sugar company. This estimate indicates that to incinerate a ton of bagasse requires a capital investment of $9.00 U.S. and a maintenance charge of $.30 U.S. Furthermore, it is quite possible that there will be an associated improvement in boiler efficiency which will ameliorate an existing noxious soot problem.

A potentially very attractive advantage in processing pith to furfural in contrast to whole bagasse is the likely large reduction in reactor volume necessary to accomplish the conversion. The difference in physical characteristics of the pith and fiber accounts for this possible process simplification. Optimistically, only small changes in the continuous tubular reactor system would be necessary with negligible changes in the total plant cost. This assumption was used in estimating the capital investment for the depithing process. The flowsheet for this process would look essentially like that in Figure 2 with the exception of additional depithing equipment and no prehydrolysis unit. Fundamentally, such a system would save the cost of prehydrolysis involved in processing whole bagasse by the substitution of costs for pith separation.

The pith could conceivably be obtained from all of the mills in which case the total furfural production would be 14,800,000 pounds per year. However, considering that Woodford Lodge and Reform contribute only 2,300,000 pounds of the total furfural production, the expense of depithing equipment at these sites plus the transport charges would far exceed the benefits of the slightly larger plant size. Transportation of the total bagasse to the furfural plant for depithing is equally unattractive due to the necessity for a replacement fuel and the three-fold increase in transportation charges. Consequently, only the Brechin Castle and Ste. Madeleine mills were considered as practical sources of raw material.

Two processing schemes were evaluated: (a) depithing at Brechin Castle (b) depithing at both plants and transporting the pith from Ste. Madeleine to Brechin Castle during the off season. In the first case the annual furfural production would be 6,650,000 pounds. While second alternative raises the total production to 12,500,000 pounds, and effects some economies of larger plant scale, these benefits are countered by the transportation cost. Tables 1 and 2 give a summary of the manufacturing expense for each process alternative.

The cost analyses indicate that neither depithing scheme is practicable based on an 8¢/lb. factory price; and that transporting the pith from Ste. Madeleine to Brechin Castle is even more uneconomical than production based on Brechin Castle pith alone. The transportation charge (about 1¢/lb. of product) is the crucial factor in attempting to use the bagasse from Sta. Madeleine for increased production. In addition, the economies of scale are somewhat raduced becausa of the necessity for duplicating a sizeabla portion of the plant (depithing equipment) at both sites.

In the case of production at Brechin Castle only, the charges for pith removal are the principal raason for making the process unattractive. This item represents approximately 40% of the total manufacturing expense so that changes in this estimate have a great bearing on plant economics. The charge of $1.50 U.S. per ton of dry bagasse, however, is a lower bound and any errors involved in this estimate will undoubtedly cause an even greater production cost. Furthermore, no charge has been made for the bagasse itself since it was assumed the fiber fraction would ba returned to the sugar mill for fuel.

It is therefore necessary to find outlets which will upgrade the fiber value above that for fuel in order to maka an economical depithing scheme for forfural production. The result of this conclusion is that the scope of the problem is broadened to the quastion of total bagasse utilization which is beyond the boundaries of this report. Two of the more obvious possibilities, howevar, are the conversion of the fiber into hardboard or pulp. In considering these alternatives for fiber utilization the following points are important:

(a) An outlet for the fiberboard or pulp must be developed whereas the use as fuel already exists.

(b) The current boilers would have to be converted to an alternative fuel.

(c) The bagasse will have to be purchased at a price equivalent to the fuel replacement value plus a small premium for the sugar mill.

(d) Much larger capital outlays will be required.

At the present time there is an apparent internal market for about 25,000 tons of diversified pulp products, roughly corresponding to 50,000 tons of dry bagasse. A single 100 ton/day pulp mill could theoretically satisfy the total market. By world standards this is a very small mill, and of course, one mill could not produce the variety of products required without a prohibitively large investment. On the other hand, certain portions of the internal market can possibly be captured by small producers. This is evidenced by the new mill installed by General Paper Corporation for production of toilet tissues. About 700 tons of product will be manufactured annually with a bagasse demand of 2000-2500 tons. In terms of a furfural plant, however, it is quite obvious that for the tonnages of bagasse required, the associated pulp product must be sold on the world market. Whether export pulp can compete with other sources is a question that cannot be resolved in this study, but which, on the surface, seems an unlikely prospect.

Utilization of the fiber fraction for the production of board presents much the same situation as for pulp. One possible advantage is the smaller capital investment needed per ton of production, but nevertheless the current internal demand (about 1500-2000 tons per year) is insufficient to warrant local production. Again, whether an export market can be developed or major changes in the Trinidad and Tobago market can be realized is a question for further investigation. An evaluation recently made for Shell (Trinidad) Ltd. showed that a fiberboard plant in Trinidad and Tobago could not be economically justified.

However, the production [illegible]. An interesting point in the [illegible] could be obtained at $3 U.S. per [illegible].

It is conceivable that by operating a furfural plant in conjunction with a hardboard (or pulp) plant, a reduction in raw material cost could be obtained by dividing the depithing costs between both plants. Hopefully, both the furfural and hardboard plants would become viable by such a maneuver. An important consideration in order to achieve maximum benefits from plant combination is the necessity for integrating the fiber utilization capacity to the pith requirements of the furfural plant. This means a fiberboard production of about 100,000 tons per year when operating in conjunction with a furfural plant based on the bagasse available at Brechin Castle. Under these conditions an estimate of the reduction in bagasse cost to the fiber mill can be made by using the expenses given in Table I. If a return on capital invested of 10% is assumed for the furfural plant and the incineration saving is still credited, the allowable cost of pith can be calculated as nearly $100,000. Spreading this over 151,000 short tons of bagasse [illegible] illustrates that at most the cost of bagasse to the fiber mill will be reduced by 66¢ U.S. per short dry ton. Applying the total credit (all of the 66¢ is not strictly deductible because of plant scale differences) to the Shell estimate of manufacturing [illegible] results in a saving of 5¢ U.S. per 1000 square feet [illegible] $2[illegible] per 1000 square feet.

While there is a definite advantage in a combination type process, it is evident that if depithed fiber is considered as a raw material for pulp or board production, these processes must be economic in their own right. The role of furfural based on pith raw material is simply a scavenger operation and cannot be expected to carry or drastically alter the economics of the other operations involved in residue utilization.

Shortly before the Furfural Mission left Trinidad and Tobago it was learned that Mitsui and Co. Limited was apparently interested in purchasing briquetted bagasse for export to their Japanese pulp mills. Such a prospect is pertinent to the furfural question in at least two ways. The briquetting process involves depithing, drying and compressing in order to make the bagasse suitable for shipping and for pulping. This means a possible cheap source of pith; and, secondly, if such a scheme is practical it undoubtedly would involve significant quantities of material. Although the pith would be a residue it still would not be available at zero cost. Two pricing alternatives are immediately apparent; one based on a pro-rated charge for expenses incurred in depithing, and another based on the fuel value should all the sugar mill boilers not be converted to a substitute fuel. From the standpoint of furfural production a value of pith can be derived by using the previously estimated allowable pith cost of $100,000 U.S. On the basis of pith this amounts to about $3.00 U.S. per ton.

The sale of briquetted bagasse fiber to Mitsui Co. Limited and the associated generation of a waste pith residue, hinges on whether the bagasse is competitive with other fiber sources. As this report was being prepared a letter written by the local marketing representative for Mitsui Company Limited was forwarded by the Industrial Development Corporation of Trinidad which stated the current cost of fiber compared to bagasse as follows:

Wood Chips:

$17.50 U.S. per cubic meter C & F

$ 9.00 U.S. per long ton is ocean freight rate

Per Long Ton of Pulp.

Wood Chips Required 3.2 cubic meters

Total Cost	=	3.2($17.50)	=	$56.00 U.S.
Freight	=	2.56($9.00)	=	23.00
Chip Cost			=	$33.00

Bagasse Required - 4 long tons

Bagasse Cost	=	4($22.40)	=	$89.60 U.S.
Freight	=	4($9.00)	=	36.00
Total				$125.60

According to the above data the price of bagasse is prohibitive. While bagasse is perhaps more costly than wood chips, the figures used in the above calculation are open to some question. The freight charge for wood chips appears to be calculated on the basis of 50 pounds per cubic foot whereas a density of about 25 pounds per cubic foot seems more realistic. If this is the case, the freight charge for wood chips would be closer to $46 U.S. with a resulting total cost of $79 U.S. per long ton of pulp. At the same time, the bagasse price and the assumed pulp yield are incompatible. The bagasse price, although subject to negotiation with Caroni Ltd. is charged out at $22.40 per ton which is obviously on a dry basis. On the other hand, the pulp yield is based on wet bagasse. Actually, the pulp yield would be closer to 40% based on dry depithed bagasse and depending upon the type of pulp produced it could be as high as 60%. Allowing for a 50% yield the cost of bagasse per long ton of pulp would be about $81.60 U.S. compared to the $125.60 estimated above, and the revised estimate of $79 for wood chips. The lower cost of bagasse, however, is contingent upon obtaining an ocean freight charge of $9.00 per ton (reportedly the current rate is $25.00 in Trinidad), and assumes the briquetting costs are incorporated in the $22.40 per ton bagasse price.

Furfural Production from the Whole Bagasse

Under this alternative the whole bagasse is digested either in a one stage or two stage process to yield furfural and a ligno-cullulosic residue. Schematic flow sheets for these processes are given in Figures 1 and 2. As in the case of the depithing alternative, a suitable outlet must be found for the residue if furfural production is to be viable. In view of the previous discussion the residue is assumed to have value only as fuel.

Two schemes of production were evaluated; one based on the bagasse available at Brechin Castle corresponding to an annual furfural production of 26 million pounds, and the other based on transporting the bagasse from Ste. Madeleine to increase production to 50 million pounds. As a matter of comparison, cost estimates for both the prehydrolysis and single stage processes were made for the smaller plant. For the 50 million pound plant only prehydrolysis was considered since it was the more economical, [redacted]. Furthermore, the capital investment for a conventional process would be much greater, undoubtedly exceeding $10 million, and it does not seem likely that any plants of this type would be constructed in the future. Since the economics of the smaller plant based on 151,000 tons of bagasse at Brechin Castle were unfavorable, the processing alternative utilizing only surplus bagasse (55,000 tons) was not considered.

The economics of production are greatly influenced by differences in operation of the sugar mill and furfural plant. Whereas the suger mill grinds cane for about 150 days, the furfural plant must operate over the entire year. This fact presents problems in bagasse storage, heat exchange and disposal. Table 8 summarizes the distribution and utilization of bagasse in terms of demands for heat in the combined sugar mill-furfural plant. In performing these calculations the heat requirements of the sugar mill were taken as the equivalent bagasse currently burned after deducting the quantity designated as surplus. No allowance was made for possible improvements in heat economy within the sugar mill.

For the plant producing 26 million pounds of furfural it is necessary to provide bagasse storage for 180 days of operation after the grinding season is over. This amounts to 82,300 short tons, leaving 68,700 tons available during the grinding season. As a result, there is a poor balance in the supply and demand of heat for the total plant. During the grinding season 146,000 tons of dry bagasse are required for fuel. Allowing for 20% removal of solid substance in the furfural process, 55,000 tons of residue are available for fuel, leaving the equivalent of 91,000 tons of dry bagasse to be purchased as replacement fuel. On the other hand, after the grinding season the amount of residue exceeds the steam generation requirements by 32,200 tons. The disposal cost of this excess was calculated by assuming that existing boilers would be used and only maintenance of 30¢/ton was chargeable. It is evident that as the grinding season gets longer the heat economy and bagasse utilization become more favorable. There will, nevertheless, always be a deficit in the heat balance unless present mill efficiencies are improved, since the total heating value of the bagasse cannot accommodate both furfural and sugar production.

It is possible to avoid the disposal cost and improve the residue utilization by prehydrolyzing the entire bagasse during the grinding season. The savings are, however, compromised by the increased plant size for prehydrolysis which will operate only during the grinding season, and the storage costs of the pentose solution. The net result is an actual increase in the cost of furfural production.

A more practical alternative to the problem of bagasse utilization is to stockpile the excess of 32,200 tons during the off season for use as fuel when the sugar mill is in operation. This has the advantage of reducing replacement fuel requirements to 58,800 tons, eliminating the incineration cost and using available storage. Storage and handling of the residue is assumed to cost $1.00/ton so the manufacturing expense of Table 3 is actually reduced by $63,500. This reduction, however, is not sufficiently large to eliminate the $179,100 operating deficit shown in Table 3.

The analogous problem of bagasse utilization and heat balance for the 50 million pound furfural plant can also be solved by storage during the off season and by transporting the bagasse equivalent to the Brechin Castle deficit (67,400 tons) from Ste. Madeleine during the first grinding season. The replacement fuel costs, however, are magnified by the necessity for replacing the total value of the Ste. Madeleine bagasse. By means of off season storage it is possible to reduce the substitute fuel requirements to the equivalent of 6800 tons of dry bagasse (above Ste. Madeleine requirements) at the added expense of $60,800 for storage. Incineration costs are also eliminated, resulting in a $119,400 reduction in the manufacturing expense shown in Table 6. The operating loss is thereby changed to $67,200.

The manufacturing expenses shown in Tables 3 and 6 and the improvements thereon mentioned above, indicate that neither type of furfural plant is economical with an 8¢/lb. factory price for furfural. The plant producing 50 million pounds essentially breaks even at the 8¢/lb. price, while the 26.6 million pound plant shows a loss of $[illegible] and a break even price of 8.7¢/lb. The plant economics with larger production are largely off set by the transportation and fuel replacement charges.

It does not appear possible to attain the sizeable decreases in the manufacturing expense which are necessary to make the considered alternatives viable. While possibilities do exist for effecting economies, they are counterbalanced by at least equal possibilities that some items have been underestimated. Furthermore, these economies are marginal and are overshadowed by the real problem of bagasse cost and availability.

The importance of the fuel replacement value is clearly emphasized in the large plant where it amounts to nearly 1/2 million dollars. The possibility of reducing the value of bagasse for fuel below $2.67 per short ton does not seem likely. This estimate, provided by the Trinidad and Tobago Electric Company, is based on the cheapest fuel available (gas @ 27¢ U.S./1000 ft.^{3}) with no allowance made for boiler conversion expenses or the usual premium to the sugar mill (50¢/ton). It would, in fact, seem more realistic to use a value of $3.25/ton. On this basis, the operating deficits shown in Tables 3 and 6 would be increased to $231,600 and $[illegible],[illegible]00 respectively. As a matter of interest, the General Paper Corporation currently pays slightly more than $8.00 U.S. per short dry ton for bagasse at the sugar mill.

The effect of having a concentrated raw material supply can be illustrated using the data in Table 6. If the bagasse for 50 million pounds of furfural per year was available at a single sugar mill, the transportation charges of $252,000 would be eliminated. In addition, there would be a reduction in the fuel replacement value equivalent to 11,000 tons of bagasse, plus the advantage that any heat economies effected in the sugar house would directly lower the purchased fuel. Where two mills are involved, however, the total heat load of one of the mills must always be replaced and the maximum improvements in the other mill are restricted by the amount of bagasse available (assuming fuel is the only outlet for the residue from digestion). If the two mills are of comparable size the total efficiency of the two will be significantly less than for one mill of the same total capacity. For a 50 million pound furfural plant based on bagasse from a single mill the savings would exceed $280,000 and could conceivably approach $450,000; or about 3.5 to 7% on invested capital. Raw material location obviously plays a crucial role in determining the economics of a furfural plant.

The cost of carbohydrate raw material can be looked at from the standpoint of the allowable charge that can be borne by the furfural process. For the processing alternatives in Tables 3 and 6, no cost was assigned to the bagasse except where another fuel was substituted. In Table 6, for example, the total charge for bagasse was shown as $465,000. The corresponding maximum allowable cost of bagasse would be $1.25/ton assuming a zero net income for the process. Actually, this figure would be reduced somewhat due to credit assumed for the value of the residue as fuel in the furfural steam requirement.

The island of Trinidad has a minor auxiliary source of furfural in the bass rejected from the coconut industry. There are 10,000 tons of essentially dry material available 30 miles distant from Brechin Castle. The pentosan content of this material is assumed to be similar to the coconut shell (taken as 30%) and the bulk density of the dry bass is probably about the same as dry bagasse. If the bass is available at zero cost and only transportation, storage and handling are charged against it, this is an economically attractive material for augmenting output at a producing furfural plant. The manufacturing expenses are given in Table 9 for the plant described in Table 6 with the previously described improvements in bagasse utilization, and the coconut bass as additional input. It should be noted that plant costs are taken the same as for the 50 million pound plant. The economics of this alternative, although not very favorable, represent the best of any alternative considered.

GENERAL EVALUATION OF RESULTS

The results of this preliminary study show that production of furfural in Trinidad is not a profitable venture. Under the best circumstances (as listed in Table 9) it is a marginal operation and other alternatives show actual losses. Two general schemes of production were considered: (a) depithing, and (b) utilization of the whole bagasse. In the case of depithing the major obstacle is the cost of pith removal, while in the use of the whole bagasse the effective raw material cost essentially controls the process economics. Fundamentally the problem lies in the availability of the raw material; that is (a) quantity (b) location, and (c) length of grinding season. Because of this and the existence of comparatively more productive sources of bagasse in other parts of the world, it is valid to question any decision to produce furfural in Trinidad.

In addition to the basic unfavorable raw material supply, there are problems specific to Trinidad regarding roads, shipping, and acid supply that must be solved. The present condition of the road between Ste. Madeleine and Brechin Castle, along with load limitations, presents a practical problem in moving any substantial quantities of material between the two plant locations. There is now under construction a new highway scheduled for completion in 1971 which will alleviate this situation. In all probability a furfural plant could not be on-stream much sooner than 1970, and in this respect the road problem is a secondary one. Similarly, a solution for obtaining the necessary bulk loading facilities may be possible by an arrangement with Federation Chemicals through the help of Caroni Ltd. as an intermediary. A private loading dock is required if port charges are to be kept at a bearable level. Ordinary longshoremen and berth charges in Trinidad are among the highest in the world because of the turn about time and must be avoided. This will also have an influence on the cost of acid which apparently will have to be imported due to the reported balance in local production and demand. It does not seem that these difficulties are insurmountable and accordingly are termed secondary relative to the problem of raw material.

It is important to note here that Trinidad does possess certain advantages which can be exploited in the production of furfural.

1. Natural gas - Approximately 13 million cubic feet per day is available from the Trinidad and Tobago Electric Company and an additional 10 million cubic feet per day can be obtained from Shell Oil Company. Using both of these sources the total current fuel requirements of Ste. Madeleine and Brechin Castle can be satisfied.

2. Trinidad is a member of the Commonwealth and as such enjoys certain trade advantages with other members of this group.

3. Labor - The cost of labor, although not as low as in the lesser developed countries, is nevertheless substantially lower than other areas of major chemical production. The population has a very high percentage of literacy, and the experience of some other industries has shown the local labor force to be of good quality--adaptable and willing to learn.

4. There is a current problem with disposing of excess bagasse which will demand capital expenditures in the near future.

5. Financial - There are a variety of governmental and international agencies through which favorable loans may be arranged. The government of Trinidad and Tobago also provides incentives for investment by means of a tax holiday.

6. Political - A stable government with apparent desire to be helpful in attracting new industry to the country.

Within reasonable bounds, however, no single one or combination of these factors can compensate for the adverse raw material situation. For changes in the outlook for furfural it is necessary to look at the possibility of future increases in sugar production or more concentrated cane grinding, upgraded utilization of the fiber portion with concomitant generation of a low cost pith fraction, increased efficiency in bagasse collection, or higher prices for furfural.

Of these possibilities the one of most immediate importance and which could modify the conclusions presented here, is the price of furfural. The question of obtaining a higher furfural price is dependent upon two factors; freight charges and the ability to sell the furfural in competition with substitutes. Assuming slightly higher than average shipping cost of 1.5¢/lb., an 8¢/lb. F.O.B. factory price results in a delivered cost of 9.5¢/lb. Compared to the quoted market prices of 13-14¢/lb. this appears to be extremely profitable. For certain uses there is no alternative material, in which case conditions of tight supply (as presently) greatly increases the price. Typical of this situation is the use of furfural in solvent extraction of unsaturates. However, the fraction of the furfural market subject to these circumstances is small. Most of the furfural is purchased in contract lots well below the quoted price.

The price of furfural is bounded by the fact that the major part of the furfural market (and the fastest growing outlet) is undergoing severe competition from petrochemicals. Du Pont, the largest single buyer, has now erected a plant for production of tetrahydrofuran from acetylene and formaldehyde. This decision is influenced by the lack of an adequate furfural supply upon which to base future expansions of the synthetic fiber production. Currently, Du Pont purchases practically all the output of South Puerto Rico Sugar on a contract at under 10¢/lb. delivered, but instability in this supply has inspired the move away from furfural [illegible] for furfural in the future (wh[illegible] attractive) is going to depend to a [illegible] of their synthetic THF plant, and the quantities of furfural that are available. Other outlets for furfural exist, but as the price goes above 10¢/lb. the market situation becomes more and more nebulous and it is not possible to easily ascertain actual market size without a very intensive study. By the same token, at the assumed 8¢/lb. factory price there is little doubt that the entire furfural potential of Trinidad could be sold.

The product value at the factory can also be judged from the standpoint of the manufacturing expenses of the competition. An 8¢/lb. price would compete favorably with the costs of South Puerto Rico Sugar Company, but due to differences in plant efficiencies and depreciation the furfural produced from corn cobs by Quaker Oats Company would have a definite advantage. Nevertheless, at the projected rate of increase in the price of corn cobs the manufacturing expenses of these plants would be expected to reach 8¢/lb. by 1972. The newest plant, just now being put through start-up operations, uses bagasse as a raw material, but departs from the conventional process at South Puerto Rico Sugar Company by using horizontal cylindrical digesters. This plant will produce 50 million pounds of furfural annually, and it must be expected that it will operate more efficiently than the conventional process. From all appearances, the plant investment per ton of product has been decreased considerably via an estimated reduction of about one sixth in reactor volume. Actual manufacturing expenses cannot be estimated at this time due to the lack of information on plant investment, furfural yield and handling charges. However, it would probably be somewhat less than 8¢/lb.

Although furfural production by itself is not economic, it is possible to generate some justification for a plant by considering the contribution to the total economy of Trinidad. After an initial deficit in foreign exchange due to the import of plant equipment, there would be net annual increase of about $4 million. At the same time, important domestic benefits are derived from employment provided (both direct and indirect) especially in view of the current situation where laborers are being displaced due to fundamental changes in the petroleum industry. Furthermore, a plant would result in upgraded bagasse utilization and provide indirect revenues through the purchase of natural gas and power. Of course, any decision of this nature is governed by the alternative uses for monies to be spent and the corresponding relative priorities.

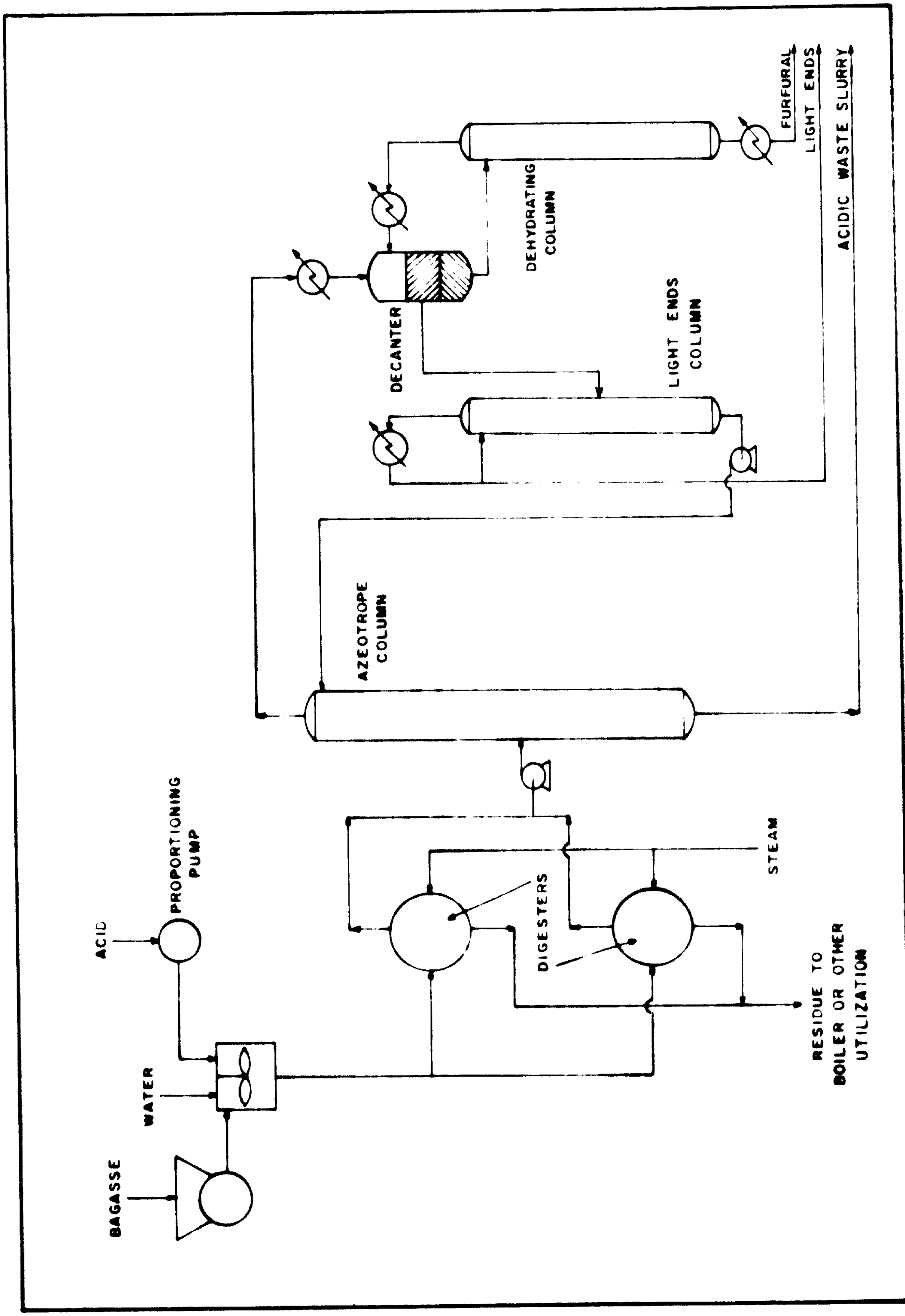
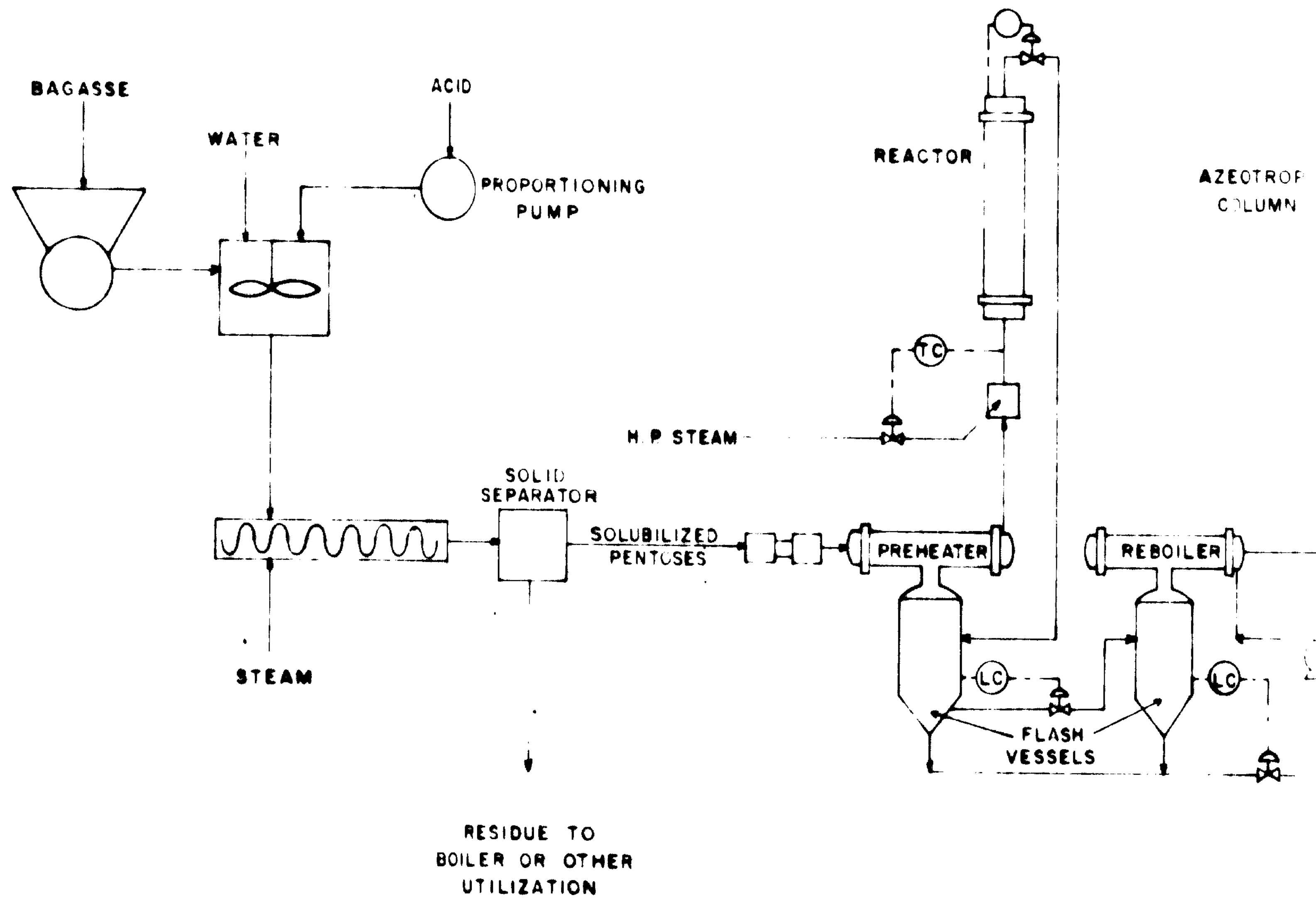

BAGASSE
WATER
ACID
PROPORTIONING PUMP
DIGESTERS
STEAM
RESIDUE TO BOILER OR OTHER UTILIZATION
AZEOTROPE COLUMN
LIGHT ENDS COLUMN
DECANTER
DEHYDRATING COLUMN
FURFURAL
LIGHT ENDS
ACIDIC WASTE SLURRY

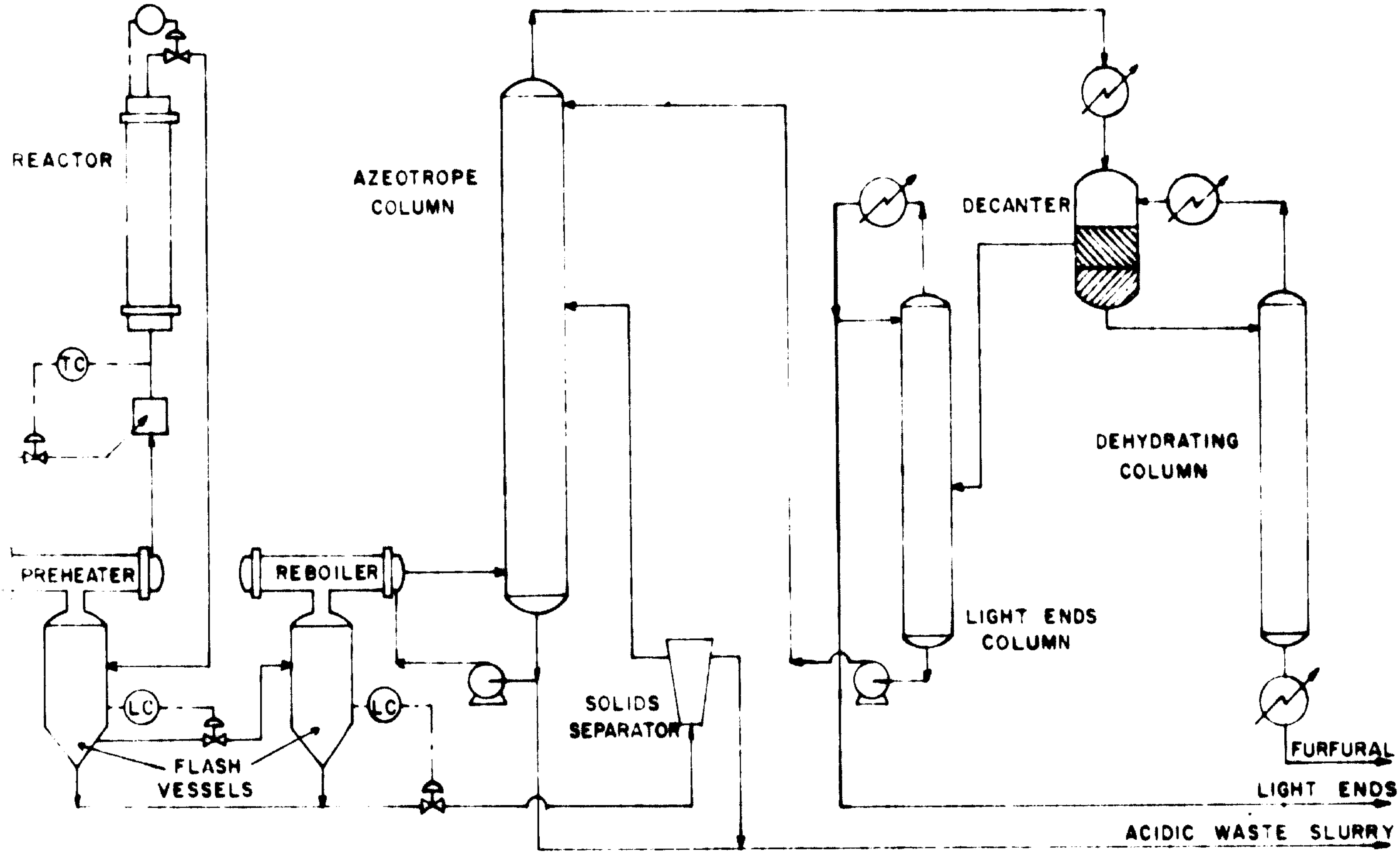
FIG 1 PAGE 26

FIGURE 2

SCHEMATIC FLOWSHEET FOR PRODUCTION OF FURFURAL
BY A TWO STAGE PROCESS


BAGASSE
WATER
ACID
PROPORTIONING
PUMP
REACTOR
AZEOTROP
COLUMN
TC
H.P STEAM
SOLID
SEPARATOR
SOLUBILIZED
PENTOSES
PREHEATER
REBOILER
LC
LC
FLASH
VESSELS
STEAM
RESIDUE TO
BOILER OR OTHER
UTILIZATION

SECTION 1



SECTION 2

FIG. 2 PAGE 27

TABLE 1

FURFURAL PRODUCTION AT BRECHIN CASTLE WITH DEPITHING

Total production = 6,650,000 lbs. per year from processing 33,750 long tons of pith. Plant cost estimated at $930,000 including $378,000 for depithing.

	U.S. $
Pith @ $1.50 per short ton[1]	$ 225,000
Acid @ $50 per short ton[2]	47,200
Steam @ 60¢/1000 lbs.	57,100
Electricity @ 0.64¢/Kwhr.	12,500
Water @ 3¢/1000 gal.	10,000
Operating labor - 14 @ $2500	35,000
Supervision	2,000
Payroll overhead	3,300
Maintenance	40,000
Supplies	4,500
Technical	25,000
Insurance	10,000
Depreciation	93,000
Total Direct Production Cost	564,600
Working Capital	
1 month operating expense	37,300
1 month raw material supply	22,500
Total Capital Investment	957,800
Sales	14,000
Administration	14,300
Total manufacturing expense	592,900

[1] No storage charge allowed, bagasse taken as zero value.

[2] Processing at 4:1 liquid solid ratio and assuming no buffering capacity from ash constituents.

Credit for incineration cost[3]	$ 32,400
Net manufacturing expense	560,500
Gross income @ 8¢ per lb.	532,000
Net Loss	$ 28,500
Cash Flow	$ 64,500

Break even price 8.9¢ per lb.

PLANT COST ESTIMATE FOR 6,650,000 POUNDS/YR. FURFURAL PRODUCTION AT BRECHIN CASTLE BY PROCESSING CONTINUOUSLY IN A TUBULAR TYPE REACTOR

Based upon an estimated plant cost in 1958 of $427,000 for a continuous plant producing 15 million pounds per year. This earlier estimate does not include land, buildings, or steam generation equipment.

Scaling the 1958 estimate for 6,650,000 pounds of production in 1967 (Marshall and Stevens Indices: 1958 = 228.5, January 1, 1967 = 256).

$$\text{Basic Cost} = \left(\frac{6.65}{15}\right)^{.6}(427{,}000)\left(\frac{256}{228.5}\right) = \$293{,}000 \text{ U.S.}$$

Steam Generation (12,500 Lbs./Hr.)	= 120,000 U.S.
Buildings and Land	= 80,000 U.S.
Overseas Packing and Freight	= 29,000 U.S.
Cost of Furfural Production Unit	= $522,000 U.S.

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[3]Credit for disposal of 27,000 tons of surplus bagasse:
10% depreciation of incineration capital cost:

0.1 ($9)(27,000)	= $24,300
$0.30 Maintenance	= 8,100
Saving per ton	$32,400 U.S.

ESTIMATION OF DEPITHING EXPENSES BASED UPON "METHODS FOR SEPARATING PITH-BEARING PLANTS INTO FIBER AND PITH," U.S.D.A. LATHROP, E.C., et.al.

Table 23 from above reference: - Estimated Operating Expense to separate whole bagasse at sugar mill into pith free fiber and pith. Case 2A - Fiber dried and baled after wet screening; pith burned wet as fuel. Basis 100 Ton o.d. bagasse per day.

	$U.S. Per Ton o.d. Bagasse		
	100-Day Operation	180-Day Operation	300-Day Operation
Fuel and power	$0.896	$0.896	$0.[illegible]
Labor, supervision, maintenance, and supplies	1.355	1.14	1.033
Fixed charges	1.381	0.961	0.751
Total operating expenses/ o.d. ton	3.632	2.997	2.6[illegible]
Credit for sugars recovered/ o.d. ton bagasse	1.00	1.00	1.[illegible]
Net operating expense/ o.d. ton	2.632	1.997	1.6[illegible]
Cost/o.d. ton fiber and pith, 90% yield	2.92	2.22	1.[illegible]7
Cost/o.d. ton fiber on basis of 68.4% yield with pith of no value	3.85	2.[illegible]2	2.46
Fuel value/o.d. ton fiber	2.50	2.50	2.5[illegible]
Cost baling/o.d. ton fiber	2.50	2.50	2.50
	$8.85	$7.92	$7.46

From Table 21 of Lathrop's article, estimated capital cost for depithing 100 ton/day for Case 2A is $105,000. (Drier for fiber unnecessary for our purposes, but assume equivalent cost for conveyor systems needed.)

Lathrop assumes 4% maintenance = $4,200 = $42/ton

For 100 day operation:
Maintenance = $0.42/ton
Supplies = 15% of maintenance = $0.06/ton

For 300 day operation:
Maintenance = $0.14/ton
Supplies = $0.02/ton

From Table 23
Labor, supervision, maintenance and supplies = $1.355/ton

and from above
Labor and supervision = $0.875/ton
For 300 ton plant labor and supervision = 1.033 - .16 = $0.873/ton

Therefore assume labor and supervision remain constant per ton @ $0.87/ton and from Lathrop the fuel and power are constant @ $0.896/ton (240 installed H.P.) Scaling the capital investment up for 151,000 short tons at Brechin Castle:

$$\left(\frac{256}{188.7}\right)\left(\frac{151,000}{150}\right)^{0.6}_{100}(105,000) = 408,000$$

The depithing equipment cost can be reduced if the number of days of depithing is allowed to be greater than the grinding season. The exact rate of production must obviously be related to the rate of fiber utilization. It was assumed above that the fiber was burned for fuel and hence the production rate was restricted to boiler demands.

Maintenance for 1000 ton/day unit = $12,000 = $.08/ton

Supplies = $0.01/ton

PROJECTED OPERATING EXPENSES FOR DEPITHING UNIT SUFFICIENT TO HANDLE BRECHIN CASTLE CAPACITY

Power and fuel	$0.896
Labor, Maintenance, Supplies, Supervision	.96
Fixed Charges	
50% of labor, supervision, and maintenance	.475
Depreciation @ 5%	.10
Taxes and insurance	.04
Total operating expense	$2.471

According to Lathrop additional sugar recovered could amount to $1.00/ton in which case the depithing cost is $1.47/ton of dry bagasse.

TABLE 2

PLANT AT BRECHIN CASTLE FOR PRODUCING 12,500,000 LB. OF FURFURAL from 135,000 LONG TONS OF DRY BAGASSE AT BRECHIN CASTLE AND 120,000 LONG TONS AT STE. MADELEINE.

Depithing at both locations estimated at $408,000. Total plant equipment cost for depithing and furfural production estimated at $1,670,000.

Pith @ $1.50 per short ton[1]	$ 425,000
Acid @ $50	93,700
Transportation[2]	126,000
Steam @ 60¢/1000 lbs.	108,000
Electricity @ 0.64¢ per Kwhr.	24,500
Water @ 3¢ per 1000 gal.	20,000
Operating Labor - 21 @ $2,500	52,500
Supervision	5,300
Payroll overhead	8,700
Maintenance	68,000
Supplies	7,000
Technical	25,000
Insurance	15,500
Depreciation	167,000
Total Production Cost	$1,146,200

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[1] No storage costs, bagasse taken as zero value.

[2] Transportation of 30,000 long tons of dry pith from Ste. Madeleine

$$\frac{\text{(lbs wet)}}{\text{(lbs dry)(bagasse)}}\;\frac{\text{(wet cost U.S.)}}{\text{(ton mile)}}\;\frac{\text{(density of bagasse)}}{\text{(density of pith)}}\;\text{(miles)}\;\frac{\text{(dry tons)}}{\text{(of pith)}} = \text{Cost of Transp.}$$

$$(2)(.075)(2)(14)(30,000) = \$126,000 \text{ U.S.}$$

Working Capital	
1 month's operating expense	$ 85,500
2 weeks' raw material	43,200
Total Capital Investment	1,678,700
Sales	27,800
Administration	24,000
Total manufacturing expense	1,198,000
Credit for incineration costs[3]	60,000
Net manufacturing expense	1,138,000
Gross income @ 8¢ per lb. f.o.b. plant	1,000,000
Net Loss	$ 138,000
Cash flow	$ 29,000

Break even price = 9.1¢ per lb.

PLANT COST ESTIMATE FOR 12,500,000 POUNDS/YR. FURFURAL PRODUCTION AT BRECHIN CASTLE BY PROCESSING CONTINUOUSLY IN A TUBULAR TYPE REACTOR

Basic Cost	$= \left(\frac{12.5}{15}\right)^{.6}(427,000)\left(\frac{256}{228.5}\right)$ =	$410,000 U.S.
Steam Generation (23,500 Lbs./Hr.)	=	180,000 U.S.
Buildings and Land	-	120,000 U.S.
Overseas Packing and Freight	=	41,000 U.S.
Cost of Furfural Production Unit	=	$751,000 U.S.

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[3] Credit for disposal of surplus 50,000 tons:

10% depreciation of incineration capital cost:

0.1 ($9)(50,000)	=	$45,000
$.3. Maintenance saving per ton	=	15,000
		$60,000

TABLE 3

FURFURAL PRODUCTION AT BRECHIN CASTLE USING THE TOTAL BAGASSE

Prehydrolysis and continuous production of furfural at Brechin Castle - 151,000 tons dry bagasse per year - 26,600,000 lbs. of furfural. Estimated plant cost (excluding prehydrolysis) = $1,310,000 U.S. Total plant cost including prehydrolysis = $4,180,000. Prehydrolysis expenses exclusive of raw material cost are taken as 1.4¢ per lb. pentose produced in a 7% solution (based on estimated costs of prehydrolyzing wood as indicated in Table 4)

Bagasse storage & handling @ $1.00/ton[1]	$ 164,600
Pentose[2]	937,000
Cost of replacement fuel[3]	243,000
Incineration[4]	9,700
Acid @ $50 per short ton	188,800
Electricity @ 0.64¢/Kwhr.	50,000
Steam @ 45¢/1000 lbs.[5]	180,000
Water @ 3¢/1000 gal	40,000
Operating Labor - 29 @ $2500	72,500
Supervision	7,300
Payroll Overhead	12,000
Maintenance	65,600
Supplies	9,800
Technical & analytical	72,700
Insurance	13,100
Depreciation	131,000
Total direct production cost	$ 2,197,100

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[1] 6 months supply of wet bagasse - 164,600 tons
[2] Bagasse taken as zero value
[3] Replacement of 91,000 short tons @ $2.67/ton
[4] Cost for off season disposal of 32,200 tons @ 30¢ ton assuming off season boiler used and no capital costs incurred
[5] Fuel value of residue taken as 25¢/1000 lbs. of steam

1 month operating expense	$150,000
1 month raw material acid	15,700
Total capital investment (including prehydrolysis)	4,346,000
Sales	43,000
Administration	63,000
Total manufacturing expenses	2,307,100
Product value @ 8¢ per lb.	2,128,000
Net Loss	$ 179,100
Cash flow	
Break even price - 8.7¢/lb.	

PLANT COST ESTIMATE FOR 26,600,000 POUNDS/YR. FURFURAL PRODUCTION AT BRECHIN CASTLE BY PROCESSING CONTINUOUSLY IN A TUBULAR TYPE REACTOR.

$$\text{Basic cost} = \left(\frac{26.6}{15}\right)^{.6}(427,000)\left(\frac{256}{228.5}\right) = \$700,000 \text{ U.S.}$$

Steam Generation (50,000 lbs./hr.)	= 420,000 U.S.
Buildings and Land	= 120,000 U.S.
Overseas Packing and Freight	= 70,000 U.S.
Cost of Furfural Production Unit	= $1,310,000 U.S.

TABLE 4

PREHYDROLYSIS EXPENSES (EXCLUSIVE OF CARBOHYDRATE RAW MATERIAL) FOR FURFURAL PLANT AT BRECHIN CASTLE. Estimated Plant Cost - $2,870,000 U.S.

Acid @ $50 per short ton	$ 83,000
Steam @ 45¢/1000 lbs.[1]	132,500
Water @ 3¢/1000 gal.	2,200
Electricity @ 0.64¢/Kwhr.	69,500
Operating labor - 20 @ $2500	50,000
Supervision	5,000
Payroll overhead	8,200
Maintenance	144,000
Supplies	21,600
Technical and analytical	105,000
Insurance	29,000
Depreciation	287,000
Total Direct Production Cost	$937,000

[1]Fuel value of residue taken equivalent to 25¢/1000 lbs. of steam

TABLE 5

SINGLE STAGE PROCESS AT BRECHIN CASTLE, USING TOTAL BAGASSE

26,600,000 lbs. Furfural - 151,000 short tons dry bagasse. Plant cost estimated as $8,100,000 U.S. based on the 1955 cost of the Dominican Republic plant ($7,000,000).

Bagasse storage & Handling @ $1.00[1]	$ 164,000
Acid @ $50.00	130,000
Cost of replacement fuel	243,000
Incineration	9,700
Steam @ 45¢ per 1000 lb.	230,000
Water @ 3¢ per 1000 gal.	26,000
Electricity @ .64¢/Kwhr.	35,000
Operating Labor - 40 @ $2500	100,000
Supervision	10,000
Payroll Overhead	16,500
Maintenance	324,000
Supplies	52,000
Technical	217,000
Insurance	81,000
Depreciation	810,000
Total Production Cost	2,448,200
Sales expenses	43,000
Administration	63,000
Total manufacturing expense	2,554,200
1 month's operating expense	180,000
2 weeks' raw material, acid	5,000
Total capital investment	8,785,000
Product value @ 8¢ per lb.	2,128,000
Net loss @ no bagasse cost	426,200
Break even price - 9.2¢ per lb.	

[1] 6 months supply of wet bagasse @ zero value

TABLE 6

FURFURAL PRODUCTION USING TOTAL BAGASSE FROM BOTH STE. MADELEINE AND BRECHIN CASTLE

Production of 50,000,000 pounds of furfural per year, transporting 120,000 long tons from Ste. Madeleine; estimated plant cost (excluding prehydrolysis) = $1,870,000, and total plant cost including prehydrolysis of $6,570,000.

Bagasse storage & handling @ $1.00/ton[1]	$ 310,000
Transportation[2]	252,000
Replacement Fuel[3]	465,000
Pentose[4]	1,557,900
Incineration[5]	18,200
Acid @ $50.00 per short ton	354,000
Electricity @ 0.64¢/Kwhr.	94,000
Steam @ 45¢/1000 lbs.[6]	337,500
Water @ 3¢/1000 gal.	75,300
Operating Labor - 40 @ $2500	100,000
Supervision	10,000
Payroll Overhead	16,500
Maintenance	93,500
Supplies	14,000
Technical & analytical	102,000
Insurance	18,700
Depreciation	187,000
Total Direct Production Cost	$ 4,005,600

[1] 6 months storage of wet bagasse, 310,000 tons.
[2] 120,000 @ $2.10/long ton dry bagasse.
[3] Replacement of 108,000 and 67,400 short tons of dry bagasse - see Table 8. This estimate does not include cost of conversion or premium to the mill.
[4] Bagasse assumed as zero value.
[5] Cost for disposal of 60,800 tons after grinding season.
[6] Fuel value of residue taken equivalent to 25¢/1000 lbs. of steam.

1 month operating expense	$ 279,000
1 month raw material acid	29,500
Total capital invested	6,880,000
Sales	78,000
Administration	103,000
Total Manufacturing Expense	4,186,600
Break even price 8.1¢/lb.	
Product Value @ 8¢/lb.	4,000,000
Net Loss	$ 186,600

PLANT COST ESTIMATE FOR 50,000,000 POUNDS/YR. FURFURAL PRODUCTION BY PROCESSING CONTINUOUSLY IN A TUBULAR TYPE REACTOR

Basic Cost = $\left(\frac{50}{15}\right)^{.6}(427{,}000)\left(\frac{256}{228.5}\right)$	=	$ 1,000,000
Steam Generation (100,000 lb./hr.)	=	615,000
Buildings and Land	=	150,000
Overseas Packing & Freight	=	100,000
Cost of Furfural Production Unit	=	$1,865,000

TABLE 7

PREHYDROLYSIS EXPENSES (EXCLUSIVE OF CARBOHYDRATE RAW MATERIAL)

Production scaled to 50,000,000 lb./yr. furfural plant.
Estimated plant cost for prehydrolysis $4,700,000 U.S.

Acid @ $50.00 per short ton	$ 156,000
Steam @ 45¢/1000 lbs.[1]	225,000
Water @ 3¢/1000 gal.	4,200
Electricity @ 0.64¢/Kwhr.	131,000
Operating labor - 30 @ $2500	75,000
Supervision	7,500
Payroll Overhead	13,900
Maintenance	235,000
Supplies	35,300
Technical & Analytical	158,000
Insurance	47,000
Depreciation	470,000
Total Direct Production Cost	1,557,900

[1]Fuel value of residue taken equivalent to 25¢/1000# steam

TABLE 8

BAGASSE UTILIZATION AND OVERALL HEAT REQUIREMENTS IN TERMS OF DRY BAGASSE[1]

Production of 26,600,000 pounds of furfural at Brechin Castle

	Grinding Season[2]	Off Season
Required equivalent heating value - short tons dry bagasse		
Prehydrolysis	11,200	13,400
Furfural Section	16,800	20,200
Sugar Mill	118,000	0
Total	146,000	33,600
Total available bagasse	68,700	82,300
Available bagasse as residue[3]	55,000	65,800
Excess for disposal	---	32,200
Deficit, required in replacement fuel	91,000	---
Continuous production of 50,000,000 pounds of furfural at Brechin Castle		
Prehydrolysis Section	21,000	25,200
Furfural Section	31,600	38,000
Sugar Mill	116,000	---
Total	170,600	63,200
Total Available	129,000	155,000
Available bagasse as residue	103,200	124,000
Excess for disposal	---	60,800
Deficit required in replacement fuel		---
at Brechin Castle	67,400	---
at Ste. Madeleine	108,000	---

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[1] Effective heating value of 10.8 x 10^6 BTU/short ton
[2] Grinding season - 150 days, off season - 180 days
[3] Based on 20% solids removed in furfural processing

TABLE 5

FURFURAL PRODUCTION AT BRECHIN CASTLE USING BAGASSE AND COCONUT BASS

Plant capacity - 52,400,000 pounds of furfural per year: 50,000,000 from the available bagasse at Brechin Castle and Ste. Madeleine, and 2,400,000 from 10,000 tons of coconut bass. Estimated plant cost (excluding prehydrolysis)- $1,[illegible]70,000; total plant cost including prehydrolysis - $6,570,000

Storage and handling @ $1.00/ton	$ 320,000
Transportation[1]	297,000
Replacement fuel[2]	288,000
Pentose	1,640,000
Acid @ $50/short ton	371,000
Electricity @ 0.64¢/Kwhr.	98,400
Steam @ 45¢/1000 lbs.	354,000
Water @ 3¢/1000 gal.	79,000
Operating labor - 40 @ $2,500	100,000
Supervision	10,000
Payroll overhead	16,500
Maintenance	93,500
Supplies	14,000
Technical & analytical	102,000
Insurance	18,700
Depreciation	187,000
Total Direct Production Cost	$ 3,989,100

[1]Transportation of bagasse from Ste. Madeleine, and 10,000 tons of coconut bass 30 miles at 15¢/ton mile.

[2]Replacement of 108,000 short tons of dry bagasse at Ste. Madeleine - coconut bass residue assumed to eliminate the need for the additional 6800 tons of dry bagasse at Brechin Castle.

1 month operating expense	$ 300,000
1 month acid supply	30,900
Total capital invested	6,900,900
Sales	78,000
Administration	103,000
Total Manufacturing Expense	4,170,100
Product Value @ 8¢/lb.	4,192,000
Net Income	$ 21,900

Cash Flow as % of Total Capital Invested - 10%

28 [illegible]

[illegible]

1. [illegible]

[illegible]

2. [illegible] had [illegible] to study the [illegible] ... On the [illegible] of information [illegible] ... price of furfural [illegible] ... Company, [illegible] ... production of [illegible] ... go out of production. [illegible] ... cost [illegible]. If [illegible] ... cost of [illegible] 8 cents per [illegible], it [illegible] ... the [illegible] could [illegible] without difficulties. If, on the other hand, [illegible] costs were [illegible] cents per lb., [illegible] ... could [illegible] to [illegible] significant [illegible]. The [illegible] ... small.

3. The crux of [illegible] production lies in the [illegible] situation. Bagasse in [illegible] is produced in two large sugar mills and three [illegible] ones. The two [illegible] sugar mills [illegible] respectively 100,[illegible] and 1[illegible] long tons [illegible] dry weight. [illegible] 14 miles apart, and [illegible] by a narrow asphalt road [illegible] poor [illegible]. Of the quantities of [illegible] available, all but 50,000 tons (dry weight) [illegible] used [illegible] fuel in the [illegible]. The relatively small quantities [illegible] in the other three plants [illegible] burnt as fuel. The pith content [illegible] dry bagasse, as reported by [illegible] ndent laboratories in the United [illegible] to whom [illegible] bagasse [illegible] sent, is 23%. The [illegible] the [illegible] is given [illegible] average of 22%.

4. Two alternative [illegible] of manufacturing furfural were considered. The first method was [illegible] the [illegible] bagasse (into fibre and pith) and producing furfural from the pith. The second alternative was to use the [illegible] bagasse. In this case two different techniques were considered:

a) the conventional Quaker Oats batch technique and

b) pre-hydrolysis followed by continuous production of furfural, as in the previous case.

[illegible] alternative [illegible] as below. [illegible]

[illegible] and [illegible] the following:

1. World [illegible] for Furfural.

2. Alternative [illegible] production of Furfural [illegible] including:

   (a) [illegible] of production;
   (b) [illegible] technology;
   (c) [illegible] project implementation;

   This [illegible]:

   (i) The [illegible] of [illegible] supplies of bagasse and [illegible] for furfural production.

   The fol[illegible] all the [illegible] fibre [illegible]:

   (a) As [illegible] for [illegible] manufacture of sugar; and
   (b) As [illegible] pulp and paper and other [illegible].

   (ii) The [illegible] of immediate commercial production of furfural [illegible], the quantity of raw material [illegible] and also [illegible] requirements of the [illegible] industry.

   (iii) The [illegible] commercial production of furfural in Trinidad and Tobago using all available bagasse and other [illegible] materials (e.g. coconut husk), and [illegible]

      (a) [illegible] of raw materials which would [illegible] maximum production economically viable; and
      (b) The need for the establishment and operation of a pilot project [illegible] scheme to handle some proportion of the planned final capacity.

3. Recommendations for further action by:

   (i) United Nations
   (ii) Trinidad and Tobago.

6. [illegible] to enable [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] and energy. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] production of each alt[illegible] [illegible] We do not expect these [illegible] [illegible] [illegible] that may be [illegible].

7. [illegible] the first [illegible] [illegible] considered the production of furfural [illegible] pith by [illegible] depithing equip[illegible] at both sugar [illegible] This [illegible] involve dive[illegible] [illegible] bagasse after [illegible] [illegible] depithing, [illegible] [illegible] into pith [illegible] fibre, [illegible] the [illegible] back into the furnace, [illegible] the pith [illegible] furfural production. Since only a quarter of the quantity could [illegible] obtained as pith, the remaining fibre would be sufficient to meet the [illegible] needs of the [illegible] [illegible]. The process will not require [illegible] [illegible] fuel [illegible] [illegible], [illegible] excess bagasse presently available [illegible] [illegible] pith, [illegible] which furfural could be produced.

8. [illegible] all the pith was available at [illegible], the project [illegible] be economic, but the practical difficulties and [illegible] of transportation of pith from one factory to one other, where the furfural plant would be located, and the need for storage has provided the breaking point. If only one plant's bagasse product was converted to furfural by depithing, then the economies of scale were lost. If depithing was done at both plants and furfural produced at one, the transportation and storage [illegible] [illegible] and costs offset the economies of scale. [illegible] [illegible] way the costs [illegible] out almost even at 8.9 cents per lb. The only element of some doubt here is depithing cost, which was taken at $1.50 per ton of dry bagasse from available literature. More precise estimates, to be obtained from [illegible] of depithing equipment, may perhaps raise them.

9. If, however, the fibre released could be used as feed stock of pulp and paper rather than as fuel for the manufacture of sugar, the economics would be considerably improved. To [illegible] this [illegible] we worked out the estimated cost of fuel replacement, which roughly [illegible] $3.25 per dry ton of bagasse. On the assumption [illegible] [illegible] bagasse fuel,

[illegible] quantity [illegible] sufficient for [illegible] of the sugar [illegible] the national [illegible] the main suppliers [illegible] Company, and the Trinidad [illegible] Electricity Corporation.

10. If, [illegible] fibre could be used for [illegible] purpose [illegible] ton, the [illegible] be advantageous. We [illegible] the local production of [illegible] which is a very small [illegible] and we could not feel [illegible] Trinidad [illegible] pulp [illegible] competitive [illegible] paper plant to use up [illegible] quantities of fibrous material [illegible] a major project in itself, [illegible] shadowing the furfural [illegible] the [illegible] the Japanese paper [illegible] be interested [illegible] although no firm offer was [illegible] a long-term contract [illegible] any other [illegible] pulp, [illegible] utilization for [illegible] manufacture could [illegible]

11. [illegible] commercial production of furfural [illegible] only [illegible] not even considered seriously because [illegible] concluded that it was too small a quantity [illegible] justify [illegible]

12. [illegible] also [illegible] to commercial production of furfural [illegible] not only the pith) and producing furfural [illegible] the largest [illegible] was most carefully studied and [illegible] calculation [illegible] method requires a high capital outlay [illegible] the cost of [illegible] about 8.5 cents per lb.

13. [illegible] which [illegible] been [illegible] the other [illegible] could [illegible]

14. [illegible] on the other [illegible] no alternative but to conclude that [illegible] production [illegible] project per se was not an economic venture. [illegible] furfural could [illegible] be produced at less than [illegible] cents per lb. and there [illegible] therefore be serious difficulties in marketing the product.

15. On the other hand, some favourable facts need to be taken into account:-

(a) The project seems so close to marginal that any favourable developments (such as a long-term contract for the sale of pulp or fibre) may make it extremely attractive.

(b) The project may not pay for itself; however, the incomes generated in producing furfural (which are chargeable as costs to the project) would make a sizeable addition to the gross domestic product of Trinidad and Tobago.

[illegible] played [illegible] ... In [illegible] in [illegible] at the [illegible] world [illegible] by the economy of the [illegible] made [illegible] economic [illegible] but [illegible] of its independent [illegible] market [illegible]

16. [illegible]

(1) [illegible] have [illegible] able to complete [illegible] for lack of [illegible] data such [illegible] agreed to devote [illegible] further [illegible] this report. [illegible] report [illegible] before the end of April, and after [illegible] the UN, the government of Trinidad and [illegible] may receive it before the end of May 1967.

(2) We do not [illegible] further United Nations action on this project [illegible] submission of our completed report.

(3) If, however, [illegible] change so as to [illegible] the project [illegible], the case may be re-opened and appropriate [illegible] may be considered for the implementation of the project.

[signature]
D. C. Desai
Leader of Mission

[signature]
J. Smuk
Member

Subject to rider
[signature]
B. Thiagarajan
Member

Rider by Mr. B. Thiagarajan

In my view there is enough justification for the UN to sponsor and participate in further investigations. This view will be presented in greater detail in the Final Report.

B. Thiagarajan

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UNIDO
by Desai
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Report on Mission to Trinidad and Tobago: 23 February - 18 March 1967

Furfural Mission

1. I was requested to lead the Mission to the Government of Trinidad and Tobago on the possibility of manufacturing furfural in Trinidad from the bagasse released in the course of sugar production from cane. An interim Report on the Mission was submitted on 29 March 1967 and the final Report on 31 May 1967 together with a letter of Transmittal containing the main recommendations of the Mission.

University of the West Indies. Industrial Research Institute

2. I was also requested by the United Nations Development Programme to look into the request for an Industrial Research Institute which the Government of Trinidad and Tobago had requested for Special Fund financing. A briefing note was given to me from the UNDP. My discussions on this subject were embodied in my memorandum of 23 March 1967 which was enclosed with the Note prepared by Mr. Alexander Campbell.

Programming of Technical Assistance

3. My third assignment was to ascertain from the Government of Trinidad and Tobago their assistance requirements in the field of industry. These resulted in an expected Special Fund Request and several projects for assistance under the Special Industrial Services Programme.

4. The Special Fund Request would be for an Industrial Project Development Centre, to be located in the Industrial Development Corporation of Trinidad and Tobago (IDC). The IDC has a number of general feasibility studies and a number of requests by private entrepreneurs for financing of likely industrial projects. The Industrial Development Corporation, however, lacks suitable machinery to process the applications or to develop the feasibility studies already made into "bankable" projects. The project would consist of four main elements:

A. Resident experts:
   1 chemical engineer
   1 mechanical engineer
   1 industrial economist
   Counterparts will be provided by IDC.

/...

B. Provision for ad hoc experts:
24-26 man-months for specific specialization on the particular industries under consideration.

C. Provision of fellowships for management and technical training.

D. Provision for testing of materials in Trinidad and Tobago and abroad.

At the time, the following industries were specifically under consideration
(i) caustic soda
(ii) textiles and garments
(iii) ceramics

5. Under the Special Industrial Services programmes the following were to be requested:

(a) The provision of an expert to examine and report on the prospects for food processing based on local fruit and vegetables;

(b) The provision of an expert to advise on the creation of a Standards Organization;

(c) Assistance for the Brickworks, Rio Claro

(i) An expert to re-appraise the project including a study of present market conditions and an assessment of the additional equipment required for commercial operations;

(ii) Procurement of the equipment needed (possibly heavy extruder and pre-drying facicities); and

(iii) Short-term management and technical experts;

(d) An expert to assist in setting up of plant layout for the dyeing operations of the Elaine Barrymore Originals Ltd. and to train a national in the dyeing operations;

(e) An expert to study the problems of implementing (including financing) proposals for the manufacture of fibre-board from locally available bagasse or fibre. (a feasibility study already exists);

(f) Assistance in efforts to strengthen the Management of Modern Methods Limited and the provision of an expert to examine the possibility of product diversification;

/...

(g) Final assistance to ascertain the practicability of a steel mill in Trinidad. There have been five or six previous investigations- (Malhotra, Pittsburg, Batelle, etc.). The Government does not want any further study but a definitive opinion based on the studies already made;

(h) Use of asphalt from the Pitch Lake. The Government would like the exploration of the industrial properties and possibilities of this natural asset of Trinidad; and

(i) Development of a petrochemical industry, particularly important since the petroleum industry of Trinidad is retrenching.

..... Some notes on projects (c) and (f) are enclosed.

R.C. Desai

NOTES

Trinidad Brickworks Limited

Trinidad Brickworks Ltd. is a Public Limited Liability Company registered in Trinidad in 1960 with a Paid up Capital of TT$600,000. The main purpose of the Company is the manufacture of hollow clay building blocks.

By 1961 the Company had Capital Assets to the value of over TT$1,000,000 and at that time Loans amounted to TT$654,000.

The output of the Kiln was estimated at five million 4 x 8 x 12 hollow clay building blocks or approximately 14,000 blocks per day, but the actual sales were: 1963-1.4 million; 1964-1.7 million and 1965-1.6 million. Breakage was exceedingly high due to the very high water content in the green bricks which the extruder and drying facilities could not extract.

Conditions went from bad to worse and by December 1965, when the plant ceased operations, Loans and Interest amounted to over TT$1,000,000. The IDC's share of this is TT$60,000 unpaid interest with a capital of TT$250,000.

Reports on the Company were made by Messrs. Platt, Llanos, and the three engineers from the University of the West Indies and they are all of the opinion that with an expenditure of about TT$275,000 the Plant can be rehabilitated and the undertaking put on a profitable basis.

Modern Methods (Caribbean) Ltd.

Modern Methods (Caribbean) Ltd. is a Private Limited Liability Company incorporated in Trinidad in September 1965 with a Paid up Capital of TT$250,000. The objects for which the Company was established are to carry on and undertake in Trinidad and Tobago the business of manufacturers, processors and producers of and dealers in plastic, thermo-plastic and thermo-setting plastic goods, materials and other such articles for industrial, commercial or domestic use.

The Company operated at a loss over the past three years and due to lack of working capital and pressure from creditors, applied to the IDC for a loan of TT$150,000. The loan was granted but one of the conditions was that a new factory must be erected on 90,000 sq. ft. of land leased to the Company by the Government.

The main needs of the Company were finance and good management as it has the capacity to produce several marketable products of high quality for which ready markets are available. The standard of workmanship is high and most of the training problems have been overcome. An adequate amount of "know-how" and expertise has been developed and the trading future appears to be both secure and profitable.

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

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