38159/1

1936

KENYA

CO533/468

38159/1

Sisal Softening: McBrae Process.

Communication of Specification to Sisal Industry Board (Tanganyika) and Board of Trustees for Sisal Research.

Previous

Main File

Subsequent

1937

(1812) Wt.31113/122. 10,000. 11/88. H.P.Co. (1.60)/778.

FILE A.

PERIC.
c.1(Sisal)

1 2. Governor Conf.No.87.------------------------ 17.7.36.
Ref.No.11 requests that Mr.McCrae be asked whether his specification can be communicated to the Sisal Industry Committee, and whether copy has been sent to the Board of Trustees for Sisal Research in London.

I submit draft letter to Mr McCrae.

[signature]
13/8/36.

No information has yet been given by Mr McCrae to the Board of Trustees, except in connection with individual members of the Board.

[signature]
17/8.

2 To J. McCrae conf. - 18 AUG 1936

3. McCrae.------------------------------ 19.8.36.
No.2 ansd; has no objection to the specification being communicated to the bodies referred to; encloses 4 further copies of memo. ~~forwarded in No.15~~ as containing more information than the specification.

3 in back of file

Mr McCrae considers that his monograph "Sisal" gives more details of his process than does the specification registered at the Patent Office. The paper "Sisal by James McCrae" has been distributed to the Gov. Kenya, the Sisal Growers Assocn, the Board of Trustees in London and the Linen Industry Assoc. at Lambeg. However he has no objection to his specification going to the Sisal Growers Assoc & the Bd of Trustees. I submit draft.

[signature]
25.8.

[signature]
25/8.

4 To Mc Brae (3 ance) 1 SEP 1936

5 To Kenya, Conf (3) (w/cs 2 & 3 w/encl to 3) 2 SEP 1936
1 Answd

Lik.

C. O.

38159/1/36.

Mr. Grossmith. 2/9

Mr. Flood 25/8

Mr.

Sir C. Parkinson.

Sir G. Tomlinson.

Sir C. Bottomley.

Sir J. Shuckburgh.

Permt. U.S. of S.

Parly. U.S. of S.

Secretary of State.

DOWNING STREET.

~~August, 1936.~~

2 SEP 1936

DRAFT.

KENYA.

CONFIDENTIAL. (3)

Gov.

Sir,

I have etc. to acknowledge the receipt of your Confidential despatch No.87 of the 17th of July and to transmit to you for your information a copy of correspondence with Mr. J. McCrae from which it will be seen that he has no objection to the communication to the Sisal Industry Committee and the Board of Trustees for Sisal Research in London of the specification of his invention for the treatment of sisal and allied fibres.

2. If it is found necessary to make extra copies of the specification for communication to the former body, I shall be obliged if you will arrange for a copy to be sent to the Board

FURTHER ACTION.

of Trustees in London, as no spare copy is available here.

I have, etc.

(Signed) W. ORMSBY GORE.

LASIS
(REGISTERED)
FIBRE PRODUCTS

JAMES McCRAE, WELLINGTON FOUNDRY, LEEDS, 1.

19th August 1936.

RECEIVED
20 AUG 1936
C. O. REGY

The Under Secretary of State,
Colonial Office,
London. S.W.1.

Sir,

Your ref. 38159/36.

2 (27)

I am obliged for your letter of 18th Inst, and am glad to hear of the interest which is being taken in my research work on Sisal.

With regard to my specification. I have no objection to this being communicated to the two bodies referred to.

See 15 on file

In order to explain my process and its objects in greater detail than was possible in this specification, I wrote a monograph on the subject. This is the paper which you were kind enough to appreciatively acknowledge in your letter of 8th July. I think that this paper conveys more detail than does the specification. Copies of this paper are now in the hands of His Excellency the Governor of Kenya, the Sisal Growers Association, The Chairman of the Board of Trustees in London, and the Director of the Linen Industry Association at Lambeg.

See 8 on 35 file

The theories which the specification and paper explain become of value only when when proved by actual demonstration. In order to do this, special machinery has had to be invented. This has been done, and has been provisionally protected in the joint names of Messrs Fairbairn Lawson Combe Barbour Ltd, and myself, in accordance with the arrangement in my memorandum of July 1935. This machinery is at present in process of manufacture and should be ready for demonstration in about three months. I am arranging to erect this plant here, in the first instance, and will have a supply of Sisal

The Under Secretary of State.

leaves from Kenya.

When this plant is ready I will communicate with you and will be very glad to place myself and this machinery at your disposal.

I beg to enclose further copies of my paper in case you should resire to transmit this information to other interested people.

I am, Sir,

Your obedient servant,

Jas. McGar

C. O.

Mr. Grossmith. 13.8.36.
Mr. Parkin 14/8
Mr. Stockdale 19/8.
Mr. Parkinson.
Sir G. Tomlinson
Sir C. Bottomley.
Sir J. Shuckburgh.
Perml. U.S. of S.
Parly. U.S. of S.
Secretary of State.

38159/36.

C.D 14 AUG D 18

DRAFT.

JAMES McCRAE, ESQ.

Downing Street.

18 August, 1936.

and 13

Sir,

I am etc. to refer to your letter of the 12th of May in which you enclosed a copy of the full specification of your invention for the treatment of sisal and allied fibres, and to inform you that a copy was sent confidentially to the Governor of Kenya. The Governor now reports that the Director of Agriculture has represented that the subject is one which is of great interest to the Sisal Industry Committee, and that having regard to the various new processes which have come to their notice, e.g. the Verdouw process, the Dwen process,

the

FURTHER ACTION.

Recirc for comm of the Patent Office [illegible]

Copy to Kenya (5)

the Mangnall decorticator and the Hollier decorticator, it is important that the Committee should be in possession of as much information as possible about your process. ~~I am accordingly to~~

2. It would be appreciated therefore if you would be good enough to state ~~enquire~~ whether there would be any objection to the communication of your specification, if necessary confidentially, to the Sisal Industry Committee in Kenya for the Committee. It would also be useful to know whether a copy of the specification has been sent to the Board of Trustees for Sisal Research in London and, if not, whether you would have any objection to supplying copies of the specification for circulation to the members of the Board.

I am, etc.

(Signed) J. E. W. FLOOD

38151

RECEIVED
10 AUG 1936
C. O.

126

KENYA.

No. 87

GOVERNMENT HOUSE,
NAIROBI,
KENYA.

CONFIDENTIAL:

17 JULY, 1936

Sir,

I have the honour to acknowledge the receipt of (11) your predecessor's confidential despatch of the 25th May, enclosing a copy of the specification filed by Mr. J. McCrae of his invention for the treatment of sisal and allied fibres.

2. I note that the specification should be treated as confidential for the present. The Director of Agriculture has, however, represented that the subject is one which is of great interest to the Sisal Industry Committee; that various new processes have come to the notice of this Committee, e.g. the Verdouw process, the Owen process, the Mangoll decorticator and the Hollier decorticator; and that in order to assess the merits of the processes concerned and to decide whether or not to devote any portion of the sisal levy fund to the conduct of experiments in connexion with any one of them, it is important that the Committee should be in possession of as much information as possible about each of the processes.

3. In these circumstances I have to suggest that Mr. McCrae might be asked whether there would be any objection to the communication of his specification, if necessary confidentially, to the Sisal Industry Committee.

It would also be useful for the Committee to know whether a copy of the specification has been sent to the Board of Trustees for Sisal Research in London.

I have the honour to be,
Sir,
Your most obedient, humble servant,

THE RIGHT HONOURABLE
W. ORMSBY-GORE, P.C., M.P.,
SECRETARY OF STATE FOR THE COLONIES,
DOWNING STREET,
LONDON, S. W. 1.

BRIGADIER-GENERAL
G O V E R N O R

S I S A L

by

James McCrae

LEEDS.
May, 1936.

SISAL.

1. Sisal history of recent years bears analogy to that of Rubber. Like the Rubber Industry which has developed in the East from seed taken from its original home in South America, and finding more congenial climatic and economic conditions in its new surroundings, so Sisal appears to be following a similar trend.

2. Mexico, the home of the Sisal industry, supplied all world requirements until three decades or so ago. Since then the plant has been introduced into Eastern Africa and the East Indies, where its expansion has been rapid, particularly in East Africa, as the following tables of annual production will show. The figures are tons.

	1927	1932	1933	1934	1935
Mexican Sisal	120,000	88,000	93,000	92,000	90,000
African "	50,000	91,000	108,000	121,000	144,000
Java & Sumatra	44,000	80,000	95,000	85,000	84,000
	214,000	259,000	296,000	298,000	318,000

3. An inference which can be drawn from these figures is that the industry is finding conditions in East Africa more suitable than either Mexico or the East Indies. As world requirements continue to expand as they are doing, there is every indication that East Africa will participate in this expansion, and should do so in an increasing ratio over the other two producing countries.

4. The industry was established in East Africa during a period when values stood around £28. Then came war and witnessed an inflation in values of all primary products, including that of Sisal, the price of which was controlled at £99, C.I.F. During the post-war period values remained

at very high levels, offering attractive investment, until the depression set in.

5. This long period of prosperity is unquestionably the main cause of the intensity of the misfortunes which overwhelmed the industry during the years of depression. The attractive profits of that period induced a phase of rapid, and haphazard development. The increased production resulting from those new post war areas coincided with the heavy fall in consumption at the beginning of the slump. The clash of those two conditions intensified the fall in Sisal values which set in during 1930, and continued until the latter end of 1935. During this long spell prices remained well below the cost of production with the result that a distressed condition developed in the industry. Many estates went into liquidation and most of those which survive find their plantations in a backward state, with plant and machinery worn out and out of date.

6. Unfortunately there was not, nor is there yet any method whereby this industry can plan and regulate production to meet world requirements. The necessity for some concerted international arrangement to adjust balances between supply and demand in the field of primary products will no doubt be evolved in the course of time, but until posterity produces a workable formula, Sisal can only direct its efforts to cheapening its production costs and extending its markets. The object of the writer is to indicate a way, which should assist the industry towards these desired ends.

7. In the case of Sisal price fluctuations have been over wide margins, as must be the case with a product catering for restricted markets as Sisal does. The bulk of the world's production of this fibre is made into binder

twine used in harvesting. Weather conditions in the grain growing areas of the world therefore exercise a very pronounced control on Sisal values, and as long as the industry continues to depend upon this one market and that market depending upon weather conditions, so will Sisal continue to be a speculative investment.

8. The experience of the past slump years is a graphic illustration of the basic weakness of the Sisal industry, intensified no doubt by the abnormal conditions which have prevailed, but clearly indicating that without a broader basis in the consuming market, prices will continue to be subjected to heavy rise and fall.

9. The prolonged period of depression has brought some compensations to the industry in the way of an extension of markets, induced very largely by low values, but there is a danger of those new markets shrinking should Sisal values rise above the prices of competitive fibres. Experience has shown that potential users of this fibre are chary of adopting it in their trades on account of price instability, particularly when its use entails the installation of special machinery. There is no doubt that more stable prices moving within narrower limits and at competitive and economic values to other fibres, would encourage consumption of Sisal in those trades which are beginning to take an interest to-day.

10. The trades referred to which are absorbing the bulk of production in excess of binder twine requirements and have thereby assisted in great measure in the recent advance in values, are parcel twine and cordage manufacturers, the bedding and upholstery trades, particularly in U.S.A. and to a very limited extent fabrics for sacks.

11. These new markets are of inestimable value to the

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industry, but as they operate on low price levels they can only be expected to continue their patronage under moderate, and more particularly, stable values.

12. A factor which must always be kept in view is the competition of Manila Hemp. This, like Sisal, is a hard fibre, and is used as an alternative to Sisal in many important markets, so has an influence upon Sisal values. For certain products such as marine cordage, Manila enjoys not only an entrenched position, but in certain qualities it has an undoubted advantage in being a more flexible and a less brittle fibre. It is believed possible however that the disability which Sisal suffers from in this market can be overcome by a simple method of converting it into a softer and more pliable fibre. This will be explained later.

13. The experience of those past years indicated that there are markets for Sisal outside the binder twine trade, markets which consume hard fibre and which have recently been doing so at an increasing rate, but due solely to the stimulus of low prices. The values of Sisal which have ruled during the slump period, and which have been the cause of this fibre finding its way into new markets, those values have been below the existing cost of production, and unless costs are brought down to a figure which will yield a profit to the producer and offered at a level which those new customers can afford to pay, then those markets cannot be considered permanent.

14. In a comprehensive survey of the industry which it is now proposed to make, we will begin with fundamentals, the first and most important being cost of production. This analysis should necessarily start with agriculture, but as that subject is best dealt with as a subject deserving

greater scope than this paper can accommodate, so we will begin with the plant ready for harvesting.

5. The writer finds difficulty in presenting a picture of continuity in this story of Sisal, the many issues being so unevenly interwoven, but trusts, that with patience, the reader will retain a constructive narrative, when all is written.

6. Depressed times forced the industry to make economies, and at the same time to stimulate research into many of its phases, including improvements in agriculture, labour, plant selection, transport, extraction, grading, baling, and the study of converting Sisal into a softer fibre suitable for new uses. The amount of activity, energy and money expended during the past years on those lines of research has been very considerable and has had the co-operation of a united industry operating through its Associations and the sympathetic and practical assistance of Home and Colonial Governments.

7. Considerable headway is to be recorded in most of those branches of research and it is to be hoped that the results of all this work will be collated in due course, and published for the general guidance of the industry.

8. The motive of this paper is to stimulate thought and discussion on the dual ideal of reducing costs and increasing markets and the writer, after years of research into both of these basic subjects, presents the results of his work, not with any attitude of dogmatism, but with the hope that it will, through controversy and arguments, induce efforts to break new ground in both of these indicated spheres, and so in time, assist to place Sisal fibre in a more prominent and stable position than it occupies to-day.

19. When the basic factor of production cost is examined however and although far reaching economies and improvements in production and preparation have been introduced, there still remains much room for improvement, particularly in the established methods of harvesting and extraction. The general system, in so far as it applies to East Africa, the largest producing centre of the world, results in a loss of approximately one half of the fibre content of the leaf. This question of waste must necessarily have a direct bearing upon costs of production, and until it is solved and reduced to within more reasonable limits the industry cannot be considered as operating at its lowest economic cost. It is well therefore to examine the factors which bring this waste about and to study any feasible method which offers improvement.

20. The existence of the waste problem is one which has exercised the industry for many years, and much thought and study have been brought to bear upon it. The writer has found however that the technique and economics of production can be improved and applied more intelligently by having a greater knowledge of actual and potential markets than is at present enjoyed, and he believes that this more thorough knowledge will be an important contributory factor towards greater efficiency.

21. The percentage of waste is a figure about which a certain amount of controversy exists. There is no doubt that it varies, variations depending upon factors such as the condition of the leaf, whether succulent or tough and leathery as it is in dry weather, the setting and condition of decorticators and so on, but under the best conditions this waste is considerable, and for purposes of this survey it has been taken as 25% of the fibre content of the leaf as harvested in the existing manner. The other 25% waste is another matter and will be dealt with later on.

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22. Waste in decortication is a problem for the engineer. Very large sums and long periods of research have been devoted to this problem. The conventional method of decortication is to pass the leaf, which has a firm thick structure, between rapidly revolving drums furnished with blades, and a rigid concave which holds the leaf in close contact with the blades. In its thickest section the leaf measures about an inch, and to enable the blades to completely remove the pulp, the clearance between the blades and concaves must be very narrow, sometimes to as small as fifty-thousandths of an inch. This firm leaf structure presented to the blow of the blades in a restricted aperture, results in many fibres being broken and lost. Another cause of loss is due to the short fibres in the leaf which terminate at various points along its length. The mechanism of the decorticator which conveys the leaf through the machine, grips the leaf in such a position that many of those shorter fibres are not secured, and so are lost. The total loss due to breakage and to shorter fibres varies under different conditions, but is generally accepted as being in the neighbourhood of 25% of the leaf as harvested.

23. The trend of modern design of decorticators is to soften the blow of the blade, and to grip more of the shorter fibres in the leaf. Those ends are attained by subjecting the leaf to a pre-crushing process, reducing its rigid firm structure to a limp state. In this condition it offers less resistance to the blade action and so fewer fibres are broken. Instead also of attempting to clean the leaf of pulp through its entire thickness in one operation which necessitates such a close setting of concave clearances, this cleaning action is applied progressively, first on one side of the leaf and then on the other. In this machine the

design of the gripper-conveyor is such that more of the short fibres are firmly held. This machine registers considerable advance over existing models, reduces waste to a very considerable extent, and by offering less resistance to the cleaning drums, requires less power to drive and maintenance cost is reduced.

24. The balance of waste, previously referred to as 25%, will now be examined, and a method will be explained later indicating how it is possible to prevent all or most of it. In order to understand this proposed method, and for those who do not know the Sisal plant, we can best illustrate by likening it to an enlarged artichoke, with leaves running from say twenty inches to over four feet long. As in an artichoke, the Sisal leaf is attached to a thick central stem or bole, with the butt ends overlapped and interlocked in a similar manner.

25. Harvesting is done by cutting the leaf by hand as near to the butt end as possible, leaving the butt adhering to the bole. This butt contains fibre of marketable value. For purposes of illustrating we will divide the fibre content of a leaf, including the butt, into 150 equal parts by weight. It has been established that the fibre content of the harvested portion contains roughly 100 parts, and 50 parts in the butt portion, which are lost. This seemingly excessive ratio in the short butt, which measures from 7" to 9" long, is explained by the fact that all the fibres in the leaf have their beginnings in the butt and that they are thicker and heavier there. As the leaf matures, the fibres which support it grow thicker along their entire length and in the butt they become woody and weak. In a mature leaf, about half of those butt fibres are of little value, but the remaining half are acceptable for use in the binder twine trade.

26. Instead of harvesting by cutting the leaf as it matures, spread over the life of 8 to 10 years of the plant, the alternative method is to strip the plant completely at an earlier age, plucking the whole leaf. Before considering the economics of this system we will examine the fibres of the butts of this younger leaf. In this case those fibres have not become so thick, are not woody and are of a strength and spinning size to be acceptable to the binder twine trade. This type of fibre is being marketed to-day and obtaining current values.

27. Plants grown to be completely stripped by plucking at an earlier age require less ground. In practice, it will be found that closer planting, varying according to soil and climatic conditions, increase the numbers of plants in a given area from three to four fold over conventional planting. The period of growth to reach the most economic yield will also vary but will be between two to three years from planting average nursery or sucker plants.

28. It has been found that the fibre content of a given area planted as suggested, is considerably greater than the average yield obtained from the same area over a period three times as long. Harvesting the entire leaf and extracting all the fibre, by a process still to be explained, we begin to approach economical Sisal production. When the system comes to be closely examined by the industry it will be found that the increased yield within a much shorter period will more than off set the additional costs which more frequent plantings will entail.

29. Under existing methods therefore the plant occupies the land for about nine years; one third of its fibre content is left behind and one quarter of the harvested part is lost in extraction and final preparation. The leaf having

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a fibre content of 5% means transport of an enormous tonnage of waste matter to the factory, in figures roughly 19,000 tons of waste transport for each 1,000 tons of fibre produced.

It has been necessary to explain at length the existing economics of the industry and to emphasise the two outstanding weaknesses under which it suffers; restricted markets and wasteful production methods, in order to fully appreciate solutions which it is the object of this paper to suggest.

To deal with the question of markets first, the importance of erecting a broader basis of consumption has been stressed. It has been shown that there are potential users of this hard fibre, but only at a low price level, a price which it is uneconomic for the industry to cater for under existing methods of production. It is reasonable to believe however that with more efficient production and waste reduced to a minimum, the production and separation of the shorter fibres which these potential trades require, can be profitably produced, leaving the longer qualities for the binder twine trade for which higher prices are obtainable.

Under existing methods of growing and extraction it is not possible to attain economic production of these lower grade fibres, and it is questionable if it will be found remunerative to recover and recondition to a sufficient degree of cleanliness, waste fibres from decortication, even for the bedding and upholstery trades. It is obviously a more constructive policy to prevent the creation of waste.

How then to expand still further into new markets? The answer to that is that Sisal is capable of being softened and converted by a process which is effective and economic to apply. This process will be explained in

the proper sequence of this story of Sisal. It can be operated under plantation conditions and so adjusted and controlled to give a range of fibres of varying degrees of softness and strength to suit the varying requirements of his customers.

34. A planter's knowledge of his industry is incomplete without a closer understanding of the consuming markets. This became so apparent after years of research into the production end of Sisal, that a prolonged study of textile trades was undertaken. Many months were devoted to this, and it is gratifying to record the willing and helpful attitude of manufacturers which was extended during that time. No effort was spared to assist to a better understanding of their requirements.

35. Contacts made during this period had the effect of stimulating the interest of spinners who had but a passing knowledge of Sisal, and it was made obvious that there were many potential users of this fibre who, for reasons already explained, were hesitant about adopting it. During this time a clearer view was obtained into the extent of markets using fibres of a higher price level, for goods which might be termed the heavy end of the soft fibre trades, in the production of which a fibre of slightly heavier nature than flax and soft hemps could be used, were they commercially available.

36. The world's production of Sisal, in relative importance to that of Jute, Flax, Cotton, etc., is insignificant and will remain so as long as it is produced as a hard fibre. However, when it enters the soft fibre trades and it becomes realised that it is cheaper to produce, and for many purposes is at least as suitable as some of the soft fibres for certain important uses,

then Sisal will gradually emerge from its comparative obscurity and becomes a product of primary importance.

7. To arrive at a complete understanding of the economics of the industry, an endeavour has been made to indicate how necessary it is for the producer to have a more intimate knowledge of his customers requirements, both actual and potential than he has to-day. No claim is made to have exhausted the various fields of this research, but sufficient evidence has been acquired to indicate clearly that more economic methods of production, coupled with a practical and applicable method of conversion of Sisal to a softer fibre, and an intimate knowledge of the various trade requirements, will go far to place the industry on a healthier basis.

8. Knowledge gained in this very wide field of research embracing production and consumption, formed a valuable background for the next step of research which it was necessary to take. A laboratory was equipped and staffed to study the structure and composition of Sisal, and to explore a possible method of softening it which could be applied economically under plantation conditions and which would produce a product likely to meet the requirements of some of the more important industries which had been investigated.

9. To form a clearer understanding of this phase of research, it is advisable to give an account of the laboratory work and findings which were arrived at. By analysis, the nature and composition of the binding gums and pectins was understood. In non-technical language, these were found to be of a compound nature, some parts of which readily reacted to mild solvents. It was found however that when those easily dissolved parts of the

compound were removed, a more obdurate residue was deposited in the form of a still harder lacquer-like film, requiring solvents of a more vigorous nature to break it down. A solvent of sufficient strength to act on this residue also attacked the fibre elements. Evidence was accumulated to prove that a solution did not lie in chemical formulae.

40. Laboratory research however was of value in that it was the means of acquiring an intimate knowledge of what constituted a strand of Sisal. In simple language, this can be likened to a strip of wood of rather cross grain. Like wood, it is built up out of tiny elements or ultimates, interlocked and held together by binding gums. These ultimates measure from 1½ to 5 m.m. long. In cross section the average strand is of crescent shape and in its lateral structure there are natural lines of cleavage. Upon closer examination it is found that after decortication, a film of pulp is left adhering to the fibre, not only on its outer surface, but in the crevice of the crescent formation and also in the inner structure of the fibre itself. It is this pulp residue which becomes hard when dry, and under existing extraction methods, confines Sisal to the category of hard fibre. The ribbed formation designed by nature to produce a rigid reinforcement to support the leaf in which it is imbedded, contributes to its hardness or stiffness.

41. When laboratory work indicated that no economic chemical formula was likely to succeed, evidence which is supported by the fact that earlier research of others along those lines has not produced a commercial result, attention was then directed to the possibilities of expressing the pulp film mechanically. The first requisite for this operation was to render the gum plastic and to reproduce the condition they were in originally as they came from the leaf. A method of doing so was evolved, and by

compound were removed, a more obdurate residue was deposited in the form of a still harder lacquer-like film, requiring solvents of a more vigorous nature to break it down. A solvent of sufficient strength to act on this residue also attacked the fibre elements. Evidence was accumulated to prove that a solution did not lie in chemical formulae.

40. Laboratory research however was of value in that it was the means of acquiring an intimate knowledge of what constituted a strand of Sisal. In simple language, this can be likened to a strip of wood of rather cross grain. Like wood, it is built up out of tiny elements or ultimates, interlocked and held together by binding gums. These ultimates measure from 1½ to 5 m.m. long. In cross section the average strand is of crescent shape and in its lateral structure there are natural lines of cleavage. Upon closer examination it is found that after decortication, a film of pulp is left adhering to the fibre, not only on its outer surface, but in the crevice of the crescent formation and also in the inner structure of the fibre itself. It is this pulp residue which becomes hard when dry, and under existing extraction methods, confines Sisal to the category of hard fibre. The ribbed formation designed by nature to produce a rigid reinforcement to support the leaf in which it is imbedded, contributes to its hardness or stiffness.

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applying pressure of varying degree and using a range of experimental machines, it was discovered that the strand could be reduced to its ultimates, a downy fluff of cotton like substance, when all gums were extruded. Here then was proof that Sisal was a soft fibre. A number of machines were constructed and a long series of experiments carried out, the results of which were submitted to textile manufacturers. In this way a clearer insight was gradually obtained into the more important requirements, and also an understanding of the fibre structure and how it responded to a varying degree of treatment.

42. Certain basic conditions began to take shape and emerge from those experiments. For instance, it became obvious that the tensile strength of raw Sisal was due to the dense mass of tiny ultimates held in close contact by the binding gums. The removal of all gums reduced the fibre to its ultimates - fluff - a condition which could be reached by increasing and intensifying pressure. A knowledge however of the tensile strength of raw Sisal, and of the strength of the various fibres with which it is intended to compete, and knowing that most of them were in comparison, weaker, guided research into the process of extrusion. This research has clearly proved that it is possible to so control the extrusion process, and to arrest it at any pre-determined point, so as to produce a result which will make Sisal suitable for a range of uses, having the requisite qualities of strength and softness, to compare favourably with its various competitors, and when produced under some system which eliminates existing wasteful methods, at a price which will withstand competitors from most fibres in its range of usefulness.

43. To encroach still further upon the markets enjoyed by soft fibres and to enable Sisal to be spun to counts or

yarns of still lighter weight, research was conducted into various methods of splitting along the natural lines of cleavage. These lines of cleavage are discernable in a strand of raw Sisal, and by breaking down the crescent formation with pressure and partially flattening it, the cleavage lines become accentuated and further minor ones are disclosed. An examination of the structure becomes easier in this condition, and it is found that the sub-strands are held together, weakly, by occasional bridging ultimates here and there along the length. To separate the substrands, those ultimates must be severed, and this has been the subject of a wide range of research in itself.

44. At this juncture, it was becoming clearly indicated that Sisal was capable of being converted into, not only one type of softer fibre, but a range of softness, fineness, and strength, each type suitable for its respective trade requirements.

45. To illustrate three distinct types of fibre which Sisal can be converted into, the following will explain. In the production of a finer or split fibre it is essential to preserve tensile strength, but it also must be softer than raw Sisal. It is found that a satisfactory result is obtained by carrying pressure only to a point to flatten the strand and to open up cleavage lines sufficiently for the entry of the pin point of the splitting machine. By a correct adjustment and balance of those two operations, a fibre of considerably enhanced value is produced, having the requisite softness, fineness and strength suitable of application to a wide range of uses.

Quite a different product is produced however by increasing pressure to extrude more gum and to further flatten the fibre. In this case no splitting is done. This fibre necessarily is slightly weakened, but not beyond

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Quite a different product is produced however by increasing pressure to extrude more gum and to further flatten the fibre. In this case no splitting is done. This fibre necessarily is slightly weakened, but not beyond

a useful point. The product is soft and pliable and spins into a denser yarn, and the resultant twine or cordage is softer, more pliable, and because of the more even nature of this fibre distributing working load on each fibre in the cord of which it is made into the degree of initial strength which it gives up in softening is more than counterbalanced by the several benefits obtained, the cord is stronger than if made of raw hard fibre.

Again the extrusion process can be carried still further and a softer product obtained. In this case the desire is to weaken the fibre to a point where standard jute machinery is capable of handling it. Sisal can be softened and flattened and spun into a yarn of the heavier counts on jute machinery, giving a higher tensile strength than Jute, and producing soft strong fabric, much more suitable for such goods as bags than is possible with raw Sisal. When this softening process is applied to Sisal, produced under the most economical conditions possible, the cost should not exceed the figure which is accepted as being the lowest economic cost of Jute, viz., £16, C.I.F. U.K., and at its point of production will be considerably lower than the cost of Jute at that point, a matter of importance when considering the manufacture of bags for local requirements.

46. Research into methods of obtaining these results had to be guided by the all important factor of cost. It is obvious that successful exploitation of a new product depends upon this, so the whole field of production had to be taken under review, and a system studied which would not only link up with a conversion process, but by combining production with conversion, costs could be brought to within economic limits, an essential basis on which to develop.

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evidence that a solution of the problem of softening Sisal did not lie in chemical formulae, but clearly indicated that mechanical process would do so. To assist in the development of suitable machinery, Government were approached and financial support was given for this work, after the matter had been fully investigated by responsible experts.

8. Financial assistance thus obtained, the next step was to approach makers of machinery and it is here desired to pay tribute to those firms who have contributed so much to this development. Without the benefit of their experience and knowledge of Sisal and textile requirements, and the co-operation so readily given, this machinery development would not only have proved more costly, but would have evolved very slowly.

9. The point where a mechanical conversion process can be most effectively applied is on the estate where Sisal is produced, so this has influenced development and machinery has been designed of a simple robust construction suitable for plantation conditions.

0. Of the mechanical operations for softening and splitting, the former will be dealt with first. Softening is brought about in two ways, by a partial removal of the pulp residue, and by breaking down the stiff structure of the strand. In the correct balance between extrusion and flattening lies the correct answer to effective softening with retention of strength. The two results are obtained in one operation of passing the fibre between rolls of special construction and under pressure. Unlike previous use of rolling machinery, in this case the first end to be attained is the extrusion of pulp on and in the fibre. The required conditions are that the pulp must be soft and plastic, and that the rolls must be in pressure contact.

The surface of the rolls must have a sufficient elasticity to provide a cushioning effect, and at the same time be dense and firm enough to stand up to continuous work under the required pressure. A cushioned surface accommodates the fibres and at the same time exerts a modified pressure on it while maintaining contact with the opposing roll between fibres in order to extrude intervening pulp and the pulp expressed from the strand. It will therefore be appreciated that by controlling the degree and number of pressings, so is it possible to produce a fibre of pre-determined softness and strength.

51. During the development phase of this machine it became apparent that as pulp residue could be expressed when it was in intimate contact with the fibre, it followed therefore that the pulp of the leaf not so securely attached to the fibre would be more easily removed. So the next step was to squeeze the pulp from the entire leaf and to soften and flatten the fibre to any desired extent, all in one operation, and to dispense with decortication.

52. Pulp residue remaining in raw hard Sisal after conventional decortication, adds to the weight of the fibre, so therefore the product becomes lighter by the extent of the pulp removed. This loss in weight is found to be moderate under normal conditions and is more than offset by the increased fibre yield to take no account of the more valuable product obtained.

53. The degree of extrusion being controllable, the process can be arranged to leave a film of pulp adhering and not to flatten the strands. This, with subsequent cleaning on a machine, developed out of the splitting machine still to be described, produces the usual hard Sisal for the binder twine trade, and does so without

loss.

54. A Sisal leaf contains roughly 5% of fibre. The conventional method of harvesting is to cut the leaf, leaving one third of its fibre content behind as already explained. After Cutting, the leaf is transported to a central factory for decortication, final preparation and baling. An estate producing 1,000 tons of fibre annually therefore transports about 19,000 tons of waste matter, incidently of value as a fertilizer to the land from which it grows. Extrusion operations reduce weight of the leaf to 15% or thereabouts, and when carried out in the field, bring about an enormous saving in cost of transport as well as depositing this valuable waste matter on the land.

55. From what has been written describing the wastefulness of the industry as it operates to-day, it will have become apparent that there is no need at this juncture to indulge in figures of fractional accuracy.

56. The product, which comes from the extrusion rollers, even when this operation is only carried to the extent of producing hard fibre, consists mostly of fibre. Pulp particles remaining are loose and easily removed. The firm leaf structure has completely gone and the dirty fibre offers practically no resistance to any subsequent cleaning operation. Power absorbed in the rolling process plus that required for cleaning is very considerably less than the power taken to overcome the resistance presented by a full leaf in a conventional decorticator. Under this proposed system therefore, there is an appreciable reduction in power.

57. Sisal planters are ready to appreciate any loosening in some of the heavy labour operations which existing conditions demand, such as cutting, loading and

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7. Sisal planters are ready to appreciate any lessening in some of the heavy labour operations which existing conditions demand, such as cutting, loading and

unloading leaf, rail lifting and relaying, decortication and brushing operatives. In all of these sections economies are brought about by adapting this proposed system of production. Plucking leaf from a younger plant is a much lighter task than the cutting of mature leaf; railway work can be dispensed with by taking portable pressure rolling machinery to the field and much handling of leaf avoided. Labour on pressure rolling machinery is less and lighter than decorticators.

A short description will now be given of the various finishing processes which are intended to be carried out in a central factory on the Estate. The leaf, after pressure rolling, either in the field or in the factory, consists mostly of fibre with particles of loose pulp and leaf juices on it. In a product where pressure has been carried far enough to remove only part of the gums and the fibre flattened sufficiently for splitting this entire fibre content of the leaf is presented to a machine into which water is introduced. The fibre is fed thinly, the content of one leaf at a time. It is important to appreciate that each fibre when in the leaf and as it is extracted by slow moving rolls is parallel and quite untangled. It is essential to maintain this condition for subsequent splitting, so this operation takes place immediately after rolling and before the natural juices become dry. The machine consists of an upper and lower apron made of a special chain to which are attached blades in its first section, followed by a graduated system of pins. As the dirty fibre enters the machine it passes between the blades which exert a gentle action, removing all pulp particles and juices which are washed away by water. There are no fibres broken, and the gripper-conveyor is arranged to securely hold all the fibres near to the butt. The cleaned fibre continues still in the same gripper-conveyor and enters the pinned section of the

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double apron where it is split into two, three or more sub-divisions according to the arrangement of the pins and the degree of flattening it has received in pressure rolling.

59. The product of this operation is softened and split Sisal both line and tow, the value of the tow being very little if anything below the value of the line product, and both of a very considerable increased value over that of raw hard Sisal.

60. To produce the usual hard fibre, the same machine is used, but in this case the pinned section is dispensed with. The advantages of this system for hard fibre production over conventional methods has been sufficiently explained to require no further elaboration.

61. The same machine is also used for cleaning fibre when pressure rolling has been carried further to produce a softer fibre for cordage purposes, and again for fibre which has been weakened sufficiently for Jute machinery.

62. An unexpected development of this machine is an automatic brusher, an ideal long desired by the industry. For this purpose it is designed to brush and straighten hard dry Sisal, produces a better result than conventional brushers, less tow, and being automatic requires labour only at the feed and delivery ends. The development of this machine as a brusher will remove the cause of most of the serious accidents which are a feature of Sisal factories.

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63. Gradual or stepped up application of the various operations of textile manufactures govern the handling and preparation of fibres throughout all processes up to the finished product. This is an accepted law evolved through long years of experience. Endeavours to short circuit any one phase of this evolution by attempts to combine two operations in one have no doubt been tried, but discarded when the untruth is exposed. An understanding of this principle helps to realise that there are two distinct requirements in extracting fibre from a Sisal leaf, a fact which has been obscured by custom in accepting the conventional decorticator as the standard method. A decorticator is an attempt to combine two operations in one, to first break down the rigid structure of the leaf, followed and combined with separating the loosened pulp from the fibre. The result is the compromise which takes place between concaves and blades with consequent waste of fibre and power. Appreciation of the fact that there are two distinct requirements, each with its logical and separate application, prepares the way for a study of economic extraction.

64. Returning to the standard method of decortication we find that by far the heaviest work it has to perform is the first operation of breaking down leaf structure and loosening pulp and cuticule. It requires no great mechanical knowledge to realise that the principle of a decorticator is about the most unsuitable method for doing this heavy work. The obvious and logical way is to crush the leaf between rollers. This is simple machinery, requiring less power, and no fibre is destroyed and lost. When the rigid thick structure of a leaf has been rendered limp and thin, and pulp matter bruised and loosened, it requires a very light operation to clean it, much lighter and gentler than it receives in this final treatment in a decorticator.

65. Having explained the basic principles which underlie and guide development of this proposed system of Sisal production, we will now turn to a detailed examination of the first operation of breaking down the structure of a leaf as an alternative to that operation performed in a decorticator.

66. For the production of hard fibre there is one rolling operation, but when softened and split fibre is wanted, a second and heavier rolling process is introduced. Each has its separate requirements, and both operations and machines will be considered in detail.

67. It is advisable to make clear that only the first rolling is required for the production of hard fibre, and that the degree of rolling for this product is the same as is required for pressure rolling for producing softened and split Sisal.

68. To consider hard fibre production first. The rolling machinery for leaf reduction is designed for field operation. It is light and easily portable, and does not demand skilled supervision. There are no delicate setting adjustments, and it is light to drive, well within the range of small Diesel units. It is a slow running machine. The machine itself consists of four pairs of rolls, the first three pairs of which are fluted and the final pair smooth with a cushioned surface. The fluted rolls are set with clearances which progressively diminish, the pitch and size of fluting becoming finer in each following pair. The top roll of each pair is heavily spring loaded, and only the final smooth pair are in contact. Leaf is fed to this machine point first, four leaves abreast. Crushing flattens and widens the leaf, so to prevent butt ends splaying out and overlapping, a special design of conductor is embodied dividing the machine into lateral

compartments, four of them about nine inches wide each. The machine is designed for manual feeding which therefore controls capacity, but a reasonable average rate is thirty leaves per minute for each compartment, giving 120 per minute for the machine. This approximates normal delivery to a decorticator. The fibre in an equal number of plucked leaves, which comes from a rolling machine, is roughly double the amount of fibre from a decorticator.

69. This rolling process expresses juices and removes much pulp. Reduction in weight is considerable and will necessarily vary according to the condition of the leaf, but a normal leaf will lose about 80%, which represents an enormous saving in transport.

70. The reduced leaf as it comes from this machine is thin and limp with its pulp structure broken down. The tough cuticule is fractured at close intervals, and the hard outer edges, even when "barky" are in a condition for complete cleaning in the subsequent process. The leaf coming from this machine preserves its shape, fibres remaining separate and parallel, a most important requirement for the final process.

71. Efficient handling of a product by high speed machinery brings mechanical problems and complications demanding trained operatives, skilled supervision, and the background of an industrialized country. Those essentials are lacking in lands where Sisal is produced, so machine design should conform to these conditions. The simple rolling process already described does so, and in particular, the feed delivery and collection of the reduced leaf, are easy manual techniques to master.

72. We will now examine the final operation of cleaning this limp leaf after pulp structure and cuticule have been bruised and loosened. This is essentially a light operation, absurdly light when compared with this part of the operation as performed on a decorticator. As previously mentioned, the fibres in this reduced leaf are separate and parallel, presenting an ideal condition for cleaning, fibre by fibre. The machine which has been developed for this does in fact clean each fibre separately, using water in the process. The volume of water required is small compared with the requirements of conventional decortication which uses 75% of its water supply, not to clean the fibre but to act as a conveyor of waste which it creates, and pulp waste which has been so costly to transport. The capacity of one cleaning machine is arranged to handle the output of one rolling machine.

73. The success of this proposed system was now focussed on the evolution of a cleaning machine capable of producing fibre without waste. This involved prolonged research and attempts were made to adapt every known and likely textile operation, but without success. It became apparent that as the requirement was probably original, some new mechanism was demanded. To this effort was brought fragments of experience gained here and there, supported with an intimate knowledge of the Sisal leaf and the requirements of production conditions. Eventually this cleaning machine was evolved which dovetails into the process and produces all the fibre of an entire leaf in a clean state, the fibre content emerging as a complete skeleton of the leaf, not one fibre lost.

74. The fibre as it leaves this machine contains a residue of pulp clinging to the lateral crevice, and in the structure of the fibre. Deleterious juices and

acids have however been more completely removed than by decortication even when followed by hydro-extraction. The fibre is still therefore a hard fibre when dry, but its condition and appearance is an improvement upon the usual product of decortication. The final section of this cleaning machine removes surplus water so that drying operations are shortened, a valuable contribution to economic production when drying machinery is installed.

75. The product of this machine represents 100% content of the leaf, which means that all the shorter fibres are retained which are normally lost in decortication. Here now we must examine the requirements of the manufacturer to assist in a clearer consideration of the economics of separating out those shorter fibres. In the development of binder twine machinery the tendency has been to increase the reach of drawing frames to conform to the longest fibre which the production industry offered. The reach of a drawing process must not be less than the length of the longest fibres, but it operates quite satisfactorily with a reasonable admixture of shorter fibres, provided they are not in such quantity as to produce uneven yarns or breakages through "birdnesting". They also must be evenly distributed throughout the parcel. It is possible however that a small proportion of the shortest fibres may fall out during the drawings, but such loss is slight, and it is believed that any lowering in value of this type of Sisal is less than the cost of separating and marketing them as tow. The final answer to that opinion will of course rest with the manufacturer.

76. Should however a producer desire to cater for a special high grade of hard fibre market, he can separate out the shorter fibres on a simple machine which can be

adjusted to remove fibres of any given length. This machine is an attachment to the cleaning machine, works on the same principle, and the operation of separation is merely an extension of the cleaning one.

77. This then is brief description of the proposed system when operated for hard fibre production. For softened and split Sisal, additional operations are introduced. This will necessarily add to the cost, but taking into consideration the substantial economies, which 100% extraction and cheaper technique bring about, the final cost will be economic, particularly when a more valuable fibre is produced.

78. The process of extruding pulp residue and flattening the crescent formation of a Sisal strand requires a plastic condition of the pulp residue as it comes from the leaf in the initial rolling process, but before cleaning. The requirements governing pressure rolling are quite different from those for the initial operation although both happen to be a rolling process. In this case as in all other fibre operations, the end is achieved gradually, the fibre passing through a series of pressure rollings, each succeeding pressing or nip controlled to give the desired result. If it is desired to produce softened split Sisal which retains strength to compete with European Hemps or Flax, the binding gums are only partly removed and the fibre sufficiently flattened to accentuate cleavage lines for subsequent splitting. Should a softer fibre be desired the pressure is increased to extrude more of the binding gums. This fibre is not split, but is intended for the cordage trade, and being pliable it produces a more even and denser rope which is stronger than one made of raw hard Sisal. Yarns for weaving into canvas can be produced on Standard Jute machinery by carrying the softening process further still. Here the requirement is for a weaker fibre which is produced by increasing the

pressure on the rolling process still further. Such fibre goes through the various breaker and finisher cards of a Jute plant, and spins into a yarn of the heavier counts which is stronger than a Jute yarn. It is also cheaper.

79. The degree of pressure required for the least of the softening results is considerable, so machinery is strong and heavy and power requirements are greater than for initial rolling. These factors exceed the practical limits for field work, so this plant is designed for factory operation.

80. It will be obvious that in the production of a uniform type of fibre from such a process, a necessary requisite is a uniform and unvarying condition of the materials presented to each machine. This condition is present in the limp leaf as it comes from field rolling, and it is only when in this state that satisfactory and uniform softening results can be attained.

81. From the pressure rolling machine the outline of the leaf is retained, the fibres separate and parallel. In this state it passes to the splitting process. This machine is exactly the same as the cleaning machine, embodies the initial water cleaning section and extended to include the splitting section.

82. The act of splitting consists of a pin point entering between the accentuated cleavage lines, drawing the pin along and severing the bridging ultimates. It was anticipated that tow production would be high, but this product is equally split and its value not much less than that of line fibre. In actual practice however it has been found that very few fibres are pulled away. This satisfactory result is of course accounted for by the fact that the fibres are presented to this machine as they were in the leaf, each fibre separate and parallel.

83. The capacity of one Splitting Machine is the same as one Softening Machine, which in turn is the same as one Field Rolling Machine.

84. A catalogue of all the fibres in commercial use in the world would make a long and interesting list, ranging from the cheapest to the most valuable, from Jute to Silk, including animal and vegetable fibres, and synthetic fibres of recent development.

85 Grouping all fibres under the one heading of a "Primary Product", we find that there is probably more competition between one fibre and another within the fibre markets for world favour, than in any other market of relative importance. There has always been a ceaseless effort, which no doubt will continue, to increase the market for one fibre at the expense of another. There is the historic case of a century or so ago of the rise of the Jute industry which enveloped the Scottish Flax trade, and the more recent developments in cellulose which have already encroached seriously upon the preserves of Cotton, Silk, and Wool.

86. New fibres, new textiles, new methods of manufacture are constantly being introduced; the scene is ever changing. The world of intense competition is more ready to-day than it ever was to accept a new fibre when it conforms to the controlling factors of suitability for standard machinery and price, particularly when there is a price advantage.

87. Two modern conditions which have arisen within recent years tend to intensify competition between certain fibres. The general state of indigestion of most consuming markets has been very pronounced in that of fibre. In some fibres, the fall in consumption and values has been aggravated by the necessity for producers to increase production in order to earn enough to live. The other condition affecting some

important fibres has been the rise of nationalism. This is not a passing phase. It is permanent, and is rapidly gathering increasing force. Trade barriers are being erected, behind the protection of which national products and manufactures are being fostered at the expense of the imported article.

88. Jute is a typical example illustrating the effect on an important industry of this modern trend. Jute, not long ago, supplied the world with containers for all its bagged commodities. It enjoyed a monopoly, but does so no longer. Countries capable of growing an alternative fibre have erected fiscal barriers against Jute goods, and are fostering the manufacture of bags from their indigenous product. It has been estimated that there are now over twenty million bags being made annually in different parts of the world from alternative fibres which used to be made of Jute. This development is still in its infancy, and is extending rapidly.

89. With regard to Sisal and its possible development. The extent to which this industry is capable of expansion will be governed by cost of production and the development of conversion methods. In the matter of costs, existing methods have been described which wastes half of the fibre grown, with an already low cost of around £15 C.I.F. This figure will be materially reduced as 100% extraction is approached. Converted Sisal will enter new markets. Development along these two lines is certain to come. With low basic costs and suitability, both as a hard and a softer fibre, Sisal is destined to encroach upon competitive fibres, and when it does so to the extent which the evidence indicates that it will, there will be yet another change to record in the fibre world.

42

S I S A L

by

James McCrae

LEEDS.
May, 1936.

SISAL.

1. Sisal history of recent years bears analogy to that of Rubber. Like the Rubber Industry which has developed in the East from seed taken from its original home in South America, and finding more congenial climatic and economic conditions in its new surroundings, so Sisal appears to be following a similar trend.

2. Mexico, the home of the Sisal industry, supplied all world requirements until three decades or so ago. Since then the plant has been introduced into Eastern Africa and the East Indies, where its expansion has been rapid, particularly in East Africa, as the following tables of annual production will show. The figures are tons.

	1927	1932	1933	1934	1935
Mexican Sisal	120,000	88,000	93,000	92,000	90,000
African "	50,000	91,000	108,000	121,000	144,000
Java & Sumatra	44,000	80,000	95,000	85,000	84,000
	214,000	259,000	296,000	298,000	318,000

3. An inference which can be drawn from these figures is that the Industry is finding conditions in East Africa more suitable than either Mexico or the East Indies. As world requirements continue to expand as they are doing, there is every indication that East Africa will participate in this expansion, and should do so in an increasing ratio over the other two producing countries.

4. The industry was established in East Africa during a period when values stood around £28. Then came war and witnessed an inflation in values of all primary products, including that of Sisal, the price of which was controlled at £99, C.I.F. During the post-war period values remained

at very high levels, offering attractive investment, until the depression set in.

5. This long period of prosperity is unquestionably the main cause of the intensity of the misfortunes which overwhelmed the industry during the years of depression. The attractive profits of that period induced a phase of rapid, and haphazard development. The increased production resulting from those new post war areas coincided with the heavy fall in consumption at the beginning of the slump. The clash of those two conditions intensified the fall in Sisal values which set in during 1930, and continued until the latter end of 1935. During this long spell prices remained well below the cost of production with the result that a distressed condition developed in the industry. Many estates went into liquidation and most of those which survive find their plantations in a backward state, with plant and machinery worn out and out-of-date.

6. Unfortunately there was not, nor is there yet any method whereby this industry can plan and regulate production to meet world requirements. The necessity for some concerted international arrangement to adjust balances between supply and demand in the field of primary products will no doubt be evolved in the course of time, but until posterity produces a workable formula, Sisal can only direct its efforts to cheapening its production costs and extending its markets. The object of the writer is to indicate a way, which should assist the industry towards these desired ends.

7. In the case of Sisal price fluctuations have been over wide margins, as must be the case with a product catering for restricted markets as Sisal does. The bulk of the world's production of this fibre is made into binder

twine used in harvesting. Weather conditions in the grain growing areas of the world therefore exercise a very pronounced control on Sisal values, and as long as the industry continues to depend upon this one market and that market depending upon weather conditions, so will Sisal continue to be a speculative investment.

8. The experience of the past slump years is a graphic illustration of the basic weakness of the Sisal industry, intensified no doubt by the abnormal conditions which have prevailed, but clearly indicating that without a broader basis in the consuming market, prices will continue to be subjected to heavy rise and fall.

9. The prolonged period of depression has brought some compensations to the industry in the way of an extension of markets, induced very largely by low values, but there is a danger of those new markets shrinking should Sisal values rise above the prices of competitive fibres. Experience has shown that potential users of this fibre are chary of adopting it in their trades on account of price instability, particularly when its use entails the installation of special machinery. There is no doubt that more stable prices moving within narrower limits and at competitive and economic values to other fibres, would encourage consumption of Sisal in those trades which are beginning to take an interest to-day.

10. The trades referred to which are absorbing the bulk of production in excess of binder twine requirements and have thereby assisted in great measure in the recent advance in values, are parcel twine and cordage manufacturers, the bedding and upholstery trades, particularly in U.S.A. and to a very limited extent fabrics for sacks.

11. These new markets are of inestimable value to the

industry, but as they operate on low price levels they can only be expected to continue their patronage under moderate, and more particularly, stable values.

12. A factor which must always be kept in view is the competition of Manila Hemp. This, like Sisal, is a hard fibre, and is used as an alternative to Sisal in many important markets, so has an influence upon Sisal values. For certain products such as marine cordage, Manila enjoys not only an entrenched position, but in certain qualities it has an undoubted advantage in being a more flexible and a less brittle fibre. It is believed possible however that the disability which Sisal suffers from in this market can be overcome by a simple method of converting it into a softer and more pliable fibre. This will be explained later.

13. The experience of those past years indicated that there are markets for Sisal outside the binder twine trade, markets which consume hard fibre and which have recently been doing so at an increasing rate, but due solely to the stimulus of low prices. The values of Sisal which have ruled during the slump period, and which have been the cause of this fibre finding its way into new markets, those values have been below the existing cost of production, and unless costs are brought down to a figure which will yield a profit to the producer and offered at a level which those new customers can afford to pay, then those markets cannot be considered permanent.

14. In a comprehensive survey of the industry which it is now proposed to make, we will begin with fundamentals, the first and most important being cost of production. This analysis should necessarily start with agriculture, but as that subject is best dealt with as a subject deserving

greater scope than this paper can accommodate, so we will begin with the plant ready for harvesting.

15. The writer finds difficulty in presenting a picture of continuity in this story of Sisal, the many issues being so unevenly interwoven, but trusts, that with patience, the reader will retain a constructive narrative, when all is written.

16. Depressed times forced the industry to make economies, and at the same time to stimulate research into many of its phases, including improvements in agriculture, labour, plant selection, transport, extraction, grading, baling, and the study of converting Sisal into a softer fibre suitable for new uses. The amount of activity, energy and money expended during the past years on these lines of research has been very considerable and has had the co-operation of a united industry operating through its Associations and the sympathetic and practical assistance of Home and Colonial Governments.

17. Considerable headway is to be recorded in most of these branches of research and it is to be hoped that the results of all this work will be collated in due course, and published for the general guidance of the industry.

18. The motive of this paper is to stimulate thought and discussion on the dual ideal of reducing costs and increasing markets and the writer, after years of research into both of these basic subjects, presents the results of his work, not with any attitude of dogmatism, but with the hope that it will, through controversy and arguments, induce efforts to break new ground in both of these indicated spheres, and so in time, assist to place Sisal fibre in a more prominent and stable position than it occupies to-day.

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19. When the basic factor of production cost is examined however and although far reaching economies and improvements in production and preparation have been introduced, there still remains much room for improvement, particularly in the established methods of harvesting and extraction. The general system, in so far as it applies to East Africa, the largest producing centre of the world, results in a loss of approximately one half of the fibre content of the leaf. This question of waste must necessarily have a direct bearing upon costs of production, and until it is solved and reduced to within more reasonable limits the industry cannot be considered as operating at its lowest economic cost. It is well therefore to examine the factors which bring this waste about and to study any feasible method which offers improvement.

20. The existence of the waste problem is one which has exercised the industry for many years, and much thought and study have been brought to bear upon it. The writer has found however that the technique and economics of production can be improved and applied more intelligently by having a greater knowledge of actual and potential markets than is at present enjoyed, and he believes that this more thorough knowledge will be an important contributory factor towards greater efficiency.

21. The percentage of waste is a figure about which a certain amount of controversy exists. There is no doubt that it varies, variations depending upon factors such as the condition of the leaf, whether succulent or tough and leathery as it is in dry weather, the setting and condition of decorticators and so on, but under the best conditions this waste is considerable, and for purposes of this survey it has been taken as 25% of the fibre content of the leaf as harvested in the existing manner. The other 25% waste is another matter and will be dealt with later on.

22. Waste in decortication is a problem for the engineer. Very large sums and long periods of research have been devoted to this problem. The conventional method of decortication is to pass the leaf, which has a firm thick structure, between rapidly revolving drums furnished with blades, and a rigid concave which holds the leaf in close contact with the blades. In its thickest section the leaf measures about an inch, and to enable the blades to completely remove the pulp, the clearance between the blades and concaves must be very narrow, sometimes to as small as fifty-thousandths of an inch. This firm leaf structure presented to the blow of the blades in a restricted aperture, results in many fibres being broken and lost. Another cause of loss is due to the short fibres in the leaf which terminate at various points along its length. The mechanism of the decorticator which conveys the leaf through the machine, grips the leaf in such a position that many of those shorter fibres are not secured, and so are lost. The total loss due to breakage and to shorter fibres varies under different conditions, but is generally accepted as being in the neighbourhood of 25% of the leaf as harvested.

23. The trend of modern design of decorticators is to soften the blow of the blade, and to grip more of the shorter fibres in the leaf. These ends are attained by subjecting the leaf to a pre-crushing process, reducing its rigid firm structure to a limp state. In this condition it offers less resistance to the blade action and so fewer fibres are broken. Instead also of attempting to clean the leaf of pulp through its entire thickness in one operation which necessitates such a close setting of concave clearances, this cleaning action is applied progressively, first on one side of the leaf and then on the other. In this machine the

design of the gripper-conveyor is such that more of the short fibres are firmly held. This machine registers considerable advance over existing models, reduces waste to a very considerable extent, and by offering less resistance to the cleaning drums, requires less power to drive and maintenance cost is reduced.

24. The balance of waste, previously referred to as 25%, will now be examined, and a method will be explained later indicating how it is possible to prevent all or most of it. In order to understand this proposed method, and for those who do not know the Sisal plant, we can best illustrate by likening it to an enlarged artichoke, with leaves running from say twenty inches to over four feet long. As in an artichoke, the Sisal leaf is attached to a thick central stem or bole, with the butt ends overlapped and interlocked in a similar manner.

25. Harvesting is done by cutting the leaf by hand as near to the butt end as possible, leaving the butt adhering to the bole. This butt contains fibre of marketable value. For purposes of illustrating we will divide the fibre content of a leaf, including the butt, into 150 equal parts by weight. It has been established that the fibre content of the harvested portion contains roughly 100 parts, and 50 parts in the butt portion, which are lost. This seemingly excessive ratio in the short butt, which measures from 7" to 9" long, is explained by the fact that all the fibres in the leaf have their beginnings in the butt and that they are thicker and heavier there. As the leaf matures, the fibres which support it grow thicker along their entire length and in the butt they become woody and weak. In a mature leaf, about half of those butt fibres are of little value, but the remaining half are acceptable for use in the binder twine trade.

26. Instead of harvesting by cutting the leaf as it matures, spread over the life of 8 to 10 years of the plant, the alternative method is to strip the plant completely at an earlier age, plucking the whole leaf. Before considering the economics of this system we will examine the fibres of the butts of this younger leaf. In this case those fibres have not become so thick, are not woody and are of a strength and spinning size to be acceptable to the binder twine trade. This type of fibre is being marketed to-day and obtaining current values.

27. Plants grown to be completely stripped by plucking at an earlier age require less ground. In practice, it will be found that closer planting, varying according to soil and climatic conditions, increase the numbers of plants in a given area from three to four fold over conventional planting. The period of growth to reach the most economic yield will also vary but will be between two to three years from planting average nursery or sucker plants.

28. It has been found that the fibre content of a given area planted as suggested, is considerably greater than the average yield obtained from the same area over a period three times as long. Harvesting the entire leaf and extracting all the fibre, by a process still to be explained, we begin to approach economical Sisal production. When the system comes to be closely examined by the industry it will be found that the increased yield within a much shorter period will more than off set the additional costs which more frequent plantings will entail.

29. Under existing methods therefore the plant occupies the land for about nine years; one third of its fibre content is left behind and one quarter of the harvested part is lost in extraction and final preparation. The leaf having

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a fibre content of 5% means transport of an enormous tonnage of waste matter to the factory, in figures roughly 19,000 tons of waste transport for each 1,000 tons of fibre produced.

30. It has been necessary to explain at length the existing economics of the industry and to emphasise the two outstanding weaknesses under which it suffers; restricted markets and wasteful production methods, in order to fully appreciate solutions which it is the object of this paper to suggest.

31. To deal with the question of markets first, the importance of erecting a broader basis of consumption has been stressed. It has been shown that there are potential users of this hard fibre, but only at a low price level, a price which it is uneconomic for the industry to cater for under existing methods of production. It is reasonable to believe however that with more efficient production and waste reduced to a minimum, the production and separation of the shorter fibres which these potential trades require, can be profitably produced, leaving the longer qualities for the binder twine trade for which higher prices are obtainable.

32. Under existing methods of growing and extraction it is not possible to attain economic production of those lower grade fibres, and it is questionable if it will be found remunerative to recover and recondition to a sufficient degree of cleanliness, waste fibres from decortication, even for the bedding and upholstery trades. It is obviously a more constructive policy to prevent the creation of waste.

33. How then to expand still further into new markets? The answer to that is that Sisal is capable of being softened and converted by a process which is effective and economic to apply. This process will be explained in

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the proper sequence of this story of Sisal. It can be operated under plantation conditions and so adjusted and controlled to give a range of fibres of varying degrees of softness and strength to suit the varying requirements of his customers.

34. A planter's knowledge of his industry is incomplete without a closer understanding of the consuming markets. This became so apparent after years of research into the production end of Sisal, that a prolonged study of textile trades was undertaken. Many months were devoted to this, and it is gratifying to record the willing and helpful attitude of manufacturers which was extended during that time. No effort was spared to assist to a better understanding of their requirements.

35. Contacts made during this period had the effect of stimulating the interest of spinners who had but a passing knowledge of Sisal, and it was made obvious that there were many potential users of this fibre who, for reasons already explained, were hesitant about adopting it. During this time a clearer view was obtained into the extent of markets using fibres of a higher price level, for goods which might be termed the heavy end of the soft fibre trades, in the production of which a fibre of slightly heavier nature than flax and soft hemps could be used, were they commercially available.

36. The world's production of Sisal, in relative importance to that of Jute, Flax, Cotton, etc., is insignificant and will remain so as long as it is produced as a hard fibre. However, when it enters the soft fibre trades and it becomes realised that it is cheaper to produce, and for many purposes is at least as suitable as some of the soft fibres for certain important uses,

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then Sisal will gradually emerge from its comparative obscurity and becomes a product of primary importance.

37. To arrive at a complete understanding of the economics of the industry, an endeavour has been made to indicate how necessary it is for the producer to have a more intimate knowledge of his customers requirements, both actual and potential than he has to-day. No claim is made to have exhausted the various fields of this research, but sufficient evidence has been acquired to indicate clearly that more economic methods of production, coupled with a practical and applicable method of conversion of Sisal to a softer fibre, and an intimate knowledge of the various trade requirements, will go far to place the industry on a healthier basis.

38. Knowledge gained in this very wide field of research embracing production and consumption, formed a valuable background for the next step of research which it was necessary to take. A laboratory was equipped and staffed to study the structure and composition of Sisal, and to explore a possible method of softening it which could be applied economically under plantation conditions and which would produce a product likely to meet the requirements of some of the more important industries which had been investigated.

39. To form a clearer understanding of this phase of research, it is advisable to give an account of the laboratory work and findings which were arrived at. By analysis, the nature and composition of the binding gums and pectins was understood. In non-technical language, these were found to be of a compound nature, some parts of which readily reacted to mild solvents. It was found however that when those easily dissolved parts of the

compound were removed, a more obdurate residue was deposited in the form of a still harder lacquer-like film, requiring solvents of a more vigorous nature to break it down. A solvent of sufficient strength to act on this residue also attacked the fibre elements. Evidence was accumulated to prove that a solution did not lie in chemical formulae.

40. Laboratory research however was of value in that it was the means of acquiring an intimate knowledge of what constituted a strand of Sisal. In simple language, this can be likened to a strip of wood of rather cross grain. Like wood, it is built up out of tiny elements or ultimates, interlocked and held together by binding gums. These ultimates measure from 1½ to 5 m.m. long. In cross section the average strand is of crescent shape and in its lateral structure there are natural lines of cleavage. Upon closer examination it is found that after decortication, a film of pulp is left adhering to the fibre, not only on its outer surface, but in the crevice of the crescent formation and also in the inner structure of the fibre itself. It is this pulp residue which becomes hard when dry, and under existing extraction methods, confines Sisal to the category of hard fibre. The ribbed formation designed by nature to produce a rigid reinforcement to support the leaf in which it is imbedded, contributes to its hardness or stiffness.

41. When laboratory work indicated that no economic chemical formula was likely to succeed, evidence which is supported by the fact that earlier research of others along those lines has not produced a commercial result, attention was then directed to the possibilities of expressing the pulp film mechanically. The first requisite for this operation was to render the gum plastic and to reproduce the condition they were in originally as they came from the leaf. A method of doing so was evolved, and by

applying pressure of varying degree and using a range of experimental machines, it was discovered that the strand could be reduced to its ultimates, a downy fluff of cotton like substance, when all gums were extruded. Here then was proof that Sisal was a soft fibre. A number of machines were constructed and a long series of experiments carried out, the results of which were submitted to textile manufacturers. In this way a clearer insight was gradually obtained into the more important requirements, and also an understanding of the fibre structure and how it responded to a varying degree of treatment.

Certain basic conditions began to take shape and emerge from those experiments. For instance, it became obvious that the tensile strength of raw Sisal was due to the dense mass of tiny ultimates held in close contact by the binding gums. The removal of all gums reduced the fibre to its ultimates - fluff - a condition which could be reached by increasing and intensifying pressure. A knowledge however of the tensile strength of raw Sisal, and of the strength of the various fibres with which it is intended to compete, and knowing that most of them were in comparison, weaker, guided research into the process of extrusion. This research has clearly proved that it is possible to so control the extrusion process, and to arrest it at any pre-determined point, so as to produce a result which will make Sisal suitable for a range of uses, having the requisite qualities of strength and softness, to compare favourably with its various competitors, and when produced under some system which eliminates existing wasteful methods, at a price which will withstand competitors from most fibres in its range of usefulness.

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To encroach still further upon the markets enjoyed by soft fibres and to enable Sisal to be spun to counts or yarns of still lighter weight, research was conducted into various methods of splitting along the natural lines of cleavage. These lines of cleavage are discernable in a strand of raw Sisal, and by breaking down the crescent formation with pressure and partially flattening it, the cleavage lines become accentuated and further minor ones are disclosed. An examination of the structure becomes easier in this condition, and it is found that the sub-strands are held together, weakly, by occasional bridging ultimates here and there along the length. To separate the substrands, these ultimates must be severed, and this has been the subject of a wide range of research in itself.

44. At this juncture, it was becoming clearly indicated that Sisal was capable of being converted into, not only one type of softer fibre, but a range of softness, fineness, and strength, each type suitable for its respective trade requirements.

45. To illustrate three distinct types of fibre which Sisal can be converted into, the following will explain. In the production of a finer or split fibre it is essential to preserve tensile strength, but it also must be softer than raw Sisal. It is found that a satisfactory result is obtained by carrying pressure only to a point to flatten the strand and to open up cleavage lines sufficiently for the entry of the pin point of the splitting machine. By a correct adjustment and balance of these two operations, a fibre of considerably enhanced value is produced, having the requisite softness, fineness and strength suitable of application to a wide range of uses.

Quite a different product is produced however by increasing pressure to extrude more gum and to further flatten the fibre. In this case no splitting is done. This fibre necessarily is slightly weakened, but not beyond

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The surface of the rolls must have a sufficient elasticity to provide a cushioning effect, and at the same time be dense and firm enough to stand up to continuous work under the required pressure. A cushioned surface accommodates the fibres and at the same time exerts a modified pressure on it while maintaining contact with the opposing roll between fibres in order to extrude intervening pulp and the pulp expressed from the strand. It will therefore be appreciated that by controlling the degree and number of pressings, so is it possible to produce a fibre of pre-determined softness and strength.

51. During the development phase of this machine it became apparent that as pulp residue could be expressed when it was in intimate contact with the fibre, it followed therefore that the pulp of the leaf not so securely attached to the fibre would be more easily removed. So the next step was to squeeze the pulp from the entire leaf and to soften and flatten the fibre to any desired extent, all in one operation, and to dispense with decortication.

52. Pulp residue remaining in raw hard Sisal after conventional decortication, adds to the weight of the fibre, so therefore the product becomes lighter by the extent of the pulp removed. This loss in weight is found to be moderate under normal conditions and is more than offset by the increased fibre yield to take no account of the more valuable product obtained.

53. The degree of extrusion being controllable, the process can be arranged to leave a film of pulp adhering and not to flatten the strands. This, with subsequent cleaning on a machine, developed out of the splitting machine still to be described, produces the usual hard Sisal for the binder twine trade, and does so without

loss.

54. A Sisal leaf contains roughly 5% of fibre. The conventional method of harvesting is to cut the leaf, leaving one third of its fibre content behind as already explained. After Cutting, the leaf is transported to a central factory for decortication, final preparation and baling. An estate producing 1,000 tons of fibre annually therefore transports about 19,000 tons of waste matter, incidently of value as a fertilizer to the land from which it grows. Extrusion operations reduce weight of the leaf to 15% or thereabouts, and when carried out in the field, bring about an enormous saving in cost of transport as well as depositing this valuable waste matter on the land.

55. From what has been written describing the wastefulness of the industry as it operates to-day, it will have become apparent that there is no need at this juncture to indulge in figures of fractional accuracy.

56. The product, which comes from the extrusion rollers, even when this operation is only carried to the extent of producing hard fibre, consists mostly of fibre. Pulp particles remaining are loose and easily removed. The firm leaf structure has completely gone and the dirty fibre offers practically no resistance to any subsequent cleaning operation. Power absorbed in the rolling process plus that required for cleaning is very considerably less than the power taken to overcome the resistance presented by a full leaf in a conventional decorticator. Under this proposed system therefore, there is an appreciable reduction in power.

57. Sisal planters are ready to appreciate any lessening in some of the heavy labour operations which existing conditions demand, such as cutting, loading and

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57. Sisal planters are ready to appreciate any lessening in some of the heavy labour operations which existing conditions demand, such as cutting, loading and

unloading leaf, rail lifting and relaying, decortication and brushing operatives. In all of these sections economies are brought about by adapting this proposed system of production. Plucking leaf from a younger plant is a much lighter task than the cutting of mature leaf; railway work can be dispensed with by taking portable pressure rolling machinery to the field and much handling of leaf avoided. Labour on pressure rolling machinery is less and lighter than decorticators.

68. A short description will now be given of the various finishing processes which are intended to be carried out in a central factory on the Estate. The leaf, after pressure rolling, either in the field or in the factory, consists mostly of fibre with particles of loose pulp and leaf juices on it. In a product where pressure has been carried far enough to remove only part of the gums and the fibre flattened sufficiently for splitting this entire fibre content of the leaf is presented to a machine into which water is introduced. The fibre is fed thinly, the content of one leaf at a time. It is important to appreciate that each fibre when in the leaf and as it is extracted by slow moving rolls is parallel and quite untangled. It is essential to maintain this condition for subsequent splitting, so this operation takes place immediately after rolling and before the natural juices become dry. The machine consists of an upper and lower apron made of a special chain to which are attached blades in its first section, followed by a graduated system of pins. As the dirty fibre enters the machine it passes between the blades which exert a gentle action, removing all pulp particles and juices which are washed away by water. There are no fibres broken, and the gripper-conveyor is arranged to securely hold all the fibres near to the butt. The cleaned fibre continues still in the same gripper-conveyor and enters the pinned section of the

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double apron where it is split into two, three or more sub-divisions according to the arrangement of the pins and the degree of flattening it has received in pressure rolling.

59. The product of this operation is softened and split Sisal both line and tow, the value of the tow being very little if anything below the value of the line product, and both of a very considerable increased value over that of raw hard Sisal.

60. To produce the usual hard fibre, the same machine is used, but in this case the pinned section is dispensed with. The advantages of this system for hard fibre production over conventional methods has been sufficiently explained to require no further elaboration.

61. The same machine is also used for cleaning fibre when pressure rolling has been carried further to produce a softer fibre for cordage purposes, and again for fibre which has been weakened sufficiently for Jute machinery.

62. An unexpected development of this machine is an automatic brusher, an ideal long desired by the Industry. For this purpose it is designed to brush and straighten hard dry Sisal, produces a better result than conventional brushers, less tow, and being automatic requires labour only at the feed and delivery ends. The development of this machine as a brusher will remove the cause of most of the serious accidents which are a feature of Sisal factories.

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63. Gradual or stepped up application of the various operations of textile manufactures govern the handling and preparation of fibres throughout all processes up to the finished product. This is an accepted law evolved through long years of experience. Endeavours to short circuit any one phase of this evolution by attempts to combine two operations in one have no doubt been tried, but discarded when the untruth is exposed. An understanding of this principle helps to realise that there are two distinct requirements in extracting fibre from a Sisal leaf, a fact which has been obscured by custom in accepting the conventional decorticator as the standard method. A decorticator is an attempt to combine two operations in one, to first break down the rigid structure of the leaf, followed and combined with separating the loosened pulp from the fibre. The result is the compromise which takes place between concaves and blades with consequent waste of fibre and power. Appreciation of the fact that there are two distinct requirements, each with its logical and separate application, prepares the way for a study of economic extraction.

64. Returning to the standard method of decortication we find that by far the heaviest work it has to perform is the first operation of breaking down leaf structure and loosening pulp and cuticule. It requires no great mechanical knowledge to realise that the principle of a decorticator is about the most unsuitable method for doing this heavy work. The obvious and logical way is to crush the leaf between rollers. This is simple machinery, requiring less power, and no fibre is destroyed and lost. When the rigid thick structure of a leaf has been rendered limp and thin, and pulp matter bruised and loosened, it requires a very light operation to clean it, much lighter and gentler than it receives in this final treatment in a decorticator.

65. Having explained the basic principles which underlie and guide development of this proposed system of Sisal production, we will now turn to a detailed examination of the first operation of breaking down the structure of a leaf as an alternative to that operation performed in a decorticator.

66. For the production of hard fibre there is one rolling operation, but when softened and split fibre is wanted, a second and heavier rolling process is introduced. Each has its separate requirements, and both operations and machines will be considered in detail.

67. It is advisable to make clear that only the first rolling is required for the production of hard fibre, and that the degree of rolling for this product is the same as is required for pressure rolling for producing softened and split Sisal.

68. To consider hard fibre production first. The rolling machinery for leaf reduction is designed for field operation. It is light and easily portable, and does not demand skilled supervision. There are no delicate setting adjustments, and it is light to drive, well within the range of small Diesel units. It is a slow-running machine. The machine itself consists of four pairs of rolls, the first three pairs of which are fluted and the final pair smooth with a cushioned surface. The fluted rolls are set with clearances which progressively diminish, the pitch and size of fluting becoming finer in each following pair. The top roll of each pair is heavily spring loaded, and only the final smooth pair are in contact. Leaf is fed to this machine point first, four leaves abreast. Crushing flattens and widens the leaf, so to prevent butt ends splaying out and overlapping, a special design of conductor is embodied dividing the machine into lateral

compartments, four of them about nine inches wide each. The machine is designed for manual feeding which therefore controls capacity, but a reasonable average rate is thirty leaves per minute for each compartment, giving 120 per minute for the machine. This approximates normal delivery to a decorticator. The fibre in an equal number of plucked leaves, which comes from a rolling machine, is roughly double the amount of fibre from a decorticator.

69.— This rolling process expresses juices and removes much pulp. Reduction in weight is considerable and will necessarily vary according to the condition of the leaf, but a normal leaf will lose about 80%, which represents an enormous saving in transport.

70. The reduced leaf as it comes from this machine is thin and limp with its pulp structure broken down. The tough cuticule is fractured at close intervals, and the hard outer edges, even when "barky" are in a condition for complete cleaning in the subsequent process. The leaf coming from this machine preserves its shape, fibres remaining separate and parallel, a most important requirement for the final process.

71. Efficient handling of a product by high speed machinery brings mechanical problems and complications demanding trained operatives, skilled supervision, and the background of an industrialized country. Those essentials are lacking in lands where Sisal is produced, so machine design should conform to these conditions. The simple rolling process already described does so, and in particular, the feed delivery and collection of the reduced leaf, are easy manual techniques to master.

72.

72. We will now examine the final operation of cleaning this limp leaf after pulp structure and cuticule have been bruised and loosened. This is essentially a light operation, absurdly light when compared with this part of the operation as performed on a decorticator. As previously mentioned, the fibres in this reduced leaf are separate and parallel, presenting an ideal condition for cleaning, fibre by fibre. The machine which has been developed for this does in fact clean each fibre separately, using water in the process. The volume of water required is small compared with the requirements of conventional decortication which uses 75% of its water supply, not to clean the fibre but to act as a conveyor of waste which it creates, and pulp waste which has been so costly to transport. The capacity of one cleaning machine is arranged to handle the output of one rolling machine.

73. The success of this proposed system was now focussed on the evolution of a cleaning machine capable of producing fibre without waste. This involved prolonged research and attempts were made to adapt every known and likely textile operation, but without success. It became apparent that as the requirement was probably original, some new mechanism was demanded. To this effort was brought fragments of experience gained here and there, supported with an intimate knowledge of the Sisal leaf and the requirements of production conditions. Eventually this cleaning machine was evolved which dovetails into the process and produces all the fibre of an entire leaf in a clean state, the fibre content emerging as a complete skeleton of the leaf, not one fibre lost.

74. The fibre as it leaves this machine contains a residue of pulp clinging to the lateral crevice, and in the structure of the fibre. Deleterious juices and

acids have however been more completely removed than by decortication even when followed by hydro-extraction. The fibre is still therefore a hard fibre when dry, but its condition and appearance is an improvement upon the usual product of decortication. The final section of this cleaning machine removes surplus water so that drying operations are shortened, a valuable contribution to economic production when drying machinery is installed.

75. The product of this machine represents 100% content of the leaf, which means that all the shorter fibres are retained which are normally lost in decortication. Here now we must examine the requirements of the manufacturer to assist in a clearer consideration of the economics of separating out those shorter fibres. In the development of binder twine machinery the tendency has been to increase the reach of drawing frames to conform to the longest fibre which the production industry offered. The reach of a drawing process must not be less than the length of the longest fibres, but it operates quite satisfactorily with a reasonable admixture of shorter fibres, provided they are not in such quantity as to produce uneven yarns or breakages through "birdnesting". They also must be evenly distributed throughout the parcel. It is possible however that a small proportion of the shortest fibres may fall out during the drawings, but such loss is slight, and it is believed that any lowering in value of this type of Sisal is less than the cost of separating and marketing them as tow. The final answer to that opinion will of course rest with the manufacturer.

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adjusted to remove fibres of any given length. This machine is an attachment to the cleaning machine, works on the same principle, and the operation of separation is merely an extension of the cleaning one.

77. This then is brief description of the proposed system when operated for hard fibre production. For softened and split Sisal, additional operations are introduced. This will necessarily add to the cost, but taking into consideration the substantial economies, which 100% extraction and cheaper technique bring about, the final cost will be economic; particularly when a more valuable fibre is produced.

78. The process of extruding pulp residue and flattening the crescent formation of a Sisal strand requires a plastic condition of the pulp residue as it comes from the leaf in the initial rolling process, but before cleaning. The requirements governing pressure rolling are quite different from those for the initial operation although both happen to be a rolling process. In this case as in all other fibre operations, the end is achieved gradually, the fibre passing through a series of pressure rollings, each succeeding pressing or nip controlled to give the desired result. If it is desired to produce softened split Sisal which retains strength to compete with European Hemps or Flax, the binding gums are only partly removed and the fibre sufficiently flattened to accentuate cleavage lines for subsequent splitting. Should a softer fibre be desired the pressure is increased to extrude more of the binding gums. This fibre is not split, but is intended for the cordage trade, and being pliable it produces a more even and denser rope which is stronger than one made of raw hard Sisal. Yarns for weaving into canvas can be produced on Standard Jute machinery by carrying the softening process further still. Here the requirement is for a weaker fibre which is produced by increasing the

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pressure on the rolling process still further. Such fibre goes through the various breaker and finisher cards of a Jute plant, and spins into a yarn of the heavier counts which is stronger than a Jute yarn. It is also cheaper.

79. The degree of pressure required for the least of the softening results is considerable, so machinery is strong and heavy and power requirements are greater than for initial rolling. These factors exceed the practical limits for field work, so this plant is designed for factory operation.

80. It will be obvious that in the production of a uniform type of fibre from such a process, a necessary requisite is a uniform and unvarying condition of the materials presented to each machine. This condition is present in the limp leaf as it comes from field rolling, and it is only when in this state that satisfactory and uniform softening results can be attained.

81. From the pressure rolling machine the outline of the leaf is retained, the fibres separate and parallel. In this state it passes to the splitting process. This machine is exactly the same as the cleaning machine, embodies the initial water cleaning section and extended to include the splitting section.

82. The act of splitting consists of a pin point entering between the accentuated cleavage lines, drawing the pin along and severing the bridging ultimates. It was anticipated that tow production would be high, but this product is equally split and its value not much less than that of line fibre. In actual practice however it has been found that very few fibres are pulled away. This satisfactory result is of course accounted for by the fact that the fibres are presented to this machine as they were in the leaf, each fibre separate and parallel.

83. The capacity of one Splitting Machine is the same as one Softening Machine, which in turn is the same as one Field Rolling Machine.

84. A catalogue of all the fibres in commercial use in the world would make a long and interesting list, ranging from the cheapest to the most valuable, from Jute to Silk, including animal and vegetable fibres, and synthetic fibres of recent development.

85. Grouping all fibres under the one heading of a "Primary Product", we find that there is probably more competition between one fibre and another within the fibre markets for world favour, than in any other market of relative importance. There has always been a ceaseless effort, which no doubt will continue, to increase the market for one fibre at the expense of another. There is the historic case of a century or so ago of the rise of the Jute industry which enveloped the Scottish Flax trade, and the more recent developments in cellulose which have already encroached seriously upon the preserves of Cotton, Silk, and Wool.

86. New fibres, new textiles, new methods of manufacture are constantly being introduced; the scene is ever changing. The world of intense competition is more ready to-day than it ever was to accept a new fibre when it conforms to the controlling factors of suitability for standard machinery and price, particularly when there is a price advantage.

87. Two modern conditions which have arisen within recent years tend to intensify competition between certain fibres. The general state of indigestion of most consuming markets has been very pronounced in that of fibre. In some fibres, the fall in consumption and values has been aggravated by the necessity for producers to increase production in order to earn enough to live. The other condition affecting some

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important fibres has been the rise of nationalism. This is not a passing phase. It is permanent, and is rapidly gathering increasing force. Trade barriers are being erected, behind the protection of which national products and manufactures are being fostered at the expense of the imported article.

88. Jute is a typical example illustrating the effect on an important industry of this modern trend. Jute, not long ago, supplied the world with containers for all its bagged commodities. It enjoyed a monopoly, but does so no longer. Countries capable of growing an alternative fibre have erected fiscal barriers against Jute goods, and are fostering the manufacture of bags from their indigenous product. It has been estimated that there are now over twenty million bags being made annually in different parts of the world from alternative fibres which used to be made of Jute. This development is still in its infancy, and is extending rapidly.

89. With regard to Sisal and its possible development. The extent to which this industry is capable of expansion will be governed by cost of production and the development of conversion methods. In the matter of costs, existing methods have been described which wastes half of the fibre grown, with an already low cost of around £15 C.I.F. This figure will be materially reduced as 100% extraction is approached. Converted Sisal will enter new markets. Development along these two lines is certain to come. With low basic costs and suitability, both as a hard and a softer fibre, Sisal is destined to encroach upon competitive fibres, and when it does so to the extent which the evidence indicates that it will, there will be yet another change to record in the fibre world.

S I S A L

by

James McCrae

LEEDS.
May, 1936.

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1\. Sisal history of recent years bears analogy to that of Rubber. Like the Rubber Industry which has developed in the East from seed taken from its original home in South America, and finding more congenial climatic and economic conditions in its new surroundings, so Sisal appears to be following a similar trend.

2\. Mexico, the home of the Sisal industry, supplied all world requirements until three decades or so ago. Since then the plant has been introduced into Eastern Africa and the East Indies, where its expansion has been rapid, particularly in East Africa, as the following tables of annual production will show. The figures are tons.

	1927	1932	1933	1934	1935
Mexican Sisal	120,000	88,000	93,000	92,000	90,000
African "	50,000	91,000	108,000	121,000	144,000
Java & Sumatra	44,000	80,000	95,000	85,000	84,000
	214,000	259,000	296,000	298,000	318,000

3\. An inference which can be drawn from these figures is that the industry is finding conditions in East Africa more suitable than either Mexico or the East Indies. As world requirements continue to expand as they are doing, there is every indication that East Africa will participate in this expansion, and should do so in an increasing ratio over the other two producing countries.

4\. The industry was established in East Africa during a period when values stood around £28. Then came war and witnessed an inflation in values of all primary products, including that of Sisal, the price of which was controlled at £99, C.I.F. During the post-war period values remained

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at very high levels, offering attractive investment, until the depression set in.

5. This long period of prosperity is unquestionably the main cause of the intensity of the misfortunes which overwhelmed the industry during the years of depression. The attractive profits of that period induced a phase of rapid, and haphazard development. The increased production resulting from those new post war areas coincided with the heavy fall in consumption at the beginning of the slump. The clash of those two conditions intensified the fall in Sisal values which set in during 1930, and continued until the latter end of 1935. During this long spell prices remained well below the cost of production with the result that a distressed condition developed in the industry. Many estates went into liquidation and most of those which survive find their plantations in a backward state, with plant and machinery worn out and out of date.

6. Unfortunately there was not, nor is there yet any method whereby this industry can plan and regulate production to meet world requirements. The necessity for some concerted international arrangement to adjust balances between supply and demand in the field of primary products will no doubt be evolved in the course of time, but until posterity produces a workable formula, Sisal can only direct its efforts to cheapening its production costs and extending its markets. The object of the writer is to indicate a way, which should assist the industry towards these desired ends.

7. In the case of Sisal price fluctuations have been over wide margins, as must be the case with a product catering for restricted markets as Sisal does. The bulk of the world's production of this fibre is made into binder

twine used in harvesting. Weather conditions in the grain growing areas of the world therefore exercise a very pronounced control on Sisal values, and as long as the industry continues to depend upon this one market and that market depending upon weather conditions, so will Sisal continue to be a speculative investment.

8. The experience of the past slump years is a graphic illustration of the basic weakness of the Sisal industry, intensified no doubt by the abnormal conditions which have prevailed, but clearly indicating that without a broader basis in the consuming market, prices will continue to be subjected to heavy rise and fall.

9. The prolonged period of depression has brought some compensations to the industry in the way of an extension of markets, induced very largely by low values, but there is a danger of those new markets shrinking should Sisal values rise above the prices of competitive fibres. Experience has shown that potential users of this fibre are chary of adopting it in their trades on account of price instability, particularly when its use entails the installation of special machinery. There is no doubt that more stable prices moving within narrower limits and at competitive and economic values to other fibres, would encourage consumption of Sisal in those trades which are beginning to take an interest to-day.

10. The trades referred to which are absorbing the bulk of production in excess of binder twine requirements and have thereby assisted in great measure in the recent advance in values, are parcel twine and cordage manufacturers, the bedding and upholstery trades, particularly in U.S.A. and to a very limited extent fabrics for sacks.

11. These new markets are of inestimable value to the

industry, but as they operate on low price levels they can only be expected to continue their patronage under moderate, and more particularly, stable values.

12. A factor which must always be kept in view is the competition of Manila Hemp. This, like Sisal, is a hard fibre, and is used as an alternative to Sisal in many important markets, so has an influence upon Sisal values. For certain products such as marine cordage, Manila enjoys not only an entrenched position, but in certain qualities it has an undoubted advantage in being a more flexible and a less brittle fibre. It is believed possible however that the disability which Sisal suffers from in this market can be overcome by a simple method of converting it into a softer and more pliable fibre. This will be explained later.

13. The experience of these past years indicated that there are markets for Sisal outside the binder twine trade, markets which consume hard fibre and which have recently been doing so at an increasing rate, but due solely to the stimulus of low prices. The values of Sisal which have ruled during the slump period, and which have been the cause of this fibre finding its way into new markets, those values have been below the existing cost of production, and unless costs are brought down to a figure which will yield a profit to the producer and offered at a level which those new customers can afford to pay, then those markets cannot be considered permanent.

14. In a comprehensive survey of the industry which it is now proposed to make, we will begin with fundamentals, the first and most important being cost of production. This analysis should necessarily start with agriculture, but as that subject is best dealt with as a subject deserving

greater scope than this paper can accommodate, so we will begin with the plant ready for harvesting.

15. The writer finds difficulty in presenting a picture of continuity in this story of Sisal, the many issues being so unevenly interwoven, but trusts, that with patience, the reader will retain a constructive narrative, when all is written.

16. Depressed times forced the industry to make economies, and at the same time to stimulate research into many of its phases, including improvements in agriculture, labour, plant selection, transport, extraction, grading, baling, and the study of converting Sisal into a softer fibre suitable for new uses. The amount of activity, energy and money expended during the past years on these lines of research has been very considerable and has had the co-operation of a united industry operating through its Associations and the sympathetic and practical assistance of Home and Colonial Governments.

17. Considerable headway is to be recorded in most of these branches of research and it is to be hoped that the results of all this work will be collated in due course, and published for the general guidance of the industry.

18. The motive of this paper is to stimulate thought and discussion on the dual ideal of reducing costs and increasing markets and the writer, after years of research into both of these basic subjects, presents the results of his work, not with any attitude of dogmatism, but with the hope that it will, through controversy and arguments, induce efforts to break new ground in both of these indicated spheres, and so in time, assist to place Sisal fibre in a more prominent and stable position than it occupies to-day.

19. When the basic factor of production cost is examined however and although far reaching economics and improvements in production and preparation have been introduced, there still remains much room for improvement, particularly in the established methods of harvesting and extraction. The general system, in so far as it applies to East Africa, the largest producing centre of the world, results in a loss of approximately one half of the fibre content of the leaf. This question of waste must necessarily have a direct bearing upon costs of production, and until it is solved and reduced to within more reasonable limits the industry cannot be considered as operating at its lowest economic cost. It is well therefore to examine the factors which bring this waste about and to study any feasible method which offers improvement.

20. The existence of the waste problem is one which has exercised the industry for many years, and much thought and study have been brought to bear upon it. The writer has found however that the technique and economics of production can be improved and applied more intelligently by having a greater knowledge of actual and potential markets than is at present enjoyed, and he believes that this more thorough knowledge will be an important contributory factor towards greater efficiency.

21. The percentage of waste is a figure about which a certain amount of controversy exists. There is no doubt that it varies, variations depending upon factors such as the condition of the leaf, whether succulent or tough and leathery as it is in dry weather, the setting and condition of decorticators and so on, but under the best conditions this waste is considerable, and for purposes of this survey it has been taken as 25% of the fibre content of the leaf as harvested in the existing manner. The other 25% waste is another matter and will be dealt with later on.

22. Waste in decortication is a problem for the engineer. Very large sums and long periods of research have been devoted to this próblem. The conventional method of decortication is to pass the leaf, which has a firm thick structure, between rapidly revolving drums furnished with blades, and a rigid concave which holds the leaf in close contact with the blades. In its thickest section the leaf measures about an inch, and to enable the blades to completely remove the pulp, the clearance between the blades and concaves must be very narrow, sometimes to as small as fifty-thousandths of an inch. This firm leaf structure presented to the blow of the blades in a restricted aperture, results in many fibres being broken and lost. Another cause of loss is due to the short fibres in the leaf which terminate at various points along its length. The mechanism of the decorticator which conveys the leaf through the machine, grips the leaf in such a position that many of those shorter fibres are not secured, and so are lost. The total loss due to breakage and to shorter fibres varies under different conditions, but is generally accepted as being in the neighbourhood of 25% of the leaf as harvested.

23. The trend of modern design of decorticators is to soften the blow of the blade, and to grip more of the shorter fibres in the leaf. These ends are attained by subjecting the leaf to a pre-crushing process, reducing its rigid firm structure to a limp state. In this condition it offers less resistance to the blade action and so fewer fibres are broken. Instead also of attempting to clean the leaf of pulp through its entire thickness in one operation which necessitates such a close setting of concave clearances, this cleaning action is applied progressively, first on one side of the leaf and then on the other. In this machine the

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design of the gripper-conveyor is such that more of the short fibres are firmly held. This machine registers considerable advance over existing models, reduces waste to a very considerable extent, and by offering less resistance to the cleaning drums, requires less power to drive and maintenance cost is reduced.

24. The balance of waste, previously referred to as 25%, will now be examined, and a method will be explained later indicating how it is possible to prevent all or most of it. In order to understand this proposed method, and for those who do not know the Sisal plant, we can best illustrate by likening it to an enlarged artichoke, with leaves running from say twenty inches to over four feet long. As in an artichoke, the Sisal leaf is attached to a thick central stem or bole, with the butt ends overlapped and interlocked in a similar manner.

25. Harvesting is done by cutting the leaf by hand as near to the butt end as possible, leaving the butt adhering to the bole. This butt contains fibre of marketable value. For purposes of illustrating we will divide the fibre content of a leaf, including the butt, into 150 equal parts by weight. It has been established that the fibre content of the harvested portion contains roughly 100 parts, and 50 parts in the butt portion, which are lost. This seemingly excessive ratio in the short butt, which measures from 7" to 9" long, is explained by the fact that all the fibres in the leaf have their beginnings in the butt and that they are thicker and heavier there. As the leaf matures, the fibres which support it grow thicker along their entire length and in the butt they become woody and weak. In a mature leaf, about half of those butt fibres are of little value, but the remaining half are acceptable for use in the binder twine trade.

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26. Instead of harvesting by cutting the leaf as it matures, spread over the life of 8 to 10 years of the plant, the alternative method is to strip the plant completely at an earlier age, plucking the whole leaf. Before considering the economics of this system we will examine the fibres of the butts of this younger leaf. In this case those fibres have not become so thick, are not woody and are of a strength and spinning size to be acceptable to the binder twine trade. This type of fibre is being marketed to-day and obtaining current values.

27. Plants grown to be completely stripped by plucking at an earlier age require less ground. In practice, it will be found that closer planting, varying according to soil and climatic conditions, increase the numbers of plants in a given area from three to four fold over conventional planting. The period of growth to reach the most economic yield will also vary but will be between two to three years from planting average nursery or sucker plants.

28. It has been found that the fibre content of a given area planted as suggested, is considerably greater than the average yield obtained from the same area over a period three times as long. Harvesting the entire leaf and extracting all the fibre, by a process still to be explained, we begin to approach economical Sisal production. When the system comes to be closely examined by the industry it will be found that the increased yield within a much shorter period will more than off set the additional costs which more frequent plantings will entail.

29. Under existing methods therefore the plant occupies the land for about nine years; one third of its fibre content is left behind and one quarter of the harvested part is lost in extraction and final preparation. The leaf having

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a fibre content of 5% means transport of an enormous tonnage of waste matter to the factory, in figures roughly 19,000 tons of waste transport for each 1,000 tons of fibre produced.

30. It has been necessary to explain at length the existing economics of the industry and to emphasise the two outstanding weaknesses under which it suffers; restricted markets and wasteful production methods, in order to fully appreciate solutions which it is the object of this paper to suggest.

31. To deal with the question of markets first, the importance of erecting a broader basis of consumption has been stressed. It has been shown that there are potential users of this hard fibre, but only at a low price level, a price which it is uneconomic for the industry to cater for under existing methods of production. It is reasonable to believe however that with more efficient production and waste reduced to a minimum, the production and separation of the shorter fibres which these potential trades require, can be profitably produced, leaving the longer qualities for the binder twine trade for which higher prices are obtainable.

32. Under existing methods of growing and extraction it is not possible to attain economic production of those lower grade fibres, and it is questionable if it will be found remunerative to recover and recondition to a sufficient degree of cleanliness, waste fibres from decortication, even for the bedding and upholstery trades. It is obviously a more constructive policy to prevent the creation of waste.

33. How then to expand still further into new markets? The answer to that is that Sisal is capable of being softened and converted by a process which is effective and economic to apply. This process will be explained in

the proper sequence of this story of Sisal. It can be operated under plantation conditions and so adjusted and controlled to give a range of fibres of varying degrees of softness and strength to suit the varying requirements of his customers.

34. A planter's knowledge of his industry is incomplete without a closer understanding of the consuming markets. This became so apparent after years of research into the production end of Sisal, that a prolonged study of textile trades was undertaken. Many months were devoted to this, and it is gratifying to record the willing and helpful attitude of manufacturers which was extended during that time. No effort was spared to assist to a better understanding of their requirements.

35. Contacts made during this period had the effect of stimulating the interest of spinners who had but a passing knowledge of Sisal, and it was made obvious that there were many potential users of this fibre who, for reasons already explained, were hesitant about adopting it. During this time a clearer view was obtained into the extent of markets using fibres of a higher price level, for goods which might be termed the heavy end of the soft fibre trades, in the production of which a fibre of slightly heavier nature than flax and soft hemps could be used, were they commercially available.

36. The world's production of Sisal, in relative importance to that of Jute, Flax, Cotton, etc., is insignificant and will remain so as long as it is produced as a hard fibre. However, when it enters the soft fibre trades and it becomes realised that it is cheaper to produce, and for many purposes is at least as suitable as some of the soft fibres for certain important uses,

then Sisal will gradually emerge from its comparative obscurity and becomes a product of primary importance.

37. To arrive at a complete understanding of the economics of the industry, an endeavour has been made to indicate how necessary it is for the producer to have a more intimate knowledge of his customers requirements, both actual and potential than he has to-day. No claim is made to have exhausted the various fields of this research, but sufficient evidence has been acquired to indicate clearly that more economic methods of production, coupled with a practical and applicable method of conversion of Sisal to a softer fibre, and an intimate knowledge of the various trade requirements, will go far to place the industry on a healthier basis.

38. Knowledge gained in this very wide field of research embracing production and consumption, formed a valuable background for the next step of research which it was necessary to take. A laboratory was equipped and staffed to study the structure and composition of Sisal, and to explore a possible method of softening it which could be applied economically under plantation conditions and which would produce a product likely to meet the requirements of some of the more important industries which had been investigated.

39. To form a clearer understanding of this phase of research, it is advisable to give an account of the laboratory work and findings which were arrived at. By analysis, the nature and composition of the binding gums and pectins was understood. In non-technical language, these were found to be of a compound nature, some parts of which readily reacted to mild solvents. It was found however that when those easily dissolved parts of the

compound were removed, a more obdurate residue was deposited in the form of a still harder lacquer-like film, requiring solvents of a more vigorous nature to break it down. A solvent of sufficient strength to act on this residue also attacked the fibre elements. Evidence was accumulated to prove that a solution did not lie in chemical formulae.

40. Laboratory research however was of value in that it was the means of acquiring an intimate knowledge of what constituted a strand of Sisal. In simple language, this can be likened to a strip of wood of rather cross grain. Like wood, it is built up out of tiny elements or ultimates, interlocked and held together by binding gums. Those ultimates measure from 1½ to 5 m.m. long. In cross section the average strand is of crescent shape and in its lateral structure there are natural lines of cleavage. Upon closer examination it is found that after decortication, a film of pulp is left adhering to the fibre, not only on its outer surface, but in the crevice of the crescent formation and also in the inner structure of the fibre itself. It is this pulp residue which becomes hard when dry, and under existing extraction methods, confines Sisal to the category of hard fibre. The ribbed formation designed by nature to produce a rigid reinforcement to support the leaf in which it is imbedded, contributes to its hardness or stiffness.

41. When laboratory work indicated that no economic chemical formula was likely to succeed, evidence which is supported by the fact that earlier research of others along those lines has not produced a commercial result, attention was then directed to the possibilities of expressing the pulp film mechanically. The first requisite for this operation was to render the gum plastic and to reproduce the condition they were in originally as they came from the leaf. A method of doing so was evolved, and by

applying pressure of varying degree and using a range of experimental machines, it was discovered that the strand could be reduced to its ultimates, a downy fluff of cotton like substance, when all gums were extruded. Here then was proof that Sisal was a soft fibre. A number of machines were constructed and a long series of experiments carried out, the results of which were submitted to textile manufacturers. In this way a clearer insight was gradually obtained into the more important requirements, and also an understanding of the fibre structure and how it responded to a varying degree of treatment.

42. Certain basic conditions began to take shape and emerge from these experiments. For instance, it became obvious that the tensile strength of raw Sisal was due to the dense mass of tiny ultimates held in close contact by the binding gums. The removal of all gums reduced the fibre to its ultimates - fluff - a condition which could be reached by increasing and intensifying pressure. A knowledge however of the tensile strength of raw Sisal, and of the strength of the various fibres with which it is intended to compete, and knowing that most of them were in comparison, weaker, guided research into the process of extrusion. This research has clearly proved that it is possible to so control the extrusion process, and to arrest it at any pre-determined point, so as to produce a result which will make Sisal suitable for a range of uses, having the requisite qualities of strength and softness, to compare favourably with its various competitors, and when produced under some system which eliminates existing wasteful methods, at a price which will withstand competitors from most fibres in its range of usefulness.

43. To encroach still further upon the markets enjoyed by soft fibres and to enable Sisal to be spun to counts or

yarns of still lighter weight, research was conducted into various methods of splitting along the natural lines of cleavage. These lines of cleavage are discernable in a strand of raw Sisal, and by breaking down the crescent formation with pressure and partially flattening it, the cleavage lines become accentuated and further minor ones are disclosed. An examination of the structure becomes easier in this condition, and it is found that the sub-strands are held together, weakly, by occasional bridging ultimates here and there along the length. To separate the substrands, those ultimates must be severed, and this has been the subject of a wide range of research in itself.

44. At this juncture, it was becoming clearly indicated that Sisal was capable of being converted into, not only one type of softer fibre, but a range of softness, fineness, and strength, each type suitable for its respective trade requirements.

45. To illustrate three distinct types of fibre which Sisal can be converted into, the following will explain. In the production of a finer or split fibre it is essential to preserve tensile strength, but it also must be softer than raw Sisal. It is found that a satisfactory result is obtained by carrying pressure only to a point to flatten the strand and to open up cleavage lines sufficiently for the entry of the pin point of the splitting machine. By a correct adjustment and balance of those two operations, a fibre of considerably enhanced value is produced, having the requisite softness, fineness and strength suitable of application to a wide range of uses.

Quite a different product is produced however by increasing pressure to extrude more gum and to further flatten the fibre. In this case no splitting is done. This fibre necessarily is slightly weakened, but not beyond

a useful point. The product is soft and pliable and spins into a denser yarn, and the resultant twine or cordage is softer, more pliable, and because of the more even nature of this fibre distributing working load on each fibre in the cord of which it is made into the degree of initial strength which it gives up in softening is more than counterbalanced by the several benefits obtained, the cord is stronger than if made of raw hard fibre.

Again the extrusion process can be carried still further and a softer product obtained. In this case the desire is to weaken the fibre to a point where standard jute machinery is capable of handling it. Sisal can be softened and flattened and spun into a yarn of the heavier counts on jute machinery, giving a higher tensile strength than Jute, and producing soft, strong fabric, much more suitable for such goods as bags than is possible with raw Sisal. When this softening process is applied to Sisal, produced under the most economical conditions possible, the cost should not exceed the figure which is accepted as being the lowest economic cost of Jute, viz., £15, C.I.F. U.K. and at its point of production will be considerably lower than the cost of Jute at that point, a matter of importance when considering the manufacture of bags for local requirements.

Research into methods of obtaining these results had to be guided by the all important factor of cost. It is obvious that successful exploitation of a new product depends upon this, so the whole field of production had to be taken under review, and a system studied which would not only link up with a conversion process, but by combining production with conversion, costs could be brought to within economic limits, an essential basis on which to develop.

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evidence that a solution of the problem of softening Sisal did not lie in chemical formulae, but clearly indicated that mechanical process would do so. To assist in the development of suitable machinery, Government were approached and financial support was given for this work, after the matter had been fully investigated by responsible experts.

Financial assistance thus obtained, the next step was to approach makers of machinery and it is here desired to pay tribute to those firms who have contributed so much to this development. Without the benefit of their experience and knowledge of Sisal and textile requirements, and the co-operation so readily given, this machinery development would not only have proved more costly, but would have evolved very slowly.

The point where a mechanical conversion process can be most effectively applied is on the estate where Sisal is produced, so this has influenced development and machinery has been designed of a simple robust construction suitable for plantation conditions.

Of the mechanical operations for softening and splitting, the former will be dealt with first. Softening is brought about in two ways, by a partial removal of the pulp residue, and by breaking down the stiff structure of the strand. In the correct balance between extrusion and flattening lies the correct answer to effective softening with retention of strength. The two results are obtained in one operation of passing the fibre between rolls of special construction and under pressure. Unlike previous use of rolling machinery, in this case the first end to be attained is the extrusion of pulp on and in the fibre. The required conditions are that the pulp must be soft and plastic, and that the rolls must be in pressure contact.

The surface of the rolls must have a sufficient elasticity to provide a cushioning effect, and at the same time be dense and firm enough to stand up to continuous work under the required pressure. A cushioned surface accommodates the fibres and at the same time exerts a modified pressure on it while maintaining contact with the opposing roll between fibres in order to extrude intervening pulp and the pulp expressed from the strand. It will therefore be appreciated that by controlling the degree and number of pressings, so is it possible to produce a fibre of pre-determined softness and strength.

51. During the development phase of this machine it became apparent that as pulp residue could be expressed when it was in intimate contact with the fibre, it followed therefore that the pulp of the leaf not so securely attached to the fibre would be more easily removed. So the next step was to squeeze the pulp from the entire leaf and to soften and flatten the fibre to any desired extent, all in one operation, and to dispense with decortication.

52. Pulp residue remaining in raw hard Sisal after conventional decortication, adds to the weight of the fibre, so therefore the product becomes lighter by the extent of the pulp removed. This loss in weight is found to be moderate under normal conditions and is more than offset by the increased fibre yield to take no account of the more valuable product obtained.

53. The degree of extrusion being controllable, the process can be arranged to leave a film of pulp adhering and not to flatten the strands. This, with subsequent cleaning on a machine, developed out of the splitting machine still to be described, produces the usual hard Sisal for the binder twine trade, and does so without

loss.

54. A Sisal leaf contains roughly 5% of fibre. The conventional method of harvesting is to cut the leaf, leaving one third of its fibre content behind as already explained. After Cutting, the leaf is transported to a central factory for decortication, final preparation and baling. An estate producing 1,000 tons of fibre annually therefore transports about 19,000 tons of waste matter, incidently of value as a fertilizer to the land from which it grows. Extrusion operations reduce weight of the leaf to 15% or thereabouts, and when carried out in the field, bring about an enormous saving in cost of transport as well as depositing this valuable waste matter on the land.

55. From what has been written describing the wastefulness of the industry as it operates to-day, it will have become apparent that there is no need at this juncture to indulge in figures of fractional accuracy.

56. The product, which comes from the extrusion rollers, even when this operation is only carried to the extent of producing hard fibre, consists mostly of fibre. Pulp particles remaining are loose and easily removed. The firm leaf structure has completely gone and the dirty fibre offers practically no resistance to any subsequent cleaning operation. Power absorbed in the rolling process plus that required for cleaning is very considerably less than the power taken to overcome the resistance presented by a full leaf in a conventional decorticator. Under this proposed system therefore, there is an appreciable reduction in power.

57. Sisal planters are ready to appreciate any lessening in some of the heavy labour operations which existing conditions demand, such as cutting, loading and

unloading leaf, rail lifting and relaying, decortication and brushing operatives. In all of these sections economies are brought about by adapting this proposed system of production. Plucking leaf from a younger plant is a much lighter task than the cutting of mature leaf; railway work can be dispensed with by taking portable pressure rolling machinery to the field and much handling of leaf avoided. Labour on pressure rolling machinery is less and lighter than decorticators.

58. A short description will now be given of the various finishing processes which are intended to be carried out in a central factory on the Estate. The leaf, after pressure rolling, either in the field or in the factory, consists mostly of fibre with particles of loose pulp and leaf juices on it. In a product where pressure has been carried far enough to remove only part of the gums and the fibre flattened sufficiently for splitting this entire fibre content of the leaf is presented to a machine into which water is introduced. The fibre is fed thinly, the content of one leaf at a time. It is important to appreciate that each fibre when in the leaf and as it is extracted by slow moving rolls is parallel and quite untangled. It is essential to maintain this condition for subsequent splitting, so this operation takes place immediately after rolling and before the natural juices become dry. The machine consists of an upper and lower apron made of a special chain to which are attached blades in its first section, followed by a graduated system of pins. As the dirty fibre enters the machine it passes between the blades which exert a gentle action, removing all pulp particles and juices which are washed away by water. There are no fibres broken, and the gripper-conveyor is arranged to securely hold all the fibres near to the butt. The cleaned fibre continues still in the same gripper-conveyor and enters the pinned section of the

double apron where it is split into two, three or more sub-divisions according to the arrangement of the pins and the degree of flattening it has received in pressure rolling.

59. The product of this operation is softened and split Sisal both line and tow, the value of the tow being very little if anything below the value of the line product; and both of a very considerable increased value over that of raw hard Sisal.

60. To produce the usual hard fibre, the same machine is used, but in this case the pinned section is dispensed with. The advantages of this system for hard fibre production over conventional methods has been sufficiently explained to require no further elaboration.

61. The same machine is also used for cleaning fibre when pressure rolling has been carried further to produce a softer fibre for cordage purposes, and again for fibre which has been weakened sufficiently for Jute machinery.

62. An unexpected development of this machine is an automatic brusher, an ideal long desired by the industry. For this purpose it is designed to brush and straighten hard dry Sisal, produces a better result than conventional brushers, less tow, and being automatic requires labour only at the feed and delivery ends. The development of this machine as a brusher will remove the cause of most of the serious accidents which are a feature of Sisal factories.

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63. Gradual or stepped up application of the various operations of textile manufactures govern the handling and preparation of fibres throughout all processes up to the finished product. This is an accepted law evolved through long years of experience. Endeavours to short circuit any one phase of this evolution by attempts to combine two operations in one have no doubt been tried, but discarded when the untruth is exposed. An understanding of this principle helps to realise that there are two distinct requirements in extracting fibre from a Sisal leaf, a fact which has been obscured by custom in accepting the conventional decorticator as the standard method. A decorticator is an attempt to combine two operations in one, to first break down the rigid structure of the leaf, followed and combined with separating the loosened pulp from the fibre. The result is the compromise which takes place between concaves and blades with consequent waste of fibre and power. Appreciation of the fact that there are two distinct requirements, each with its logical and separate application, prepares the way for a study of economic extraction.

64. Returning to the standard method of decortication we find that by far the heaviest work it has to perform is the first operation of breaking down leaf structure and loosening pulp and cuticule. It requires no great mechanical knowledge to realise that the principle of a decorticator is about the most unsuitable method for doing this heavy work. The obvious and logical way is to crush the leaf between rollers. This is simple machinery, requiring less power, and no fibre is destroyed and lost. When the rigid thick structure of a leaf has been rendered limp and thin, and pulp matter bruised and loosened, it requires a very light operation to clean it, much lighter and gentler than it receives in this final treatment in a

65. Having explained the basic principles which underlie and guide development of this proposed system of Sisal production, we will now turn to a detailed examination of the first operation of breaking down the structure of a leaf as an alternative to that operation performed in a decorticator.

66. For the production of hard fibre there is one rolling operation, but when softened and split fibre is wanted, a second and heavier rolling process is introduced. Each has its separate requirements, and both operations and machines will be considered in detail.

67. It is advisable to make clear that only the first rolling is required for the production of hard fibre, and that the degree of rolling for this product is the same as is required for pressure rolling for producing softened and split Sisal.

68. To consider hard fibre production first. The rolling machinery for leaf reduction is designed for field operation. It is light and easily portable, and does not demand skilled supervision. There are no delicate setting adjustments, and it is light to drive, well within the range of small Diesel units. It is a slow running machine. The machine itself consists of four pairs of rolls, the first three pairs of which are fluted and the final pair smooth with a cushioned surface. The fluted rolls are set with clearances which progressively diminish, the pitch and size of fluting becoming finer in each following pair. The top roll of each pair is heavily spring loaded, and only the final smooth pair are in contact. Leaf is fed to this machine point first, four leaves abreast. Crushing flattens and widens the leaf, so to prevent butt ends splaying out and overlapping, a special design of conductor is embodied dividing the machine into lateral

compartments, four of them about nine inches wide each. The machine is designed for manual feeding which therefore controls capacity, but a reasonable average rate is thirty leaves per minute for each compartment, giving 120 per minute for the machine. This approximates normal delivery to a decorticator. The fibre in an equal number of plucked leaves, which comes from a rolling machine, is roughly double the amount of fibre from a decorticator.

69. This rolling process expresses juices and removes much pulp. Reduction in weight is considerable and will necessarily vary according to the condition of the leaf, but a normal leaf will lose about 80%, which represents an enormous saving in transport.

70. The reduced leaf as it comes from this machine is thin and limp with its pulp structure broken down. The tough cuticle is fractured at close intervals, and the hard outer edges, even when "barky" are in a condition for complete cleaning in the subsequent process. The leaf coming from this machine preserves its shape, fibres remaining separate and parallel, a most important requirement for the final process.

71. Efficient handling of a product by high speed machinery brings mechanical problems and complications demanding trained operatives, skilled supervision, and the background of an industrialized country. Those essentials are lacking in lands where Sisal is produced, so machine design should conform to these conditions. The simple rolling process already described does so, and in particular, the feed delivery and collection of the reduced leaf, are easy manual techniques to master.

72. We will now examine the final operation of cleaning this limp leaf after pulp structure and cuticule have been bruised and loosened. This is essentially a light operation, absurdly light when compared with this part of the operation as performed on a decorticator. As previously mentioned, the fibres in this reduced leaf are separate and parallel, presenting an ideal condition for cleaning, fibre by fibre. The machine which has been developed for this does in fact clean each fibre separately, using water in the process. The volume of water required is small compared with the requirements of conventional decortication which uses 75% of its water supply, not to clean the fibre but to act as a conveyor of waste which it creates, and pulp waste which has been so costly to transport. The capacity of one cleaning machine is arranged to handle the output of one rolling machine.

73. The success of this proposed system was now focussed on the evolution of a cleaning machine capable of producing fibre without waste. This involved prolonged research and attempts were made to adapt every known and likely textile operation, but without success. It became apparent that as the requirement was probably original, some new mechanism was demanded. To this effort was brought fragments of experience gained here and there, supported with an intimate knowledge of the Sisal leaf and the requirements of production conditions. Eventually this cleaning machine was evolved which dovetails into the process and produces all the fibre of an entire leaf in a clean state, the fibre content emerging as a complete skeleton of the leaf, not one fibre lost.

74. The fibre as it leaves this machine contains a residue of pulp clinging to the lateral crevice, and in the structure of the fibre. Deleterious juices and

acids have however been more completely removed than by decortication even when followed by hydro-extraction. The fibre is still therefore a hard fibre when dry, but its condition and appearance is an improvement upon the usual product of decortication. The final section of this cleaning-machine removes surplus water so that drying operations are shortened, a valuable contribution to economic production when drying machinery is installed.

75. The product of this machine represents 100% content of the leaf, which means that all the shorter fibres are retained which are normally lost in decortication. Here now we must examine the requirements of the manufacturer to assist in a clearer consideration of the economics of separating out those shorter fibres. In the development of binder twine machinery the tendency has been to increase the reach of drawing frames to conform to the longest fibre which the production industry offered. The reach of a drawing process must not be less than the length of the longest fibres, but it operates quite satisfactorily with a reasonable admixture of shorter fibres, provided they are not in such quantity as to produce uneven yarns or breakages through "birdnesting". They also must be evenly distributed throughout the parcel. It is possible however that a small proportion of the shortest fibres may fall out during the drawings, but such loss is slight, and it is believed that any lowering in value of this type of Sisal is less than the cost of separating and marketing them as tow. The final answer to that opinion will of course rest with the manufacturer.

76. Should however a producer desire to cater for a special high grade of hard fibre market, he can separate out the shorter fibres on a simple machine which can be

adjusted to remove fibres of any given length. This machine is an attachment to the cleaning machine, works on the same principle, and the operation of separation is merely an extension of the cleaning one.

77. This then is brief description of the proposed system when operated for hard fibre production. For softened and split Sisal, additional operations are introduced. This will necessarily add to the cost, but taking into consideration the substantial economies, which 100% extraction and cheaper technique bring about, the final cost will be economic, particularly when a more valuable fibre is produced.

78. The process of extruding pulp residue and flattening the crescent formation of a Sisal strand requires a plastic condition of the pulp residue as it comes from the leaf in the initial rolling process, but before cleaning. The requirements governing pressure rolling are quite different from those for the initial operation although both happen to be a rolling process. In this case as in all other fibre operations, the end is achieved gradually, the fibre passing through a series of pressure rollings, each succeeding pressing or nip controlled to give the desired result. If it is desired to produce softened split Sisal which retains strength to compete with European Hemps or Flax, the binding gums are only partly removed and the fibre sufficiently flattened to accentuate cleavage lines for subsequent splitting. Should a softer fibre be desired the pressure is increased to extrude more of the binding gums. This fibre is not split, but is intended for the cordage trade, and being pliable it produces a more even and denser rope which is stronger than one made of raw hard Sisal. Yarns for weaving into canvas can be produced on Standard Jute machinery by carrying the softening process further still. Here the requirement is for a weaker fibre which is produced by increasing the

pressure on the rolling process still further. Such fibre goes through the various breaker and finisher cards of a Jute plant, and spins into a yarn of the heavier counts which is stronger than a Jute yarn. It is also cheaper.

79. The degree of pressure required for the least of the softening results is considerable, so machinery is strong and heavy and power requirements are greater than for initial rolling. These factors exceed the practical limits for field work, so this plant is designed for factory operation.

80. It will be obvious that in the production of a uniform type of fibre from such a process, a necessary requisite is a uniform and unvarying condition of the materials presented to each machine. This condition is present in the limp leaf as it comes from field-rolling, and it is only when in this state that satisfactory and uniform softening results can be attained.

81. From the pressure rolling machine the outline of the leaf is retained, the fibres separate and parallel. In this state it passes to the splitting process. This machine is exactly the same as the cleaning machine, embodies the initial water cleaning section and extended to include the splitting section.

82. The act of splitting consists of a pin point entering between the accentuated cleavage lines, drawing the pin along and severing the bridging ultimates. It was anticipated that tow production would be high, but this product is equally split and its value not much less than that of line fibre. In actual practice however it has been found that very few fibres are pulled away. This satisfactory result is of course accounted for by the fact that the fibres are presented to this machine as they were in the leaf, each fibre separate and parallel.

83. The capacity of one Splitting Machine is the same as one Softening Machine, which in turn is the same as one Field Rolling Machine.

84. A catalogue of all the fibres in commercial use in the world would make a long and interesting list, ranging from the cheapest to the most valuable, from Jute to Silk, including animal and vegetable fibres, and synthetic fibres of recent development.

85 Grouping all fibres under the one heading of a "Primary Product", we find that there is probably more competition between one fibre and another within the fibre markets for world favour, than in any other market of relative importance. There has always been a ceaseless effort, which no doubt will continue, to increase the market for one fibre at the expense of another. There is the historic case of a century or so ago of the rise of the Jute industry which enveloped the Scottish Flax trade, and the more recent developments in cellulose which have already encroached seriously upon the preserves of Cotton, Silk, and Wool.

86. New fibres, new textiles, new methods of manufacture are constantly being introduced; the scene is ever changing. The world of intense competition is more ready to-day than it ever was to accept a new fibre when it conforms to the controlling factors of suitability for standard machinery and price, particularly when there is a price advantage.

87. Two modern conditions which have arisen within recent years tend to intensify competition between certain fibres. The general state of indigestion of most consuming markets has been very pronounced in that of fibre. In some fibres, the fall in consumption and values has been aggravated by the necessity for producers to increase production in order to earn enough to live. The other condition affecting some

important fibres has been the rise of nationalism. This is not a passing phase. It is permanent, and is rapidly gathering increasing force. Trade barriers are being erected, behind the protection of which national products and manufactures are being fostered at the expense of the imported article.

88. Jute is a typical example illustrating the effect on an important industry of this modern trend. Jute, not long ago, supplied the world with containers for all its bagged commodities. It enjoyed a monopoly, but does so no longer. Countries capable of growing an alternative fibre have erected fiscal barriers against Jute goods, and are fostering the manufacture of bags from their indigenous product. It has been estimated that there are now over twenty million bags being made annually in different parts of the world from alternative fibres which used to be made of Jute. This development is still in its infancy, and is extending rapidly.

89. With regard to Sisal and its possible development. The extent to which this industry is capable of expansion will be governed by cost of production and the development of conversion methods. In the matter of costs, existing methods have been described which wastes half of the fibre grown, with an already low cost of around £15 C.I.F. This figure will be materially reduced as 100% extraction is approached. Converted Sisal will enter new markets. Development along these two lines is certain to come. With low basic costs and suitability, both as a hard and a softer fibre, Sisal is destined to encroach upon competitive fibres, and when it does so to the extent which the evidence indicates that it will, there will be yet another change to record in the fibre world.

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