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PLANTATION DEVELOPMENTS IN NATURAL RUBBER PROCESSING

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The exigencies of competition from synthetic substitutes prompted the modernisation of the natural rubber (NR) industry. During the past eight years NR, has effectively transformed itself from a simple agricultural commodity to a sophisticated industrial raw material with a concomitant increase in processing efficiency and product competitiveness.

This paper discusses the changes in the organisation, processing techniques and machinery in Malaysian rubber factories and some future developments.

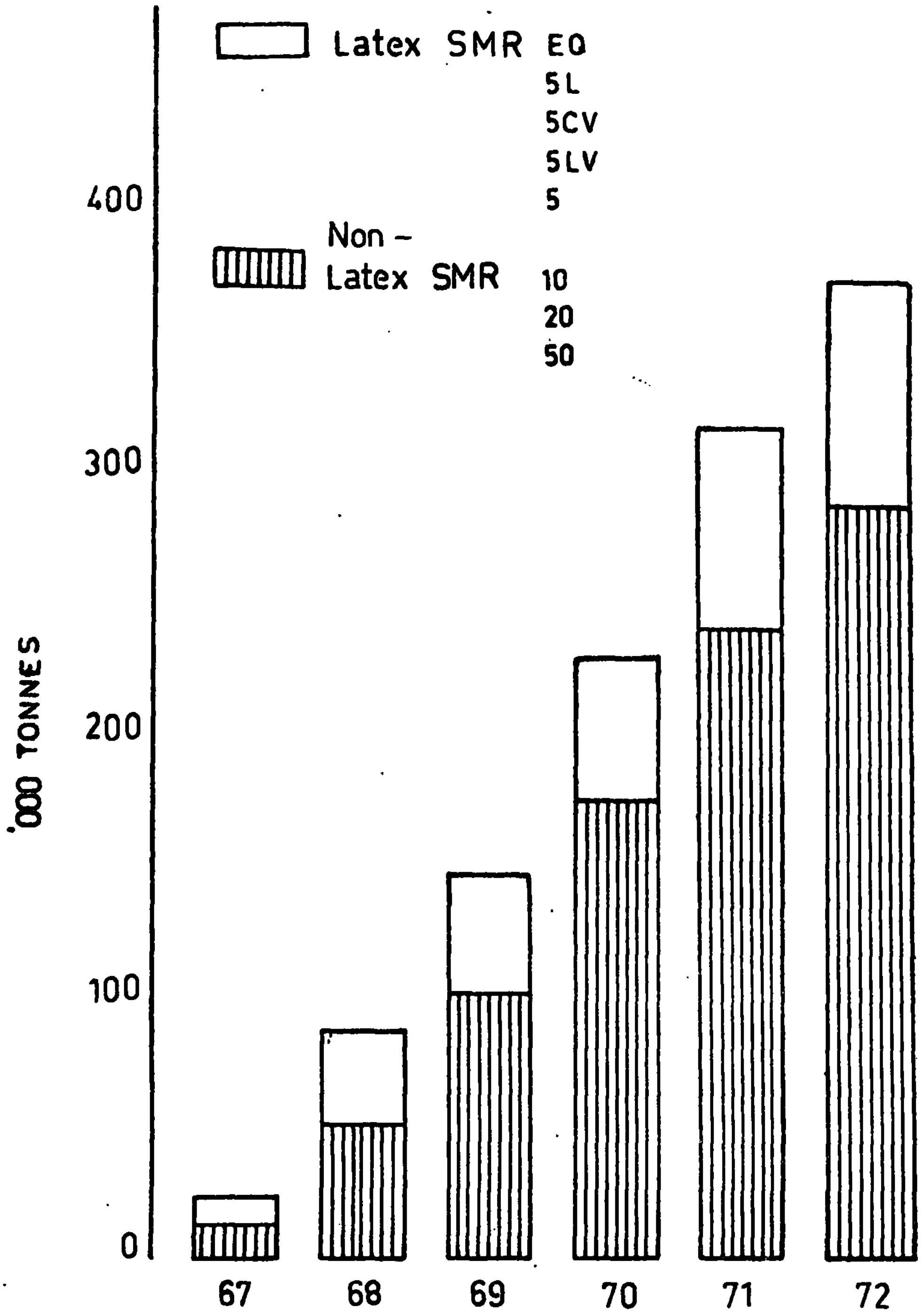
CHANGES IN PRODUCTION SCENE

The raw materials of latex and field coagula are traditionally processed by sheeting or crepeing into a multitude of types and grades. These conventional forms of NR are graded by appearance, artificial contamination and visual defects into 8 types and 35 grades of sheets, crepe and blankets. The advent of Heveacrumb and mechanical comminution methods of processing in 1963-64 and technical grading as embodied in the Standard Malaysian Rubber (SMR) Scheme in 1965 heralded the beginnings of NR presentation in modern dress. These processes convert wet coagulum into small granules which are thoroughly washed, dried at 100 °C for 4-6 h and compressed into 33.3 kg bales. As opposed to the conventional forms of NR, new process SMR are tested and graded to stringent specification limits, wrapped in a polyethylene film and palletised in 1 tonne wooden crates, all in a matter of 24 hours. Consumer acceptance of SMR has continually increased at a phenomenal rate as illustrated by 707 tonnes shipped in 1965 compared to 367,200 tonnes shipped in 1972 (Fig. 1). These rubbers have been shipped to more than 55 countries around the world, and now represents almost 28 per cent of the total rubber production. Together with this rapid increase in SMR production was the establishment of large central processing factories with improved processing techniques, with more efficient machineries and a new outlook of management towards the production of rubber as an industrial raw material.

Central Processing Factories

Processing facilities are centralised to justify heavy capital investment, to reduce overhead charges and to facilitate better quality control. To a large extent this approach has been adopted by large estate groups for the production of latex concentrate and the remilling factories for the production of compos, ambers and flat bark crepe. The optimum size of these factories is determined by several factors including the market price of the grades produced, the size and distribution of the planted areas and the economics of transporting available feed materials to these factories.

Fig.1 SHIPMENT OF SMR



For a production capacity of less than 5 tonnes per day, the capital investment on a new process SMR factory normally exceeds that of conventional factories. The initial producers of new process SMR were the large estate groups and remilling factories which have the built-in capital structure, organisation and the technical know-how. The attitude adopted by them was one of improvisation—that is to modify existing equipment for a smooth changeover. As the stages of processing SMR are reception, precleaning, size reduction, drying and packing, the only item which was less familiar to them was size reduction, and operation which facilitated drying. Hence the innovations of the mechanical comminution and the Heveacrumb processes were timely and accelerated the changeover. Simple flow lines were adopted at these factories in anticipation of building experience for future expansion.

The new process SMR factories presently vary between 5 and 100 tonnes per day. In the case of estates where the holdings are mainly the 400-2000 hectare range, the production capacity of such factories normally fall within 5 to 20 tonnes per day. As the estates have a tighter control over the choice of clonal latices and the collection of latex, they have been able to produce light colour SMR EQ and 5L grades. Production of 5 CV and 5 LV usually presents no problems. Good field hygiene enables the factories to process the bulk of their cuplumps to SMR 10. The estates which feed the central factories tend to have common ownership or are run by a common management group for ease of administration and financial control. These factors tend to restrict the production capacity. For the remilling factories, production capacities within the range of 40-100 tonnes per day are common. This is because the unsmoked sheets and cuplumps can be economically collected over a wider geographical area and conveniently stored for the maintenance of a buffer stock. As the materials tend to be variable, the general practice of remilling factories is to blend the various types of materials to one grade SMR 20. In cases where the raw materials are of a lower quality, SMR 50 is produced.

The most significant change in the plantation scene is the establishment of large central factories for processing smallholders' produce to SMR grades and latex concentrate. This effort was launched as a result of two successful experimental central processing and marketing schemes initiated in 1967. The factories had a production capacity of 5-8 tonnes per day. Since then more factories have been sited in dense rubber growing areas, each with production capacities of 20-40 tonnes per day. Latex, unsmoked sheets and cuplump are processed at these factories. The Malaysian Rubber Development Corporation (MRDC) manages these central factories which process smallholding rubber into quality SMR grades and sell directly to the consumers. In 1972, six Heveacrumb factories were in operation and produced 21,500 tonnes SMR. The grades produced were SMR 5CV, LV 5, 5L, 10 and 20. Two latex concentrate factories were in operation at the end of 1972 and together produced 528 tonnes. By 1975, the Corporation would have in operation a total of 28 factories which would then have the capacity of producing 300,000 tonnes of rubber per year.

In addition, central processing factories have also been constructed by the Federal Land Development Authority (FELDA), the State Economic and Development Corporation and the private sector to cater for smallholders. In the FELDA Schemes, the centralised smallholdings are highly organised and are managed similarly to estates. The majority of these schemes are about 800-1600 hectares, often located very close to each other. In such schemes, the production capacity of the central processing factories range between 20-60 tonnes per day.

PROCESSING TECHNIQUES AND MACHINERY

Latex grades

Preservation: The establishment of central processing factories resulted in the transport of latex over longer distances. This necessitated the use of higher levels of ammonia (*ca.* 0.08—0.12%) to keep the latex in a satisfactory fluid state. Two major disadvantages were experienced:

(*a*) The chemical cost of preservation and coagulation is substantially increased.

(*b*) The resultant rubber is of a dark brown colour and normally fails to meet the SMR 5L colour specification limit of 6 Lovibond units.

Investigations into this problem resulted in a recommendation to use a composite system of boric acid and ammonia for preservation (Cheong & Ong, 1973). This system adequately preserves the latex for the required periods while maintaining the light colour property of the processed rubber. The effectiveness of the composite system is shown in Table 1. The cost of using this composite system is comparable to the ammonia system (Table 2).

In the case where the latex is intended for the production of viscosity-stabilized rubbers, *e.g.* CV, LV, the use of another composite system of hydroxylamine neutral sulphate and ammonia was successfully developed (Cheong & Ong, 1973). In this composite system, the hydroxylamine neutral sulphate performs as a viscosity-stabilizer as well as a latex preservative. The effectiveness of this composite system is illustrated in Table 3. The presence of 0.15% wt. of hydroxylamine neutral sulphate enables the ammonia level to be reduced by half when compared with the conventional ammonia system. Acid consumption is then reduced by about 60 per cent (Table 4).

Latex coagulation

Three methods of coagulating latex have been principally used by factories. These are acid, natural and assisted biological coagulation using molasses. Natural and assisted biological coagulation yield rubbers with a lower PRI, a higher Mooney viscosity and a faster cure than acid coagulated rubbers (Table 5). In practice, natural and assisted biological coagulation tend to yield a rubber which is less consistent in raw rubber properties. For this reason, most latex rubber grades are coagulated with formic acid.

Processing machinery

The choice of machinery for processing latex rubber is straightforward. It is dependant mainly on the required throughput of the factory and on the types of receptacle used for latex coagulation.

Coagulation receptacles

The three types of receptacles used for coagulation are:

(*a*) Conventional coagulation tanks (3 m x 0.9 m)

(*b*) Coagulation tubs

(*c*) Coagulation troughs.

TABLE 1

EFFECTIVENESS OF THE BORIC ACID-AMMONIA SYSTEM

Preservative system		Duration of preservation, h	
Boric acid % w/w on latex	Ammonia % w/w on latex	Estate latex	Smallholders' latex
0.2	0.03	16	11—15
0.3	0.07	32—60	29—40
0.5	0.03	34—44	20—27
0.5	0.05	39—43	36—43
—	0.15	44—56	43—50

TABLE 2

ECONOMIC ADVANTAGE OF THE HYDROXYLAMINE-AMMONIA SYSTEM

Chemical	Price per kg	Ammonia system Level[b]	Ammonia system Cost US cts/kg[c]	HNS/Ammonia system Level[b]	HNS/Ammonia system Cost US cts/kg[c]
Hydroxylamine neutral sulphate (HNS[a])	$1.15	0.15%	0.53	0.15%	0.53
Ammonia	$1.21	0.14%	0.56	0.07%	0.28
Formic acid	$0.95	2.52%	2.40	1.06%	1.01
TOTAL			3.49		1.82

a For the preparation of SMR 5CV, the same amount of hydroxylamine will be required—irrespective of the preservative system used.

d The levels of hydroxylamine NS and formic acid on weight of dry rubber (d.r.c. of latex=30%), and that of ammonia on weight of latex.

c Cost is based on US cts/kg (rubber)

TABLE 3

EFFECTIVENESS OF THE HYDROXYLAMINE-AMMONIA SYSTEM

Preservative system Hydroxylamine NS with ammonia		Duration of preservation, h	
%wt on rubber	%wt on latex	Estate latex	Smallholders' latex
0.15	0.03	11	5
0.15	0.05	11—19	5—11
0.15	0.07	19—30	11—20

TABLE 4

ECONOMIC ADVANTAGE OF THE BORIC ACID-AMMONIA SYSTEM

Chemical	Price/kg	Ammonia system		BA/Ammonia system	
		Level[a]	Cost US cts/kg[b]	Level[a]	Cost US cts/kg[b]
Boric acid (BA)	\$1.15	—	—	0.50%	1.92
Ammonia	\$1.20	0.15%	0.60	0.05%	0.20
Formic acid	\$1.00	3.75%	3.75	0.47%	0.47
TOTAL			4.35		2.59

[a] The levels of boric acid and ammonia are based on the weight of latex and that of formic acid on weight of dry rubber (d.r.c. of latex=30%).

[b] Cost is based on US cts/kg (rubber).

TABLE 5

EFFECT OF COAGULATING METHOD ON RUBBER PROPERTIES

Method	PRI %	Mooney Viscosity	TC Strain
Acid coagulation	95	74	66
Natural coagulation	57	92	53
Assisted biological coagulation	84	82	62

The conventional aluminium coagulation tanks produced thin coagula, in discrete 0.9 m long pieces or continuous lengths, which can be conveniently fed directly to a machine for size reduction. Their high capital cost, large floor area and labour requirement make it less attractive for large scale operations (Table 6). They are however amply suited for low outputs and have been utilised during the early changeover to new process rubbers from RSS.

After initial interest, coagulation tubs are now no longer competitive because of high capital and operating costs.

Coagulation troughs, built with glazed tile-lined brick walls, produce sausage-like coagula measuring about 0.5 m x 0.5 m x 15 m. This coagulum when floated on water is amenable to handling. Due to its low capital outlay and low labour requirement, this system is rapidly gaining acceptance.

Premachining and size reduction

The individual slabs of coagula derived from the conventional tanks are cut into small pieces before feeding to an extruder or granulator for size reduction. For low outputs this procedure is the simplest.

For continuous slabs of coagula derived from the conventional tanks, these are best subjected to one pass through a creper and to a granulator or a creper-hammermill for size reduction. The latter is preferred for high outputs particularly when the Hevea-crumb process is adopted.

The long sausage-like coagulum from the troughs is most conveniently handled by a crusher, two crepers and a creper-hammermill. A creper-hammermill is favoured because it minimises electrical peak loads.

Limited practical experience on the recently developed KGSB Extruder suggests a potential use of this machine for size reduction. The extruded strands are uniform in diameter and should lead to uniform drying. The base of the dryer trolley (or box) required to hold these strands can be simplified to a series of widely spaced parallel wires or a square mesh. This design suggests a lesser need for cleaning and its attendant reduction in any possible contamination. Current efforts are directed towards adapting it to the trough system of coagulation.

Field coagulum grades

Storage: Many modes of storage of cuplump have been employed in the past. Recent experiments suggest that the best method for storing cuplump is "store dry under the shade" (Table 7). Raw rubber properties such as P_o and PRI are not harmfully affected by dry storage. However, storage in water for a short period can be beneficial for removing surface dirt while not significantly affecting P_o and PRI.

Precleaning: While the choice of machinery to handle unsmoked sheets is relatively simple, a variety of machinery has been successfully used for processing cuplump grades. This is due to the variable quality and form of cuplumps.

Clean unsmoked sheets are best processed through a series of crepers and washed with plenty of water during crepeing. Prior to crepeing, dirty unsmoked sheets can be cleaned of surface dirt by using a specially designed brush washer.

TABLE 6

COMPARISON OF COAGULATION SYSTEMS

Systems used	PLANT 5,000 kg/day A[a]	B[b]	C[c]	OUTPUT 10,000 kg/day A[a]	B[b]	C[c]
Surface area for coagulation equipment (m^2)	156	180	167	280	302	281
Cost of floor area (\$ 76/m^2)	11,850	13,700	12,700	21,300	23,300	21,400
Equipment cost (\$)	57,300	106,600	59,665	100,200	125,400	75,474
Labour requirement (man-hours)	48	44	25	92	84	48
Water (l)	15,070	34,500	27,700	30,100	50,200	50,600
Power (kw-h)	58	55	148	115	109	296
Cost of coagulation						
Depreciation \$/day (life 5 years @ 320 days/year)	35.80	66.50	37.30	62.60	78.40	47.20
Labour \$ (50 cts/h)	24.00	22.00	12.50	46.00	42.00	24.00
Water \$ (11 cts/1000 l)	1.65	3.80	3.05	3.30	5.50	5.55
Electricity \$ (8 cts/kw-h)	4.65	4.40	11.80	9.20	8.70	23.70
Maintenance \$	1.75	3.85	4.30	3.00	5.25	7.10
Total cost/day \$	67.94	100.55	68.06	124.10	139.85	107.55
Cost of coagulation (cts/kg dry rubber)	1.36	2.01	1.38	1.24	1.40	1.08

[a] System A: Conventional tanks
[b] System B: Coagulation vats
[c] System C: Coagulation troughs

TABLE 7

INFLUENCE OF STORAGE CONDITION ON PROPERTIES OF FIELD GRADES

Storage condition	Fresh rubber P_o	PRI	Month-old rubber P_o	PRI
Soaked water	44	64	38	65
Soaked in phosphoric acid	44	69	38	81
Stored dry under shade	43	65	41	62
Exposed to sunlight	42	56	30	60
Stored in smoke house	43	58	27	70

Cuplump materials usually arrive at the factory as fairly discrete small pieces or lumps. Large lumps are normally sliced into smaller pieces manually or by rotary knives. Clean cuplump can be processed either through crepers or directly through other size reduction machines. Dirty cuplumps require pre-cleaning. This can be effectively carried out by repeated passes through a creper and a creper-hammermill (Fig. 2).

A large remiller has found granulators quite effective for decreasing the level of dirt. Granulators are preferred for their low noise level when in operation but require greater attention for machinery maintenance as in the sharpening of knives.

Blending and initial processing

By their very nature, unsmoked sheets and cuplump materials are very variable, particularly in dirt and viscosity. With the current stress on uniformity between batches and within a SMR grade, blending of rubbers assumes a very important role in rubber processing. The blending of rubbers from different sources can be achieved by the following techniques :

1. During reception at the factory, the different lots of rubber are evenly distributed into several receptacles simultaneously, giving a good blend of the various lots in one receptacle.
2. In between the various precleaning steps, the rubber is evenly distributed into blending receptacles. When blankets are made, these can be spread over the factory floor or rolled into reels which facilitate blending at a later stage.
3. During crepeing, the crepes are blended by multiple and overlapping passes through the crepers.

In treating both unsmoked sheets and cuplump materials, crepers are essential to shear the rubber coagulum so that the final crumbs can be dried easily by hot air convection dryers.

Final size reduction

The creper-hammermill is suitable for the size reduction of unsmoked sheet and cuplump blankets. A certain amount of cleaning occurs even at this stage and is therefore beneficial.

For clean materials, the extruder can be used and offers the advantages mentioned earlier. For very clean estate cuplumps, a process employing a granulator followed by an extruder has been effective. In addition, the extruder shears cuplump materials very well and therefore minimises the chances of obtaining patches of wet rubber.

Shredders with a cutting roll rotating against a fixed plate have proved to be very popular for the size reduction of remilled rubber in Singapore. These have the advantage of every high throughput coupled with low noise levels. Shredders are generally more suitable for large factories.

The most cost-effective machine for size reduction appears to be the creper-hammermill (Table 8). For low output and clean materials, a process involving the extruder may be cheaper. For large outputs, the shredder may be favoured because of a much lower noise level.

Fig. 2 REMOVAL OF DIRT BY HAMMERMILL CREPER AND GRANULATOR

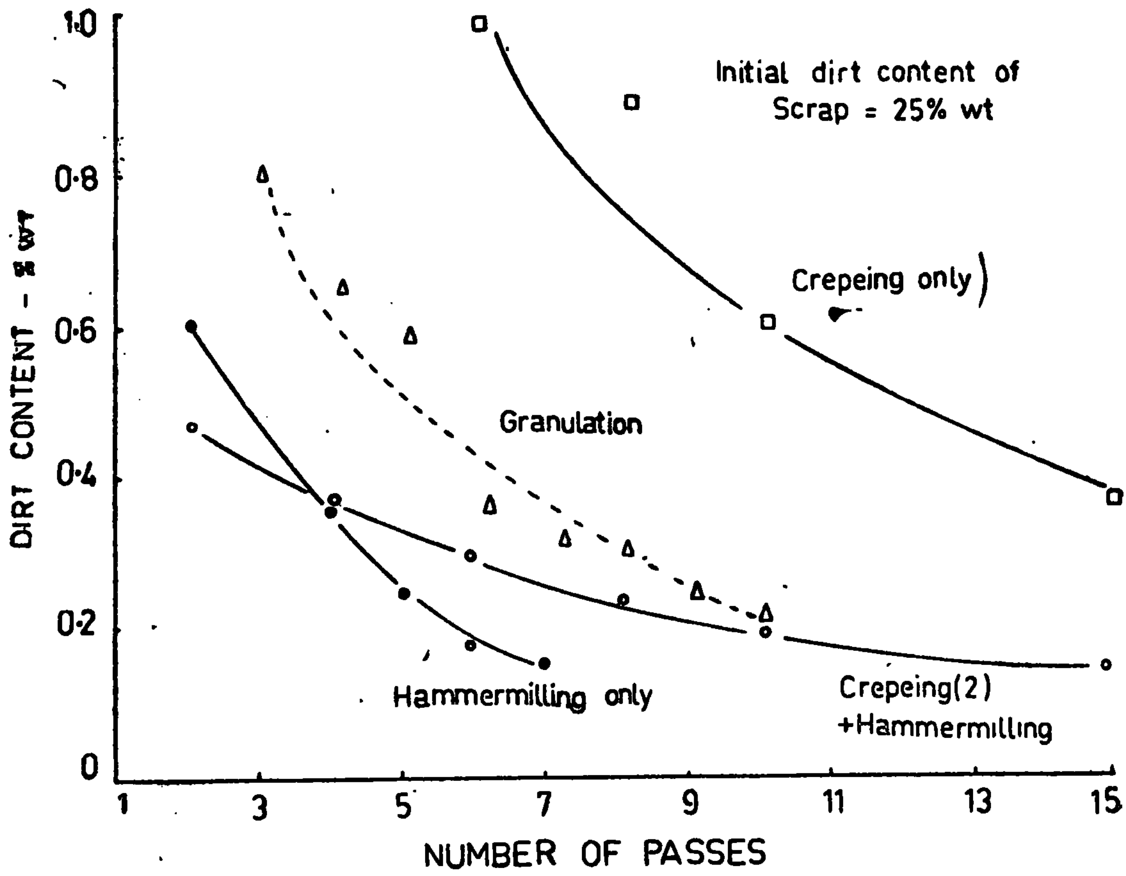


TABLE 8

COMPARISON OF FINAL SIZE-REDUCTION EQUIPMENT (LATEX RUBBER)

System used	PLANT				OUTPUT			
	5,000 kg/day				10,000 kg/day			
	A[a]	B[b]	C[c]	D[d]	A[a]	B[b]	C[c]	D[d]
Cost of machinery ($)	14,050	24,200	40,000	17,500	28,100	24,200	40,000	35,000
Labour (man-hours)	14	5	10	12	28	10	20	24
Power (kw–h)	26.10	44.70	67.10	18.70	52.20	44.7	67.10	37.40
Cost of final size reduction								
Depreciation ($/day) life 5 years — 320 days/yr.	8.80	15.10	25.00	11.10	17.60	15.10	25.00	22.20
Labour (50 cts/h)	7.00	2.50	5.00	6.00	14.00	5.00	10.00	12.00
Electricity (8 cts/kw-h)	17.50	10.70	16.10	10.05	35.00	21.40	42.20	20.10
Maintenance ($/day)	4.40	4.30	4.00	10.59	8.80	7.50	6.80	21.00
Total cost ($/day)	37.70	32.60	50.10	37.65	75.40	49.00	74.00	75.30
Cost of final size reduction (cts/kg dry rubber)	0.75	0.65	1.00	0.75	0.75	0.49	0.74	0.75

[a] System A: Granulator

[b] System B: Creper-hammermill

[c] System C: Creper-creper-shredder

[d] System D: Extruder

Dryers for latex and field grades

All the several types of dryers employ the same basic principle of drying *i.e.* circulation of air at 100 °C through a deep bed of rubber. They vary in construction, handling, heating system *etc.*

The three basic types of dryers are:

1. Batch or chamber dryer with trolleys.
2. Single layer tray dryer.
3. Multiple layer tray dryer.
4. Apron dryer.

Differences in dryer performance can be attributed to difference in the standard of maintenance, the basic design and the heating system. Fig. 3 compares the various types of dryers, based on data obtained from a survey of dryers in use in Malaysia.

Single layer tray dryers with direct fired heater is suitable for throughputs up to 500 kg/h. Chamber dryers occupy less floor area and are suitable for throughputs up to 1000 kg/h. Apron dryers involve high capital cost and appear to be suitable for much higher throughputs and for handling the semi-processed materials from remilling factories in Singapore.

Baling presses

Hydraulic presses with either manual or automatic time interval settings are widely used in SMR factories for baling rubber. However, converted screw presses, similar to the ones used for sheet baling, cost less and have a higher output although the bales are not as well pressed.

Flow charts

The flow charts shown in Fig. 4 summarise the currently favoured lines for latex and field grade rubbers. Some details of machinery specifications, throughput, electrical loadings and labour requirements before pre-machining and final size reduction for both lines are described elsewhere, (Sethu, 1972, 1973).

Cost of production

From a detailed study (Rubber Research Institute of Malaya, 1972) of several factories, the average total variable cost of production was 10.28 cts/kg; the largest cost items are packing and labour which averaged 2.54 and 2.14 cts/kg respectively. Although these costs are higher than sheet and crepe production, the regular premiums of SMR grades over a long period have increased the profitability of the new process factories.

FUTURE DEVELOPMENTS

The versatility of the new process SMR factories enables definitive product improvement so necessary for maintaining product competitiveness. Light coloured SMR 5CV and tyre rubber are two examples of these rubbers which offer processing advantages in internal mixer operations, extrusion and calendering at the end-user's factory. The production of oil-extended rubber masterbatches, enzyme-deproteinised rubber and carbon black masterbatches are also manifestations of a new outlook of management

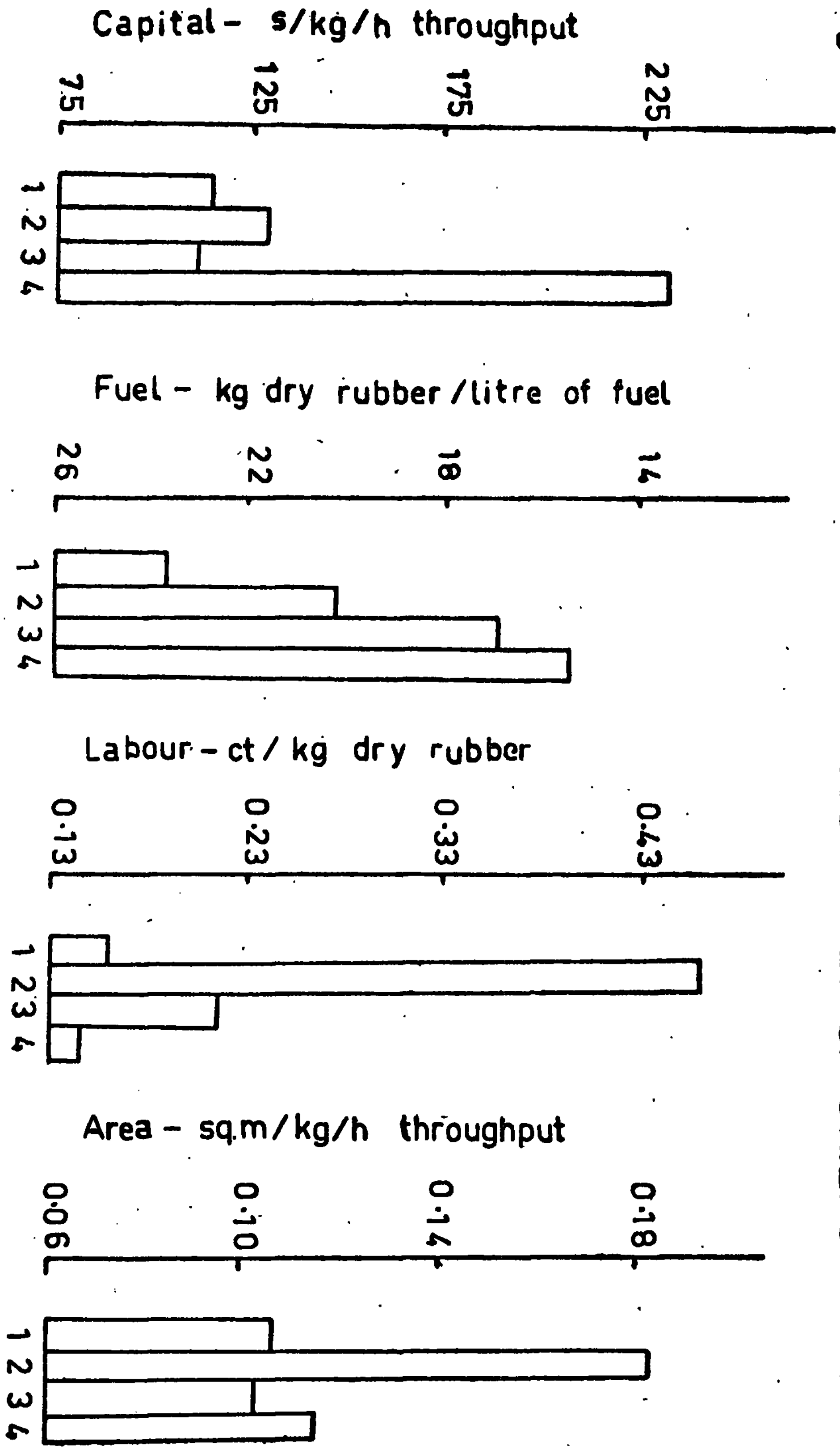


Fig.3 COMPARISON OF VARIOUS TYPES OF DRIERS

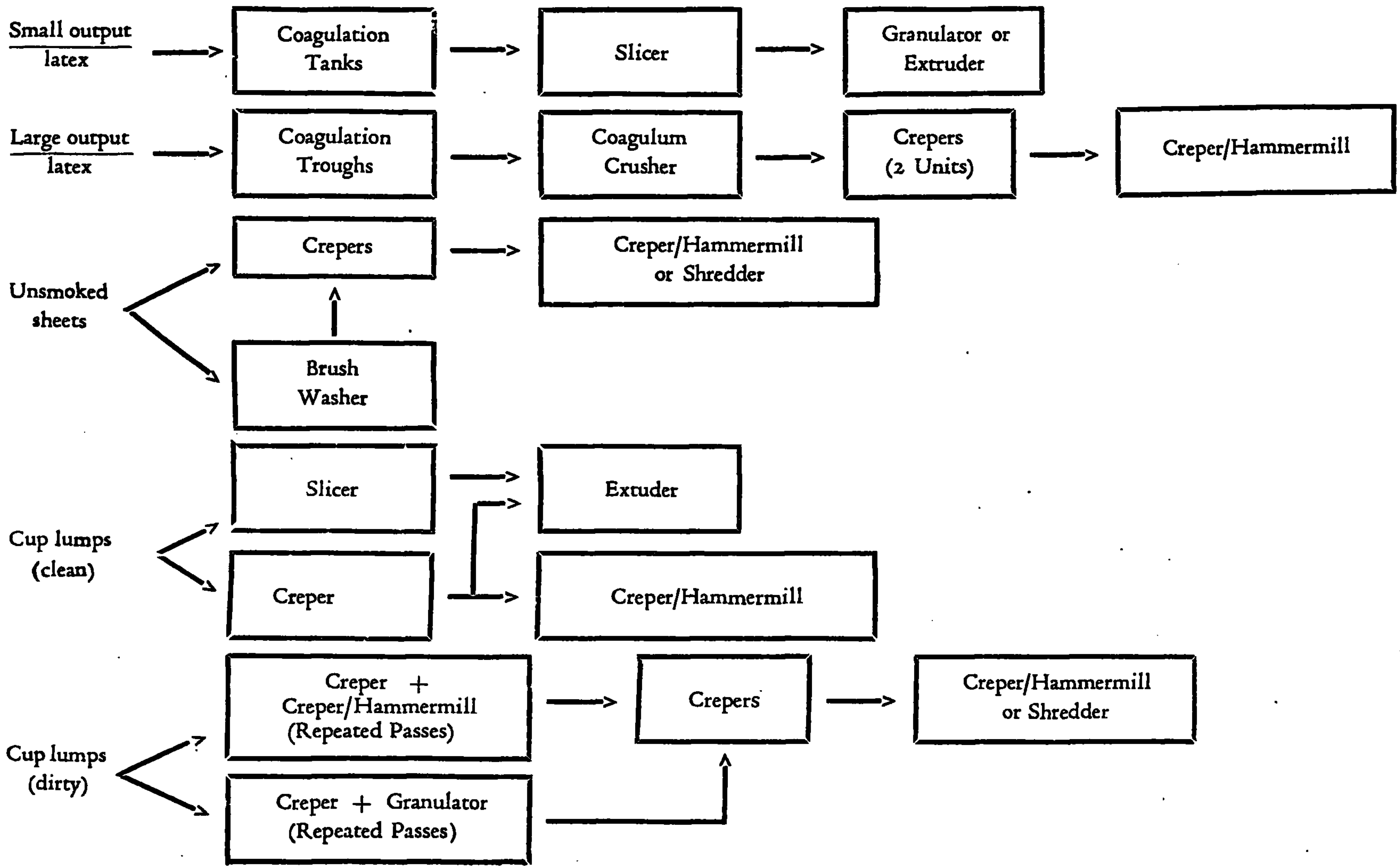


FIG. 4 FLOW CHART OF LATEX AND FIELD COAGULUM PROCESSING

to tailor-make their products to the needs of the end-user. Attempts to engage in horizontal integration of a processing factory with one manufacturing rubber or latex goods represent yet another approach to provide an industrial raw material which would meet the technical and economic requirements of the end-user. In terms of machinery development, an area of future development is associated with the coagulation of latex. New devices are likely to be developed to facilitate the coagulation process and the handling of the latex coagulum. Various approaches to the development of a method for continuous coagulation of latex have already been made. For processing field grades new machines for dirt removal and handling will continually be experimented with.

CONCLUSION

It is clear that several dynamic changes occurred in the plantation scene particularly over the past eight years. The industry has successfully imbibed the processing innovations developed through purposeful research and development and its new outlook towards rubber production will maintain NR's rightful senior position amongst the family of elastomers.

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