Control of Crude Oil Dilution in Palm Oil Mills

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This paper discusses the results of development work on the control of crude oil dilution in palm oil mills. The importance of crude oil dilution in palm oil mills is clearly shown by a simple cost-benefit analysis. Preliminary results from a three-phase decanter trial have shown that, besides a clarification system using horizontal or vertical clarifiers, dilution control is also important to a decanter system.

A practical approach to the automatic control of crude oil dilution using a flow ratio control system is discussed in depth in this paper. Results obtained from the evaluation of Doppler and magnetic flowmeters have shown that the major obstacle in automatic control of crude oil dilution, i.e., the selection of a suitable flowmeter to measure crude oil flow, has been overcome.

Control of crude oil dilution has been a formidable problem in process control for palm oil mills. This is due mainly to the difficulty in selecting a suitable flowmeter for crude oil measurement, as crude oil is a non-Newtonian, thixotropic fluid which cannot be measured using ordinary differential pressure flowmeters. As the oil loss in effluent sludge ex-clarification/centrifuging processes is a major source of oil loss in the overall milling operation (Fig. 1), there is an urgent need to improve the control of crude oil dilution to achieve better oil recovery efficiency.

Before introducing any automatic control system for crude oil dilution, it is necessary to evaluate the available measurement and control instruments for their suitability in terms of cost, accuracy and reliability for the palm oil mills.

IMPORTANCE OF DILUTION CONTROL

The main objective of the clarification/centrifuging processes is to separate as much oil as possible from the crude oil. Studies conducted by Lim and Whiting (2) illustrate conclusively that the optimum oil settling rate for crude oil is achieved with approximately 25% to 35% of water dilution to diluted crude oil. Figure 2 shows a typical crude oil settling curve. Manual control of crude oil dilution has been found to be highly unsatisfactory due to the following reasons:

- High variation in crude oil flowrate due to intermittent operation of the presses.
- Throughput variation in the operation of presses due to varying crop quality. To achieve the required results, it is obviously necessary to look into the possibility of using automatic control of crude oil dilution.

A PRACTICAL APPROACH

Automatic control of crude oil dilution can be carried out in three ways: (i) flow measurement and ratio control; (ii) viscosity measurement and control, and (iii) composition analysis and control.

Flow ratio control, using flow as the measurement and control parameter, is the most simple and straightforward system of the three. Viscosity and composition measurement and control, require more complicated and rather expensive instruments, e.g., viscometer and composition analyzer, respectively. The flow ratio control system is therefore the logical choice and will be covered in depth in this paper.

Before any flow ratio control system can be implemented, it is necessary to select a suitable flowmeter to measure undiluted crude oil (UCO) or diluted crude oil (DCO) flowrate which cannot be measured by ordinary differential pressure flowmeters. Two types of flowmeters were selected for the evaluation, the Doppler flowmeter and the magnetic flowmeter.

A Polysonic Model LCDT Doppler flowmeter was assessed for DCO measurement by using a quantitative mass balance approach (1). Results obtained showed that the Polysonic Doppler flowmeter is suitable for measuring DCO flowrate, giving an acceptable overall percentage error of 3.8% (Table 1).

A Kent Veriflux Model VTC magnetic flowmeter was also evaluated, using a rotary basculator as a reference meter. Recordings of total quantity of flow for both test and reference meters were carried out hourly for eight days. It was found that the Kent Magnetic flowmeter is ideal for DCO flowrate measurement, with an overall percentage error of 1% (Table 2).

Because the measurement principles of both the flowmeters do not depend on the viscosity and density of the fluid to be measured, we can safely say that they are also suitable for flow measurement of undiluted crude oil. A magnetic flowmeter capable of measuring fluid with a minimum conductivity of one μS/cm is recommended for UCO.

DIRECT METHOD FLOW RATIO CONTROL USING UCO MEASUREMENT

System A. For System A (Fig. 3) UCO from the pressing station is first discharged to a UCO tank which will then be pumped to a DCO tank. The UCO tank is necessary to ensure full pipe flow which is measured using a suitable flowmeter. The UCO is diluted with hot water (W) from a constant-head tank, and the hot water flow rate is measured by a differential pressure flowmeter.

The ratio controller receives signals from both UCO and hot water flow transmitters. The flow rate measurement of dilution water (W) comes into the summing junction of the controller. The set point of the controller is generated by taking the flow measurement of UCO and multiplying by the desired ratio (K1). At all times W must be equal to K1 × UCO, so that if $W > K1 \times UCO$ the controller decreases W and vice versa. In this ratio control system, control is achieved by

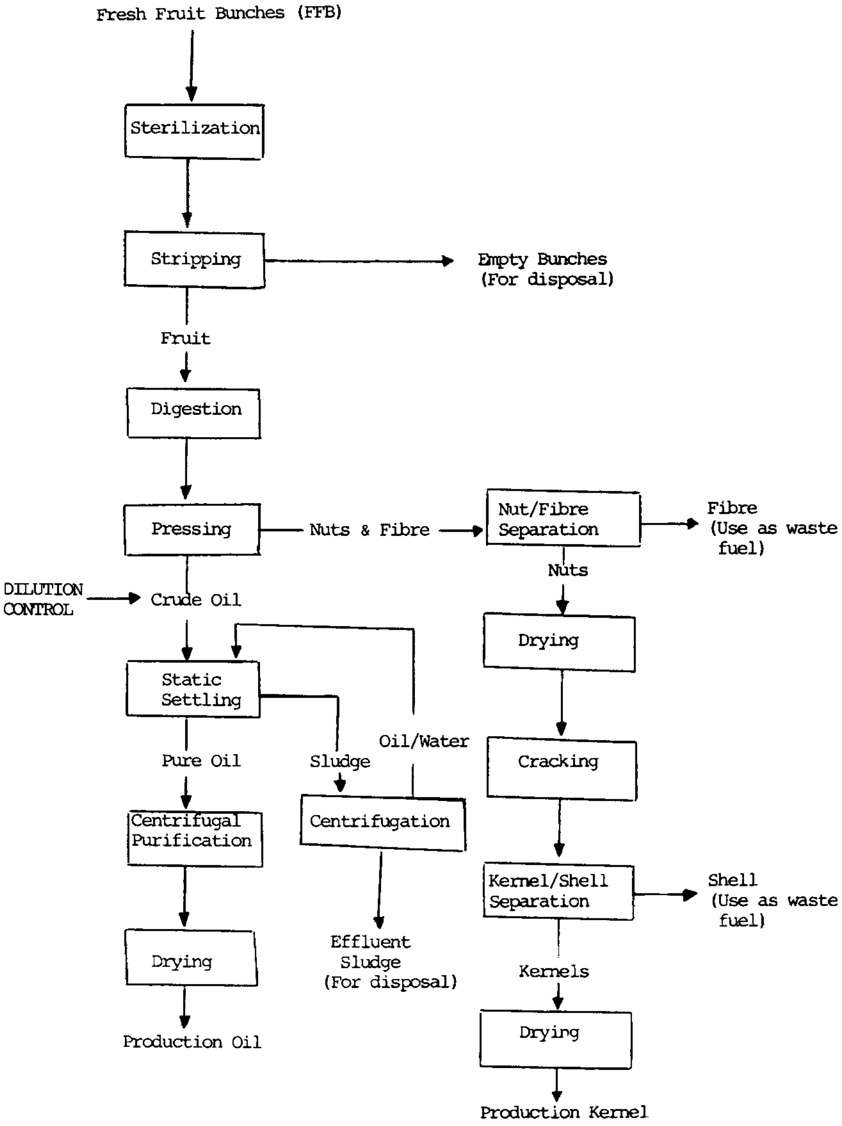

FIG. 1. Flow diagram of the extraction process in a typical palm oil mill.

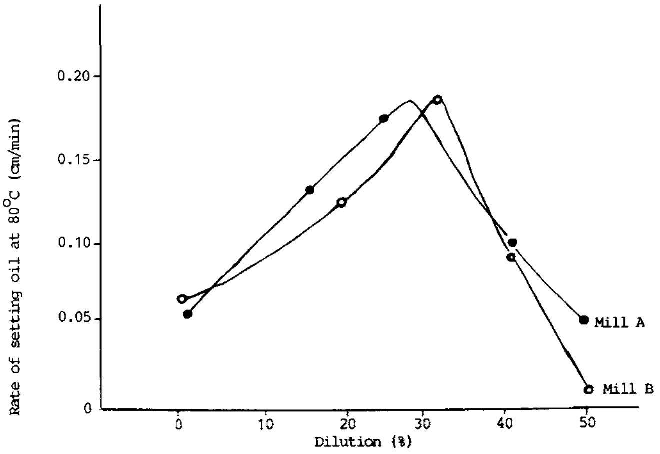

FIG. 2. Graph showing rate of settling vs percentage of dilution with water.

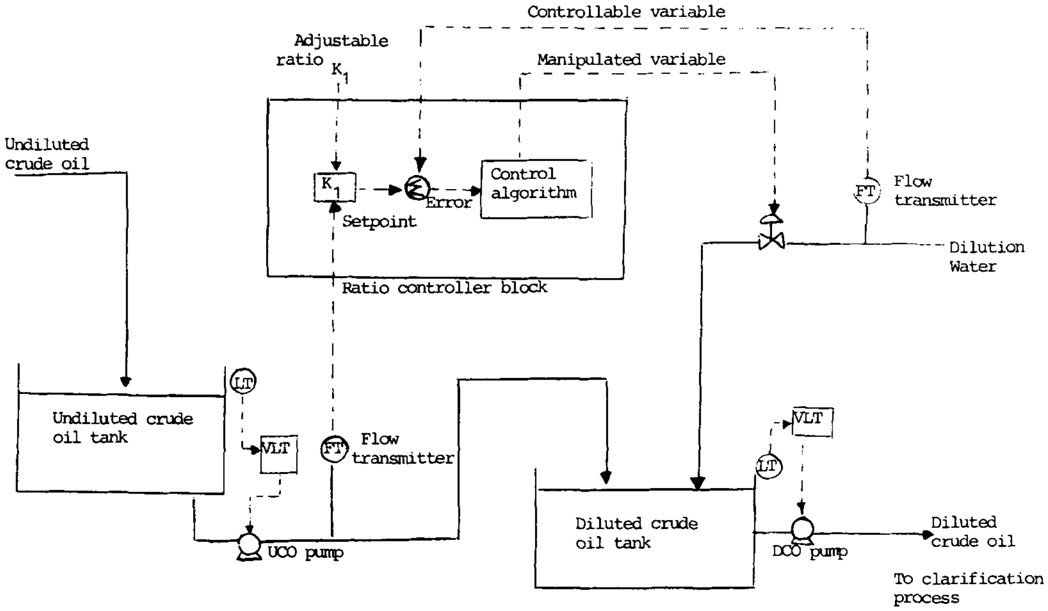

FIG. 3. Ratio control system for automatic crude oil dilution using direct method (UCO measurement) - System A.

TABLE 1

Mass Balance Measurement vs Doppler flowmeter Measurement of Diluted Crude Oil

Day	Mass balance measurement (tons)	Doppler flowmeter measurement (tons)	% Error
1	88.71	89.33	+ 0.70
2	124.44	125.34	+ 0.72
3	88.72	84.14	- 5.16
4	119.13	109.36	- 8.20
5	177.50	167.74	- 5.50
6	77.01	78.65	- 4.36
7	72.36	69.94	- 3.76
Total	747.87	719.50	
Mean			- 3.80

TABLE 2

Rotary Basculator Measurement vs Magnetic Flowmeter Measurement of Diluted Crude Oil

Day	Rotary basculator (Reference meter) (m3)	Magnetic flowmeter (Test meter) (m3)	% Error
1	148.512	150.655	+ 1.42
2	130.032	131.186	+ 0.88
3	75.488	77.165	+ 2.17
4	106.736	105.075	- 1.58
5	128.352	127.757	- 0.47
6	64.400	66.510	+ 3.28
7	81.984	83.580	+ 1.95
8	77.280	79.000	+ 2.23
Total	812.784	820.273	
Mean			+ 1.00

manipulating a valve which controls W while the flow rate of undiluted crude oil is left uncontrolled.

This system requires an additional UCO tank, UCO pump and variable speed drive which are not normally used in manual dilution control. If the extra equipment cost is not justifiable or the additional UCO tank cannot be accommodated into the existing system due to limitation of space, the indirect method flow ratio control using DCO measurement (System B) as shown in Figure 4 should be considered.

INDIRECT METHOD FLOW RATIO CONTROL USING DCO MEASUREMENT

System B. In the indirect method flow ratio control System B, the flowrate of DCO is measured instead of UCO. The ratio controller maintains the flow rates of dilution water (W) and DCO at a desired ratio (K2), i.e. W is equal to K2 × DCO, by manipulating a valve which controls W. Correct sizing of the DCO tank is essential to give the minimum capacity for the system to operate.

Instrumentation for automatic control of crude oil dilution using system B. Evaluation using the indirect method of flow ratio control System B without modification to the existing piping arrangement was carried out in a palm oil mill. The instruments used were a magnetic flowmeter, hot water flowmeter, frequency-current converter, ratio controller, flow recorder and totalizer, electropneumatic converter, pneumatic control valve, automatic voltage regulator, static frequency converter and air compressor.

The schematic layout of the control system is shown in Figure 5.

Trial results for automatic dilution control system (System B). The automatic dilution control system with setpoint at 30% was evaluated for both precision and accuracy in maintaining the desired crude oil dilution ratio. Table 3 summarizes the results of crude oil dilution ratios maintained at 15-min intervals for a four-day period. The mean crude oil dilution ratio at 15-min intervals was kept very close to the desired 30% setpoint with small variations. The automatic dilution control system can be said to have good precision.

Table 4 summarizes the daily dilution ratios achieved using the automatic dilution system for nine-day period.

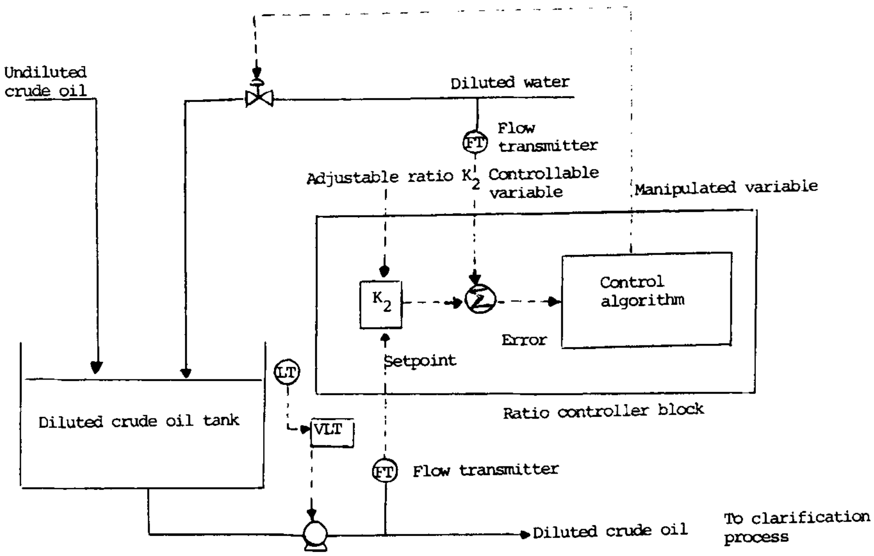

FIG. 4. Ratio control system for automatic crude oil dilution using indirect method (DCO measurement) - System B.

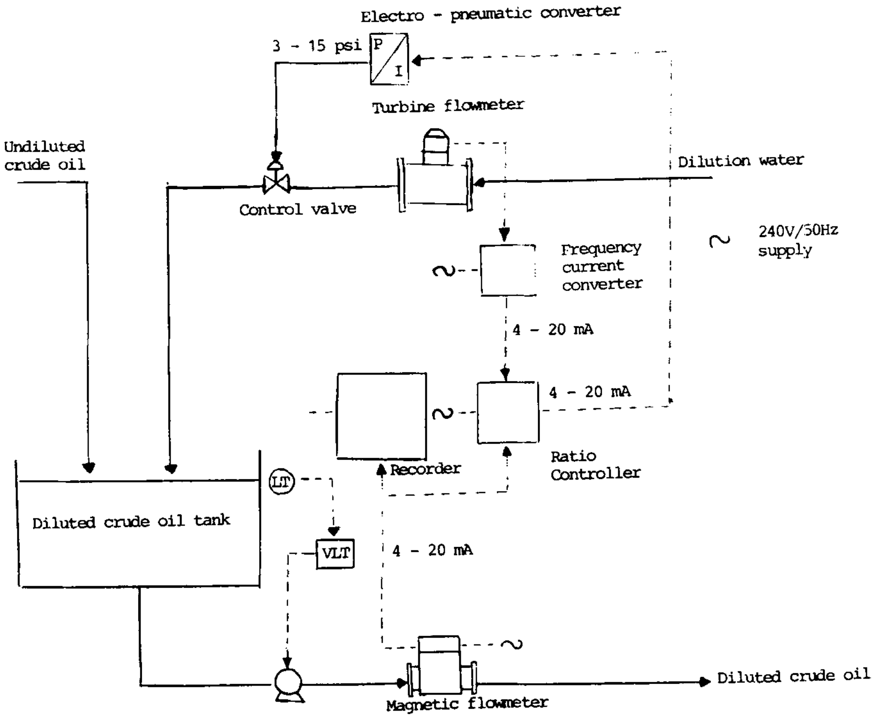

FIG. 5. Schematic configuration of instruments for flow ratio control of crude oil dilution using System B.

TABLE 3

Assessment of Precision of Automatic Dilution Control

Time (p.m.)	DCO[a] (m3)	W[b] (m3)	W/DCO × 100%[c]
Day 1			
1:00	1.44	0.47	32.64
1:15	1.77	0.53	29.94
1:30	1.78	0.55	30.90
1:45	3.22	0.93	28.88
2:00	3.48	1.02	29.31
2:15	2.84	0.83	29.23
2:30	1.94	0.59	30.41
2:45	2.82	0.85	30.14
3:00	3.16	0.91	28.80
3:15	3.29	0.92	27.96
3:30	2.34	0.72	30.77
3:45	1.70	0.51	30.00
4:00	3.18	0.89	27.99
4:15	-	-	-
4:30	6.45	1.81	28.06
Mean $\bar{x}$			29.65
SD n-1			1.32
n			14
Day 2			
1:45	-	-	-
2:00	8.63	2.48	28.74
2:15	-	-	-
2:30	-	-	-
2:45	5.42	1.62	29.89
3:00	-	-	-
3:15	1.24	0.39	31.45
3:30	1.47	0.47	31.37
3:45	2.71	0.85	31.37
4:00	3.53	1.02	28.90
4:15	3.76	1.13	30.05
4:30	4.23	1.25	29.55
4:45	2.19	0.75	34.25
5:00	2.40	0.71	29.58
5:15	1.59	0.39	24.53
5:30	3.01	1.09	36.21
5:45	2.73	0.91	33.33
6:00	3.39	0.71	20.94
6:15	3.85	1.11	28.83
6:30	2.98	0.88	29.53
6:45	3.82	1.11	29.06
7:00	3.68	1.08	29.35
7:15	3.98	1.04	26.13
7:30	2.12	0.75	35.38
7:45	3.80	1.09	28.68
8:00	2.86	0.79	27.62
8:15	3.56	1.07	30.06
8:30	2.41	0.52	21.58
8:45	2.82	0.98	34.75
9:00	2.72	1.06	38.97
Mean $\bar{x}$			30.03
SD n-1			4.09
n			26
Day 3			
12:30	-	-	-
12:45	2.67	0.80	29.96
1:00	3.42	0.99	28.95
1:15	3.19	0.97	30.41
1:30	2.93	0.89	30.38
1:45	4.04	1.23	30.45
2:00	4.51	1.34	29.71
2:15	4.12	1.14	27.67
2:30	4.06	1.20	29.56
2:45	4.32	1.15	26.62
3:00	3.94	1.30	32.99
Mean $\bar{x}$			29.67
SD n-1			1.72
n			10
Day 4			
3:00	-	-	-
3:15	2.98	1.00	33.54
3:30	1.34	0.42	31.34
3:45	1.88	0.58	30.85
4:00	3.63	1.02	28.10
4:15	2.44	0.69	28.28
4:30	2.04	0.62	30.39
4:45	-	-	-
5:00	4.18	1.28	30.62
Mean $\bar{x}$			30.42
SD n-1			2.04
n			6

[a] Diluted crude oil.
[b] Dilution water.
[c] Dilution ratio.

TABLE 4

Assessment of Accuracy of Automatic Dilution Control System

Day	DCO[a] (m3)	W[b] (m3)	W/DCO × 100%[c]
1	39.41	11.53	29.26
2	84.91	25.25	29.74
3	37.20	11.01	29.60
4	18.49	5.61	30.34
5	62.71	19.00	30.30
6	75.90	22.01	29.00
7	135.30	39.33	29.10
8	136.62	40.67	29.77
9	136.79	40.28	29.45
Mean $\bar{x}$			29.61
SD n-1			0.48
n			9

[a] Diluted crude oil.
[b] Dilution water.
[c] Dilution ratio.

TABLE 5

Total Cost Benefits Yearly for Three Typical Size Mills

Mill size (tons FFB/hr)	20	30	40
Total FFB processed (tons)	80,000	120,000	160,000
Additional oil recovered (tons)	40	60	80
Gain in revenue based on crude palm oil price of US$280/ton	11,200	16,800	20,000
Estimated implementation cost (US$)	12,800	16,800	20,800
Payback time	14 mo	1 yr	11 mo

TABLE 6

System With Three-Phase Decanter but Without Static Clarifier

	Low losses							High losses	
Day	1	2	3	4	5	6	7	8	9
Dilution (%)	5.2	5.4	6.3	8.1	8.2	9.0	12.6	19.3	26.5
Oil loss in solids ex-decanter (kg/ton FFB)	1.32	1.10	1.46	1.47	1.37	1.15	1.46	1.55	1.79
Oil loss ex-separator discharge (kg/ton FFB)	3.52	3.86	2.64	1.84	3.82	3.15	2.64	5.19	6.56
Total oil losses ex-system (kg/ton FFB)	4.75	4.96	4.10	3.31	5.19	4.30	4.10	6.74	8.35

FFB, fresh fruit bunch.

The daily mean was kept very close to the desired 30% dilution ratio with small variations. The automatic dilution control system can be said to have good accuracy.

COST-BENEFIT ANALYSIS

Using manual dilution control, the industrial average oil loss in the sludge from the clarification/centrifuging process (using static clarifiers) of well-operated palm oil mills is about 0.5% to FFB (fresh fruit bunches) or 5 kg/ton FFB. With automatic dilution control, the oil loss achievable can be reduced to below 0.45% to FFB or 4.5 kg/ton FFB. Assuming an improvement in oil loss of 0.5 kg/ton FFB, the total estimated cost benefits per annum for three typical size mills are given in Table 5.

Preliminary results of an evaluation of a three-phase decanter system in a palm oil mill have shown that total oil losses from decanter increase rapidly when the dilution rate exceeds a certain value, depending on the type of configuration used, i.e., crude oil direct or underflow from a clarifier (Tables 6 and 7). The increase in total oil losses is due mainly to the following reasons caused by over-dilution:

- Reduced retention time for separation in decanter bowl
- Poorer settling rate

It can be concluded that good control of crude oil dilution is vital to both types of clarification systems employing either vertical or horizontal-flow clarifiers and decanters.

From the cost-benefit analysis, it is obviously justifiable to introduce automatic control of crude oil dilution to palm oil mills using the proposed flow ratio control approach successfully tested in a palm oil mill. Overcoming the most formidable hurdle of selecting suitable flowmeters for crude oil flow measurement has made process control of crude oil dilution a practical reality.

TABLE 7

System With Three-Phase Decanter and Static Clarifier

	Low losses				High losses	
Day	1	2	3	4	5	6
Dilution rate (%)	15.5	16.5	20.5	21.2	22.6	24.6
Oil loss in solid ex-decanter (kg/ton FFB)	0.82	1.03	0.97	0.75	1.05	1.08
Oil loss ex-separator discharge (kg/ton FFB)	2.22	2.21	2.50	2.66	2.85	3.28
Total oil losses ex-system kg/ton FFB)	3.04	3.24	3.47	3.41	3.90	4.36

FFB, fresh fruit bunch.

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REFERENCES

1. Sivasothy, K., and Nicholas B.H. Lim, *J. Am. Oil Chem. Soc.* *62*:267 (1985).
2. Lim, K.H., and D.A.M. Whiting, Malaysian International Symposium on Oil Palm Processing and Marketing, Kuala Lumpur, 1976.
3. Tiong, K.H., and Nicholas B.H. Lim, PORIM Workshop on Current Status of Automation in Malaysian Palm Oil Mills, Kuala Lumpur, 1987.

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