CONTINUOUS STERILIZATION: THE NEW PARADIGM FOR MODERNIZING PALM OIL MILLING

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ABSTRACT

This paper examines the current status of development and impact of a new process for continuous sterilization on palm oil milling. The process leads to improvements in the design of mills, reduces the number of process operators, lowers the operating and maintenance costs, and simplifies mill operation. Mills using the process can be more easily supervised and automated. By avoiding the use of pressure vessels for sterilization and cages and cranes for the handling of bunches, palm oil mills are made safer for operators. The use of conveyors in place of cages also minimizes spillage of fruits and oil making mills cleaner.

Keywords: sterilization, continuous sterilization, palm oil milling, modern mill, mill technology.

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INTRODUCTION

Much of the technology used in a conventional palm oil mill can be attributed to the comprehensive research carried out in Congo in the 1950s as reported in the Mongana Report. The spectacular growth of the palm oil industry in Malaysia since the 1960s did not lead to any significant advances in the process used for extracting oil and kernels from fresh fruit bunches. There is increasing awareness of the need for the palm oil industry in Malaysia to upgrade to remain viable and competitive in the light of various new challenges, including more stringent environmental regulations, labour shortage and competition from other palm oil producing countries. Acute labour shortage has made the palm oil industry in Malaysia highly dependent on immigrant workers.

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In the conventional milling process, bunches are loaded into cages and pushed into sterilizers, where they are cooked in batches using steam at 40 psig. The process arrests oil quality deterioration due to enzymatic activity. It also facilitates the stripping of fruits from bunch stalks and the extraction of oil and kernel. The use of steam at high pressure and intermittent pressure releases to achieve good sterilization however makes it difficult to achieve continuous processing. Many methods have been suggested for continuous sterilization (Mongana Report, 1955; Olie and Tjeng, 1974; Sivasothy, 1989; Cheah and Maycock, 1991; Sivasothy *et al*., 1993; Loh, 1994) but none has proven to be really effective and economically viable. Recently though, efforts to transform palm oil milling technology have been given a boost from a new process for continuous sterilization pioneered by MPOB.

In the new process, the closed-knit arrangement of the spikelets in bunches is first disrupted using a double-roll crusher. The bunches are then heated using live steam at low pressure to facilitate continuous processing. *Figure 1* illustrates a system based on the new continuous sterilization process. Laboratory-scale and pilot-scale studies (Sivasothy and Rohaya, 2000; Sivasothy *et al*., 2000; 2002; 2005) demonstrated the technical and economic viability of the new process and a commercial-scale system was subsequently built in the MPOB Palm Oil Mill Technology Centre (POMTEC) in Labu.

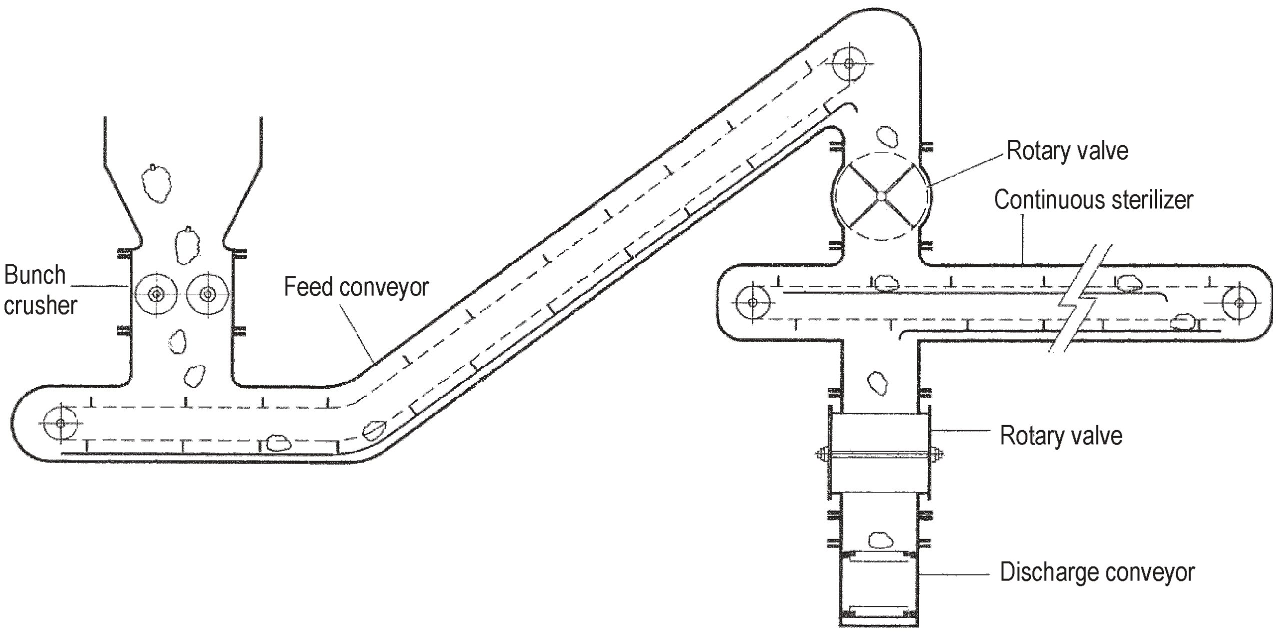

Figure 1. System for continuous sterilization.

To date, 16 palm oil mills are using the new process and another three mills are under construction (*Table 1*). The continuous sterilization process provides the impetus for new paradigms in the design and operation of palm oil mills. This paper examines the current status of its development and its impact on palm oil milling.

TABLE 1. MILLS USING CONTINUOUS STERILIZATION SYSTEM

Mill capacity (t hr^{-1})	Number of mills completed	Number of mills under construction	Total number of mills
5	6	-	6
10	5	1	6
12	1	-	1
15	1	-	1
20	2	1	3
45	1	1	2
Total	16	3	19

PROCESS EFFICIENCY

A total of three palm oil mills in Malaysia are completely based on the new continuous sterilization process (*Table 2*). *Tables 3* and *4* compare the performances of the two latest mills using the new process, *i.e.* Bukit Puteri Palm Oil Mill and Ladang Pasir Besar Palm Oil Mill, with other nearby mills. *Tables 5* and *6* show the average performance of Bukit Puteri Palm Oil Mill in July 2005. *Tables 7* to *9* show the day-to-day performance of the same mill from 1 August 2005 to 18 August 2005.

From *Tables 3* and *4*, it can be noticed that the oil extraction rate (OER) of Bukit Puteri Palm Oil Mill and Ladang Pasir Besar Palm Oil Mill appear to be among the best in their respective locations. The OER in Bukit Puteri Palm Oil Mill in August 2005 (*Table 7*) has been consistently maintained above 21% and has often been above 22%.

The kernel extraction rate (KER) of mills using continuous sterilization appears to be comparatively low (*Tables 2, 3* and *4*). Nevertheless, there are indications that this problem is being overcome. The KER in Bukit Puteri Palm Oil Mill (*Tables 5* and *7*) has climbed steadily over the period from April to August 2005 to reach a level comparable to conventional mills. The increase in KER appears to have been achieved mainly by drying the nuts prior to nut cracking and by reducing the kernel losses in wet shell.

Although the new process is carried out using steam at low or atmospheric pressure, the process significantly improves strippability of bunches. This has been observed in most mills using continuous sterilization. Only about 2% to 3% of bunches still have unstripped fruits (*Table 5*). The unstripped bunches have only a small percentage of the fruits originally present in fresh fruit bunches. There are none of the highly unstripped bunches that are commonly observed with the batch sterilization process. Nevertheless, it has been observed in some mills that the stripping efficiency of the drum stripper can be less than 100%. An attempt is being made to tackle this problem using a two-stage stripping process in Bukit Puteri Palm Oil Mill, with the bunches crushed using a roller crusher prior to the second stripping stage.

Oil loss in the sterilizer condensate from the continuous sterilization process is avoided by modifying the condensate discharge arrangements so that it is discharged together with bunches through the outlet valve.

Although the fruits from the continuous sterilization process appear to be not as well cooked as the fruits from the batch process, it can still be further processed using the conventional milling process. The moisture content and the oil content of the fibre in mills using continuous sterilization process were initially observed to be slightly higher than in the case of the batch sterilization process. Both of the mills mentioned above are using horizontal digesters to more effectively drain the free oil from the digester prior to pressing. The oil loss in press cake in Bukit Puteri Palm Oil Mill (*Tables 5* and *8*) has reached a level that is comparable to conventional mills. The lower oil loss appears to have been achieved at the expense of higher broken nuts in the press cake.

The oil content in press cake in Ladang Pasir Besar Palm Oil Mill was consistently maintained below 8% (dry basis) over the last few months.

The oil loss in the sludge from the clarification process in Bukit Puteri Palm Oil Mill (*Table 9*) appears to be higher than in a conventional mill. Day-to-day fluctuations in the amount of sludge discharged from the clarification process appear to be quite significant, possibly indicating that the operation of this plant has not yet been fine-tuned.

Oil loss in the sludge in POMTEC has been observed to be not significantly different from a conventional mill. The amount of sludge discharged from the clarification process in POMTEC increases from about 38% of the FFB processed for the batch sterilization process to about 43% for the continuous sterilization process. The difference in the clarification process performance between Bukit Puteri Palm Oil Mill and POMTEC may be due to differences in the equipment set-up between the two mills.

TABLE 2. PALM OIL MILLS USING CONTINUOUS STERILIZATION PROCESS IN MALAYSIA

Palm oil mill	State	Year commenced operation	Annual capacity (t FFB)	OER* (%)	KER* (%)
Melalap	Sabah	2003	96 000	23.05	3.73
Bukit Puteri	Pahang	2005	120 000	21.98	4.54
Ladang Pasir Besar	Negeri Sembilan	2005	60 000	20.02	5.01

Note: *Average performance in June 2005.

TABLE 3. COMPARATIVE PERFORMANCE OF BUKIT PUTERI PALM OIL MILL WITH OTHER NEARBY MILLS

Palm oil mill	District	Annual capacity (t FFB)	Capacity utilization+ (%)	OER+ (%)	KER+ (%)
Bukit Puteri*	Kuala Lipis	120 000	80.81	21.98	4.54
Kerdau	Temerloh	194 000	101.76	20.11	5.03
Mill A	Kuala Lipis	259 200	23.24	21.83	4.39
Mill B	Raub	240 000	87.11	19.39	5.87

Notes: * Commenced operation in March 2005.
+ Average performance in June 2005.

TABLE 4. COMPARATIVE PERFORMANCE OF LADANG PASIR BESAR PALM OIL MILL WITH OTHER NEARBY MILLS

Palm oil mill	District	Annual capacity (t FFB)	Capacity utilization+ (%)	OER+ (%)	KER+ (%)
Ladang Pasir Besar*	Tampin	60 000	39.51	20.02	5.01
Kota Bahagia	Rompin	160 000	99.33	20.26	5.12
Mill A	Tampin	350 000	98.74	19.32	5.97
Mill B	Tampin	120 000	47.03	19.54	5.45
Mill C	Jempol	360 000	75.53	18.10	4.93

Notes: * Commenced operation in February 2005.
+ Average performance in June 2005.

TABLE 5. AVERAGE PERFORMANCE OF BUKIT PUTERI PALM OIL MILL IN JULY 2005

Parameter	Average value
OER	20.91
KER	5.17
Mill throughput (t FFB hr^{-1})	15.90
Mill utilization (%)	61.89
Processing hours	389.40
FFB processed (t)	6 189
Oil produced (t)	1 303
Kernel produced (t)	320
Unstripped bunches (%)	2.97
Oil loss (Screw Press 1) (OCDB) (%)	9.03
Oil loss (Screw Press 2) (OCDB) (%)	8.96
Broken nuts in press cake (Screw Press 1) (%)	24.07
Broken nuts in press cake (Screw Press 2) (%)	23.93
Oil loss (Sludge Centrifuge 1) (OCWB) (%)	0.84
Oil loss (Sludge Centrifuge 2) (OCWB) (%)	0.91
Oil loss (Sludge Centrifuge 3) (OCWB) (%)	0.99
Oil in clarifier underflow (wet basis) (%)	3.46

TABLE 6. AVERAGE PERFORMANCE OF BUKIT PUTERI PALM OIL MILL IN JULY 2005

Parameter	Average value
Kernel loss in cyclone fibre (%)	2.20
Kernel loss in wet shell (%)	2.36
Kernel loss in dry shell (Winnower 1) (%)	1.55
Kernel loss in dry shell (Winnower 2) (%)	0.96
Cracking efficiency (Ripple Mill 1) (%)	97.35
Cracking efficiency (Ripple Mill 2) (%)	98.18
Admixture in production kernel (%)	4.19
Volatile matter in production kernel (%)	5.09
Broken kernel in production kernel (%)	28.56
FFA in production oil (%)	4.25
Volatile matter in production oil (%)	0.090
Dirt in production oil (%)	0.004

TABLE 7. DAILY PERFORMANCE OF BUKIT PUTERI PALM OIL MILL FROM 1 AUGUST 2005 TO 18 AUGUST 2005

Day	FFB processed (t)	OER	KER	Kernel in cyclone fibre (%)	Kernel in wet shell (%)	Kernel in dry shell (Winnower 1) (%)	Kernel in dry shell (Winnower 2) (%)
1	193.98	21.88	5.22	1.90	2.25	1.90	1.30
2	214.80	21.57	5.50	2.20	2.20	2.70	1.60
3	375.09	22.91	5.70	2.30	2.45	2.10	1.70
4	369.96	22.74	5.65	1.80	3.00	2.20	2.00
5	295.66	21.38	5.70	2.25	2.75	2.40	1.70
6	101.38	21.27	5.54	2.10	2.45	0.70	0.80
7	124.88	21.12	5.70	1.90	2.25	0.90	0.60
8	175.00	21.13	5.80	2.00	1.90	0.80	0.90
9	381.51	20.45	5.71	1.90	1.55	0.70	0.50
10	168.93	21.57	5.77	1.80	3.50	1.20	1.60
11	183.92	21.31	5.65	1.50	7.35	1.60	1.00
12	316.58	21.01	5.71	2.15	2.30	2.40	1.70
13	299.54	22.08	5.89	2.10	2.80	0.66	1.20
14	194.15	22.05	5.72	2.35	2.30	2.40	2.00
15	150.05	22.24	5.69	2.15	3.10	0.80	0.90
16	137.25	21.02	5.61	1.90	1.95	1.60	1.80

TABLE 8. DAILY PERFORMANCE OF BUKIT PUTERI PALM OIL MILL FROM 1 AUGUST 2005 TO 18 AUGUST 2005

Day	Oil loss (Press 1) (OCWB) (%)	Oil loss (Press 1) (OCDB) (%)	Oil loss (Press 2) (OCWB) (%)	Oil loss (Press 2) (OCDB) (%)	Oil loss (empty bunches) (OCWB) (%)	Broken nuts (Press 1) (%)	Broken nuts (Press 2) (%)
1	6.53	12.01	5.13	8.45	2.73	11.24	23.97
2	6.08	11.01	4.48	7.27	3.51	16.67	17.11
3	5.67	10.09	4.45	7.21	3.30	5.63	10.90
4	6.12	12.36	5.14	7.83	4.11	4.36	35.47
5	4.77	6.81	6.08	10.06	3.74	20.10	40.50
6	6.03	9.75	5.45	7.82	2.73	9.97	11.25
7	6.15	10.82	-	-	2.15	14.98	-
8	5.67	8.83	-	-	5.47	25.69	-
9	5.50	9.67	7.33	11.82	4.69	13.42	15.93
10	5.15	9.54	5.36	7.75	4.93	19.12	38.41
11	6.32	10.64	4.91	8.43	5.67	19.85	15.09
12	4.26	6.65	4.48	7.72	5.05	11.98	27.34
13	5.54	9.31	5.61	9.37	4.80	16.85	14.20
14	5.84	10.68	-	-	2.37	13.65	-
15	4.69	7.76	-	-	1.95	19.74	-
16	4.77	8.34	5.38	7.13	2.10	14.77	27.07

TABLE 9. DAILY PERFORMANCE OF BUKIT PUTERI PALM OIL MILL FROM 1 AUGUST 2005 TO 18 AUGUST 2005

Day	Oil loss (Centri-fuge 1) (OCWB) (%)	Oil loss (Centri-fuge 1) (OCDB) (%)	Oil loss (Centri-fuge 2) (OCWB) (%)	Oil loss (Centri-fuge 2) (OCDB) (%)	Oil loss (Centri-fuge 3) (OCWB) (%)	Oil loss (Centri-fuge 3) (OCDB) (%)	Oil loss in sludge (kg t^{-1} FFB)	Sludge produced (t t^{-1} FFB)
1	0.83	11.37	0.79	13.55	0.94	12.95	8.32	0.98
2	0.96	12.90	0.90	16.67	1.06	15.82	6.88	0.71
3	1.16	14.25	1.00	16.56	1.07	15.01	9.46	0.89
4	0.72	11.11	0.94	7.39	0.90	10.37	7.41	0.87
5	1.11	17.45	0.91	18.06	1.11	18.97	11.85	1.14
6	1.15	17.37	0.80	16.99	1.20	17.80	10.55	0.99
7	0.98	24.77	0.82	16.53	0.90	17.94	7.85	0.86
8	0.85	14.17	0.84	15.36	0.95	15.35	8.81	1.02
9	1.22	17.53	1.02	20.00	1.22	17.18	8.35	0.73
10	0.84	12.88	0.94	16.58	0.79	8.86	6.66	0.77
11	1.01	15.86	0.89	16.82	1.06	16.67	7.65	0.78
12	1.20	17.42	1.07	18.42	1.15	17.32	7.66	0.67
13	0.91	14.87	0.87	16.67	0.93	15.50	8.29	0.92
14	1.00	16.67	0.77	16.59	0.98	17.22	12.87	1.40
15	1.16	19.37	1.16	22.88	1.21	20.00	11.37	0.97
16	0.95	14.68	0.83	14.19	0.92	8.76	10.39	1.15

PROCESSING COST

By avoiding the use of much of the equipments used for batch sterilization, such as sterilizer cages, rail tracks, overhead cranes, tippers, transfer carriages and tractors, the maintenance cost of the section of the mill from the loading ramp to the stripper can be reduced significantly. It is estimated that the annual maintenance cost of this section in a conventional mill is in the range from RM 1.30 to RM 2.50 t^{-1} FFB.

Most continuous sterilization mills are comparatively new and have not yet undergone major repairs and maintenance. Disruption of the closed-knit arrangement of the spikelets in bunches in the new process is achieved using a double-roll crusher. The use of this crusher provides many advantages, including low maintenance and operating costs. Conveyor chains will require replacement after a few years operation. It is estimated that the annual maintenance cost of the continuous sterilization system should be about RM 0.72. This implies a reduction in maintenance cost of about RM 0.58 to RM 1.78 t^{-1} FFB processed.

The new process also leads to significant reduction in manpower requirements. *Table 10* shows that the manpower reductions are more significant for large-capacity mills. *Table 11* examines the savings in process labour cost in a mill processing 30 t of FFB hr^{-1} and handling a yearly crop of 144 000 t FFB. The mill process labour in a conventional mill is usually divided into two shifts of approximately 25 persons per shift. Depending on the monthly average wage, cost savings up to RM 3.13 t^{-1} FFB processed can be achieved by using the new process.

Table 12 shows the impact of operating mills 24 hr day^{-1} without stopping. Fixed cost, which is approximately 50% of the overall operating cost currently, is expected to reduce from RM 15 to RM 10 t^{-1} FFB processed. There will be no need to use diesel fuel if the mill can be operated 24 hr day^{-1}. The potential cost savings if the mill operates 24 hr day^{-1} will therefore be RM 8.60 t^{-1} FFB processed.

Table 13 shows that the overall potential cost savings that can be achieved by mills using continuous sterilization process is about RM 12.28 t^{-1} FFB processed.

TABLE 10. NUMBER OF PROCESS OPERATORS

Mill capacity	Batch sterilization	Continuous sterilization
10	15	8
20	20	10
30	25	-
45	30	15

TABLE 13. POTENTIAL PROCESSING COST SAVINGS DUE TO CONTINUOUS STERILIZATION

Parameter	Cost savings (RM t^{-1} FFB)
Reduction in process labour	2.50
24-hr mill operation	8.60
Reduction in sterilizer maintenance	1.18
Total cost savings	12.28

TABLE 11. IMPACT OF CONTINUOUS STERILIZATION PROCESS ON PROCESS LABOUR COST

Average monthly wage (RM)	Process labour cost (RM)		
	Batch sterilization^{+}	continuous sterilization^{++}	Cost saving (RM t^{-1} FFB)
750	450 000	180 000	1.88
1 000	600 000	240 000	2.50
1 250	750 000	300 000	3.13

Notes: $^{+}$ Based on 25 operators per shift.
$^{++}$ Based on 10 operators per shift.

TABLE 12. EFFECT OF SWITCHING FROM 16- TO 24-hr OPERATION PER DAY ON PROCESSING COST

Processing hours per day	FFB processed per year (t)	Mill utilization (%)	Fixed cost* (RM t^{-1} FFB)	Variable cost (RM t^{-1} FFB)	Diesel fuel cost (RM t^{-1} FFB)	Total processing cost (RM t^{-1} FFB)
16	144 000	67	15.00	11.40	3.60	30.00
24	216 000	100	10.00	11.40	nil	21.40

Note: * Fixed cost assumed to be 50% of total cost in a typical mill.

MILL OPERATION

The boiler pressure and back pressure of a mill using the continuous sterilization process fluctuate much less than in a conventional mill. By avoiding the use of multiple peak sterilization cycles, the steam demand remains approximately constant, thereby minimizing fluctuations in the steam pressure and electrical voltage and frequency. Such fluctuations would normally lead to problems such as higher product losses, poor product quality and reduced throughput.

One of the advantages of the new process is that the constant steam demand makes it unnecessary for periodic manual firing of the boiler to cope with fluctuations in steam demand. Manual firing of the boiler tends to upset the air/fuel ratio in the furnace and is an important factor responsible for black smoke emissions from boiler stacks.

In a conventional mill, sterilized bunches are fed from sterilizer cages to a hopper, and from this hopper to the stripping drum. Wide fluctuations are known to occur in the rate at which bunches are fed to the stripping drum, and this introduces problems for the stripper and the rest of the milling process. Stripping becomes less efficient if the stripping drum is overloaded. Wide fluctuations in flow cause the level of fruits in the digester to vary, making digestion less effective. In palm oil mills with multiple screw presses, the last screw press is often operated intermittently, making pressing less efficient. Nut/fibre separation is less effective if the depericarper column is subjected to wide load fluctuations. It will also be difficult to precisely control the amount of water added to the press liquour to optimize the oil/sludge separation during clarification.

Wide fluctuations in flow necessitate close process supervision to compensate for the disturbances/problems introduced by the fluctuations, making it difficult to achieve significant manpower reduction.

The ability to precisely regulate the flow bunches as they are discharged from FFB hoppers offers a number of advantages to the milling operation. The continuous sterilization process and the rest of the milling process can be operated at close to steady-state conditions throughout the day, making it unnecessary for operators to make frequent changes to compensate for the types of disturbances encountered in a conventional mill. This, not only makes significant manpower reduction possible, but also facilitates automation and reduces the loss of oil and kernel during processing.

Compared to the conventional palm oil milling process, it will be much easier to introduce an additional processing step for removing the trash from fresh fruit bunches as the bunches are being continuously conveyed. Removing the trash from bunches prior to processing offers a number of advantages:

- the removal of sand will lead to lower operating and maintenance costs and minimize disturbances to the milling operation; and
- quality of oil is likely to improve, since the presence of abrasive sand particles can lead to higher iron pick-up by the oil.

A trash removal system has been installed in POMTEC prior to continuous sterilization. Although this system is still being fine-tuned, it has been shown to be capable of removing up to 93% of the trash entering the palm oil mill.

AUTOMATION

A significant advantage of continuous sterilization over batch sterilization is that it renders the palm oil milling process a continuous operation from start to finish, making it cost-effective to automate the bunch handling operations. A plant-wide control system can be used to facilitate overall monitoring and control of the mill from a control room. Such a system has recently been installed in POMTEC (*Figure 2*). Automation to the scale undertaken in this project has never been previously attempted in palm oil mills.

The functions of the plant-wide control system installed in POMTEC are:

Real-Time Process Monitoring

All the important information pertaining to the status of equipment and processes are being monitored by the control system using animated process graphic and text displays. Real-time monitoring permits much more comprehensive and in-depth assessment of equipments and process performance and process dynamics than is possible manually.

Automatic Control

Control loops are used for all the critical process variables. Although control loops can be used to ensure that process parameters such as temperature and level are maintained at desired values, the added complexity and the cost of implementing such control loops can only be justified if there are tangible benefits. Until process analysis studies are able to confirm the benefits of automatic control, remote monitoring from the control room and periodic adjustments by field operators will be considered sufficient.

Centralized Motor Control

To promote greater automation and to facilitate monitoring and control of the mill from a control room, the plant-wide control system is used to monitor the on/off/trip status of all motors. The system also monitors the load on all equipments in the mill and provides alarms when the load is abnormally high.

The system is used for start-up and shutdown sections of the mill and to perform emergency shutdown if there is an abnormal condition.

Inverters are used for the more critical motors to facilitate changing the retention time and/or throughput from the control room.

Visual Surveillance

A CCTV system is used to monitor operations that need to be closely monitored but cannot yet be completely automated and to beef up security surveillance in the palm oil mill.

MILL DESIGN

The design of palm oil mills has not changed much since the 1950s. The breakthrough achieved in continuous sterilization, however, has provided the impetus to re-examine the design of palm oil mills. The use of technology that is simple and uncomplicated for continuous sterilization ensures that the system is competitively priced.

The new process eliminates the use of sterilizer cages, rail tracks, overhead cranes, tippers, transfer carriages and tractors and thereby facilitates the design and construction of mills having significantly smaller footprints than conventional mills. Palm oil mills designed using the new process are more easily managed than conventional mills.

Most palm oil mills in the past were designed without sufficiently addressing issues related to safety and cleanliness. Spillage of oil and fruits is quite common. Weaknesses in the design make it difficult to keep mills clean. Accidents in palm oil mills are quite common and can be fatal.

By avoiding the use of pressure vessels for sterilization, and cages and cranes for the handling of bunches, palm oil mills are made much safer for workers.

The use of conveyors for the handling of bunches also ensures minimum spillage of fruits and oil during processing making mills cleaner.

It is necessary to exercise good quality control during equipment fabrication and construction of the mill to minimize leakages from conveyors. If this can

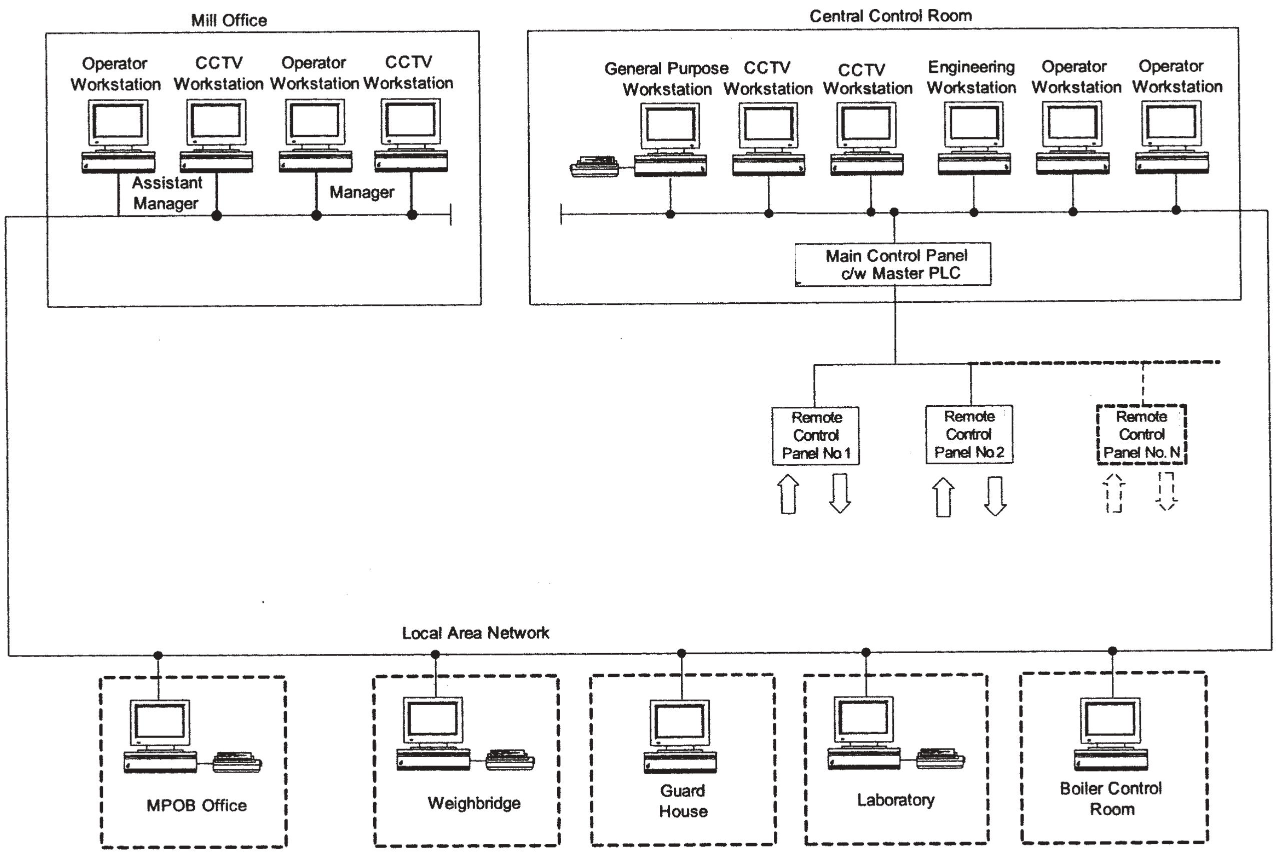

Figure 2. Plant-wide control system architecture.

be done, daily cleaning of mills, as practiced currently, may not be necessary and further manpower savings can be achieved.

It appears timely to take a more holistic approach to modernizing palm oil milling by capitalizing on the developments in continuous sterilization and automation, so that the new palm oil mills that are built will truly reflect the state-of-the-art in palm oil milling.

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