12-10 Energy Flow of Factory

12-10-1 Energy Flow

(1) Heat balance of kiln line

Calculation of the kiln line heat balance was carried out to analyze energy flow .

Table 12-25 Calculation of Heat Balance

Heat Intake

Items	Heat kcal/kg-cli.	(%)
(1) Heat of combustion of fuel	563.1	58.0
(a) Kiln fuel coal	170.4	
(b) F.F fuel oil	136.1	
(c) F.F fuel coal	256.6	
(2) Sensible heat of fuel	1.3	0.1
(a) Kiln fuel coal	0.4	
(b) F.F fuel oil	0.3	
(c) F.F fuel coal	0.6	
(3) Heat of combustion of material	361.6	37.2
(4) Sensible heat of material	20.4	2.1
(5) Sensible heat of primary air	1.5	0.2
(a) Kiln (primary air + coal conveying air)	0.4	
(b) F.F furnace (primary air + coal/shale conveying air)	1.1	
(6) Sensible heat of cooling air of coolers	22.9	2.4
Total (1)+(2)+(3)+(4)+(5)+(6)	970.8	100.0

Heat output

Items	Heat kcal/kg-cli.	(%)
(7) Heat for clinker burning	412.5	42.5
(8) Sensible heat taken away by clinker	25.9	2.7
(9) Sensible heat taken away by exhaust gas from cooler	145.2	15.0
(10) Heat of vaporization of water content in materials	9.5	1.0
(11) Sensible heat taken away by exhaust gas from preheater	315.1	32.4
(12) Sensible heat taken away by dust	10.2	1.0
(13) Heat loss due to radiation, etc.,	52.4	5.4
Total (7)+(8)+(9)+ (10)+(11)+(12)+(13)	970.8	100.0

Because of the usage of coal shale as clay materials in this works, there is a characteristic higher heat intake calorie of raw meal, at 361.6 kcal/kg-cli., which is approximately 37.2 (%) of the total heat intake. And the sensible heat of preheater and cooler exhaust gas are high, accounting for approximately 47.5 (%) of the total heat.

(2) Gas and heat energy flow of the whole plant

Based on the measurement results, it is very difficult to calculate the gas, material and heat balance of the whole plant. Therefore, this calculation was carried out in consideration of (a) kiln operation data under stable conditions, (b) measurement data of the energy audit and (c) existing data measured by works engineers, Table 12-24 shows the result thereof. And Fig 12-14 and Fig 12-15 show gas and heat energy flow respectively.

In terms of the calculation results, the following matters are evident.

1) Results of gas balance

a) The total leakage air volume of the whole process is around 29.5 (%) of the total exhaust gas volume.

b) Leakage air volume of the burning process is around 15.5 (%) of kiln line exhaust gas volume.

c) Leakage air volume at the cooler is around 28.2 (%) of cooler exhaust gas volume.

d) Compared with the conventional NSP, preheater exhaust gas volume is excessive, at 2.11 Nm^3/kg-cli.

2) Results of heat balance

a) Heat consumption of this kiln is rather high, at 924.7 kcal/kg-cli., compared with the conventional NSP kiln.

b) Fuel consumption of the kiln and F.F furnace is 170.4 kcal/kg-cli. and 754.3 kcal/kg-cli., respectively, that is, around 82 (%) of total fuel is burned in the F.F furnace. This fuel ratio is abnormal compared with the conventional NSP.

c) Sensible heat taken away by cooler exhaust gas totals 145.2 kcal/kg-cli., which is exhausted from use. Sensible heat of 149.2 kcal/kg-cli., which forms part of the sensible heat taken away by preheater exhaust gas, is utilized to dry raw material and coal. However, the remaining 165.9 kcal/kg-cli. is not utilized.

d) Cooler heat recovery efficiency is poor, at about 52.8 (%). This is caused by the poor recouped air volume for burning fuel in the F.F furnace., that is , the recouped air volume is low and the cooler exhaust gas volume is high.

Table 12-24 Gas, Material and Heat Balance Data < APMC Rawang Works >

Calculated based on operation data of 25/Feb. '98 and related measuring data

ITEM / PROCESS	Material (t/h)	Material (kg/kg-cli.)	Gas / Air (Nm^3/Min)	Gas / Air (Nm^3/kg-cli.)	Tg / Tm (℃)	Heat (kcal/kg-cli.)
(A) Clinker Production	**5,250** (t/day)					
	218.7	1.0000				
(B) Raw Material						
(1) Limestone	293.9	1.3439			55	
(2) Coal Shale	77.6	0.3548			72	
(1) + (2)	371.5	1.6987				
(C) Fuel						
(3) Kiln Fuel Coal	5.7	0.0261			59	170.4
(4) F.F Fuel Oil	3.1	0.0142			52	136.1
(5) F.F Fuel Coal	8.6	0.0393			59	256.6
(6) F.F Fuel Coal Shale	77.6	0.3548			72	361.6
Heat Consumption						**924.7**
(D) Cooler						
(7) Cooler Inlet	—	1.0719			(1350)	369.0
(8) Cooler Outlet	—	0.9685			141	- 25.9
(9) Cooler Quenching Air			7700	**2.1125**	35	22.9
(10) Secondary Air			760	0.2085	1226→900	- 62.6
(11) Tertiary Air			*1710	0.4601	* 825	- 128.5
(12) Exhaust Gas			*5250	1.4403	* 354	- 145.2
(13) Cooler-GBF leakage			2060	0.5652	35	(6.1)
(14) GBF Outlet	Fly Dust 35.2kg/h 90mg/Nm^3		7310	**2.0055**	(185)	(- 115.0)
Cooler Efficiency						**η=52,8(%)**
(E) Kiln						
(15) Kiln Fuel Coal	5.7	0.0261	—	—	59	170.4
(16) Primary Air	—	—	* 50	0.0137	32	0.1
(17) Coal Transport. Air	—	—	78	0.0214	40	0.4
(18) Kiln Inlet Gas	—	—	988	**0.2711**	1076→900	(Ref 87.7)
(a) Combustion Gas	—	—	705	0.1862	—	
(b) Excess/Leakage Air	—	—	283	0.0776	—	
(F) Preheater						
(19) F.F Fuel Oil	3.1	0.0142			52	136.1
(20) F.F Fuel Coal	8.6	0.0393			59	256.6
(21) F.F Fuel Coal Shale	77.6	0.3548			72	361.6
(22) Limestone	293.9	1.3439			55	—
(23) Primary Air			186			
(24) Coal Transport. Air			45	0.0853	40	1.1
(25) C/S Transport. Air			80			
(26) F.F Outlet Gas			6442	**1.7673**		
(a) Combustion Gas			4632	1.2708		
(b) Vco2 + H_2O			1130	0.3100		
(c) Excess/Leakage air			680	0.1866		

Note : * Measuring data during Energy Audit

ITEM / PROCESS	Material (t/h)	(kg/kg-cli.)	Gas / Air (Nm^3/min)	(Nm^3/kg-cli.)	Tg / Tm (℃)	Heat (kcal/kg-cli.)
(27) Preheater Outlet Gas			***7703**	**2.1133**	445	- 315.1
(a) Combustion Gas			5337	1.4644		
(b) $V_{CO_2} + H_2O$			1130	0.3100		
(c)Moisture in R.Meal			40	0.0110		
(d) Excess/Leakage air			1195	0.3278		
(e) Fly Dust	27.8	0.1271	—	—		- 10.2
(G) Coal Dryer / Mill						
(28) Hot Gas			410	**0.1125**	230	- 8.7
(a) P.H. Exhaust Gas			213	0.0585	420	
(b) Ambient Air			200	0.0549	35	
(29) Coal Mill	14.44	0.0660				
(a) Hot Gas			121	0.0332	230	
(b) Leakage Air			189	0.0519		
(c)Exhaust Gas			310	0.0851	75	
(30) Coal Dryer	15.2	0.0695				
(a) Hot Air			289	0.0793	230	
(b) Leakage Air			174	0.0478		
(c) Moisture of Coal			16	0.0043		
(d) Exhaust Gas			479	0.1314	75	
(H) Coal Shale Dryer / Mill						
(31) Coal Shale Dryer	90	0.4115				
(a) Hot Gas			2120	0.5816	436	-88.8
(b) Leakage Air			818	0.2244		
(c)Exhaust Gas			3180	0.8724	160	
(32) Coal Shale Mill	78.3	0.3580	305	0.0837	74	
(33) C/S Dryer/ Mill outlet			3485	**0.9561**		
(I) Limestone Mill			1283	0.3520	420	-51.7
(34) Roller Press/H-Mill	100	0.4572				
(a) Hot Gas			469	0.1286		
(b) Leakage Air			234	0.0642		
(c) Exhaust Gas			786	0.2156	75	
(35) Limestone Mill	260	1.1888				
(a) Hot Gas			814	0.2234	420	
(b) Leakage Air			244	0.0669		
(c)Moisture of L/stone			216	0.0593		
(d) Exhaust Gas			1274	0.3496	120	
(36) L/Stone Line Outlet			2060	**0.5651**		
(J) G.C.T						
(37) G.C.T Line						
(a) Hot Gas			4087	1.1213	420	-165.9
(b) Leakage Air			366	0.1002		
(c)Spray Water	50		934	0.2561		
(d) Exhaust Gas			5386	**1.4776**		
(K) E.P for Limestone (I)	Flydust	10.7kg/h	3700	1.0151	112	- 39.2
(L) E.P for Limestone (II)		15.4kg/h	3745	1.0274	130	- 46.7
(M) E.P for Coal Shale		1.27kg/h	3485	0.9561	140	- 46.8
(K) + (L) + (M)			**10930**	**2.9986**		- 132.7

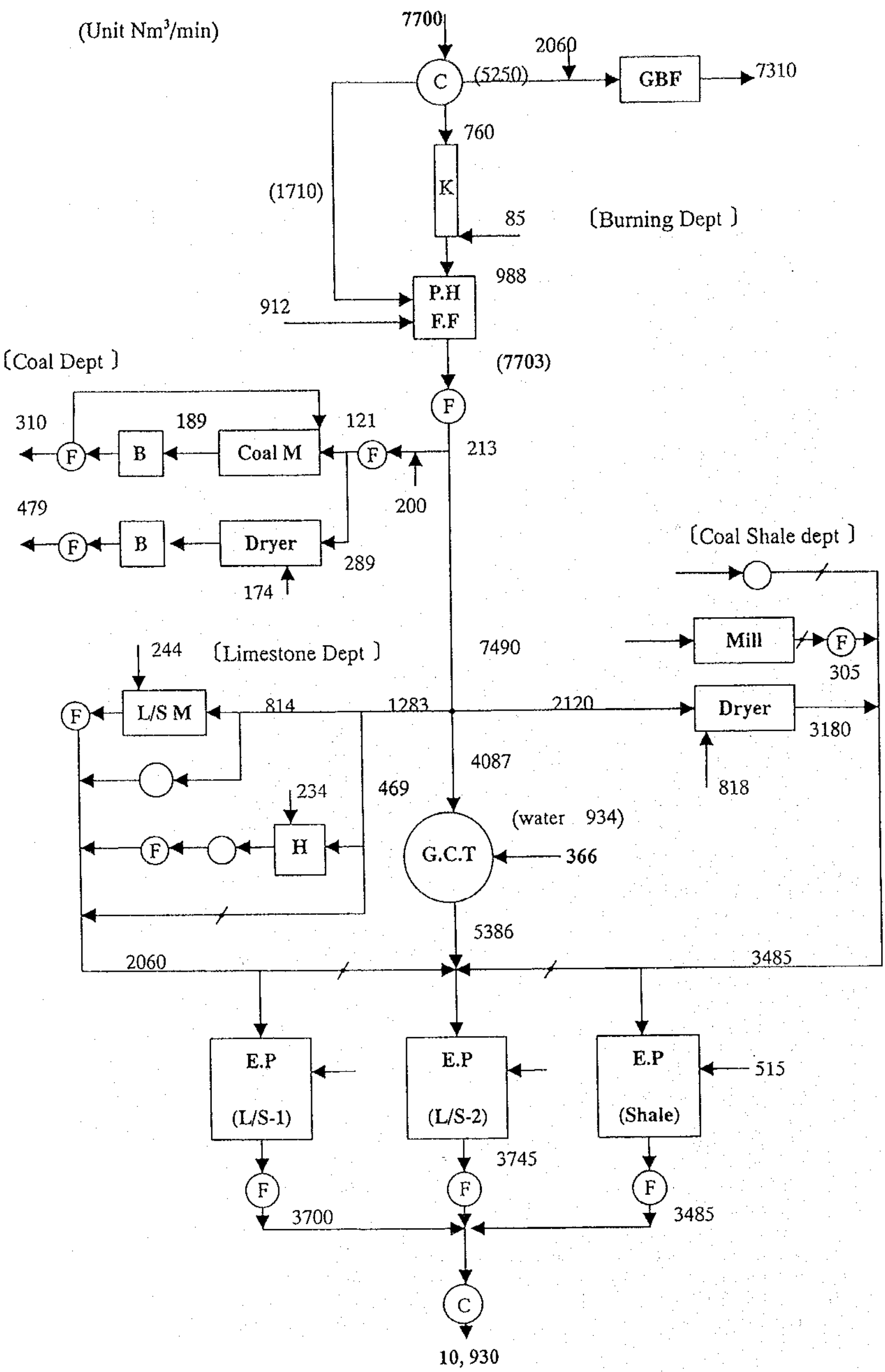


Fig. 12-14 Gas Flow Diagram

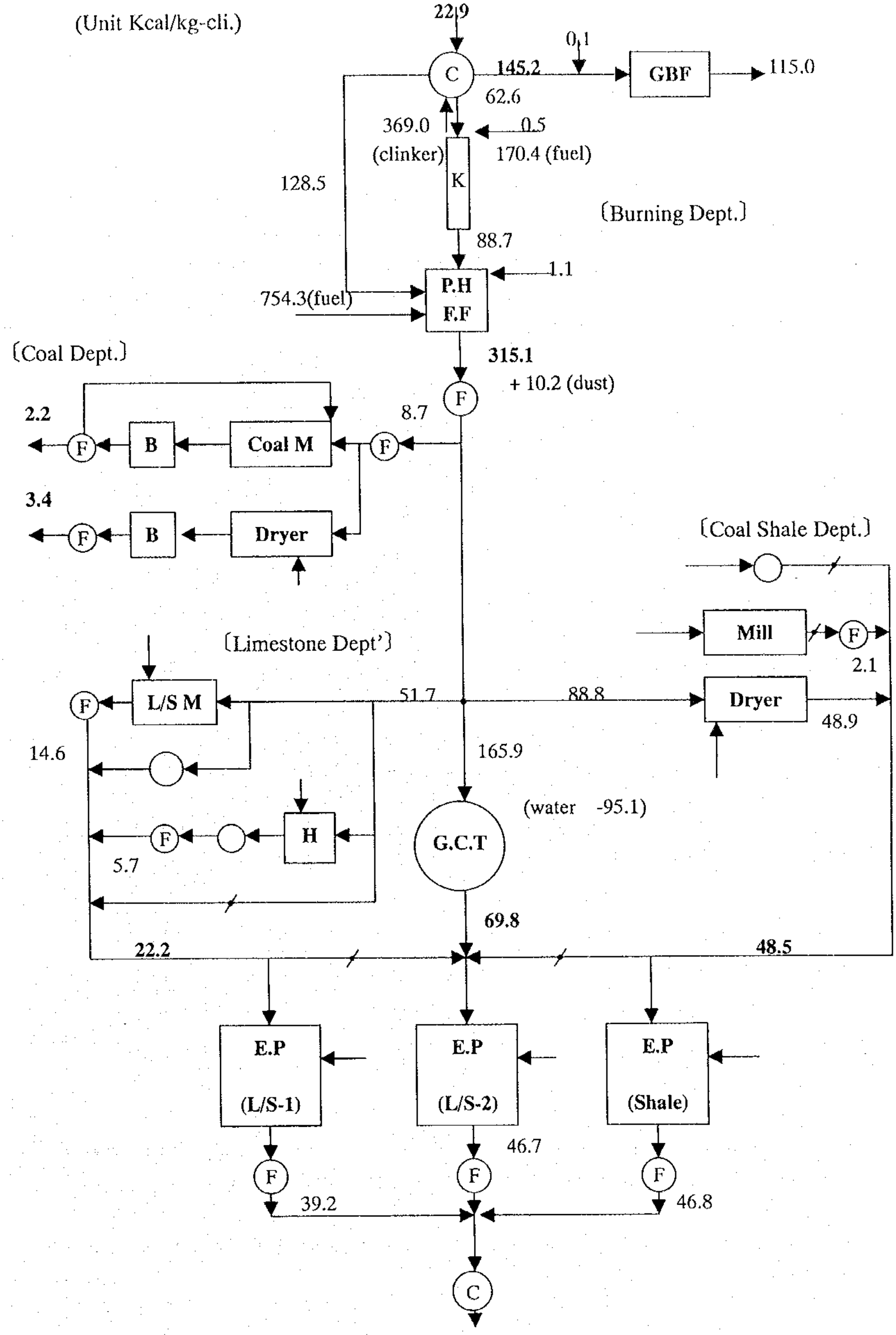


Fig. 12-15 Heat Flow Diagram

12-10-2 Energy Consumption

Trends in energy consumption of the APMC Rawang Works of Malaysia and the Cement Industry of Japan are shown in Table 12-10 and Table 12-28. Furthermore, trends in heat consumption and power consumption during the past 25 years in the Japanese cement industry are shown in Fig 12-18 and Fig 12-19. At the same time, recent heat and power consumption of each country comprises part of each figure.

Table 12-10 Malaysia APMC Rawang Works Data

Year	Cl. Production, (tonnes/year)	Ratio (%)	Kiln Opera-tion rate(%)	Heat Cons. (kcal/kg-cl.)	Power Con. (kWh/t-cem)	Labor Pro-ductivity(t/m)
1992	999,070	100	76.4	952	131.3	(1780)
1993	1120,055	112.3	82.9	1071	137.1	—
1994	1299,175	130.3	84.5	1124	138.9	—
1995	1474,031	147.8	86.1	984	129.8	—
1996	1554,895	155.9	87.1	912	130.3	—
1997	1560,055	156.5	88.6	915	134.2	2,786

Table 12-28 Trends of Energy Consumption in Japan
[Statistic Data of Japan Cement Industry]

Year	Cl. Production (1000 t/y)	Ratio (%)	Kiln Opera-tion rate(%)	Heat Con. (kcal/kg-cl.)	Power Con. (kWh/t-cem)	Labor Pro-ductivity (t/m)
1992	87,391	100	n.a.	730.5	95.3	12,459
1993	87,436	100.1	n.a.	724.3	95.4	12,798
1994	89,695	102.6	n.a.	725.6	94.4	13,681
1995	89,095	101.9	n.a.	728.0	95.1	15,282
1996	91,599	104.8	n.a.	709.6	95.8	17,338
1997	88,462	101.2	n.a.	683.1	97.8	16,824

Note: n.a. = not available

Energy consumption of the Malaysian cement industry is not conspicuous, however, energy consumption of APMC Rawang Works is very high compared with that of Japan, as we can see from this table.

And labor productivity, which bears no relation to energy efficiency, is lower than one sixth of that of Japan.

Differences in energy consumption are roughly as follows.

(1)	Heat consumption:	+ 210 kcal/kg-cli.
(2)	Power consumption;	+ 37 – 38 kWh/t-cem
	Raw Material Grinding Department:	+ 5 - 6 kWh/t-cem
	Burning Department:	+ 14 - 18 kWh/t-cem
	Cement Grinding Department:	+ 4 - 5 kWh/t-cem
	Others:	+10 – 11 kWh/t-cem

However, power consumption in each department varied considerably in accordance with the department's scope.

12-10-3 Energy Management, Energy Efficiency and Attendant Problems

It is fair to say that the energy consumption of a cement factory is determined by the general layout of the plant at the time of its construction; the selection of main facilities; and its design. Therefore, at the contract signing of a plant construction project, a guarantee of heat consumption and power consumption is normally requested.

Further, heat and power consumption are affected by the skill of operation and maintenance of machinery after construction.

The following matters on energy management and energy efficiency are points at issue in the case of this factory.

(A) Problems with plant

(1) Unlike a conventional cement plant, limestone raw material and coal shale as clay materials are ground separately, and stored in silos separately. Limestone raw meal drawn out from the silo is fed to the top cyclone inlet, while coal shale raw meal is fed to the F.F furnace in the preheater. This system in the Rawang Works is unique in the world. It is surmised that the reason for the higher heat consumption of this factory comes from the re-carbonation phenomena of powdery limestone fed to the cyclone preheater.

(2) Pneumatic conveyer systems are utilized for raw meal and cement transportation.

(3) For the treatment of cooler exhaust gas, a GBF (Gravel Bed Filter) is installed, which has a larger pressure loss and lower collecting efficiency.

(4) In spite of installing a vertical roller mill, which drys and grinds the coal at the same time after coal conversion, a coal dryer is also installed. This coal mill capacity is insufficient due to the increased kiln capacity.

(5) Modification of the preheater cyclone and F.F furnace for increased production and fuel conversion were insufficient, that is: (a) the inner volume of the F.F furnace is small and (b) the pressure loss of the cyclone preheater is large, etc.,

(6) 4 existing small-capacity mills remain and are still used.

(B) Problems with operation

(1) This plant is operating at 5000 t/d by modification from the initial design of 4000 t/d.

(2) At first, this kiln was operated by oil firing, but now it is coal-fired. However, after the above-mentioned modification, coal mill capacity was inadequate, necessitating partial use of coal.

(3) In relation to problems with the plant (A)-(1), the ratio of kiln fuel(Fk) to F.F furnace fuel(Fs), Fk/Fs, is normally 40/60, but in the case of this kiln, Fk/Fs is 18/82, that is, the fuel ratio of the F.F furnace is extremely high.

(4) In relation to problems with the plant (A)-(1), homogenization of kiln feed raw meal is poor due to the separate grinding and separate feeding of limestone and coal shale raw materials.

(5) The clinker cooler was replaced with the latest CFG cooler, however, heat recovery efficiency was inadequate.

(C) Problems based on the check list

Using the check list, the plant's existing facilities were investigated from an energy efficiency point of view, apart aside from the above problems. That is, according to Table 12-26 " Energy Efficiency Promotion --Checklist for existing equipment", the existing equipment and operating conditions of each department were checked by a 3-step evaluation of A (good), B (average) and C (poor) during the energy audit in cooperation with works engineers.
The following results were obtained in respect to a total of 172 check items.

A = 26 (16.4 %)
B = 94 (59.1 %)
C = 39 (24.5 %)

Apart from the conclusion obtained from Chapter 12-9 "Measuring Results", the problems concerning energy efficiency at the works were evident from these results. In particular, check items rated with C (poor) account for 25 % (39 items) of the total, and these matters should be carried out as the measures of energy efficiency promotion.

Fig. 12-18 Trend of Heat Consumption in Japan

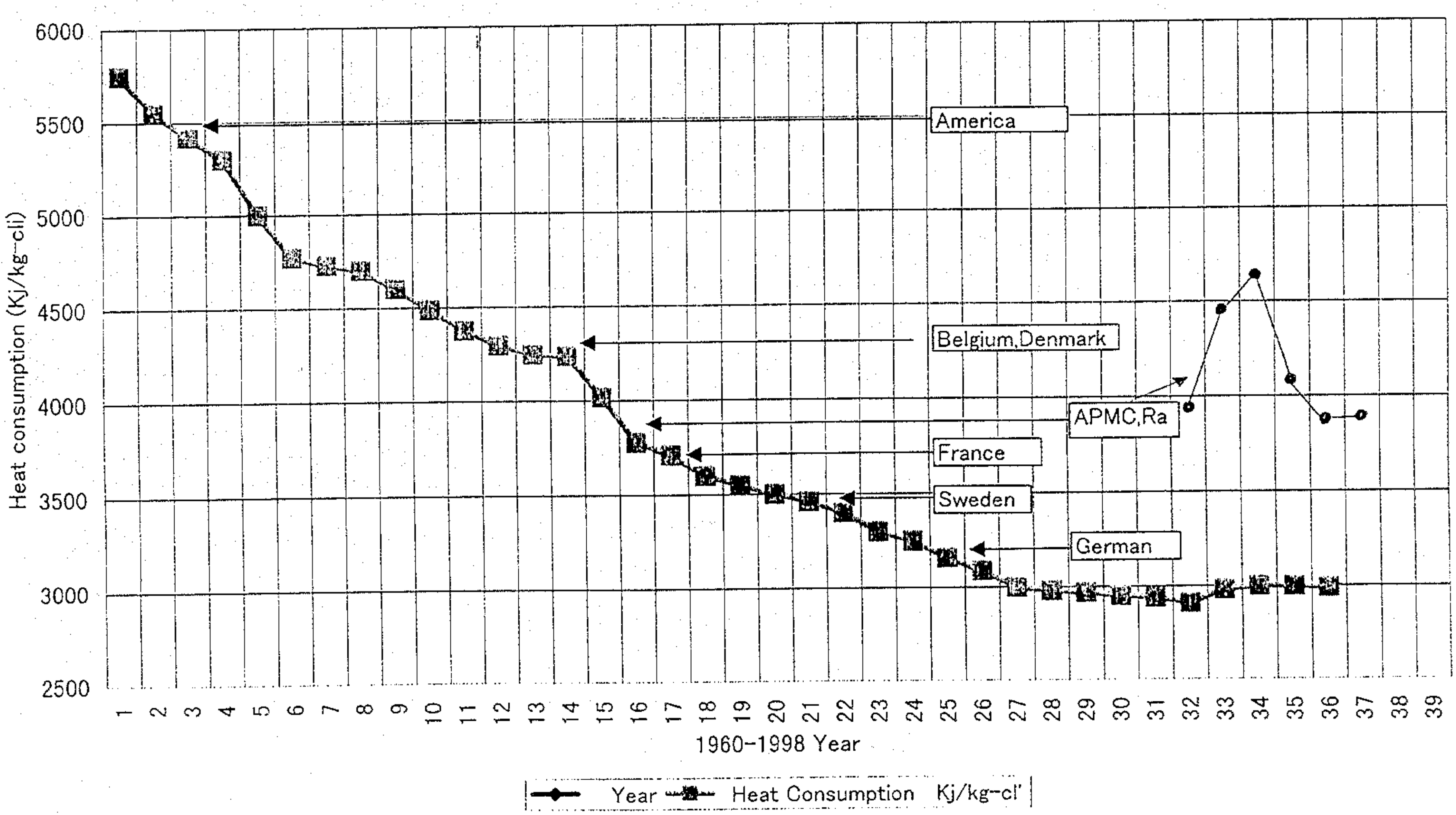


Fig. 12-19 Trend of Power Consumption in Japan

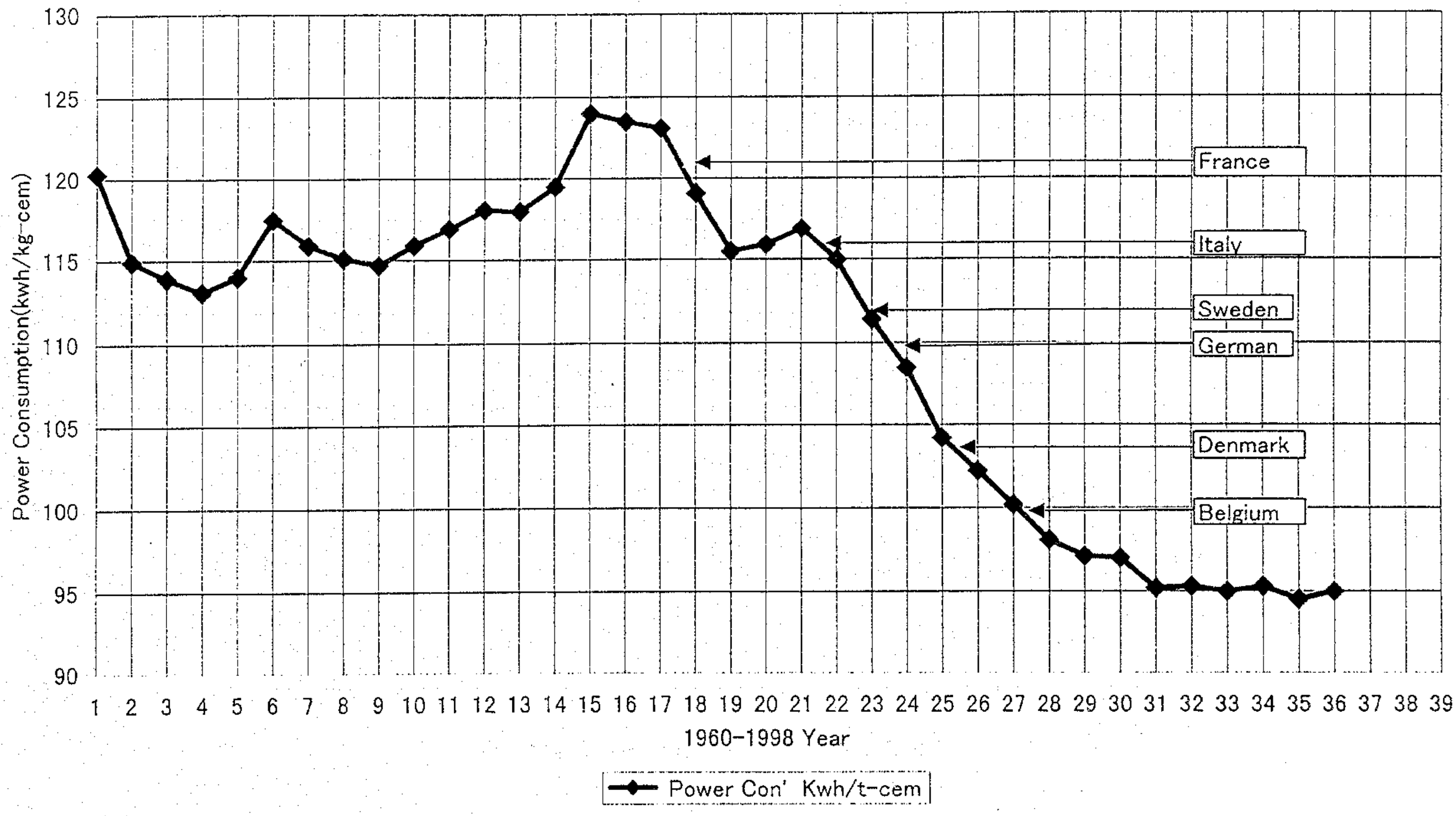


Table 12-26 Energy Efficiency Promotion – Checklist for Existing Equipment

(**A** Good or Yes ; **B** Normal or Ave ; **C** Bad or Nil)

Department / Equipment	Check Items	Result A, B, C,	Remarks
Raw Material Grinding Process	(1) Check air-leakage at mill department	B	Check for air-leakage
[1] Limestone Mill & Cyclone-Separator (CS)	(2) Check air-leakage at mill outlet	B	—ditto—
	(3) Adjust dedusting air in mill department	B	Check dusty spots
	(4) Check sufficiency of driving mill motor power	B	
	(5) Check current drawn by bucket elevator motor	B	
	(6) Check the wear condition of mill liners.	A	
	(7) Check grinding ball charge and gradation	A	
	(8) Check the presence of broken or worn out ball	A	2nd compartment
	(9) Check mill diaphragm slit condition (I comp)	A	
	(10) Check mill diaphragm slit condition (II comp)	A	
	(11) Check sufficiency of grinding ball charge	A	
	(12) Check reversal phenomena of grinding ball	A	Slit width Opening
	(13) Check whether width/opening ratio of slit is normal	B	Slit 14mm 13.6%
	(14) Check wear condition of CS blades/blade number	B	Partition 16mm 10.8%
	(15) Check rotational speed of CS is optimum	A	
	(16) Check V-belt tension of CS drive	—	Check V-belt slip
	(17) Check whether operation of circulating fan is normal	A	30Nm³/min/(t/h)
	(18) Check whether fineness of raw meal is normal	B	Coarse or fine
	(19) Check venting air damper opening is correct	B	Abt 20% of circulating air volume
	(20) Check dust accumulation inside circulating air duct / cyclone inlet	A	
	(21) Is cyclone flap damper movement normal	B	Check for air-leakage
	(22) Control moisture content in raw meal product	C	w=1.0-1.5(%)
	(23) Adjust conveying air volume of air slide	B	
[2] Roller Press	(24) Check air-leakage at crusher inlet	C	Check for air-leakage
	(25) Is cyclone flap damper movement normal	—	Check for air-leakage
	(26) Is fineness of raw meal normal	C	Coarse or fine
	(27) Control moisture content of raw meal product	C	
	(28) Adjust dedusting air of limestone silo	B	Check dusty spots

[3] Coal Shale Dryer	(29) Check air-leakage at dryer inlet	C	Check of air-leakage
	(30) Check air-leakage at dryer outlet	C	- Ditto -
	(31) Check whether exhaust gas temperature is normal	B	
	(32) Control moisture content at outlet of coal shale	C	w=1.0-1.5(%)
	(33) Check sufficiency of heat insulation of dryer	C	
[4] Coal Shale Mill & Cylone-Separator (CS)	(34) Check air-leakage at mill department	B	Check for air-leakage
	(35) Confirm air-leakage at mill outlet	B	〃
	(36) Adjust dedusting air in mill department	B	Check for dusty spots
	(37) Check sufficiency of driving mill motor power	B	
	(38) Check current drawn by bucket elevator motor	B	
	(40) Confirm the wear condition of mill liners	A	
	(41) Check grinding ball charge and gradation	A	
	(42) Check the presence of broken or worn out ball	A	
	(43) Check mill diaphragm slit clogging by grit	A	Ist compartment
	(44) Check mill diaphragm slit clogging by grit	A	2nd compartment
	(45) Confirm sufficiency of grinding ball charge	A	
	(46) Check reversal phenomena of grinding ball	A	width opennig
	(47) Check whether width/opening ratio of slit is normal	B	Slit 14mm 13.6%
	(48) Check wear condition / number of CS blade	B	Partition 16mm 10.8%
	(49) Check rotational speed of CS is optimum	A	
	(50) Check whether operation of circulating fan is normal	A	30Nm^3/min/(t/h)
	(51) Check whether fineness of coal shale meal is normal	B	Coarse or fine
	(52) Check venting air damper opening is correct	B	Abt 20% of circulating
	(53) Check dust accumulation inside circulating air duct	A	air volume
	(54) Check cyclone flap damper movement is normal	B	Check for air-leakage
	(55) Control moisture content of coal shale product	B	w=1.0-1.5(%)
	(56) Adjust conveying air volume of air slide	B	
	(57) Check the fluctuation in calorific value of coal shale	B	
Coal Grinding [5] Coal Dryer	(58) Check for air-leakage in gas duct lines	C	Check for air-leakage
	(59) Check air-leakage in Bag-Filter lines	C	〃
	(60) Check whether exhaust gas temperature is normal	B	
[6] Coal Grinding Mill	(61) Check whether setting of roller's oil pressure is proper	B	
	(62) Is height of dam-ring optimum ?	B	

	(63) Check whether the air intake area of B-Ring is optimum	B	
	(64) Check the relation between rotation speed of Sep' and pressure difference of mill is correct	B	
	(65) Check for air-leakage at mill and cyclone	B	Check for air-leakage
	(66) Check whether exhaust gas temperature is normal	A	
	(67) Check the wear condition of liner / roller	B	
	(68) Check whether coal grinding capacity is reduced	B	
	(69) Adjust dedusting air at conveying lines	B	check for dusty spot
	(70) Is fineness of pulverized coal normal?	B	90μ ±1.0%→±1.6kcal
	(71) Control pulverized-coal weigher accuracy	B	
Burning Process			
[7] Raw meal feeding Limestone R/M (From L/Stone silo to Preheater inlet)	(72) Adjust dedusting air at conveying lines	B	Check for dusty spots
	(73) Check for air-leakage at limestone feed point	B	Check for air-leakage
	(74) Is fineness of limestone meal normal ?	B	
Coal Shale R/M (From C/S silo to F.F furnace inlet)	(75) Adjust dedusting air at conveying lines	B	Check for dusty spots
	(76) Check for air leakage at coal shale feed point	A	Check for air-leakage
	(77) Is split feed of coal shale uniform rate ?	NA	
	(78) Is fineness of coal shale product normal ?	B	
[8] Preheater			
C1 Top Cyclone	(79) Check for cyclone deformation ,if any	A	Check for thermal Deformation of cyclone
	(80) Is execution of heat insulation good ?	C	
	(81) Is surface temp. of C1-cyclone normal ?	C	
	(82) Is adjustment of flap damper weight proper ?	B	Check for F/D movement
	(83) Check for air-leakage around C1-cyclone	C	Check for air-leakage
	(84) Is gas & meal temp. of C1-cyclone normal ?	C	tg=330-350℃
	(85) Is pressure loss across C1-cyclone normal ?	C	
C2 Cyclone	(86) Is surface temp. of C2-cyclone normal ?	C	
	(87) Is adjustment of flap damper weight proper?	B	Check for F/D movement
	(88) Check for air-leakage around C2-cyclone	B	Check for air-leakage
	(89) Is gas & meal temp. of C2-cyclone normal ?	C	tg=495-515℃
	(90) Is pressure loss across C2-cyclone normal ?	C	

C3 Cyclone	(91) Is surface temp. of C3-cyclone normal ?	C	
	(92) Is adjustment of flap damper weight proper ?	B	Check for F/D movement
	(93) Check for air-leakage around C3-cyclone	B	Check for air-leakage
	(94) Is gas & meal temp. of C3-cyclone normal ?	C	tg=635-655℃
	(95) Is pressure loss of C3-cyclone normal ?	C	
C4 Cyclone	(96) Is surface temp. of C4-cyclone normal ?	C	
	(97) Is adjustment of flap damper weight right ?	B	Check for F/D movement
	(98) Check for air-leakage around C4-cyclone	B	Check for air-leakage
	(99) Is gas & meal temp. of C4-cyclone normal ?	C	tg=760-770℃
	(100) Is pressure loss across C4-cyclone normal ?	C	
C5 Cyclone	(101) Is surface temp. of C5-cyclone normal ?	C	
	(102) Is adjustment of flap damper weight proper ?	B	Check for F/D movement
	(103) Check for air-leakage around C5-cyclone	B	Check for air-leakage
	(104) Is gas & meal temp. of C5-cyclone normal?	C	tg=865-875℃
	(105) Is pressure loss across C5-cyclone normal ?	C	
Top-IDF Inlet Duct	(106) Is execution of heat insulation good?	—	
	(107) Check for air-leakage at inlet duct of ID Fan	B	Check for air-leakage
	(108) Control the draft gas balance of IDF(1)/(2) lines	B	
	(109) Is fuel ratio between Fk/Fs correct ?	B	Fs≦60%
F.F furnace	(110) Is tertiary air flow (Nm³/min) enough ?	C	
	(111) Is fineness of pulverized coal suitable ?	B	
	(112) Check burning condition of fuel in F.F furnace	B	
	(113) Control O_2/CO% at outlet of F.F furnace	B	
	(114) Is combustion of coal shale complete ?	C	
[9] Kiln	(115) Is fuel ratio to kiln correct ?(Fk≧40%)	B	
	(116) Check sufficiency of thermal load per burning zone cross section (kcal/m3h)	B	Q≧3,5x10^{6kcal}/$_{m3h}$
	(117) Check whether burning zone temp. is enough	B	tg≧1450℃
	(118) Check sufficiency of clinker temp. at kiln outlet	B	tcl≧1300℃
	(119) Control O_2/CO% at kiln inlet hood	C	O_2=1.2-1.6(%)
	(120) Check whether the setting of kiln hood pressure is optimum	C	
	(121) Is burning condition of kiln burner good ?	C	
	(122) Check primary air flow rate	C	About 10-12(%)
	(123) Is fineness of pulverized coal suitable?	B	
[10] Cooler	(124) Is clinker load per grate area optimum ?	B	1.3-1.5 t/m²/h

	(125) Is total quenching air volume normal?	A	2.3-2.5Nm^3/kg-cl
	(126) Is quenching air flow for 1-3 chambers normal?	B	
	(127) Is cooler exhaust gas flow/temp. normal ?	C	1.45-1.55Nm^3/kg-cl
	(128) Control clinker temp. at cooler outlet	C	tcl=120-130℃
	(129) Check for air-leakage around cooler	C	Check for air-leakage
	(130) Adjust dedusting air on exhaust gas lines	B	Check for dusty spot
	(131) Control draft gas balance of cooler exhaust fan (1)/(2) lines	C	
	(132)Adjust dedusting air from conveying lines around clinker silo	B	Check for dusty spot
Cement Grinding			
[11] No1-3 Cement Grinding Mill	(133) Check sufficiency of driving mill motor power	B	
	(134) Check current drawn by bucket elevator motor	B	
	(135) Is mill sound level control optimum ?	NA	1st Ch S/L 105-107dB
	(136) Confirm the wear condition of mill liners	B	
	(137) Check the presence of broken or worn out ball	A	
	(138) Check mill diaphragm slit clogging by grit	B	
	(139) Check reversal phenomena of ball inside mill	A	
	(140) Check whether width/opening ratio of slit is normal	B	Width Opening
	(141) Check whether partition flow-control valve is normal	NA	Slit 6mm 6-8%
	(142) Is rotational speed of separator optimum	B	Partition 8-10mm8-10%
	(143) Check V-belt tension of CS drive	B	Check of V-belt slip
	(144) Check whether operation of circulating fan is normal	B	30Nm^3/min/(t/h)
	(145) Check whether fineness control of cement is normal	B	BL=3100cm^2/g
	(146) Check venting air damper opening is correct	B	Abt 20% of circulating
	(147) Check dust accumulation inside circulating air duct	B	air volume
	(148) Is cyclone flap damper movement normal ?	B	
	(149) Control cement temperature at mill outlet	B	tce=115-130℃
	(150) Control water injection inside mill	B	< Grinding Cap. x 1.0%
	(151) Check whether the use of grinding aids is optimum level	NA	Grinding Cap. x 0.02-3%
	(152) Adjust dedusting air in the mill department	B	Check for dusty spot

[12] No 4-5 Cement Grinding Mill	(153) Check sufficiency of driving mill motor power	B	
	(154) Check current drawn by bucket elevator motor	B	
	(155) Is mill sound level control optimum ?	NA	1st Ch S/L 105-107dB
	(156) Confirm the wear condition of mill liners	B	
	(157) Check the presence of broken or worn out ball	A	No4→A/No5→C
	(158) Check mill diaphragm slit clogging by grit	B	
	(159) Check reversal phenomena of ball inside mill	A	width opening
	(160) Check whether width/opening ratio of slit is normal	B	Slit 6mm 6-8%
	(161) Check whether partition flow-control valve is normal	NA	Partition 8-10mm8-10%
	(162) Is rotational speed of separator optimum	B	
	(163) Check V-belt tension of cyclone separator drive	—	Check of V-belt slip
	(164) Check whether operation of circulating fan is normal	B	$30Nm^3/min/(t/h)$
	(165) Check whether fineness control of cement is normal	B	$Bl.=3100cm^2/g$
	(166) Check venting air damper opening is correct	B	Abt 20% of circulating
	(167) Check dust accumulation inside circulating air duct	C	air volume
	(168) Is cyclone flap damper movement normal ?	B	Check of F/D movement
	(169) Control cement temperature at mill outlet	B	tcl=115-130℃
	(170) Control water injection inside mill	B	< Grinding Cap. x 1.0%
	(171) Check whether the use of grinding aids is at optimum level	NA	Grinding Cap. x 0.02-3%
	(172) Adjust dedusting air in the mill department	B	Check for dusty spots

Results of check of " Checklist for Existing Equipment " by APMC engineers and JICA team are :

A= 26 (16.4 %)

B=94 (59.1 %)

C=39 (24.5 %)

12-11 Measures for Energy Efficiency Promotion

As improvement items in respect to the problems described in Chapter 12-10-3, measures for energy efficiency promotion were selected specifically in terms of related equipment and operation etc. These items are shown in Table 12-27.

Table 12-27 Selected Measures for Energy Efficiency Promotion

Measures for Energy Efficiency Promotion	Purpose of saving	
	Power	Heat
< Process & Facility >		
1. Raw material department		
1-1 Limestone grinding process		
(1) Prevention of air-leakage at exhaust gas duct	◎	
1-2 Coal shale dryer		
(2) Prevention of air-leakage at dryer inlet and outlet	◎	
1-3 Coal shale mill		
(3) Prevention of air-leakage at mill exhaust gas duct	◎	
(4) Rationalization of transport system (Pneumatic→Mechanical)	◎	
2. Coal drying & grinding department		
2-1 Coal grinding mill/ Coal dryer		
(5) Construction of mill (Cap. 20 t/h x 1 set)	◎	◎
(6) Prevention of air-leakage at exhaust gas duct of dryer & mill	◎	
3. Burning department		
3-1 Raw meal feeding process		
(7) Coal shale raw meal→Change of transportation system to FF Feed Pump19.02-1A/1B/1C→BE/As transportation	◎	
(8) Change of feeding point of coal shale to F.F furnace Feeding to F.F furnace → To C3 or C4 cyclone		◎
(9) Change of feeding system of coal shale Pneumatic feed by FK pump → Cyclone/B.F/R.F system		◎
3-2 Preheater Cyclone		
(10) Reduction of pressure loss →Modification of C3/C4 cyclone	◎	
(11) Modification of C5 cyclone to maintain higher collecting eff.		◎
(12) Prevention of air-leakage → Total leakage 330-340Nm^3/min	◎	◎
(13) Adoption of waste heat boiler/ generator system	◎	◎
3-3 F.F furnace		
(14) Modification/ Enlargement of F.F furnace inner volume		◎
(15) Enlargement of tertiary air duct		◎
(16) Adoption of Venturi flow meter and control damper		◎
3-4 Kiln		
(17) Adoption of lifter brick at kiln backend part		◎
(18) Adoption of adjustable orifice at rising duct		◎
(19) Prevention of air-leakage at kiln hood and backend part		◎

Measures for Energy Efficiency Promotion	Purpose of saving	
	Power	Heat
< Process & Facility >		
3-5 Cooler (20) Adoption of waste heat boiler and generator (21) Replacement of cooler GBF to EP Prevention of air-leakage/ Easy control of kiln hood pressure, etc.	◎ ◎	◎
4. Cement Grinding department (22) Terminate No.1,2,3 cement mill operations Adopt Pre-Grinding system for No.4,5 cement mills (23) Adopt O-Sepa → Replace cyclone separator (24) Rationalize of transportation system (Pneumatic → Mechanical)	◎ ◎ ◎	
< Operation >		
1. Coal drying / grinding department (1) Terminate coal dryer operation → (Operate during dry season only) < Terminate raw coal transportation facilities and fans > Terminate F-1 / F-2 (Dryer) / F-3 Terminate bag filter process	◎	
2. Burning department (2) Change fuel ratio of kiln to F.F furnace Kiln / F.F = 18 / 82 → 42 / 58 (3) Change fuel from oil (partial use) to 100% coal firing (4) Reduce kiln rotation speed to maintain sound clinker quality	 ◎	◎ ◎
3. Cement grinding department (5) Adopt and use grinding aids	◎	

Selected measures for energy efficiency promotion consist of 24 items concerning process & equipment, and 5 items concerning operation, as mentioned above.

12-11-1 Prevention of Air-leakage

The air-leakage volume of each department was estimated from the measurement and investigated results. Results are as follows. (Please refer Fig 12-14, "Gas flow diagram", and Fig 12-24, "Gas, material and heat balance data", respectively.)

(1) Limestone grinding process (a) Roller press/hammer mill line ....234 m^3/min

(b) Limestone mill line ....244 m^3/min

(2) Coal shale dryer/ mill line ....818 m^3/min

(3) Coal dryer/mill process (a) Coal mill line ....189 m^3/min

(b) Coal dryer line ....174 m^3/min

(4) Preheater line ....147 m^3/min
(5) Kiln line ....85 m^3/min
(6) GCT (Gas Conditioning Tower) .... 366 m^3/min
(7) Cooler exhaust gas line .... 2,060 m^3/min
Total .... 4,317 m^3/min

Total air-leakage volume is around 39.5 (%) of the total exhaust gas volume (10,930 Nm^3/min). By reducing this air-leakage, it is possible to save approximately 825 kWh/h of electricity, that is 6,330,000 kWh per year,
The anticipated reduction in power consumption is around 3.8 kWh/t-cli., that is, (1) around 0.7 kWh/t-cli. in the Raw Material Department and (2) around 3.1 kWh/t-cli. in the Burning Department.

12-11-2 Rationalization of Transportation System

In this factory, pneumatic transportation facilities, that is, an FK pump and compressor, are installed for coal shale and cement transportation. Power consumption of these facilities is approximately 1493 kWh/h, and is about 2126 kW. as rated motor power.
By modifying this transportation system into a mechanical bucket elevator (BE) and air slide (AS) system, a considerable reduction in power consumption is expected, as described below. That is,

(1) Raw Material Department (coal shale transportation): Abt -140 kWh/h (Abt 0.6 kWh/t-cli.)
(2) Burning Department (coal transportation): Abt -275 kWh/h (Abt 1.2 kWh/t-cli.)
(3) Cement Grinding Department: Abt -825 kWh/h (Abt 3.5 kWh/t-cli.)
Total **- 1240 kWh/h = - 9,523,000 kWh/y (Abt 5.3 kWh/t-cli.)**

12-11-3 Mill Construction

Due to the insufficient capacity of the coal mill, about 3.1 t/h of fuel oil is used in the F.F furnace. This is equivalent to around 15 (%) of total heat energy. The fuel cost of oil is about double that of coal. Therefore, it is important to construct a coal mill that enables reduced fuel costs and does not require fuel oil.
The following two plans are considered as measures.

(1) Existing coal mill (Cap 12.0 t/h) + small vertical roller mill (Cap 7.5 t/h)

(2) Construction of new large vertical roller mill (Cap 21.0 t/h)

The measurement result of electricity required in the coal drying and grinding process is about 767 kWh/h at present. Adding to this, the 45 kWh/h electricity of the oil firing equipment gives a total of 812 kWh/h (3.73 kWh/t-cli.).

In the case of (1), power consumption will be approximately 6.0 kWh/t-cli., including electricity consumption of about 500 kWh/h for the small mill. In the case of (2), a dryer and related transportation equipment are not necessary. Therefore, power consumption will be around 820 kWh/h (3.76 kWh/t-cli.), which is similar to the present level.
The difference in power consumption of (1) and (2) is about 2.3 kWh/t-cli.

Therefore, in consideration of works rationalization and energy efficiency promotion, adoption of plan (2) is desirable.

12-11-4 Change of Feeding Point and Feeding System of Coal Shale

(1) From the results of differential thermal analysis (DTA) and thermogravimetric analysis (TG) of coal shale, it is deemed necessary to investigate changing the feeding point from direct feeding to the F.F furnace to the C4 cyclone inlet in consideration of coal shale burning conditions. This charge is expected to improve coal shale burning in the F.F furnace.

(2) Reduction of heat consumption by changing the coal shale feeding system from a pneumatic to a mechanical system:
Conveying air volume of coal shale 44 m^3/min x 2 lines → 72 Nm^3/min
Calculate reduction in heat consumption → replace above conveying air with high temperature recouped air.
75 Nm^3/min x 750℃ x 0.33 kcal/Nm^3℃ = 17,820kcal/min → 8,210 x 10^6 kcal/y
Conversion to coal: 8,210 x 10^6 kcal/y / 6,528 kcal/kg = 1,258 t-coal / y

12-11-5 Reduction of Cyclone Pressure Loss (Refer to Table 12-16)

(unit : mmAq)

Pressure loss of cyclone	Present (measured)	After modification(assumed)	Effect
C3 cyclone	240	160	80
C4 cyclone	190	160	30
C1～C5 cyclone	950	840	110

The effect of reducing pressure loss is calculated as a reduction of electricity consumption. The reduction of electricity consumption of the above pressure loss, 110 mmAq, corresponds to approximately 430 kWh/h (≒ 2.0 kWh/t-cli.)

This is expected to yield a saving of **approximately 3,300,000 kWh/y** in annual electricity consumption.

12-11-6 Improvement of C5 Cyclone Collecting Efficiency

As Table 12-16 shows, the collecting efficiency of the C5 (bottom) cyclone was poor, at η = 66.3 (%). Consequently, exhaust gas temperature of the C1(top) cyclone increased. Through modification to maintain the normal collecting efficiency, the following energy saving is expected.

	At present	After modification	Difference
(1) Loss of pressure	150 mmAq	210 mmAq	60 mmAq increase
(2) Drop of exhaust gas temp.	450℃	390－400℃	Abt 50-60℃ decrease

Increase of electricity consumption by pressure loss increase

230 kWh/h (= 1.05 kWh/t-cli.) .... **1,770,000 kWh/y**

Reduction of heat consumption by exhaust gas temperature decrease

2.11 Nm^3/kg-cli. x 50℃ x 0.315 kcal/Nm^3℃ = 33.2 kcal/kg-cli... 55,584 x 10^6 kcal/y

Conversion to coal (saving in quantity of coal) .... **Abt 8,510 t-coal/y**

12-11-7 Waste Heat Boiler / Generator System

Sensible heat taken away by exhaust gas from the preheater (315.1 kcal/kg-cli.) and from the cooler (145.2 kcal/kg-cli.) account for about 47.4 (%) of the entire heat intake. At present, around 30 (%) of this is utilized for dry raw materials and coal. The remaining 70 (%) of heat

intake is not used efficiently. Therefore, adopting a waste heat boiler / generator system is regarded as an effective utilization technology.
(Refer to Chapter 12-10-1 " Energy Flow")

This waste heat boiler / generator system technology has been already utilized at 50 (%) of cement companies in Japan .

Power generation capability in this works : 15,800 kW
Effective amount of power generation : 13,700 kW
Total amount of power generation per year : 101,007,000 kWh (assumed)

This figure corresponds to around 43.2 (%) of total electricity consumption (233,670,000 kWh) of the works in 1997.

12-11-8 Modification of F.F Furnace

As mentioned in Chapter 12-9-3 (1) "Combustion conditions of fuel in F.F furnace", around 35-40 (%) of unburned fuel is fed to the kiln with kiln feed raw meal, due to poor combustion in the F.F furnace. The causes of this are (1) around 35-40 (%) of recouped air volume is insufficient (2) retention time for fuel burning in the F.F furnace is short, about 1.5 seconds, due to the furnace's smaller inner volume.
The following measures for this are considered:

(a) Modification to enlarge the inner volume of the F.F furnace.
(b) Enlargement of the recouped air duct and adoption of a Venturi flow meter

However, in practice, it is very difficult to carry out these measures. And, even if the above mentioned measures are carried out, it is very difficult to estimate the improvement of combustion in the F.F furnace and the consequent energy saving.

12-11-9 Lifter Brick at Kiln Backend Part

As mentioned in Section 12-11-8, unburned carbon is fed to the kiln with kiln feed raw meal. One measure considered to burn this unburned carbon effectively is to line with lifter brick.
With the same objective, 23 kilns of the 74 kilns operating in Japan have adopted the lifter brick.
It is estimated that exhaust gas temperature decreases about 15℃ and heat consumption is reduced by **around 11.7 kcal/kg-cli.** as a result.

12-11-10 Replacement of Cooler GBF

Three kinds of precipitators for cooler exhaust gas are available: GBF (Gravel Bed Filter) which is used at present; BF (Bag Filter); and EP (Electrostatic Precipitator). However, with the GBF used at present, (1) collecting efficiency is bad, and (2) it is difficult to control the pressure of the kiln hood for reasons of its function. For reason (2) above, the gas flow rate of the kiln line and preheater line fluctuate, and operation of the burning process becomes unstable.

To maintain stability of the burning process, it is desirable to install an EP instead of the GBF.

As a result,

(a) Combustion of kiln and F.F furnace will be stable due to stability of the whole process. The consequent heat consumption saving is estimated at around 20 kcal/kg-cli. (30 x 109 kcal/y).

(b) It will be possible to prevent air-leakage of the cooler exhaust line (air-leakage quantity 2,060 Nm^3/min) and kiln hood. The reduction in electricity is estimated at approximately 3,000 kWh/d (960,000 kWh/y) by preventing this air-leakage.

(c) It will be possible to improve collecting efficiency. By reducing clinker fly dust, about 250 ton of clinker will be recovered annually.

12-11-11 Rationalization of Cement Grinding Process

Power consumption for cement grinding at this factory is high because of the tube mill and cyclone separator system. One of measures to reduce power consumption is to simplify the grinding process by introducing a pre-grinding mill.

There are two kinds of pre-grinding mill: (a) Vertical Roller Mill and (b) Roller Press, but it is desirable to adopt the Vertical Roller Mill considering its cheaper maintenance cost.

The following specific measures will be carried out:

(1) Terminate operation of No.1,2,3 mills (Cap 28 t/h each) and No.6 mill (Cap 15 t/h).

(2) Install a pre-grinding mill for No.4,5 mills (Cap 70 t/h each) to increase the capacity of each to 120 t/h each.

The adoption of a pre-grinding system is expected to reduce electricity consumption by **12,210,000 kWh/y**

12-11-12 Grinding Aids

This factory does not employ grinding aids. However, the small-scale use of these would increase grinding capacity and reduce the power used in the grinding mill. According to actual data of Japanese mills, the addition of grinding aids by 0.01(%) increases mill grinding capacity about 5 (%) and decreases power consumption about 5 (%).

Depending on the price of grinding aids, this technology should be investigated as a measure for energy efficiency promotion.

Effect of reducing power consumption (use of grinding aids : assumed as 0.02 %)

40.7 kWh/t-cem x 0.1 = 4.07 kWh/t-cem .... **7,500,000 kWh / y**

12-12 Selection of Energy Efficiency Promotion Technology

Among the energy efficiency promotion measures selected in Section 12-11, that is, (1) 24 items concerning the plant and (2) 5 items concerning the operation, the following 4 items have been selected as technologies that are sufficiently effective for energy efficiency promotion.

(1) Waste heat boiler / generator system

The waste heat boiler / generator system was selected for recovery of sensible heat of preheater exhaust and cooler exhaust gas. This system is composed of (1) a boiler to recover sensible heat of preheater exhaust gas, (2) a boiler to recover sensible heat of cooler exhaust gas and (3) a turbine,generator and condenser to convert steam generated by both boilers into electricity.

The following shows one example of the waste heat boiler / generator system adopted by this factory.

Boiler capacity of preheater side ....432,000 Nm^3/h at 445℃ →
Boiler capacity of cooler side..242,400 Nm^3/h at 350℃ →
Specification of turbine / generator ....15,800 kW
Condenser capacity ....76 t / h

A systematic diagram of a waste heat recovery power plant is show in Fig 12-20

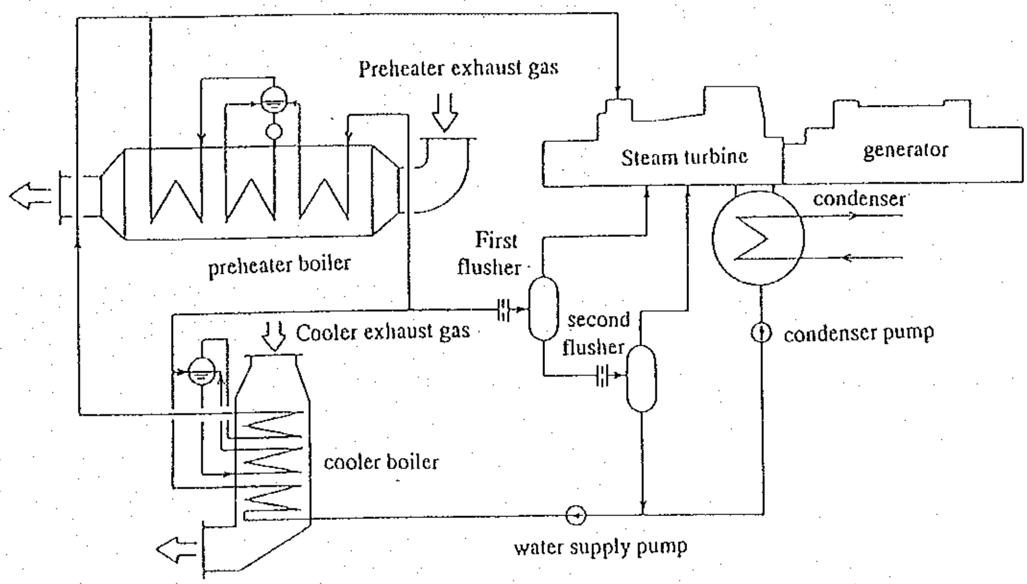


Fig. 12-20 Schematic Diagram of Waste Heat Recovery Power Plant with 2-Stage Flash System

(2) Pre-grinding system for cement grinding

Reduced electricity consumption and reduced repair and maintenance costs would result from rationalizing the existing cement grinding system. That is, terminate No.1,2,3 and No.6 mill, then install a pre-grinding system for No.4,5 mills.
This system is composed of (1) a pre-grinding mill and O-sepa separator and (2) O-sepa separators for each mill.

Capacities of this system are as follows

Pre-grinding mill (Type CKP-240) 500 t/h x 2,200 kW
O-sepa (Type N-3000) 3,000 m^3/min

(3) Construction of coal drying / grinding mill

The grinding capacity of the existing coal mill is small, therefore, expensive oil is used in the F.F furnace. To reduce cost by the 100 % use of coal, instead of oil, a coal drying / grinding system was selected. This system is composed of (1) a vertical roller mill for drying and grinding the coal, (2) a bag filter and (3) a set of pulverized coal weigher.

Capacities of this system are as follows.

Coal drying and grinding mill: Vertical Roller Mill UM20.2D 21.0 t/h x 340 kW
Bag Filter
A set of pulverized coal weighers

(4) Adoption of lifter brick

A lot of unburned carbon returns to the kiln due to poor fuel combustion in the F.F furnace of the preheater. To reduce heat consumption by maintaining efficient combustion of unburned carbon in the kiln, technology to line the lifter brick inside the kiln was selected.

12-13 Cost of Measures for Energy Efficiency Promotion

(1) Waste heat boiler / generator system

Amount of power generation: 15,800 kW
Effective amount of power generation: 13,700 kW

Price of equipment (incl. supervisor fee of construction / operation) ....2,400,000 Yen
Construction cost at site (incl. civil work fee) .... 600,000 Yen
Total .... 3,000,000 Yen
Assumed 31.05 ¥ / RM .... (96,618,000 RM)

(2) Pre-grinding system for cement grinding

Pre-grinding mill (KHI Type CKP-240 or equivalent) 500 t/h x 2200 kW
O-Sepa Type N-3000 / O-Sepa Type N-1000 x 2 sets

Price of equipment (incl. Supervisor fee of construction / operation) .... 1,050,000 Yen
Construction cost at site (incl. civil work fee) .... 1,150,000 Yen
Total .... 2,200,000 Yen
(70,853,000 RM)

(3) Construction of coal drying / grinding mill

Coal drying / grinding mill (UBE Type UM20.2D or equivalent) 21 t/h x 370 kW
Bag filter, fan, and a set of pulverized coal weighers

Price of equipment (incl. supervisor fee of construction / operation) ....595,000 Yen
Construction cost at site (incl. civil work fee) .... 355,000 Yen
Total ....950,000 Yen
(30,595,000 RM)

(4) Adoption of lifter brick

Execution of lifter brick lining 6 lines → 200 mm x 15 m
Price of brick and lining work fee ....10,000 Yen
(322,000 RM)

12-14 Potential of Energy Efficiency Promotion

(1) Waste heat boiler / generator system

Items		Preheater exhaust gas	Cooler exhaust gas
(1) Exhaust gas volume	(Nm^3/kg-cli.)	2.11	1.44
	(Nm^3/h)	432,000	242,400
(2) Gas temperature	(℃)	445	350
(3) Sensible heat of exhaust gas	(kcal/kg-cli.)	315.1	145.2
(4) Dust content	(g/Nm^3)	100	25
(5) Gas temperature at boiler outlet	(℃)	250	130
(6) Sensible heat of boiler outlet gas(kcal/kg)		89.0	40.4
(7) (3) – (6)		226.1	104.8
(8) Evaporation of steam	(kg/t-cli.)	285	64
	(t/h)	62.2	13.9

Total sensible heat of exhaust gas: 460.3 kcal/kg-cli.,

Recovery sensible heat by boiler: about 331 kcal/kg-cli.,

Amount of steam evaporation at boiler is about 76 t/h, and power generation by this steam is estimated at around 15,800 kW.

1) Average power generation (90 % : load factor) 14,200 kW
2) Power consumption of auxiliaries 500 kW
3) **Net power generation 13,700 kW**
4) Operation time per year 320 days
5) Total amount of power generation per year **101,007,000 kWh**

   13,700 kW x 24 h/d x 320 d/y x 0.96 = 101,007,000 (96 % : running factor)

In the electricity generated by this waste heat boiler / generator system, electricity that can be utilized as effective electric power in this factory corresponds to around 37.8 (%) of total electricity (233,670 000 kWh) in 1997.

(2) Pre-grinding system for cement grinding

Maintain grinding capacity of mills at 239-240 t/h by installation of a pre-grinding mill for No.4,5 cement mills (total grinding capacity : 140 t/h), after terminating No.1,2,3 and No.6 mills (total grinding capacity: 99-100 T/h)

Present power consumption of No.4,5 mills (Table 12-20)............................... 31.5 kWh/t-cem

Effect of capacity increase 70 t/h → 120 t/h 31.5 kWh/t-cem x 70/120 = 18.5 kWh/t-cem

Power consumption increase by installation of pre-grinding mill .... About 7.0 kWh/t-cem

Power consumption (kWh/t-cem) → Refer to Table 12-20

(Unit : kWh/t-cem)

	Present Power Con. (Mar.'98 – Aug.'98)	Existing No. 4,5 Mill system	Pre-grinding mill System
(1) Mill power consump.	32.1	31.5	18.5
(2) Related equipment	8.6	—	(8.6)
(3) Pre-grinding power	—	—	7.0
(4) Total power consump.	**40.7**	—	**34.1**

Saving potential of power consumption

(40.7 – 34.1) kWh/t-cem x 1,850,000 t/y = **12,210,000 kWh / y** → ≒ **1450 kWh/h**

(3) Construction of coal drying / grinding mill

Instead of oil, which is used partially at present, change to 100 (%) coal firing.

Oil consumption: 33,447 t/y (1997) → 0 (Refer to Table 12-8)

Substituted coal consumption: 33,447 t/y x 9584 / 6528 = 49,105 t-coal/y

By constructing a coal mill, coal can be made finer to the residue on 90μ from 10% to 5%, thanks to sufficient mill capacity. The anticipated effects of this are (a) heat consumption saving of around 15.5 kcal/kg-cli. and (b) power consumption increase of around 0.3 kWh/t-cli.

(a) Heat consumption saving: 15.5 kcal/kg-cli. x 5,200 t/d x 320 d/y = 25,792 x 10^6 kcal/y

Energy saving converted into coal: 25,792 x 10^6 kcal/y / 6,528 kcal/kg-coal = **3,950 t-coal/y**

(b) Electricity increase: -0.3 kWh/t-cli' x 5,200 t/d x 320 d/y = **499,200 kWh/y**

(4) Adoption of lifter brick

Preheater exhaust gas temperature decrease: about 15℃

Heat consumption saving: 2.11 Nm^3/kg-cli. x 0.37 kcal/Nm^3℃ x 15℃ = 11.7 kcal/kg-cli.

11.7 kcal/kg-cli. x 5200 t/d x 320 d/y = 19,468,800 x 10^3 kcal/y

Energy saving converted into coal : → 19,468,800 x 10^3 kcal/y / 6528 kcal/kg = **2982 t-coal/y**

12-15 Effectiveness of Energy Efficiency Promotion

(1) Waste heat boiler / generator system

The effective amount of power generation is 13,700 kWh/h and the total amount of power generation per year is 101,007,000 kWh. The effect of this follows.

(a)	kilowatt of max. demand	: 13,700 kW x 16.2 RM/kW x 12 m/y =	2,663,280	RM/y
(b)	Peak Period	: 101,007,000 kWh x 0.178 RM/kWh x 14/24 =	10,487,900	RM/y
(c)	Off-Peak Period	: 101,007,000 kWh x 0.098 RM/kWh x 10/24 =	4,124,450	RM/y
	Total	(a)+(b)+(c)	**17,275,630**	**RM/y**

(2) Pre-grinding system for cement grinding

Saving of electric power is 12,210,000 kWh/y (1,450 kWh/h). The effect of this follows

(a)	kilowatt of max. demand	: 1450 kW x 16.2 RM/kW x 12 m/y =	281,880	RM/y
(b)	Peak Period	: 12,210,000 kWh /y x 0.178 RM/kWh x 14/24 =	1,267,800	RM/y
(c)	Off-Peak Period	: 12,210,000 kWh /y x 0.098 RM/kWh x 10/24 =	498,580	RM/y
	Total	(a)+(b)+(c)	**2,048,260**	**RM/y**

(3) Construction of coal drying / grinding mill

The effect of rationalizing the Coal Drying and Grinding Department by adopting a big vertical roller mill (Cap, 21 t/h), is as follows.

(a)	Effect by reduced oil consumption	33,447 t/y x 422 RM/t	=14,114,630	RM/y
(b)	Loss by increased coal consumption	49,105 t/y x 135 RM/t	= 6,629,170	RM/y
(c)	Effect of reduced heat consumption owing to finer coal powder	3,950 t/y x 135 RM/t	= 533,250	RM/y
(d)	Loss by increased electric power consumption owing to finer coal powder			
	Peak Period	499,200 kWh/y x 0.178 RM/kWh x 14/24	= 51,830	RM/y
	Off-Peak Period	499,200 kWh/y x 0.098 RM/kWh x 10/24	= 20,380	RM/y
	Total	(a)- (b)+(c)-(d)	7,946,500	RM/y

(4) Adoption of lifter brick

Heat consumption reduction by adoption of lifter brick is as follows.

60,800,000 kcal/d x 320 d/y x 0.0208 RM/10^3 kcal = **404,685 RM/y**

12-16 Benefit of Measures for Energy Efficiency Promotion

In this section, benefits are estimated of the measures for energy efficiency promotion, based on the current price of energy in Malaysia.

12-16-1 Current Price of Energy for APMC Rawang Works

(1) Fuel

Table 12-29 shows the unit prices and heat values of fuels for APMC Rawang Works.

Table 12-29 Price and Heat Value of Fuel

	Heat Value (kcal/kg)	Unit Price (RM/ton)
Fuel Oil	10,200 (net 9,584)	422
Fuel Coal	6,800 (net 6,528)	135
Coal Shale	700	5.7

(2) Electricity

The current price of electric power conforms to category E-3 (special rate for qualified customers) of TENAGA NASIONAL's tariff, effective from May 1, 1997, in the case of APMC Rawang Works. The following rates are applied, according to this category of tariff.

- Peak load rate (between 800 and 2200 hours): 0.178 RM/kWh
- Off-peak load rate (between 2200 and 800 hours): 0.098 RM/ kWh
- Maximum demand charge: 16.2 RM/kW/month

12-16-2 Benefit of Measures

Table 12-29 summarizes the benefits of the measures recommended in section 12-15, based on the energy prices in Table 12-28.

Table 12-30 Benefits from Measures

Measures	Benefit (RM/year)
Waste heat boiler/generator system	17,275,630
Pre-grinding system for cement grinding	2,048,260
Construction of coal drying/grinding mill	7,946,500
Adoption of lifter brick	404,685

12-17 Financial Evaluation of Measures

In this section, financial evaluations are made for the following measures requiring investment and obtaining numerical benefits in order to ascertain the financial feasibility of the measures.

- Waste heat boiler/generator system
- Pre-grinding system for cement grinding
- Construction of coal drying/grinding mill
- Adoption of lifter brick

12-17-1 Method of Financial Evaluation

(1) Applied Method

Two different methods, both widely used and accepted for financial evaluation of the investment projects, are applied in the study. The first method is the payback period method to calculate the payback period, defined as the period required to recover the investment outlay through the accumulated net cash flows earned by the project. The second method is the internal rate of return (IRR) method on a discounted cash flow basis. The Financial Internal Rate of Return on Investment (FIRROI) is defined the discount rate for which the present value of net receipts from the project is equal to the present value of the investment.

(2) Payback Period

Net cash flow is defined as follows:

1) Increased Sales Revenue
2) Less: Fixed Investment
3) Less: Pre-production Expenditure
4) Less: Increase in Net Working Capital
5) Less: Increased Operating Costs
6) Less: Increased Marketing Costs
7) Less: Increase in Corporate Tax Paid

In the case of investment for improved energy efficiency, the change in sales revenue and marketing cost should be zero. The changes in net working capital and pre-production expenditure are negligible for the case of a project for improved energy efficiency. Fixed investment was estimated in the previous section. Changes in operating costs, which consist mainly of changes in utility bills such as electricity and fuel, were also estimated. Corporate tax change is calculated based on the change in taxable profit due to changes in operating costs in consideration of the country's tax rate, and depreciation system.

When calculating the payback period, a cash flow table starting from the construction period to the operating period is created. Accumulated net cash flow is negative during construction due to fixed investment and pre-production expenditure, however it will increase by the recovery of capital and become zero in a certain year. The payback period is defined as the period from the start of operation until the year when the cumulative net cash flow is zero.

(3) Internal Rate of Return (IRR)

The calculation procedure begins with the preparation of a cash flow table in the same way as the payback period method. Then, the discount rate when the cumulative net cash flow of the project becomes zero is obtained by trial-and-error. The discounted rate thus obtained is the Financial Internal Rate of Return on Investment (FIRROI).

12-17-2 Premises for Financial Evaluation

Financial evaluations are made on the following premises.

1) Exchange rate: US$ 1 = RM 3.8 ; US$ 1 = JY 118

2) Project life: 15 years from the start of operation

3) Corporate tax rate: 30 percent

4) Depreciation: The straight-line method is applied. The depreciation period is 15 years for the plant and machinery.

5) Fixed investment: Table 12-31 summarizes the fixed investment cost for the measures.

Table 12-31 Fixed Investment Cost for Measures

Measures	Fixed Investment Cost (RM)
Waste heat boiler/generator system	96,618,000
Pre-grinding system for cement grinding	70,853,000
Construction of coal drying/grinding mill	30,595,000
Adoption of lifter brick	322,000

12-17-3 Results of Financial Evaluation

Table 12-32 shows FIRROI before tax, FIRROI after tax and the payback period for the measures. Estimated cash flow tables for these measures are presented in Tables 12-33 through 12-36.

Table 12-32 Results of Financial Evaluation

Measures	FIRROI before tax	FIRROI after tax	Payback Period
Waste heat boiler/generator system	15.9%	11.8%	6.9 years
Pre-grinding system for cement grinding	- 9.0%	- 5.7%	n.a.
Construction of coal drying/grinding mill	25.1%	18.6%	5.0 years
Adoption of lifter brick	125.7%	90.0%	1.1 years

Table 12-33 Cash Flow Table (Measure: Waste Heat Boiler/Generator System)

Unit: Thousand RM

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Less: Fixed investment	96,618	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276
Less: Corporate tax increased	0	3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250
Incremental Cash Flow (before Tax)	-96,618	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276	17,276
Incremental Cash Flow (After Tax)	-96,618	14,025	14,025	14,025	14,025	14,025	14,025	14,025	14,025	14,025	14,025	14,025	14,025	14,025	14,025	14,025
Cumulative net cash flow	-96,618	-82,593	-68,567	-54,542	-40,517	-26,492	-12,466	1,559	15,584	29,610	43,635	57,660	71,686	85,711	99,736	113,761
Depreciation	0	6,441	6,441	6,441	6,441	6,441	6,441	6,441	6,441	6,441	6,441	6,441	6,441	6,441	6,441	6,441

Table 12-34 Cash Flow Table (Measure: Pregrinding System for Cement Grinding)

Unit: Thousand RM

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Less: Fixed investment	70,853	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048
Less: Corporate tax increased	0	-803	-803	-803	-803	-803	-803	-803	-803	-803	-803	-803	-803	-803	-803	-803
Incremental Cash Flow (before Tax)	-70,853	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048	2,048
Incremental Cash Flow (After Tax)	-70,853	2,851	2,851	2,851	2,851	2,851	2,851	2,851	2,851	2,851	2,851	2,851	2,851	2,851	2,851	2,851
Cumulative net cash flow	-70,853	-68,002	-65,151	-62,300	-59,450	-56,599	-53,748	-50,897	-48,046	-45,195	-42,345	-39,494	-36,643	-33,792	-30,941	-28,090
Depreciation	0	4,724	4,724	4,724	4,724	4,724	4,724	4,724	4,724	4,724	4,724	4,724	4,724	4,724	4,724	4,724

Table 12-35 Cash Flow Table (Measure: Construction of Coal Drying/Grinding Mill)

Unit: Thousand RM

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Less: Fixed investment	30,593	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946
Less: Corporate tax increased	0	1,772	1,772	1,772	1,772	1,772	1,772	1,772	1,772	1,772	1,772	1,772	1,772	1,772	1,772	1,772
Incremental Cash Flow (before Tax)	-30,593	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946
Incremental Cash Flow (After Tax)	-30,593	6,174	6,174	6,174	6,174	6,174	6,174	6,174	6,174	6,174	6,174	6,174	6,174	6,174	6,174	6,174
Cumulative net cash flow	-30,593	-24,419	-18,244	-12,070	-5,895	279	6,453	12,628	18,802	24,977	31,151	37,325	43,500	49,674	55,849	62,023
Depreciation	0	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040

Table 12-36 Cash Flow Table (Measure: Adoption of Lifter Brick)

Unit: Thousand RM

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Less: Fixed investment	322	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405
Less: Corporate tax increased	0	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115
Incremental Cash Flow (before Tax)	-322	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405
Incremental Cash Flow (After Tax)	-322	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290
Cumulative net cash flow	-322	-32	257	547	837	1,127	1,416	1,706	1,996	2,285	2,575	2,865	3,155	3,444	3,734	4,024
Depreciation	0	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21

12-17-4 Conclusion of Financial Evaluation

According to the information obtained during the field survey, the lending rate in Malaysia has been ranging from 12 to 14% per annum recently. This rate could be regarded as an indication of the opportunity cost of capital in Malaysia.

A waste heat boiler/generation system would generate the largest benefit among the recommended measures, at RM 17,275,630 per year, although it requires the largest amount of fixed investment cost, RM 96,618,000. FIRROIs before tax and after tax are 15.9% and 11.8%, respectively. Its payback period is estimated at 6.9 years. It could be said that this measure is at a marginal level of financial feasibility under the conditions set for the study.

A pre-grinding system for cement grinding would generate only a small benefit in terms of energy saving. Capital investment cannot be recovered in 15 years and FIRROIs show negative values. It is concluded that this measure is not financially feasible.

Construction of a coal drying/grinding mill has sound financial feasibility, as FIRROIs before and after tax are 25.1% and 18.6%, respectively. The payback period is 5 years, which is considered to be in the reasonable range. It would be fair to say that this measure is financially feasible.

Adoption of lifter brick has excellent financial feasibility, with a 1.1-year payback period and quite high FIRROI. A low investment cost of RM 322,000 is the advantage of this measure.

12-18 Recommendations for Energy Efficiency Promotion

Based on the energy audit and subsequent study for APMC Rawang Works, the following measures are recommended for improving its energy efficiency.

(1) Measures for Energy Efficiency Promotion based on Financial Evaluation

Among the four measures selected in section 12-12, the following three measures are recommended, based on the results of the financial evaluation.

(a) Waste Heat Boiler/Generation System

This measure enables the recovery of sensible heat of preheater exhaust gas and cooler exhaust gas. This system is composed of (1) a boiler to recover sensible heat of preheater exhaust gas, (2) a boiler to recover sensible heat of cooler exhaust gas, and (3) a power generator system consisting of a turbine, a generator and a condenser. It could be said that this measure is at a marginal level of financial feasibility under the conditions set for the study. It is recommended that a detailed investigation be conducted for this measure.

(b) Construction of Coal Drying/Grinding Mill

Expensive fuel oil is used in the F.F furnace together with coal, because of the limited capacity of the existing coal mill. The recommended measure is to construct a coal drying/grinding mill that is composed of (1) a vertical roller mill for drying and grinding the coal, (2) a bag filter, and (3) a set of pulverized coal weighers. By this measure, all the fuel oil used in the factory will be shifted to coal, resulting in fuel cost saving. In addition, combustion efficiency will be improved by combustion of fine coal powder. It could be said that this measure is financially feasible. It is recommended that a coal drying/grinding mill be constructed.

(c) Adoption of Lifter Brick

The energy audit revealed that a lot of unburned carbon is returned to the kiln because of poor fuel combustion in the preheater F.F furnace. It is recommend that the inner wall of kiln be lined with lifter brick so that heat consumption can be reduced by maintaining efficient combustion of unburned carbon from the preheater F. furnace. This measure is recommended, as it is excellent in terms of financial feasibility.

(2) Other Measures for Energy Efficiency Promotion

(a) Prevention of Air-leakage

During the energy audit, air leakage was observed from various locations in the plant such as the limestone grinding process, coal shale dryer/mill line, coal dryer/mill process, preheater line, kiln line, gas conditioning tower, and cooler exhaust gas line. Total air leakage volume is estimated at around 39.5% of the total exhaust gas volume. 3.8 kWh/ton-clinker of power saving is anticipated by reducing this air leakage. It is recommended that this measure be investigated.

(b) Rationalization of Transportation System

Currently, coal shale and cement are transported by pneumatic transportation facilities such as an FK pump and compressor. By modifying this transportation system into a mechanical bucket elevator and air slide system, about a 5.3 kWh/ton-clinker power saving is expected. Further investigation is recommended for this measure.

(c) Change of Feeding Point and Feeding System of Coal Shale

From the results of differential thermal analysis (DTA) and thermogravimetric analysis (TG) of coal shale, it is deemed necessary to investigate changing the feeding point from direct feeding into the F.F furnace to the C4 cyclone inlet, in consideration of coal shale burning conditions.

In addition to this, it is recommended that the feeding system of coal shale be changed from a pneumatic to a mechanical system. 1,258 ton-coal/year of heat saving is expected by this measure.

(d) Improvement of C5 Cyclone Collecting Efficiency

It was observed that the collecting efficiency of the C5 (bottom) cyclone was poor. Consequently, exhaust gas temperature of the C1 (top) cyclone increased. By improving the collecting efficiency, 8,510 ton-coal/year of heat saving is expected through exhaust gas temperature reduction, although electricity consumption would increase by 1,770,000 kWh/year due to an increased pressure drop. This measure is recommended.

(e) Replacement of Cooler GBF

It is suggested that investigation be made into the replacement of the existing Gravel Bed Filter (GBF) with an Electrostatic Precipitator (EP) for cooler exhaust gas. By this measure, the following benefits are expected.

- About a 20 kcal/kg-clinker heat saving by stable combustion in the kiln and F.F. furnace
- Approximately 960,000 kWh/year of electricity saving by preventing air leakage from the cooler exhaust line and kiln hood, and
- About 250 ton of clinker recovery by improving collecting efficiency

It is recommended that this measure be investigated further.

(f) Grinding Aids

It is recommended that investigation be made into the use of grinding aids, although the economics of the measure depend on its price in Malaysia. 7,500,000 kWh/year of power saving is expected at the grinding mill, assuming a 0.02% addition of grinding aids.

Chapter 13 Food Processing

13-1 Outline of Food Processing Factory Energy Audit

During the first field survey carried out in February 1998, the JICA study team decided to conduct the energy audit at Central Sugar Refinery Sdn Bhd as the candidate factory of the food processing industry. There are various types of energy consumption in this factory, such as utilization of light fuel oil, generated steam and electrical power.

This factory started operation at a capacity of 150 ton-melt raw sugar per day in October, 1965, and is now producing 1,300 ton-melt per day. It has the second largest production capacity, accounting for 30 per cent of the total among Malaysia's four sugar refinery factories.

13-2 Characteristics of Refined Sugar Factory

There are four main factories producing refined sugar in Malaysia, as shown in Table 13-1. The production share of Central Sugar Refinery in the sugar refinery sub-sector is about 30 per cent.

Table 13-1 Rated Capacity of Sugar Refinery Sub-sector

Factory	Rated Capacity (ton melt/day)
Central Sugars Refinery Sdn Bhd	1,300
A	2,000
B	700
C	600

13-3 Outline of Factory, Facilities and Operation

13-3-1 Outline of Factory

1) Name of the Factory: Central Sugars Refinery Sdn Bhd
2) Address: Batu Tiga, 40000 Shah Alam, Selangor, Malaysia
Telephone: 03-5591414/7 Fax No: 603-5598792

3) Factory Organization: General Manager: Mr. Lem Cheng Hoc
Technical Adviser: Chan Choong Lim
Engineering Manager: Ir. Lim Chin Chuan

4) Type of the Industry: Food processing industry,
Sugar refinery sub-sector (private)

5) Capital: 33 million RM

6) Organization Chart: See Figure 13-1

7) Number of Employees: 290

8) Number of Engineers: 14
- Mechanical engineers 4, - Chemical engineers 5,
- Electrical engineers 2, - Instrumental engineers 2

9) Number of Energy-Related Engineers:
- Heat 1, - Electricity 5

10) General Layout of the Factory:
- Factory area 16 acres (Total)
- Building area 6.4 acres

11) Factory Layout: See Figure 13-2

12) Major Products: Refined sugar
- White sugar
- Brown sugar
- Liquid sugar

13) Trends in Annual Sales Amount:
See Table 13-2

Table 13-2 Trends in Annual Sales Amounts

Products	1994	1995	1996	1997 (estimate)	1998 (plan)
Refined Sugar	300,081 ton	315,875 ton	332,500 ton	350,000 ton	300,000 ton
Retail price	(1.20 RM/kg)	(1.20 RM/kg)	(1.20 RM/kg)	(1.20 RM/kg)	(1.45 RM/kg)

14) History of the Factory: Operation started Oct. 1965 at a capacity of 150 ton-melt/day

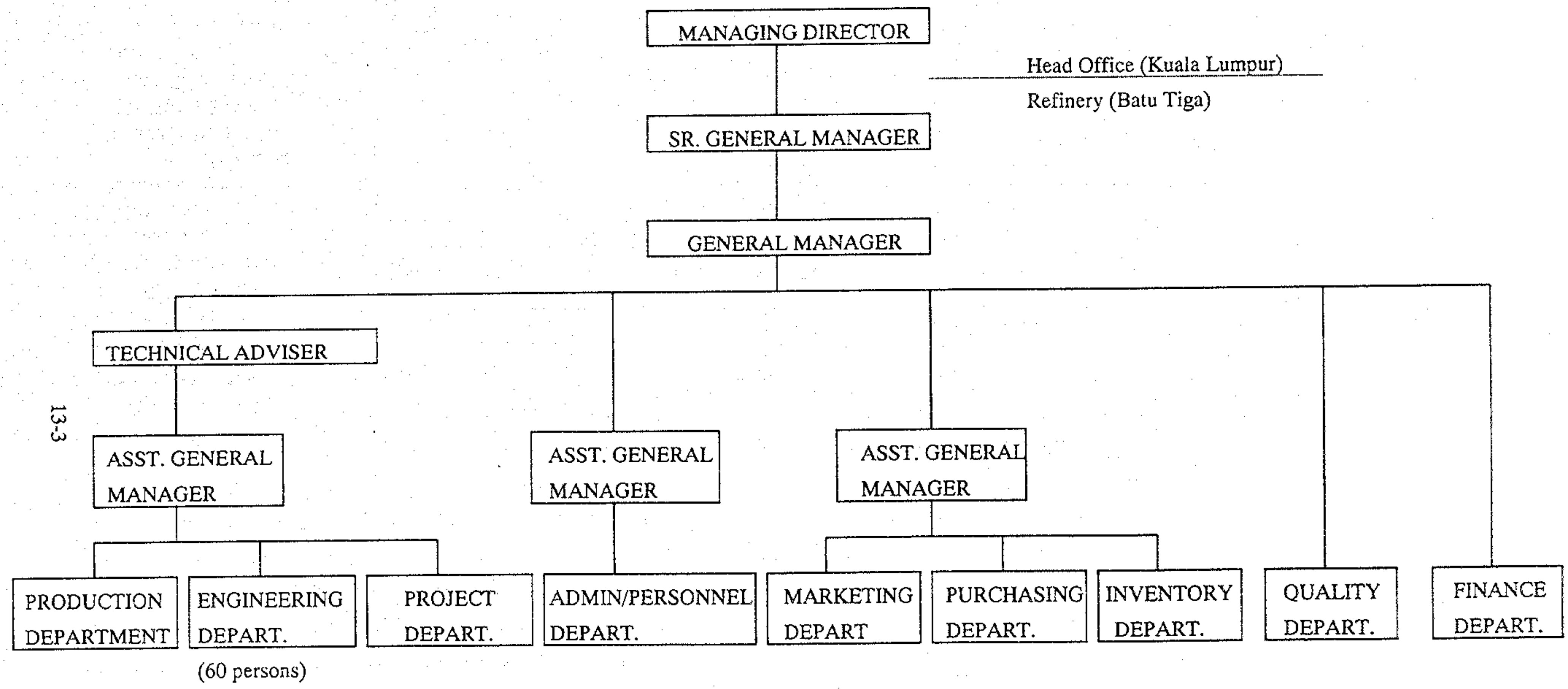
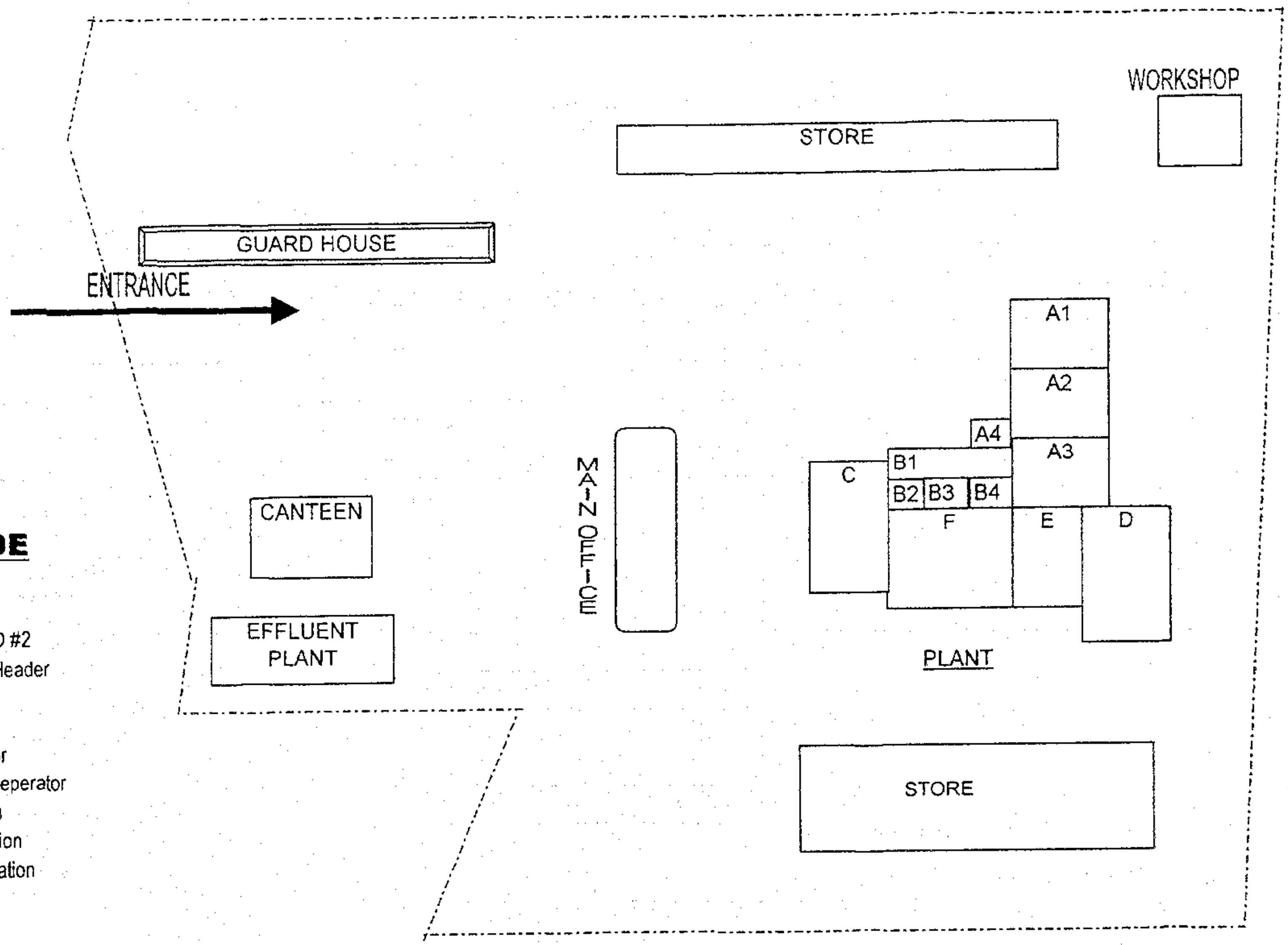


Figure 13-1 Company Organization Chart



AREA CODE

A1 : BOILER #4
A2 : BOILER #3
A3 : BOILER #1 AND #2
A4 : High Pressure Header
B1 : Turbine # 4
B2 : Turbine #3
B3 : Steam Seperator
B4 : Beside Steam Seperator
C : Affination Station
D : Clarification Station
E : Crystalization Station
F : Curing Station

Figure 13-2 Factory Layout (Central Sugars Refinery)

13-3-2 Outline of Production Facilities

The main product of the factory is refined sugar, as mentioned above. The production scheme is roughly illustrated in Figure 13-3. The factory is planning to increase production capacity from 1,300 to 1,500 ton-melt per day by modifying the affination station.

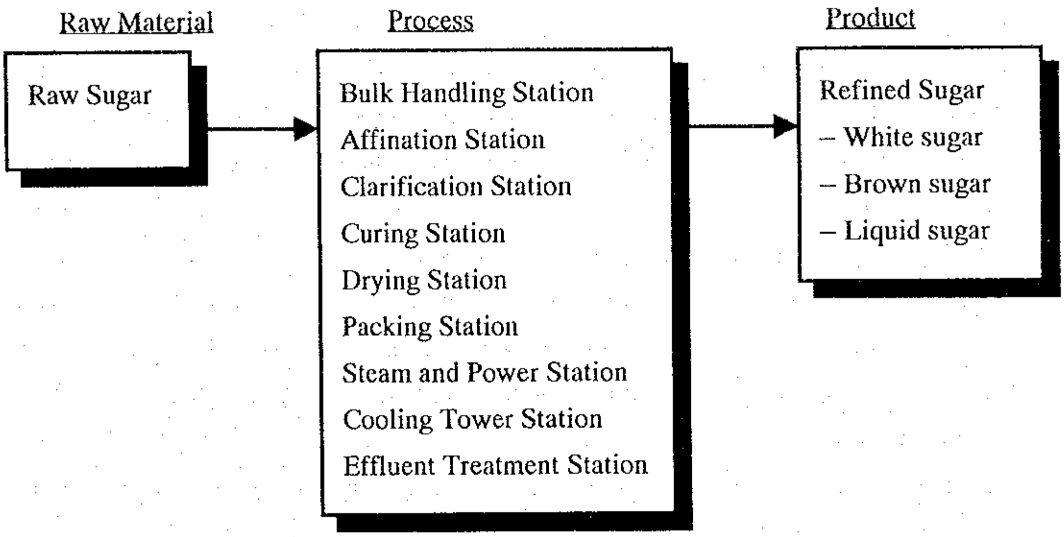


Figure 13-3 Outline of Production Facilities

13-3-3 Flow Sheet for Sugar Refining

Figure 13-4 shows a simplified production flow diagram of the factory.

(1) Bulk handling station

Raw sugar from the port is carried by trucks or trailers to the factory and then fed to the affination station.

(2) Affination station

Raw sugar is conveyed to the weighing scales and loaded into the raw sugar buffer bin. From there, the sugar is mixed with affination syrup and then goes on to the mingler. Raw sugar magma from the mingler is overflowed and then magma is purged in the affination centrifuge to separate the molasses and any impurities from the magma and recovered affined sugar.

Affined sugar is remelted in the melter and the melted sugar is screened by mesh screening before flowing to the raw liquor buffer tank.

(3) **Clarification station**

Raw liquor is treated with milk of lime and then passes to carbonators, where CO_2 gas is pumped through the limed liquor to form calcium carbonate precipitate and absorb any impurities and coloring matters from the liquor. The CO_2 gas is extracted from the boiler flue gas.

The carbonated liquor is filtered by pressure filters to separate the calcium carbonate precipitate from clear liquor or brown liquor by using rotary pressure filters. Brown liquor is stored in the brown liquor tank. Calcium carbonate precipitate or mud is discharged from the filters then pumped to the filter press to recover the sugar in the mud.

Brown liquor is pumped through ion exchange resin columns in order to decolourize.

(4) **Curing station**

Fine liquor from the ion exchange resin columns flows to the fine liquor tank and is then pumped to the multi effect evaporator. The fine liquor is concentrated by the evaporator and then pumped to the fine liquor tank for further boiling and crystallizing.

Refined sugar centrifuge are employed for the sugar separation and purging.

(5) **Drying station**

Sugar from the centrifuge is subsequently screened by a vibrating screen to separate the lumps of sugar, and then it is fed to the fluid bed cooler.

(6) **Packing station**

Dry cooled sugar is conveyed to sugar storage bins and bagged in sacks, which are delivered to the sugar warehouse.

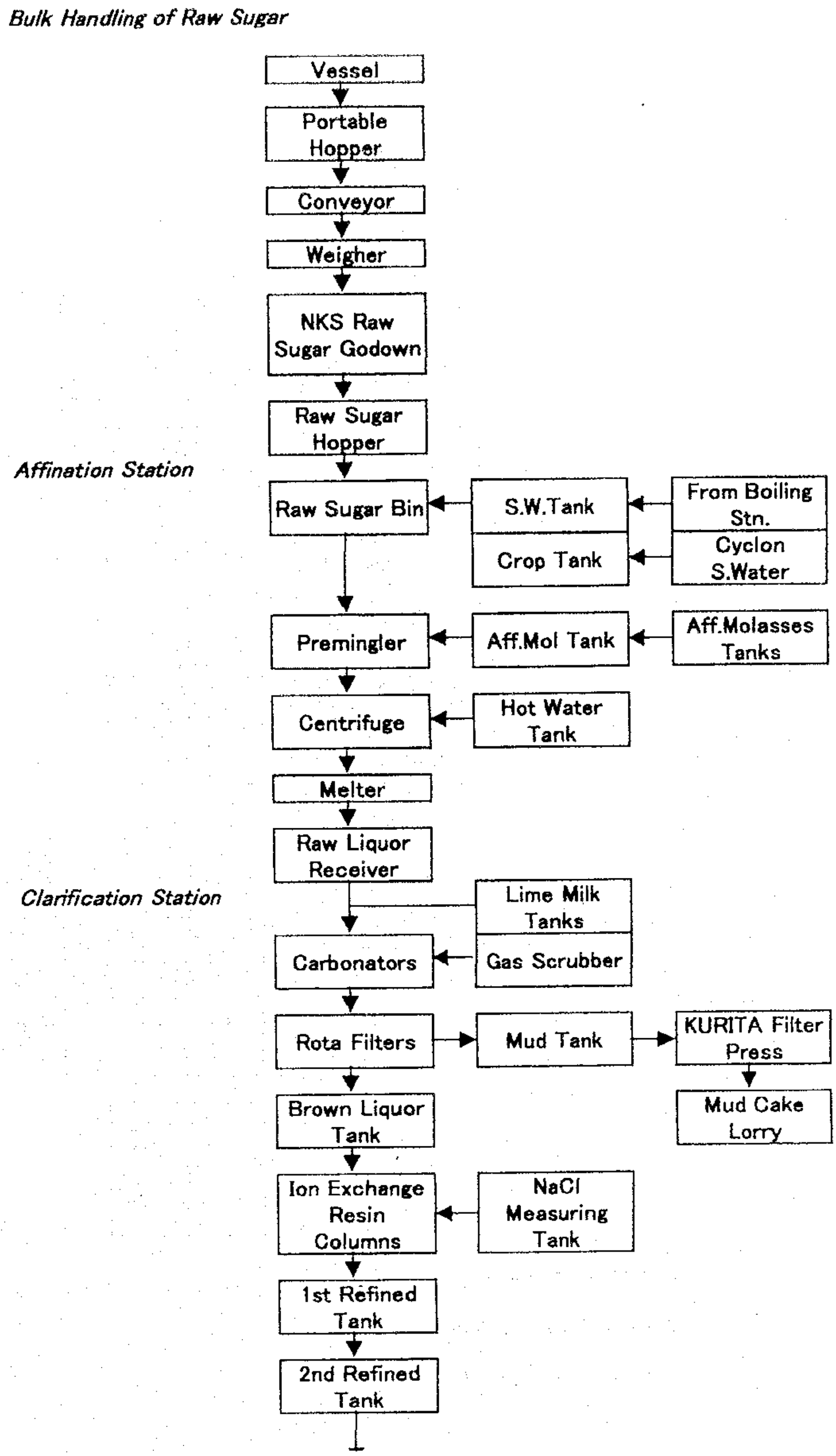


Figure 13-4 Simplified Flow Sheet of Sugar Refining

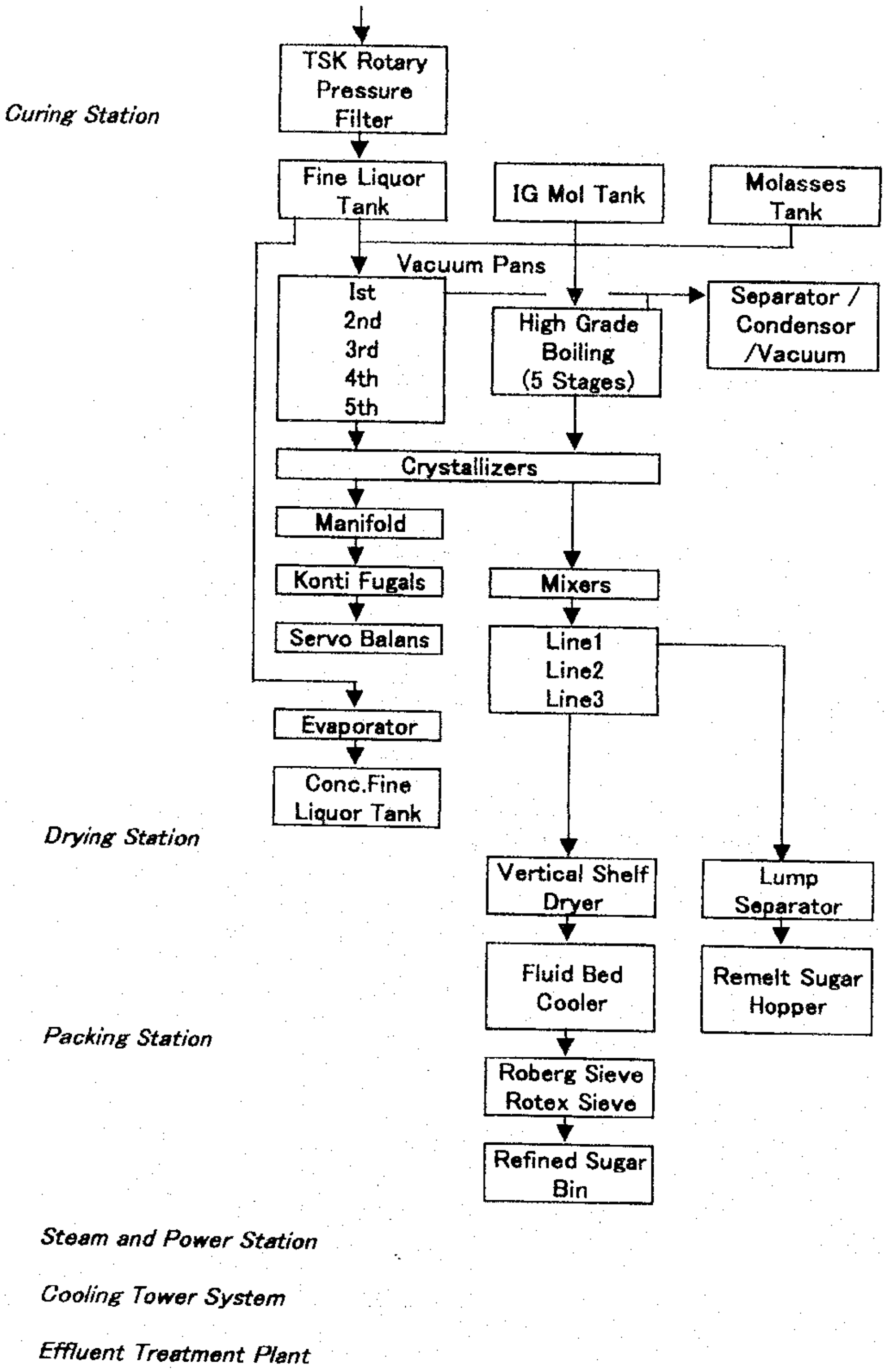


Figure 13-4 Simplified Flow Sheet of Sugar Refining

13-4 Outline of Operating Conditions

(1) Plant Operation Modes

The operation mode of the plant is continuous, working 24 hours a day, 330 days a year. A group of centrifuges deployed at the affination and curing stations are each controlled in a parallel sequential manner in order to level off the power demand profile.

(2) Plant Maintenance Modes

The factory is mainly applying preventive maintenance and ceases operation for several days each time.

13-5 Production and Energy Consumption

(1) Production Capacity, Trends in Production Amounts of Major Products and Annual Operating Hours: See Table 13-3

Table 13-3 Production Capacity, Production Amounts and Annual Operating Hours

	Production Capacity (ton-melt/day)	Production Amount (ton/year)	Annual Operating Hours (hours/year)
1994	1,300	312,584	7,920
1995		329,036	7,920
1996		346,354	7,920
1997		364,583	7,920
1998		312,500	7,920

(2) Trend in Unit Consumption Figures of Raw Materials and Energy for Major Products: See Table 13-4

(3) Trends in Annual Utility Consumption: See Table 13-5

(4) Production Costs of each Major Product: N.A (Confidential)

(5) Trends in Unit Energy Price: Medium fuel oil 400 RM/ton (Average for recent year)

(6) Energy Flow Chart: N.A

Table 13-4 Unit Consumption Figure of Raw Materials and Energy for Each Major Product

Name of major product	Unit consumption figure	Unit	1994	1995	1996	1997 (estimate)	1998 (plan)
Refined sugar	1. Raw materials						
	(1)Raw sugar	raw melt ton / ton refined	0.96	0.96	0.96	0.96	0.96
	2. Energy						
	(1) Heat/melt sugar	10^3 kcal/ ton raw sugar	801	828	853	875	783
	(2)Electricity/melt sugar	kWh/ ton raw sugar	79.178	79.444	77.752	77.650	78.144

Table 13-5 Annual Utility Consumption and Unit Price

No.	Name of utility	Unit	Lower heating value (kcal/kg)	1994		1995		1996		1997(estimate)		1998 (plan)	
				Con-sump-tion	Unit price	Con-sump-tion	Unit price	Con-sump-tion	Unit price	Con-sump-tion	Unit price	Con-sump-tion	Unit price
1.	Medium Fuel oil	ton	10,100	24,806		26,979		29,265		31,614		24,248	
2.	Steam	ton		359,687		391,195		424,342		458,408		351,596	
3.	Electricity	10^6 kWh		24.75		26.14		26.93		28.31		24.42	
4.	Process water	10^6 m^3		1.19		1.19		1.20		1.20		1.20	
5.	Cooling water	10^6 m^3		33.3		33.3		33.3		33.3		33.3	
6.	Boiler feed water	ton		374,074		406,843		441,315		476,730		365,659	
7.	R.O output	10^6 ton		-		-		0.32		0.32		0.32	

13-6 Present Situation of Energy Management and Energy Efficiency Promotion

(1) Establishment of Energy Efficiency Target

18.5 ton medium fuel oil / ton raw-melt (Year 1997)

At the beginning of every fiscal year, the factory executives make some target for energy efficiency on unit consumption figures of fuel and electricity.

(2) Systematic Activities for Energy Efficiency Promotion in the Factory

Under the control of the Engineering Manager, the Energy Saving Committee, consisting of about 10 members managers and engineers in technical department, has been held once a month for the past 10 years.

(3) Energy Management Utilizing Data and Records

The Engineering Department controls the operation data for the steam boiler, steam turbine electricity and so on, while other operation data are controlled by the Production Department. Some of the facilities such as the steam boiler are operated by computer, thus data can be utilized through the computer.

(4) Education, Training of Employees for Energy Management

Operating training is given for a certain period inside the factory especially for newly-hired employees. Brief meetings are also held to discuss both operation conditions and energy management every morning.

(5) Maintenance Management of the Facilities

1) Preventive maintenance is carried out every day in accordance with checklists to monitor each main facility including steam traps.
2) Corrective action is periodically implemented according to preventive maintenance data. (4-5 days / period)

(6) Measures Carried Out for Energy Efficiency Promotion and Their Effects

Installation of capacitor(s) to improve power factor above 0.8

(7) Planning Measures for Energy Efficiency Promotion and Their Expected Effects

Target figure management system, improving 5-7 per cent / year

(8) Economic Condition of the Factory and its Industrial Sub-sector

Fluctuates greatly, reflecting the nation's economic situation

(9) Problems in Promoting Energy Efficiency

1) Rather long pay-out time for energy saving investment
2) Shortage of measuring equipment, especially for steam system

(10) Environmental Pollution Management

1) Working Condition: Good (Air Conditioner in Control Room and Electricity Room)
2) Waste Gas:
   No exhaust gas analysis equipment in the boiler chimney, though the CO_2 content should be lower than the Department of Environment (DOE) regulation figures of 10 per cent for CO_2. Most of the carbon dioxide contained in exhaust gas is recovered in the gas scrubber to make calcium carbonate.
3) Waste Water: Activated sludge treatment plant
4) Waste Disposal: 10 ton / day (sugar cake mud by lorry)

13-7 Current Condition and Problems with Facilities

13-7-1 Problems in Major Energy-Consuming Facilities

1) Shortage of steam flow meter around steam main piping
2) Lack of energy flow chart
3) Stable operability should be required

13-7-2 Considered Problems with Energy Consumption and Request Items for Energy Audit

After the first field survey, the following problems were considered to be audited.

1) Measuring the exact steam flow rate
2) Establishment of energy flow chart
3) More steam condensate recovery
4) Maintaining the correct working condition of steam traps
5) Improvement of thermal insulation

6) Measuring the exact compressed air flow rate

7) Improvement of power factor

8) Increase power generation from steam turbine generator

9) Details of Major Energy-Related Facilities

See Table 13-6, 13-7, 13-8, 13-9, 13-10 and 13-11

- Boiler: No.1 / 2 15 t/h 11 bar x 2 (stand-by)
  No.3 30 t/h 11 bar x 1 (stand-by)
  No.4 50 t/h 17 bar x 1 (in operation)
- Steam turbine generator:
  No.1 800 kW x 1 (stand-by)
  No.2 1,200 kW x 1 (stand-by)
  No.3 2,500 kW x 1 (stand-by)
  No.4 3,500 kW x 1 (in operation)
  No.5 1,000 kW x 1 (stand-by)
- Air compressor No.1, 3,4
- Centrifugal machine x 15

10) Electric Consumption Ratio of House Generation versus Receiving Power:

10 - 15 per cent of total power consumption
(receiving power from outside)

House generation power capacity; 4,375 kVA

11) Electric Power Receiving

- Receiving Voltage, volt: 415 (50 Hz)
- Maximum Demand, kWh: 3,200 (Total Demand)
  600 (receiving from TENAGA)
- Power Factor, per cent: 80
- Transformer Capacity per Unit and Number of Transformers:
  1,500 kVA x 5
  1,250 kVA x 1
  750 kVA x 2
  630 kVA x 1
  200 kVA x 1
- Capacity of Receiving Power Generation for
  Emergency: 1,000 kW x 1 unit, 440 volt, 60 Hz

Table 13-6 Details of No.3 Boiler

No.	Particulars of boilers	Specifications
1.	Manufacturer's name	Maxitherm
2.	Date of construction / Modification	1980
3.	Type of boiler	Water tube type Packaged boiler
4.	Max. continuous evaporation rate	30 t/hr
5.	Max. working pressure	17.5 bar G
6.	Normal pressure	20 bar G
7.	Normal temperature	300 ℃ (Super heated steam)
8.	Boiler heat transfer area	748.8 m^2
9.	Super heater heat transfer area	29.6 m^2
10.	Fuel	Medium fuel oil
11.	Burner type / Number	Hamwoothy oil burner
12.	Drafting method	Forced draft
13.	Smoke stack (top bore x height)	1.4 m ϕ x 43.33 m H

Table 13-7 Details of No.4 Boilers

No.	Particulars of boilers	Specifications
1.	Manufacturer's name	Vickers Hoskins (M) Sdn Bhd
2.	Date of construction / Modification	1988
3.	Type of boiler	Water tube type Packaged boiler
4.	Max. continuous evaporation rate	50 t/hr
5.	Max. working pressure	24 bar G
6.	Normal pressure	20 bar G
7.	Normal temperature	310 ℃ (Super heated steam)
8.	Boiler heat transfer area	898.0 m^2
9.	Super heater heat transfer area	37.0 m^2
10.	Economizer heat transfer area	not insatlled
11.	Air pre-heater heat transfer area	1,150 m^2
12.	Combustion chamber volume	3,600 cubic ft
13.	Fuel	Medium fuel oil
14.	Burner type / Number	Y-jet steam atomised burner (Saakle burner)
15.	Drafting method	Forced draft
16.	Smoke stack (top bore x height)	1.4 mϕ x 50 m H
17.	Control system	YOKOGAWA

Table 13-8 Equipment List (Turbine Generator No. 3)

No.	Equipment	Quantity	Main Specification	Remarks
	Turbine Generator No.3	1	<u>Turbine side</u> a) Manufacturer : Nadowski b) Speed : 7,620 rpm c) Steam inlet pressure : 11 bar d) Steam inlet temperature : 290 ℃ e) Exhaust steam pressure : 1 bar f) Steam rate : 13.1 kg/kwh <u>Generator side</u> a) Manufacturer : AEG b) Speed : 1,800 rpm c) Output capacity : 2,500 kw d) Voltage output : 3,300 volt e) Output current : 546 Amp f) Cycle : 60 Hz	(stand-by)

Table 13-9 Equipment List (Turbine Generator No. 4)

No.	Equipment	Quantity	Main Specification	Remarks
	Turbine Generator No.4	1	Turbine side a) Manufacturer : Shin-Nippon Machinery b) Speed : 6,545 rpm c) Steam inlet pressure : 17 bar d) Steam inlet temperature : 310 ℃ e) Exhaust steam pressure : 1 bar f) Steam consumption : 38,200 kg/h g) Steam rate : 10.9 kg/kwh Generator side a) Manufacturer : Shinko b) Speed : 1,800 rpm c) Output capacity : 3,500 kw d) Voltage output : 3,300 volt e) Output current : 765 Amp f) Cycle : 60 Hz	(in operation)

Table 13-10 Equipment List (Air Compressor No. 1, 3 & 4)

No.	Equipment	Quantity	Main Specification	Remarks
	Air compressor No.1	1	Model : JG x GE HP : 150 HP Inlet capacity @ 100 psi : 817.1 cfm Max. pressure : 150 psig Compressor speed : 705 rpm Bore stroke : 14-1/2 - 10 x 7 Motor service factor : 1.15 SF	
	Air compressor No.3	1	Model : VMD 500 HP : 125 HP Free air del. : 560 cfm @ 100psig Max. pressure : 150 psig Speed : 735 rpm	
	Air compressor No.4	1	Type : Screw HP : 30 HP Output Capacity: 130 cfm Delivery Pressure : 5 bar (min.) 7.5 bar (max.) 7.0 bar (normal)	

Table 13-11 Equipment List (Centrifugal Machine)

No.	Equipment	Quantity	Main Specification	Remarks
	TSK Centrifugal machine	15	a) Manufacturer : TSK (Japan) b) Process type : batch c) Basket capacity : 600 kg/batch d) Main motor capacity : 220 kw e) Normal speed : 1,800 rpm f) Max. current : 400 Amp	

13-8 Method and Procedure of Energy Audit

Based on the current condition and problems with facilities, an analysis and measuring plan has been prepared as follows.

13-8-1 Items to Note for Implementation of Energy Audit

The factory's periodic shutdown schedule is usually determined by considering both plant maintenance and market demand. It is necessary to give notification the energy audit schedule one month in advance.

The following items were discussed and confirmed during the field survey.

1) Drawings of the target facilities for energy audit
2) Detailed structure and size of the target facilities for energy audit
3) Precautions for arrangement of measuring equipment for energy audit
4) Confirmation of measuring equipment installation for energy audit
5) Necessary procedure of approval for measurement equipment installation
6) Possible measuring equipment owned by factory for energy audit
7) Utilization of installed instrumental equipment in the plant for energy audit

13-8-2 Analysis and Measuring Points

Analysis and measuring points for the energy audit are listed in Table 13-12 for each major item of energy audit. Their main points are shown in the following figures respectively.

Figure 13-5 Steam System Flow

Figure 13-6 Power System

A detailed schedule of analysis and measurement is shown in Table 13-13. They were planned so that actual analysis and measuring work at the factory would be finished within 10 working days with the cooperation of factory personnel.

13-8-3 Modification for Analysis and Measuring Work

(1) Installation of Orifice Flow Meter

1) Purpose of the Installation

Through discussions with factory personnel, the study team concluded that one of the most important items for energy audit at the factory is to measure the exact steam flow rate, in anticipation of the following effects.

1. It is essential to develop a steam balance for the energy audit at the sugar factory, and it is necessary to measure steam flow rate for that purpose.
2. Measuring steam flow rate will be helpful for operational management of steam supply and demand between the boiler and the steam turbine generator and the other steam consumers.
3. Measuring steam flow rate will be additionally effective for energy management.

2) Selection of Measuring Points

There is one steam flow meter to measure total generated steam from the boiler. The study team planned to install two sets of orifice flow meters, one in the line to the Plate Evaporator and another in the line to the Steam Accumulator, both from the New HP header, as shown in Figure 13-5.

3) Equipment Specification

Each measurement system of orifice flow meter is consisted of the following devices.

1. An orifice plate assembly, plate and flange with taps
2. A differential pressure transmitter
3. A distributor
4. A recorder of steam flow rate

Detailed design data is shown in Table 13-14.

4) Modification Work for Orifice Flow Meter Installation

The following modification work was performed by the factory side.

1. Cutting piping at the measuring points and installing orifice assemblies by welding. Each line of the up-stream or the down-stream of orifices should have a straight line of 20 times or 10 times the tube diameter, respectively
2. Mounting a differential pressure transmitter, and piping works from the flange taps to the transmitter
3. Mounting a local type distributor and flow recorder
4. Instrumental works and electrical power supply

Table 13-12(1) Detailed Plan of Analysis and Measurement for Energy Audit (Food Processing)

Major Items of Energy Audit	Method of Analysis and Measurement								Personal Allocation (Number)			Schedule (Duration)
	Subject Items and Points	Measurement, Estimate or Trend Record	Equipment of Analysis and Measurement									
			Required Equipment	Factory	Local Consultan	JICA	Local Labo	Addition	JICA	Local Consultant	Factory	
1. Boiler System	<Boiler>		Design Data	X								
	(1) Medium Fuel Oil								1	1	1	2
	① Heating Value	E or M	Supplier's Data or Analysis	X			X					
	(LHV & HHV : kcal/kg)											
	② Specific Gravity	E or M	Supplier's Data or Analysis	X			X					
	③ Viscosity (c.p)	E or M	Supplier's Data or Analysis	X			X					
	④ Flow Rate (t/h)	T or M	Ultrasonic Flowmeter	X		X						
	⑤ Elemental Analysis											
	Carbon(wt%)	E or M	Supplier's Data or Analysis	X			X					
	Hydrogen(wt%)	E or M	Supplier's Data or Analysis	X			X					
	Nitrogen(wt%)	E or M	Supplier's Data or Analysis	X			X					
	Oxygen(wt%)	E or M	Supplier's Data or Analysis	X			X					
	Sulfur (wt%)	E or M	Supplier's Data or Analysis	X			X					
	(2) Boiler Feed Water								1	1	1	2
	① Flow Rate(t/h)	T or M	Ultrasonic Flowmeter	X		X						
	② Temperature	T or M	Bar Thermometer	X		X						
	③ Pressure(bar)	T or M	Pressure Gauge	X		X						
	④ Electric Conductivity (μS/cm)	M	Electric Conductivity Meter			X						
	⑤ pH	M	pH meter			X						
	(3) Return Condensate								1	1	1	2
	① Flow Rate(t/h)	T or M	Ultrasonic Flowmeter	X		X						
	② Temperature	T or M	Bar Thermometer	X		X						
	③ Pressure(bar)	T or M	Pressure Gauge	X		X						
	④ Electric Conductivity (μS/cm)	M	Electric Conductivity Meter			X						
	⑤ pH	M	pH meter			X						

Table 13-12(2) Detailed Plan of Analysis and Measurement for Energy Audit (Food Processing)

Major Items of Energy Audit	Method of Analysis and Measurement								Personal Allocation (Number)			Schedule (Duration)
	Subject Items and Points	Measurement, Estimate or Trend Record	Equipment of Analysis and Measurement									
			Required Equipment	Factory	Local Consultan	JICA	Local Labo	Addition	JICA	Local Consultant	Factory	
1.Boiler System	(4) R.O Treated Water								1	1	1	2
	① Flow Rate(t/h)	T or M	Ultrasonic Flowmeter	X		X						
	② Temperature	T or M	Bar Thermometer	X		X						
	③ Pressure(bar)	T or M	Pressure Gauge	X		X						
	④ Electric Conductivity (μ S/cm)	M	Electric Conductivity Meter			X						
	⑤ pH	M	pH meter			X						
	(5) Combustion Air								1	1	1	2
	① Flow Rate(Nm3/h)	T or M	Pitot Tube Gas Flowmeter	X		X						
	② Temperature(℃)	M	Bar Thermometer	X		X						
	③ Pressure(bar)	M	Pressure Meter for Furnace	X		X						
	(6) Generated Steam								1	1	1	2
	① Flow Rate(t/h)	T	Operation Data	X								
	② Temperature(℃)	T	Operation Data	X								
	③ Pressure(bar)	T	Operation Data	X								
	(7) Exhaust Gas								1	1	1	2
	① Oxygen(vol%)	T or M	Oxygen Content Meter for Exhaust Gas	X		X						
	② CO_2 (vol%)	M	CO/CO_2 Content Meter			X						
	③ CO(vol%)	M	CO/CO_2 Content Meter			X						
	④ Flow Rate (Nm3/h)	M or E	Pitot Tube Gas Flowmeter			X						
	⑤ Temperature(℃)	M	Bar Thermometer			X						

Table 13-12(3) Detailed Plan of Analysis and Measurement for Energy Audit (Food Processing)

Major Items of Energy Audit	Method of Analysis and Measurement								Personal Allocation (Number)			Schedule (Duration)
	Subject Items and Points	Measurement, Estimate or Trend Record	Equipment of Analysis and Measurement						JICA	Local Consultant	Factory	
			Required Equipment	Factory	Local Consultan	JICA	Local Labo	Addition				
2. Steam Generator (Electric Power Generator)	<Steam Turbine Generator>		Design Data	X					1	1	1	2
	(1) Inlet Steam											
	① Flow Rate(t/h)	E						X				
	② Temperature (℃)	T or M	Bar Thermometer	X		X						
	③ Pressure (bar)	T or M	Pressure Gauge	X		X						
	(2) Exhaust Steam								1	1	1	2
	① Flow Rate(t/h)	E						X				
	② Temperature (℃)	M	Bar Thermometer	X		X						
	③ Pressure (bar)	M	Pressure Gauge for Steam	X		X						
	(3) Condensed Steam								1	1	1	2
	① Flow Rate(t/h)	M	Ultrasonic Flowmeter			X						
	② Temperature (℃)	M	Bar Thermometer			X						
	③ Pressure (bar)	T or M	Pressure Gauge	X		X						
	④ Cooling Water (t/h)	T or M	Ultrasonic Flowmeter	X		X						
	⑤ C.W Inlet Temperature(℃	T or M	Bar Thermometer	X		X						
	⑥ C.W Outlet Temp.(℃)	T or M	Bar Thermometer	X		X						
	(4) Generated Power (kWh/h	T	Operation Record & Data	X					1	1	1	1
	(5) Power Factor (%)	T	Operation Record & Data	X					1	1	1	1
	(6) Rotation (rpm)	M	Rotation Speed Meter (*1)			X			1	1	1	1

*1: Marking of Rotating Part is necessary during shut-dowm.

Table 13-12(4) Detailed Plan of Analysis and Measurement for Energy Audit (Food Processing)

Major Items of Energy Audit	Method of Analysis and Measurement								Personal Allocation (Number)			Schedule (Duration)
	Subject Items and Points	Measurement, Estimate or Trend Record	Equipment of Analysis and Measurement									
			Required Equipment	Factory	Local Consultan	JICA	Local Labo	Addition	JICA	Local Consultant	Factory	
3. Heat	<Heating Materials>		Design Data	X					1	1	1	2
Consuming	① Flow Rate (t/h)	E						X				
Facilities	② Inlet Temperature (℃)	T or M	Bar Thermometer	X		X						
(Evaporator)	③ Inlet Pressure (bar)	T or M	Pressure Gauge for Steam	X		X						
(Vacuum Pan)	④ Outlet Temperature (℃)	T or M	Bar Thermometer	X		X						
(Dryer)	⑤ Outlet Pressure (bar)	T or M	Pressure Gauge for Steam	X		X						
(Ejector)	⑥ Steam Header Flow Rate	M	Orifice Installation and					X				
(Others)	(t/h)		Portable Meter (2 sets)									
	<Heated Materials>								1	1	1	2
	① Composition (wt%)	E		X								
	② Flow Rate (t/h)	T or M	(Ultrasonic Flow Meter)	X		X						
	③ Inlet Temperature (℃)	T or M	Bar Thermometer	X		X						
	④ Inlet Pressure (bar)	T or M	Pressure Gauge for Steam	X		X						
	⑤ Outlet Temperature (℃)	T or M	Bar Thermometer	X		X						
	⑥ Outlet Pressure (bar)	T or M	Pressure Gauge for Steam	X		X						
4. Steam Trap	<Steam Trap>								1	1	1	1
(Prevenstion of	(1) Working Condition	M	Steam Trap Checker					X				
Heat Energy												
Loss)												
5. Thermal	(1) Surface Temperature of								1	1	1	2
Insulation	Main Equipments											
System	1) Dryer>	M	Surface Thermometer			X						
(Prevention of	2) Evaporator	M	Surface Thermometer			X						
Heat Energy	3) Vaccum Pan	M	Surface Thermometer			X						
Loss)	4) Ejector	M	Surface Thermometer			X						
	(2) Steam Piping to Turbine								1	1	1	2
	1) Boiler outlet point											
	① Steam Temperature(℃)	T or M	Bar Thermometer	X		X						
	② Steam Pressure (bar)	T or M	Pressure Gauge	X		X						
	③ Surface Temperature (℃)	M	Surface Thermometer			X						
	④ Atm. Temperature (℃)	M	Temperature-Humidity Meter			X						

Table 13-12(5) Detailed Plan of Analysis and Measurement for Energy Audit (Food Processing)

Major Items of Energy Audit	Method of Analysis and Measurement								Personal Allocation (Number)			Schedule (Duration)
	Subject Items and Points	Measurement, Estimate or Trend Record	Equipment of Analysis and Measurement									
			Required Equipment	Factory	Local Consultan	JICA	Local Labo	Addition	JICA	Local Consultant	Factory	
5. Thermal Insulation System (Prevention of Heat Energy Loss)	2) Turbine inlet point											
	① Steam Temperature (℃)	T or M	Bar Thermometer	X		X						
	② Steam Pressure (bar)	T or M	Pressure Gauge	X		X						
	③ Surface Temperature (℃)	M	Surface Thermometer			X						
	④ Atm. Temperature (℃)	M	Temperature-Humidity Meter			X						
	<Insulation Material>								1	1	1	2
	① Thermal Conductivity (kcal/m·h·℃)	E	Specification Data	X								
6. Air Compressor System (Electric Power	<Induction Motor>		Supplier's Data						1	1	1	1
	① Rotation Speed (rpm)	M	Rotation Speed Meter (*1)			X						
	②Electricity Consumption (kWh/h)	T or M	Voltage-Ampere-Watt Meter	X		X						
	③ Voltage	M	Voltage-Ampere-Watt Meter	X		X						
	④ Ampere	M	Voltage-Ampere-Watt Meter	X		X						
	⑤ Power Factor (%)	M	Power Factor Meter	X		X						
	<Air>								1	1	1	1
	① Air Flow Rate (Nm^3/h)	M	Hot Wire Anemometer			X						
	② Air Inlet Temperature (℃)	T or M	Bar Thermometer	X		X						
	③ Air Inlet Pressure (bar)	T or M	Pressure Gauge for Air	X		X						
	④ Air Outlet Temperature (℃)	T or M	Bar Thermometer	X		X						
	⑤ Air Outlet Pressure (bar)	T or M	Pressure Gauge for Air	X		X						
7. Hot Water Cooling Tower (Electric Power Consumption)	<Fan Motor>								1	1	1	1
	① Rotation Speed (rpm)	M	Rotation Speed Meter			X						
	② Electricity Consumption (kWh/h)	T or M	Voltage-Ampere-Watt Meter	X		X						
	③ Voltage	T or M	Voltage-Ampere-Watt Meter	X		X						
	④ Ampere	T or M	Voltage-Ampere-Watt Meter	X		X						
	⑤ Power Factor (%)	T or M	Power Factor Meter	X		X						

Table 13-12(6) Detailed Plan of Analysis and Measurement for Energy Audit (Food Processing)

Major Items of Energy Audit	Method of Analysis and Measurement								Personal Allocation (Number)			Schedule (Duration)
	Subject Items and Points	Measurement, Estimate or Trend Record	Equipment of Analysis and Measurement									
			Required Equipment	Factory	Local Consultan	JICA	Local Labo	Addition	JICA	Local Consultant	Factory	
(Heat Consumption)	<Hot Water>								1	1	1	1
	① Flow Rate (kg/h)	T or M	Ultrasonic Flowmeter	X		X						
	② Inlet Temperature (℃)	T or M	Bar Thermometer	X		X						
	③ Inlet Pressure (bar)	T or M	Pressure Gauge	X		X						
	④ Outlet Temperature (℃)	T or M	Bar Thermometer	X		X						
	⑤ Outlet Pressure (bar)	T or M	Pressure Gauge	X		X						
	⑥ Piping Surface Temp. (℃)	M	Surface Thermometer			X						
	<Insulation Material>								1	1	1	1
	① Thermal Conductivity (kcal/m·h·℃)	E	Specification Data	X								
	<Atomosphere>								1	1	1	1
	① Atm. Temperature (℃)	M	Temperature-Humidity Meter			X						
	② Humidity (%)	M	Temperature-Humidity Meter			X						
8. Electrical Power Genetating and Distribution (Electric Power Consumption)	<3.3kv Bus Bar>								1	1	1	3
	① Voltage	T	Voltage-Ampere-Watt Meter	X								
	② Ampere	T	Voltage-Ampere-Watt Meter	X								
	③ Power Factor (%)	T	Power Factor Meter	X								
	<Distribution Board>											3
	① Voltage	T	Voltage-Ampere-Watt Meter	X								
	② Ampere	T	Voltage-Ampere-Watt Meter	X								
	③ Power Factor (%)	T	Power Factor Meter	X								
	<Control Board>											3
	① Voltage	T	Voltage-Ampere-Watt Meter	X								
	② Ampere	T	Voltage-Ampere-Watt Meter	X								
	③ Power Factor (%)	T	Power Factor Meter	X								

Table 13-12(7) Detailed Plan of Analysis and Measurement for Energy Audit (Food Processing)

<table>
<tr><th rowspan="3">Major Items of Energy Audit</th><th colspan="8">Method of Analysis and Measurement</th><th colspan="3">Personal Allocation (Number)</th><th rowspan="3">Schedule (Duration)</th></tr>
<tr><th rowspan="2">Subject Items and Points</th><th rowspan="2">Measurement, Estimate or Trend Record</th><th colspan="6">Equipment of Analysis and Measurement</th><th rowspan="2">JICA</th><th rowspan="2">Local Consultant</th><th rowspan="2">Factory</th></tr>
<tr><th>Required Equipment</th><th>Factory</th><th>Local Consultan</th><th>JICA</th><th>Local Labo</th><th>Addition</th></tr>
<tr><td>9.Transformer (Electric Power Consumption)</td><td><Transformer>
① Voltage
② Ampere
③ Power Factor (%)
④ Iron Loss (kW)</td><td>
T or M
T or M
T or M
E</td><td>
Voltage-Ampere-Watt Meter
Voltage-Ampere-Watt Meter
Power Factor Meter
Design Data</td><td>
X
X
X
X</td><td></td><td>
X
X
X</td><td></td><td></td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>10.Phase Balance (Electric Power Consumption)</td><td><3-Phase 4-Way System>
① Phase Current, Amp.
② Phase Voltage
③ Balance Estimation</td><td>
T.Data or M
T.Data or M
E</td><td>
Voltage-Ampere-Watt Meter
Voltage-Ampere-Watt Meter</td><td>
X
X</td><td></td><td>
X
X
X</td><td></td><td></td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>11.Field Investigation</td><td>(1) Preparation of Equipment List
(2) Investigation of Drawings
(3) Operating Condition Observation for Equipment and Facilities</td><td>Review

Investigation
Observation</td><td>Existing List

Existing Drawings
Operation Record</td><td>X

X
X</td><td></td><td></td><td></td><td></td><td>1</td><td>1</td><td>1</td><td>8</td></tr>
</table>

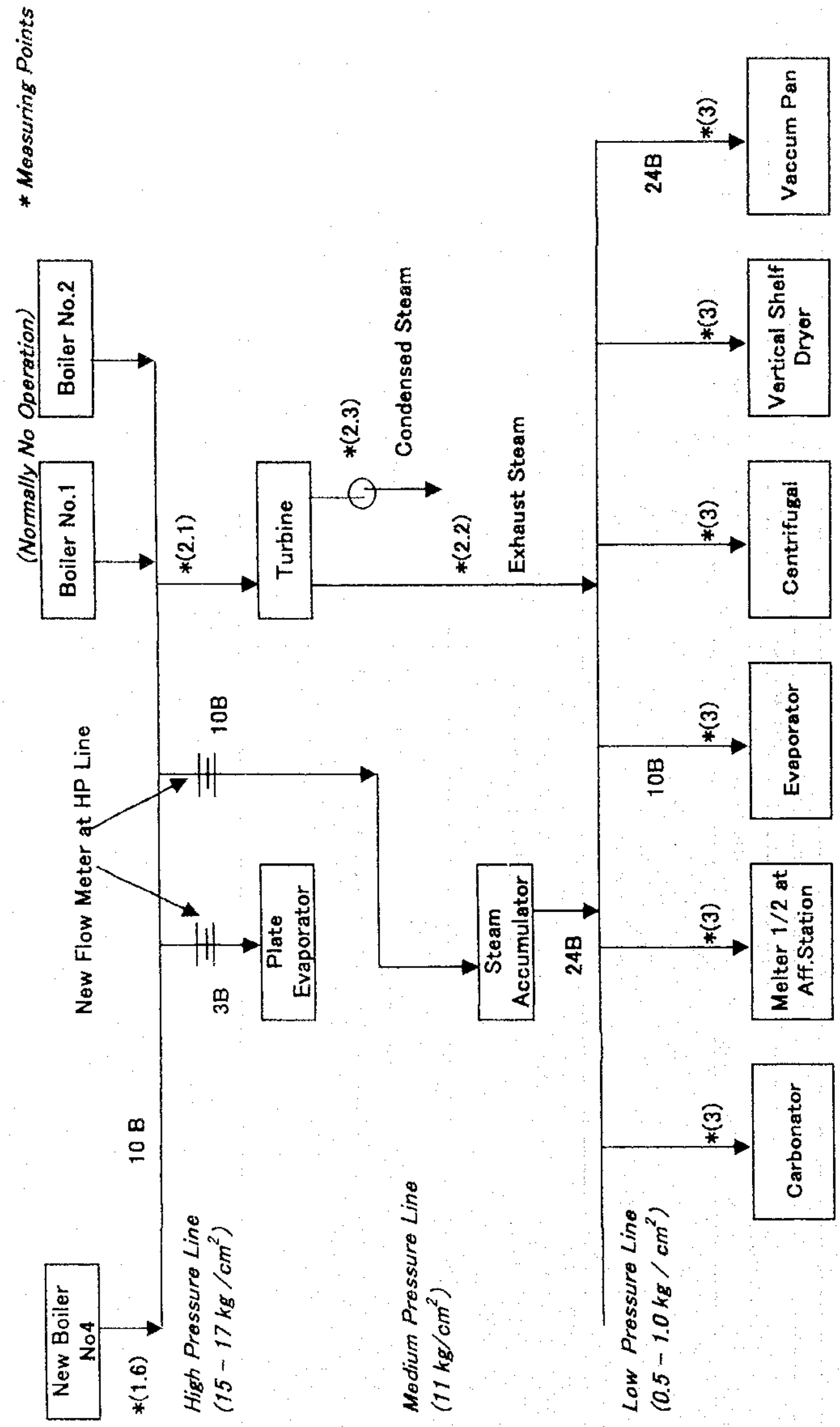


Figure 13-5 Steam System Flow

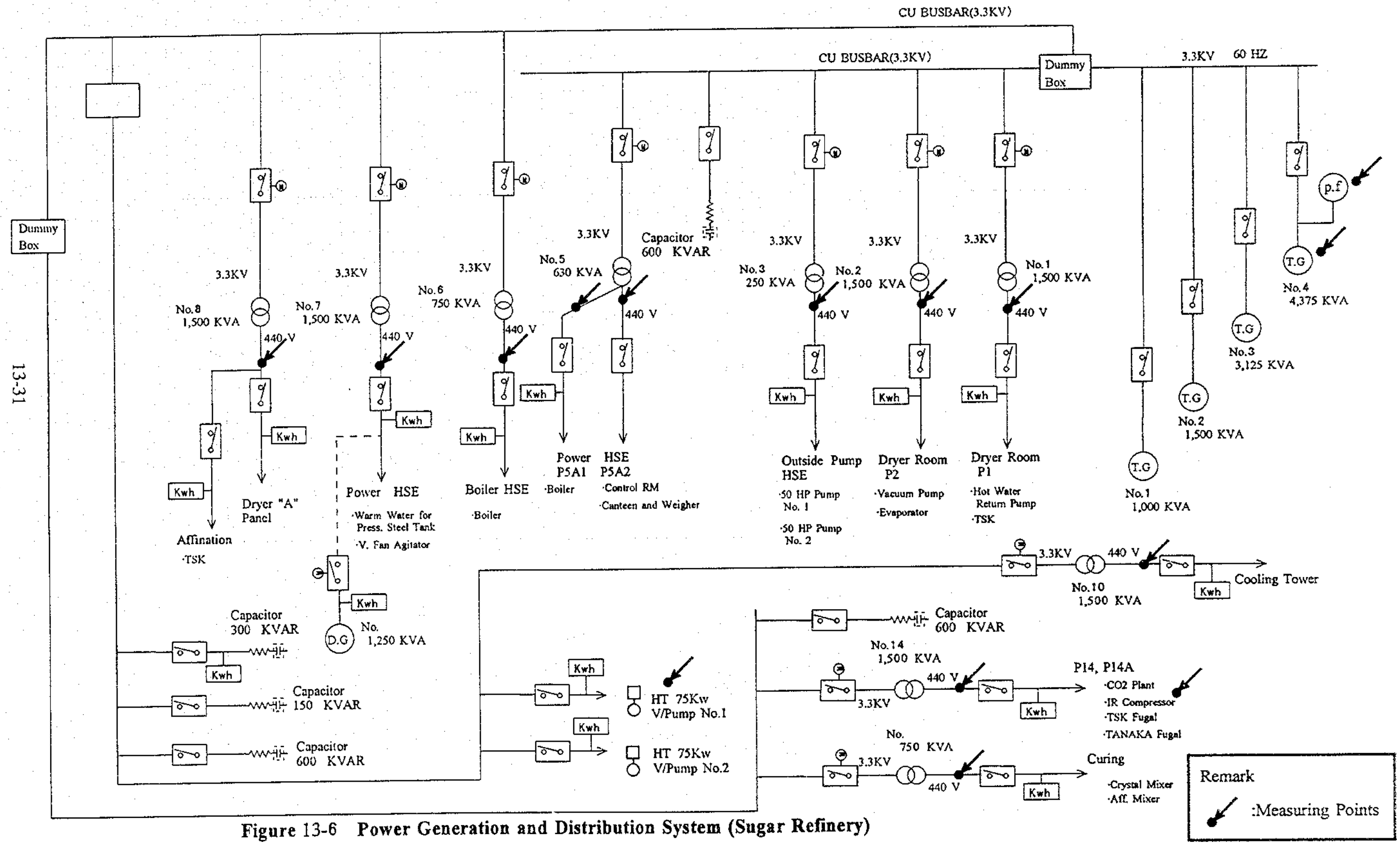


Figure 13-6 Power Generation and Distribution System (Sugar Refinery)

Table 13-13 Schedule of Analysis and Measurement for Energy Audit (Food Processing)

Major Items of Energy Audit Subject Items and Points	Working Day										Remarks
	1	2	3	4	5	6	7	8	9	10	
0. Preparation	X										
1. Boiler System											
(1) Medium Fuel Oil		X	X								
(2) Boiler Feed Water		X	X								
(3) Return Condensate		X	X								
(4) R.O Treated Water		X	X								
(5) Combustion Air		X	X								
(6) Generated Steam		X	X								
(7) Exhaust Gas		X	X								
2. Steam Turbine Generator											
(1) Inlet Steam				X	X						
(2) Exhaust Steam				X	X						
(3) Condensed Steam				X	X						
(4) Generated Power				X	X						
(5) Power Factor				X	X						
(6) Rotation				X	X						
3. Heat Consuming Facilities											
<Evaporator>						X	X				
<Vacuum Pan>						X	X				
<Dryer>						X	X				
<Ejector>						X	X				
<Others>						X	X				
4. Steam Trap System						X	X	X			
5. Thermal Insulation System											
<Evaporator>						X	X				
<Vaccum Pan>						X	X				
<Dryer>						X	X				
<Ejector>						X	X				
<Piping>						X	X				
6. Air Compressor System								X			
7. Hot Water Cooling Tower								X			
8. Electrical Power		X	X	X							
9.Transformer					X						
10.Phase Balance						X					
11.Field Investigation		X	X	X	X	X	X	X	X		
12. Review and Discussion										X	

Table 13-14 Specification for Orifice Steam Flow Meter

Items / Points	HP Steam to Plate Evaporator	HP Steam to Steam Accumulator
Fluid	HP Steam	HP Steam
Piping Dimension	3 inch	8 inch
Inner Diameter (mm)	77.92	202.74
Outer Diameter (mm)	88.9	219.1
Piping Spec. Ratings	Sch. 40	Sch. 40
Material	API Pipes	API Pipes
Temperature (°C) Normal	270 - 310	270 – 310
Temperature (°C) Design	300	300
Pressure (kg/cm^2) Normal	11.0	10 – 12.0
Pressure (kg/cm^2) Design	20.0	24.0
Flow Rate (t/h) Normal	1.9	5 – 6.0
Flow Rate (t/h) Design	5.0	25.0
Density (kg/m^3)	4.5955	4.5955
Viscosity (cP)	0.0202	0.0202
Differential Pressure at Scale Range (mmH_2O)	6,500	5,000

13-9 Measurement Procedure

13-9-1 Outline of Measurement and Analysis

(1) Major Items and Types of Energy Audit

Measurement and analysis work were carried out in accordance with the following major items and types of energy audit in the factory.

1. Thermal efficiency of steam boiler
2. Energy balance around steam turbine generator
3. Management of steam and steam condensate lines
4. Management of steam trap system
5. Management of thermal insulation system
6. Management of electricity consumption

(2) Participants in the Energy Audit

Measurement and analysis work were carried out by the following members at the factory and at temporary laboratory of SIRIM.

1) Factory:	Mr. Ng. Ah Loy, Mr. Abdullah Azra Mochtar,
	Mr. Abu Safian B. Hj.Sabri, Mr. Tan Choon Hai
2) SIRIM (*):	Mr. Syed Anuar, Ms. Chew Thean Yean
	Mr. Hassan Ismail, Mr. Zulkarnain Abdullah
	Mr. Rahim B. Tambi
*SIRIM:	SIRIM Berhad
	Local assistants of measurement employed by JICA team
3) JICA:	Mr. Shunichi Iizuka, Mr. Hiroshi Omoiri
	Mr. Yasuo Ishibashi, Mr. Muneteru Yoshizawa

13-9-2 Energy Audit Schedule

Energy audit for the factory was carried out from September 21 to October 2, 1998, as follows.

(1) Preparation Work

17. Sep. (Thu)	Confirmation of energy audit schedule
18. (Fri) to 20. Sep. (Sun)	Analysis and preparation for audit

(2) **Measurement and Analysis Work**

21. Sep. (Mon)	Transportation and adjustment of measuring equipment
22. Sep. (Tue)	Discussion, confirmation of audit plan and installation of measuring equipment
	Factory observation
23. Sep. (Wed)	Measurement and data-gathering around electrical system
	Data-gathering around boiler, turbine and steam system
	Preparation of steam-trap checker
24. Sep. (Thu)	Measurement around boiler and affiliated system
	Measurement around electrical system using clamp-on meter
	Preparation of steam-trap checker
	Data-gathering around turbine
25. Sep. (Fri)	Measurement around boiler and affiliated system
	Measuring around electrical system using clamp-on meter
	Preparation of steam –trap checker
	Data gathering around turbine
26. (Sat) to 28. Sep. (Mon)	Analysis of measurement results
29. (Tue) to 30 Sep. (Wed)	Preparation of multi-channel recorder
	Gathering of operation data
	Heat balance calculation around boiler
	Heat loss calculation from piping
	Preparation for elemental analysis of fuel oil
	Instrumental adjustment of orifice flow meter in steam system and data-gathering
	Operational analysis of steam condensate line
	Preparation of motor list
	Preparation of transformers and capacitor list
	Surface temperature measurement of transformers
1. Oct. (Thu)	Summarization of measurement data
	Document preparation for final meeting
	Packing of instruments
2. Oct. (Fri)	Packing of instruments and loading to lorry for transport
	Discussion of preliminary audit results
3. (Sat) to 4. Oct. (Sun)	Analysis of measurement results

Table 13-13 shows a detailed schedule of analysis and measurement.

13-9-3 Measuring Items, Points and Measuring Equipment

To calculate and evaluate the current condition of energy consumption and to develop an energy balance, the analysis and measurement work described below was carried out according to the prepared schedule of major energy audit items.

The elemental analysis of fuel oil was conducted by SIRIM.

(1) Thermal efficiency of steam boiler

1) Medium fuel oil: Heating value, elemental analysis (carbon, hydrogen, nitrogen, oxygen and sulfur) and flow rate
2) Boiler feed water: Flow rate and temperature
3) Combustion air: Flow rate and temperature
4) Generated steam: Flow rate, temperature and pressure
5) Exhaust gas:Oxygen, carbon monoxide, carbon dioxide
Temperature

(2) Energy balance around steam turbine generator

1) Inlet steam: Temperature and pressure
2) Exhaust steam: Temperature and pressure
3) Condensed steam: Flow rate, temperature and pressure
4) Generated power: Power and power factor

(3) Management of steam and steam condensate lines

1) Confirmation of overall steam flow
2) Confirmation of steam condensate recovery system
3) Measurement of steam flow rate (turbine by-pass and evaporator inlet)

(4) Steam trap system

1) Confirmation of steam trap list
2) Investigation of malfuctioning steam traps

(5) Management of thermal insulation system

1) Surface temperature measurement of insulated steam piping
2) Confirmation of insulation material
3) Confirmation of pipe dimension (diameter, length and thickness)

(6) Management of Electricity consumption

1) Generated power: Voltage, current, power and power factor

2) Main transformers: Voltage, current, power and power factor

3) Major facilities: Voltage, current, power and power factor

Details of measurement items, points and measuring equipment are shown in Table 13-12.

13-9-4 Analysis and Measuring Equipment Used on Site

Required equipment of analysis and measurement is shown in Table 13-12 for each energy audit item. Their specifications are as follows.

(1) Thermal efficiency of steam boiler

1) Medium fuel oil:
   - a) Heating value: Supplier's data
   - b) Elemental analysis (carbon, hydrogen, nitrogen, oxygen and sulfur): Laboratory of SIRIM
   - c) Flow rate: Trend record

2) Boiler feed water:
   - a) Flow rate: Trend record
   - b) Temperature: Trend record

3) Intake air:
   - a) Flow rate: Hot wire anemometer (JICA)
     - Velocity range, m/s: 0-50
     - Temperature range, °C: 0-500
   - b) Temperature: Hot wire anemometer (JICA: ditto)

4) Generated steam:
   - a) Flow rate: Trend record
   - b) Temperature: Trend record
   - c) Pressure: Trend record

5) Exhaust gas:
   - a) Oxygen, carbon monoxide, carbon dioxide

     Flue gas analyzer (JICA)

Temperature, °C:	0-650
O_2, vol% :	0-20.9
CO, ppm:	0-4,000
NO, ppm:	0-2,000

CO_2, vol%: Adjustable

b) Temperature Trend record

(2) Energy Balance around steam turbine generator

1) Inlet steam:

a) Temperature Trend record

b) Pressure Trend record

2) Exhaust steam:

a) Temperature Trend record

b) Pressure Trend record

3) Condensed steam:

a) Flow rate Volumatic flow measuring apparatus (JICA)

b) Temperature Trend record

c) Pressure Trend record

4) Generated power:

a) Power Clamp-on meter (Voltage-Current-Watt meter: JICA)

Range, V:	150 / 300 / 600
Range, A:	20 / 50 /100 / 200 /500
Range, kW:	300 / 600 /900

b) Power factor Clamp-on meter (ditto)

(3) Management of steam and steam condensate lines

1) Confirmation of overall steam flow

Drawings and piping observation of the field

2) Confirmation of steam condensate recovery system

Drawings and field observation

3) Measurement of steam flow rate (turbine by-pass and evaporator inlet)

a) Orifice flow meter for turbine by-pass with recorder (JICA)

Scale Range, T/H:	25
Normal Flow, T/H:	5.5
Pressure, kg/cm^2 G:	11
Temperature, °C:	300

b) Orifice flow meter for evaporator with recorder (JICA)

Scale Range, T/H:	5
Normal Flow, T/H:	1.9
Pressure, kg/cm^2 G:	11

Temperature, °C: 300

(4) Steam trap system

1) Confirmation of steam trap list

List and field observation

2) Investigation of malfunctioning steam traps

Steam trap checker with recorder (JICA)

Measuring period, sec: 15

Temperature range, °C: 0-450

Manual or automatic judgement

(5) Management of thermal insulation system

1) Surface temperature measurement of insulated steam piping

Surface thermometor (JICA)

Measurement Range, °C: -50-600

Indicator: Digital

Bar thermometor (JICA)

Measurement Range, °C: -20-100

2) Confirmation of insulation material

Insulation design data and field observation

3) Confirmation of pipe dimension (diameter, length and thickness)

Piping design data and scale

(6) Management of Electricity consumption

1) Generated power: Voltage, current, power and power factor

Clamp-on meter (Voltage-Ampere-Watt meter: JICA)

Range, V: 150 / 300 / 600

Range, A: 20 / 50 /100 / 200 /500

Range, kW: 300 / 600 /900

2) Main transformers: Voltage, amperage, power and power factor

Clamp-on meter (ditto)

3) Major facilities: Voltage, amperage, power and power factor

Clamp-on meter (ditto)

13-9-5 Estimation Method for Boiler Combustion Control

For the estimation of combustion control around the boiler, the following equations are applied:

1) Theoretical Air Volume, A_0: Air volume necessary to burn 1 kg of solid or liquid fuel

A_0 = 1/0.21 x {22.4/12 x c + 22.4/4 x (h- o/8) + 22.4/32 x s

= 8.89 x c + 26.7 x (h- o/8) + 3.33 x s [Nm3/kg]

c: Carbon content in 1 kg of fuel　　h: Hydrogen content in 1 kg of fuel

o: Oxygen content in 1 kg of fuel　　s: Sulfur content in 1 kg of fuel

2) Theoretical air ratio, m:

Ratio of theoretical air volume (A_0) and real air volume (A)

$$m = 1 + \frac{(O_2) - 0.5 \times (CO)}{\{1.867 \times C + (h - o/8) + 0.7 \times S\} \times \{(CO_2) + (CO)\}/\{1.867 \times C + 0.7 \times S\}}$$

(O_2), (CO_2), (CO) : Exhaust gas content

or m = A_0 / A

3) Heat loss from flue gas, lg:

Heat loss from flue gas is calculated as follows.

lg = (Lg/Hl) x 100　　[%]

Lg = [G_0 +(m-1) x A_0] x Cg x (Tg-To)

Go = 0.79Ao + 1.867 x c + 11.2 x h + 0.7 x s + 1.24 x w + 0.8 x n

where;	H1	= lower heating value of fuel
	m	= air ratio
	Cg	= 0.33 [kcal/Nm3 x °C
	Tg	= flue gas temperature, °C
	To	= ambient temperature, °C
c, h, n, s, o and w		= elementary analysis of fuel in fraction

13-9-6 Heat Loss from Insulated Piping

Q = Heat loss through insulation per meter and hour [kcal/(m x h)]

= (T1 – T2)/{Ln(d2/d1)/2 x 3.14 x b} + 1/(3.14 x d2 x a)

T1: Steam temperature in piping, °C　　T2: Atmospheric temperature, °C

d1: Pipe outer diameter, m

d2: Insulation outer diameter, m

a: Heat transfer rate from insulator's outer surface, kcal/(m^2 x h x °C)

normally, 10 kcal /(m^2 x h x °C) is used

b: Thermal conductivity of insulation material, kcal/(m x h x °C)