9-5 Potential of Energy Efficiency Promotion

The energy efficiency promotion potentials are summarized in this section.

(1) Power Saving in Lift System

1) Operation Management Control	Avoiding empty car operation already adopted
2) Introduction of Inverter Control System for the Lift Power Supply	157-210 kWh/day

(2) Improvement of Boiler Combustion Conditions

1) Improvement of Air Ratio	Hard to control strictly because of automatic on/off operation
2) Reduction of Exhaust Gas Temperature	Standard value already achieved (no exact standard data available for on/off boilers)

(3) Solution for Frequent Over-Current Trip Problem

Installation of Capacitor	Stable chiller operation would be achieved after installation of 170 kVA capacitor for chiller #1 and #3 power supply

(4) Improvement of TNB Power Receiving System

Adjustment of Automatic Capacitor Control Set-up	Avoid problems due to leading current: Facility life time, power loss

(5) Introduction of Latent Heat Storage System (available only after future chiller expansion)

Reduction of Demand Power Charge	150 kW / month
Energy Charge peak period off-peak period	 1,400 kWh per day -2,000 kWh per day
Reduction of Chiller Design Capacity	650 to 500 kW

9-6 Cost of Measures for Energy Efficiency Promotion

Budget-type costs were estimated for two recommended modification works (1) power saving in lift system (2) solution to frequent over-current trip problem and (3) introduction of latent heat storage system. Note that item (3) is only for reference, applicable after future chiller expansion.

(1) Introduction of inverter control system for lift power supply

	RM
1. Lift replacement (L# 1, 6, 7, 8)	1,550,400
2. Lift replacement (L# 2, 3, 4, 5)	1,594,400
(Inverter controller installation: L# 1,2,3,4,5,6,7,8)	(314,480)
TOTAL	3,144,800

(2) Solution to frequent over-current trip problem

	10^3 Yen
1. Capacitor (25 kVar x 7 unit = 175 kVar)	3,220
2. Installation work (2 man-day)	100
TOTAL	3,320

(3) Introduction of latent heat storage system

	10^3 Yen
1. Water chiller (capacity: 390 kW)	19,500
2. Brine chiller (capacity: 110 kW)	9,000
3. Phase change material and tank (tank : carbon steel, 70 m^3)	10,500
4. Installation work	6,000
TOTAL	45,000

9-7 Benefit of Measures for Energy Efficiency Promotion

9-7-1 Current Price of Energy in Malaysia

Electric power could be saved by all the recommended measures for energy efficiency promotion. The current price of electric power conforms to category C2 of TENAGA NASIONAL's tariff, effective from 1 May, 1997, in the case of Hospital Seremban. The following rates are applied, according to this category of tariff.

-Peak load rate (between 800 and 2200 hours):	0.208 RM/kWh
-Off-peak load rate(between 2200 and 800 hours):	0.128 RM/ kWh
-Maximum demand charge:	25.7RM/kW/month

9-7-2 Benefits of Measures

The benefits of the measures are estimated and the results are summarized in Table 9-6.

Table 9-6 Estimation of Benefit from Measures

Measures	Benefit, RM/year
Introduction of Inverter Control System for the Lift Power Supply	20,569
Introduction of Latent Heat Storage System	57,273

9-8 Financial Evaluation of Measures

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

- Introduction of Inverter Control System for the Lift Power Supply
- Introduction of Latent Heat Storage System

The financial evaluation for the first measure is made under the assumption that the measures would be taken at a time when overage lifts were to be replaced by new lifts. As for the second measure, the financial evaluation is made assuming that the latent heat storage system is introduced into the hospital at the time of chiller system expansion. Under such conditions, only the amount of money that will be used for energy-saving equipment is considered as fixed investment in order to obtain the energy-saving benefit. The remaining invested money is regarded as a cost that is necessary, regardless of energy saving.

In fact, for the first measure, only the cost related to inverters is counted as the fixed investment for the purpose of the financial evaluation, assuming VVVF system lifts with inverters are introduced at the time of lift replacement. As for the second measure, the fixed investment cost for the financial evaluation is defined as the difference between the fixed investment in the case that latent heat storage is installed and that in which latent heat storage is not installed.

9-8-1 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:	No tax is imposed on Hospital Seremban, as it is a government organization.
4) Depreciation:	None
5) Fixed investment:	Fixed investment cost is shown in Table 9-7 in Malaysian Dollars. For the latent heat storage system, only the inverter controller installation is counted. As for the second measure, the fixed investment cost was obtained by subtracting the cost of a 650 kW-

water chiller (32.5 million Japanese Yen) from the total investment (45.0 million Japanese Yen), and converting it to Malaysian Dollars.

Table 9-7 Fixed Investment for Measures

Measures	Fixed Investment, RM
Introduction of Inverter Control System for the Lift Power Supply	314,000
Introduction of Latent Heat Storage System	402,542

9-8-2 Results of Financial Evaluation

Table 9-8 shows FIRROI before tax, FIRROI after tax and payback period for the two measures.

Table 9-8 Results of Financial Evaluation

Measures	FIRROI before tax	FIRROI after tax	Payback Period
Introduction of Inverter Control System for the Lift Power Supply	-0.2%	-0.2%	15.3 years
Introduction of Latent Heat Storage System	11.4%	11.4%	7.0 years

In addition to the above, three kinds of indicators are calculated for the two measures on the assumption that electricity tariff rises to the rate shown in Table 9-9, which is considered to be the current level in Japan. This calculation is made in order to find out the effect of electricity tariff on the financial feasibility of those measures.

Table 9-9 Assumed Rise in Electricity Rate for Study

	Assumed Electricity Rate for Study		Reference (C2 tariff)
Peak Load Rate	0.483 RM/kWh	(15 JY/kWh)	0.208 RM/kWh
Off-peak Load Rate	0.113 RM/kWh	(3.5 JY/kWh)	0.128 RM/kWh
Max. Demand Charge	49.9 RM/kW/month	(1,550 JY/kWh/month)	25.7 RM/kW/month

Table 9-10 shows the results of the evaluation at the electricity rate assumed in Table 9-9.

FIRROI before tax and after tax increased by about 12% for the first measure and 46% for the second. The payback periods were shortened by 8.5 years and by 5.3 years for the first and second measures, respectively.

Table 9-10 Results of Financial Evaluation at Assumed Increased Electricity Rate

Measures	FIRROI before tax	FIRROI after tax	Payback Period
Introduction of Inverter Control System for the Lift Power Supply	12.0%	12.0%	6.8 years
(Difference from the base)	(+12.2%)	(+12.2%)	(-8.5 years)
Introduction of Latent Heat Storage System	57.3%	57.3%	1.7 years
(Difference from the base)	(+45.9%)	(+45.9%)	(-5.3 years)

9-8-3 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 taken as an indication of the opportunity cost of capital in Malaysia.

The measure of installing an inverter control system in the lift power supply is not financially feasible, assuming an inverter system is installed together with lift replacement. Currently, the hospital consumes electricity at a relatively low rate in the lift system, because of the low frequency of lift operation. Therefore, no large effect is expected by the installation of an inverter control system. Another reason for low feasibility is due to the low electricity tariff in Malaysia. If the electricity tariff increases to the current Japanese level, its financial feasibility will be improved to the marginal levels shown in Table 9-10.

The latent heat storage system measure is evaluated under the assumption that it is installed at the time of chiller expansion, as mentioned before. It is concluded that the measure is at the marginal level of financially feasibility under the conditions of the study. Its FIRROI is 11.4% and the payback period is 7 years. However, it is said that the measure will become financially feasible if electricity tariff increases to the current Japanese level, judging from the indicators shown in Table 9-10. It is recommended that the introduction of latent heat storage be investigated at the time of chiller expansion.

9-9 Recommendations for Energy Efficiency Promotion

Based on the energy audit and subsequent study for Hospital Seremban, the following measures are recommended for improving its energy efficiency.

(a) For space cooling, Hospital Seremban currently uses a combination of natural ventilation, mechanical ventilation, centralized air-conditioning and local air-conditioning systems. Approximately forty percent of main building areas are cooled by the centralized system. In the near future, expansion of air-conditioning will become inevitable instead of natural ventilation and mechanical ventilation. In the event of such air-conditioning system expansion, it is recommended that the introduction of latent heat storage be investigated. This technology will enable effective peak load saving and reduction in maximum demand by shifting peak demand into off-peak demand. As a result of the financial evaluation, we conclude that this measure has a marginal level of financial feasibility under the conditions set for the study.

(b) The chiller system often stops because of the over-current trip problem. According to the investigation by the study team during the energy audit, this system has two problems: extraordinarily low power factor and high current quite close to the trip set value of 300 amperes. The following measures should be investigated.

- Clarifying the cause of low power factor
- Increasing the fuse from 300 ampere to 350 ampere
- Installation of capacitor
- Replacing distribution line cable with a larger size

(c) Negative power factor values were observed at the power receiving system from TNB during the energy audit by the study team. It is recommended the automatic control system of the capacitor bank be adjusted.

(d) The air ratio of boiler exhaust gas exceeds the Japanese guideline. Improvement is desired by reinforcement of operation management from an energy efficiency point of view, although the current air ratio may be affected by the on-off operation of boilers.

Chapter 10 Cement (APMC Rawang Works)

10-1 Outline of Cement Industry in Malaysia

The first commercial cement plant was established in 1953, in Rawang, Selangor, by Malayan Cement Limited. Subsequently, Malaya Industrial and Mining Corporation began operations in 1958, also in Selangor, followed by Tasek Cement Limited and Pan Malaysia Cement Works, Ltd., in Perak in 1964. Between the 70's and 80's, several cement manufacturers, including the two cement grinding plants, one each in Sabah and Sarawak, were established to augment supply.

There were ten cement manufacturers operating in Malaysia in 1995 (six integrated plants and four cement grinding plants all ensuring a regular supply of high quality cement to meet the nation's growing needs).
Key data of the cement industry for 1996 follows. (Data Source: Cement & Concrete Association)

Total clinker production : 9.29 million tons
Total cement production : 12.71 million tons
Total cement consumption : 15.19 million tons
Average cement price : 198.00 RM/tons (9.90 RM/50kg bag)
Per capita consumption : 717.0 kg

In March 1967, Malayan Cement and Pan Malaysia Cement Works merged their manufacturing operations to form Associated Pan Malaysia Sdn Berhad (APMC). Since then, APMC has invested huge sums to expand and modernize both factories. Upon completion of an upgrading exercise in 1993, its rated production capacity stood at 2.8 million tons of clinker per annum. Another 1.8 million tons of clinker production capacity at Kanthan is expected to be on-stream in 1997.

APMC produces ordinary portland cement, masonry cement and portland pulverized fuel ash cement, all in compliance with Malaysian and equivalent British standards. It is also able to produce other special cements depending on market demand.

10-2 Outline of Factory, Facilities and Process of Major Product

10-2-1 Outline of Factory

1) Name of Factory : Associated Pan Malaysia Cement Sdn, Berhad. Rawang Works

2) Address :
Head Office : Wisma APMC : No 2, Jaran Kilang 46050 Petaling Jaya Selangor Darul Ehsan
Tel : 03-7918344 Fax : 03-7917309 / 7942518
Rawang Plant : Rawang Works : 48000 Rawang Selangor Darul Ehsan
Tel : 03-6916711 / 4 Fax : 03-6919361

3) President (Name) : Mr. Saw Zwe Seng / Factory Manager : Mr. Chen Choon Siong

4) Energy Manager (Engineering Manager) : Mr. Tan Chek Luck
(Operations Manager) : Mr. R. Jaya Kumaran

5) Number of Employees / Number of Engineers : Total 560 persons

	Managers	Staff/Engineers	Workers	Sub-Total
Administrative Department	9	14	3	26
Production Department	56	123	294	473
Mining Department	4	5	52	61
Total	69	142	349	560

(* Not Include Plant Manager 1)

6) Number of Energy-Related Engineers : 13 persons
General Manager (Plant Manager): 1 person
Fuel-Related Engineers : 5 persons
Electricity-Related Engineers : 7 persons

7) Major Products and Trends in Annual Sales Amount: (unit ton/year) :

Table 10-1 **Trends in Annual Sales Amount : (unit ton/year)**

Year Kinds of cement	1992	1993	1994	1995	1996	1997
(1) Ordinary portland Cement	1,096,596	1,129,533	1,161,363	1,213,085	1,256,472	1,296,728
(2) Fly ash cement	86,323	160,870	197,364	341,168	383,265	435,895
(3) Masonary cement	167,741	183,634	208,035	180,592	143,230	159,614
Total	1,367,352	1,474,041	1,566,762	1,734,645	1,782,967	1,892,237

8) History of Factory :

Malayan Cement Berhad (MCB) was established as the country's first major cement plant in Malaysia at Rawang, Selangor, in 1953. It is a member of Blue Circle Group (UK), one of world's largest cement producers. Two wet kilns and associated crushers, mills, etc., were constructed and operated until 1981, but are not operating at present.

The new 5-stage, twin-string SF precalciner plant was erected and commissioned by IHI Japan early in 1981. This 4,000 t/day SF precalciner was modified to a 5,000 t/day, 5-stage NSF precalciner plant in 1992.

9) Share and Position in its Industrial Sub-sector

APMC is the No. 1 cement company in Malaysia and its market share is about 33 percent.

10) Plant Capacity (Design & Actual) :

Designed Capacity : 1,500,000 t-clinker/year

Actual Capacity : 1,600,000 t-clinker/year (1,860,000 t-cement/year)

11) Employment and Training

For newly hired employees, operations training through on-the-job training (OJT) and safety education are carried out for a certain period inside the factory. However, energy efficiency training for employees is not executed directly. Details of operations training and safety education were not available.

10-2-2 Outline of Cement Manufacturing Process

Figure 10-1 shows the material, gas and fuel of APMC's Rawang Works.

(1) Quarrying of Raw Materials

Limestone is quarried nearby and transported by dump trucks to a crusher, which reduces the size of stone to smaller than 30mm. Shale is extracted from reserves about 24 km away and transported by lorries to the works, where it is crushed and blended in a reclaimer store.

(2) Raw Material Preparation

Limestone and shale (after drying) are ground separately in the roller-press and closed circuit tube mills. Ground limestone and shale raw meals are stored separately in silos for final homogenization to ensure that the quality of raw meal is consistent with predetermined quality standards.

(3) Clinker Burning

The new 5-stage twin-string precalciner dry-process plant at Rawang was constructed and commissioned by IHI Japan early in 1981. This 4,000 t/day SF precalciner was modified to a 5,200 t/day, 5-Stage NSF precalciner plant in 1992.

The operation of this kiln is unique. Primary raw materials, i.e., limestone and secondary raw material, i.e., coal shale blended with iron rich clay, are separately ground, blended and stored in silos. From blending and storage silos, limestone raw meal is fed to the top of a 5-stage cyclone preheater and coal shale raw meal is fed directly into a flash furnace (Precalciner) before entering a rotary kiln. Limestone raw meal flows down through cyclones and finally reaches decarbonation temperature of 900℃ at the fifth stage cyclone, where it mixes with coal shale and enters the rotary kiln at about 88 % decarbonation for conversion into cement clinker. In the kiln, successive chemical reactions occur and material is sintered to cement clinker at about 1,450℃.

(4) Clinker Cooling

Red hot clinker leaves the kiln at about 1,250℃ and is rapidly cooled in a grate-cooler before being conveyed to clinker storage silos.

(5) Cement Grinding

From the clinker silos, clinker is extracted and ground with the addition of approximately 5 % gypsum in closed-circuit tube mills to produce cement. Gypsum is added to control the setting time of cement. Cement leaving the grinding mill is pumped and stored in cement silos ready for dispatch.

(6) Packing and Dispatch

Cement drawn from cement silos is fed to high-speed rotary packers in the packing plant for bagging. Bags are filled to 50 kg and discharged for loading into trucks and rail wagons. Bulk tankers are loaded directly from cement silos. Bulk cement is also loaded into rail wagons for delivery to the company's depots .

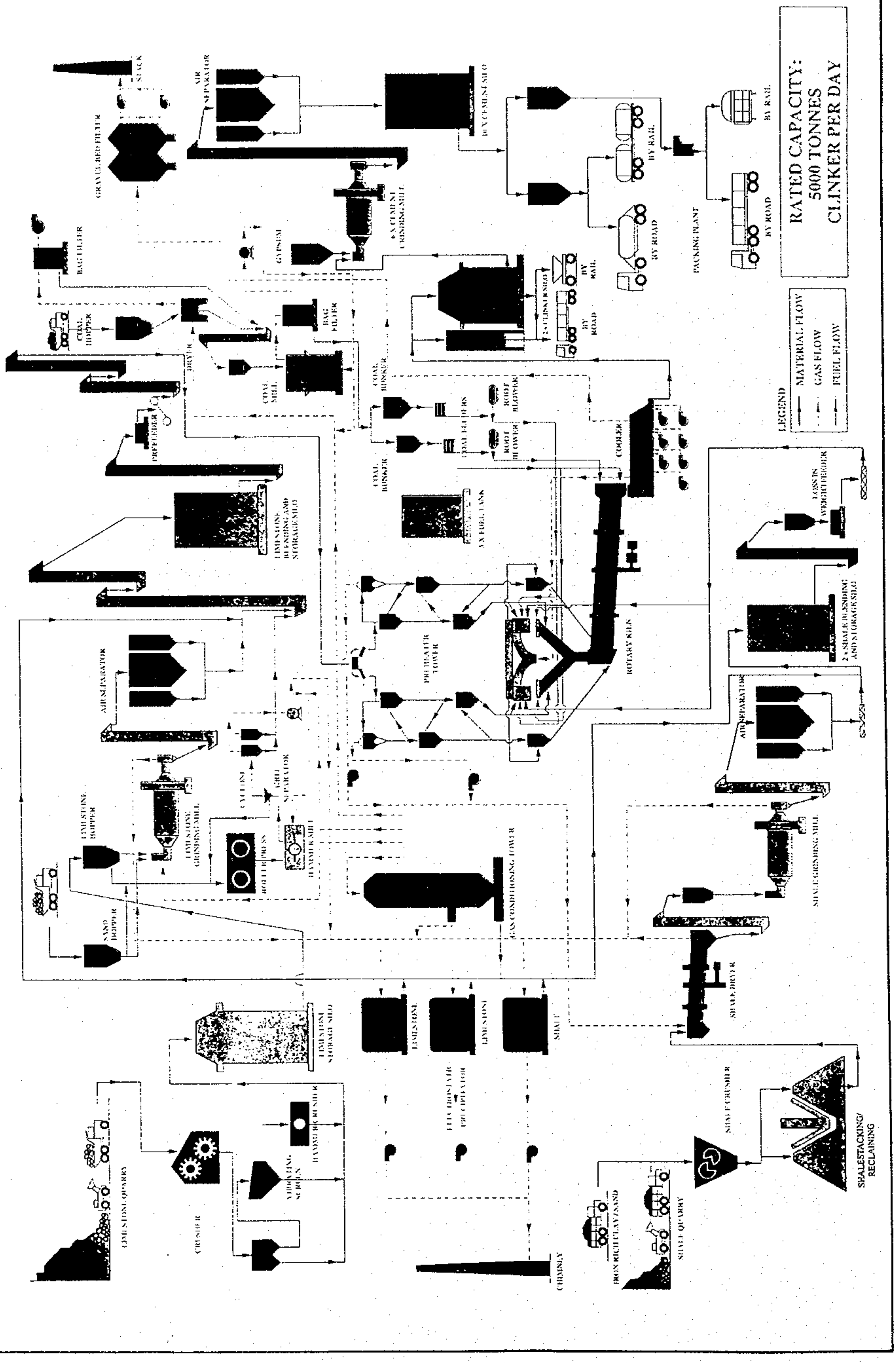
(7) Quality Control

The laboratory at Rawang Works is equipped with the latest Multi-Channel Simultaneous X-ray analyzer, automatic samplers and other test equipment. Proportioning of raw materials is strictly controlled at all stages of the process to ensure that the quality of finished product well exceeds the standards set by the Standard & Industrial Research Institute of Malaysia (SIRIM).

(8) Environment Control

The dry process plant at each location is well-equipped with high efficiency electrostatic precipitators, gravel bed filters and bag filters at various stages of the process to ensure that the dust emission level is maintained well below the limits stipulated by the authorities at all times.

igure 10-1 Rawang Works Dry-process Flow Chart



10-3 Trends in Energy Consumption

Table 10-2 and Table 10-3 show the trends in annual energy consumption and unit consumption in the past 6 years, and the fuel and electricity consumption in 1997, respectively.

Table 10-2 Trends in Annual Energy Consumption and Unit Consumption

Year Name of utility	1992	1993	1994	1995	1996	1997
(1)Fuel oil ton	16,796	24,460	29,755	42,590	32,235	33,447
(2)Bituminous coal ton	63,512	88,845	99,702	111,324	148,160	153,413
(3)Other fuel (Coal shale) ton	516,682	348,967	405,282	404,651	403,514	349,017
(4)Electricity 1000 kWh	158,614	180,297	205,006	213,546	222,624	233,670
(5)Clinker Production ton	997,070	1,120,055	1,299,175	1,474,030	1,554,895	1,560,055
(t/day)	3,567.6	3,701.0	4,214.6	4,691.6	4,875.6	4,826.4
(6)Cement Production ton	1,360,602	1,474,041	1,566,762	1,734,845	1,782,967	1,892,237
(7)Heat Consumption (kcal/kg-cli')	952	1071	1124	982	912	915
(8)Power Consumption (kWh/t-cli')	159.1	161.0	157.8	144.9	143.2	149.8
(kWh/t-cem)	131.3	137.1	138.9	129.8	130.3	134.2

Table 10-3 Annual Energy Consumption (1997)

Name of Utility	Consumption (ton/year)	Heat value (kcal/kg)	Calorific value (10^9 kcal/y)	(%)	Unit price (RM/t)	Cost 10^3 RM/y (%)
Fuel oil	33,447	10,200	341.2	(21.4)	422	14,114.6 (18.6)
Coal (wet)	153,413					
(dry)	130,401	6,500	847.6	(53.0)	135	20,710.8 (27.2)
Coal (wet)	349,017					
Shale (dry)	296,664	700	207.7	(13.0)	5.7	1,989.4 (2.6)
*-1	(10^3 kWh/y)	(kcal/kWh)			Tariff E-3	
Electricity	233,670	860	201.0	(12.6)	Special	39,259.2 (51.6)
Total	—	—	1597.5	(100.0)	—	76,074.0(100.0)

Judging from the trends of energy consumption and unit consumption, the results of completing the upgrading exercise from 4,000 t/day to 5,000 t/day of clinker production in 1993 were as follows.

(1) Clinker production increased from 3,701 t/d to 4,876 t/d (in 1996)

(2) Heat consumption decreased from 1,071 kcal/kg-cli' to 915 kcal/kg-cli'

(3) With power consumption, however, there was little change, decreasing from 137.1 kWh/t-cem to 134.2 kWh/t-cem.

(4) Nevertheless, the above figures of unit consumption are approximately 25-30 percent higher than those of Japan.

Table 10-3 and Table 10-4 show a comparison of energy consumption in 1997.

Table 10-4 Relative Comparison of Energy Consumption (1997)

Name of utility	Calorific base (%)	Monetary base (%)	Calorie price RM/10^3 kcal	Unit price ratio
(1) Fuel oil	21.4	18.6	0.0414	2
(2) Coal	53.0	27.2	0.0208	1
(3) Coal shale	13.0	2.6	0.0081	0.4
(4) Electricity *-1	12.6	51.6	0.169 - 0.195	8 - 9
Total	100.0	100.0	—	—

N.B: *-1 The price calculated assuming that the peak/off-peak ratio is 58/42, and assuming the contracted demand charge is 30,400 kW.

(5) Consumption of electrical power is not more than 13 % of total energy consumption on a calorific basis, but is shown to reach approximately 52 % on a monetary basis.

(6) Consumption of oil energy is under 22 % of total energy consumption on a calorific basis, and about 19 % on a monetary basis. Therefore, it is desirable to reduce the use of oil.

(7) In terms of calorie price, the price of electricity is 8-9 times higher than that of coal, and the price of oil is double that of coal. Thus we can see that the price of electricity is very expensive.

10-4 Energy Audit Method and Procedure

A factory survey for the energy audit was carried out through interviews and plant observations based on questionnaires and data sheets prepared by the Study Team. As for these results, high figures were recorded for power consumption and also heat consumption at this works in spite of the latest facilities. For this investigation, the study team carried out an energy audit concerning the energy consumption of facilities and equipment, instrumental and control equipment, and operations.

To conduct an energy audit at this cement works, field investigations such as the analysis of operation data is the first essential step, followed by many kind of measurements. The results of the energy audit, including an evaluation of the results and recommendations for energy efficiency, are described in this chapter.

Major items and types of energy audits in cement works are as follows.

1. Heat consumption of burning department
    (1) Preheater and F.F furnace
    (2) Kiln
    (3) Cooler
2. Electricity consumption of the raw material grinding department
3. Electricity consumption of the coal drying and grinding department
4. Electricity consumption of the cement grinding department

10-5 Measurement Execution Procedure

To calculate and evaluate the current condition of energy consumption and to develop an energy balance, including gas and material balance, the measurements and operation data analysis described below were carried out, according to the schedule and corresponding to major items for energy audit.

(1) Raw Material Grinding Dept'

1. Limestone mill : Grinding capacity & mill kW
2. Coal shale mill : Grinding capacity & mill kW; F.K Pump/Compressor kW, flow rate; DTA / TG analysis of coal shale.

(2) **Coal Drying & Grinding Dept'**

1. Coal dryer : Drying capacity & kW; moisture content; exhaust gas volume / temp.
2. Coal mill : Grinding capacity & kW; moisture content; exhaust gas volume / temp.

(3) **Cement Grinding Dept'**

No. 1~3 mill : F.K Pump / Compressor kW, flow rate; grinding capacity & mill kW
No. 4~5 mill : F.K Pump / Compressor kW, flow rate; grinding capacity & mill kW

(4) **Burning Department**

1. Preheater Cyclone	:	Temperature & pressure; combustion gas ($O_2/CO/CO_2$ %) Exhaust gas flow rate; dust content; surface temperature
2. F.F furnace	:	Coal/oil/coal shale feed rate; conveying air volume, temperature; surface temperature; quantity of unburned carbon
3. Kiln	:	Coal feed rate; conveying air volume; primary air flow rate; surface temp; combustion gas ($O_2/CO/CO_2$ %) flow rate
4. Cooler	:	Cooling air flow rate; exhaust gas flow rate; recouped air flow rate/temp; surface temperature; outlet clinker temp.
5. Clinker Quality	:	Chemical composition of kiln feed raw meal and clinker

(5) **General energy consumption**

(6) **Field investigation**

1. Review of equipment list
2. Investigation of drawings
3. Observation of operating conditions of equipment and facilities

10-6 Measurement and Investigation Items and Analysis Results Thereof

10-6-1 Measurement and Investigation Items

(1) Raw materials, fuels and energy consumption
(2) Measurement of air and exhaust gas volume
  1) Measurement of kiln primary air volume
  2) Measurement of F.F furnace primary air volume

    3) Measurement of exhaust gas volume at coal dryer and mill outlets
    4) Measurement of cooler exhaust gas volume
    5) Measurement of recouped air volume (tertiary air volume)
    6) Measurement of IDF exhaust gas volume
(3) Measurement and investigation results of cyclone outlet static pressure, and igloss (LOI) of cyclone outlet raw meal
    1) Cyclone outlet static pressure measurement
    2) Measurement and investigation of igloss (LOI) of cyclone outlet raw meal
(4) Measurement and investigation results of O_2/CO/CO_2 %
(5) Analysis results of kiln feed raw meal and clinker
(6) Measurement of surface temperature
(7) Investigation of electricity consumption and unit power consumption of each equipment piece
(8) Investigation of coal shale combustion characteristics

10-6-2 Data Analysis and Conclusion

From the measurement results carried out in the energy audit and the results of investigating and analyzing existing data, the following items became evident concerning the facilities and operation of this works.

(a) Heat consumption is high, at 950 – 970 kcal/kg-cli'.
(b) The measurement result of recouped air (tertiary air) volume was around 60 % of the necessary air volume (2,900 Nm3/min) for combustion of fuel feed to the F.F furnace. This shows that the combustion air volume for burning fuel is around 40 % less than required.
(c) The gas, material and heat balance was calculated and its result is shown in Table 10-6. Main data are as follows.
    1) Heat consumption : 924.7 kcal/kg-cli'
    2) Cooler heat recovery efficiency : 52.8 %
    3) Sensible heat taken away by cooler exhaust gas : 145.2 kcal/kg-cli'
    4) Sensible heat taken away by preheater exhaust gas : 315.1 kcal/kg-cli'

    This sensible heat taken away by exhaust gas 3) + 4) = 460.3 kcal/kg-cli' is extremely high. It is better to recover this heat by waste heat recovery power system.
(d) Compared with other cyclones, the pressure loss of C3 and C4 cyclones is rather high. It is desirable to consider measures to counter the pressure loss of these cyclones.

(e) The calculation result of the collecting efficiency of C5 (bottom) cyclone is low at approximately 66.3 %. If it is possible to improve the collecting efficiency of the cyclone, power consumption will increase in proportion to the increased pressure loss, while heat consumption will decrease by the fall in exhaust gas temperature,

(f) The following items can be confirmed from the recording chart of O_2 (%) ,

1) O_2 (%) at kiln inlet housing: Short-term fluctuation is around 0.6-1.0 % and long-term fluctuation is 1.4-1.6 %.
2) O_2 (%) at C5 cyclone outlet: Fluctuates at 15-minute intervals at a rate of around 0.6-2.5 %

These fluctuations are attributed to the feeding accuracy of the coal feeding apparatus and the fluctuation of preheater and kiln line exhaust gas volume.

(g) To confirm the burning conditions of fuel in the F.F furnace, the calorific value of kiln feed raw meal was measured. The average measurement result was 213 kcal/kg.

Calculation based on the material balance indicates that around 35-40 % of unburned carbon is generated. This coincides with the result of (b) above.

10-7 Energy Flow of Factory

(1) Heat balance of kiln line (Refer to Table 10-5)

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

Because of the use 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 is high, accounting for approximately 47.5 % of the total heat.

Table 10-5 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

(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 10-6 shows the result, thereof.

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 Nm3/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 of fuel in the F.F furnace., that is , the recouped air volume is low and the cooler exhaust gas volume is high.

10-8 Energy Consumption

Trends in energy consumption of the APMC Rawang Works of Malaysia and the cement Industry of Japan are shown in Table 10-7 and Table 10-8. Furthermore, trends in heat consumption and power consumption during the past 25 years in the Japanese cement industry are shown in Figure 10-2 and Figure 10-3. At the same time, recent heat and power consumption of each country comprises part of each figure.

Table 10-6 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)	(kg/kg-cli')	Gas / Air (Nm^3/Min)	(Nm^3/kg-cli')	Tg / Tm (℃)	Heat (kcal/kg-cli')
(A) Clinker Production	**5250** (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) Vco$_2$ + H$_2$O			1130	0.3100		
(c) Excess/Leakage air			680	0.1866		

N.B: * : 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) Vco$_2$ + H$_2$O			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)	Fly dust	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

Table 10-7 Malaysia APMC Rawang Works Data

Year	Cl. Production (tonnes/year)	Ratio (%)	Kiln Operation rate(%)	Heat Cons. (kcal/kg-cl.)	Power Con. (kWh/t-cem)	Labor Productivity (t/m)
1992	999,070	100	76.4	952	131.3	(1,780)
1993	1120,055	112.3	82.9	1,071	137.1	–
1994	1299,175	130.3	84.5	1,124	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 10-8 Trends in Japan's Energy Consumption

[Statistical data of the Japan Cement Industry]

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

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 Dept':	+ 5 - 6	kWh/t-cem
Burning Dept':	+ 14 - 18	kWh/t-cem
Cement Grinding Dept':	+ 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.

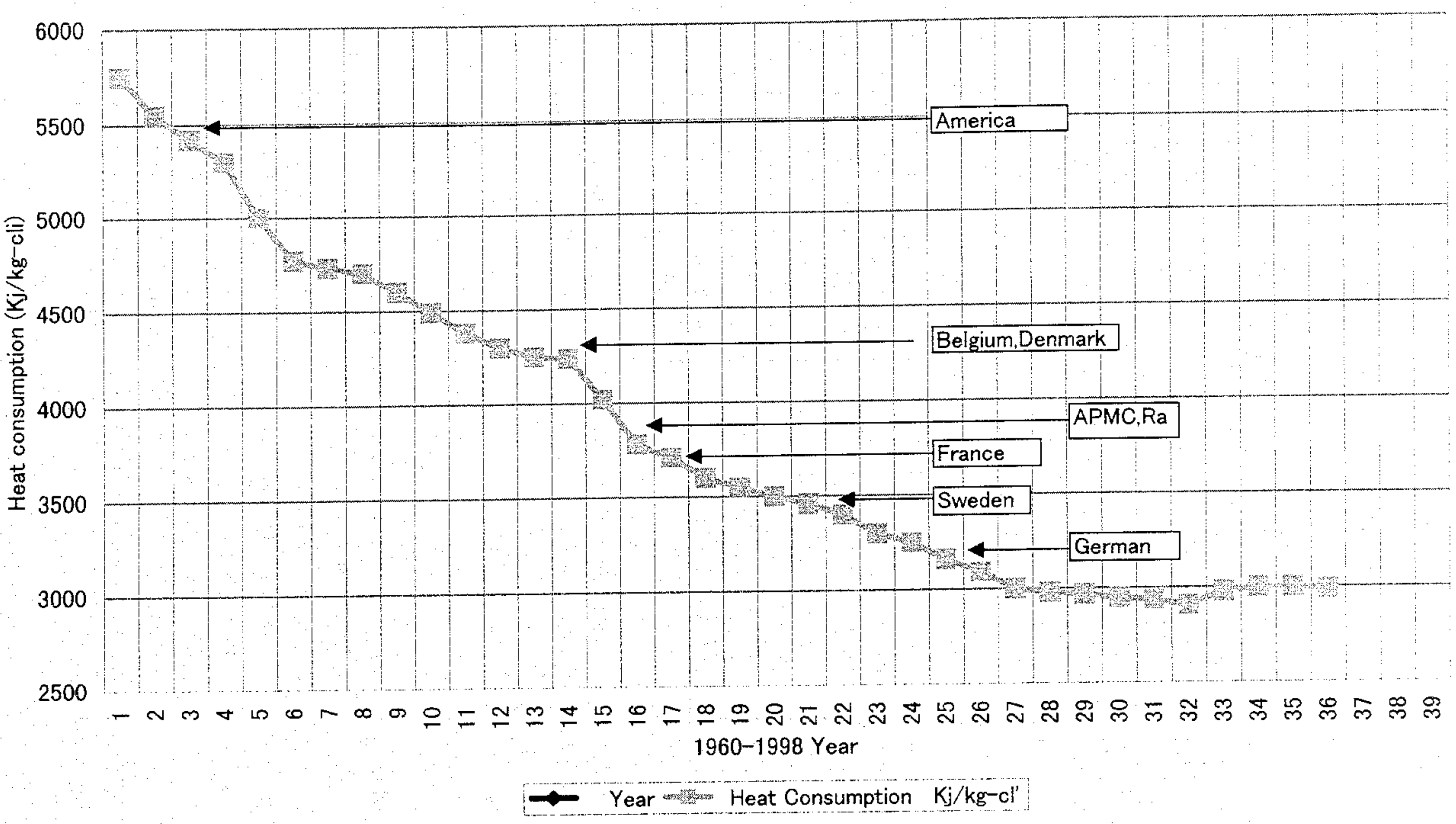


Figure 10-2 Trend Heat Consumption in Japan

Figure 10-3 Trend Power Consumption in Japan

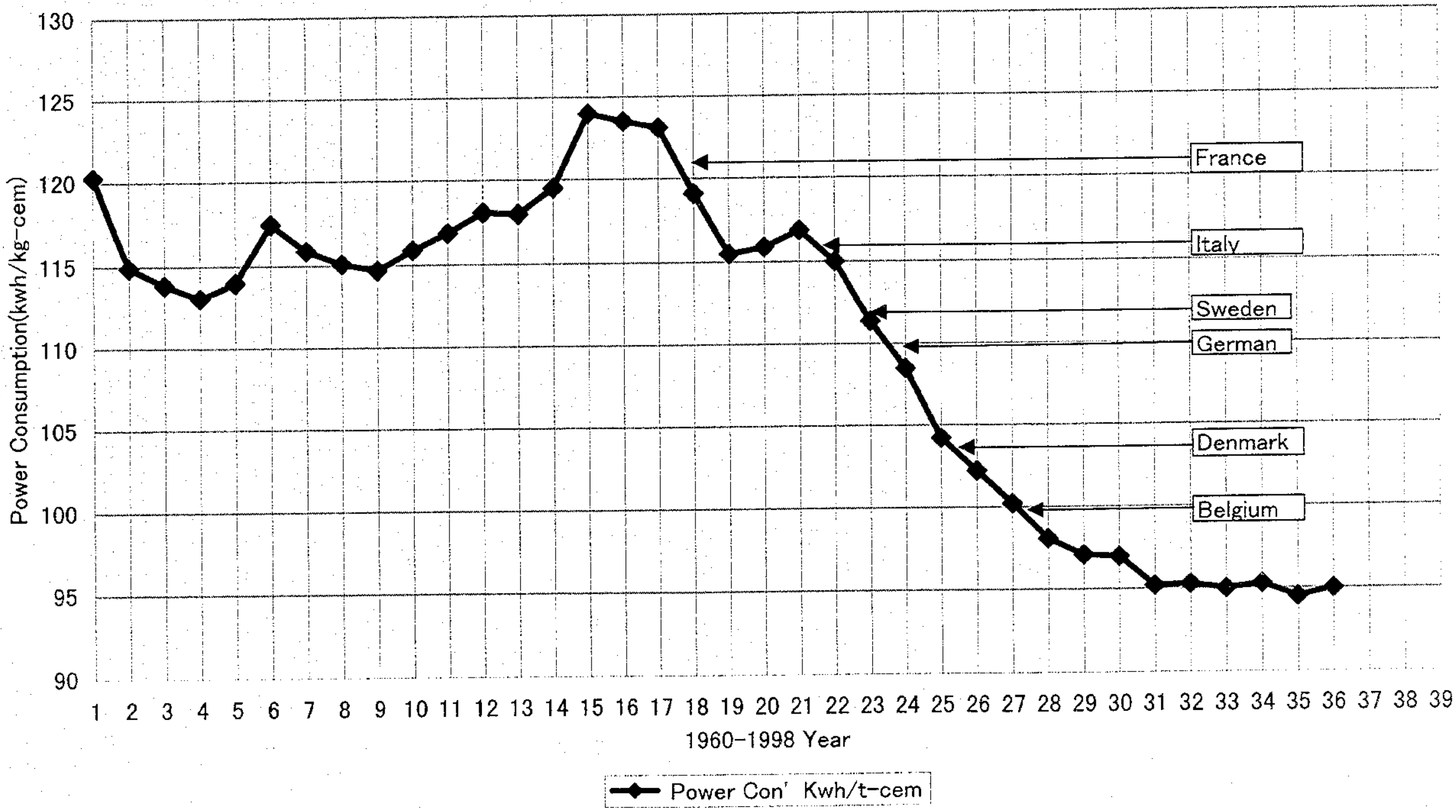


Figure 10-3 Trend Power Consumption in Japan

10-9 Present Situation of Energy Management and Energy Efficiency Promotion

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 works.

(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 works 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 of 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, and consequently partial use of oil.

(3) In relation to problems with the plant (A)-(1), the fuel ratio of kiln to F.F furnace 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, 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 10-6-2 " Data analysis and conclusion ", 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 measures for works energy efficiency promotion.

10-10 Measures for Energy Efficiency Promotion

As improvement items in respect to the problems described in Chapter 10-9, measures for energy efficiency promotion were selected specifically in terms of related equipment and operation, etc. These items are shown in Table 10-9.

Table 10-9 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 F.F 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 F.K 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 330-340Nm3/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 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 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 good quality of clinker	◎	
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.

From among them, the major energy efficiency promotion measures and their effects are described in detail in section 10-10-1 to section 10-10-12. The results are summarized in Table 10-12, "A list of measures for energy efficiency promotion", and the investment costs and calculated profits thereof concerning the 4 selected items in these energy efficiency promotion measures, are also shown in this table.

10-10-1 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 Table 10-6, "Gas, material and heat balance data" .)

Table 10-10 A List of Measures for Energy Efficiency Promotion

Measures of Energy Efficiency Promotion	Energy Saving Effect		Investment (10^3 yen) (RM)	Calculation IRR, N(year)
	Heat/Power Consumption	Monetary Amount (Yen/y) (RM/y)		
1) Prevention of air-leakage	3.8 kWh/t-cli' (6,336,000 kWh/y)	916,000 RM/y		
2) Rationalization of transportation system	5.3 kWh/t-cli' (9,523,000 kWh/y)	1,377,000 RM/y		
3) Mill construction	Reduce oil + 33,447 t/y Increase coal 49,105 t/y Reduction of heat 25,792 x 10^6 kcal/y (Convert into coal 3950 t/y) Increase of power 499,200 kWh/y	-14,114,630 RM/y + 6,629,170 RM/y - 533,250 RM/y + 72,180 RM/y Σ7,946,500 RM/y	950,000 (30,595,000)	
4) Change of feeding point and feeding system of coal shale	8,210 x 10^6 kcal/y (Convert into coal 1258 t/y)	169,830 RM/y		
5) Reduction of cyclone pressure loss	2.0 kWh/t-cli' 3,300,000 kWh/y	477,180 RM/y		
6) Improvement of C5 cyclone collecting efficiency	Reduction of heat (Convert into coal 8510 t/y) Increase of power 1,770,000 kWh/y	- 1,148,850 RM/y + 255,950 RM/y Σ 892,900 RM/y		
7) Waste heat boiler/generator system	Power generation Capacity 15,000 kW 101,007,000 kWh/y	15,132,000 RM/y	3,000,000 (96,618,000)	
8) Modification of F.F furnace	—	—	—	
9) Lifter brick at kiln backend part	11.7 kcal/kg-cli' 19,470 x 10^6 kcal/y (Convert into coal 2982 t/y)	404,685 RM/y	10,000 (322,000)	
10) Replacement of cooler GBF	Reduction of heat (Convert into coal 4596 t/y) Reduction of power 960,000 kWh/y Recover of clinker 250 t/y	620,460 RM/y 138,800 RM/y 49,500 RM/y Σ 808,760 RM/y		
11) Rationalization of cement grinding process	Reduction of power 12,210,000 kWh/y	2,048,260 RM/y	2,200,000 (70,853,000)	
12) Grinding aids	Reduction of power 4.07kWh/t 7,500,000 kWh/y Cost up by grinding aids (Addition 0,02 %)	1,084,500 RM/y - 634,300 RM/y Σ 450,200 RM/y		

(1) Reduction of heat 21,300 t-coal/y (converted into coal) (In respect to total heat Abt. 17.3 %)

(2) Reduction of electricity 37,559,800 kWh/y (126,033,800 kWh/y)*-1, (In respect to total electricity Abt. 16.1 % (53.9 %)) *-1

(3) Energy saving effect 30,623,315 RM/y (In respect to total investment cost 209,282,000 RM Abt. 14.6 %)

*-1 : ( ) shows the case including waste heat generation power in electric power saving effect

(1)	Limestone grinding process	(a) Roller press/hammer mill line	234 Nm3/min
		(b) Limestone mill line	244 Nm3/min
(2)	Coal shale dryer/ mill line		818 Nm3/min
(3)	Coal dryer/mill process	(a) Coal mill line	189 Nm3/min
		(b) Coal dryer line	174 Nm3/min
(4)	Preheater line		147 Nm3/min
(5)	Kiln line		85 Nm3/min
(6)	GCT (Gas Conditioning Tower)		366 Nm3/min
(7)	Cooler exhaust gas line		2,060 Nm3/min
	Total		4,317 Nm3/min

Total air-leakage volume is around 39.5 % of the total exhaust gas volume (10,930 Nm3/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.

10-10-2 Rationalization of Transportation System

In this works, pneumatic transportation facilities, that is, an F.K pump and compressor, are installed for coal shale and cement transportation. Power consumption of these facilities is approximately 1,493 kWh/h, and is about 2,126 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 **- 1,240 kWh/h = - 9,523,000 kWh/y (Abt 5.3 kWh/t-cli')**

10-10-3 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.

10-10-4 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 change 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 system to a mechanical system:
Conveying air volume of coal shale 44 m3/min x 2 lines → 72 Nm3/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

10-10-5 Reduction of Cyclone Pressure Loss

Pressure loss of cyclone(mmAq)	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.

10-10-6 Improvement of C5 Cyclone Collecting Efficiency

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	60mmAq 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/Nm3℃ = 33.2 kcal/kg-cli' → 55,584x10^6 kcal/y

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

10-10-7 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 10-7 " Energy Flow of Factory ")

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.

10-10-8 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.

10-10-9 Lifter Brick at Kiln Backend Part

As mentioned in Chapter 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.

10-10-10 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' (30×10^9 kcal/y)

(b) It will be possible to prevent air-leakage of the cooler exhaust line (air-leakage quantity 2060 Nm3/min) and kiln hood. The reduction in electricity is estimated at approximately 3000 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.

10-10-11 Rationalization of Cement Grinding Process

Power consumption for cement grinding at this works 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.

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

10-10-12 Grinding Aids

This works does not employ grinding aids. However, the small-scale use of these would increase grinding capacity and reduce the power used in grinding. 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**

10-11 Benefit of Measures for Energy Efficiency Promotin

10-11-1 Current Price of Energy for APMC Rawang Works

(1) Fuel

Table 10-11 shows the unit prices and heat values of fuels for APMC Rawang Works.

Table 10-11 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

10-11-2 Benefits of Measures

Table 10-12 summarizes the benefits of the measures.

Table 10-12 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

10-12 Financial Evaluation of Measures

In this section, financial evaluations are made for the following measures requiring investment 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

10-12-1 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 10-13 summarizes the fixed investment cost for the measures.

Table 10-13 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

10-12-2 Results of Financial Evaluation

Table 10-14 shows FIRROI before tax, FIRROI after tax and the payback period for the measures.

Table 10-14 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

10-12-3 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.

10-13 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 the previous section, 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 11 Food Processing (Sugar Refinery)

11-1 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, account for 30 percent of the total among Malaysia's four sugar refinery factories.

11-1-1 Outline of Factory

1) Name of the Factory: Central Sugars Refinery Sdn Bhd
2) Address: Batu Tiga, 40000 Shah Alam, Selangor, Malaysia
3) Factory Organization: General Manager: Mr. Lem Cheng Hoe
   Technical Adviser: Chan Choong Lim
   Engineering Manager: Ir. Lim Chin Chuan
4) Capital: 33 million RM
5) Number of Employees: 290
6) Number of Energy-Related Engineers: - Heat 1, - Electricity 5
7) General Layout of the Factory: - Factory area 16 acres (Total)
   - Building area 6.4 acres
8) Major Products: Refined sugar
   - White sugar - Brown sugar - Liquid sugar
9) Trends in Annual Sales Amount:

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)

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

11-2 Outline of Production Facilities and Flow Sheet of Major Product

(1) Production Facilities

The main product of the factory is refined sugar, as mentioned above. The production scheme is roughly illustrated in Figure 11-1. The factory is planning to increase production capacity from 1,300 to 1,500 ton-melt per day by modifying the affination station.

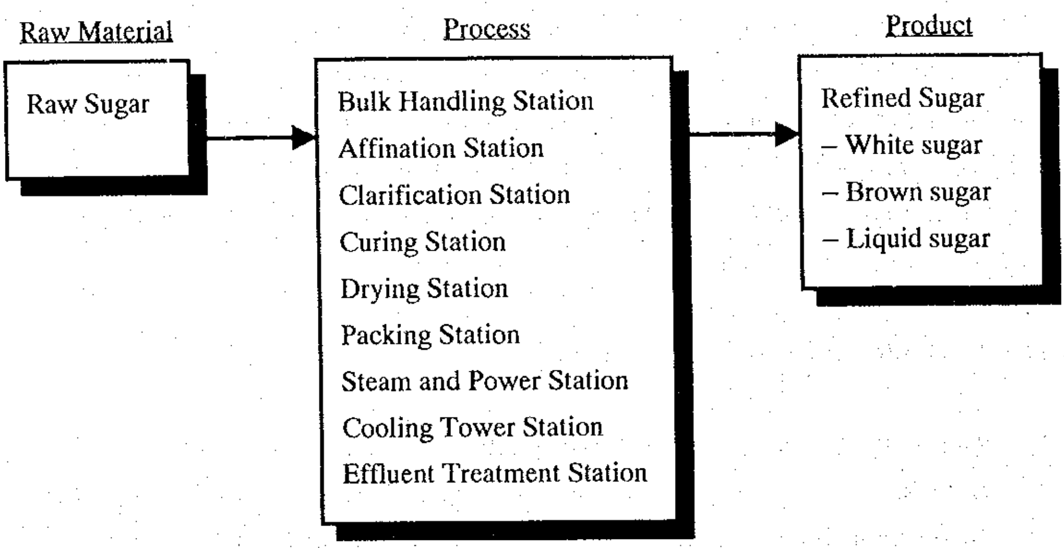


Figure 11-1 Outline of Production Facilities

Figure 11-2 shows a simplified production flow diagram of the factory.

(2) Major Energy-Related Facilities

1) 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)

2) 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)

3) Air compressor No.1, 3,4

4) Centrifugal machine x 15

5) 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

6) Electric Power Receiving
Receiving Voltage, volt: 415 (50 Hz)
Maximum Demand, kWh: 3,200 (Total Demand) 600 (receiving from TENAGA)
Power Factor, per cent: 0.8
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

11-3 Production and Energy Consumption

(1) Production Capacity, Trends in Production Amount of Major Products and Annual Operating Hours: See Table 11-1

Table 11-1 Production Capacity, Production Amount 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) Trends in Unit Consumption Figure of Raw Materials and Energy for Major Products:
See Table 11-2

(3) Trends in Annual Utility Consumption: See Table 11-3

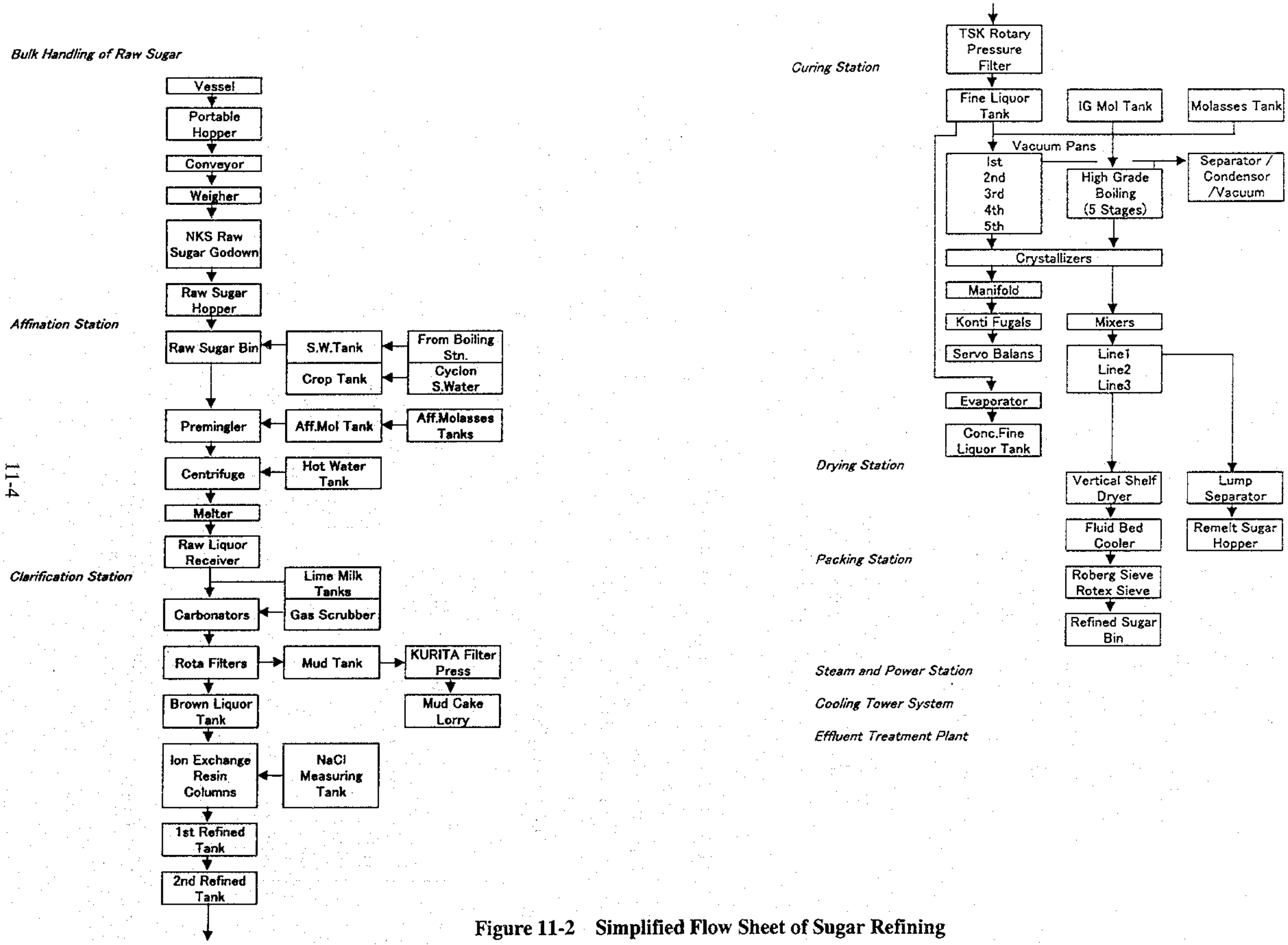


Figure 11-2 Simplified Flow Sheet of Sugar Refining

Table 11-2 Unit Consumption Figure of Raw Materials and Energy for Each Major Product

Name of major project	Unit consumption figure	Unit	1994	1995	1996	1997 (estimate)	1998 (plant)
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 11-3 Annual Utility Consumption and Unit Price

No.	Name of Unity	Unit	Lower Heating Value (kcal/kg)	1994		1995		1996		1997 (estimate)		1998 (plant)	
				Con-sumption	Unit price	Con-sumption	Unit price	Con-sumption	Unit price	Con-sumption	Unit price	Con-sumption	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	10^6kWh		24.75		26.14		26.93		28.31		24.42	
4.	Process water	10^6m^3		1.19		1.19		1.20		1.20		1.20	
5.	Cooling water	10^6m^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	10^6ton		-		-		0.32		0.32		0.32	

11-4 Method and Procedure of Energy Audit

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

(1) Items to Note for Implementation of Energy Audit

The following problems were considered to require audit.

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) Increasing of power generation from steam turbine generator

(2) Analysis and Measuring Points

The main analysis and measuring points for the energy audit are shown in the following figures respectively.

Figure 11-3 Steam System Flow
Figure 11-4 Power System

(3) Modification for Analysis and Measuring Work

There is one steam flow meter to measure the total generated steam from the boiler. The study team planned to install two 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 Figure 11-3 shows.

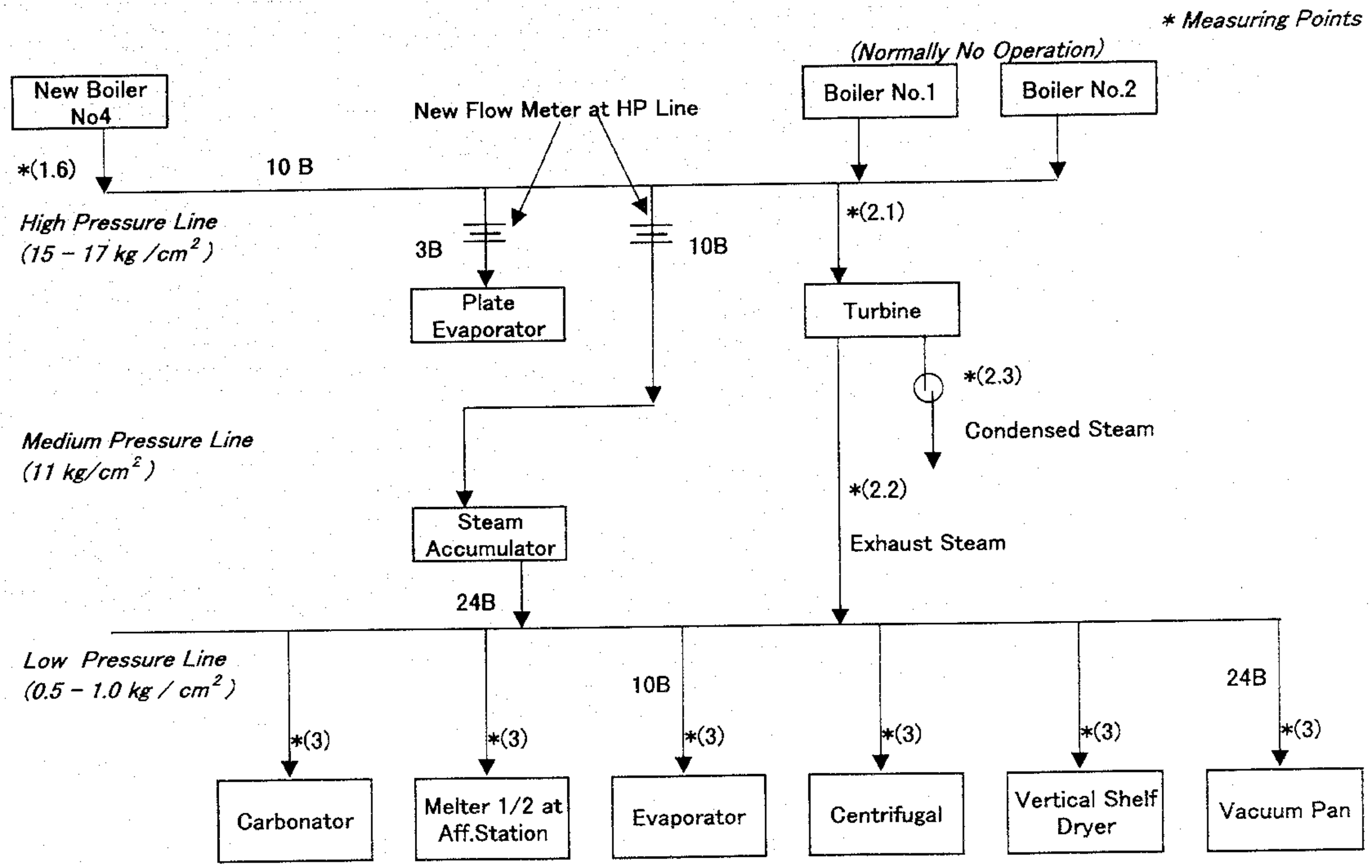


Figure 11-3 Steam System Flow

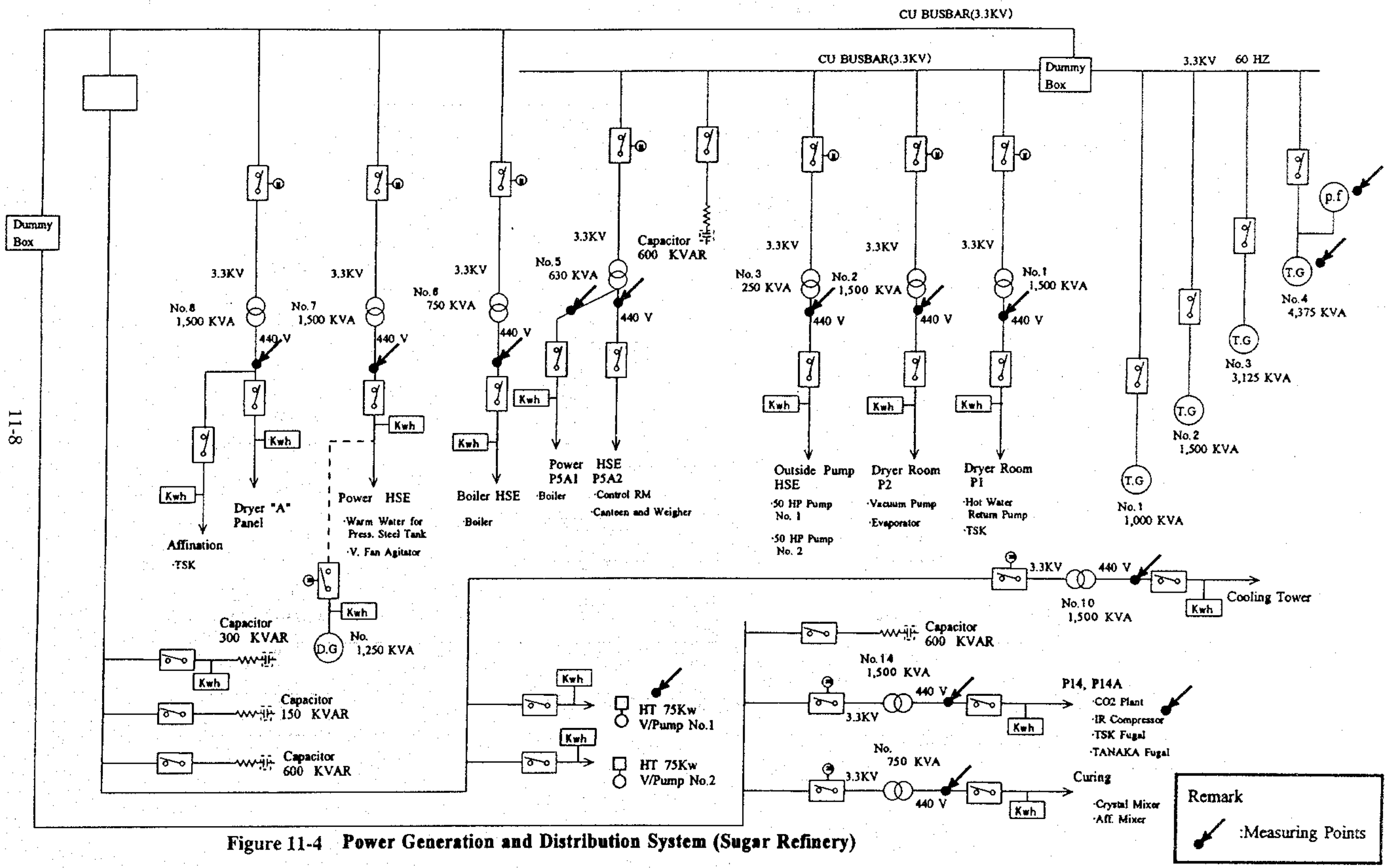


Figure 11-4 Power Generation and Distribution System (Sugar Refinery)

11-5 Measurement Procedure

11-5-1 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

11-5-2 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 malfunctioning 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

11-6 Measurements Results

The results of measurement and analysis described in this section are categorized as the following six items.

1. Steam boiler and related facilities
2. Steam turbine generator
3. Steam trap system
4. Thermal insulation system
5. Electricity consumption

11-6-1 Steam Boiler and Related Facilities

(1) Air Intake Data

For audit purposes, air intake data were taken three times. The results are as follows:

Velocity (m/s)	19.20	14.93	17.00
Flow rate (m^3/min)	812.97	632.17	719.81
Temperature 1 (°C)	39.38	38.23	40.23
Temperature 2 (°C)	92.0	-	-

Temperatures 1 & 2 represent the temperatures before and after pre-heater, respectively.

(2) Flue Gas Data

Flue gas data were taken three times as shown below.

O_2 (%)	2.1	2.3	2.1
CO_2 (%)	14.3	14.0	14.2
CO (ppm)	45	5	9
Temperature 1 (°C)	374.7	362.4	368.6
Temperature 2 (°C)	231.9	-	-

Temperatures 1 & 2 represent the temperatures before and after pre-heater, respectively.

(3) Fuel Consumption Data

Flue consumption was measured three times as shown below.

Flow rate (kg/hr)	2588.5	2785.8	2807.0

A sample of the fuel was taken to SIRIM Environmental & Energy Technology Center and the analysis results are as follows:

Parameters	Amount (wt %)
Carbon	83.79
Hydrogen	11.44
Oxygen	2.23
Sulfur	2.05
Nitrogen	0.403
Moisture	0.091

(4) Steam Consumption Breakdown

The steam consumption breakdown on average is as follows:

To Plate Evaporator	=	1.15 tons/hr	(2.6%)
To Steam Accumulator	=	11.06 tons/hr	(25.1%)
To Power Plant	=	31.87 tons/hr	(72.3%)

The actual steam consumption, which causes the variation of boiler operation, varies from one hour to another depending on the demand.

(5) Air Ratio Calculation

λ = Actual Air Quantity / Theoretical Air Quantity
= A / Ao= 1.136

but, A = v_{air}.A.(273/273+θ) / Q_{fuel} (Nm^3/kg_{fuel})
= 14.93*0.706*3,600*(273/(273+39.38))/ 2785.8=11.89

and, Ao = 8.89C + 26.7(H-O/8) + 3.33S (Nm^3/kg_{fuel})
= 8.89*0.8379+26.7(0.1144-0.0223/8)+3.33*0.0205 = 10.497

where, v_{air} = air intake velocity (m/s)
A = air intake area (m^2)
θ = air intake temperature (°C)
Q_{fuel} = fuel intake flowrate (kg/hr)
C, H, O and S = elementary analysis of fuel in fraction

(6) Heat Loss from Flue Gas

Heat loss from flue gas is calculated as follows.
lg = (Lg/Hl) x 100[%] =(800/10632)*100=7.5%

Lg = [G_0 +(m-1) x A_0] x Cg x (Tg-To)
=(11.168+(1.136-1)*10.497)*0.33*(231.9-39.38)=800

Go = 0.79Ao + 1.867 x C + 11.2 x H + 0.7 x S + 1.24 x W + 0.8 x N
= 0.79*10.497+1.867*0.8379+11.2*0.1144+0.7*0.0205+1.24*0.00091+0.8*0.00403
=11.168

where, H1 = lower heating value of fuel
=8,100*0.8379+34,000(0.1144-0.0223/8)+2,500*0.0205
=10,632
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

11-6-2 Steam Turbine Generator

Table 11-4 shows operational data for the turbine generator No.4.

11-6-3 Steam Trap System

64 steam traps in operation were investigated out of 90 traps installed in steam piping and steam consuming facilities. The types of steam traps are categorized into two, DISC and FLOAT type.

(1) Analysis of Malfunctioning Steam Traps

Table 11-5 shows the summarized failure analysis, including the estimated monetary loss resulting from steam leakage from malfunctioning traps

The measurement result shows that 30 traps are working well and 31 traps are malfunctioning, while 3 traps are not in service.

Table 11-5 Summarized Failure Analysis of Steam Traps

Malfunction Category	Good	Failed	No service	Total	Monetary Loss (US$/year)
Good	30	0	0	30	0
Leaking	0	9	0	9	2,757
Blowing	0	1	0	1	1,356
Low Temperature	0	14	0	14	0
Blocked	0	7	0	7	0
No Data	0	0	3	3	0
TOTAL	30	31	3	64	4,113

Figure 11-5 illustrates the analysis on malfunctioning traps by type and malfunction categories.

11-6-4 Thermal Insulation System

Thermal insulation conditions of steam piping were checked along the main steam lines. Heat losses from each steam line were estimated as summarized in Table 11-6.

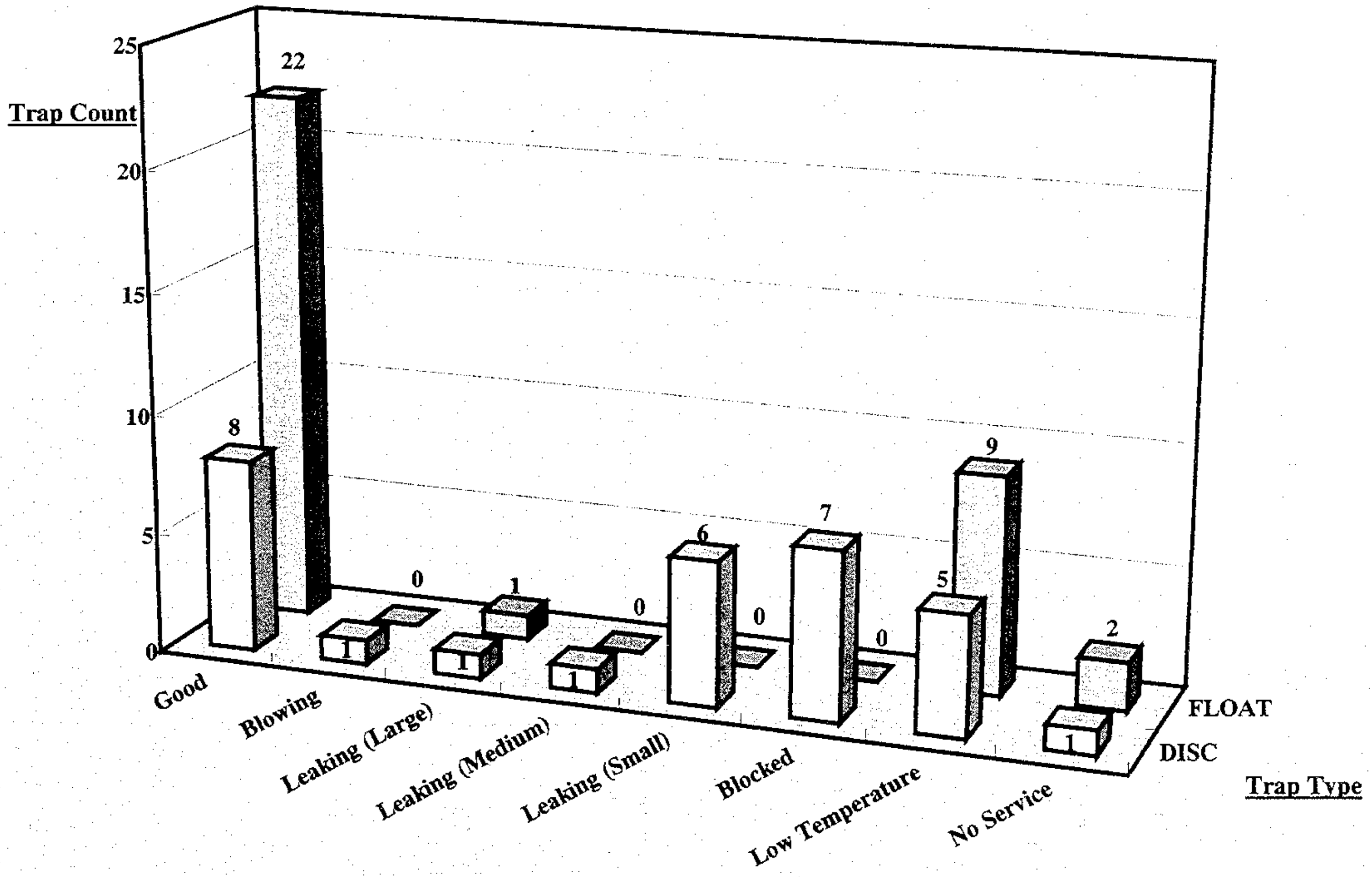


Figure 11-5 Steam Trap Failure Analysis

Table 11-4 Operation Data for Steam Turbine Generator

Equipment No. Turbine Generator No.4

Date /Hours	Inlet Steam			Extracted Steam			Steam Released to Atm.			Condensed Steam			Turbine	Generator					
	Flow Rate (kg/h)	Temp. °C	Pressure (bar)	Flow Rate (kg/h)	Temp. °C	Pressure (bar)	Flow Rate (kg/h)	Temp. °C	Pressure (bar)	Flow Rate (kg/h)	Temp. °C	Pressure (bar)	Speed (rpm)	Speed (rpm)	Output (kW)	Volt	Ampere (A)	Power Factor	Cumulative Output (KWh)
Design Spec.	38,200	310.0	17		120	1							6,545	1,800	3,500	3,300	765		
23/9/98																			
10.00 am	NA	277.7	17.2	NA	112	0.55	0	NA	NA	102	69	Atm	6,600	1,815	2,810	3,340	615	NA	6,480,800
12.00 pm	NA	277.8	17.2	NA	112	0.50	0	NA	NA	NA	78	Atm	6,614	1,819	2,790	3,340	560	NA	NA
2.30 pm	NA	277.4	17.4	NA	113	0.58	0	NA	NA	NA	NA	Atm	6,621	1,821	2,680	3,240	550	-0.93	NA
4.30 pm	NA	277.7	17.6	NA	112	0.58	0	NA	NA	NA	NA	Atm	6,636	1,825	2,960	3,270	597	-0.93	6,499,100
Average		**277.65**	**17.3**		**112**	**0.55**	**0**			**102**	**74**	**Atm**	**6,618**	**1,820**	**2,810**	**3,298**	**581**	**-0.93**	**2,815**
24/9/98																			
10.00 am	NA	277.9	17.2	NA	113	0.6	0	NA	NA	NA	NA	Atm	6,600	1,815	2,700	3,340	558	-0.95	6,548,700
12.00 pm	NA	277.8	17.2	NA	113	0.5	0	NA	NA	NA	NA	Atm	6,600	1,815	3,080	3,320	498	-0.94	NA
2.30 pm	NA	278	17.2	NA	113	0.55	0	NA	NA	NA	NA	Atm	6,618	1,820	2,720	3,370	530	-0.89	NA
4.30 pm	NA	277.9	17.2	NA	113	0.59	0	NA	NA	NA	NA	Atm	6,632	1,824	2,800	3,340	570	-0.92	6,566,900
Average		**277.9**	**17.2**		**113**	**0.56**	**0**			**NA**	**NA**	**Atm**	**6,612**	**1,819**	**2,825**	**3,343**	**539**	**-0.93**	**2,800**
25/9/98																			
10.00 am	NA	277.4	16.7	NA	113	0.5	0	NA	NA	NA	NA	Atm	6,610	1,818	2,670	3,370	500	-0.97	6,615,900
12.00 pm	NA	278.1	17.2	NA	113	0.55	0	NA	NA	NA	NA	Atm	6,629	1,823	3,300	2,900	521	-0.95	NA
2.30 pm	NA	277.1	17.7	NA	113	0.55	0	NA	NA	NA	NA	Atm	6,614	1,819	2,860	3,410	525	-1.00	NA
4.30 pm	NA	277.5	17.2	NA	113	0.58	0	NA	NA	NA	NA	Atm	6,629	1,823	2,890	3,310	535	-0.94	6,633,900
Average		**277.53**	**17.2**		**113**	**0.55**	**0**			**NA**	**NA**	**Atm**	**6,620**	**1,821**	**2,930**	**3,248**	**520**	**-0.96**	**2,769**

Table 11-6 Heat Loss from Steam Main Line

Line	Rated Flow rate	Steam Pipe		Insulation		Heat Loss, Q	Steam Loss	Steam Loss
		O.D	Length	Material	Thickness			
	(t/hr)	(mm)	(m)		(cm)	(kcal/hr)	(kg/hr)	(%)
Pressure: 17 bar Steam Temperature: 280 °C Atmospheric Temperature: 33 °C								
Boiler #4 to HP Header	50.0	250	50	rock wool	5.0	10,770	15.1	0.030
HP Header to T.G #4 a)	38.5	250	27	rock wool	5.0	5,816	8.1	0.021
Pressure: 11 bar Steam Temperature: 260 °C Atmospheric Temperature: 33 °C								
HP Header to Plate Evaporator	5.0	100	90	rock wool	3.8	10,133	14.3	0.286
HP Header to Accumulator b), c)	5.0	250	85	calcium silicate	5.0	18,041	25.5	0.510
Pressure: 0.5 bar Steam Temperature: 110 °C Atmospheric Temperature: 33 °C								
T.G #4 to LP Header d)	38.5	400	26	calcium silicate	5.0	2,516	3.9	0.010
LP Header to Vacuum Pan e)	30.0	600	70	calcium silicate	5.0	9,780	15.0	0.050
LP Header to Vertical Shelf Dryer e)	5.3	50	20	rock wool	2.5	474	0.7	0.014
LP Header to Melter #1 e)	Not known	250	35	rock wool	5.0	1,779	2.7	N.A
LP Header to Melter #2,3 e)	Not known	200	40	rock wool	5.0	1,691	2.6	N.A
LP Header to Steam Header for Evaporators e)	5.7	250	50	rock wool	5.0	2,542	3.9	0.069
LP Header to Molasses Plate Heater e)	1.5	100	25	rock wool	3.8	748	1.2	0.077
TOTAL						64,290		

Applied Heat Conductivity Value for Insulation Material

	110 °C	260 °C	280 °C
Calcium Silicate;	0.0485	0.0547	0.0557
Rock Wool ;	0.0376	0.0490	0.0507

Note:
a) = abnormal surface temperature (120 °C) was observed at this line
b) = No insulation at expansion joint
c) = No insulation at flow meter
d) = No insulation at a small section of straight pipe
e) = No insulation for valves around LP header

11-6-5 Electricity Consumption

(1) Measurement of Power Supply and Distribution System

This factory has one turbine generator to supply the entire power demanded at the sugar plant. Electric power consumption was measured at each point, as illustrated in Figure 11-4.

(2) Major Motors

This factory has installed about 426 motors, which are classified by rated capacity as follows.

1)	less than 10 kW	270
2)	10 – 30 kW	91
3)	30 – 50 kW	27
4)	50 – 100 kW	14
5)	more than 100 kW	24

Power factor for the biggest motor, the cooling water pump, was kept at 0.9 or more during the measurement.

(3) Generated Power Profile

Figure 11-6 shows the generated power consumption measured hourly on September 29, 1998. Output power fluctuates between 2,800 and 3,200 kW just to accommodate the plant power demand.

Power factor at the supply end was manually kept at 0.8 or higher.

(4) Power Profile for Air Compressor and Centrifuge

A detailed view of power consumption trends in the air compressor and TSK centrifuge showed some fluctuations due to the frequent load-unload operation.

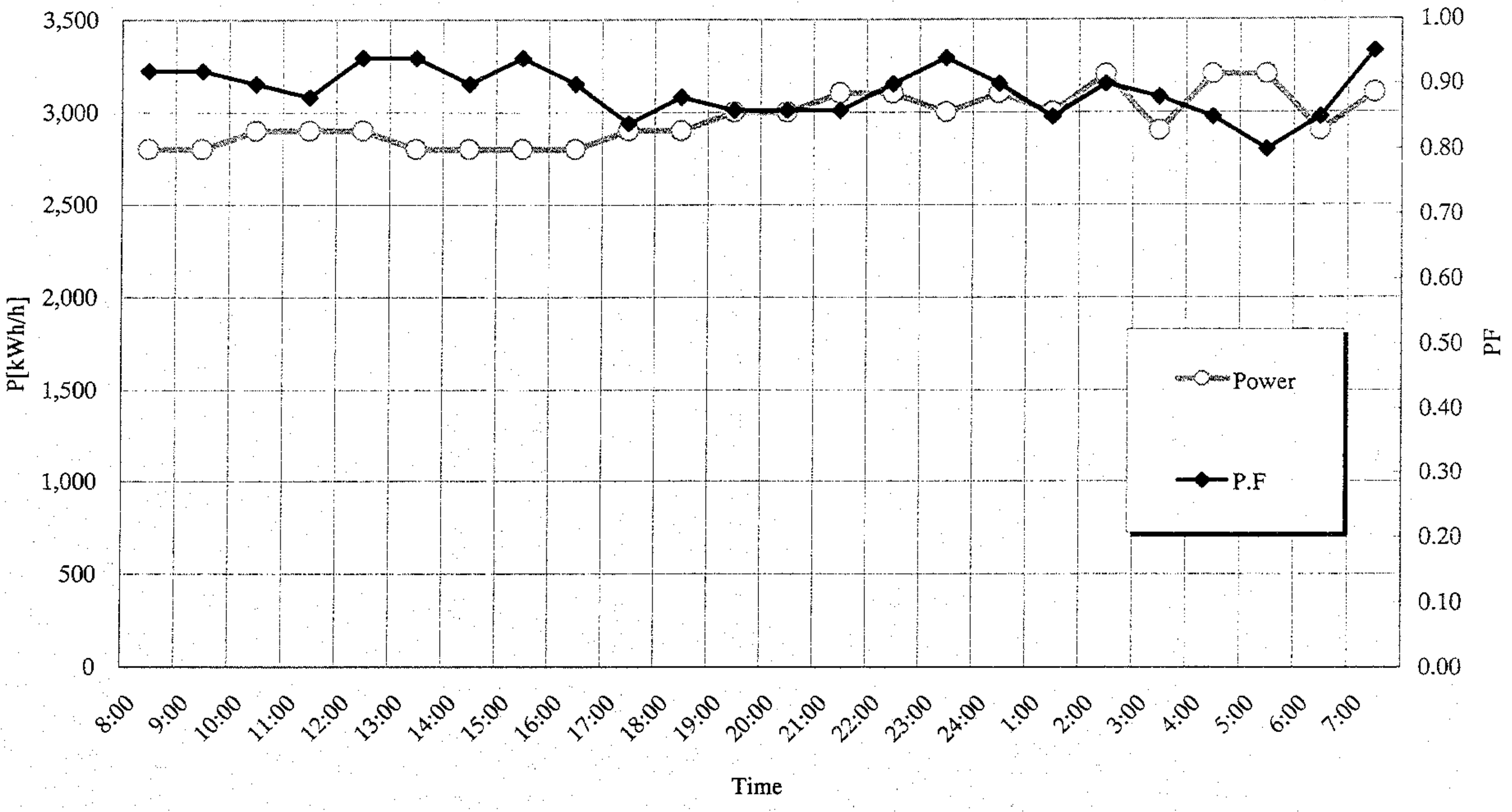


Figure 11-6 Electricity Consumption - Power and Power Factor at TG #4 Output (29 Sep. 1998)

11-7 Energy Flow Chart of Major Energy-Consuming Facilities

11-7-1 Energy Flowchart around the Steam Boiler

Based on the result of measurement and analysis, the energy balance around the steam boiler was calculated as follows.

Table 11-7 Energy Flow around Steam Boiler

	Quantity	Temperature (°C)	Pressure (bar)	Heat(Kcal/h)	Ratio(%)
Inlet					
1) Fuel Oil	2,785.8 kg/hr	30	Ambient	29,620,000	86.28
2) Air	33,294 Nm^3/hr	38	Ambient	310,000	0.90
3) Feed Water	27.3 ton/hr	29	Ambient	800,000	2.33
4) Recycled Condensate	15.5 ton/hr	113	0.5	1,700,000	4.95
5) Steam (Deaerator)	2.9 ton/hr	113	0.5	1,900,000	5.54
Total				34,330,000	100.00
Outlet					
1) Steam	44,060kg/h	282	20.6	31,340,000	91.29
2) Blow Down	1.6 ton/hr	282	20.6	340,000	0.99
2) Exhaust gas	35,078Nm^3/hr	231.9	-	2,600,000	7.57
3) Heat Loss	-	-	-	50,000	0.15
Total				34,330,000	100.00

From these calculated results, it is judged that the boiler was operated under sound conditions with suitable heat efficiency (steam/fuel oil) of 91.29%.

11-7-2 Energy Flowchart around Steam Transfer Line

The heat balance around the steam transfer line was also calculated as follows in Table 11-8.

Table 11-8 Energy Balance around Steam Transfer Line

	Quantity	Temperature (°C)	Pressure (bar)	Heat Energy (kcal/h)	Ratio (percent)
INPUT					
1) Generated Steam	44,060 kg/hr	282	20.6	31,340,000	100.00
Total	44,060 kg/hr			31,340,000	100.00
OUTPUT					
1) Steam to Film Evaporator	1,000 kg/hr	278	17.2	710,000	2.27
2) Steam to Accumulator	11,060 kg/hr	278	17.2	7,850,000	25.05
2) Steam to Turbine Generator	32,000 kg/hr	278	17.2	22,720,000	72.50
3) Heat Loss from Pipe Surface	-	-	-	60,000	0.18
Total	44,060 kg/hr			31,340,000	100.00

11-7-3 Energy Flowchart around Steam Turbine Generator

The heat balance around the steam turbine generator was also calculated as follows in Table 11-9.

Table 11-9 Energy Balance around Steam Turbine Generator

	Quantity	Temperature (°C)	Pressure (bar)	Heat Energy (kcal/h)	Ratio (percent)
INPUT					
1) Steam Inlet	32,000 kg/hr	278	17.2	22,720,000	100.00
Total				22,720,000	100.00
OUTPUT					
1) Extracted Steam	31,098 kg/hr	113	0.55	19,902,720	87.60
2) Steam Released to Atmosphere	0 kg/hr	-	-	0	0.00
3) Condensed Steam	102 kg/hr	74	Atm.	7,550	0.03
4) Generated Power	2,900 kWh	-	-	2,494,000	10.98
5) Loss	Balance			315,730	1.39
Total				22,720,000	100.00

11-7-4 Energy Flowchart around Pressure Control Valve to Steam Accumulator

The energy balance around the steam pressure reducing valve to the Steam Accumulator was also calculated as follows in Table 11-10.

Table 11-10 Energy Balance around Steam Control Valve to Accumulator

	Quantity	Temperature (°C)	Pressure (bar)	Heat Energy (kcal/h)	Ratio (percent)
INPUT					
1) Steam for Steam Accumulator	11,060 kg/hr	278	17.2	7,850,000	100.00
Total	11,060 kg/hr			7,850,000	100.00
OUTPUT					
1) Steam to Steam Accumulator	11,060 kg/hr	113	0.55	7,131,500	90.85
2) Kinetic Energy Loss by Control Valve	-	-	-	718,500	9.15
Total	11,060 kg/hr			7,850,000	100.00

11-7-5 Electricity Consumption Network

Electrical power consumption balance is shown in Table 11-11.

Table 11-11 Electrical Power Balance

Service	Quantity (kWh)	Ratio (%)	Remarks
Inlet			
1) Generated Power	2,900	94.16	Turbine Generator No.4
2) Receiving from TNB	180	5.84	
TOTAL	(3,080)	(100.00)	
Outlet			
1) Office Use (TNB)	120	3.90	
2) No. 1 Line (P1ACB2)	85	2.76	LINT IT4(35), Others(50)
3) No. 2 Line (P2ACB2)	510	16.56	NIRO Evaporator(60), Film Eva.(50), Others(400)
4) No. 3 Line (TNB)	60	1.95	Vacuum Pump(60)
5) No. 5 Line (P5A1,2)	160	5.19	Boiler(80), Lighting(80)
6) No. 6 Line (P6)	320	10.39	Boiler(320)
7) No. 7 Line (P7A1)	500	16.23	Pan Agitator & Others (500)

Service	Quantity (kWh)	Ratio (%)	Remarks
8) No. 7 Line (P7A2)	65	2.11	TSK, ASEA, Others (65)
9) No. 8 Line (P8A1)	200	6.49	TSK, MCCB, Others (200)
10) No.12,13 Line	100	3.25	Vacuum Pump #1, 2
11) No.14 Line (P14M)	450	14.61	Air Compressor(100), TANAKA(250), Others(100)
12) No.15 Line (P15C)	300	9.74	Cooling Water Pump(280), Others(20)
13) No.16 Line (MCCSP)	40	1.30	Mixer, Others (40)
14) Balance	170	5.51	
Total	(3,080)	(100.00)	

11-7-6 Overall Energy Flow

An overall energy flowchart of the sugar plant is shown in Figure 11-7.

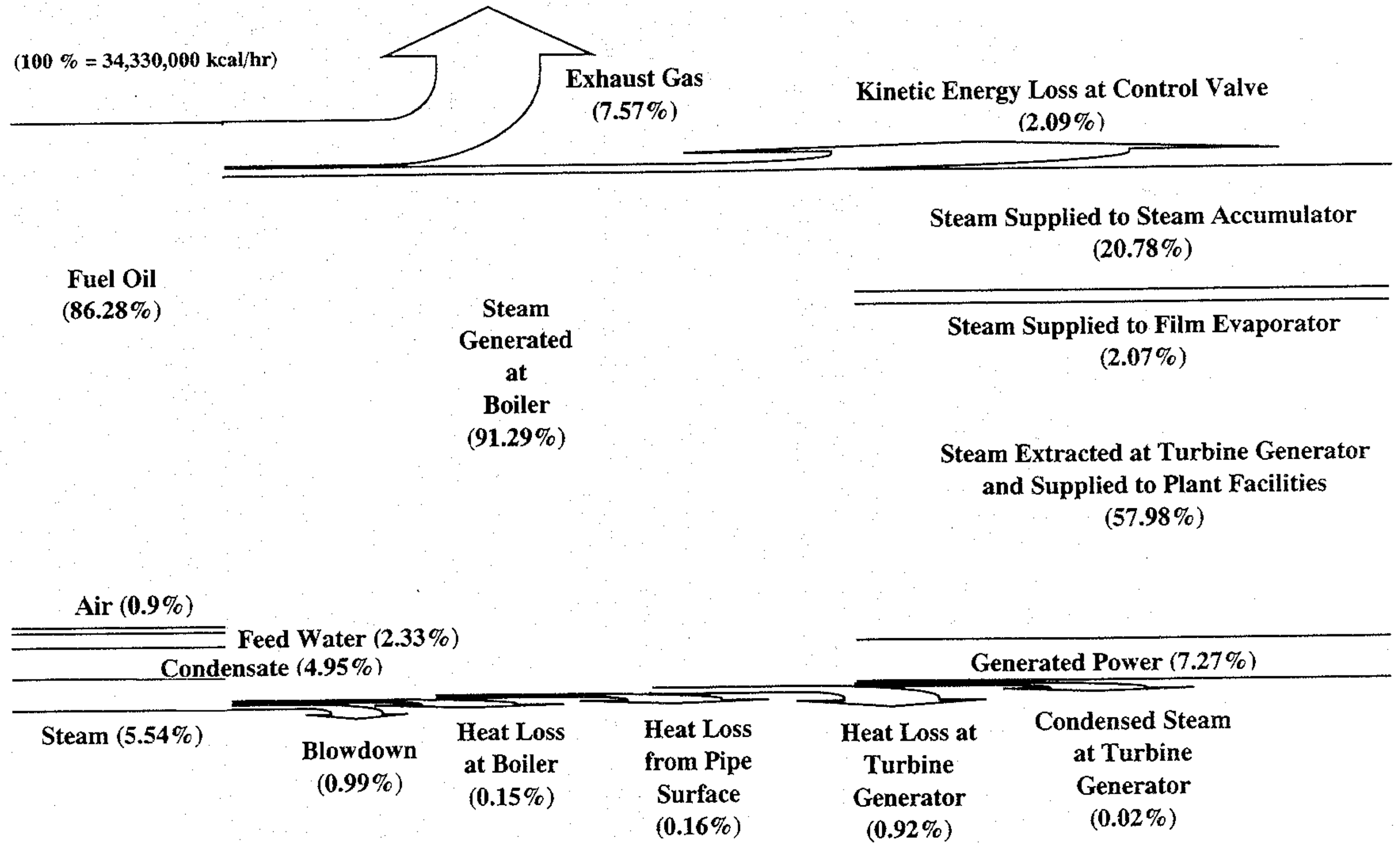


Figure 11-7 Overall Energy Flowchart (Central Sugars Refinery)

11-8 Unit Consumption of Raw Materials and Energy for Major Products

Table 11-2 shows the trend of unit consumption figure of raw materials and energy for major products.

11-9 Present Situation of Energy Management and Energy Efficiency Promotion

(1) Establishment of the Target for Energy Conservation

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 conservation on unit consumption figures of fuel and electricity.

(2) Systematic Activities for Energy Conservation in the Factory

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

(3) Energy Management Utilizing Data and Records

The Engineering Department is controlling the operation data for the steam boiler, steam turbine electricity and so on. Some of the facilities such as steam boiler are operated by using computer, therefore data can be utilized through the computer.

(4) Education, Training of Employee for Energy Management

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

(5) Maintenance Management of the facilities

1) Preventive maintenance is carried out to monitor each main facility including steam trap using checklist sheet every day.
2) Corrective action is periodically implemented according to the 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 Conservation 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 considerably, reflecting the nation's economic situation

(9) Problems in Promotion of Energy Conservation

1) Rather long payout 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 analyzing equipment at 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 at 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)

11-10 Current Condition and Problems with Facilities

11-10-1 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

11-11 Measures for Energy Efficiency Promotion

In accordance with the results of the factory energy audit, recommended of measures for energy efficiency promotion are described and discussed as follows.

1. Improvement of heat energy efficiency in the steam and steam condensate recovery system
2. Improvement of steam trap system
3. Decreasing heat loss in the thermal insulation system
4. Recovery of electric power from energy loss in steam control valve

11-11-1 Improvement of Heat Energy Efficiency in Steam and Condensate System

(1) Steam System

Judging from the present material and heat balance of the steam and condensate system, there are several items for improving the energy utilization of heat energy in flue gas.

The temperature of flue gas was recorded at 232°C, which is rather high, compared to similar Japanese facilities.

Table 11-12 Standard and Target Temperature of Boiler Flue Gas Standard (Target)

Boiler Capacity	Flue Gas Temperature (°C)			
	Solid Fuel		Liquid Fuel	Gas Fuel
	Fixed Bed	Fluid Bed		
Over 30 ton/hr	200 (180)	200 (170)	200 (160)	170 (150)
10 to 30 ton/hr	250 (180)	200 (170)	200 (160)	170 (150)
5 to 10 ton/hr	—	- (300)	220 (200)	200 (180)
Under 5 ton/hr	—	- (320)	250 (220)	220 (200)

As this table shows, flue gas temperature should be around 160 °C to 200 °C. In other words, the economic feasibility of heat recovery in this temperature range can be expected in the factory.

There are three kinds of heat recovery, shown below.

- Direct heat exchange between feed air and flue gas (expansion of existing pre-heater)
- Economizer installation for steam heating
- Utilization of low temperature fluid as heat recipient

Taking into account the recovery of steam condensate, preheating of boiler feed water was selected in this study.

(2) Condensate System

The recovery ratio of steam in this factory is around 30 to 40 percent of boiler feed water. It is estimated that there are three reasons for the low recovery ratio, as described below.

- Direct steam injection to the process system
- Contamination by process fluid in the system
- Low static pressure of condensate for recycling

In the sugar manufacturing process, the amount of direct steam injection and contamination by process fluid is not so great. The main reason could be the low static pressure of condensate. However the huge investment cost of condensate recovery could be minimized through the utilization of rather cheap carbon steal materials in piping, tanks and pumps. It is recommended that a recovery system be installed.
A schematic plan for the recommendation is illustrated in Figure 11-8.

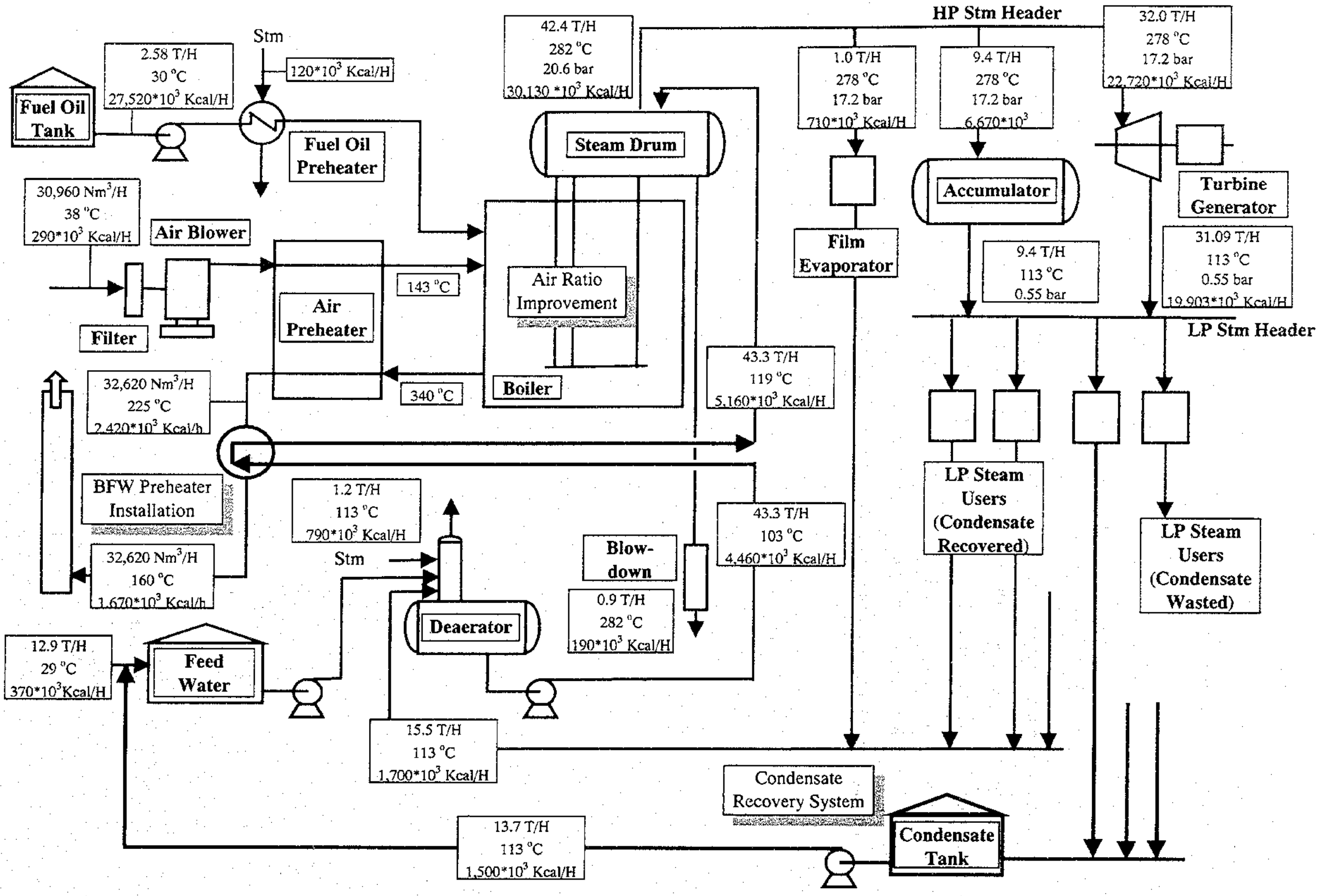


Figure 11-8 Material and Heat Balance of Boiler System (recommendation)

11-11-2 Improvement of Steam Trap System

There are about 64 steam traps installed in steam-utilizing facilities. Their working condition and maintenance are generally satisfactory. However, some steam traps are blowing or leaking and some are blocked. The service life of steam traps is usually 3-5 years.
The following are recommended: 1) to replace the leaking or blowing traps, 2) to conduct a scheduled maintenance for the blocked or low-temperature traps as shown in Table 11-13.

11-11-3 Decreasing Heat Loss in the Thermal Insulation System

Heat loss from major steam lines is not so great, as Table 11-6 shows. Some portions of the straight lines or some of the valves and flanges were left uninsulated to facilitate maintenance and inspection work, but insulation should be applied to these portions.

11-11-4 Recovery of Electric Power from Energy Loss in Steam Control Valve

A rough estimation from the energy balance shows that the kinetic energy lost in the pressure reducing control valve would have the capability to generate about 750 kW of electrical power.

(718,500 kcal/hr / 860 kcal/kW x 0.90 = 750 kW)

The additional installation of a supplementary turbine is recommended.

Since steam and electrical power are roughly balanced now, the generated power should be supplied to outside users through TNB. This means that tariff system reconstruction is essential.
This turbine should also have some operational flexibility to absorb the change of supply steam pressure and quantity with EH-governor control.

Table 11-13 Failed Trap List

Trap No.	Type	Model	Size (mm)	Failure Mode	Steam Loss(t/y)	Monetary Loss($/y)	Recommended Measures	Recommended Steam Trap Type (Model)	Spec.(kg/h)	Price (10^3 yen)
A10-00001	DISC	TD42	20	Leak(S)	23	185	Replace	FLOAT (SSIN-21)	140	31.5
A10-00003	FLOAT	FT20	20	Low temp	0	0	Overhaul	FLOAT (JH3X-22)	560	118.5
A10-00004	DISC	TD42	20	Leak(S)	33	263	Replace	FLOAT (SSIN-21)	140	31.5
A10-00005	DISC	TD42	20	Leak(M)	60	470	Replace	FLOAT (SSIN-21)	140	31.5
A10-00006	FLOAT	FT20	20	Leak(L)	83	655	Replace	FLOAT (JF3X-5)	640	32.5
A10-00009	FLOAT	FT20	20	Low temp	0	0	Overhaul	FLOAT (JF3X-5)	640	32.5
A40-00001	DISC	TD32F	25	Blocked	0	0	Overhaul	FLOAT (SSIN-21)	140	42.5
A40-00002	DISC	TD42	25	Leak(L)	84	661	Replace	FLOAT (SSIN-16)	140	32.0
A40-00003	DISC	TD32F	25	Low temp	0	0	Overhaul	FLOAT (SSIN-21)	140	42.5
A40-00004	DISC	TD42	25	Blowing	172	1,356	Replace	FLOAT (SSIN-16)	140	32.0
A50-00001	DISC	TD3-7	20	Blocked	0	0	Overhaul	FLOAT (SSIN-21)	140	31.5
A50-00004	DISC	TD42	25	Blocked	0	0	Overhaul	FLOAT (SSIN-16)	140	32.0
A71-00001	DISC	TD42	25	Blocked	0	0	Overhaul	FLOAT (SSIN-16)	140	32.0
A71-00002	DISC	TD42	25	Blocked	0	0	Overhaul	FLOAT (SSIN-16)	140	32.0
A71-00003	DISC	TD42	25	Leak(S)	11	87	Replace	FLOAT (SSIN-10)	65	32.0
A72-00001	DISC	TD42	25	Leak(S)	15	115	Replace	FLOAT (SSIN-10)	65	32.0
A72-00002	DISC	TD42	25	Leak(S)	29	226	Replace	FLOAT (SSIN-16)	140	32.0
A80-00001	DISC	TD32F	20	Low temp	0	0	Overhaul	FLOAT (SSIN-21)	65	39.0
B10-00001	DISC	TD42	20	Blocked	0	0	Overhaul	FLOAT (SSIN-21)	140	31.5
B10-00002	DISC	TD32F	20	Leak(S)	12	95	Replace	FLOAT (SSIN-10)	65	39.0
B10-00004	DISC	TD42	20	Low temp	0	0	Overhaul	FLOAT (SSIN-21)	140	31.5
B30-00001	FLOAT	FT20	25	Low temp	0	0	Overhaul	FLOAT (JF5X-16)	700	60.0
B30-00002	FLOAT	FT20	25	Low temp	0	0	Overhaul	FLOAT (JF5X-16)	700	60.0
C10-00001	FLOAT	FT10-4.5	50	Low temp	0	0	Overhaul	FLOAT (J75X-1)	16,000	347.0
E50-00004	FLOAT	GM8	100	Low temp	0	0	Overhaul	FLOAT (J8X-1)	22,000	550.0
Ex0-00001	DISC	TD32F	25	Low temp	0	0	Overhaul	FLOAT (SSIN-10)	65	42.5
F10-00001	FLOAT	FT10-1	25	Low temp	0	0	Overhaul	FLOAT (J7X-16)	2,100	102.0
F30-00001	FLOAT	FT14-020	20	Low temp	0	0	Overhaul	FLOAT (JF3X-10)	600	32.5
F40-00001	FLOAT	GM2	50	Low temp	0	0	Overhaul	FLOAT (J7LX-1)	4,800	150.0
F40-00002	FLOAT	GM2	50	Blocked	0	0	Overhaul	FLOAT (J7LX-1)	4,800	150.0
F40-00003	DISC	TD3-2	20	Low temp	0	0	Overhaul	FLOAT (JF5X-10)	870	58.5