The cost used for the economic evaluation is the total cost of US$19.05 million which does not include the contingency.

b. Construction schedule

The upgrading works will be carried out during the scheduled shut down and periodical overhaul as much as possible. The actual works are expected to start at the beginning of 1990 and completed within the year. Therefore, this study assumed that the project cost would be disbursed in 1990.

c. Benefit

The upgrading plan will have about two main economic effects, improvement of SSC coal blending ratio and plant reliability and performance.

The economic benefit by implementation of the upgrading project is summarized as follows:

Table 2-5 Summary of the Economic Benefit by Upgrading Plan

Upgrading Plans		Fuel Saved	
Plans for increase of SSC blend ratio			
A.1	Improvement of SSC blend ratio by 10%	Coal:	44,435 t
B.4	Improvement of SSC blend ratio by 5%	Coal:	23,354 t
Subtotal		Coal:	67,789 t
Plans for improvement of reliability/performance			
B.1	Prevention of 50 MW load down two times a week in a rainy season	Oil:	1,521 kl.
	Prevention of a unit trip per year	Oil:	878 kl.
B.2	Prevention of two unit trips per year	Oil:	6,143 kl.
B.3	Improvement of efficiency by 0.1%	Coal:	889 t
	Prevention of two unit trips per year	Oil:	878 kl.
D.	Improvement of reliability and controllability		–
Subtotal		Coal: Oil:	889 t 9,420 kl.
Total		Imported Coal: Imported Oil:	68,678 t 9,420 kl.

With the economic merits tabulated above, the implementation of the upgrading project saves the foreign exchange amounting to ₱69 million, or ¥463 million annually, and through 19 years from 1991 to 2009, the foreign exchange saving will be accumulated to ₱1,318 million, ¥8,787 million.

d. Result of economic evaluation

Based on the above-mentioned conditions, the EIRR was calculated in 2 cases: Case A (base); improvement of SSC blend ratio by 9% (15% x 60% of the year when the alkali content becomes smaller than 6%), Case B; improvement of SSC blend ratio by 15%.

	EIRR (%)
Case A (based):	16.37
Case B:	24.27

The obtained EIRR of each case exceeds the hurdle rate of 15% set by NEDA. The upgrading project is justified as economically profitable to the Philippines.

(3) Financial Evaluation

a. Cost

a) Project cost

The overall project cost for financial evaluation is the sum of the revalued cost of ₱6 billion or ¥40 billion of the original project and the cost of this upgrading project amounting to ₱439 million, or ¥2,926 million including the contingency. The cost totals ₱6,471 million, or ¥43,142 million.

b) Operating expenses

For a period from October 1984 to the end of 1986, the actual operating record with some revision is used. For 4 years from 1987 to 1990, the blending ratio of 50:50 is assumed. And after upgrading works in 1990 up to the retirement of the plant in September 2009, the blend ratio of 51:49 is assumed to continue. (For a period of 60% of a year, the plant will be operated with blend ratio of 65:35 but for the remaining period, the blend ratio will not be changed.) The plant efficiency is assumed to be improved by 0.1%.

b. Benefit

The upgrading plan is assumed to contribute to the increase of capacity factor by about 2% (sum of the prevention of unit trips and others) by improvement of reliability, decrease of troubles and maintenance shutdowns. Thus, after upgrading works, about 44 GWh of salable energy generated by 2% increase in the capacity factor is appropriated in the cash flow.

The benefit of the power plant is the revenue of electricity sales after station service loss, transmission loss and general account not attributable to the plant's revenue for 25 years from commissioning to retirement.

The power rate of 1.0552 ₱/kWh used in the financial calculation is an average of 1986 Luzon Grid.

c. Financial internal rate of return (FIRR)

The FIRR calculated with the conditions above recorded 13.54%. Since the obtained FIRR well clears the opportunity cost of capital at 8.5%, if this upgrading project is implemented, the cost for and raise of generating cost by the upgrading project is well absorbed in the cash flow of the original project and financial soundness of Calaca Power Plant operation is justified.

d. Cashflow

In 1999, the 16th year after commissioning, the debt service ratio will fall to 0.99 as shown in the Income Statement. After tiding over of the hardest year, NAPOCOR will be able to accumulate the profit of ₱8,566 million, or about ¥57 billion at the final year of operation after it would have paid up the loan repayment of the original and upgrading projects. Repayment Scheudle, Income Statement and Cash Flow Statement are shown on Tables 10-5 to 10-7.

(4) With/Without Financial Evaluation

After the upgrading project (With project) which intends the maximum use of the domestic coal of higher cost, the influence of the upgrading project on the financial condition of the power plant (Without project) was studied with the result below.

Table 2-6 Summary of Financial Evaluation

		Without	With	Increase/Decrease
Plant efficiency	(%)	35.3	35.4	+0.1
Capacity factor	(%)	68	70	+2
Generation	(GWh)	1,787	1,839	+52
Coal consumption	(t)	830,858 (100%)	878,531 (100%)	+47,673
Semirara (SSC)	(t)	415,429 (50%)	518,333 (59%)	+102,964
Australia	(t)	415,429 (50%)	360,198 (41%)	- 55,231
Fuel cost	(10^3 Peso) (Million Yen)	591,987 (3,947)	631,884 (4,213)	+39,897 (+266)
Gen. cost	(₱/kWh)	0.6954	0.6982	+0.0028

The With and Without FIRR recorded 13.67% and 14.14%, respectively based on the conditions above.

As compared with the Without case, the With case will bring about an accumulated loss of ₱866 million, or ¥5,774 million.

2-2 Semirara Coal Mine

The survey was conducted based on the data provided by NAPOCOR and the information obtained during the reconnaissance of the Semirara Mine site. The coal quality evaluations including the conceptual design of the coal preparation system were done mainly based on the results of analysis of the coal samples obtained at the mine site. The conclusions and recommendations are all on the basis of the said information and data.

2-2-1 Outline of Semirara Coal Mine

(1) Semirara Coal Mine was developed to supply fuel coal to the coal-fired power plant scheduled to be constructed by NAPOCOR at Calaca, Batangas in Luzon Island.

(2) The coal mine is situated on Semirara Island which lies at 12°N, between Mindoro Island and Panay Island. Semirara is a small island of 13 km in length and 4 km in width, at approximately 300 km to the south of Manila, the capital of Philippines, and at 16 km to the south of Mindoro Island.

(3) There are three possible mining areas in Semirara Island, which are Unong, Himalian and Panian. Amongst these areas, the Unong area was developed because of easier access and mining conditions.

(4) The development of the coal mine was financed by the Austrian loan and the engineering, erection of the equipment, construction of the facilities, start-up and training were all done by Austromineral, a mining consultant firm in Austria, on a turn-key basis. The mine construction was commenced in 1980 and the first shipment was made to the Calaca Power Plant of NAPOCOR, in July 1984. The main mining system is continuous mining with bucket wheel excavators (BWE).

(5) The coal seams in Unong Pit are composed of the Main seam which forms as much as 80% of the total coal reserves in the pit and the other minor coal seams. The coal extraction was done by a whole seam recovery including all mudstone plies, and the extracted coal is the socalled "run-of-mine" coal.

(6) In October 1984, NAPOCOR refused the acceptance of the Semirara coal because of its inferior quality, containing much clay, which caused various troubles in the boiler of the plant as well as in the coal handling system.

(7) In order to solve the problems, Semirara Coal Mine modified the mining method to a selective mining which extract only coal plies by removing mudstone plies in the Main seam.

Consequently, NAPOCOR resumed the acceptance of the Semirara coal in February 1985. The trouble of the boiler, however, has been unsolved due to the high alkali content in the Semirara coal. Thus NAPOCOR still relies on the blending with imported coal so as to reduce the alkali content, as well as moisture.

2-2-2 Current Status of Unong Pit

(1) The mining operation in Unong Pit employs four bucketwheel excavators and the supporting belt conveyor systems. The elevation of the pit bottom is 62 m below sea level.

(2) The coal reserves in Unong Pit are estimated to be 17,220,000 tons in the feasibility study report, but, the reserve calculation on the basis of the provided data shows only 6 to 7 million tons of remaining coal reserves as of the end of 1986.

(3) Slope slides have been experienced on the northeastern high-wall of Unong Pit. The pit slope angle affects the mineable coal reserves in the pit as well as the safe mining operation. Thus, it is urgently needed to make the slope stability study based on accurate geotechnical survey.

(4) In connection with the pit slope stability study, a detailed study is also required to establish the countermeasure against the seawater incursion. It is essential, because the pit is not only adjacent to the seacoast but also below sea level.

2-2-3 Production Increase Schemes

(1) The most realistic and economical way to improve the current coal production is to increase the yearly operating days as well as to increase the actual cutting time of the BWE's by full utilization of existing mining equipment.

The estimated annual production by selective mining is approximately 600,000 tons by 301-days-per-year operation and 700,000 tons by 360-days operation, based on the geological and coal seam conditions described in the feasibility report prepared by Austromineral

However, the actual geological and coal seam conditions are not as favorable as estimated by Austromineral.

(2) By introducing additional shovels and trucks, a little production increase is expected, but it is not so advantageous because of the operational difficulties during the wet season which lasts for about 6 months per year.

(3) As of the end of 1986, coal reserves suited to selective mining is only 6 – 7 million tons in Unong Pit, considerably smaller than the originally estimated reserves of 17,220,000 tons.

(4) There is some concerns in the accuracy of the geological exploration and interpretation as well as the basic data for coal reserve calculations, so that a detailed geological study must be made, on which the detailed mining plan is to be established.

(5) The detailed pit slope stability study must be made for decision of the final pit wall angle which affects the pit design as well as the mineable coal reserves. Currently, a slide has been experienced on the northeastern slope of the pit, so that the study must include the measures to stabilize the slide as well.

(6) Because Unong Pit lies lower than sea level and close to the surrounding ocean, seawater incursion may be intensified in the future, and therefore reliable and reasonable countermeasures should be studied based on the geological and hydrological data.

2-2-4 Coal Quality Upgrading

(1) The Main seam which forms as much as 80% of the total coal reserves in Unong Pit is composed of 14 plies, of which 3 plies are clay partings, so that the extracted coal contaminated with clay.

(2) According to the analysis data of the past coal shipment, the alkali content in ash is as high as 2 to 9%, and in addition to that, it varies widely depending upon the locations of working in the pit.

(3) The coal in Unong Pit is classified as subbituminous close to lignite and is featured by high porosity and easier water absorption.

(4) It is almost impossible to reduce sodium (Na) content in coal ash by the current coal preparation technology, since Na is mainly distributed in the coal plies. The estimated yield of the coal preparation plant is only 53% in obtaining almost the same quality as SSC. The total moisture in the processed coal is as high as 32% as a result of processing with water. Furthermore, the coal preparation facilities cost 28 million dollars and moreover a great deal of costs are required for the construction of the supporting system such as a desalting plant for fresh water, expansion of the captive power plant, laboratory, maintenance facilities and others. The unit operating cost of the coal preparation plant turns out to be US$11.28/ton (₱226/ ton) of the processed coal, excluding all construction costs for the supporting facilities. Considering these negative factors, the coal preparation is not a realistic scheme for the coal produced from Unong Pit. However, coal preparation should be restudied when the other coal reserves are to be mined.

(5) The result of the desliming test on the #11 ply sample, washable coal, at the pilot coal preparation plant shows not much water soluble material content. Accordingly it is advantageous to blend #11 ply with salable coal without washing. By blending #11 ply with salable coal, the sodium (Na) and potassium (K) contents in ash are lowered.

(6) SSC+#11 ply needs to be blended with about 37% of imported coal without a dryer system. Considering its higher energy recovery and the coal quality closest to the required specifications after blending with the imported coal, SSC+#11 ply may be the most advantageous method. However, the blending ratio is subject to change depending upon the required Na_2O+K_2O contents in ash.

(7) The use of the Semirara coal is restricted by its Na_2O+K_2O contents in ash as well as its higher moisture content. Consequently, a dryer installation may be considered in the future, depending upon the prospect of Na_2O+K_2O contents.

(8) Judging from the Na_2O+K_2O contents in ash of the samples obtained from the mining face, SSC after drying may be used by blending with a few per cent of the imported coal. However, the blend ratio varies depending on the Na_2O+K_2O contents in ash, so that the contents must be verified by extensive analysis of the drill core samples from the future mining area.

(9) The final decision should be made by comparing the economy of the SSC

with a dryer system plus a few per cent of imported coal blending and the SSC+#11 ply without dryer plus about 37% of imported coal blending. However, as SSC+#11 ply with dryer plus 9.4% of imported coal has more allowance in the Na_2O+K_2O content in ash, it may be more practical and safer than SSC with a dryer system.

(10) As the assessment of the various scenarios is entirely dependent upon the sodium and potassium contents in ash of the coal supplied to the Calaca Power Plant, the accurate quality and quantity estimates are essential along with the accurate mining plan.

2-2-5 Recommendations for Semirara Coal Mine (Unong Pit)

(1) The increase of coal production should be made by increasing the operating days as well as the cutting time of the BWE's, utilizing the existing mining equipment to the full extent.

(2) Accurate geological exploration and interpretation should be made.

(3) The detailed mining plan must be established based on the accurate geological interpretation so that the estimate of the future coal production in terms of quality and quantity may be estimated.

(4) The pit slope stability study should be made based on the accurate geotechnical data for the formulation of the detailed mining plan and the safe mining operation.

(5) Coal quality evaluation should be made of SSC with a few per cent of imported coal blending and SSC+#11 ply with about 10% of imported coal blending, in case of a dryer installation at Calaca Power Plant. Without the dryer system, SSC+#11 ply with approximately 40% of imported coal is considered to be most advantageous.

(6) #11 ply which is currently tested at the pilot coal preparation plant could be blended with product coal without washing, judging from the low desliming rate of the ply.

(7) Coal preparation is not recommendable for the coal produced from Unong Pit because of its high construction cost and lower energy recovery and yield. However, it should be restudied when all reserves on the island are considered.

(8) The development of alternative pits such as Himalian and Panian should be advanced timely in accordance with the future fuel supply schedule for Calaca Power Plant, since the remaining mineable coal reserves in Unong Pit is estimated to be only 6 – 7 million tons for selective mining.

(9) The costs for the necessary studies are estimated as follows:

a. Detailed mining plan study for Unong Pit, including geological survey and coal analysis.

Geological survey and coal analysis	8 months
Detailed mining plan study	8 months

$12,000,000

b. Unong Pit slope stability, seawater incursion and drainage studies — 6 months

$ 700,000

c. Detailed geological survey of all coal reserve areas on the island including coal analysis — 2 years

$ 7,200,000

3. Status of the Electric Power

3-1 Power Supply System

3-2 Power Generating Plants

3-3 Power Demand and Supply

3-4 Power Development Program

3. Status of Electric Power

3-1 Power Supply System

National Power Corporation (NAPOCOR) under the control of the Ministry of Energy of the Government of the Philippines operates almost all the power generating plants, the major transmission lines and the major substations, and Manila Electric Power Company (MERALCO) in Metro Manila and more than 100 Electric Cooperatives in the rural areas distribute the electric power sold by NAPOCOR to the consumers.

And for promotion of the rural electrification, the National Electrification Administration (NEA) under the control of the Malacañan procures the funds, prepares the bid documents, purchases the facilities for the expansion and the development of the distribution systems in the rural area.

3-2 Power Generating Plants

The power generating plants owned by NAPOCOR in the whole Philippines have the total installed capacity of 5,787.9 MW as detailed in Table 3-2.

The Luzon Grid, to which Calaca Unit No. 1 is connected, has the installed capacity of 4,111 MW in total, but the available capacity is derated as shown in the following Table 3-1 due to the aged deterioration and other causes.

Table 3-1 Power Generating Capacity in Luzon Grid

	Installed Capacity	Available Capacity
Hydro	1,226 MW	856 MW
Geothermal	660	545
Coal-fired Thermal	300	285
Oil-fired Thermal	1,925	1,685
Total	4,111	3,371

The power generating facilities in the Luzon Grid are mainly thermal and subsidiary hydro, consisting of 47% of the oil-fired thermal, 30% of the hydro, 7% of the coal-fired thermal and 16% of the geothermal as shown in Table 3-2.

Table 3-2 Existing Generating Plants as of End of 1986

LUZON

Year of Comm.	Name of Plant	Installed Cap. (MW)
1946–48	Botocan H.E.	17.0
1947–50	Caliraya Unit 1–4	32.0
1956–57	Ambuklao Unit 1–3	75.0
1957	Barit M.H.	1.8
1959	Cawayan M.H.	0.4
1960	Binga Unit 1–4	100.0
1967–68	Angat HE	212.1
1977	Pantabangan	100.0
1978–86	Angar Aux.	16.0
1982	Kalayaan P HE	300.0
1983–84	Magat HE Unit 1–4	360.0
	Total Hydro	1,226.2
1979	Tiwi Plant A	110.0
1979	Mak-Ban Plant A	110.0
1979–80	Tiwi Plant B	110.0
1980	Mak-Ban Plant B	110.0
1981–82	Tiwi Plant C	110.0
1984	Mak-Ban Plant C	110.0
	Total Geo.	660.0
1984	Calaca Coal	300.0
	Total Coal	300.0
1965–66	Manila 1 & 2	200.0
1968–70	Sucat 1 & 2	350.0
1971–72	Sucat 3 & 4	500.0
1972–77	Bataan 1 & 2	225.0
1975–79	Malaya 1 & 2	650.0
	Total Oil Based	1,925.0
	TOTAL LUZON	4,111.2

VISAYAS

Year of Comm.	Name of Plant	Installed Cap. (MW)
1957–67	Loboc Unit 1–3	1.2
1962	Amlan Unit 1 & 2	0.8
	Total Hydro	2.0
1977	Tongonan Pilot	3.0
1980–82	Palinpinon Pilot	6.0
1983	Palinpinon Geo. I	112.5
1983	Tongonan Geo. I	112.5
	Total Geo.	234.0
1981	Naga Coal I	50.0
1986	Naga Coal II	50.0
	Total Coal	100.0
1977–78	Cebu Diesel I	43.8
1978	Amlan Diesel I	11.0
1978	Bohol Diesel I	11.0
1974–81	Panay Diesel I	36.5
1981	Power Barge 1 & 2	64.0
1982–83	Cebu Diesel II	57.8
1985	Power Barge #3	32.0
1986	Bohol Diesel II	3.4
	Total Oil Based	259.5
	TOTAL VISAYAS	595.5

MINDANAO

Year of Comm	Name of Plant	Installed Cap. (MW)
1957	Agusan M.H.	1.6
1953–77	Agus VI Unit 1–5	200.0
1979	Agus II Unit 1–3	180.0
1982–83	Agus VII Unit 1–2	54.0
1985	Agus V Unit 1 & 2	55.0
1985	Agus IV Unit 1–3	150.0
1985–86	Pulangi IV Unit 1 & 3	255.0
	Total Hydro	895.6
1977	Aplaya Diesel I.	11.0
1979–81	Aplaya Diesel II	115.7
1980	Gen. Santos Diesel	21.9
1985	Power Barge #4	32.0
	Total Oil Based	180.6
	TOTAL MINDANAO	1,976.2

NAPOCOR is exerting efforts to develop hydro, geothermal and coal-fired thermal power plants in accordance with the government policy of the utilization of the indigenous energy sources. Especially, many geothermal resources have been surveyed and developed because the volcanic zone runs from north to south through the Philippine Archipelago, and lively volcanic activities make rich geothermal resources. The geothermal power plants have the installed capacity of 660 MW in the Luzon Grid and 894 MW in the whole Philippines, and the Philippines is ranked second in the world, following the USA in geothermal generation.

Transmission line systems are mainly composed of 230 kV, 138 kV, 115 kV and 69 kV lines and the respective lengths of the transmission lines of each voltage are 3,484 km of the 230 kV line, 2,501 km of the 138 kV line, 484 km of the 115 kV line, 4,773 km of the 69 kV line and 732 km of the other lower voltage lines as of the end of 1986.

The 230 kV transmission line which runs through Luzon Island from north to south is the trunk line of the Luzon Grid. And the power generated by the hydro power plants in the Northern Luzon and by the geothermal power plants in the Southern Luzon are transmitted to Metro Manila, the largest demand center, by the 230 kV transmission lines.

Further, the 500 kV transmission lines which are planned to run through Luzon Island from north to south through Metro Manila will be constructed to prepare for the future development of the hydro and the coal-fired thermal power plants in northern Luzon and the geothermal power plants in southern Luzon, and a part of the 500 kV transmission lines has already been completed between Naga and Kalayaan and is under construction between Kalayaan and San Jose.

The transmission line network is shown in Fig. 3-1.

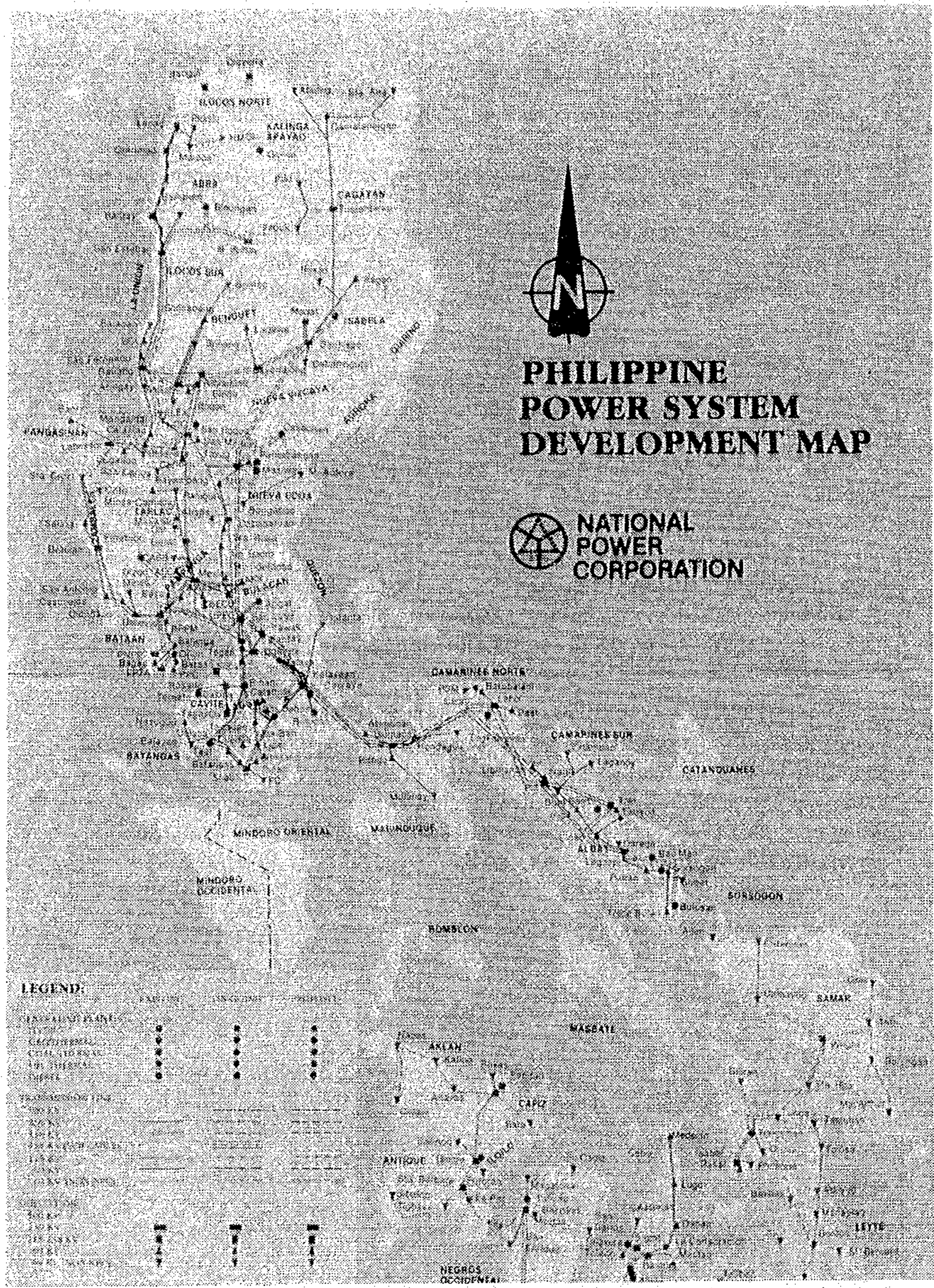


Fig. 3-1 Philippine Power System Development Map

Table 3-3 Mar. 1987 Long Term Energy Sales Forecast Luzon Grid

Year	UTILITIES				IND	MISC	TOTAL LUZON
	MERALCO	OTHER PUs	COOPS	TOTAL UTIL			
1985	9,742	585	1,234	11,561	1,065	451	13,077
1986	10,179	531	1,117	11,887	1,073	471	13,431
1987	10,688	549	1,210	12,447	1,094	496	14,037
1988	11,251	574	1,245	13,070	1,138	516	14,724
1989	11,890	605	1,299	13,794	1,189	521	15,504
1990	12,524	646	1,370	14,540	1,247	539	16,326
1991	13,179	694	1,458	15,331	1,311	543	17,185
1992	14,088	748	1,556	16,392	1,384	564	18,340
1993	14,949	805	1,664	17,418	1,456	577	19,451
1994	15,883	864	1,783	18,530	1,520	586	20,636
1995	16,783	923	1,916	19,622	1,598	595	21,815
1996	17,783	988	2,054	20,825	1,707	607	23,139
1997	18,838	1,056	2,197	22,091	1,827	620	24,538
1998	19,956	1,125	2,345	23,426	1,933	635	25,994
1999	21,157	1,198	2,498	24,853	2,059	653	27,565
2000	22,433	1,275	2,656	26,364	2,197	672	29,233
Growth Rate (%)							
1985-1986	4.5	-9.2	-4.6	2.8	0.8	4.4	2.7
1986-1987	5.0	3.4	2.8	4.7	2.0	5.3	4.5
1987-1988	5.3	4.6	2.9	5.0	4.0	4.0	4.9
1988-1989	5.7	5.4	4.3	5.5	4.5	1.0	5.3
1989-1990	5.3	6.8	5.5	5.4	4.9	3.5	5.3
1990-1991	5.2	7.4	6.4	5.4	5.1	0.7	5.3
1991-1992	6.9	7.8	6.7	6.9	5.6	3.9	6.7
1992-1993	6.1	7.6	6.9	6.3	5.2	2.3	6.1
1993-1994	6.2	7.3	7.2	6.4	4.4	1.6	6.1
1994-1995	5.7	6.8	7.5	5.9	5.1	1.5	5.7
1995-1996	6.0	7.0	7.2	6.1	6.8	2.0	6.1
1996-1997	5.9	6.9	7.0	6.1	7.0	2.1	6.0
1997-1998	5.9	6.5	6.7	6.0	5.8	2.4	5.9
1998-1999	6.0	6.5	6.5	6.1	6.5	2.8	6.0
1999-2000	6.0	6.4	6.3	6.1	6.7	2.9	6.1
1986-1990	5.2	2.0	2.1	4.7	3.2	3.6	4.5
1991-1995	6.0	7.4	6.9	6.2	5.1	2.0	6.0
1996-2000	6.0	6.7	6.7	6.1	6.6	2.5	6.0
1986-2000	5.7	5.3	5.2	5.6	4.9	2.7	5.5

3-3 Power Demand and Supply

The total electric power generated by NAPOCOR in 1986 was 19,263 GWh in the whole Philippines and 14,756 GWh in the Luzon Grid. On the other hand, the total electric power sold by NAPOCOR in 1986 was 17,645 GWh in the whole Philippines and 13,431 GWh in the Luzon Grid.

The gross power generated by Calaca Power Plant in 1986 was 1,690 GWh, the transmitted power was 1,526 GWh, and the sold power was approximately 1,400 GWh on the assumption that the transmission loss is 8%, which shows that the power supply from Calaca Power Plant exceeded 10% of the demand in the Luzon Grid.

The maximum demand of electric power in the Luzon Grid was 2,435 MW in 1986, and the generating capability of the Luzon Grid as of the end of 1986 was 3,371 MW as shown in Table 3-2. On this basis, it seems that the Luzon Grid has some margin for power supply, but the power supply/demand situation of the Grid is still tight because of the large share of hydro power plants, the capability of which is greatly influenced by the season, lower reliability of old thermal power plants by deterioration and little change in the power demand throughout the year.

The increase of the power demand in the future Luzon Grid is anticipated at 4.5% on an annual average from 1986 to 1990 and 6.0% from 1,991 to 2,000 (Refer to Table 3-3).

3-4 Power Development Program

NAPOCOR reviewed the previous development program because the commissioning of PNPP-I, the first nuclear power plant in the Philippines, was mothballed by the new government after the revolution in 1986, and is planning the power development and expansion program involving the addition of Calaca Unit No. 2, the development of Bacon-Manito geothermal power plant, Isabela coal-fired thermal power plant, Casecnan hydro power plant, etc. to cope with the shortage of the power supply capacity in the Luzon Grid.

Simultaneously, NAPOCOR promotes the rehabilitation of the existing power plants to improve the reliabilities and to restore the capabilities. The rehabilitation of the Malaya oil-fired thermal power plant No. 2 and No. 1 Units was completed in January 1987 and in October 1987 respectively. And the rehabilitation of the Sucat oil-fired thermal power plant No. 1 and 4 Units will be carried out in 1989 and 1990 respectively.

The power generation expansion program in the Luzon Grid by NAPORCOR is shown in Table 3-4. Since the Calaca Coal-Fired Thermal Power Plant is the latest base load plant which uses local coal will have to perform the important role as the key power plant of the Luzon Grid for a long time into future as well as at present.

Table 3-4 Luzon Grid June 1987 Generation Expansion Program

Year	Plant	Capacity (MW)
1987	REHAB MALAYA 1 *1	1 x 300
1988	ROCKWELL *2	3 x 60
1989	GAS TURBINE A	3 x 50 1 x 150
1990	GAS TURBINE B REHAB SUCAT 1 *3	4 x 50 1 x 300
1991	BACON-MANITO I GEO REHAB SUCAT 4 *3	2 x 55
1992	CALACA II COAL RETIRE ROCKWELL	1 x 300 (3 x 60)
1993	PANTAY HYDRO BACON-MANITO II GEO PINATUBO GEO	2 x 11.5 2 x 55 2 x 55
1994	LABO GEO IROSIN GEO	2 x 55 2 x 55
1995	ISABELA COAL	2 x 150
1996	SAN ROQUE HYDRO	3 x 130
1997	CASECNAN HYDRO	2 x 50 1 x 12 3 x 52
1998	BINONGAN HYDRO GEOTHERMAL	3 x 58.3 2 x 55
1999	COAL A	2 x 150
2000	COAL B	2 x 150

*1 Schedule of Rehabilitation: Feb. – Aug. 1987
(Does not consider operation of Rockwell)
*2 Dependable Capacity: 3 x 35 MW
*3 Sucat 1 Rehab: Jul. 1989 – Jan. 1990
Sucat 4 Rehab: Nov. 1990 – Nov. 1991

Table 3-5 Generation Program of Luzon Grid

Year	Plant addition (Completion Year)	Plant capacity (MW)	Total Installed Capacity					Capability (MW)	System Dispatch (GWh)					System Reqr.* (b) (GWh)	Differ (a)-(b) (GWh)	Remark
			Hydro	Geo. thermal	Oil thermal	Coal thermal	Total (MW)		Hydro	Geo. thermal	Coal thermal	Oil thermal	Total (a)			
1985	Existing Hydro	1,216	1,216				1,216	3 811	2,869	4 284	1,471	5,825	14,449			
	Existing Geo.	660		660			660									
	Existing Oil	1,925			1,925		1,925									
	Existing Coal	300				300	300									
	Total	4,101					4,101									
1986			1,216	660	1,925	300	4,101	3,511	2,559	4,597	1,678	5,557	14,391	14,139	252	
1987	Malaya 2 Rehabili.		1,216	660	1,925	300	4,101	3,611	2,751	4,223	1,836	5,836	14,646	14,605	41	
1988	Malaya 1 Rehabili.		1,216	660	1,925	300	4,101	3,911	2,751	4,223	1,836	6,401	15,211	15,190	21	
1989			1,216	660	1,925	300	4,101	3,811	2,751	4,223	1,836	7,156	15,966	15,949	17	
1990	Sucat Rehabili.		1,216	660	1,925	300	4,101	3,721	2,751	4,223	1,836	8,007	16,817	16,907	-90	Shortage
1991	Sucat 4 Rehabili.		1,216	770	1,925	300	4,211	4,131	2,751	4,974	1,838	8,386	17,947	17,921	26	
	Bacon-Manito	110														
1992	Calaca 2	300	1,216	770	1,925	600	4,511	4,431	2,751	4,974	3,668	7,627	19,020	18,996	24	
1993	Isabela 1 & 2	200	1,239	770	1,925	800	4,734	4,654	2,905	4,974	4,880	7,406	20,165	20,135	30	
	Pantay	23														
1994	Isabela 3	100	1,239	770	1,925	900	4,834	4,754	2,905	4,974	5,500	8,017	21,396	21,343	53	
1995	Casecnan & Others	268	1,507	770	1,925	900	5,102	5,022	4,284	4,974	5,500	7,901	22,659	22,623	36	

Note: 1. 1985 are actual figures. 1986 are budget figures.
Figures of 1987 and after are results of computer simulation by System Planning Dept.
2. Sucat 1 rehabilitation starts in July 1989. recommissioning in Jan. 1990.
3. Sucat 4 rehabilitation starts in Nov. 1990. recommissioning in Nov. 1991.

4. Present Status of Calaca Power Plant

4-1 Operation, Maintenance and Management of the Plant

4-1-1 Operation
4-1-2 Maintenance
4-1-3 Coal Management
4-1-4 Environmental Conditions
4-1-5 Education and Training

4-2 Present Condition of the Plant Facilities

4-2-1 Present Conditions and Problems of Boiler and Auxiliaries
4-2-2 Coal Unloading and Coal Handling Facilities
4-2-3 Ash Disposal Facilities

4-3 Boiler Combustion System

4-3-1 Combustion Management
4-3-2 Combustion Management Instrument
4-3-3 Automatic Boiler Control

4. Present Status of Calaca Power Plant

4-1 Operation, Maintenance and Management of the Plant

4-1-1 Operation

(1) Past Operating Conditions

Calaca Power Plant is a power plant designed to fire the coal from Semirara Coal Mine.

In preparation for the commissioning of the power plant, approximately 150,000 tons of Semirara Run-of-Mine (ROM) coal was delivered to the power plant in July to October 1984. When this coal was used, the clay mingled with the coal and high moisture caused clogging of the hoppers in the coal handling system and coal silos, and the troubles of tripping of the coal feeders and coal mills occurred frequently, which led to frequent plant trips. Therefore, the test operation was carried out mainly with the imported coal from Australia.

After February 1985, Selected Semirara Coal (SSC) was delivered in place of ROM coal, and the coal clogging troubles were solved by the use of this SSC, but the trouble of slagging in the furnace and fouling of the rear pass of the boiler occurred anew. And it developed so that the unit had to be shut down frequently for ash removal. At that time, the mixed firing method of feeding the Australian coal to two of the three mills and Semirara coal to another mill was adopted with oil firing time to time for stabilizing of combustion.

For the purpose of finding countermeasures against slagging, tests were conducted with several blend ratios of coal, and the following rules were formulated.

- Use of ROM coal to be discontinued.

- Load to be limited below 225 MW with 100% SSC.

- Load to be limited below 260 MW with blended coal of SSC and Australian Coal (AC) at 60/40 of mixing ratio.

- MCR (full output) operation is possible if alkali ($Na_2O + K_2O$) content in the SSC/AC blended coal is less than 4%.

– Firing of 100% imported coal is not desirable because of high flue gas temperature.

It seems that about 80,000 tons of ROM coal was fired finally in the boiler and the remainder was resold.

After this, the operation was continued with the coal firing ratio of 40/60 of local coal and imported coal with 3 mills. But with the mixed firing, ABC could not be used in automatic mode and the poor combustion resulted. And after the middle of 1986, coal blending by the reclaimers was started and firing of 50/50 blended coal was in practice in February 1987. By this method, combustion was good and ABC could be used in the automatic mode.

In 1987, such new brands of coal as Luvimin coal and Montenegrin coal were received and NAPOCOR used them after evaluation of the slagging and fouling tendencies by the use of these brand coals.

The problem of slagging and fouling was solved by blending the local coal with imported coal, but NAPOCOR wants to limit the use of imported coal for saving of the foreign exchange and intends to continue the tests for increase in blend ratio of local coal.

Past operation record is as shown in Table 4-1.

Table 4-1 Past Operation Record

	84	85/ First Half	85/ Second Half	86/ First Half	86/ Second Half	87/ First Half
Utilization Factor (%)	29	55	55	57	71	80
Number of Plant Trip	34	43	14	11	20	9
Thermal Efficiency (%)	30.7	33.2	33.9	33.6	35.8	35.3
Operating Hour (h)	1,196	3,442	3,363	2,496	3,875	3,814
Forced Outage Rate (%)	7.2	11.7	17.4	3.1	0.8	5.5
Coal Consumption (t)						
Local Coal	24,498	199,659	141,934	141,109	222,281	235,669
Imported Coal	53,395	99,527	161,391	154,030	222,281	230,795

(Including some assumed figures)

(2) Current Status of Operation

Prior to the combustion test, the unit used to be operated at rated load of 300 MW with Australian/Semirara blended coal of 55/45 blend ratio on Monday through Friday, and at 225 MW with exclusive Semirara coal on Saturday and Sunday, when the system load was low. The boiler was operated at low O_2 of 2.5% indicated by the recorder in the central control room. However, out of the four O_2 meter probes, two on A-side and two on B-side, three probes were out of order, and only one meter on A-side was operating normally, due to the delay of procurement procedure of spare parts.

The air port dampers installed on the lower part of the boiler were 50% open for prevention of fouling and slagging in accordance with the instruction by FOSTER WHEELER ENERGY CORPORATION (FWEC), the boiler manufacturer. And since a part of the combustion air is supplied through the lower air port, the wind box differential pressure around the burners was low. And hence the whirling power for thepulverized coal was low and combustion was not too good.

In spite of the fact that Calaca Unit No. 1 was under load limiter operation, the generator load was fluctuating by 15 to 20 MW, which is much larger than the usual value of ±2 MW.

For the purpose of confirming the cause of this load fluctuation, observation on the normal operation and review of the trend recorder charts were made, and the dynamic characteristics test of the boiler was carried out during the combustion test.

As a result of the analysis, it was observed that the stability of the main steam pressure control and the drum level control was rather poor when the load was fluctuated. And it was judged that both the main steam pressure control and the drum level control needed fine readjustement and modification of the system.

It was observed also that the throttling of the governing valve by high frequency decreased the generator output greatly, and this triggered instability of the control system and caused the large load fluctuation.

The survey of the causes of recent plant trips revealed that there had been frequent trips due to "critical flame out" and they have been disturbing the stable operation of the power plant. (Critical flame out: The boiler is tripped when the flame detector judges that 6 burners have lost flame.)

The patrol check sheets for daily operation have been prepared and used by the operators at the patrol carried out 3 times a day.

The hourly readings of the main meters in the central control room have been recorded in the operation log, and operators are checking the operating condition comparing with the reference value on the log sheets.

The unit start-up and shut-down procedures on A-1 size board and the starting and stopping curves in A-2 size are placed in the central control room, and the procedures seem to be understood fairly well by the operators through experience.

Samples of EP ash, economizer ash, etc. are displayed in the central control room. Operators have contrasted current fly ash with these samples and have tried to operate the plant so that unburnt carbon contents will be reduced.

(3) Trouble Records

As shown in Table 4-2 Summary of Plant Trip of Calaca Unit No. 1 which describes the record of the troubles occurred since the commissioning of the plant in September 1984 up to June 1987, plant trips due to the trouble in the control and instrumentation system are the most frequent case accounting for more than 60 percent of the plant trip of 110 cases in total.

The major reason of the above is supposed to be due to insufficient adjustment time of control systems during the commissioning caused by often hindrance on the continuous plant operation like clogging of coal silo and/or chutes of coal handling system derived from the use of ROM coal.

As it can be known by the chronological change in the frequency of forced plant trips shown in Fig. 4-1, that most of so called initial trouble were encountered during the period since plant commissioning in September 1984 up to May 1985 and countermeasures were already given to almost all trouble items. However, as mentioned above there are still some troubles left unsolved due to insufficiency of adjustment/tuning time for controls during the commissioning and trial operation of the plant.

Those troubles are malfunctioning of critical flame out of the burners and occasional instability of ABC during the plant load fluctuation.

Another problem still unsolved is the plant instability triggered by sharp change in system frequency, the countermeasure of which needs system wide study.

The second most frequent troubles which entailed irregular shutdown of the plant are slagging, fouling and resulting tube leak problems of the boiler, caused by the use of ROM coal or SSC from Semirara Island.

These problems, including those of boiler auxiliaries, account for 19 percent of the total troubles.

These problems, however, have been already solved by serious efforts of plant personnel and no slagging/fouling problems are currently encountered under the plant operation with blended coal, SSC and Australian coal.

But, future increase in the number of troubles is apprehended because of the insufficient maintenance tools, delayed delivery of spare parts due to long procurement time of NAPOCOR, etc. which hinders timely maintenance work of the plant.

The third and fourth most frequent trouble items, which account for 8 percent each of the total, are system faults and turbine/generator troubles, and the fifth trouble item is other items which account for 6 percent.

As explained above all the trouble items and their corresponding cause have been thoroughly studied and mostly solved with much efforts by NAPOCOR, however, the items summarized below are left unsolved due to various constraints.

a. Critical flame out

b. Instability of the plant performance due to change in the load and/or the system frequency

c. Power plant trip by system fault

The solution for these problems are described in Chapter 8 of this report. The past plant trips, categorized according to the reason, are tabulated in Table 4-3.

Table 4-2 Summary of Plant Trip of Calaca Unit No. 1

Trouble Item	Number of Plant Trip	Remarks
1. Instrumentation & Control		Total shutdown hour
1) Critical flame out	12 times	: 70
2) MFT trip	7	: 18
3) Furnace pressure high/low	24	: 206
4) Drum level high/low	8	: 26
5) Loss of primary air	5	: 8
6) Loss of igniter	2	: 8
7) EHC trouble	2	: 5
8) Mill trouble	4	: 5
9) Others	2	: 5
Subtotal	66	351
2. System Fault or Irregular Frequency		
1) System frequency high/low	6	: 63
2) System trouble	3	: 44
Subtotal	9	107
3. Boiler and Auxiliaries		
1) Boiler		
a. Slagging/Fouling	3	: 202
b. Tube leak	6	: 976
2) Coal silo clogging	3	: 55
3) Auxiliaries	9	: 308
Subtotal	21	: 1,541
4. Turbine/Generator		
1) Turbine	0	
2) Auxiliaries	5	: 183
3) Generator	4	: 33
Subtotal	9	216
5. Others	5	: 136

$$\text{Forced Shutdown Rate} = \frac{\text{Forced shutdown hour (h)}}{\text{Operating hour (h)} + \text{Forced shutdown hour (h)}} = 11.4\%$$

(Up to June 1987 since commissioning)

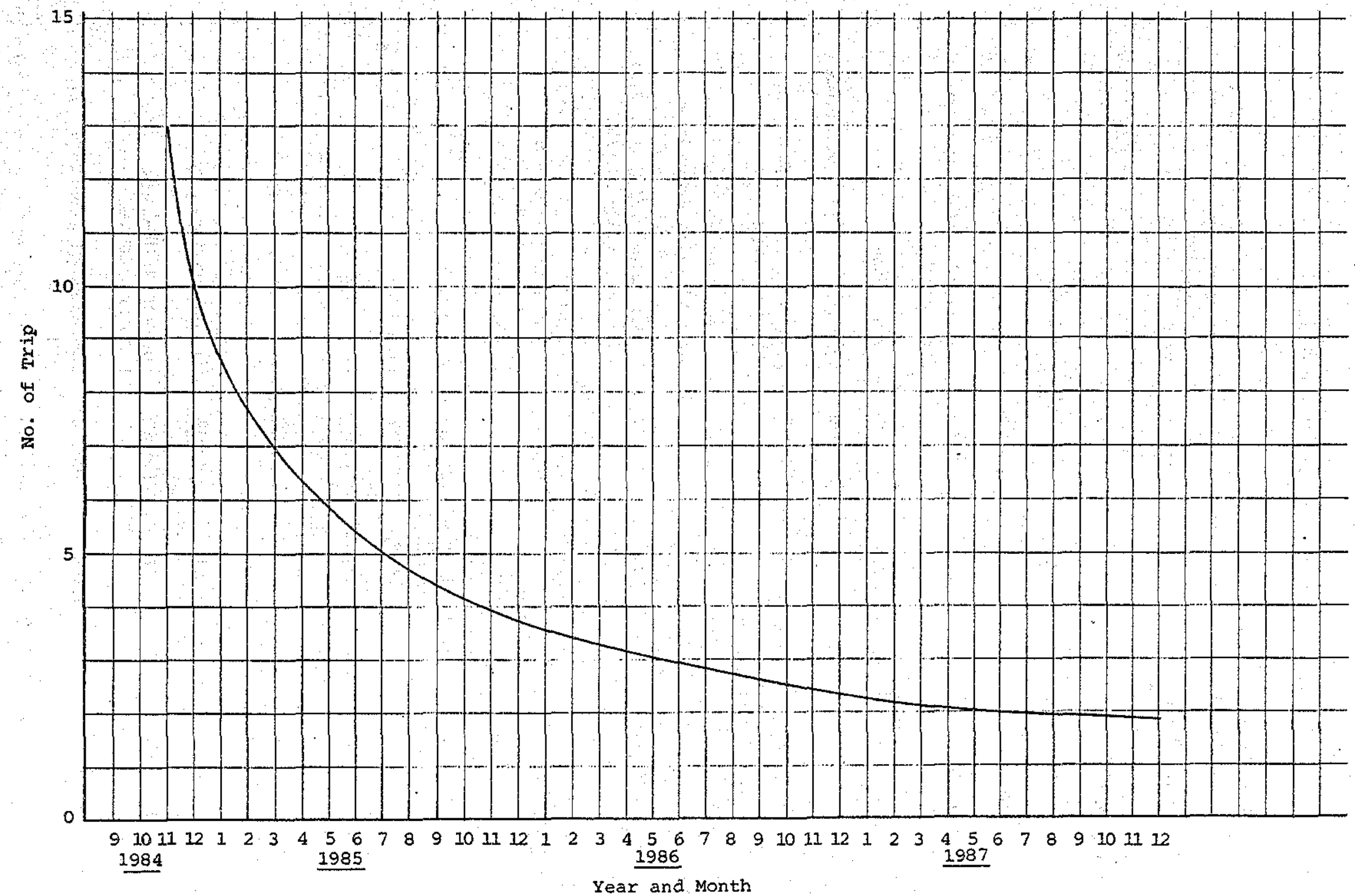


Fig. 4-1 Trend Curve of Forced Shutdown Trouble of Calaca Unit No. 1

Table 4-3 Category of Troubles

1. Instrumentation & Control

Trouble Item/Shutdown Time		Description	
		Output	Cause, etc.
1) Critical flame out			
09–26–84	41.47 h	154 MW	Critical flame out
11–06–84	3.13 h	125 MW	
12–03–84	1.15 h	90 MW	Loss of ignition at low load, critical flame out, MFT.
12–04–84	1.04 h	125 MW	Loss of all flame
		131 MW	Critical flame out, low furnace pressure
01–13–85	1.80 h	205 MW	Critical flame out while shutting down one primary air fan.
01–17–85	1.50 h	77 MW	Tripped due to critical flame out while shutting down one primary air fan.
01–18–85	2.00 h	70 MW	Tripped due to critical flame out while shutting down one primary air fan.
02–27–85	1.33 h	235 MW	Critical flame out (MFT burner management interpose logic system)
04–24–85	11.21 h	280 MW	Flame out & MFT
05–01–85	0.90 h	175 MW	Critical flame out
05–25–85	1.52 h	204 MW	Critical flame out
09–02–85	3.07 h	157 MW	Critical flame out
12 times	70.12 h		
2) Tripped due to MFT			
09–30–84	6.18 h	80 MW	MFT (low atomizing air)
12–05–84	1.17 h	124 MW	Loss of igniter (BMS fail) Furnace pressure low, MFT.
12–08–84	1.03 h	106 MW	Loss of igniter, low furnace pressure, MFT.

Trouble Item/Shutdown Time		Description	
		Output	Cause, etc.
01–06–85	0.90 h	110 MW	Loss of all fuel
03–15–85	2.88 h	260 MW	MFT
07–13–85	2.85 h	185 MW	MFT (Fuel controller)
06–06–86	2.82 h	300 MW	MFT (Furnace pressure high)
7 times	18.00 h		
3) Furnace pressure high & low			
10–31–84	2.97 h	324 MW	F.P. high
11–20–84	1.83 h	115 MW	F.P. low
11–21–84	1.72 h	75 MW	F.P. high
11–22–84	0.80 h	145 MW	F.P. low
12–03–84	1.62 h	109 MW	F.P. low
12–29–84	0.98 h	125 MW	F.P. low
01–02–85	13.27 h	132 MW	F.P. low
01–05–85	0.87 h	105 MW	F.P. low
01–13–85	2.67 h	226 MW	F.P. high
02–16–85	5.80 h	270 MW	F.P. low
02–16–85	2.55 h	190 MW	F.P. low
02–18–85	89.25 h	232 MW	F.P. low (Primary S.H. clogging)
03–13–85	1.20 h	229 MW	F.P. low
04–08–85	5.42 h	85 MW	F.P. high (Malfunction of IDF controller)
04–08–85	1.60 h	71 MW	F.P. low
04–08–85	1.47 h	56 MW	F.P. low
04–09–85	1.25 h	141 MW	F.P. high
04–26–85	0.97 h	175 MW	F.P. high

Trouble Item/Shutdown Time		Description	
		Output	Cause, etc.
04–26–85	57.75 h	140 MW	F.P. low
12–27–85	0.90 h	200 MW	F.P. high ("A' IDF trip)
12–27–85	0.82 h	68 MW	F.P. high
01–06–86	3.38 h	212 MW	F.P. high
06–11–86	4.15 h	300 MW	F.P. high ("A" IDF trip)
12–03–86	2.83 h	220 MW	F.P. low (Primary air inlet control vane)
24 times	206.07 h		
4) Drum level high & low			
09–30–84	1.45 h	260 MW	Drum level low and popping of safety valve
11–18–84	0.63 h	108 MW	D.L. high
04–16–85	13.45 h	252 MW	D.L. low
12–23–85	0.57 h	9 MW	D.L. high
04–24–86	2.03 h	70 MW	D.L. high
04–24–86	1.63 h	45 MW	D.L. high
07–26–86	5.68 h	300 MW	D.L. low (Mill trouble hunting)
10–13–86	0.57 h	45 MW	D.L. high
8 times	26.01 h		
5) Loss of primary air			
10–07–84	2.68 h	160 MW	Loss of primary air (L.O.P.A.)
04–09–85	0.87 h	49 MW	"
06–02–86	0.90 h	65 MW	"
06–02–86	1.35 h	89 MW	"
03–25–87	2.60 h	300 MW	"
5 times	8.40 h		

Trouble Item/Shutdown Time			Description	
			Output	Cause, etc.
6) Loss of igniter				
	12–07–84	1.95 h	119 MW	at low load B-3
	12–07–84	6.10 h	21 MW	"
	2 times	8.05 h		
7) EHC trouble				
	10–31–84	1.03 h	10 MW	EHC malfunction
	11–05–84	4.32 h	21 MW	EHC trouble
	2 times	5.35 h		
8) Mill trouble				
	10–06–84	1.38 h	162 MW	No oil support to pulverizer
	01–15–85	0.80 h	109 MW	C mill tirp
	02–27–85	1.52 h	171 MW	Trip due to "D" mill shut-off damper closed.
	09–07–86	1.00 h	230 MW	Sudden closing of shut-off damper
	4 times	4.70 h		
9) Others				
	01–16–85	1.60 h	160 MW	Tripped due to boiler load less than 30% initiated by low signal from main steam flow.
	04–09–87	3.00 h	300 MW	Instantaneous furnace upset causing drum level low
	2 times	4.60 h		

2. System Fault or Irregular Frequency

Trouble Items/Shutdown Time			Description	
			Output	Cause, etc.
1)	System frequency high/low			
	11–02–84	3.22 h	147 MW	System frequency high
	03–21–85	3.53 h	303 MW	System frequency high
	09–16–85	2.80 h	170 MW	System frequency high
	12–25–85	3.15 h	154 MW	Over frequency
	03–19–87	0.10 h	3 MW	System frequency high
	05–30–87	50.0 h	223 MW	System frequency high
	6 times	62.80 h		
2)	System trouble			
	07–12–85	1.07 h	112 MW	System trouble (Kalayaan pump trip)
	08–21–86	11.06 h	300 MW	System trouble
	10–06–86	31.38 h	123 MW	Low System demand
	3 times	43.51 h		

3. Boiler and Auxiliaries

Trouble Item/Shutdown Time			Description	
			Output	Cause, etc.
1)	Boiler			
	a. Slagging/fouling			
	09–29–84	4.47 h	168 MW	Reheater blocked
	03–06–85	126.76 h	232 MW	Clogging of primary SH upper bank
	03–22–85	70.82 h	243 MW	Clogging of primary SH
	3 times	202.05 h		

Trouble Item/Shutdown Time		Description	
		Output	Cause, etc.
b. Tube leak			
10–31–84	115.07 h		Upper eco. tube leak and No. 1 eco. hopper clogging
08–07–85	446.13 h	15 MW	Boiler tube leak maintenance
08–26–85	147.05 h	15 MW	Boiler tube leak
05–06–86	69.72 h	192 MW	Repair of boiler tube leak
10–18–86	109.65 h	30 MW	Boiler tube leak (Partition wall tube)
01–14–87	88.37 h	3 MW	Repair of lower eco. tube leak
6 times	975.99 h		
2) Coal silo clogging			
01–18–85	52.60 h	71 MW	Tripped manually due to clogging of silos of C & D and also to cut down fuel oil consumption
01–24–85	1.17 h	191 MW	Unit isolated to the system due to clogging of coal on C & D silos and due to repair works on heavy oil pump and heaters.
06–22–85	1.05 h	108 MW	Clogging-up of silo D
3 times	54.82 h		
3) Auxiliaries			
10–02–84	61.07 h	10 MW	Shutdown for repair of valve of aux. steam feeder
11–07–84	8.18 h	200 MW	Emergency tripping due to malfunctioning of aux. steam control valve
11–12–84	92.87 h	125 MW	Shutdown for repair of eco. non-return valve
01–01–85	15.20 h	5 MW	Shutdown to facilitate repair of leak on SH spray
12–21–85	66.58 h	5 MW	Drum level gauge root valve leak

Trouble Item/Shutdown Time		Description	
		Output	Cause, etc.
05–31–86	53.07 h	230 MW	Safety valve trouble
09–03–86	6.62 h	260 MW	Outage of B mill
10–18–86	1.15 h	58 MW	Fuel oil supply trouble
06–19–87	3.40 h	250 MW	Loss of all fuel by lube oil pump tripping
9 times	308.14 h		

4. Turbine/Generator

Trouble Item/Shutdown Time		Description	
		Output	Cause, etc.
1) Turbine			
NONE			
2) Auxiliaries			
07–14–85	0.67 h	94 MW	Turbine control valve stick
07–15–85	94.65 h	100 MW	Maintenance of turbine CV
09–01–85	15.77 h	50 MW	Inspection of intercept valve
06–20–87	63.40 h		Leaking drain valve and malfunction of EHC
06–23–87	8.19 h		Restricted control valve movement
5 times	182.68 h		
3) Generator			
04–22–86	1.00 h	5 MW	Generator reverse power Ry.
08–13–86	14.28 h	300 MW	Generator stator cooling system trouble
09–27–86	13.33 h	275 MW	Excitation lock out Ry.
03–19–87	4.30 h	260 MW	Generator stator cooling water trouble
4 times	32.91 h		

5. Others

Trouble Item/Shutdown Time		Description	
		Output	Cause, etc.
11–19–84	2.18 h	75 MW	Tripped due to loss of primary air
12–06–84	1.17 h	103 MW	Loss of primary air
01–11–85	1.20 h		
02–11–85	59.65 h	None	Unit unable to synchronize due to hammering on CRH line
04–19–85	72.02 h	75 MW	Unit shutdown to repair S/B 6L
5 times	136.22 h		

4-1-2 Maintenance

It was observed that much efforts are being exerted by plant personnel to maintain the power plant in good condition, however, it seems that some improvement will be needed for better maintenance works. Some defective equipment and/or facilities were also seen left unrepaired because of the delay of spare parts supply or lack of maintenance tools. This delayed delivery of spare parts and/or maintenance tools due to long time procurement procedure is Corporate wide problem and seems to be solved by some substantial improvement in procurement processing.

For higher reliability of future operation of the power plant, the following are recommended to be considered by NAPOCOR.

(1) Preparation of Maintenance Manual and Standard Maintenance Procedure

Instruction books of the manufacturers are only available for maintenance works at present, however, it is recommendable to compile a maintenance manual covering total plant system introducing to it empirical maintennance practices acquired from the past operation/maintenance of the plant.

(2) Keeping and Compilation of Maintenance and Measuremnt Records

Maintenance record, which is important for the plant management, and measurement records showing the chronological change of the plant have to be properly kept, and a computerized management of them is recommended.

(3) Keeping of "All Point Review" Output of Data Logger

During the site survey of the plant and boiler combustion test by JICA this time, data has been collected in accordance with the format prepared by JICA survey team and "All Point Review" of data logger.

It is recommendable that the "All Point Review" data at different loads of each month should be kept so that they can be utilized effectively in the future planning of the maintenance and improvement program and as the reference data of the chronological changes.

(*All Point Review: All the data on the major measuring points of the plant are output by data logger on the recording paper.)

(4) Annual Overhaul

Review was made by JICA team on the overhaul record of Calaca Unit No. 1 [FIRST BCFTPP* ANNUAL SHUTDOWN REPORT] of the first overhaul conducted from February 9 to April 24, 1986, and it was found that the report covers the measurement and adjustment data and records of test runs mainly of the turbine and generator, but few records concerning the details of the maintenance/repair work were found.

Therefore, inspection records, repair records, survey data, trial operation records after overhaul, pending items, repair items to be attended in the next overhaul, etc. are recommended to be added in the overhaul report.

(*BCFTPP: Batangas Coal Fired Thermal Power Plant)

(5) Procurement of Proper Repair Tools for Conveyor System

Because of frequent troubles of the coal reclaiming conveyor system, blending of coal has become impossible many times and the mixed firing by feeding different coals to different hoppers is frequently resorted to. Especially to cope with the occurrence of cut conveyor belts, procurement of proper repair tools is quite urgent.

(6) Maintenance and Management of Coal Mills

a. Inspection intervals

For Calaca Unit No. 1, the overhaul inspection of the mills has been carried out every 3,300 – 5,000 hours, while the manufacturer's recommendation is every 2,500 – 3,000 hours. At Calaca, especially, as the coal quality largely changes, it would be necessary to shorten the overhaul intervals as recommended by the mill manufacturer, and the measurement of fineness and adjustment of classifier vanes should properly be made to maintain good mill performance. Mill inspection record is shown on Table 4-4.

b. Performance of coal mills

a) The guarantee values of fineness by FWEC are as follows:

70% through #200 USS mesh
98% through # 50 USS mesh
at 25% – MCR load (boiler)

b) Measurement of fineness

The results of measurement of fineness of coal at the time of combustion test (at 300 MW load) were as shown in Table 4-5, and these values satisfied the guarantee values. However, for more satisfactory combustion, it is advisable to set the target of fineness at more than 80% pass through #200 USS mesh and 99% pass through #50 USS mesh, and when the ratio of the Selected Semirara Coal is increased or exclusive Semirara coal firing is made, more careful observation of the fineness would be necessary.

In this sense, when the blend ratio is changed, it is most important for satisfactory combustion and control of boiler efficiency to repeat the fineness measurements and grasp the change in the mill performance.

Table 4-4 Mill Inspection Record

Mill No.	Inspection Date	Operating Hours		Classifier Vane Opening	Remarks
		Total	from Last Insp.		
A	Jan. 10, '85	1,334	–	7"	OK
	Oct. 3, '85	1,981	647	7–1/16"	OK
	Feb.–Mar. '86	2,750	769	7"	Roller oil changed.
	Dec. '86–Jan. '87	5,367	2,617	7"	OK
B	May 10, '85	1,411		–	High vibration
	Feb.–Mar. '86	5,322	3,911	7"	OK
	Jan. 9–Feb. 6, '87	10,081	4,758	7"	Replacement of roller, Build up of ring.
C	Aug. 7, '85	1,007	–	7"	OK
	Feb.–Mar. '86	4,233	3,266	7–1/16"	Roller oil changed.
	July '86	7,372	4,139	7–1/2"	Air port ring replaced.
	Feb. '87–Jan. '87	9,242	870	7"	OK
D	July 26, '85	3,590	–	8" to 7"	Erosion on air port ring.
	Feb.–Mar. '86	7,005	3,415	7–1/2"	OK
	Dec. '86–Jan. '87	11,931	4,926	7"	Roller build up on damage.

Notes: Manufacturer's recommended interval of overhauls: 2,500–3,000 hours.

Table 4-5 Coal Fineness Test (at Load 300 MW)

Coal Blend Ratio (S/A)	Mill No.	Coal Flow (t/h)	Coal/Air Temp. (°C)	Mesh Pass (%)			Remarks
				200	100	50	
55/45	A	51.15	69	79.38	94.69	98.73	
	B	49.91	69	81.00	95.76	99.00	
	C	50.85	70	78.44	93.86	98.80	
	Ave.	–	–	79.60	94.77	98.84	5.23% remaining on 100 Mesh
60/40	A	47.98	70	81.79	95.74	99.39	
	B	49.01	71	81.07	95.95	99.28	
	C	52.01	70	78.80	94.18	98.94	
	Ave.	–	–	80.55	95.28	99.20	4.72% remaining on 100 Mesh
70/30	A	50.28	75	78.72	94.44	98.75	
	B	49.84	76	79.05	94.68	98.99	
	C	49.84	74	72.98	91.65	97.95	
	Ave.	–	–	76.92	93.59	97.57	6.41% remaining on 100 Mesh
100/0	A	42.26	69	77.54	95.17	98.65	
	B	42.30	67	73.43	92.47	98.58	Load 225 MW
	C	43.22	65	70.26	91.00	98.26	
	Ave.	–	–	73.74	92.88	98.50	7.12% remaining on 100 Mesh

Percentage remaining on 100 mesh:

S/A = 55/45: 5.23%
= 60/40: 4.72%
= 70/30: 6.41%

4-1-3 Coal Management

(1) Control of Received Coal Storage

a. Present status

a) Semirara coal (Unong Coal) is shipped by 5,000 DWT class coalers and for the quality control, the samples taken from each lot (1,000 tons) at the time of shipping from Semirara are analyzed (proximate analysis: moisture, ash, volatile matter, fixed carbon, calorific value and sulphur) at the coal mine and at the power plant separately, and the results are used for confirmation of the conditions of transaction.

Seven NAPOCOR employees are stationed at Semirara Coal Mine as the coal receiving staff.

b) The scaling values at the time of shipment from Semirara Coal Mine is submitted as the quantity of coal delivered to the power plant, together with the analysis and this is recorded as the quantity of coal received.

c) In the control of the coal storage, the stored coal quantity is obtained by the difference between the received coal quantity and the quantity of coal fired in the boiler (total of coal flow readings of individual coal feeders). In the case of blended coal, the calculation is made by proportion according to the planned blend ratio.

d) No spontaneous combustion is seen with the Australian coal, but it is observed at several parts of the coal pile of the Selected Semirara coal, which is a young brown coal.

b. Problems

a) It is recommended that the received coal shall be sampled and analyzed by the power plant for management of coal quality and confirmation on the condition of the coal transaction.

b) The auto-sampler is out of order due to delay of requisitioned *spare parts, however, soonest repair and regular operation of it* is recommendable for the above purpose.

c) The coal scale for the receiving coal is out of order also due to delay of requisitioned spare parts which is used for confirmation of transaction.

d) It is recommendable to make proper management of as fired coal by utilizing the discharge coal scale (installed on B-12). Since the reclaimers are not equipped with the integrating coal flow meters, it is recommended to provide those for proper blending of coal.

(2) *Control of Consumed Coal*

The present status and problems of quality control of consumed coal are described below.

a. Daily sampling and analysis of as fired coal are not being practiced.

b. For the daily heat control, the calorific value of the received coal is used, which is suspected to be different from the calorific value of the actually fired coal. Especially, it seems to be improper that the heat rate are required on the daily report to the head office. It is practical that the average heat rate in a week or a month will be reported to the head office because the coal analysis takes a certain period.

c. In the combustion test, the survey team presented an advice on the inspection and maintenance of the sampling points at the coal feeders and the frequency of sampling, and it is hoped that the advice will also be observed in the future plant operation.

d. Since various manners of combustion such as blended coal firing, exclusive firing and mixed firing are adopted in the plant, the coal quality control seems rather difficult, however study on the better practice for energy management is recommended.

(3) Control of Blend Ratio

At present, for the purpose of preventing the boiler slagging and fouling, the

Semirara coal and the Australian coal are reclaimed by two separate reclaimers, and the reclaiming flows are controlled to match the blend ratio. In the combustion test, temporary recorders were installed on the reclaimers, and the blend ratio was computed, error of which was in the order of ±7%.

As the indications of the coal flow meter installed on the reclaimer and the temporary recorders were both in t/h and the reclaiming flow fluctuated widely, the calculation of the blend ratio from these readings was very inefficient.

Ideal blending of coal will be possible if a coal blending facility is installed.

As an alternative and less expensive idea, even though it will give lower accuracy in blending ratio, one integrating flow meter each shall be installed on the reclaimer. And the reclaiming coal quantity and blend ratio shall be calculated and indicated on recorder per half cycle of reclaiming, and the reclaiming operation shall be automatically controlled to maintain the set coal flow and blend ratio.

4-1-4 Environmental Conditions

(1) Outline

The environmental policy in the Philippines is regulated by the NPCC (National Pollution Control Commission) established by the Presidential Decree (Offficial Gazette dated June 5, 1978). The contents of NPCC regulations are as follows:

Chapter 1. General Provisions and Administrative Procedures

Chapter 2 Air Quality Standards and Rules and Regulations Relating to Air Pollution Control

Chapter 3 Water Quality Criteria and Rules and Regulations Relating to Water Pollution Control

Chapter 4 Miscellaneous Regulations – Noise Control Regulations and Odor Emission Control

Chapter 5 Permit Regulations

The environmental division of Calaca Power Plant has prepared an environmental protection manual, and set the following targets in its foreword, for monitoring the environmental conditions around the power plant.

a. Measurement of pollution level

b. Determination of changes and trends of the environmental conditions around the power plant before and after the commissioning of the power plant.

c. Evaluation and recommendation relating to the alleviation of the impacts of the operation of the power plant and anticipated complaints.

These level of the pollution are being regularly monitored not only by the environmental division of Calaca Power Plant but also by EMD (Environmental Management Division) of NAPOCOR head office.

(2) Present Status of Monitoring at Calaca Power Plant

a. Meteorological observation

Measurement of the wind direction and velocity, temperature and relative humidity is continued, but the relative humidity sensor, the wind direction and wind velocity sensors at 100 m height are now out of order.

b. Exhaust gas from the smoke stack

The exhaust gas density is regulated by NPCC to be 1,500 mg/scm or less for (SO_2 + NO_2 + CO + CO_2), 300 mg/scm or less for dust and 2μg/scm or less for NOx, respectively. (scm: Standard Cubic Meter)

If the above pollutive gases are assumed as totally equivalent SO_2 525 ppm of equivalent SO_2 will be the regulated value.

The reading of SO_2 meter during the combustion test is as shown in Table 4-6.

c. Peripheral SO_2 density

Peripheral SO_2 density on the ground is regulated by NPCC to be 396 μg/scm or less, and measurement by air auto-sampler is conducted every month.

The record of the recent measurement is shown in Table 4-7.

d. Suspended dust particle

The density of suspended dust particle regulated by NPCC is 250 $\mu g/m^3$ or less and it is measured by Hi Volume Sampler every month at the same location as SO_2 measurement. The record of the recent measurement is shown in Table 4-8.

The reason why the higher value than regulation is measured seems to be the effect of the dust from the unpaved road.

In order to know the effect from the power station, the measuring point should be located adjacent to the border of the power plant compound and the wind direction/velocity, weather, atmospheric temperature and relative humidity are also recommended to be measured at the same time.

e. Water quality

Water quality standard for such items as temperature, conductivity, solid content, turbidity, pH, alkalinity-P and -M values, toxic substances - Cd, Pb, Cr, As, Mn, etc. regulated by NPCC.

Location and frequency of water sampling are as listed below.

Power Station

Condenser outlet:	Everyday
Cooling water discharge channel:	Once a week

Drainage of ash disposal area:	Twice a week
Discharge water from neutralization and oil/water separating pond:	Once a week
Coal storage yard drainage:	Every rainfall

Other Places

Raw water intake:	Once a month
River water:	Twice a month
Underground water:	Twice a month
Peripheral area:	Every rainfall

Actual measurement data are as shown in Table 4-9. As for the toxic substances, minimum limits of detection are not clear for some items, therefore, it is necessary to define the specific measurement method and minimum limit of detection for them.

f. Noise level

Noise levels around the Calaca Power Plant are regulated as follows:

Time	Daytime	Morning/Evening	Night
Regulation (db)	75	70	65

Noise levels in the peripheral area as well as in the power station compound are measured every month and the actual measurement data are as shown in Table 4-10. In order to identify the effect of the power station, noise level measurement is also recommended to be conducted in the area adjacent to the border of power station compound.

Table 4-6 Stack SO_2 Monitoring Record

DATE	TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	AVE.
	ppm SO_2	290	290	285	290	300	300	300	300	270	270	305	305	315	350	350	335	330	350	370	370	380	410	410	390	
	LOAD	251	252	245	251	245	244	249	246	249	253	247	247	248	245	251	245	248	255	289	296	298	302	290	290	
7-21-87	FUEL	55%D/45%E																								
	ppm SO_2	400	380	380	380	370	390	420	430	420	410	390	400	390	390	405	420	440	430	420	425	425	405	410	405	
	LOAD	264	221	225	200	202	207	296	290	291	300	307	304	296	300	302	302	296	299	299	296	300	300	300	298	
7-22-87	FUEL	55%D/45%E																								
	ppm SO_2	230	145	130	175	250	270	320	350	360	380	390	380	390	395	400	405	400	405	390	360	370	360	350	340	
	LOAD	-	85	100	210	253	282	250	292	204	201	227	227	231	269	278	295	300	302	299	297	299	304	305	303	
7-25-87	FUEL	60%E/40%D																								
	ppm SO_2	310	300	320	340	340	350	400	440	480	540	540	545	540	570	550	570	510	500	510	515	490	470	470	470	
	LOAD	301	298	296	296	294	296	296	222	222	222	220	222	228	225	225	229	227	221	222	224	224	220	218	224	
7-26-87	FUEL	60%E/40%D																								
	ppm SO_2	270	250	245	240	245	245	245	255	285	310	310	340	380	370	370	350	345	340	330	330	330	340	320	310	
	LOAD	217	224	226	222	225	217	226	226	223	224	225	293	302	300	304	301	296	291	294	296	291	251	241	219	
8-06-87	FUEL	56%D/44%E																								
	ppm SO_2	345	330	330	345	345	370	350	330	315	310	310	300	315	315	275	280	310	320	320	325	330	330	305	325	
	LOAD	250	256	260	259	266	298	300	304	300	294	293	300	297	295	302	303	297	300	306	302	296	253	231	231	
8-07-87	FUEL	60%D/40%E																								
	ppm SO_2	320	325	330	335	340	350	355	360	360	380	385	400	380	410	420	400	400	410	420	410	350	330	330	320	
	LOAD	220	223	220	220	207	208	207	205	210	209	-	225	-	220	-	280	293	302	298	309	301	245	250	250	
8-08-87	FUEL	70%D/30%E																								
	ppm SO_2	360	360	360	355	355	380	385	385	390	390	380	370	360	370	380	380	380	380	390	400	380	390	400		
	LOAD	299	298	301	300	296	294	300	302	302	296	300	305	300	300	297	299	299	299	300	295	294	256	255		
8-11-87	FUEL	60%D/40%E																								
8-15-87	ppm SO_2	400	400	400	395	400	430	460	480	510	520	530	500	490	520	525	525	495	490	490	500	450	410	390		

TYPES OF FUEL
A - LIGHT COAL
B - HEAVY COAL
C - SEMIRARA COAL
D - SELECTED SEMIRARA COAL
E - AUSTRALIAN COAL
F - OTHERS

REMARKS: Combustion Test
The NPCC air quality standard
1. SO_2 emission - 1500 mg/scm SO_2 (525 ppm)
2. Ambient SO_2 - 396 µg/scm (24 hrs. exposure time): 0.139 ppm
Note: scm - standard cubic meter

$$mg/scm = ppm \times \frac{64}{22.4}$$

Table 4-7 Environmental Monitoring Data Monthly Average

A. Ambient SO_2

	SO_2 $\mu g/m^3$	NPCC Std.
January, 1987	11.55	396 $\mu g/m^3$
February	10.79	
March	4.60	
April	8.37	
May	–	
June	8.86	
July	–	

Stations:		Direction:
Calaca	– 3 kms from the plant	North East
Resettlement	– 2 kms	South East
Baclaran	– 2 kms	West
Balayan	– 5 kms	West
Main Gate	– 200 meters	East
Camastilisan	– 4 kms	East
Madalunot	– 5 kms	North East

Table 4-8 Environmental Monitoring Data Monthly Average

Air Particulates (Hi-Vol)

Station	Dust Concentration ($\mu g/m^3$)						NPCC Std.
	Jan.	March	April	May	June	July	
Resettlement	*173.84	–	136.16	181.26	47.08	–	250 $\mu g/m^3$ 1 hr
Plant Site	44.14	84.98	–	–	–	–	exposure time
Baclaran	**191.91	*337.87	*286.41	*329.57	150.66		
Calaca	34.47	210.21	220.27	84.75	–	11.77	
Met. Station	–	145.67	88.28	–	–	–	
Camastilisan	–	–	*285.43	–	–	185.38	
Balayan (Bonville)	–	–	–	19.44		*296.61	
Madalunot	–	–	–	–	–	43.55	

Note: *Normally heavy road dust
**Testing of Luvimin/SSC coal

Table 4-9 Monitoring Data of Water Quality

Item	Unit	NPCC Regulation	Condenser Cooling Water Outlet	Ash Pump Discharge
Temperature	°C	less than 40°C	29.0–33.3	26.0–36.0
pH		5.5–9.0	8.14–8.25	8.3–9.0
SS	mg/l	200		
Oil	mg/l	15		
Residual Chloride	ppm	1.0	0.05–0.11	
Cd	ppm	0.1		
Cu	ppm	0.5		
Pb	ppm	0.5		
Cr	ppm	0.1		
As	ppm	0.5		
Hg	ppm	0.002		

Table 4-10. Noise Level Monitoring (Outside of the Plant Compound)

Limit – 75 dBA at Daytime, 9 AM to 6 PM

Station	Date/Time Sampled	Noise Level
1. Resettlement Area	1–14–87 bet 1750 to 2100	53 (Average of six stations)
2. Resettlement Area (Blk 4)	2–18–87	53
	3–09–87/1050	52
	4–01–87/1115	52
3. Baclaran	1–14–87/2230	52
	3–02–87/1325	51
	4–06–87/1030	42
4. Balayan	1–14–87/2330	49
	7–03–87/1000	51
5. Calaca	1–14–87/1220	52
	3–11–87/1110	51
	3–16–87/1010	52
	6–16–87/1010	53.5
	8–07–87/1040	52
6. Meteorological Station	2–18–87	52
	3–02–87/1115	45
	4–01–87/1120	51
	4–06–87/1115	52
7. Dacanlao	2–26–87/1135	59
8. Tuy	6–01–87/1000	52
9. Madalunot	7–03–87/1045	52
	7–22–87/1100	52

4-1-5 Education and Training

The following education and training courses are applied for employees as a total education system of NAPOCOR.

(1) Classification of Education/Training Course

a. Basic/core course

This course will be applied for the following employees.

a) New or comparatively new employees who are assigned to the job.

b) Employees for newly constructed power plant and/or facilities, for operation, maintenance and management.

c) The cases that more than 500 employees are assigned to the corresponding job.

b. Refresher or retraining course

It is planned that this course will be applied to the employees who have completed the basic course for further improvement of the technology of their own field and to acquire the knowledge of newly developed technology. It is ideal to apply this course to the employees three years after their accomplishment of basic course, however, this course is actually applied after ten years.

c. Enhancement course

The enhancement courses are for employees who would benefit from specialized and more sophisticated courses along their field; these are also for employee who need extra supplementary learning either for present job effectiveness, or for additional or higher responsibilities.

(2) Contents of Education

a. Basic course

a) Operation program

i. Thermal power plant operation
ii. Geothermal power plant operation and maintenance course
iii. Hydro power plant operations course
iv. Diesel power plant operation and maintenance course

b) Maintenance Program

i. Maintenance training series program
ii. Instrumentation and control course

c) Power system program

i. Basic lineman's course
ii. Substation operations and maintenance course
iii. Power system analysis course (Load flow analysis)
iv. Power system analysis course (Fault analysis)

d) Training program for engineering group

i. Project/program planning, scheduling, monitoring and control
ii. Statistics for engineers

e) Computer courses

i. Microsoft disk operating system
ii. Wordstar (Software application for word processing)
iii. Lotus 1-2-3
iv. Database III plus

f) Safety programs

i. Occupational safety and health standard course

b. Refresher/retraining course

a) Safety program
b) Fire brigade training

c. Enhancement course

a) Power system program
b) Power system protection and operation

d. Others

Other than the above, the following education programs are considered.

a) Organization development program
b) The NAPOCOR scholarship program
c) External training program

(3) Education and Training in Calaca Thermal Power Plant

In Calaca Thermal Power Plant, 2)-a.a) Operation program and b) Maintenance program in the above basic course are given to the plant employees as a part of education. In addition to the above, refreshing training course is applied as on the job training. Education/training are given in the form of classroom training through lecture and discussion in combination with simulation training or OJT in the field.

Training program of operators in Calaca Power Plant are shown in Annex 8.

(4) Enhancement of Education/Training

Calaca Power Plant is the first coal fired plant in the Luzon Grid. Almost all plant personnel have been transferred from other oil fired plants and geothermal plants. Those personnel have commenced their job without experience for the coal fired unit, but from the plant manager to operating and maintenance crew are exerting their utmost effort to maintain this plant absorbing new technology. Many problems encountered in the beginning of plant operation were cleared and situation is being improved so much. In order to promote further improvement of plant reliability as a base load unit in the Luzon Grid, education/training of plant personnel are important factor. For this purpose, the following improvement on the existing education system are recommended.

a. Improvement of new employee education

a) It seems very seldom in NAPOCOR that change of job assignment for new employees is being done from their original assignment to a specific job. To know whole system and behavior of power plant, experience of operation is very important. Based on this consideration, it is recommended that all new employee including personnel for engineering division be assigned to shift operation of the plant for a certain period (one or two years) after common or general education, then they shall be reassigned to new job. Rotation of job afterwards is also important.

b) Not only internal troubles but also faults arisen from outside system were found in the past operation record. To cope with the emergency cases, training of operator is indispensable. In the future development plan, coal fired plant will be increased. To give appropriate education/training, it is desirable to install a operation simulator. In the utility company in Japan, operators with experience of two or three years after their employment by the company are trained by operation simulator.

c) To cope with increase of necessity of training, the training center will be necessary including the above operation simulator.

d) Since the main purpose of this study is to improve the equipment/facilities of the power plant, survey and study for education/training system of NAPOCOR was not done in detail, but it is needless to say that this matter is of high priority. It is recommended for NAPOCOR to study the case of other countries in detail and establish an ideal one in the Philippines.

4-2 Present Condition of Facilities

4-2-1 Present Conditions and Problems of Boiler and Auxiliaries

(1) Boiler Proper and Auxiliaries

The following troubles have been caused on the boiler and power plant operation by the use of Semirara coal.

a. By the use of the Run-of-Mine coal (ROM coal) received initially at the time of commissioning, the high clay content and high moisture caused frequent coal clogging in coal unloading and handling facilities, coal silos, hoppers and chutes, tripping of coal mills and unit trips. And the rated output could not be attained.

b. After February 1985, the Semirara coal was upgraded from ROM coal to Selected Semirara Coal (SSC), and the clogging problem was solved, but new boiler troubles of slagging in the furnace and fouling of the rear pass occurred and it became necessary to shutdown the unit frequently for the ash removal.

c. Since the middle of 1986, the method of coal blending by the reclaimers has been adopted and the blended coal of SSC and the imported coal has been fired. However, the property of ash (alkali content of Na_2O + K_2O) of Semirara coal, which affects the slagging and fouling, was very unstable and this became the most significant limiting factor of coal blend ratio.

d. The following operation policy will be studied in this report.

a) Exclusive firing of ROM coal or SSC

b) Stable operation with decreased blend ratio of imported coal.

(2) Other Problems

The following equipment are defective at present. Spare parts for repair works were already ordered, however, required repairs are not yet carried out due to delay of procurement. Expenses for repair works will be accelerated if troubles are left unattended. Therefore, procurement procedures must be reviewed to enable smooth and timely purchase of spare parts.

a. Drum level gauge

Bi-color glass level gauges are provided on each end of the steam drum. The level gauge on the left end of the drum is equipped with a TV camera for monitoring the level on the TV screen in the central control room, and the gauge on the right end of the drum is for local monitoring. At present, however, both the gauges are out of use because of leakage.

The drum level is at present monitored by the recorder and CRT in the central control room. However, the drum level gauges are important supervisory equipment, and should be maintained in good condition.

b. Leak in boiler proper, air duct and gas duct

There are some leaking expansion joints in the boiler proper and air and gas duct system.

c. Inspection of the rear pass (Primary SH)

At present, the inspection of slagging and fouling in the furnace is made through the inspection holes, but as there is no inspection hole for the rear pass, the big manhole for maintenance purposes is opened for inspection. It is advisable to make a small inspection hole for the rear pass.

d. Operating floor of lower air port damper

It is necessary to modify and improve the operating floor for the lower air port damper. At present, a very dangerous posture is required for the checking of the indicator.

4-2-2 Coal Unloading and Coal Handling Facilities

Since the power station was commissioned, three different types of coal, namely Semirara ROM coal, Selected Semirara Coal and imported coal from Australia, have been used either singly or mixedly.

The ROM coal was used initially, and caused the various troubles, mainly coal clogging. If the ROM coal is to be used at this power plant in the future, the countermeasures should be taken.

Improvements and/or repairs shall also be made for use of the Selected Semirara Coal and Australian coal, either singly or mixedly.

The problems and corresponding countermeasures of the existing coal unloading and coal handling facilities relating to the handling of ROM coal, were described in The Preliminary Report on The Coal handling Facilities submitted in June 1987. The Problems are as follows.

(1) Problems of Facilities

a. Unloader and hopper chutes

a) During ROM coal unloading, clay mingled with coal sticks on the unloader hoppers and branch chutes, and troubles such as decrease of unloader capability and non availability of unloading occurs.

b) In the rainy season, coal handling is made impossible by coal slipping due to standing water on the receiving conveyors B–1 and B–2. (Refer to Fig. 4-2 Coal Handling System Layout.)

b. Transfer tower hopper and chutes

During ROM coal unloading, clay mingled with coal sticks on the hopper and chutes in each transfer tower and coal handling capability is decreased, and also dropping of coal occurs frequently.

c. Reclaimer

Reclaiming capability is lowered by sticking of clay on the bucket wheel.

d. Vibrating screen and ring crusher

a) Unloading capability is decreased by large size ROM coal and sticking of clay and clogging of screen meshes in vibrating screen. For prevention of clogging in coal silo located at boiler side,

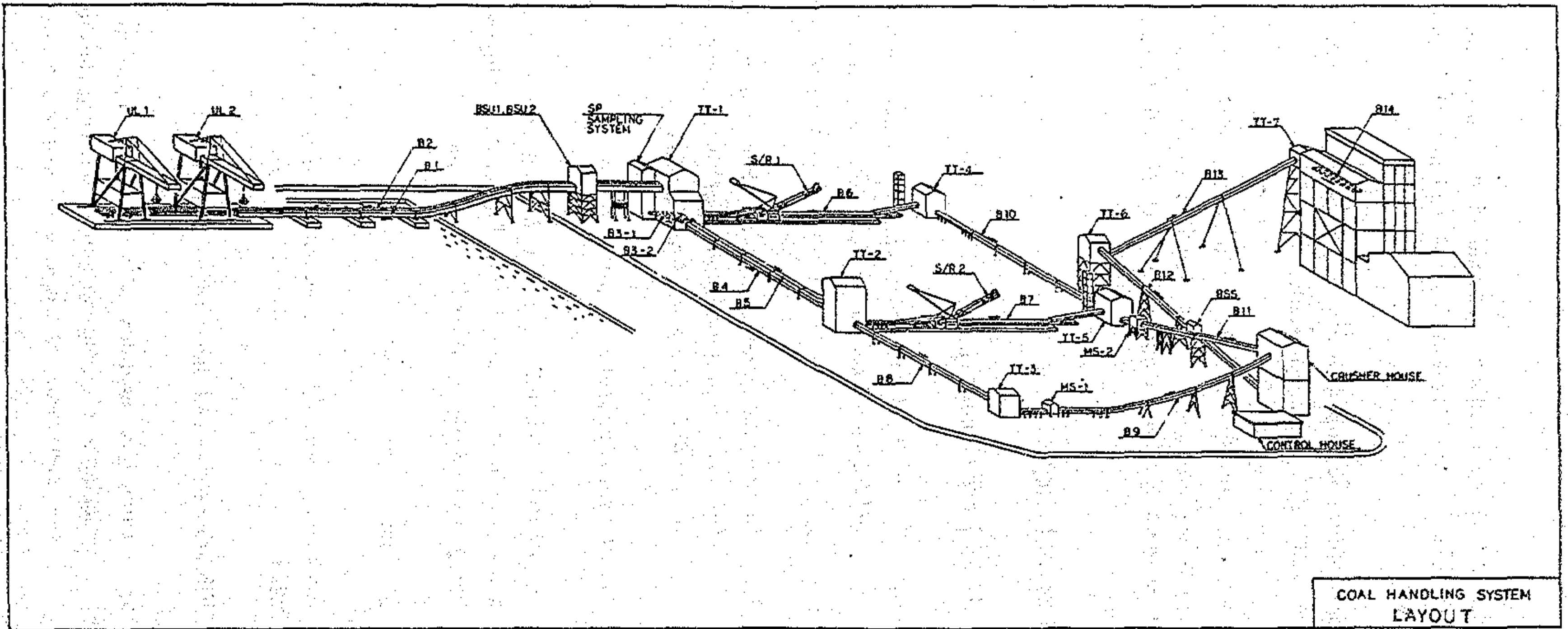


Fig. 4-2 Coal Handling System Layout

screen meshes were enlarged from 35 mm x 70 mm to 80 mm x 70 mm at present.

b) Coal crusher is of the ring hammer type, coal is crushed in between rotatory ring and crush screen underneath. The screen is clogged with ROM coal, the crushing capability is decreased and sometimes coal handling is made impossible by the clogged screen.

e. Coal silo and coal chutes

a) By the use of ROM coal at the time of test operation, frequent accidents of coal feeder and mill trips occurred by the coal clogging, which caused load limitation by boiler unstable combustion, boiler flame out and unit trip.

b) Coal grade of Semirara coal was changed to SSC from ROM coal in February 1985, and problems of the coal clogging was solved. At present operation with blended coal of SSC and imported coal is carried out.

c) Air blasters are installed at coal silo for prevention of clogging, however, the effect is limited.

(2) Problems on Coal Management

a. Management of coal storage

a) Coal sample by a lot (1,000 ton) for as received coal is taken at the time of coal loading. Proximate analysis is carried out by SCC and NAPOCOR for confirmation of coal quality.

b) The value measured at the time of coal loading is recorded as the received coal volume.

c) At present, the as received coal flow meter and the autosampler are out of order. Those should be repaired and adjusted immediately.

d) Spontaneous combustion is observed at several parts of SSC piles.

b. Management of coal quality

a) Coal grade of Semirara coal was changed to SSC, however, slagging and fouling occurred anew, and operation was carried out by coal blending with Australian coal.

b) As it is necessary to grasp the coal ash characteristics for increase of SSC blend ratio, installation of analyzing equipment donated by JICA is planned.

c) In case of the blending by the existing reclaimer, the blending error is about ±15%.

c. Pollution by dust

a) Coal dust is dispersed from unloader during SSC unloading.

b) Clouds of coal dust are generated by the wind from coal storage yard. The coal dust is flying from the surface of coal piles in dry season and from reclaimer during operation, and those affect the power plant and surrounding residential area.

c) Coal dropping at transfer towers and coal dust in bunker room cause inferior working conditions, damages of rotating machinery, etc.

4-2-3 Ash Disposal Facilities

(1) Present Status

The ash disposal system is composed of three systems as follows.

a. Bottom ash disposal (Furnace bottom ash)

Ash is held in the water-filled hopper and transported to the ash disposal area by the jet pulsion pump once every 8 hours.

b. Economizer and air heater ash

Ash is sent to the ash bin by the blower once every 8 hours, and transported to the ash disposal area by jet pulsion pump according to the ash level in the bin.

c. EP ash

Ash is sent to the EP ash bin by the blower once every 8 hours, and when the ash level in the bin reaches a set level, the ash is transported to the ash disposal area by the jet pulsion pump.

(2) Problems

a. Disposal of EP ash

The EP ash bin is provided in consideration of the utilization of EP ash (at cement mills, etc.), but the ash is discarded in the ash disposal area for the moment. Usually, unburnt carbon content should be limited less than 5% for sales. The fluctuation of coal quality used in Calaca No. 1 boiler seems to make the ash quality unstable. The ash bin (silo) is not equipped with the ash classifier.

b. Clogging of economizer ash hopper

a) Phenomenon

Large clinkers are sometimes produced in the economizer ash hopper. Some clinkers are very hard and some are easily breakable, but in general, the inside of these clinkers is still burning, and the clinkers are made of ash of high unburnt carbon content. The frequent occurrence of this phenomenon has been one of the causes of the limitation of the power plant output.

b) Probable cause

It is suspected that this phenomenon is caused by the properties of coal and poor combustion in the boiler.

Because of the low-O_2 operation carried out with Calaca No. 1 boiler, coal can not burn completely in the furnace, and the ash still burning is brought into the rear pass. The slagging and fouling property of the Semirara coal plays an important role in this phenomena, but it is essential that coal burns completely before it leaves the furnace.

c) Countermeasure

Based on the results of the combustion test, adoption of proper O_2 value for combustion and change of operation of the lower air ports could realize stable operation without ash clogging of the economizer hopper, even with the exclusive use of Semirara coal and with the blend ratio of 60/40.

4-3 Boiler Combustion System

4-3-1 Combustion Management

For combustion management in a power plant, usual management of factors directly effecting the boiler combustion and management of mill pulverization capability are indispensable.

As a result of the evaluation on the combustion management of Calaca Unit No. 1, the following are advised.

Firstly, sticking of the deflector vanes which decide the fineness of the coal produced by the mill is a serious problem. This problem affects the quantity of unburnt carbon which directly represents the combustion result and the mill capacity, and causes response delay of actual combustion in terms of ABC control. Good management of mills is one of the most important factors for the combustion management of the coal-fired boiler.

Secondly, the condition of each devices relating to the combustion around the burners affects directly the boiler combustion condition, and the operating condition of those devices should be grasped quantitatively. Discrepancy between the actual openings and the outside position indicators of the burner air registers should be corrected because the opening of the burner air register affects the ignition and the combustion process of fuel coal.

Thirdly, since the result of combustion is judged referring the variation of O_2 content in the boiler exhaust gas, perfect and proper maintenance of the flue gas O_2 meters is essential for the combustion management. The flue gas O_2 meters including selection of the representative sampling points should be reviewed and corrected.

Fourthly, understanding on the combustion management in terms of the operation management shall be promoted.

The combustion management will be satisfactorily accomplished by the total management of the following factors.

(1) Mill Operation Corresponding to Coal Quality

The optimum positions of the classifier vanes corresponding to coal grindabilities and change in the mill capacity corresponding to the moisture content of coal should be grasped and those should be applied to the actual operation of the mills.

(2) Operational Management on Combustion Result

Since the front parallel burner firing is adopted to Calaca No. 1 boiler, the combustion results at burner front reach the economizer by laminar flow through the furnace and the rear pass. And the poor combustion result caused by a burner is found out sometimes at only the sampling point corresponding to the flow line of the combustion gas of the poor burner, therefore the visual inspection of the flame conditions at burner throats and the monitoring of the operational factors with good understandings on the existing sampling points for the O_2 meters are necessary for the operational management on the combustion results.

(3) Consideration on Combustion in View of O_2 Value of Flue Gas

a. In case of imbalanced O_2 value between A and B side flue gas

Each feed rate of the pulverized coal from the operating mill to four (4) burners may be uneven or the gas flow rates of the both ducts may be imbalanced. In this case, the opening positions of the burner outlet registers, the differential pressure at the burner wind box and the flow rate of the primary and the secondary air should be inspected.

b. In case of fluctuation of O_2 in flue gas and furnace draft

This phenomenon is mostly the fluctuation of the total combustion in the furnace caused by unstable ignition of a burner. The black skirt length and the fluctuation of the flame should be checked through the peepholes on the side walls of boiler and the position of the air register should be adjusted.

Lastly, adjustment of the air flow control system of the Automatic Boiler Control (ABC) system is judged to be incomplete.

The air flow control system is a three-element-control composed of the feed-forward signal, the fuel follow signal and the flue gas O_2 signal. Generally with a coal-fired boiler, the automatic boiler operation with the flue gas O_2 control is difficult because of difficulty of the sampling, delay of indication of the O_2 value due to delay of the combustion, and so forth. Therefore, the signal of the air-fuel rate determined based on the O_2 percentage obtained by the boiler static characteristics with the parameters of the unit loads and the coal properties should be adopted as the flue gas O_2 signal in the foregoing three-element control, the primary control system of the air flow.

Then, the O_2 control system can be treated as a supplementary system even with the condition of whole sampling devices of the flue gas O_2 in service.

4-3-2 Combustion Management Instrument

(1) Flue Gas O_2 Meter

The flue gas O_2 meter is one of the most important instruments for boiler combustion monitoring. Three (3) flue gas O_2 meters out of four (4) sets installed were out of order, and the O_2 value in A side gas duct was only recorded. Furthermore, big discrepancy of O_2 content in flue gas between A and B gas ducts was revealed by the Orsat analysis conducted during the combustion test and gave a difficulty in combustion management.

The defective parts should immediately be replaced and the flue gas O_2 meters should be restored to the normal condition.

(2) Traversing for O_2 Sampling

Traversing of the measuring points for O_2 content in the flue gas at the economizer outlet and the sampling points for the Orsat analysis had not been conducted since the commissioning. Traversing of those measuring points and sampling points was difficult because of the gas leakage through the expansion joint at the economizer outlet of the B side gas duct.

The leaking expansion joint should be repaired during the overhaul and the O_2 meter probes should be fitted at the points giving average O_2 content in the flue gas by traversing the measuring points at economizer outlet of the flue gas duct.

(3) Position Indicators

The discrepancy between the actual opening and the indication of the local position indicators of the air registers of the burners and the classifier vanes of the coal mill provide operational problem. Besides, the position indicators of the burner air registers at the central control room were out of order and the position of the air registers could only be confirmed by the local position indicators.

The local position indicators should be adjusted and the indicators at the central control room should be repaired during the overhaul.

(4) Calibration of Monitoring Instrument

Calibration of O_2 meters, draft gauges of the air and gas systems, etc., which are the important instruments for boiler combustion control and monitoring, should be conducted periodically. Calibration was conducted only when the request was made from the operator, or excessive error or abnormality was observed.

Calibration of O_2 meters, draft gauges, etc. should be conducted twice a month at least to maintain those instruments so that correct indications can be obtained all the time.

(5) Thermometers for Reheater (RH) Tube Metal

High temperature indication exceeding the alarm level was observed at two (2) points of RH tube metal. That abnormality is suspected to come from the defective thermocouples, because the other temperature indications of RH tube metal were normal. The seal material of the local terminal box of the temperature measuring circuit for the RH tube metal might be deteriorated, since abnormal decrease of temperature indication were observed on a rainy day.

The temperature measurement circuit of RH tube metal should be inspected and recovered to the normal condition for the proper operation and monitoring.

(6) Matching of the Readings of Instruments

Concerning Air Preheater (AH) outlet gas temperature, mill outlet temperature, air flow rate, etc., discrepancies were observed between indicated values of the recorders, controllers, data logger and CRT. These discrepancies gave difficulty in proper judgement of the operating conditions.

Measured/recorded values of recorders, controllers, data logger and CRT should be matched with each other by calibration and/or repair of defective parts.

(7) Readjustment of Flame Detecting System

Calaca Unit No. 1 has frequently tripped by the "critical flame out'. Since Calaca Unit No. 1 is a large capacity and an important unit as the base load plant, reduction of the number of unit trips will contribute to the stable power supply of the Luzon Grid.

It was informed by the plant personnel that change of the cooling air fan suction place to clean area from dusty place has reduced the malfunction of the flame detector significantly.

But JICA team considers that there is some inherent defect in the logic of the flame detecting system.

The defects in the design are as mentioned below;

o Once flame out is detected, the flame out signal is retained for fifteen (15) seconds without reset even after the detection of flame recovery, and

o When one (1) mill stops or trips, the flame out signal is retained for fifteen (15) seconds similarly.

The following improvements of the logic can reduce the number of unit trips caused by the defects of the "critical flame out" logic;

- o When flame recovery is detected after the detection of flame out, the flame out signal should be reset immediately, and

- o When a mill stops or trips, the flame out signal should immediately be excluded from the critical flame out logic.

4-3-3 Automatic Boiler Control

On the basis of the data and information as to the present operational condition of Calaca Unit No. 1 collected during the first and second surveys, analysis and study were made mainly on the function of Automatic Boiler Control (ABC). And it was revealed that the present ABC system had insufficient capability for stable plant operation.

Therefore, the causes of the above and corresponding countermeasures are described in the following.

(1) Basic Condition of the Analysis

a.	Operation mode:	Load limiter operation (Turbine EHC control: manual)
b.	ABC mode:	Boiler follow, full automatic
c.	Operated mill:	A, B and C mills (3 sets)
d.	Fuel:	Blended coal firing, exclusive SSC firing
e.	Data for analysis:	Fig. 4-5 ABC system Disturbance due to Over-response of Feedwater Control System under Constant Plant Load Fig. 4-6 ABC System Disturbance due to Over-reduction in Feedwater Flow Caused by Change in Load Corresponding to Governing Valve Actuation

(2) Ideal Control System for Feed Water Control

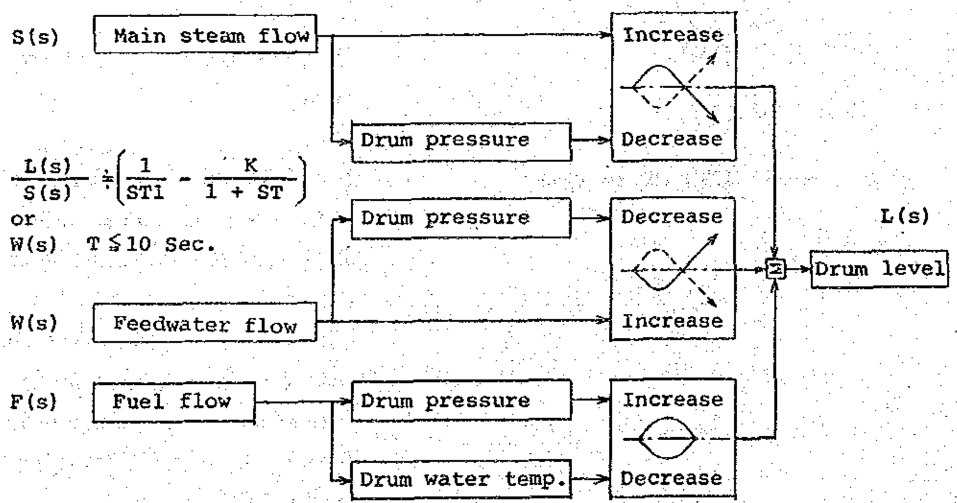
The objective control process component is the coal-fired drum type boiler of Calaca Power Plant.

Prior to the analysis on the present condition of the ABC, the ideal control system for the feedwater regulation is described to provide preliminary knowledge for understanding.

a. Dynamic characteristics of drum level (Refer to Fig. 4-3.)

The remarkable feature of the dynamic characteristics of the drum level is the transient negative response corresponding to the change in main steam flow and feedwater flow.

This is due to the change in the steam evaporation corresponding to the change in the drum pressure caused by fluid flow variation, and this transient negative response must be compensated in negative direction in view of the control and special consideration is needed on this irregular phenomenon. And even the fluid inflow and outflow is balanced, there is always a minor fluctuation of the drum level because of fluctuation in heat absorption of boiler, however, this kind of fluctuation can be neglected in the control system.



$$\frac{L(s)}{S(s)} \fallingdotseq \left(\frac{1}{ST1} - \frac{K}{1 + ST} \right)$$

or

W(s) $T \leqq 10$ Sec.

$$\frac{L(s)}{F(s)} \fallingdotseq \left(\frac{1}{1 + ST} - \frac{e^{-SL}}{1 + ST} \right) \quad T \leqq 30 \text{ Sec.}$$

Fig. 4-3 Dynamic Characteristics of Drum Level

b. Ideal control system (Refer to Fig. 4-4.)

The following block diagram shows the basic idea for the negative response compensation in feedwater control by correcting the error signal of drum level with the differential signal of steam pressure and fluid flow which are processed through the function generator Fxp and Fxw respectively.

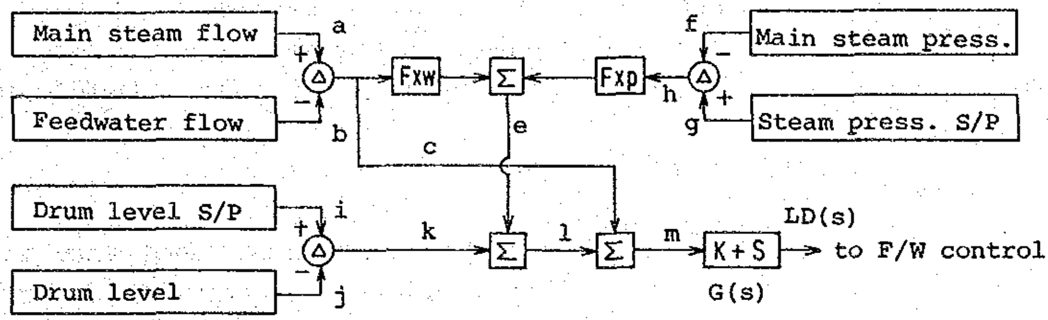


Fig. 4-4 Ideal Feedwater Control System

(3) Analysis on the Disturbance for ABC System at the Constant Load (Refer to Fig. 4-5.)

The fact that the generator output varies by ±8 MW (±2.6% ECR) with the constant control valve opening means the fluctuation in thermal input to the turbine, expressed as the function of steam pressure and steam inflow, assuming that the steam temperature is constant. Since Fig. 4-5 shows no fuel variation in fuel flow at the beginning of load variation, the change in load is supposed to be caused by the change in feedwater flow.

And as one of the causes of feedwater flow instability, there is over response of feedwater flow for compensation on drum level deviation in the closed loop of feedwater control system, which triggers seesaw movement with 180°C phase difference between drum level and feedwater flow eventually entailing the continuous hunting of both variables.

The primary cause of that over response of feedwater flow in the closed loop is supposed to be insufficient coordination between Master and Slave controllers in the cascaded control system, or gain mismatching between loading signal of BFP and feedwater flow.

(4) Analysis on ABC System Disturbance during the Load Change (Refer to Fig. 4-6.)

Fig. 4-6 shows the results of the dynamic characteristics test by reducing the load (0.5% ECR/min.). As the plant performance before the test was quite stable, the analysis of the dynamic characteristics of the control system could properly be made. At first, the assumed normal performance of the major variables during the time, the control valve was being closed in ramp mode from 55% to 50%, are plotted by broken line. These normal performance curves are described on the basis of the experience on the coal-fired boiler.

a. Generator active power

Generator active power should change in proportion to the change in governor valve position, the actual change, however, is much larger than expected. The reason of it is due to the extraordinary lower main steam pressure and temperature at the governor valve inlet than the designated value.

b. Turbine inlet steam pressure

Since the governing valve is being closed during the load reduction, steam pressure at the turbine inlet becomes higher due to the temporary pressure rise can be settled down to normal value soon as far as there will be boiler input (fuel and feed-water) precisely corresponding to the plant load.

The major reason why the actual steam pressure sharply declines from the normal locus is the over effect of the feedforward signal generated by the first stage pressure of the turbine, which cause sharp feedwater pressure drop and corresponding over reduction in fuel supply.

c. Main steam flow

The main steam flow is dependent on the differential pressure at the governing valve and is proportional to the opening of the governing valve because the deviation of the main steam pressure is rather small