(5) Aliphatic Hydrocarbon, Aromatic Hydrocarbon

The limit value of the total amount of aliphatic hydrocarbon and aromatic hydrocarbon emission from No.1 - No.3 Boiler permitted by local authority in 1992 was 24.27 kg/h.
The actual emission level of total hydrocarbon in 1992 is 12.81 kg/h.
There is no problem with hydrocarbon emission at the present.
In Japan, hydrocarbon emissions is discharged form tank vents and loading facilities.
Accordingly, it is the case that there is no data emissions from combustion flue gas for oil fired boilers.

5.7.3 Present condition of effluent in power plant

(1) Effluent produced in power plant

As mentioned in 5.5.6 (1), the effluent usually produced in a power plant is as follows:

1) Waste water from boiler feed water treatment system
2) Dust collector cleaning water
3) Air preheater cleaning water
4) Chemical cleaning water
5) Turbine room floor drain
6) Boiler room floor drain
7) Boiler blow water
8) Condenser cooling water
9) Drain from around fuel-related equipment
10) Sanitary water
11) Rain water from power plant site

We tried to determine the volume and composition of waste water, the treatment procedure in the power plant and the composition of the treated waste, but we could not obtain detailed data.

(2) Present condition of waste water treatment and effluent in power plant

The power plant site is provided with two facilities: a neutralization facility for the waste water from the boiler feed water treatment system and a treatment facility for the sanitary water. There are no other treatment facilities for other waste water.
It is designed in such a manner that all waste water other than rain water flows into the main pipe of System 1 header of the waste water system of the oil refinery and petrochemical plants, and rain water flows into the main rain water header coming from the oil refinery area. Both waste waters are finally treated in the central general waste water treatment facility as shown in Figure 5.5-5. Therefore, the effluent from the power plant are acid, alkaline and oil containing waste water.

5.7.4 Evaluation of effluent from power plant

In public power plants, dedicated waste water treatment facilities are generally provided, and the waste water produced in such power plant is completely treated in the aforementioned waste water treatment facilities so that waste water of a quality which meets the necessary standard value can be discharged. However, as the present power plant is only one facility of the PPSA complex and there is a central general waste water treatment facility, it is not necessary to provide dedicated waste water treatment facility as is the case with public power plants. However, the size of this plant is considerably large, and the volume of waste water to be produced is also anticipated to be large.

Therefore, in order to avoid the corrosion of the pipe, it would be better to avoid sending alkaline and acid waste water such as boiler blow water, dust collector cleaning water, air preheater cleaning water and chemical cleaning water, without treatment into the main header pipe. It is better to neutralize the alkaline or acidic waste water within the power plant site before sending them into the main header pipe.

Table 5.7-1 AIR POLLUTION FROM POWER STATION (1/3)

* from 11 July 1991
** from 30 December 1992

Boiler Name	00320 No.1 ~ No.3		00420 No.4 ~ No.7	
Year	in 1992	in 1993	in 1992	in 1993
[SO_2]				
State Standard (Valid to 31 Dec. 1997)	1,720 g/GJ	1,720 g/GJ	1,720 g/GJ	1,720 g/GJ
State Standard (After 31 Dec. 1997)	170 g/GJ	170 g/GJ	170 g/GJ	170 g/GJ
Real Emission from Boiler	1,228 g/GJ	1,140 g/GJ	1,280 g/GJ	1,132 g/GJ
Permission of Local Authority for Emission	* 618.44 kg/hr	** 309.22 kg/hr	* 811.70 kg/hr	** 405.85 kg/hr
Real Emission from Boiler	733 kg/hr	677.7 kg/hr	935 kg/hr	800 kg/hr
[NO_X]				
State Standard (Valid to 31 Dec. 1997)	160 g/GJ	160 g/GJ	160 g/GJ	160 g/GJ
State Standard (After 31 Dec. 1997)	160 g/GJ	160 g/GJ	160 g/GJ	160 g/GJ
Real Emission from Boiler	170.6 g/GJ	192 g/GJ	163 g/GJ	175 g/GJ
Permission of Local Authority for Emission	* 141.56 kg/hr	** 58.59 kg/hr	* 185.79 kg/hr	** 76.73 kg/hr
Real Emission from Boiler	101.85 kg/hr	114 kg/hr	119 kg/hr	124 kg/hr

Source ; P.P.S.A.

Table 5.7-1 AIR POLLUTION FROM POWER STATION (2/3)

* from 11 July 1991
** from 30 December 1992

Boiler Name	00320 No.1 ~ No.3		00420 No.4~ No.7	
Year	in 1992	in 1993	in 1992	in 1993
[Dust]				
State Standard (Valid to 31 Dec. 1997)	0 g/GJ	0 g/GJ	0 g/GJ	0 g/GJ
State Standard (After 31 Dec. 1997)	0 g/GJ	0 g/GJ	0 g/GJ	0 g/GJ
Real Emission from Boiler	15 g/GJ	15 g/GJ	11.3 g/GJ	11 g/GJ
Permission of Local Authority for Emission	* 35.56 kg/hr	** 35.56 kg/hr	* 46.67 kg/hr	** 46.67 kg/hr
Real Emission from Boiler	8.8 kg/hr	6.6 kg/hr	10.8 kg/hr	7.8 kg/hr
[CO]				
State Standard (Valid to 31 Dec. 1997)	0 g/GJ	0 g/GJ	0 g/GJ	0 g/GJ
State Standard (After 31 Dec. 1997)	0 g/GJ	0 g/GJ	0 g/GJ	0 g/GJ
Real Emission from Boiler	8.4 g/GJ	8.4 g/GJ	6.9 g/GJ	7.1 g/GJ
Permission of Local Authority for Emission	* 163.13 kg/hr	** 163.13 kg/hr	* 213.33 kg/hr	** 213.33 kg/hr
Real Emission from Boiler	5 kg/hr	5 kg/hr	5 kg/hr	5 kg/hr

Source ; P.P.S.A.

Table 5.7-1 AIR POLLUTION FROM POWER STATION (3/3)

* from 11 July 1991
** from 30 December 1992

Boiler Name	00320 No.1 ~ No.3		00420 No.4~ No.7	
Year	in 1992	in 1993	in 1992	in 1993
[Aliphtic Hydrocarbon]				
State Standard (Valid to 31 Dec. 1997)	0 g/GJ	0 g/GJ	0 g/GJ	0 g/GJ
State Standard (After 31 Dec. 1997)	0 g/GJ	0 g/GJ	0 g/GJ	0 g/GJ
Real Emission from Boiler	17.2 g/GJ	12.7 g/GJ	21.2 g/GJ	21.1 g/GJ
Permission of Local Authority for Emission	* 19.72 kg/hr	** kg/hr	* 25.87 kg/hr	** kg/hr
Real Emission from Boiler	10.25 kg/hr	7.6 kg/hr	15.5 kg/hr	14.9 kg/hr
[Aromatic Hydrocarbon]				
State Standard (Valid to 31 Dec. 1997)	0 g/GJ	0 g/GJ	0 g/GJ	0 g/GJ
State Standard (After 31 Dec. 1997)	0 g/GJ	0 g/GJ	0 g/GJ	0 g/GJ
Real Emission from Boiler	4.3 g/GJ	3.2 g/GJ	5.3 g/GJ	5.3 g/GJ
Permission of Local Authority for Emission	* 4.55 kg/hr	** kg/hr	* 5.96 kg/hr	** kg/hr
Real Emission from Boiler	2.56 kg/hr	1.9 kg/hr	3.9 kg/hr	3.7 kg/hr

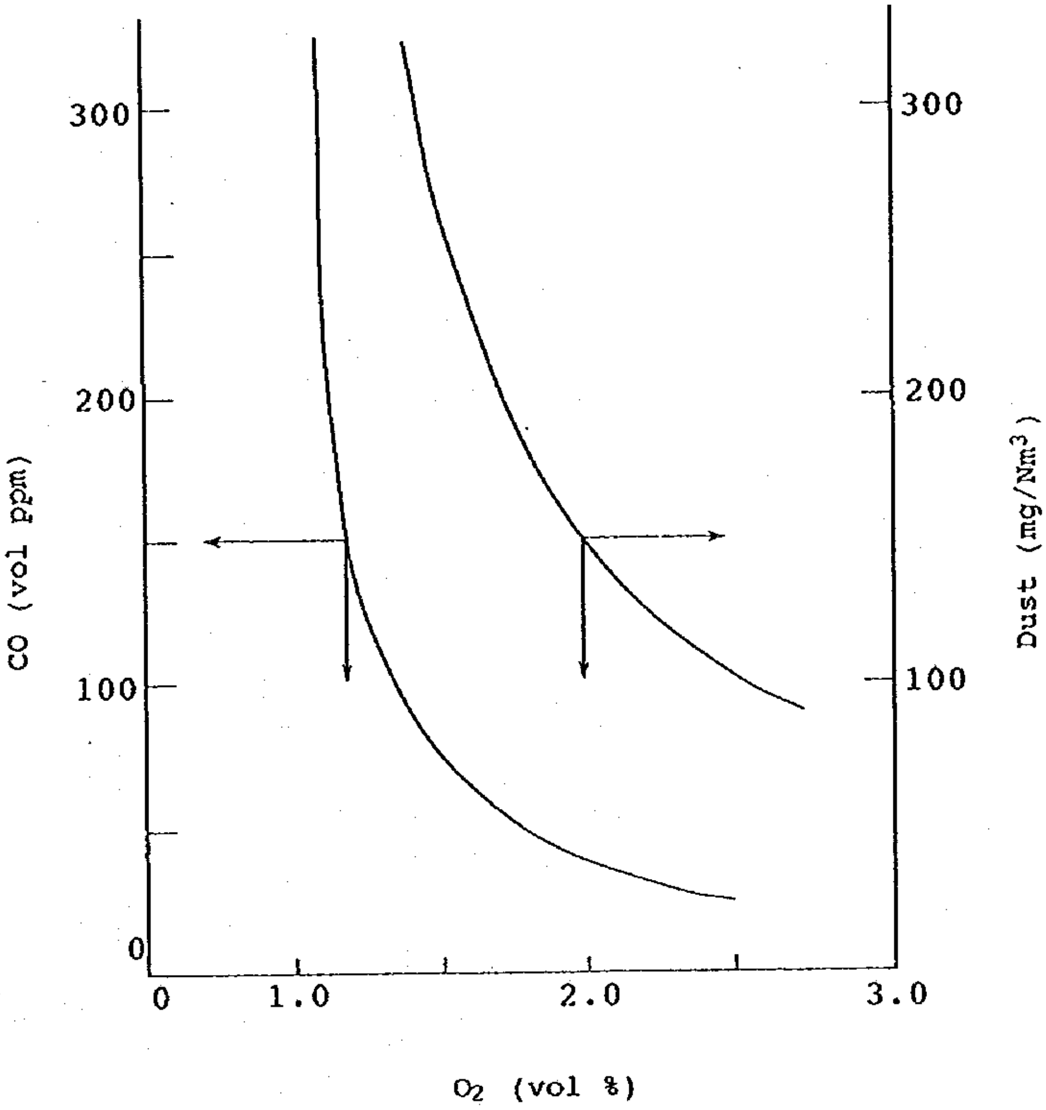
Source ; P.P.S.A.

Table 5.7-2 EMISSION OF AIR POLLUTION AND FEES FROM POWER STATION

Year	in 1991		in 1992		first half of 1993	
Item	Emission	Fee	Emission	Fee	Emission	Fee
Unit	ton	million zl	ton	million zl	ton	million zl
SO_2	41,770.1	28,403.7	32,068.7	24,692.7	15,018.5	18,022.2
NO_x	3,562.2	2,422.3	4,179.0	3,217.8	2,412.9	2,895.5
CO	195.0	0.0	269.4	56.6	96.7	29.0
CO_2	-	0.0	-	0.0	401,686.8	401.7
Aliphatics Hydrocarbon	495.9	89.3	556.9	117.0	256.5	77.0
Aromatics Hydrocarbon	49.6	89.3	62.5	131.2	28.5	88.3
Dust	430.6	77.5	375.0	157.5	145.2	87.1
V	-	0.0	-	0.0	2.2	6.8
Ni	-	0.0	-	0.0	0.7545	754.5
Cr	-	0.0	-	0.0	0.0382	38.2
Pb	-	0.0	-	0.0	0.0057	2.9
Cd	-	0.0	-	0.0	0.0003	0.2
Waste	50.0	9.0	50.0	10.0	3.5	0.9
Total	-	31,091.1	-	28,382.0	-	22,403.0
Fuel Consumption	664,906.0 tons		631,589.0 tons		328,027.0 tons	
Heating Value	9,604.0 KCAL/KG		9,686.0 KCAL/KG		9,616.0 KCAL/KG	
Sulfur Content (Average)	3.0 wt %		2.5 wt %		2.3 wt %	

Source ; P.P.S.A.

Figure 5.7-1 CORRELATION AMONG CO, DUST AND O_2 IN FLUE GAS



Boiler Load	145 T/H
Boiler Capacity	250 T/H
Combustion Method	Corner Firing 2 Stage Conbustion
Fuel Vac.Residue Oil	85 %
Fuel Gas	15 %

Source ; T.Sasaki , Technical Document of Power Plant Seminer , (1982

5.8 Evaluation of Cooling Water System, Heat Recovery and Waste Water

5.8.1 Present Condition of Cooling Water System

(1) Type and capacity of cooling water system

For the cooling water method of the PPSA complex, a recirculating cooling water system is adopted. The present supply capacity to the power plant facilities is 3,600m^3/h.

(2) Quality of make-up water to be supplied to cooling water system.

The make-up water of cooling water is that taken from the Vistula river. It is treated in the treating facility as shown in Figure 5.5-1. Its analytical value is shown in the column "Cooling Water K-1" of Table 5.5-4.

(3) Cooling water treatment and associated troubles

1) Cooling water treatment

In order to prevent troublesome corrosion, scale, slime and so on from being produced in the cooling water system by cooling water, chemical agents from NALCO or others are used. The dosage of such agents is 15-60ppm.

2) Troubles produced

a. Corrosion
   Petrochemical plant: < 0.1mm/year
   Refinery : 0.2mm/year or more
b. Scale : 0-10g/m^2/day
c. Slime : removed by filter

5.8.2 Points at issue, evaluation and measures to be taken regarding the cooling water system

(1) Type and Capacity of Cooling water System

It is a standard type of cooling water system which is adopted in many refineries and petrochemical plants. The present cooling water supply capacity to the power plant is 3,600m^3/h. However, a supply of 15,000m^3/h cooling water will be required for the operation of the newly installed the power plant extracting-condensing turbine which is a very important part of the future plan. Therefore, it will be necessary to secure a source of cooling water supply and greatly increase the size of the cooling water pipe.

(2) Quality of make-up water to cooling water system

The quality of the make-up water is far inferior to that of the standard industrial water used as make-up water in Japan. The quality of the cooling water K-1 and that in use in Japan are shown in Table 5.8-1 below.
As can be seen from Table 5.8-1, the quality of the make-up water is far inferior to that in use in Japan and closer to that of recirculating water of 5 times concentration in Japan. The quality of the make-up water is of such a level as might easily cause scale problems. However, as the silica content, which is considered difficult to treat, is very low, it seems to be relatively easy to treat the water, though the quality is generally inferior.

Table 5.8.1 COOLING WATER K-1 AND THE WATER IN JAPAN

Item	Make-up water In Japan	Cooling Water K1	5 Times Concentration
pH	7 - 7.6	8.6	8.8 - 9.0
M Alkaline level ($mgCaCO_3/l$)	40 - 80	128	250 - 350
Ca-hardness ($mgCaCO_3/l$)	40 - 80	453	250 - 350
Chlorine ion (mgCl/l)	20 - 40	117	120 - 180
Silica ($mgSiO_2/l$)	20 - 80	7	100 - 180
Turbidity ($mgSiO_2/l$)	5 - 10	16	10 - 15

(3) Troubles and Countermeasures

1) Corrosion and related countermeasures

In petrochemical product systems, a value of 0.1mm/year or less is considered as posing no problem, if such value is the maximum corrosion depth.
In refinery product systems, a value of 0.2 mm/year or more is considered to be no problem if such value is measured one or two year(s) after the start of operation, but too high if it is measured about four years after the start of operation.
In the case of heat exchanger tubes, for example, changes in the maximum corrosion with the passage of time is expressed by the following formula:

y = axb

y : maximum corrosion depth
x : time (year)
a : constant (maximum corrosion depth during the first year)
b : constant (generally 0.3 to 0.4)

The curve of the above formula is shown in Figure 5.8-1. As is know from the formula which expresses aged deterioration of the corrosion time or Figure 5.8-1, corrosion is at its maximum at the early stage of the operation. Therefore, if corrosion of 0.2mm/year or more occurs in a refinery product system at the early stage of operation, it is not serious, but if it occurs after about four years, the value is considered too high.
Where corrosion inhibitor is used in a cooling water system, the treatment is in many cases targeted at 10mmd (0.048mm/year) at the average corrosion rate of carbon steel. From Table 5.5-4 which shows the quality of the cooling water, the maximum concentrations of Cl^- and SO_4^{2-} are respectively 260mg/l and 90mg/l. The influence of $\{Cl^- + SO_4^{2-}\}$ concentration on anti-corrosive effect at each corrosion inhibitor stage is shown in Figure 5.8-2. From the facts that the volume of make-up water to cooling water system is about 3% of recycled volume and that evaporation loss and scattering loss are respectively 1.0 - 1.2% and 0.5%, the concentration multiple can be estimated at about 1.6. Accordingly, if a phospho type corrosion inhibitor is used, sufficient anti-corrosive effect can be expected.
Where the calcium hardness is low, the concentration of corrosion inhibitor should be increased, but knowing the average Ca^{2-} concentration in the make-up water is 88mg/l (207 mg/lm as $CaCO_3$), sufficient anti-corrosive effect can be expected at $5\{PO_4^- mg/l\}$ as shown in Figure 5.8-8.

2) Scale and related countermeasures

The scale adhesion rate is 0 - 10 $g/m^2/day$, which is considered very large. Generally, about 3.3$g/m^2/day$ is considered as an admissible value.

Generally, as a scale preventive measure for cooling water systems, scale inhibitor is used. The scale adhesion rate is related to fluid velocity. If a scale inhibitor is used and an adequate fluid velocity is adopted, scale adhesion problems will be largely reduced. Here, the relation between fluid velocity and calcium carbonate adhesion rate is shown in Figure 5.8-4. Where water of a total hardness of about 250mg/l ($CaCO_3$) is used as the make-up water for the cooling system without any treatment, scale preventive measures will be very difficult to implement. In PPSA, since the softening treatment with sedimentation is provided, the treated water is said to be within the level at which treatment using a normal scale inhibitor agent can be easily carried out. Especially, as it does not contain so much silica which is very difficult to treat, phosphon type chemical treatment seems to be adequate.

3) Slime and related countermeasures

Microorganisms such as bacteria, filamentous bacteria (a kind of mold) and algae breed by utilizing nutrients contained in the water. Slime troubles are caused by the adhesion or settlement of a soft sludge form of dirt formed mainly of these microorganisms mixed with inorganic matters such as earth and sand. The COD of the water from the Vistula river is about 60mg/l, which is a very severe slime condition. However, it is not taken as a very important problem in PPSA, because the water from the Vistula river is treated by the softener and sedimentation and its pH level is increased to about 10. The pH level which provides optimum growing conditions for the microorganisms existing in cooling water is about 6 - 9, and the breeding potential dramatically drops at pH 10 as shown in Figure 5.8-5. Further, sufficient slime measures are considered to be taken from the fact that the chlorine treatment is provided for the make-up water to the cooling system. Recently, the lowering of sterilizing power of chlorine type germicides tends to be prevented by using a bromine type slime control agent at the same time.

Figure 5.8-1 AGED DETERIORATION OF MAXIMUM CORROSION DEPTH

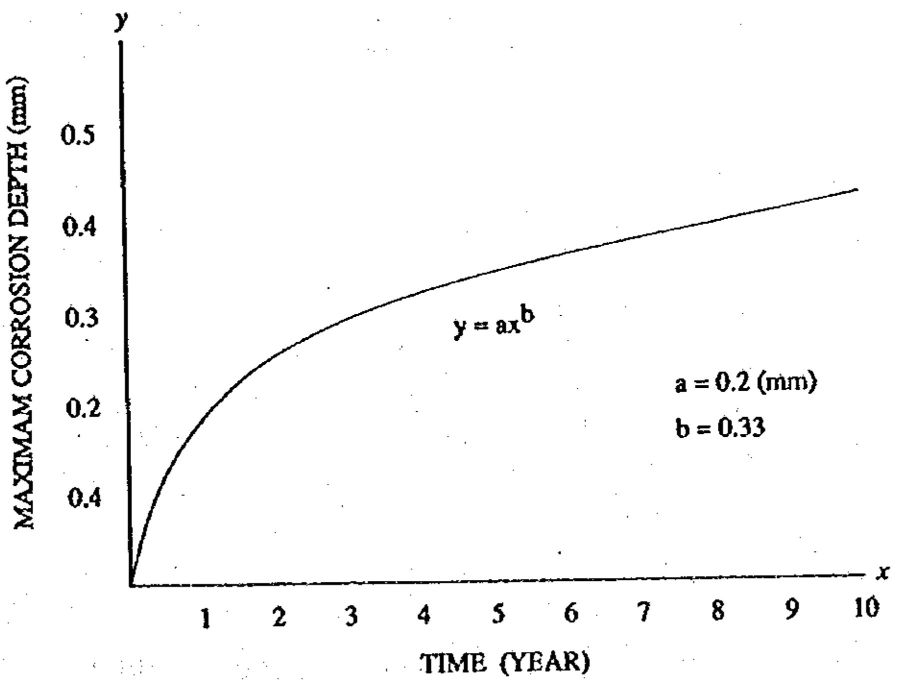
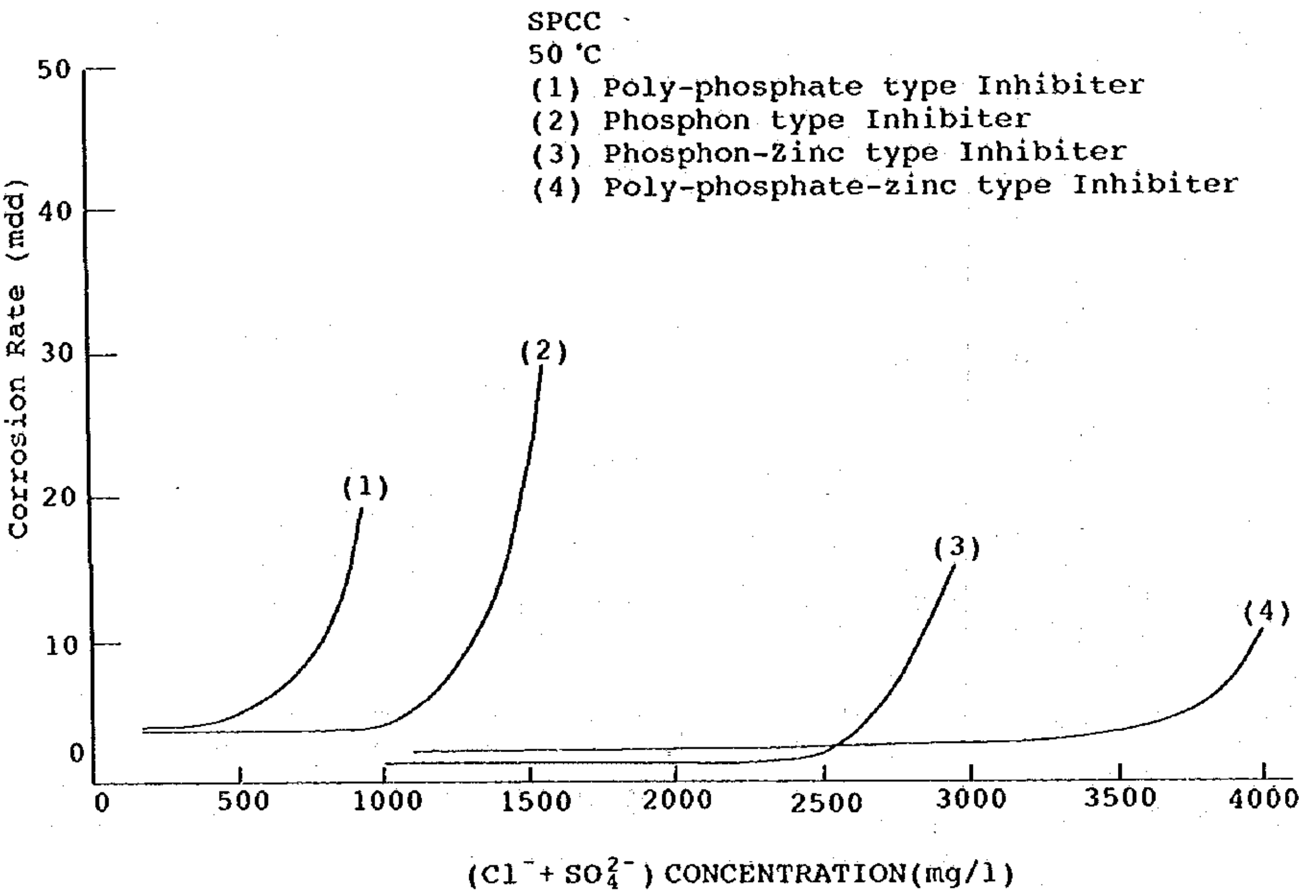
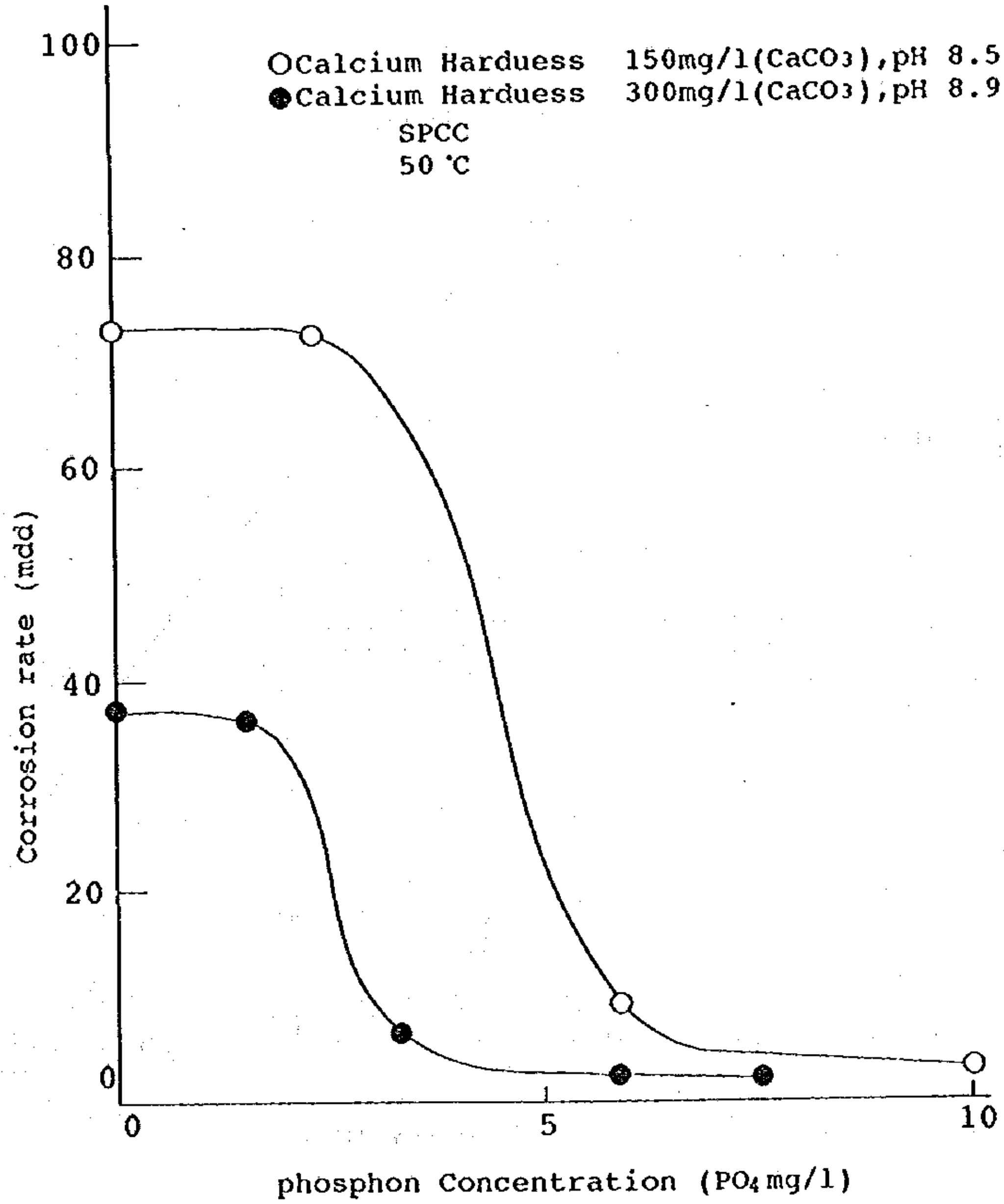


Figure 5.8-2 CORRELATION BETWEEN ION(Cl^- + SO_4^{2-}) CONCENTRATION AND CORROSION RATE



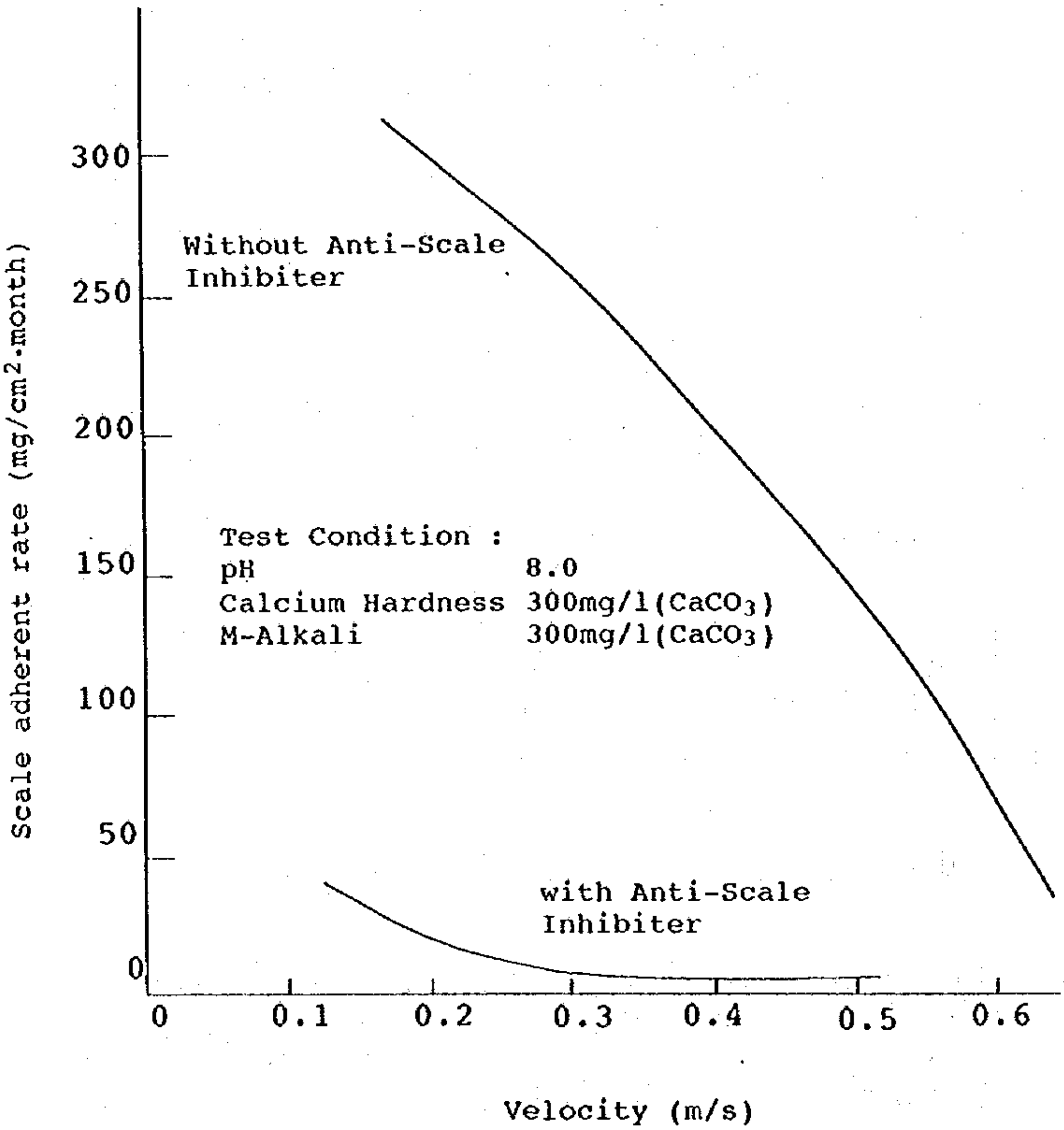
Source ; Technical Handbook for Chemical ,
published by Kurita kogyo co.,LTD (1988)

Figure 5.8-3 ANTI-CORROSIVE EFFECT FOR CARBON STEEL



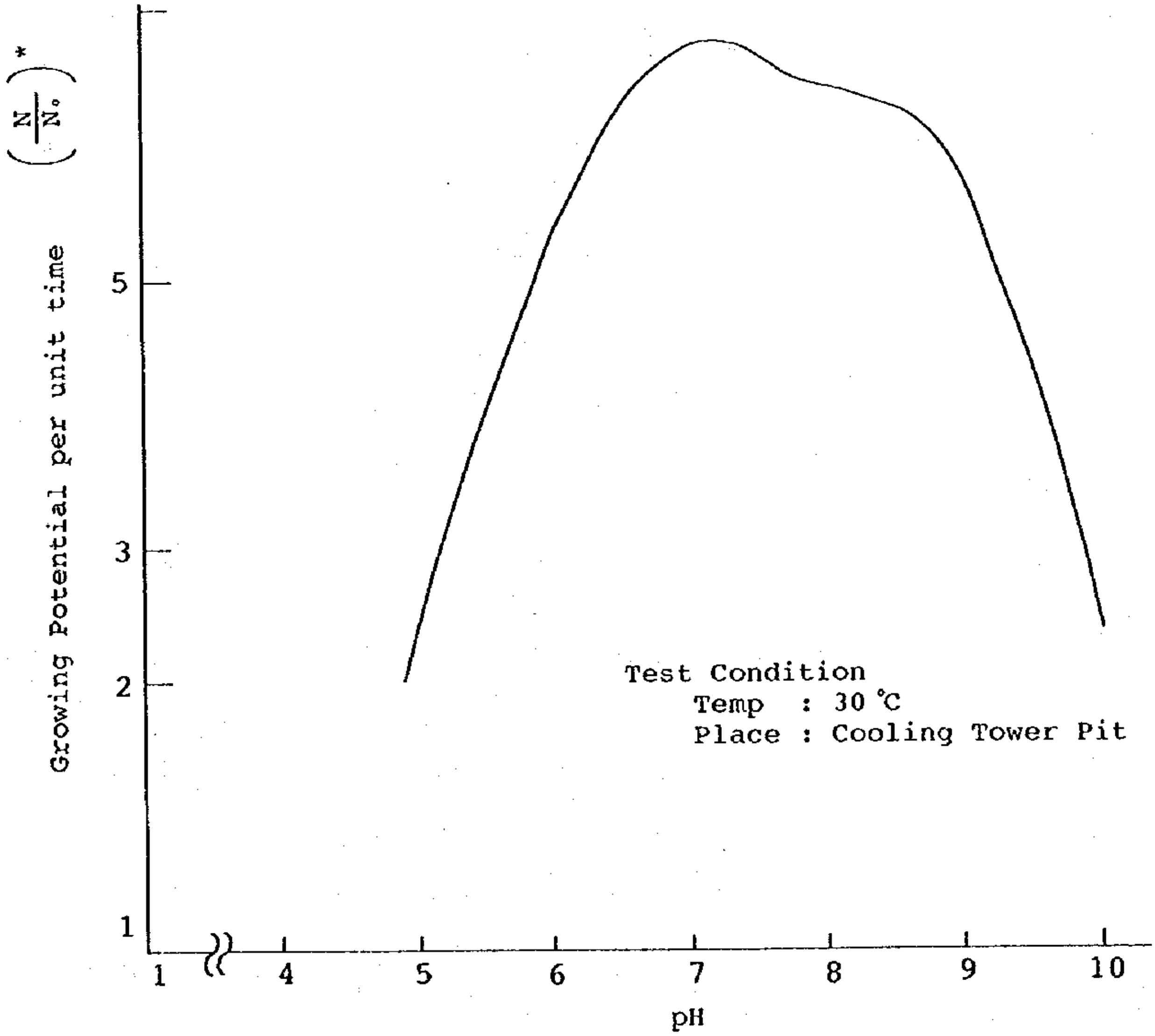
Source ; Technical Handbook for Chemical ,
published by Kurita kogyo co.,LTD (1988)

Figure 5.8-4 CORRELATION BETWEEN VELOCITY AND ADHERENT SPEED



Source ; T.Suzuki , Technical Document in the 12th Conference of Japan Material Society P91 (1977)

Figure 5.8-5 CORRELATION BETWEEN pH AND GROWING POTENTIAL OF MICROORGANISMS



* $\frac{N}{N_0} = e^{\mu t}$

N : number of microorganisms after t hours

t : time

N_0 : initial number of microorganisms

μ : relative glowing rate

Source ; Technical Handbook for Chemical , published by Kurita kogyo co.,LTD (1988)

5.9 Review of Environmental Measurement and Monitoring System

5.9.1 Confirmation on sampling methods

As in the case of No.1 unit in Section 3.7.1, when compared to JIS methods there is no noticeable problem on sampling methods including location, position, collection tube, and duct except for the following items.

(1) SO_2 : When absorbing samples in liquid for manual chemical analysis, a sample tube is to be heated.

(2) HCl/HF : ENERGOPOMIAR corporation is assigned as outside contractor to conduct measurement and analysis on behalf of PPSA. No problem is noticed with the bubbler which is a way of collecting samples in liquids.

(3) Dust : Sampling is the most critical factor in dust measurement. JIS sets forth vacuum sampling in equal velocity. It is requisite to conduct vacuum sampling in equal velocity for measurement of mass concentration of dust.
Since PPSA and ENERGOPOMIR have used the method of vacuum sampling in equal velocity, no problem is found.

5.9.2 Confirmation on analysis procedures

(1) SO_2
The same as Paragraph 3.7.2.

(2) NOx
The same as Paragraph 3.7.2.

(3) CO
The same as Paragraph 3.7.2.

(4) HCl/HF

ENERGOPOMIAR is assigned for measurement. It seems that the measured values are accurate since they have techniques of very high level although analysis is made by the manual Absorption Method.

In Poland, there are no national standards such as JIS so that it is desirable to set forth standards including range of quantitative analysis as soon as possible since it is very difficult to determine the lower limit for quantitative analysis under the current system.

(5) O_2

PPSA uses MADUR GA-60. The measurement principles are chemical electrics method and electrode method as in the case of JIS. On the other hand, ENERGOPOMIAR uses continuous measurement equipment based on a method of magnet wind principle, which is also set forth in JIS.

In Japan, Orsat method which is used for combustion control of boilers is widely used in analysis of flue gas. This method is well-known for easiness to prepare reagents and equipment as well as for accuracy of measurement although some experience is required for operation.

Continuous measurement equipment of magnet wind method can be calibrated at each measurement by use of standard gas, but it is believed that when an abnormal value is measured it is difficult to make a judgment whether the value is abnormal because of the short span of vacuum sampling.

Taking those matters into account, it is recommended to make parallel measurement with Orsat method.

5.9.3 Emission values in flue gas

Emission values measured in flue gas from collective chimney for No.1 and No.2 boilers (BEM0198) are as shown below.

Item	MD MADUR GA-60	Gas detector	Brand name
CO (ppm)	15	15	1L
SO_2 (ppm)	891	1000	5M
NO (ppm)	304	No measure't	11S
NO_2 (ppm)	16	No measure't	11S
NOx (ppm)	320	No measure't	No. 10
O_2 (%)	7.39	7.0	No. 31
CO_2 (%)	9.8	-	-
Cl_2 (ppm)	-	ND < 0.5	8La

(Note) ND: Not detected

5.9.4 Location for measurement in PPSA and the measured values

Refer to Table 5.5-1

5.10 Review of Management System

There are boilers, the boiler water feed system, and steam-turbine generator as main units in the thermoelectric power plant. Management system of No.1, 2, and 3 boilers and the boiler feed water system which are subject to modernization are diagnostically reviewed here. Mechanical- and process-related problems concerning operation management are treated in Section 5.1.

5.10.1 Operation management

(1) Organization

The power plant sector has responsibility for operation management of all 10 boilers, 5 steam-turbine generators, and the boiler water feed system so that organization only for No.1, 2, and 3 boilers, as well as the boiler water feed system could not been separated for evaluation from the whole organization of the power plant shown in Figure 5.10-1.

As shown in Tables 5.10-1 and 5.10-2, the power plant is operated by three eight-hour, 16 day-cycle shifts consisting of about 80 workers per shift. Most work by mechanics and process engineers are done by day.
The total number of employees in the power plant is 695, while the operation of 10 boilers (total capacity 2,980 ton/hour), 5 power generators (total capacity 275 MW) and the boiler water feed systems is conducted by 80 workers per shift.

Figure 5.10-2 indicates, for example, the organization chart of the power plant sector in a complex of 100,000 BPSD-scale oil refinery and petrochemical works in Japan.

This sector has four boilers with maximum capacity of 390 ton/hour and three generators of 44 MW, equipped with advanced automatic systems like distributed control system (DCS). In contrast to these modern plants, No.1, 2, and 3 boilers and the boiler water feed system of PPSA have been obsolete with no automatic equipment, hence, a direct comparison of organization makes little sense. Total employment of 695 and 80 workers per shift, however, is regarded to be excessive.

One of major causes swelling the structure of the power plant is as follows. PPSA has a maintenance system described in item 3.8.2 and the system carries out maintenance work on the refinery and petrochemical works, and plants outside PPSA under the supervision of the Technical Director. The power plant supervised by the Technical Director also has an independent maintenance section of the maintenance system which implements most maintenance works except periodic maintenance done by maintenance system. This type of distributed maintenance system consequently oversizes the structure.

Improving the efficiency of work for operation duties of shift workers should focus on operation, and the work of the electrical section and the chemical laboratory assigned to shifts should be transfered to day works. Reengineering of maintenance mentioned in item 3.8.2 (1) such that it isolates inefficient engineering work from current commission of the maintenance section and relies on external engineering companies should be studied in the restructuring of PPSA.

(2) Working hours and labour cost

Working hours of employees of the power plant are presented in Table 5.10-3. The power plant is operated by three eight-hour and 16 day-cycle shifts of about 80 workers per shift, as shown in Tables 5.10-1 and 5.10-2.

Employees of the power plant are classified into 17 categories of job positions under the education and training system; wages for each rough classification of all job categories are given in Table 5.10-4 and the average wages are 8.0 x 10^6 Zl/month as of October in 1993.

5.10.2 Maintenance management

Most of the evaluation results of the power plant on 5.10-2 maintenance management are similar to those of No.1 unit explained in the item 3.8.1. Only the characteristic problems of the power plant are explained in the following:

(1) Periodic maintenance during turnaround

Table 5.10-5 shows scheduled periodic maintenance days of 7 high-pressure steam boilers during turnaround in 1988 to to 1992 and the actual number of start-ups in 1992. The average number of start-ups in 1992 amounts to 9 per boiler and availability of boilers is quite low, although minor periodic maintenance was scheduled once a year, and major periodio maintenance every 4 or 5 years.

Efforts to reduce work volume and costs of maintenance by implementation of planned maintenance should be made by taking active measures based on the concept of corrective maintenance against causes of repetition troubles, i.e. fouling of boiler tubing and corrosion by sulphuric acid. Particularly, No.1, 2, and 3 boilers have been shut down for cleaning about every two months because of soot pile-up on tubes. Maintenance cost and utility loss for cleaning for each boiler is listed in Table 5.10-6.

(2) Maintenance costs

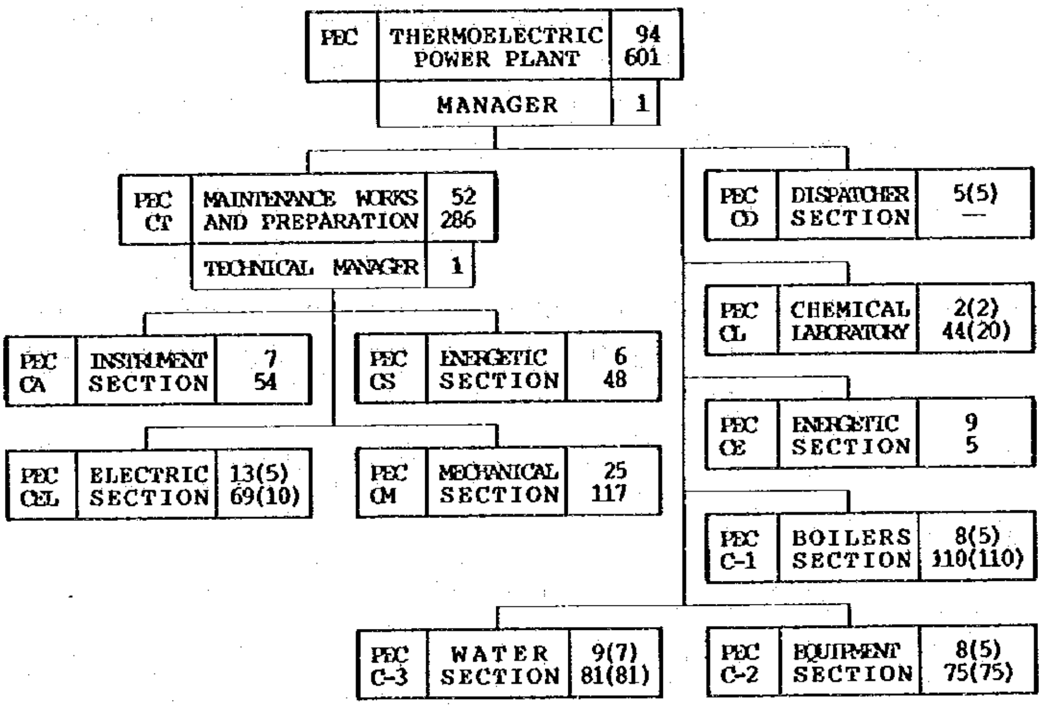
Data of maintenance costs for No.1, 2, and 3 boilers was not available but budget and actual results of maintenance costs, actual costs of maintenance works conducted by itself, and re-acquisition cost of 10 boilers and 6 turbines are shown in Table 5.10-7.

Table 5.10-8*1,*2 shows investigation results of maintenance costs, for example, of heavy industries, i.e. steel, ammonium sulphate, vinyl chloride, soda, rayon, sugar refining, and oil, held in U.S.A. in 1957 and in Japan in 1961 almost the same time as when the power plant was constructed. Ratio of maintenance costs to re-acquisition cost in the middle 50 percent of companies in USA is 5.9 percent and in the case of Japan 7.2 percent. 1989 and 1990 would be years when wild fluctuation of the inflation rate took place and data of those years is not considered to be useful for comparison so that data of 1991, 1992, and 1993 is taken into consideration. Ratio of maintenance costs to re-acquisition cost is 6.8 to 9.5 percent, a little higher when compared to the case of USA or Japan.

As mentioned in item 3.8.2 (4) 3), indices are required for control of maintenance to slash maintenance costs and improve efficiency of maintenance works:
especially those which are unlikely to be affected largely by wild fluctuation of the inflation rate needs.

*1 Factory Magagine, Feb. (1957), Maintenance Cost Guide.
*2 Management, Jun. (1961), What is the focus of plant engineering.

Figure 5.10-1 ORGANIZATION CHART OF POWER PLANT



The upper figures in squares show the number of staffs and the lower labourers. Figures in blankets indicates the number of shift workers. This organization chart was drawn on 31 December, 1991.

Table 5.10-1 SHIFT OF EMPLOYEES FOR PRODUCTION OF UNIT NO.1

SHIFT	SYMBOL	NUMBER OF WORKERS	ON-DUTY TIME
1ST SHIFT	①	80	06:00 - 14:00
2ND SHIFT	②	80	14:00 - 22:00
3RD SHIFT	③	80	22:00 - 06:00
OFF DUTY	○	80	-

Table 5.10-2 SCHEDULE FOR WORK ON THREE EIGHT-HOUR SHIFTS

SHIFT	DAY															
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
SHIFT I:	①	①	①	①	○	③	③	③	③	○	○	②	②	②	②	○
SHIFT II:	②	②	②	○	①	①	①	①	○	③	③	③	③	○	○	②
SHIFT III:	③	○	○	②	②	②	②	○	①	①	①	①	○	③	③	③
SHIFT IV:	○	③	③	③	③	○	○	②	②	②	②	○	①	①	①	①

Figure 5.10-2 INSTANCE OF STRUCTURE OF SHIFT WORKERS FOR OPERATION OF A PLANT IN A JAPANESE REFINERY AND PETROCHEMICAL COMPLEX

4 BOILERS: 390 T/H

3 GENERATORS: 44 MW

BOILER FEED WATER SYSTEM:

LOW PURITY: 232 T/H
HIGH PURITY: 800 T/H

UTILITIES:

SW, AIR
INDUSTRIAL WATER

AREA: 21,989 m²

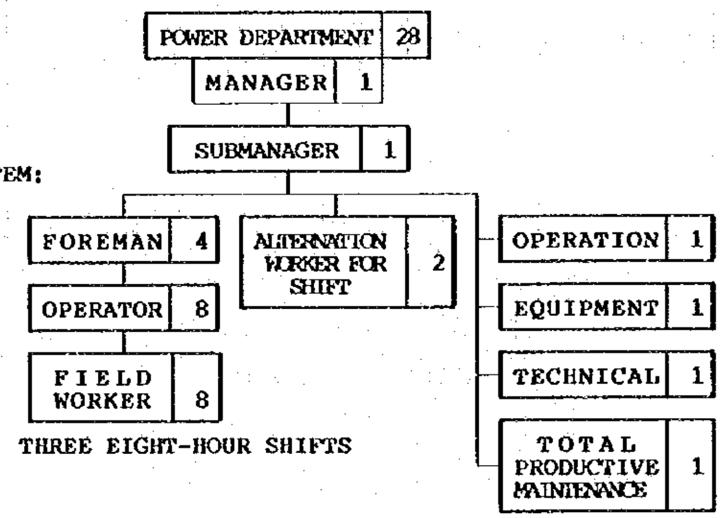


Table 5.10-3 WORKING HOUR OF EMPLOYEES FOR THE POWER PLANT

WORKER	WORKING HOURS (HR)		
	HR/DAY	HR/MONTH	HR/YEAR
DAY WORKER	8	198	2376
SHIFT WORKER	8	180	2190

Table 5.10-4 EMPLOYMENT

AS OF OCTOBER 1993

JOB POSITIONS	EMPLOYEES	AVARAGE SALARY/10' Z1
UNIT MANAGEMENT	12	13.7
TECHNICIAN	73	12.3
OFFICE WORKER	2	6.0
CLERK	3	8.1
SERVICING PERSONNEL	5	6.4
INDUSTRIAL LABOURER	554	7.3
TOTAL	649	8.0

Table 5.10-5 PLANNED SHUTDOWN DAYS AND NUMBER OF START-UP OF 7 BOILERS

BOILER NO.	PLANNED SHUTDOWN DAYS					NUMBER OF START-UPS
	1988	1989	1990	1991	1992	1992
1	37	37	45	43	110	9
2	35	36	15	122	151	12
3	37	37	45	44	60	11
4	45	46	46	92	61	7
5	48	48	46	89	50	13
6	45	46	46	214	50	3
7	48	45	46	53	61	10

Table 5.10-6 COSTS FOR CLEANING OF TUBES OF EACH BOILER

COST	NUMBER OF CLEANING NO / Y	UNIT COST /10^6 zl	COST REDUCTION /10^6 zl/Y
MAINTENANCE COST	6	40	240
UTILITY LOSS	6	40	240
TOTAL			480

Table 5.10-7 MAINTENANCE COSTS OF THE POWER PLANT

YEAR		1989	1990	1991	1992	1993
a:PLANED COST OF MAINTENANCE	(x 10^6 zl)	2571	22509	49748	49824	85919
b:REAL COST OF MAINTENANCE	(x 10^6 zl)	5873	41884	73423	98210	115932
c:MAINTENANCE COST BY REFINERY	(x 10^6 zl)	1814	13178	21726	39280	28317
d:VALUE OF CAPITAL COST	(x 10^6 zl)	22999	135205	1080200	1251686	1221920
e:(b/a) x 100	(%)	228.4	186.1	147.6	197.1	134.9
f:(c/b) x 100	(%)	30.9	31.5	28.1	40.0	24.4
g:(b/d) x 100	(%)	25.5	31.0	6.8	7.8	9.5
h:($d/d_{PREVIOUS\ YEAR}$) x 100	(%)	-	587.9	798.9	115.9	97.6

Table 5.10-8 MAINTENANCE COSTS OF FACILITIES IN HEAVY INDUSTRIES IN U.S.A. AND JAPAN

	RATE OF MAINTENANCE COSTS TO PRODUCTION			RATIO OF MAINTENANCE COST TO PRODUCTION COST			RATIO OF MAINTENANCE COST TO ACQUISITION COST		
	LOWER 25 %	MIDDLE 50 %	UPPER 25 %	LOWER 25 %	MIDDLE 50 %	UPPER 25 %	LOWER 25 %	MIDDLE 50 %	UPPER 25 %
USA	3.39	5.01	7.65	4.76	7.25	10.87	3.95	5.80	7.90
JAPAN	1.54	2.93	4.00	1.83	3.46	5.40	4.27	7.08	10.48

Chapter 6

Examination of Possibilities and Alternative Plans for Modernization of the Thermoelectric Power Plant

Contents of Chapter 6

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Chapter 6 Examination of Possibilities and Alternative Plans for Modernization of the Thermoelectric Power Plant

6.1 Evaluation of the Alternative Design Idea for the Boiler Feed Water Treating System

6.1.1 Subjects for modernization of the boiler feed water treating system

There are two points to be improved in the boiler feed water treating system. They are the large consumption of chemicals for regeneration of ion exchange resin, and the low yield of pure water.

Table 6.1-1 shows the current value and target value for each subject. Table 6.1-2 shows the quality of raw water as a study base.

Table 6.1-1 TARGET VALUE FOR SUBJECTS OF MODERNIZATION

Subject	Current Value	Target Value
I. Reduction of chemical consumption		
HCl	0.696 kg/m^3-Pure Water	0.400 kg/m^3-Pure Water
NaOH	0.898 kg/m^3-Pure Water	0.500 kg/m^3-Pure Water
II. Reduction of raw water consumption		
Raw Water	1.40 m^3/m^3-Pure Water	1.10 m^3/m^3-Pure Water

Source: PPSA

Note : All chemical consumption is converted to 100% conc

Table 6.1-2 THE QUALITY OF RAW WATER AS A STUDY BASE

	Study base	Actual data
pH		9.8 - 10.6
SS (mg/l)		
COD (mg-O_2/l)	49.5	33.0
Ca (mg-$CaCO_3$/l)	206.3	137.5
Mg (mg-$CaCO_3$/l)	49.5	33.0
Na (mg-$CaCO_3$/l)	202.5	135.0
K (mg-$CaCO_3$/l)	8.3	5.5
Total Cation	466.6	311.0
HCO_3 (mg-$CaCO_3$/l)	3.0	2.0
SO_4 (mg-$CaCO_3$/l)	114.8	76.5
Cl (mg-$CaCO_3$/l)	244.5	163.0
NO_3 (mg-$CaCO_3$/l)	1.5	1.0
CO_2 (mg-$CaCO_3$/l)	87.0	58.0
SiO_2 (mg-$CaCO_3$/l)	15.8	10.5
Total Anion	466.6	311.0

Source: PPSA

Here, Table 6.1-3 shows an additional subject, the increase of throughput capacity, requested by PPSA for the second field survey in June '94.

Table 6.1-3 TARGET VALUE FOR ADDITIONAL SUBJECT

Subject	Current Value	Target Value
I. A,B,C Unit	Total 240 m^3/h	Total 500 m^3/h
II. D,E,F,G,H Unit	Total 500 m^3/h	Total 1,100 m^3/h

Source: PPSA

Although the refinery is equipped with water softeners and recovered condensate treating units as part of the water

treating, this section focuses only on the feed water treating units for high-pressure boilers.
The reasons are that the service needs of low-pressure boilers are low and the consumption of regenerants at the condensate treating units is slight, as shown in Table 6.1-4 below.

Table 6.1-4 CHEMICAL CONSUMPTION OF CONDENSATE TREATING UNIT

Item	Current value
HCl	0.016 kg/m^3-Pure Water
NaOH	0.037 kg/m^3-Pure Water

Source: PPSA
Note : All chemical consumption is converted to 100% conc.

6.1.2 Countermeasures for modernization of the boiler feed water treating system

At first, countermeasures for reducing chemical consumption during ion exchange resin regeneration of the present facilities will be considered.
Secondly, the probability for increasing throughput capacity of boiler feed water treating facilities will be considered.

(1) Subject 1. Reduction of chemical consumption

[Step 1] Improvement of the existing units

As described before, one of the items to be improved is the large chemical consumption during regeneration of ion exchange resin. The causes of this are explained in item (2) in Chapter 5 section 5.5.2.

Here the following countermeasures are proposed based on the P & I D and a manufacturing drawing of an ion exchange resin tower which was obtained during the first visit of the JICA team.

1) Selection of proper contact method

The main factor for improving chemical consumption is the contact method between ion exchange resin and chemicals used for regeneration.
The following is a proposed countermeasure ;

(a) Application of counterflow regeneration method

As shown in Figure 5.5-4, as the regeneration commences at the adsorption layer, which has a weak affinity to ion exchange resin, regeneration efficiency and purity of the treated water will improve.

2) Having uniform distribution in resin tower

Design throughput for A, B, C units is 80 m^3/h with the 2,600 mm diameter towers. This means the designed volumetric velocity is 4.2 mm/sec at the design throughput which is extremely low.
It is necessary to have uniform distribution in the ion exchange resin towers as follows ;

(a) Installation of a ladder type distributor instead of a reflector type upstream of water flow

(b) Installation of a reflector type distributor upstream of chemical flow

(c) Installation of a gathering chemical collector

3) Pouring chemicals in series

All units of boiler feed water treating facilities have two cation towers and two anion towers. These towers are regenerated independently. Accordingly, it is recommended to pour NaOH and HCl in series so that the solution, after regenerating strong acid (or strong alkali) ion exchange resin, is used for weak acid (or weak alkali) ion exchange resin.
Therefore, this is effective to reduce chemical consumption for regeneration of ion exchange resin.

4) Elimination of leakage from valves and dead ends of piping

The existing boiler feed water treating units can be operated in any operating condition by arranging the pipes. In case of valve leakage and insufficient purge at the dead ends of pipes, ion exchange capacity of ion exchange resin will be decreased.
Therefore, it is recommnended to simpify the arrangement of the existing pipe line around ion exchange resin towers.

After adoption of all measures mentioned above, it is assumed that the target value of subject I can be attained.

[Step 2] Increase of throughput capacity

In general, in the case of design work of boiler feed water treating facilities, it is recommended to take an actual raw water sample in order to test for selection of suitable ion exchange resin and for determination of operating conditions. In particular, break through capacity is determined experimentally for selected exchange resin.
Here, Table 6.1-5 shows break through capacity used in this study and actual current data as reference, provided by PPSA.

Table 6.1-5 **THE BREAK THROUGH CAPACITY OF ION EXCHANGE RESIN AS A STUDY BASE**

kinds of resin	study base	current data *1
Cation resin	55 g-$CaCO_3$/l-resin	53.5 g-$CaCO_3$/l-resin
Weak anion resin	40 g-$CaCO_3$/l-resin	38.1 g-$CaCO_3$/l-resin
Strong anion resin	35 g-$CaCO_3$/l-resin	33.8 g-$CaCO_3$/l-resin

Note: *1; Calculated from the value based on l-pure water provided by PPSA

Generally, it is required to satisfy the following two criteria in order to increase throughput capacity.

Criterion 1. to have an adequate height for resin packing in regard to the crush resistance of the resin

Criterion 2. to keep the height of free-board in case of resin layer back wash

Required packing height of ion exchange resin is generally presented as the following equation.

$$H_{RESIN} = C_{ION} \times Q \times Cycle \times Factor / BTC + \Delta H \quad (Eq.6.1\text{-}1)$$

where,

H_{RESIN} = Required packing height of resin (m)

C_{ION} = Ion concentration (g-$CaCO_3/m^3$)

- for Cation tower, total cation 466.6 g-$CaCO_3/m^3$
- for Weak anion, 50% of SO_4, NO_3, Cl 180.4 g-$CaCO_3/m^3$
- for Strong anion, the remain of anion 286.2 g-$CaCO_3/m^3$

Q = Throughput (m^3/h)

Cycle = Time per 1 cycle generation (hr)

Factor = Correction factor (-)

BTC = Break Through Capacity (g-$CaCO_3/m^3$-l resin)
Refer to Table 6.1-4.

ΔH = Equivalent volume of resin expansion during regeneration (1)

Figure 6.1-4 and Figure 6.1-5 show the results of calculation by Eq.6.1-1.

1) Criterion 1. (Allowable packing height of resin)

$H_{RESIN,ALLOW} \times Flow = F_{ALLOW}$ (Eq.6.1-2)

where,

$H_{RESIN,ALLOW}$	=	Allowable packing height	(m)
Flow	=	Space velocity	(m/h)
F_{ALLOW}	=	Factor	(m^2/h)
		Cation resin 50 - 60	
		Anion resin 30 - 40	

For A,B,C unit, the diameter of ion exchange tower is 2.6 m. And for D,E,F,G,H, it is 3.0 m. These values are substituted into Eq.6.1-2.

The results are shown in Figure 6.1-4 and Figure 6.1-5 as allowable packing height.

2) Criterion 2. (Consideration of the height of free-board)

The expansion rate of the resin layer during back wash operation is important data. This data can be calculated by the following equation.

$Exp = 9,810 \times \mu \times V_0 / (g \times Dp \times (\;_r - \;_0))$ (Eq.6.1-3)

where,

Exp	=	Expansion rate of resin layer	(%)
μ	=	Viscosity	(Pa·sec)
V_0	=	Rising velocity	(m/sec)
g	=	gravity acceleration velocity	(m/sec^2)
Dp	=	Particle size	(m)

r = Density of resin (kg/m^3)
= Dencity of water (kg/m^3)

Source: Yagi et al, KAGAKU KIKAI, 16 ,307 (1952)

The correlation between velocity of back wash water and expansion rate of resin layer is shown in Figure 6.1-6 and Figure 6.1-7 for cation resin and anion resin, respectively.
Accordingly, the following data listed in Table 6.1-6 is adopted in this study.

Table 6.1-6 EXPANSION RATE OF ION EXCHANGE RESIN LAYER

Type of resin	Expansion rate
Cation resin	1.50
Weak anion resin	1.90
Strong anion resin	1.40

Source: Technical hand book proposed by one water treating company.

In ion exchange resin towers, the differential pressure of the resin layer gradually increases during long operation. The resin is gradually crushed and it is therefore necessary to remove accumulated solid on the resin layer by back wash blowing before pouring chemicals for regeneration.
At that time the resin layer expand and this expanding height of resin layer is called the height of free-board.
In general, the space of 50-100% for packing resin height is kept on the resin layer.
The correlation between throughput capacity and required height of resin layer consideraing of this height of free-board is shown in Figure 6.1-5 and Figure 6.1-6.

Here the size of resin towers of existing units are listed in Table 6.1-7. The potential capacity of the existing resin towers is evaluated by using Figure 6.1-6,7,8 and 9. The results of the evaluation are listed in Table 6.1-8.
When the height of free-board is insufficient, the crushed resin will not be completely separated from the sound resin. In such a case a reduction in efficiency can be expected in long term operation, due to, for example, large increases in friction loss through the packing layer and higher replenishment of resin.
Adequate height of free-board is therefore an essential requirement to maintain good performance for a year long operation.
This table shows that the loading amount of resin is restricted by the height of free-board for all units.
As a result, it is assumed that the potential capacity of A,B,C units is 80 m^3/h and D,E,F,G,H is 110 m^3.

Table 6.1-7 THE SIZE OF ION EXCHANGE RESIN TOWER

Unit	Number	Diameter	Length (TL-TL)
[A,B,C Train]			
Cation tower I	2	2.60 m	2.95 m
Cation tower II	1	2.60 m	2.95 m
Weak anion tower	1	2.60 m	2.95 m
Strong anion tower	1	2.60 m	2.95 m
[D,E,F,G,H Train]			
Cation tower I	1	3.00 m	3.75 m
Cation tower II	1	3.00 m	3.00 m
Weak anion tower	1	3.00 m	3.75 m
Strong anion tower	1	3.00 m	3.00 m

Source: PPSA

Table 6.1-8 THE POTENTIAL CAPACITY OF RESIN TOWER

Unit	Criterion 1	Criterion 2
[A,B,C Train]		
Cation tower I	140-150 m^3/h	150 m^3/h
Cation tower II	140-150 m^3/h	150 m^3/h
Weak anion tower	90-100 m^3/h	80 m^3/h
Strong anion tower	80- 90 m^3/h	80 m^3/h
[D,E,F,G,H Train]		
Cation tower I	140-150 m^3/h	140 m^3/h
Cation tower II	180-190 m^3/h	170 m^3/h
Weak anion tower	120-130 m^3/h	120 m^3/h
Strong anion tower	110-120 m^3/h	<u>110 m^3/h</u>

Note: under line shows critical capacity

Even if some resin towers are replaced by new ones having the same diameter as existing towers in order to solve criterion 2 (restraint from the height of free-board), it is assumed that the targets for increasing throughput capacity shown in Table 6.1-3 are impossible to attain. This is because criterion 1 (allowable packing height) will restrain the maximum packing height of resin. Consequently, new installation will be required to solve the shortage of throughput capacity which is the difference between present total capacity 740 m^3/h and target total capacity 1,600 m^3/h. For selection of the type to be installed, refer to Annex 3.

(2) Subject 2. Reduction of raw water consumption

In general, the greater part of raw water loss is waste water during regeneration operation of ion exchange resin. Here, the information for amount of waste water, provided by PPSA, is listed in Table 6.1-9.

Table 6.1-9 **THE AMOUNT OF WASTE WATER DURING ONE CYCLE OPERATION IN A,B,C UNIT**

Ion exchange resin tower	number	amount of treated water	amount of waste water
Cation Tower	2	1,300 m^3/Cycle	140 m^3/Cycle
Weak anion tower	1	940 m^3/Cycle	135 m^3/Cycle
Strong anion tower	1	5,000 m^3/Cycle	135 m^3/Cycle
Slica polisher	1	28,000 m^3/Cycle	57 m^3/Cycle

Source: PPSA

From these data shown in Table 6.1-9, the amount of waste water per 1 m^3 pure water production can be calculated, and the result is summarized in Table 6.1-10.

Table 6.1-10 **THE AMOUNT OF WASTE WATER DURING REGENERATION OF ION EXCHANGE RESIN**

Ion exchange resin	Amount of waste water
Cation tower	0.108 x 2 = 0.216 m^3/m^3-pure water
Weak anion tower	0.144 m^3/m^3-pure water
Strong anion tower	0.027 m^3/m^3-pure water
Slica polisher	0.002 m^3/m^3-pure water
Total	0.389 m^3/m^3-pure water

Table 6.1-10 shows that only waste water during regeneration of resin per 1 m^3 pure water production reaches about 0.4 m^3. From Table 5.5-7 also shows the amount of back wash water of sandfilters accounts for approximately 50% of total waste water from boiler feed water treating facilities and this back wash water is not recovered.

The countermeasures to reduce waste water are as follows;

1) Pouring chemicals in series

This countermeasure is common for reducing chemical consumption. This means that cation towers more than 2 and anion towers more than 2 are regenerated in series, respectively. By adoption of this method it becomes possible to reduce the number of regeneration operation for ion exchange resin. Accordingly, it is possible to reduce the amount of waste water during the regeneration operation.

2) Recovery of back wash water from sand filters

In the Japanese example, the ion concentration in raw water is very low (less than one third or one fourth of PPSA), and there are many cases of using the floatation process upstream of filters as a pretreatment system in order to guard ion exchange resin from demineralizing. Therefore, the back wash water is recycled upstream of the floatation process and back wash water can be recovered.
In PPSA, ion exchange resin scavenger are mounted downstream of sand filters as a guard system of ion exchange resin demineralization.
Since there is not any equipment to discharge suspended solids and other materials in PPSA, it is impossible to recover back wash water from sand filters. This is because suspended solids and other materials are concentrated in the boiler feed water treating facilities when the back wash water is recycled to the raw water line.
Consequently, it is necessary to implement pretreatment such as the floatation process in order to remove suspended solids and other materials in PPSA. It seems that the installation cost of this pretreatment system is very expensive for saving raw water consumption.

For example, the installation cost of the floatation process of 300 m^3/h is estimated to be about 1.4 million US dollars. However the benefit of saving raw water consumption is only about 64,000 dollers.
Therefore, it is not recommended to recover the back wash water of sand filters.

However, when the new boiler water treating facilities are installed and the pretreating system which is the type which removing the suspended solids is adopted in future, the recovery of back wash water from the existing sandfilters will contribute to significantly reduce raw water consumption.

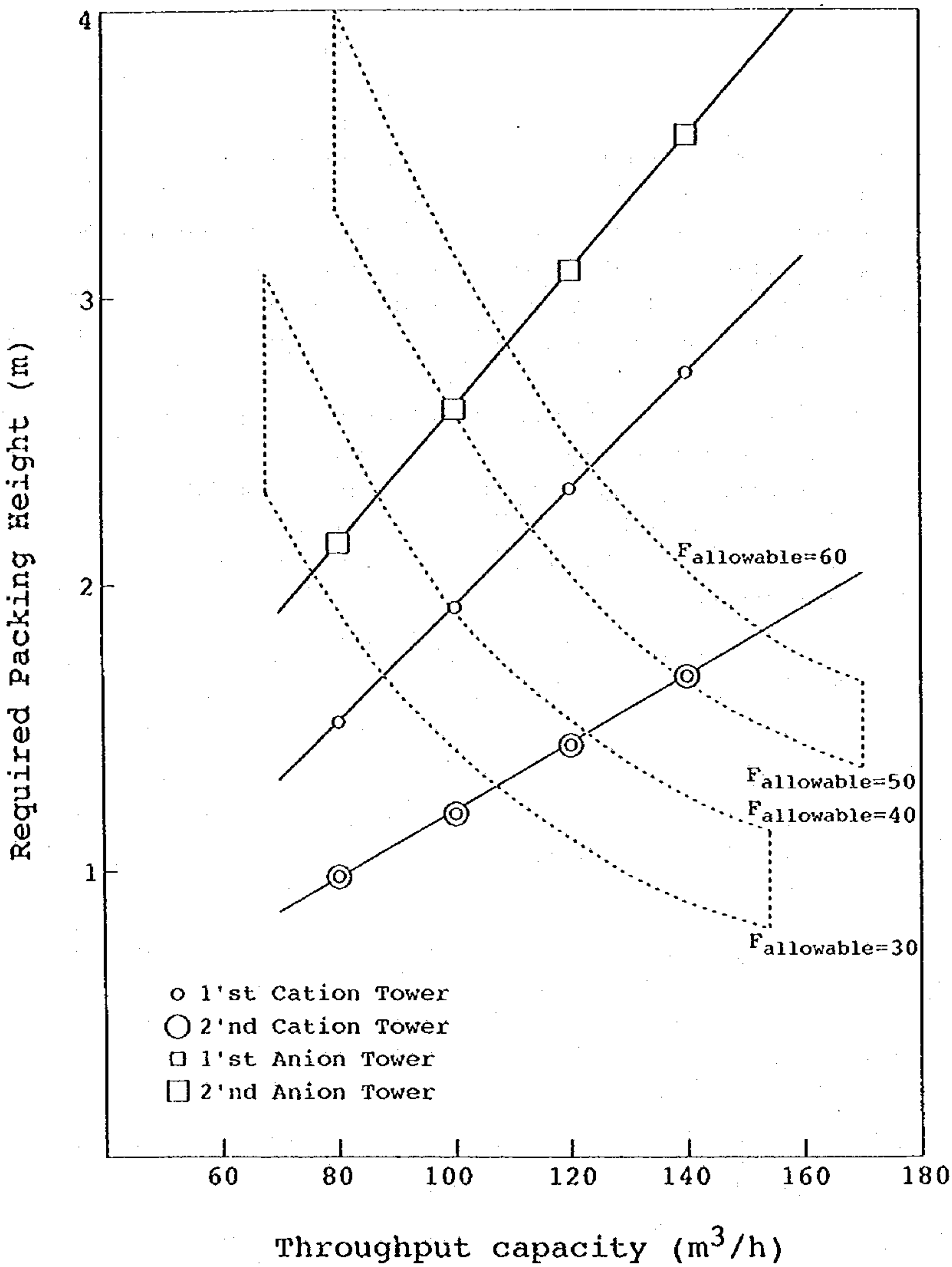


Figure 6.1-1 CORRELATION BETWEEN REQUIRED PACKING HEIGHT AND THROUGHPUT CAPACITY OF A, B, C, UNIT

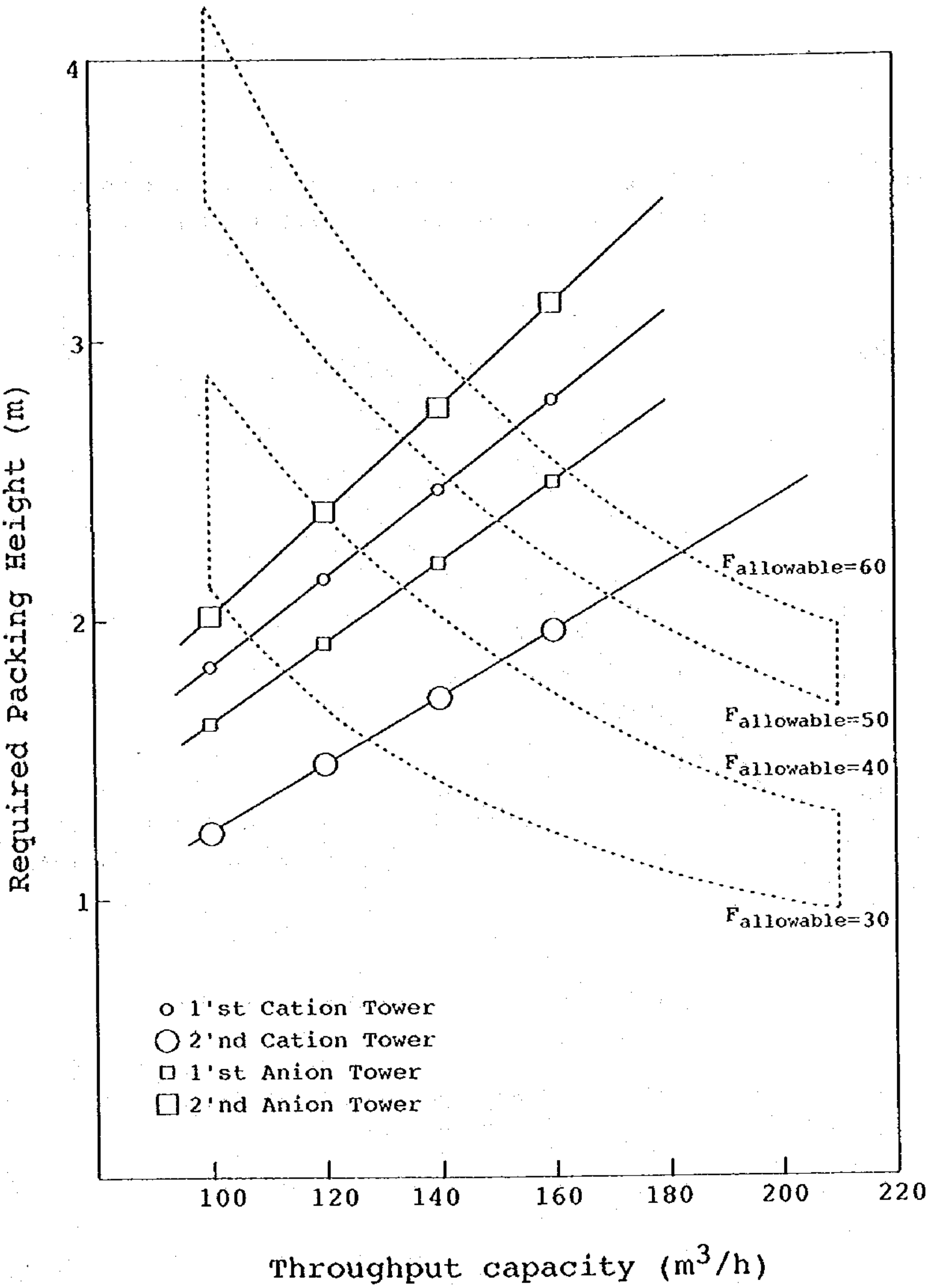
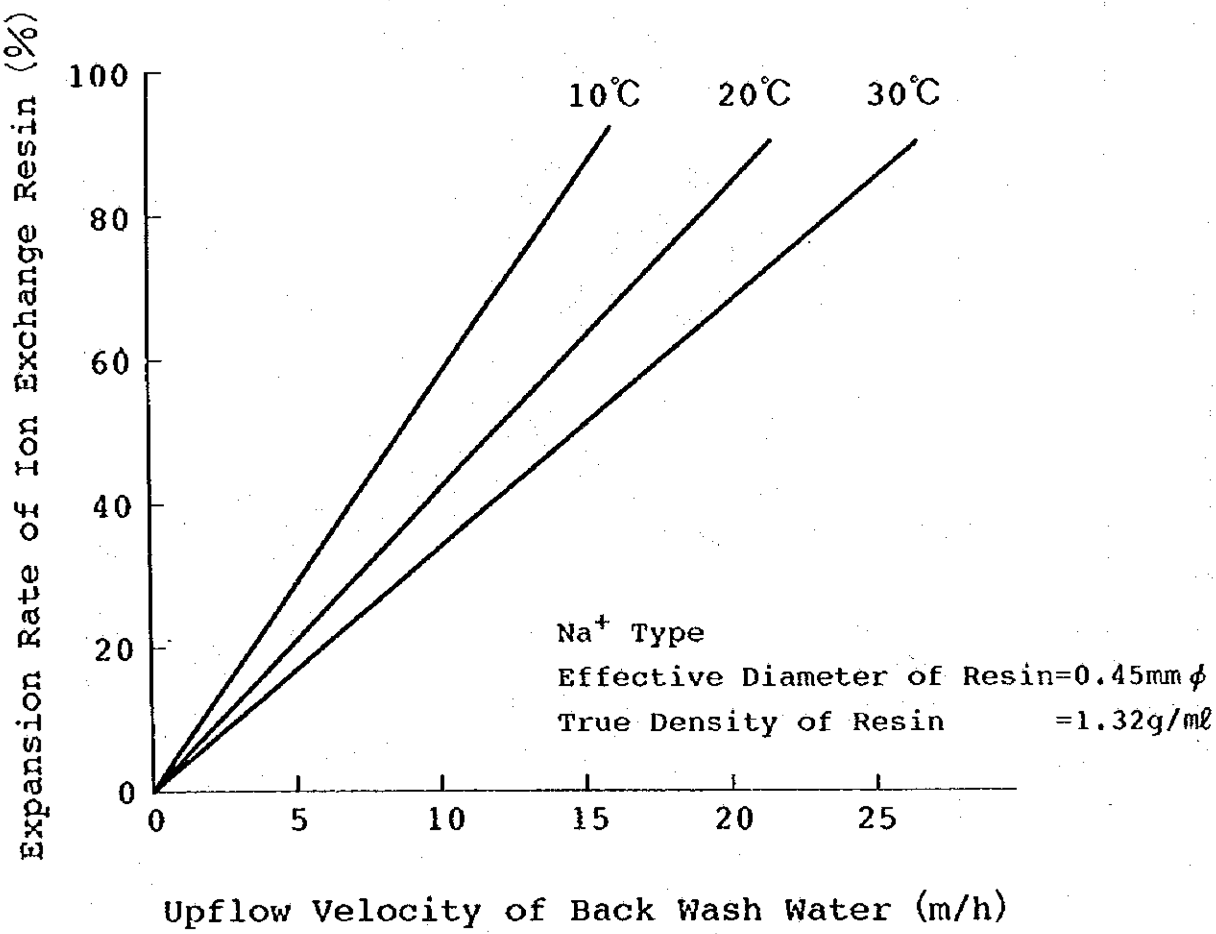


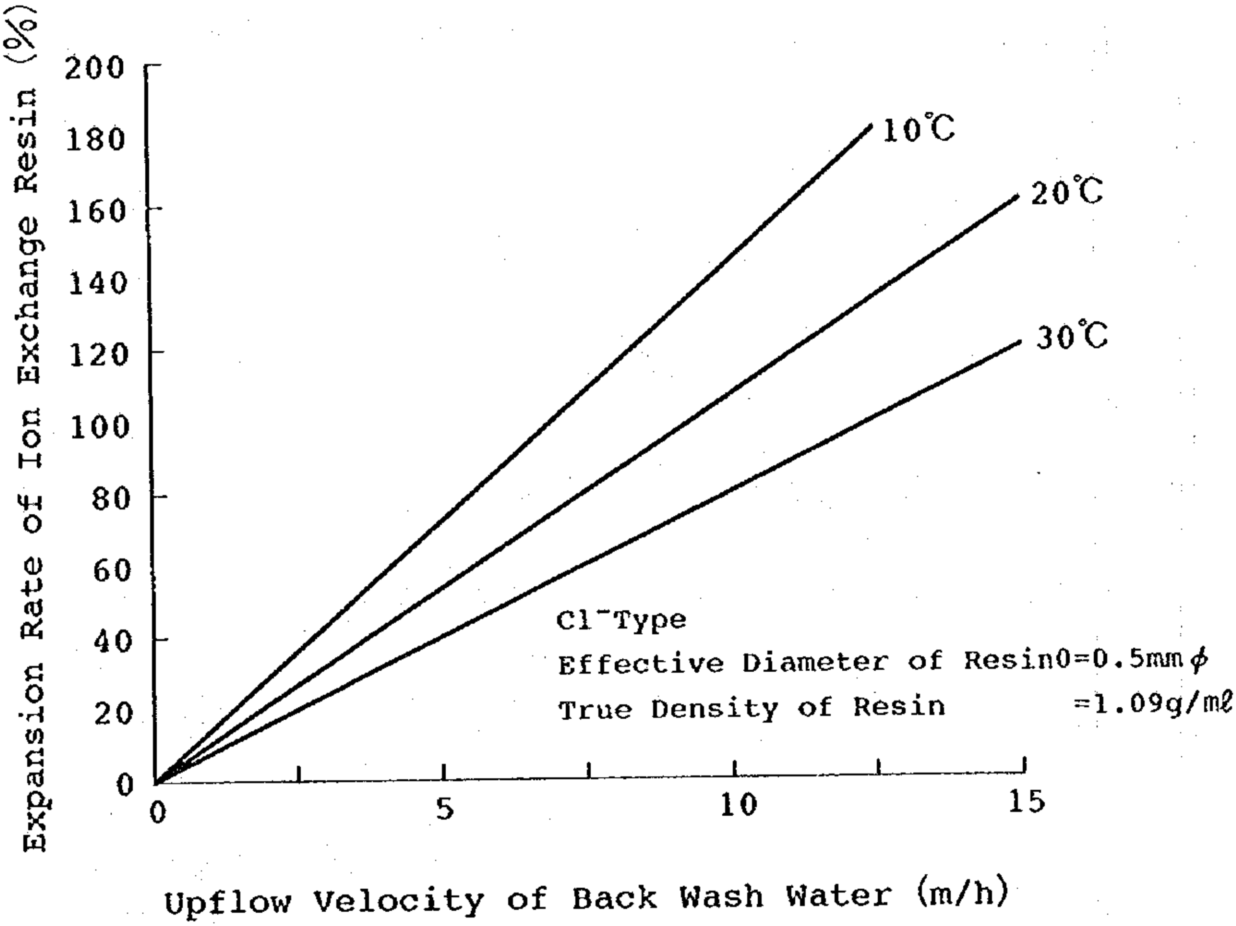
Figure 6.1-2 **CORRELATION BETWEEN REQUIRED PACKING HEIGHT AND THROUGHPUT CAPACITY OF D, E, F, G, H UNIT**

Figure 6.1-3 EXPANSION RATE OF ION-EXCHANGE RESIN PACKING LAYER DURING BACK-WASH OPERATION (AMBERLITE IR-124)



Source ; The technology and application of Ion Exchange Resin, published by ORGANO Campany (1986)

Figure 6.1-4 **EXPANSION RATE OF ION-EXCHANGE RESIN PACKING LAYER DURING BACK-WASH OPERATION (AMBERLITE IRA-910)**



Source ; The technology and application of Ion Exchange Resin , published by ORGANO Campany (1986)

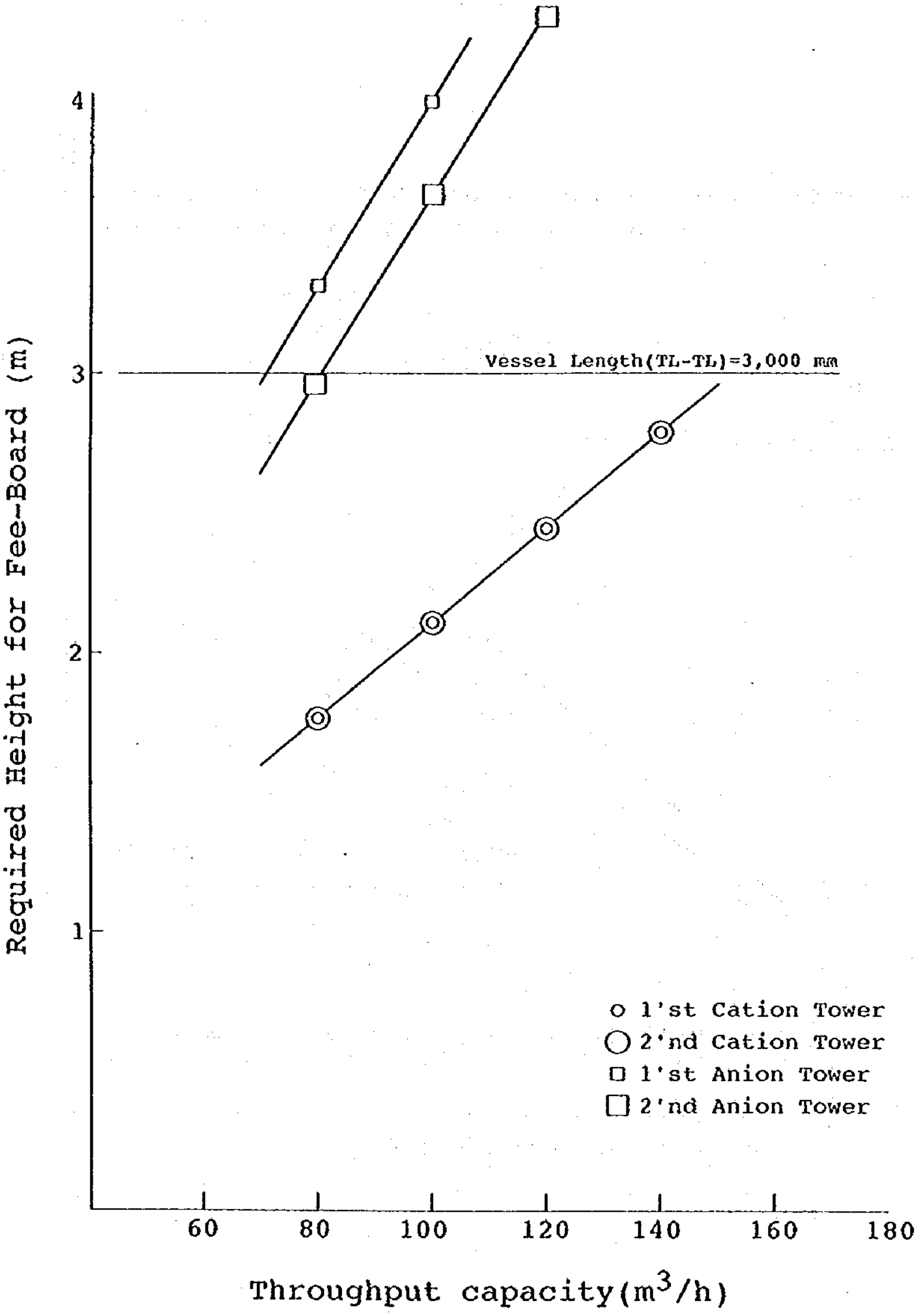


Figure 6.1-5 **CORRELATION BETWEEN REQUIRED HEIGHT OF FREE-BOARD AND THROUGHPUT CAPACITY (A, B, C, UNIT)**

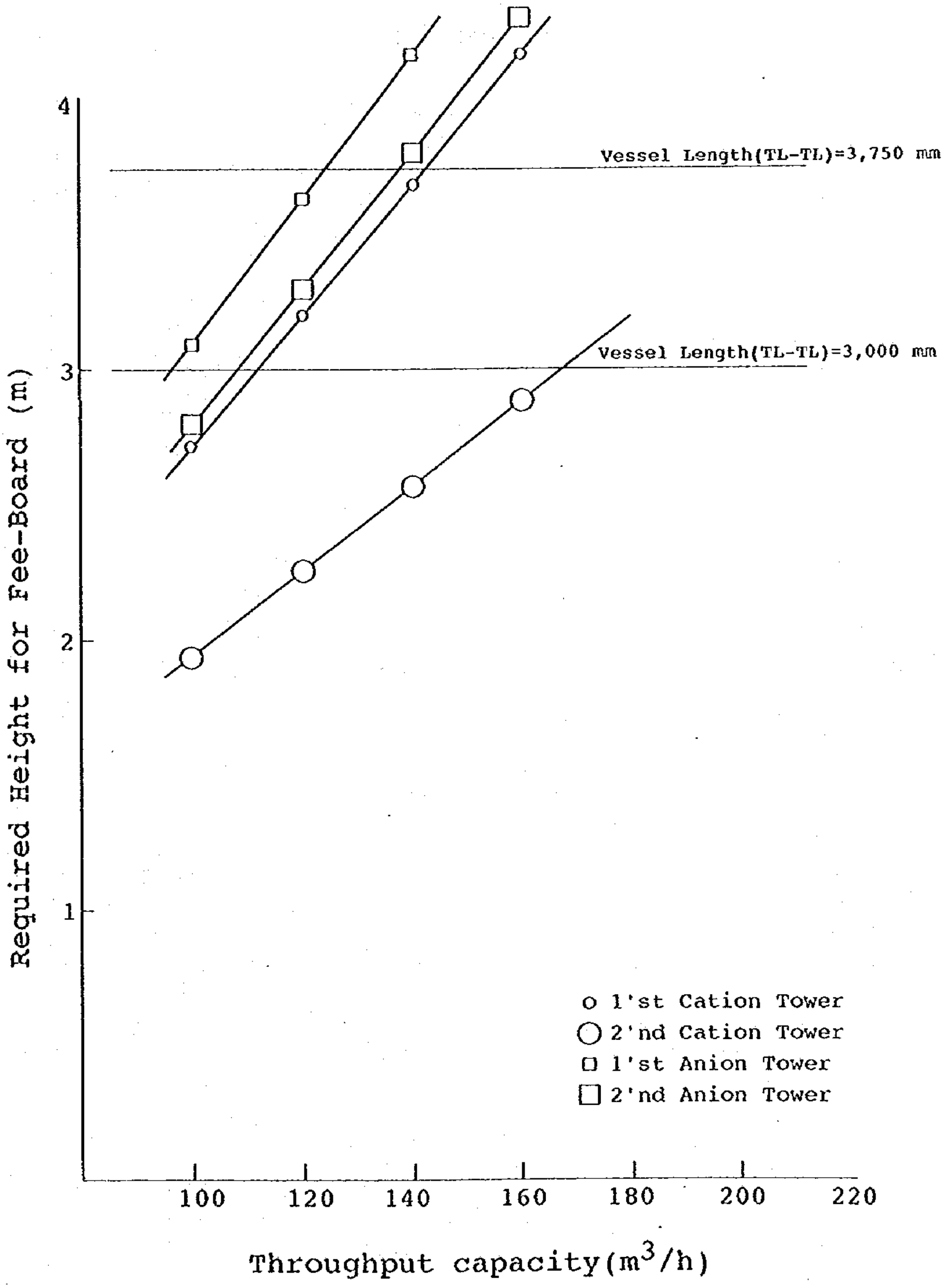


Figure 6.1-6 CORRELATION BETWEEN REQUIRED HEIGHT OF FREE-BOARD AND THROUGHPUT CAPACITY (D, E, F, G, H UNIT)

6.2 Evaluation of Effective Alternative Measures for Increasing Thermal Efficiency.

6.2.1 Subjects for modernization of power plant

As calculated in Chapter 5.4, thermal efficiency of No.2 boiler is 92.4% on the basis of the net heating value. However, thermal efficiency decreases as the operation hours increase due to fouling of boiler tubes.
Since the thermal efficiency drops by 4% before the shut down of the boiler, the average thermal efficiency would be about 90%.
Table 6.2-1 shows the current value and target value for each subject.

Table 6.2-1 TARGET VALUE FOR SUBJECTS OF MODERNIZATION

	subject	Current value	Taget value
I.	Improvement of thermal efficiency		
	efficiency	avg 90 %	avg 92 - 93 %
II.	Reduction of excess air for combustion		
	excess air	1.60	1.08
	(O_2 conc.)	(7.9 %)	(1.6 %)
III.	Reduction of NO_x in flue gas		
	NOx	170.6 g/GJ*1	160.0 g/GJ*2

Source: The report of previous survay team
Note : *1, PPSA (Dec.,'93), *2, PPSA (July,'94)

6.2.2 Countermeasures for modernization of the power plant

(1) Subject I. Improvement of thermal efficiency

As described in Chapter 5.1, the two items to be improved are pointed out, i.e., the short operation hours and maintenance of capacity. Therefore there are two approches to improve thermal efficiency as follows ;

- to decrease the rate of lowering thermal efficiency
- to increase the thermal efficiency

1) Method to decrease the rate of lowering thermal efficiency

(a) Prevention of fouling of boiler tubes

According to the information of PPSA, boiler tubes become fouled as the operation hours increase. Thus the flue gas temperature increases.

Because of this, the boiler is shut down for cleaning when the flue gas temperature of No.2 super heater inlet is over 880°C or flue gas temperature at the inlet of Jungstrom reaches 400°C.

According to the operation results of 1992, as shown in Figure 5.1-10, the average load during the operation is about 70%.

Flue gas temperature at the inlet of Jungstrom is estimated to be about 317°C at the 70% load by proportioning of the data at the load of 56% and 84% in Table 5.1-7.

It is reported that a 1% drop in thermal efficiency is equal to an increase of flue gas temperature from 18°C to 20°C.

Therefore the thermal efficiency will drop about 4% before the boiler is shut down.

In order to reduce the fouling of boiler tubes, as described in Chapter 5 section 5.2, it is necessary to increase the quantity of the atomizing steam to burners for improving combustibility and install soot blowers to blow off the soot on the boiler tubes.

These countermeasures are explained as follows;

a) Replacement of burner tip

The existing burner tip should be replaced by a new one with bigger holes so that a larger volume of atomizing steam, equal to 13% of fuel consumption, can be injected.

b) Installation of soot blowers

It is customary to install soot blowers up and down stream of each super heater and at the heat transfer element of Jungstrom, for the boilers which use heavy fuel oil.

The recommended locations for sootblowers are shown in Figure 6.2-1.

As for the type of the soot blowers, the long retracting type for high temperature zones and the fixed position rotating type for low temperature zones are recommended.

Subject to the limitation of the layout of the boiler, and judging from the scale of the boilers, it would be necessary to have a space of 12 to 13 meters as a movement distance for soot blower nozzles of the retracting type.

The thermal efficiency would be improved by about 2% if the boiler tube fouling was reduced by the proposed countermeasures.

(b) Replacement of Jungstrom

Heat loss by flue gas accounts for 5.53% in total heat loss as shown in the heat balance in Figure 5.4-1.

This means that judging from the volume of the air leakage, a large clearance is suspected at the sealing zone. The latest Jungstrom with proper sealing can decrease the air leakage by about 5 to 6%.

There are two seal mechanisms in Jungstrom, one is at the axis and the other is around the circumference.

The leakage to the flue gas is mainly due to the poor seal mechanism at the circumference. However, leakage from the seal mechanism at the axis is also suspected. The volume of the leakage from the seal mechanism at the axis is not estimated because this leakage causes only depreciation of heat recovery.
Judging from the volume of the leakage of Jungstrom, it would be difficult to repair the seal mechanism because Jungstrom has a rotation heat transfer element.
Therefore it is recommended to renew all the existing Jungstrom.

2) Method to improve thermal efficiency

(a) Heat recovery from the continuous blow water from the drum

Trace quantities of impurities in boiler feed water is concentrated in the disengaging drum and becomes the cause of formation of sludges and scales and corrosion. If these impurities were carried over to desuperheaters and turbines, problems would arise.
In order to prevent such problems and to operate the boiler unit stably, the concentration of total solids and other qualities of the boiler drum water shall be controlled by blowing of the drum water.
The following equation is to get the quantity of continuous blow when the analysis data of boiler feed water and drum water are given ;

$$B = \frac{f \times F}{m_0}$$

Here,

B = Quantity of blow (t/h)
f = Concentration of the material to be controlled in boiler feed water (ppm)

F = Flow rate of boiler feed water (t/h)

m_0= Concentration of the material (ppm)
to be controlled in the drum water

In general, silica or chloride is chosen as the material to be controlled.
The following are methods to be applied for that recovery from continuous blow ;

a) A vessel for continuous blow is connected to low pressure steam.
This countermeasure is adopted already in PPSA and 7.5 ata steam is recovered.
For reference, about 2 t/h low pressure steam would be recovered if the volume of continuous blow is assumed to be about 6 t/h in this case.

b) Continuous blow water is reused as boiler feed water for low pressure boiler for which the specification is milder.
This method would not be applied in PPSA because there is a possibility of shut down of low pressure boiler.

(b) Recovery of vent steam from deaerator.
Oxygen in a boiler drum is one of the main causes of corrosion. Therefore it is required to reduce oxygen content in boiler feed water as much as possible. In order to reduce oxygen content, it is recommended to apply two step reduction as follows;

- to reduce oxygen content mechanically by deareator
- to reduce oxygen content chemically by adding deoxidation chemicals

It is reported that deaerator can reduce more than 90% of dissolved oxygen content in the boiler feed water.

Low pressure steam is used as a heat source for a deaerator. It is natural to minimize consumption of the low pressure steam, however, vent value is closed too much and interferes with the emission of the dissolved gas.
A spray scrubber type deaerator is often used. This type of deaerator has a tendency to reduce the efficiency with steam and water in case of low load operation.
Therefore, the quantity of deaeration steam required is about 1% of the feed rate of the boiler feed water.
Since the capacity of the No.3 boiler is 320 t/h, deaerator steam rate is estimated to be about 3 t/h.
It is proposed to recover this steam at the turbine gland seal condenser and others. If this method is applied, it would be possible to recover the heat of 1.80×10^6 kcal/h which means 0.7% improvement of thermal efficiency.
However, vent steam from the deaerator is corrosive because it contains oxygen.
Therefore, the following materials should be used in the vent steam condenser.

- Heat exchange tube ... SUS 304 (Stainless steel)
- Shell, Channel Cover, and Other ... Carbon Steel

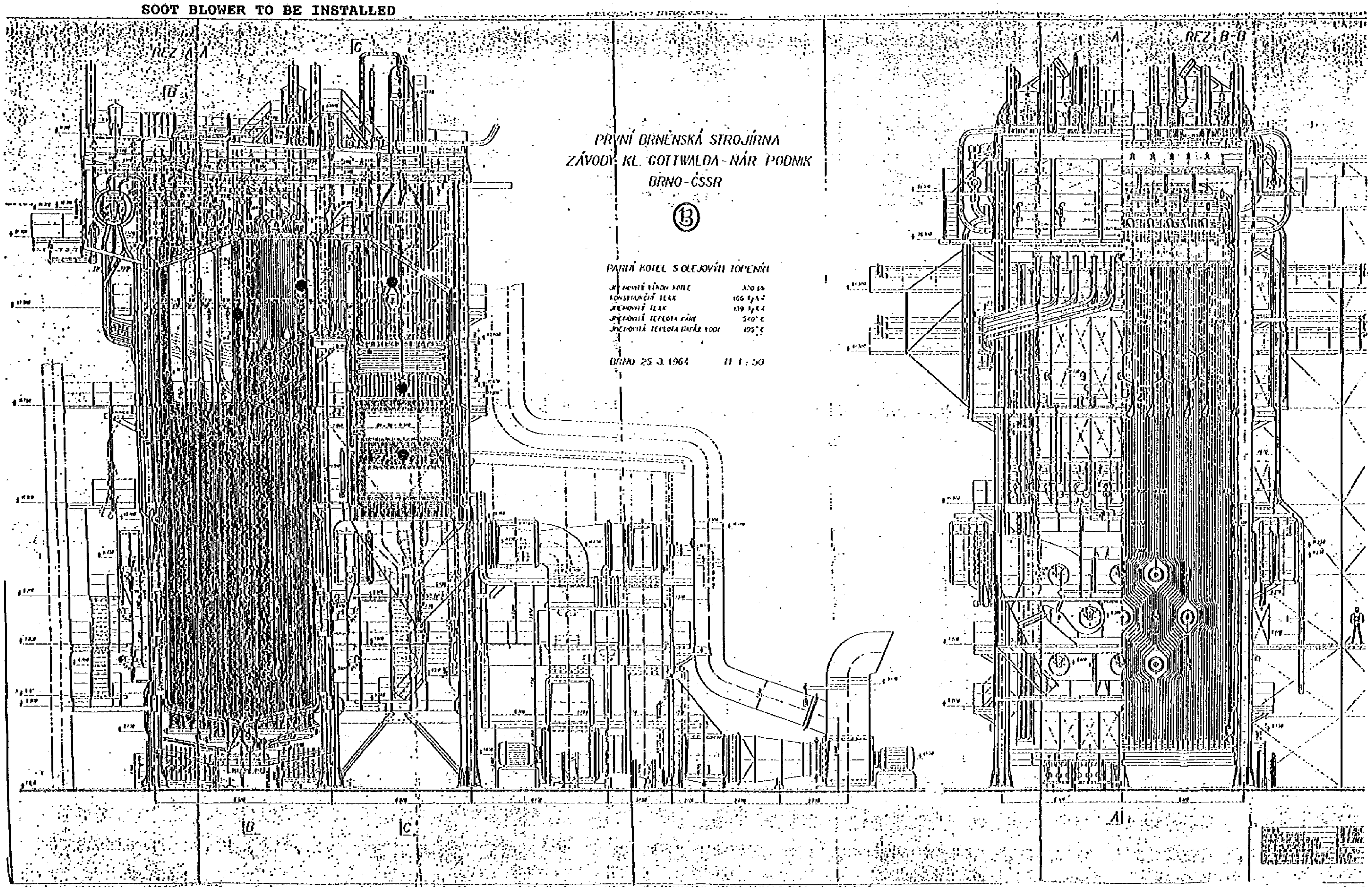
The feasibility for recovery of vent steam from deaerator is influenced by piping route and other conditions.
In general, in Japan this measure is adopted, when the capital be recovered within about three years.

(c) Improvement of boiler efficiency by setting optimum boiler load.
After modernization of Power Plant, it is expected to increase the operational reliability of power Plant and improve the thermal efficiency by setting optimum load of each boiler.
Actually, the following are considered.

a) to set high pressure boiler load 75 - 85% of rated load

b) to stop low pressure boiler by sapling all low pressure steam through extraction steam from turbine.
For example, it is expected to raise 1% of efficiency when boiler load is 70% before modernization and change to 80% load after modernization.

Figure 6.2-1 RECOMMENDED POSITION OF SOOT BLOWER TO BE INSTALLED



6.3 Evaluation of Needs and Possibilities for Installing Condensing Turbine in the Plant

6.3.1 Necessity of condensing turbine

Not only does the utility section in PPSA provide PPSA with utilities such as electric power, steam, and industrial water, but it supplies hot water services to Plock city. This causes heavy seasonal fluctuation. To be more precise, the city's increased needs for hot water in the winter heighten the boiler loads, resulting in bigger electric power generation.

Here the thermal load of hot water for each month is shown in Figure 6.3-1, and steam generation based on pressure levels for each month in Figure 6.3-2.

The following table lists the average electric energy purchased and sold per hour on the basis of the data in Figure 5.1-6.

Table 6.3-1 PURCHASED AND SOLD ELECTRIC ENERGY FOR EACH MONTH

Month	Total purchased el.	Purchased el./h	Total sold el.	Sold el./h
	MW•h/Month	kW•h/h	MW•h/Month	kW•h/h
Jan.	2,200	2,960	14,500	19,490
Feb.	5,000	7,440	8,500	12,650
Mar.	8,400	11,290	6,100	8,200
Apr.	17,900	24,860	1,600	2,220
May	28,500	38,300	1,000	1,340
Jun.	41,600	57,780	1,000	1,340
Jul.	43,800	58,870	1,300	1,750
Aug.	55,800	75,000	1,300	1,750
Sep.	48,400	67,220	1,000	1,340
Oct.	26,000	34,950	4,500	6,050
Nov.	14,500	20,140	4,800	6,670
Dec.	9,600	12,900	7,200	9,680

Note: Refer to Figure 5.1-6.

These data show the following considerations.

(1) In the winter season of January and February, sold electric energy exceed purchased electric energy. In other words, the electricity generated can match the demand for electricity in these months.

(2) In the period from March to December, consumed electric energy exceeds generated electric energy, and the balancing electric power can be supplied by purchased electric energy.

(3) The generated electric energy was at a minimum in August, and consumed electric power was about 85 x 10^3 MW·h/Month (114 MW·h/h). On the other hand, the generated electric power was about 29 x 10^3 MW·h/Month (39 MW·h/h), and the purchased electric power was about 56 x 10^3 MW·h/Month (75 MW·h/h).

(4) The demand for steam varies drastically depending on seasons although the demand for electric power hardly fluctuates all through the year. Hot water for heating is supplied to Plock city by PPSA. The heat source of this hot water is 1.2 ata steam. The demand for this hot water varies drastically depending on seasons.
For example, the demand for hot water in January was 92 GJ, while the demand in June was only 15 GJ.
Accordingly, in order to solve the shortage of electric power excluding January and February, it is required to install a new generating system which will not be influenced by the demand for steam.
Here, PPSA can supply surplus electricity to electric power companies for sale, so a newly installed generating system will be able to operate all the year round.

6.3.2 Prediction of amount of extracted steam and condensate for extraction turbine

As for extraction loads of a newly-installed turbine, it is assumed that the extraction amount is the sum of the amount of steam passing through the reducing valve and the increased consumption of low-pressure steam that will be recommended in this study for modernization of the Power Plant.

(1) Present actual data of flow rate passing through reducing valves.

Steam of 70 ata, 45 ata, 35 ata, 18 ata, and 7.5 ata can be delivered from 139 ata steam through reducing valves in present system of PPSA. The flow rates of steam passing through these valves are shown in Table 6.3-2.

Table 6.3-2 ACTUAL STEAM FLOW AMOUNT AT EACH REDUCING VALVE IN 1992

Steam pressure	Annual flow amount	Hourly flow amount
70 ata	1,472 t/y	0.17 t/h
45 ata	331,612 t/y	38.34 t/h
35 ata	143,842 t/y	16.65 t/h
18 ata	44,790 t/y	5.18 t/h
7.5 ata	1,000 t/y	0.16 t/h

Source: PPSA

In this table, it is evident that the flow rates of the 45 and 35 ata steam are by far bigger than the rest (38 t/h and 16 t/h respectively). Depressurizing steam through reducing valves means that the reduced-pressure steam is made without passing through a generator. Therefore, it can be pointed out that the potential generating capacity is not fully utilized.

(2) Increase of usage of low pressure steam

The description in section 5.2 recommends increasing the amount of atomizing steam as a measure to improve combustion of vacuum residue oil. This measure results in an increased consumption of the 18 ata steam, which corresponds to 9 wt % of the fuel consumption. Furthermore, in section 6.2, it is recommended that the capacity of steam air heaters for combustion air be reinforced. When the 18 ata steam is used to heat the outlet temperature of combustion air at the steam air heaters up to 105°C, the required amount of the steam increases in proportion to the temperature rise from ambient temperature as well as boiler loads. The increased amount of the 18 ata steam for each month is shown in Table 6.3-3, based on the fuel consumption of boilers and the generation of steam listed in Tables 5.1-1 and 5.1-2.

Table 6.3-3 PREDICTION OF THE INCREASED AMOUNT OF 18 ATA STEAM

Month	Average Ambient temp. (* 1)	SAH load	Average boiler load t/h x No. of boilers	Required amount for SAH-STM	Increased amount of ATMIZ.STM
Jan.	-3.3°C	108.3°C	237 x 6	63.3 t/h	10.5 t/h
Feb.	-2.5°C	107.5°C	224 x 6	59.4 t/h	9.0 t/h
Mar.	1.3°C	103.7°C	197 x 6	50.4 t/h	8.8 t/h
Apr.	7.5°C	97.5°C	224 x 5	44.9 t/h	7.5 t/h
May	13.0°C	92.0°C	178 x 5	33.5 t/h	6.1 t/h
Jun.	17.0°C	88.0°C	162 x 5	29.3 t/h	5.1 t/h
Jul.	18.1°C	86.9°C	133 x 5	23.8 t/h	4.2 t/h
Aug.	17.4°C	87.6°C	146 x 5	26.2 t/h	4.9 t/h
Sep.	13.2°C	91.8°C	141 x 6	31.8 t/h	5.7 t/h
Oct.	8.2°C	96.8°C	230 x 5	45.8 t/h	8.1 t/h
Nov.	3.3°C	101.7°C	179 x 7	52.3 t/h	8.9 t/h
Dec.	-0.7°C	105.7°C	193 x 7	58.6 t/h	9.7 t/h

Source: * 1 RIKA NENPYO '1992 (Table of Science '92 edition)

The ambient temperatures in the table 6.3-3 refer to the average temperatures for the past 30 years in Warsaw which are quoted from Table of Science ('92 edition).

(3) Prediction of amount of condensate generated in a newly installed extraction turbine.

The biggest factor which determines the amount of electric energy generated by an extraction turbine is the amount of cooling water for the surface condenser at the turbine exhaust. The flow rate of cooling water for the surface condenser is planned to be 11,000 m^3/h. Since about 4,000 m^3/h of cooling water is used in existing boiler facilities, the total amount of cooling water is 15,000 m^3/h, which is almost the upper limit. This is because the linear velocity in the main header of cooling water reaches 3.7 m/sec, as the diameter of main header is 1,200 mmϕ.
This quantity of cooling water can condense 210 t/h of turbine exhaust steam under the condition that the temperature of cooling water reaches 32°C in summer.
This condensing capacity increases to about 550 t/h when temperature of cooling water is about 20°C in winter.
In reality, the amount of condensate converges on a certain level, affected by boiler loads in the existent facilities. It is presumed that it should be kept under the capacity of the boiler when considering the amount of condensate and the increased consumption of low-pressure steam in Table 6.3-3.

6.3.3 Evaluation of installation of condensing turbine generating system

In PPSA, installation of an extraction turbine is under study to cut back the purchased electric energy in the

summer. The planned generator-end output of the turbine is 65,000 kW, which seems to be a reasonable installation capacity since it is a maximum of electric energy that can drive from cooling water for surface condenser in the summer.
Here, it is possible to operate a newly-installed turbine for all seasons, because the balanced electricity can be supplied to the national grid for sale in PPSA.
Therefore, the operational load of a new condensing turbine will be estimated under the following conditions.

(1) Operating condition of existing extraction turbines are constant before and after modernization.

(2) A newly installed condensing turbine will be operated at full load for all seasons, and the balanced electricity will be supplied to the national grid for sale.

(3) The new turbine can extract 45 ata, 18 ata,and 1.2 ata steam. As for the economical evaluation of this turbine, it is assumed that the extraction amount is the sum of the steam passing through the reducing valve and the increased consumption of low pressure steam for improvement of fuel atomizing and so on.

The consumption of high pressure steam and generation of condensate are estimated under the above conditions, when the electricity of 65,000 kW are generated by the turbine. The results are summarized in Table 6.3-4.

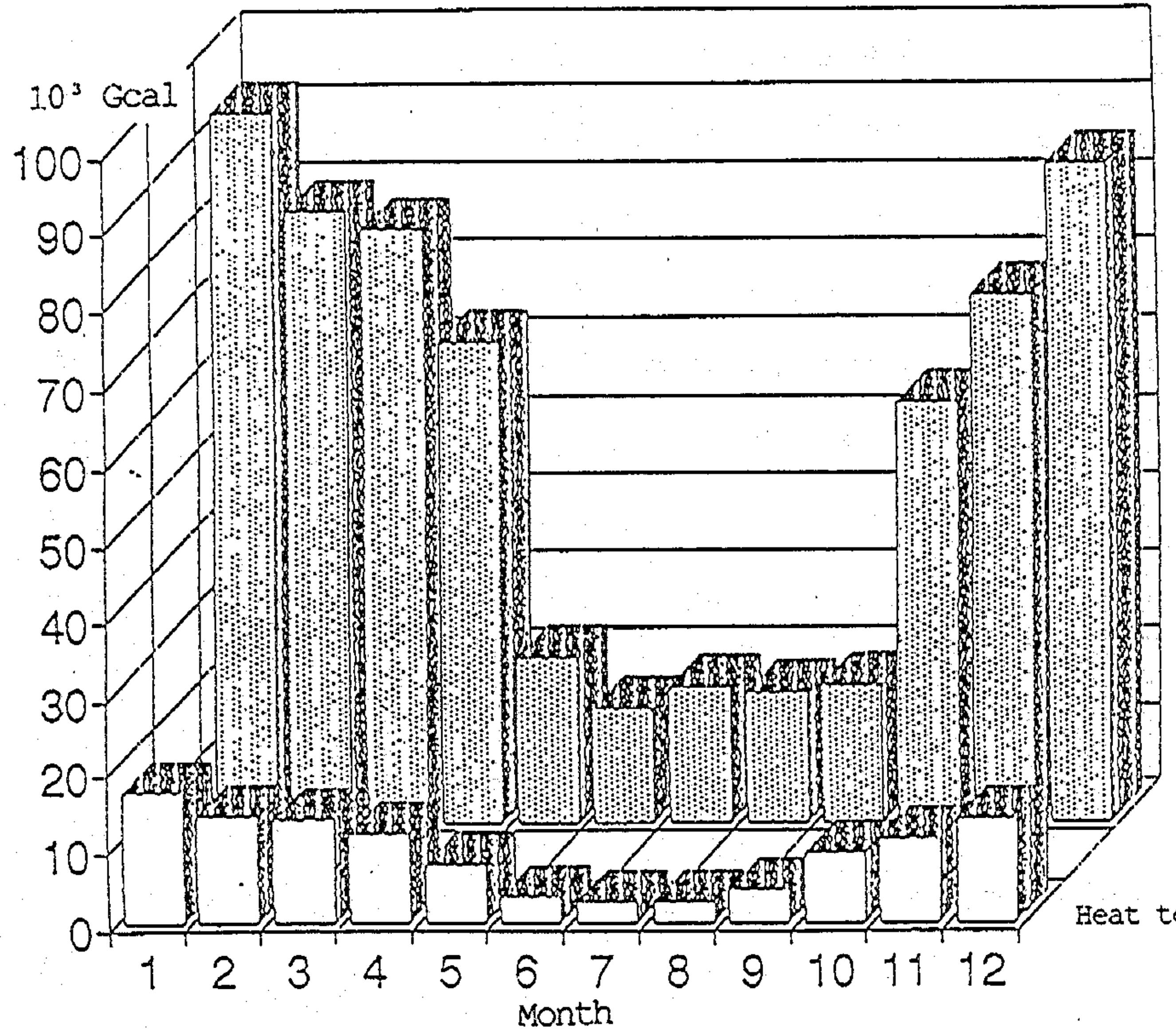
Table 6.3-4 UTILITY CONSUMPTION OF A NEWLY INSTALLED CONDENSING TURBINE

Month	Generated Electricity	Consumption of High Press. Steam	Consumption of Cooling Water
	(kW•h/h)	(t/h)	(t/h)
1	65,000	174	4,350
2	65,000	179	5,470
3	65,000	182	6,260
4	65,000	185	7,270
5	65,000	191	8,750
6	65,000	191	10,500
7	65,000	196	11,000
8	65,000	196	10,800
9	65,000	191	8,750
10	65,000	184	7,230
11	65,000	183	6,290
12	65,000	180	5,500
Total*1	569,400,000 kW•h/y	1,629,720 t/y	67,393,200 t/y
Total*2	514,800,000 kW•h/y	1,473,450 t/y	60,930,840 t/y

Note: * 1 Annual cumulative value

: * 2 Annual cumulative value correlated with 330 days/year

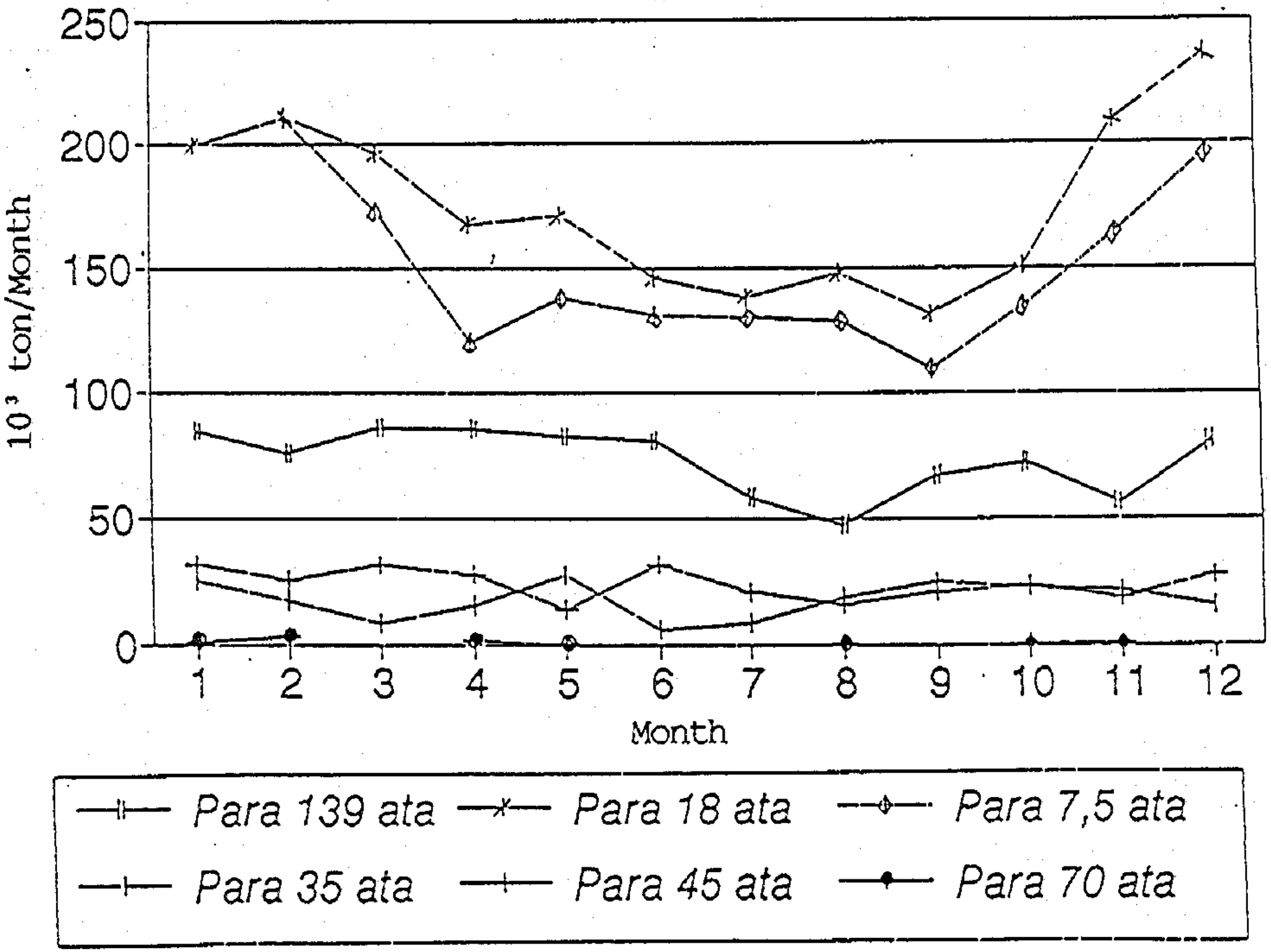
Figure 6.3-1 PRODUCTION CONSUMPTION OF HEAT ENERGY (1992) IN PPSA



M-c	to Plock City	to P.P.S.A
	Gcal	
1	91.939	16.947
2	79.072	13.900
3	76.844	13.322
4	62.311	11.457
5	21.698	7.586
6	14.975	3.451
7	17.939	2.701
8	17.057	2.608
9	18.088	4.362
10	54.672	9.053
11	68.002	10.976
12	85.096	13.400

Source : P.P.S.A.

Figure 6.3-2 STEAM GENERATION VERSED ON PRESSURE LEVEL (1991)



Source ; P.P.S.A.

6.4 Formulation of Conceptual Design for an Appropriate Project for Modernization

The countermeasures required in the present power generation facilities were already described in sections 6.1, 6.2 and 6.3. Since all countermeasures relate to each other, an overall viewpoint is required for adoption of these measures. In this section, the countermeasures to be adopted will be selected and evaluated according to the effects on the economical study. Here, the preconditions for cost estimation of each countermeasures are attached in Annex 2.

6.4.1 Countermeasures to be adopted in modernization plan

(1) Boiler plant

1) replacement of burner tips (reinforcement of fuel atomization)
2) installation of soot blowers
3) rearrangement of economizer tube
4) replacement of Jungstrom
5) recovery of vent steam from deaerator
6) adoption of low NOx burners

(2) Boiler feed water treating facilities

1) adoption of ladder type distributer for water stream
2) adoption of reflecter type distributer for regenerant
3) adoption of ladder type collecter for regenerant
4) piping rearrangement for pouring chemicals in series
5) elimination of leakage from valves and dead ends of piping

(3) Extraction condensing turbine generator system

1) installation of extraction condensing turbine generator system

6.4.2 Effect on improvement for the modernization plan

Since countermeasures adopted in suitable modernization plans relate to each other, various effects are produced.

(1) Boiler plant

As mentioned in 5.5.1(3), in order to clear the SO_2 emission limit, it is necessary to reduce the sulfur content of fuel or to treat the combustion flue gas of high sulfur fuel by the desulfurization unit.
In this section, the improvement effects are studied for both cases.

1) Reducing effect of fouling on boiler tubes

After adoption of countermeasures 1), 2), 3) for the boiler plant as described above, it is expected to reduce the fuel consumption because of reduction of fouling on boiler tubes. The preconditions for the evaluation of improvement effects are as follows ;

(a) Average load of No.1, No.2 and No.3 boilers is 70%.
(b) After boiler tube cleaning the inlet temperature of Jungstrom is 317°C and the boiler is shut down when it reaches 400°C in order to clean up.
(c) After modernization this temperature rise is within 10°C per year.
(d) The leakage air is 90,000 Nm^3/h @ 70% load.

Accordingly, the improvement effect corresponds to a 39°C temperature rise of flue gas,
because ((400 - 317) - 10/2) = 39°C

Therefore, saving energy is the sum of the dry base heat contents difference and heat contents differnce of steam in flue gas equivalent to a 39°C temperature rise. Here, the dry base heat contents of flue gas (Q_{O2}) is as follows ;

$$Q_{O2} = W_{FUEL} \times Load \times V_{D-FG} \times Cp_{FG} \times 39 + (V_{AIR} / 22.4) \times Cp_{AIR} \times 39$$

where

W_{FUEL}	=	fuel consumption	(kg/h)
Load	=	boiler load	(-)
V_{D-FG}	=	dry flue gas volume per fuel	(Nm^3/kg)
Cp_{FG}	=	specific heat of flue gas	(kcal/(kg•°C))
V_{AIR}	=	amount of leaking air	(Nm^3/kg)
Cp_{AIR}	=	specific heat of air	(kcal/(kg•°C))

Therefore,

$$Q_{O2} = 21{,}690 \times 0.7 \times 10.090 \times 0.33 \times 39 + (90{,}000/22.4) \times 7.00 \times 39 = 3.069 \times 10^6 \text{ Kcal/h}$$

Heat of steam in flue gas (Q_{O3}) is as follows ;

$$Q_{O3} = W_{FUEL} \times load \times (V_{W-FG} - V_{D-FG}) \times Cp_{STM} \times 39$$

where

W_{FUEL}	=	fuel consumption	(kg/h)
Load	=	boiler load	(-)
V_{W-FG}	=	amount of wet flue gas per fuel	(Nm^3/kg)
V_{D-FG}	=	amount of dry flue gas per fuel	(Nm^3/kg)
Cp_{STM}	=	specific heat of steam	(kcal/(kg•°C))

Therefore,

$$Q_{O3} = 21{,}690 \times 0.7 \times (11.391 - 10.090) \times 0.45 \times 39 = 0.367 \times 10^6 \text{ Kcal/h}$$

Consequently,

The amount of energy saved $= (3.069 + 0.367) \times 10^6 = 3.436 \times 10^6$ Kcal/h

Since the heating value of fuel is 9,708 kcal/kg, the amount of energy saved = 354 kg-Fuel/h

In this section, the improvement effects are independent of sulfur content in fuel.

Therefore,

The amount of energy saved in low sulfur fuel case
= 354 kg-Fuel/h

The amount of energy saved in high sulfur fuel case
= 354 kg-Fuel/h

On the other hand, it is required to increase the amount of atomizing steam from 4% of fuel to 13% in order to attain the above fuel savings.

The amount of atomizing steam to be increased
= 21,690 x (0.13 - 0.04) x 0.70 = 1,366 kg/h

2) Reducing effect of amounts of flue gas and combustion air

After adoption of countermeasures 4), it is expected to reduce the load of the air blower for combustion, the flue gas induced blower and the charge blower of the flue gas desulfurization unit (hereinafter FGD unit) which will be newly installed in the future. Here, the main specifications of the air blower and the flue gas induced blower are listed in Table 6.4-1.

Table 6.4-1 MAIN SPECIFICATIONS OF BLOWERS IN EXISTING NO.1, NO.2 AND NO.3 BOILERS

Item	Quantity	Capacity	Head	Electric power	Voltage
	(-)	(Nm^3/h)	($m-H_2O$)	(kW)	(V)
Air Blower	2	183,600	0.30	320	6,000
Flue gas Fan	2	331,200	0.235	320	6,000

Source: PPSA

The preconditions for evaluation of improvement effects are as follows ;

(a) The present loads of flue gas fans are 300,000 Nm^3/h as shown in Table 5.1-9 and these are reduced to 220,000 Nm^3/h after modernization.

(b) The present loads of air blowers are 270,000 Nm^3/h as shown in Table 5.1-9 and these are reduced to 180,000 Nm^3/h after modernization.

(c) The present current data of flue gas fans motor is 22 Ampere as shown in Table 5.1-9.

Present electricity consumption of flue gas fans

$= 6,000 \times 22 \times 0.80 \times \sqrt{3} = 183$ kW

Accordingly, Saving of electricity from flue gas fans

$= 183 - 183 \times 220,000/300,000 = 49$ kW

Here, since the quantity of flue gas fans are two for each boiler, the saving of electricity from flue gas fans are approximately 100 kW for each boiler.

For air blowers, since there is no operation data for electricity, the saving of electricity from air blowers is estimated by using operation data for flue gas fans.

Present electricity consumption of air blower

$= 183 \times 270,000/300,000 \times 0.35/0.235$

$= 245$ kW

Accordingly, saving of electricity from air blower

$= 245 - 245 \times 180,000/220,000 = 82$ kW

Here, since the quantity of air blowers are two for each boiler, the saving of electricity from air blowers is estimated to be approximately 160 kW for each boiler. Reducing the amount of flue gas influences electricity consumption of the charge blower of FGD unit. It seems that it is possible to save 160 kW when the charge blower head is assumed to be almost the same as an air blower with reserve.

Consequently,
Total saving of electricity per boiler in low sulfur fuel case = 100 + 160 = 260 kW
Total saving of electricity per boiler in high sulfur fuel case = 100 + 160 + 160 = 420 kW

3) Increasing of heat exchange by replacement of new Jungstroms

If the tight seal type Jungstroms are used, it is considered to reduce not only air leakage to the flue gas duct side but also axial leakage. According to the maker's catalog, the leakage of the most up-to-date model is approximately 3% less than the conventional type. Accordingly, it is assumed that present leakage is improved 6% (twice the catalog information).
Here, the 39°C temperature difference of the boiler flue gas corresponds to 3.436×10^6 kcal/h as shown in this chapter 6.4.2 (1)-1). The actual temperature difference between inlet and outlet temperatures of Jungstrom is about 175°C.
Accordingly,
Increasing of heat exchange

$$= 3.436 \times 10^6 \times 175/39 \times 0.06 = 0.925 \times 10^6 \text{ kcal/h}$$
$$= 95.3 \text{ kg-Fuel/h}$$

The improvement effects are independent of sulfur content in fuel.
Therefore,
The amount of saving energy in low sulfur fuel case
= 95 kg - Fuel/h
The amount of saving energy in high sulfur fuel case
= 95 kg - Fuel/h

4) Reducing effect of SO_2 emission

[Low sulfur fuel case]

In low sulfur fuel case, it is forecast that sulfur content of fuel is reduced to 0.3 wt %.

In this case, the decreasing of sulfur content is equivalent to reducing SO_2 emission.

Consequently,

Reducing effect of SO_2 emission in low sulfur fuel case

= 21,690 x 0.70 x (0.03 - 0.003) x 2

= 820 kg/h as SO_2

[High sulfur fuel case]

The capacities of FGD units under planning by PPSA are 1,100,000 Nm^3/h x 2 Trains. These capacities are enough to treat the flue gas from approximately 2,400 t/h boiler, if the O_2 concentration in flue gas is about 3%. In the present plans of PPSA, the flue gas duct from No.1, No.2 and No.3 boilers will be connected to the suction duct for FGD charge blowers. Therefore, when the flue gas from No.1, No.2 and No.3 boilers are decreased by replacement of Jungstroms, it is expected to increase the chance for treating these flue gases by FGD units and to reduce SO_2 emission from these boilers.

The preconditions for evaluation of the reducing effect of SO_2 emission are as follows ;

(a) Sulfur content in fuel oil is 3.0 wt %.

(b) The present amount of flue gas is 300,000 Nm^3/h as shown in Table 5.1-9 and this is reduced to 220,000 Nm^3/h after modernization.

Accordingly,

Reducing effect of SO_2 emission in high sulfur fuel case

$= 21,690 \times 0.7 \times 0.03 \times 64/32 \times (300,000 - 220,000)$
$/ 300,000 = 243$ kg-SO_2/h

5) Reduction effect of NOx emission

If low NOx burners are adopted as countermeasures for reducing NOx, it is presumed that NOx concentration can attain 250 ppm at rated load and 220 ppm at 70% of rated load.
Here, present emission level is 170.6 g/GJ as shown in Table 5.7-2. This value corresponds to 270 ppm.

The preconditions for evaluation of the reducing effect of NOx emission are as follows ;

(a) Boiler load is 70% of rated load.

As NOx concentration 220 ppm corresponds to 140 g/GJ and the heating value of fuel is 41,000 kJ/kg.
The amount of present NOx emission
$= 170.6 \times 10^{-6} \times 21,690 \times 0.70 \times 41,000 = 106$ kg/h

After modernization, the amount of NOx emission
$= 140.0 \times 10^{-6} \times 21,690 \times 0.70 \times 41,000$
$= 87$ kg/h

(2) Boiler feed water treating facilities

1) Reducing effect of chemical consumption for resin regeneration

Reducing effects of chemical consumption for resin regeneration after modernization are shown in Table 6.4-2.

Table 6.4-2 EXPECTED CHEMICAL CONSUMPTION OF BOILER FEED WATER FACILITIES

Subject	Current Value	After modernization
I. Reduction of chemical consumption		
HCl	0.696 kg/m^3-Pure Water	0.400 kg/m^3-Pure Water
NaOH	0.898 kg/m^3-Pure Water	0.500 kg/m^3-Pure Water

Source: PPSA
Note : All chemical consumptions is converted to 100% conc

2) Increase of throughput capacity

In Chapter 6.1.2, the probability of increasing capacity is considered. However, it is impossible to attain a large capacity increase, because the existing resin towers are not sufficient to increase the throughput capacity. Table 6.4-3 summarizes the potential capacity.

Table 6.4-3 POTENTIAL THROUGHPUT CAPACITY OF EACH UNIT

Unit	Current Value	Potential capacity
I. A,B,C unit	Total 240 m^3/h	Total 240 m^3/h
II. D,E,F,G,H unit	Total 500 m^3/h	Total 550 m^3/h

Source: PPSA

3) Reduction of raw water consumption

In order to reduce raw water consumption of the boiler feed water treating facilities in PPSA, large scale reconstruction will be required. Therefore, there are no suitable countermeasures to recover back wash water of sandfilters, which is the biggest source of waste water

However, when chemical consumption can be reduced during regeneration of ion exchange resin, it is impossible to reduce some parts of waste water. This is because, pouring chemicals in series is recommended as one of the counter-measures for reducing chemical consumption during regeneration operation of ion exchange resin. This measure is the same for the regeneration operation of all cation towers (or all anion towers) simultaneously. Table 6.1-9 shows the amount of treating water per one cycle of operation. For example, the present amount of treating water for one cycle of operation of cation tower is 1,300 m^3, but this amount increase to 2,600 m^3 in the case of simultaenous regeneration. Accordingly, the frequency of regeneration operation can be reduced to approximately 60%.
Since present waste water is 0.40 m^3/m^3 - P.W. ;
Estimated reduction of waste water = 0.40 x (1-0.6)
= 0.16 m^3/m^3 - P.W.
Actually, series washing is accompanied by a decrease in some efficiency, so reduction of waste water is estimated to be about 0.10 m^3/m^3 - P.W.

The reduction effect of raw water consumption after modernization is shown in Table 6.4-4.

Table 6.4-4 THE REDUCTION EFFECT OF RAW WATER CONSUMPTION

Unit	Current Value	After modernization
Raw water consumption	1.40 m^3/m^3-Pure water	1.30 m^3/m^3-P.W.

(3) Condensing turbine generating system

The electricity balance is considered under the condition of full load operation of newly installed condensing turbine generating system based on the electricity balance in 1992.
These result are listed in Table 6.4-5.

Table 6.4-5 ELECTRICITY BALANCE AFTER MODERNIZATION

Month	Electricity generated	Electricity consumed	Sold electricity	Purchased electricity
	(kW·h/h)	(kW·h/h)	(kW·h/h)	(kW·h/h)
Jan.	65,000	2,960	62,040	0
Feb.	65,000	7,440	57,560	0
Mar.	65,000	11,290	53,710	0
Apr.	65,000	24,860	40,140	0
May	65,000	38,300	26,700	0
Jun.	65,000	57,780	7,220	0
Jul.	65,000	58,870	6,130	0
Aug.	65,000	65,000	0	10,000
Sep.	65,000	65,000	0	2,200
Oct.	65,000	34,950	30,050	0
Nov.	65,000	20,140	44,860	0
Dec.	65,000	12,900	52,100	0
Total *1	569,400,000	292,658,160	276,741,840	9,038,400
Total *2	514,800,000	264,595,050	250,204,950	8,171,700

Note: *1 Annual cumulative value (kW·h/year)
*2 Annual cumulative value correlated with 330 days/year

However, in order to operate this generating system, high pressure steam as a driving power and cooling water for the turbine exhaust steam are required. The amount of these utilities are listed in Table 6.4-6.

Table 6.4-6 UTILITY CONSUMPTION OF A NEWLY INSTALLED CONDENSING TURBINE

Month	Generated Electricity	Consumption*1 of High Press. Steam	Consumption of Cooling Water
	(kW·h/h)	(t/h)	(t/h)
1	65,000	174	4,350
2	65,000	179	5,470
3	65,000	182	6,260
4	65,000	185	7,270
5	65,000	191	8,750
6	65,000	191	10,500
7	65,000	196	11,000
8	65,000	196	10,800
9	65,000	191	8,750
10	65,000	184	7,230
11	65,000	183	6,290
12	65,000	180	5,500
Total*2	569,400,000 kW·h/y	1,629,720 t/y	67,393,200 t/y
Total*3	514,800,000 kW·h/y	1,473,450 t/y	60,930,840 t/y

Note: *1 This value is equal to the amount of condensate generated

*2 Annual cumulative value (kW·h/year)

*3 Annual cumulative value correlated with 330 days/year

Chapter 7

Capital and Operation Cost Estimation for the Modernization of the No.1 Crude Distillation Unit and the Modernization of the Thermoelectric Power Plant

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Chapter 7 Capital and Operation Cost Estimation for the Modernization of the No.1 Crude Distillation Unit and the Modernization of the Thermoelectric Power Plant

7.1 Capital Cost Estimation

7.1.1 Preconditions for calculation of total project costs

The total project costs can be broadly divided into the foreign currency category and the domestic currency category, according to the source of supply for each item. The foreign currency and the domestic currency categories include the following items respectively.

(1) Foreign currency categories:

- Costs for local procurement of equipment and materials
- Costs for inland transportation of equipment and materials, including imported items
- Dismounting and erection costs
- Civil engineering and construction work costs
- Construction machinery costs
- Taxes payable to the Polish government

Each base cost was first calculated in the relevant currency and then was converted to US dollars at the official exchange rate as of the end of December 1993.

The following official exchange rates were used.

US$ = Zl. 21,200
US$ = ¥112.00 (¥1.00 = Zl.189.29)

7.1.2 Total capital requirement

As descriptions of the costs related to the equipment, materials and construction work are given in the following Section, other costs are explained in this Section.

(1) Taxes

Under the existing Polish tax system, the following three taxes should be taken into consideration in calculating the total project costs.

- Corporate tax
- Value Added Tax (VAT)
- Import duties

In any country, there is a strong possibility that interpretation of the actual application of the tax system to a project will vary according to the priority given to the project, the intent of the loan-providing country, the procedures for filing applications and the negotiations which are conducted concerning the three taxes applicable to the project.

1) Corporate Tax

The corporate tax imposed in Poland is 40% on profits

2) Value Added Tax (VAT)

In Poland, all goods and services including imported goods and services are subject to the VAT. The tax rate is 22%.

3) Import duties, etc.

The level of import duties differs by commodity groups and the average level in 1992 was 18.4%. In this Project, cost estimation was performed including import duties for each item.

7.1.3 Capital cost estimation, by cost categories

Tables 7.1-1 and 7.1-2 show the summaries of capital cost estimation for No.1 CDU and power plant. Details of each estimation are attached to the latter part of ANNEXES 1 and 2 respectively.

Capital cost estimation consists of the following categories:

- Equipment and materials to be supplied from foreign countries and/or local sources.
- Field construction work.
- Engineering, Procurement, and Supervising man hours (EPS-MH) and related expenses.
- Import duty and materials

(1) Equipment and materials

- The greater portion of equipment and materials are available to procure inside of Poland, so that foreign supplied equipment and materials are minimized.

Cost of equipment and materials includes the following items.

- Ocean and inland transportation
- Transportation insurance

- Ordinarily, spare parts for start-up
- Vendors' specialist to be dispatched to the Job site

Cost of foreign and locally supplied equipment and materials are CIF price at Job site

(2) Field Work

All field works are available by local contractors and supply of bulk consumable materials materials such as oil and grease for construction use also can be supplied by local vendors.
Rental or supply of all construction equipment and tools will be done by local contractors.

Cost of field work includes the following items:

- Bulk and consumable materials
- Construction equipment and tools
- Transportation to the Job site
- Temporary facilities
- Erection piping, electrical, instruments, insulation, painting, civil and architectural work
- Field test and pre-commissioning work
- Erection Insurance, Workmen's Accident Compensation Insurance and Third Party Liability Insurance
- Demolishing work of existing facilities

The following items are excluded:

- Piling work
- Demolishing work of existing stabilizer and splitter column
- Disposal of demolished equipment and materials outside of the Refinery

- Purging work for existing plant
- Fire insurance for existing plant
- Commissioning and test operation

(3) EPS-MH and expenses

Cost of EPS-MH and expenses includes the following items.

- Basic and detailed engineering
- Procurement, expediting, test/inspection and shipping
- Field supervising
- Schedule and quality control
- Coordination between PPSA and contractor
- Contractor's home and field office expenses

Some payments to outside organizations will of course be incurred. However, also within PPSA, there are man-hours and costs which arise with the implementation of the project, therefore, these are also counted as project cost.

(4) Import duty and VAT

1) Import duties shall be paid for equipment and materials to be supplied by foreign vendors.

The calculation formula is as follows,

$T = B + C + D$
T: Amount of import duty
A: SAFE value of equipment and/or material
B: (Specific tax) : $A \times 0.15$
C: (Basic tax) : $(A + A \times 0.15) \times 0.06$
D: $[A + A \times 0.15 + (A + A \times 0.15) \times 0.06] \times 0.22$
i.e. $T = A \times 0.48718 \neq A \times 0.49$

2) VAT of 22% shall be paid for the cost of locally supplied equipment and materials, field work, EPS-MH and expenses.

7.1.4 Pre-operation expenses

Major pre-operation cost items are training cost for training the plant's employees to cope with the introduction of new technologies like DCS, at the vendor's plant, and test-run expenditures.

The total expense amount required for this purpose was estimated as 5% of plant cost.

7.1.5 Contingency

The physical contingency is to cover possible changes in the conceptual design, the estimating conditions and the method of implementation of the construction work. The percentages applied are 5% for equipment and 10% for civil and building works. In this Study, price contingency is not taken into consideration because all cost and price items are assumed to remain constant throughout the project implementation period.

7.1.6 Interest during construction

According to the practice at PPSA, 50% of the total project costs will be covered by short-term loans sourced from domestic financial institutions, the rate on which is 12.5% per year. It was assumed that this rate is applicable to the project.

7.1.7 Initial working capital

Generally speaking, the following items are taken into consideration:

- Cash in hand
- Inventory of raw materials
- Inventory of intermediate products
- Inventory of products
- Accounts receivable
- Accounts payable

However, because of the nature of this project, there is no inventory of processing materials nor inventory of products. AS for other items, the following assumption is made based on the data and information supplied from PPSA:

- 9 days of cash in hand on output value from No.1 CDU;
- 30 days of inventory of raw materials;
- 14 days of accounts receivable on output value; and
- 14 days of accounts payable on raw materials cost.

Table 7.1-1 SUMMARY OF NO.1 CDU

Unit: US$

		Equipment & Material		Field work	EPS–MH and expenses	Sub total	Import duty	VAT	Total
		Foreign	Local						
1	Rearrangement of heat exchange	–	992,946	2,232,550	433,920	3,569,416	–	804,078	4,463,494
2	Installation of air preheater	306,250	656,000	708,180	189,990	1,860,420	150,063	341,917	2,352,400
3	O_2 control in flue gas from Pc–1 and Pc–2	15,400	65,000	51,600	19,800	151,800	7,546	30,008	189,354
4	Replacement to DCS	633,000	794,200	242,800	214,080	1,884,080	310,170	275,238	2,469,488
5	Reducing offensive odor sub stance in sewages	–	6,400	10,000	–	16,400	–	3,608	20,008
6	Installation of coalescer	338,000	–	84,600	12,700	435,800	165,865	22,790	624,455
	Grand Total	1,292,650	2,514,546	3,329,730	870,490	8,007,916	633,644	1,477,639	10,119,199

Table 7.1-2 SUMMARY OF POWER PLANT

(Unit: US$)

		Equipment & Material		Field work	EPS-MH and expenses	Sub total	Import duty	VAT	Total
		Foreign	Local						
B-1	Modification of 3 Boilers	1,973,100	2,355,960	647,110	212,230	5,188,400	966,819	707,366	6,862,585
G-1	Condensing Turbine Generator	8,000,000	5,500,000	6,272,680	1,676,868	21,449,548	3,920,000	958,901	26,328,449
W-1	Boiler feed water facilities	66,000	28,800	348,760	89,130	532,690	32,340	102,672	667,702
	Grand Total	10,039,100	7,884,760	7,268,550	1,978,228	27,170,638	4,919,159	1,768,939	33,858,736

7.2 Operating Cost Estimation

All of the operating costs have a close connection with the financial evaluation. Accordingly a detailed explanation of these costs will be made in Chapter 9.

Chapter 8

Formulation of Implementation Arrangement and Schedule

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Chapter 8 Formulation of Implementation Arrangement and Schedule

8.1 Implementation Planning and Schedule

8.1.1 General and Goals

Factors to be taken into account for the project implementation are:-

(1) To maintain quality of the design, supplies and construction of the facilities, including easiness and efficiency in the operation;

(2) Investment cost minimization in achieving low operating cost.

(3) Shortest feasible project time schedule, to realize profit earning at an earlier time, and to reduce interest accrual during the construction; and

Further, for this Study since revamping of the existing facilities are included, it is necessary to keep in mind of:

(4) Shortest feasible shut-down period of the existing facilties, in order to minimize production loss.

(5) Safety of construction, since the project entails the modification of the existing facilities.

Of course, these targets are very often conflicting with each other, and trade-off among those goals may be required during implementation planning.

Planning of a project involves various steps before the project requires physical actions by PPSA and shows actual progress of works. These steps can be enumerated as follows:-

(1) Provide a complete definition of the work requirements, including definition of scope of works and specifications.

(2) Identify and define investment cost requirements in detail, through development of a work breakdown structure (WBS) and pricing out the work breakdown structure.

(3) Arrangement of finances for the execution of the works, in consideration of costs of finance and total cost of the projects.

(4) Establishment of the implementation schedule

(5) Establishment of Procurement Packages, with due attention to the capability of PPSA and financier's requirements.

(6) Formulation of appropriate procurement and contracting methods

The planning process shall greatly depend on which component of the plant is involved, and plans shall accordingly be made for the differing nature of works required for the different plant components.

For this Study, there are three distinctly different plant components, each with its own distinct nature of works involved.
These are;

(1) Modernization of No.1 Distillation Unit, which includes revamping of the existing facilities in operation.

(2) Modernization of Boilers (No.1, 2 and 3) and water treatment facilities, which is also modification of the existing equipment.

(3) Installation of a new turbine and generator system.

Therefore, the planning and the approach for the implementation of the project shall differ according to plant components and nature of works.

8.1.2 Consideration for Implementation Approach

In this section, establishment of the implementation and procurement packages, and procurement method will be studied for the projects.

The formation of implementation and procurement package(s) mainly depends on (a) source of finance; (b) complexity of technology and (c) nature of the works to be done. And this will also greatly affect the time schedule.

(1) Influence by the financial sources

Use of international or bilateral development funds bears generally low interest rates and it is beneficial to projects in this regard. However, such finances have certain complexities, as follows:

1) For this kind of financing, the financier takes a longer time to appraise the project and conclude a loan agreement for the project, sometimes more than one year. Also, various authorities are involved in the decision making process, and this is one of the main causes of complexity.

2) Such financier(s) normally require international competitive bidding and that involves various steps. Furthermore, sometimes at each step the documents, evaluation and contracts require prior approval or concurrence of the financier(s).

On the other hand, when using own funds or local bank finance, in general no procurement rule of third parties is imposed by the financier(s), and procurement can be done according to the applicable rule of PPSA. This will save time considerably compared with the procurement under the rules of international financier(s).

When PPSA plans to execute the project with the supplier's credit, the procedure of procurement is different, and it is better to make the procurement packages large enough to attract bids from various sources.

As explained in the preceeding chapter, this Study is based on the assumption that finance will be by own funds and local bank finance, and the plan will be prepared on the conditions that there will be no particular constraints by financier(s) with regard to procurement method.

(2) Difference due to the complexity of technology

When a project includes complex licenses and technology for a facility as a whole, it will be very useful to give one organization full responsibility up to completion of the project. For example, for a process facility in which a performance guarantee is to be secured, a full responsibility contract, either in the form of "FOB plus Supervisor" or "Turn-key" contract will be preferable, although this may be rather expensive.

On the other hand, where process guarantee is not involved and the technology is not so complex, division of responsibility will permit cheaper investment cost and better utilization of own resources for PPSA.

For modernization of No.1 Crude Distillation Unit, since no particular license is required and technology is not highly complicated, dividing the works into different categories will be a suitable arrangement to utilize the broad experience and capability of PPSA in design and operation.

The modernization of the boilers and water treatment facilities is a modification of package units. Installation of a new turbine and generator is also procurement of a package unit. These will be studied in the following section.

(3) Nature of the project

The Modernization of No.1 Distillation Unit is by its nature a so-called revamping of the process facilities. This implies that during the course of the implementation various uncertainties such as unexpected change of equipment may be encountered by PPSA and by contractor(s). For this reason, splitting the works into various categories and contractual arrangement shall be done, paying attention to the nature of the revamping works.

As for modernization of boilers and water treatment facilities, it is quite useful to obtain the technical cooperation of the manufacturers or suppliers of the existing facilities. For this purpose, a direct contracting procurement method shall be adopted to execute the works in order to secure greater confidence in the renovated plant's mechanical systems and performance, although the cost may be higher.

On the other hand, installation of new turbines and generators can be done by any capable suppliers, and competitive bidding will be appropriate.

8.1.3 Implementation Method and Procurement Packages

As mentioned earlier, there are three components of works to be carried out for the projects, namely, revamping of No.1 Distillation Unit, revamping of boilers and water treatment unit, and installation of a new turbine-generator unit. The following sections describe the implementation method and procurement packages for each category.

(1) No.1 Distillation Unit

According to PPSA, for the project of revamping of the No.2 Distillation Unit, which is under implementation and which includes such modifications as replacement of heaters, vacuum system, some pumps, internals parts of columns and instrument system (DCS), following are the arrangements made by PPSA.

1) Basic design and detail design is under preparation by the engineering department of PPSA, other than details of internal parts of the atmospheric distillation column and vacuum distillation column (these are designed by tray manufacturers).

2) Procurement of required equipment and materials have been done by PPSA.

3) Construction work will be awarded to local construction firm(s)

4) Commissioning and start-up by PPSA.

The above division of works and responsibility are in line with the considerations explained in 8.1.2 and there is no reason to change them. For the No.1 Distillation Unit, the same arrangement is appropriate.

(2) Modernization of Boilers (No.1, 2 and 3) and Modernization of Water Treatment Unit

As mentioned earlier, it is necessary to obtain the technical cooperation and support of the manufacturers or suppliers of the equipment for the modernization. With this approach, only direct contracting will be possible for the execution of the works. Of course, the manufacturers of boilers and water treatment units are in many cases different, so two separate contracts will be required. With direct contracts;

1) Design and engineering are to be finalized between PPSA and the original suppliers or manufacturers.

2) Procurement of additional equipment is to be included in the scope of the suppliers.

3) Installation of additional equipment can be done by the original suppliers or by the PPSA maintenance group with the assistance of the suppliers.

4) Commissioning and start-up is to be done by PPSA and the supplier jointly.

(3) Installation of a new turbine-generator system

There are two possibilities in purchasing the system. One is to place one package order including turbine and generator. This will place the coordination between the two equipment components under full responsibility of one supplier, and PPSA itself will not need to perform technical coordination between turbine and generator. The second possibility is to procure turbine and generator separately. This will allow procurement of the combination of the lowest cost equipment, however, PPSA will have to carry out a high level of technical coordination.

In the light of the fact that PPSA has not procured such a system for a long time, since 1973, it is recommendable to buy the system as a whole, including generator and turbine.

The construction may be done by local construction firm(s) under a contract with PPSA. However, in this case, it will be better to have construction supervisors from the equipment supplier.

Start-up and initial operation can be done by PPSA with the cooperation of the suppliers.

8.1.4 Time Schedule

Time schedules for implementation of the projects are established in this section. Pre-conditions derived from the preceeding discussions are:-

(1) There will be no restrictions or constraints on scheduling imposed by the source of finance.

(2) Direct contracting will be applied for the implementation of modernization of boilers, and for the modernization of water treatment system separately.

(3) With regard to No.1 Crude Distillation unit, procurement of equipment and contract for the construction will be made through international limited competitive bidding.

Based on the above conditions, typical implementation schedules have been drawn up as shown in Figure 8.1-1 and 8.1-2.

Figure 8.1-1 IMPLEMENTATION SCHEDULE (NO.1 DISTILLATION UNIT)

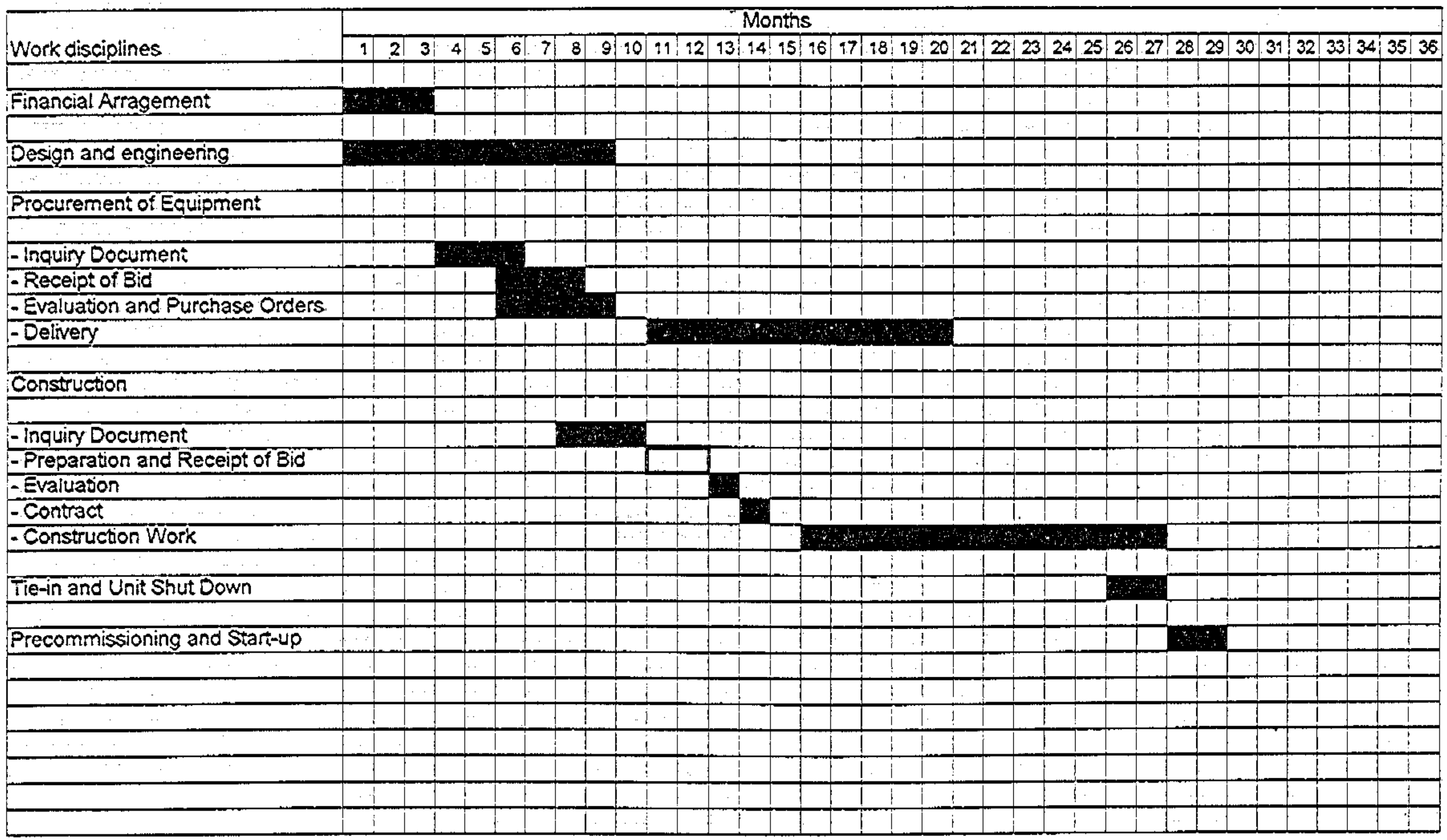
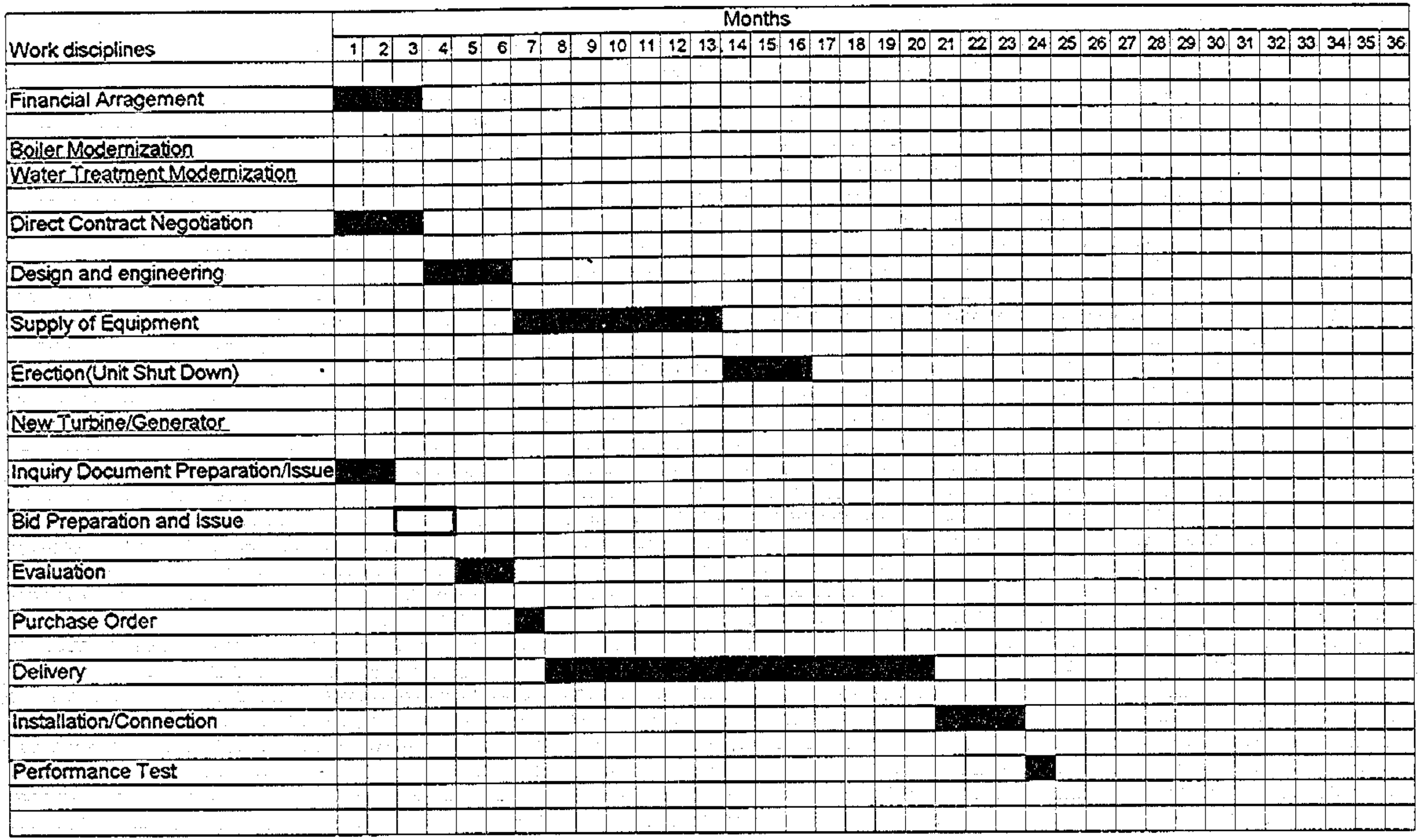


Figure 8.1-2 IMPLEMENTATION SCHEDULE (POWER PLANT)



8.2 Efficient Arrangement for Project Design, Engineering, Procurement, Construction and Operation

In section 8.1, the implementation method and procurement packages have been studied. In order to execute the work in an efficient and expeditious manner, the following shall be considered. An organization within PPSA appropriate for the implementation is very important, and this will be studied separately in section 8.3.

8.2.1 Efficient arrangement for project design and engineering

PPSA has capability and its own staff to carry out the majority of the basic design and all of the detailed design as performed or anticipated to be performed for the revamping of other Distillation Units. In order to complete the design for best fit to the existing facilities in an expeditious manner, the following shall be arranged.

(1) Preparation of all of the original design data and documents

The modernization works are modernization of the existing No.1 Unit. Therefore, it is essential to prepare complete design data and documents to be used as base data for the modernization. Such technical documents required shall include;

- Piping and Instrument Flow Diagram
- Process Flow Diagram
- Definitive Plot Plan
- Equipment Data Sheets
- Drawings
- Calculation Sheets
- Loading Data., etc.

These data and documents shall be readily available whenever they are necessary for design.

(2) Preparation of the latest updated data on existing equipment

Since the initial construction of the facilities, it is understood that various modification works have been carried out from time to time on the facilities. These modifications shall be incorporated into the data and documents mentioned in (1) above.

(3) Preparation of the operation data

Operation data at maximum and minimum throughput is required for the modernization design. All of the data shall be presented in a consistent manner and shall not include discrepancies among them. When any contradictions are found, thorough investigation shall be made to rectify them.

(4) Modernization items

Modernization items shall be detailed in the plan so that the design engineers can easily understand their purpose. These items must include not only the process requirements, but also portions mechanically deteriorated shall be identified and included in the present work plan to avoid repeated revamping of the facilities.

Regarding advance control by DCS, information on the relative merits of various suppliers will be necessary to determine what items shall be acquired for the modernization.

8.2.2 Procurement

All the procurement work is to be carried out by PPSA, and a suitable arrangement for the procurement work is required.
Selection of the suppliers of equipment (and materials) can be done through international (including local) competitive bidding with short listing of suppliers. The reasons are;

(1) The names of manufacturers of refinery equipment are rather easy to identify, and there will be no need of public anouncement for invitation to bid. This will enable PPSA to select qualified manufacturers and to reduce the time span for delivery of equipment.

(2) Among the short listed manufacturers, competitive bidding can be performed, by which it can be ensured that price for the equipment will be reasonable and cost minimization can be attained.

However, in carrying out competitive biddings, fairly complete bidding documents must be prepared by PPSA. Bidding documents normally comprise:-

(1) Technical Specifications

(2) Instruction to Bidder

(3) Terms and Conditions of Purchase

(4) Proposed Price and Price Schedule

(5) Other pertinent documents

For definition of technical specifications, it is important that (a) Design Basis particular to PPSA shall be clearly identified; (b) An appropriate Code and Standard shall be decided; (c) Items for inspection by the manufacturer and by PPSA shall be defined; and (c) specifications shall not be biased to a particular manufacturer.

For other parts of the bidding documents, preparation of standard forms are quite helpfull to maintain consistency thoroughout the procurement, and to save time and man-hour efforts of PPSA.

In the terms and conditions of purchase, such factors as;

- Payment mode and conditions
- Performance guarantees
- Mechanical warranty
- Delivery conditions and time guarantee

etc., shall be clearly stated with the applicable penalties when such are not met by the manufacturer. These items are also very important, apart from the prices, for the evaluation of the bids.

8.2.3 Construction

For this modernization of No.1 Crude Distillation Unit, it is anticipated that erection and construction works are to be contracted to local construction firm(s).

Construction contracts have a number of variations. In principle, however, there are two types of contract, "cost plus fee" and "lumpsum contract". Between the two principals, it is possible to work out various mutually advantageous alternatives combining something of the nature of both types of contract.

A competitive lumpsum contract can result in the lowest price for the projects; however, lumpsum contract is only satisfactory for contractor and owner when a detailed description of the work scope has been prepared according to specific, complete drawings and to specific equipment purchased by the owner. This implies that a long leading period will be required until the contract is awarded, and the total period of project implementation will be prolonged.

Cost plus contract covers all the costs of direct materials and labor plus a set fee which encompasses incidental costs and contractor office costs and his profit. Sometimes, this type of contract does not provide an incentive for the contractor to hold costs down, unless the owner provides a strong field force to follow closely the job progress and efficiency, although this kind of contract can be awarded at the earliest timing.

Between these two extremes, there is a Unit Price Contract by which unit prices of construction are defined and payment will be made according to the actual quantities of works performed. For this to work, specifications must be complete at the time of bidding.

In consideration of time and cost factors, it is advisable to adopt a lump sum cost with a unit price adjustment clause within a limited range of variations. By this type of contract,

(1) The bidding and contracting can be done before all the detail engineering is completed, and time will be saved.

(2) Competitive bidding can be adopted, which results in lower price for construction.

Of course, it is essential that only competent and financially sound contractors should be invited for bidding because the contractor's responsibility is mainly based on a lumpsum.

Further, since the project is for the modernization of existing facilities, close coordination between PPSA and the contractor selected for execution of the works is very important.

For the construction, it must be noted that it is necessary to shut down the Unit for as short a time as possible. Therefore, modification works such as civil, building and installation work during the operation of the Unit are inevitable. No damage to the existing operating plant can be allowed, and special measures are required in the works to prevent fire and explosion in the operating Unit. In the planning, one important means to minimize the field work is to arrange for pipings to be prefabricated in the shop contractor's shop before installation.

8.2.4 Operation

(1) Preparation of Precommissioning and commissioning sequences

For the construction, a critical path method (CPM) schedule will be prepared by the contractor, however, for precommissioning and commissioning, a CPM chart shall be prepared by PPSA for completion within the shortest feasible time period.

(2) Coordination with utility section

It is important to coordinate with the utility section especially before the precommissioning because supply of required utilities must be sufficient and stable for precommissionning and commissioning of the modernized Unit. Unexpected emergency shut-down must be avoided for smooth operation.

(3) Operation manuals

Since the implementation of the modernization will be carried out by the leadership of PPSA, revision of the plant operating manual to suit the operation after modernization shall be done by PPSA. This shall be prepared well in advance of the precommissioning to give enough time for the operators to study the manual.

(4) Training for DCS will be described in section 8.4.

8.3 Suitable Organizational and Administrative Arrangement

8.3.1 General

For the implementation of a project, an organization appropriate to the size of the project and method of implementation shall be established in the light of other work volumes and responsibilities of PPSA. In the existing organization of PPSA, power plant and distillation units are separated. Accordingly, for the implementation organization of the modernization also, it will be appropriate to set up two different organizations, one for No.1 Crude Distillation Unit and another for the Power Plant.

In this section, studies will be made for the organization for the modernization of No.1 Crude Distillation Unit as a typical case. A similar organizational arrangement for the modernization of the Power Plant will be required in actual implementation, in consideration of its difference from the No.1 Crude Distillation Unit and of the split of responsibilities and scope of works within PPSA, as explained in the paragraph above.

8.3.2 Organization and job description

In establishing the organization for carrying out the modernization of No.1 Crude Distillation Unit, important elements are:

(1) Project management, for the execution of the works and for adhering to the pre-determined costs schedule;

(2) Design and engineering functions to carry out the works keeping quality and cost in mind, because they will be

within the responsibility and scope of PPSA themselves;

(3) Technical coordination among various stages and categories of the works;

(4) Procurement function to carry out all the procurement works.

(5) Coordination with general administration and accounting of PPSA.

A proposed organization for the implementation of the projects by PPSA is depicted in the attached Figures 8-2-1 and 8-2-2.

(1) Project management

The project management team is very crucial for attaining the goals of the project as described at the outset of this chapter, namely, quality, schedule, cost and safety. Normally, a project manager, assistant project manager and project engineer will be assigned for the project management, depending on the size of the project. Taking into consideration the implementation method and magnitude of the modernization of No.1 Crude Distillation Unit, one project manager plus one project engineer who supplements the project manager and whose functions are mainly in the project control, will be sufficient.

The project manager shall be responsible for all the activities of the project, with respect to the management of PPSA. Day-to-day works will be performed by the project member assigned to him, but he shall direct and supervise them in order for the project to reach the established targets and goals. The project engineer shall assist the project manager mainly in the function of schedule control, cost control, and contract or purchase order administration, with the cooperation of schedule and cost engineer(s).

Key functions of the different disciplines organized and working under the project management are further explained below:-

(2) Engineering Disciplines

Since all the basic and detailed engineering will be performed by PPSA, there should be an engineering team which can carry out the basic and detailed engineering of various disciplines as shown in the organization chart. In addition to the specialists for different disciplines in sufficient numbers, an engineering coordinator (very often also called by the name of engineering manager) shall be assigned to coordinate interfaces of different disciplines and to;

- Monitor the design for progress input to the scheduling engineer
- Monitor the design for cost input to the cost engineer
- Coordinate with the operation department to reflect their requirements in the operation of the renovated plant.

Further, for the procurement of equipment, the engineering team shall undertake;

- Preparation of technical specifications
- Technical evaluation of bids
- Provide technical review of the manufacturer's design

(3) Purchase

In addition to the procurement and placement of orders described in Section 8.2.2, the procurement work involves;

- Coordination for review of the design by manufacturers
- Expediting of the manufacturing of the items supplied
- Inspection of the equipment manufactured in the factories

Review of the design will be done by the engineering team, however, expediting and inspection shall be performed by the Purchase team. For the timely completion of the modernization, timely expediting is crucial. Such actions as weekly expedition by telephone, monthly factory visit and preparation of expediting reports shall be taken. Inpection by PPSA in the manufacturers' factories can be done by PPSA's engineers when there is enough of their time resource available, or otherwise, it can be contracted to third party inspection firm(s).

(4) Schedule and Cost Engineer

A schedule engineer and a cost engineer are assigned for monitoring the schedule of implementation and costs of the project. Very often, only one engineer is assigned for these two functions, depending on the capability and experience of the assigned personnel.
The functions are;-

- Monitor and report on the design, procurement and construction schedule
- Studies/Recommendations for improving schedule
- Man-power/Performance evaluation
- Review all Contracts, and make any necessary change orders prior to approvals

- Review Estimates
- Monitor committed costs; purchase orders, contracts, etc
- Analize and report on controls and forecasts
- Coordinate with PPSA accounting and administration

(5) Construction Team

In addition to the functions of cost and schedule monitoring as mentioned above, PPSA function is limited to the following areas, since construction will be carried out by construction contractor(s). Please note that although it is obligatory for each contractor to have its own safety officer, PPSA should also have one assigned particularly for this modernization and his authority must be sufficient to prevent any accident;

1) Quality Assurance

- Assure contractor's work, NDT test records, examination so that results comply to job specifications, drawings, and codes
- Conduct and record Quality Control Audit of QC program
- Issue non-conformance reports for corrective actions
- Provide technical guidance as necessary for improving quality problem areas
- Assist shop inspectors as required

2) Safety Officer

- Conduct safety audits
- Coordinate with refinery tie-ins/hot work permit
- Liaison with refinery regulations
- Jobsite security management
- First aid/medical management

3) Material Control

- Coordinate transportation/customs/bonded storage procedures
- Monitor protective storage for equipment and commodities
- Assist in confirming costs so that purchase orders can be closed.

(6) Operation Supervisor

- Coordinate with the design team and construction team for incorporating the opinions and philosophy of the operating department.
- Coordinate with the operation team for pre-commissioning and commissioning

Figure 8.3-1 RECOMMENDED OWNER'S ORGANIZATION – ENGINEERING/PROCUREMENT PHASE
MODERNIZATION OF NO.1 DISTILLATION UNIT

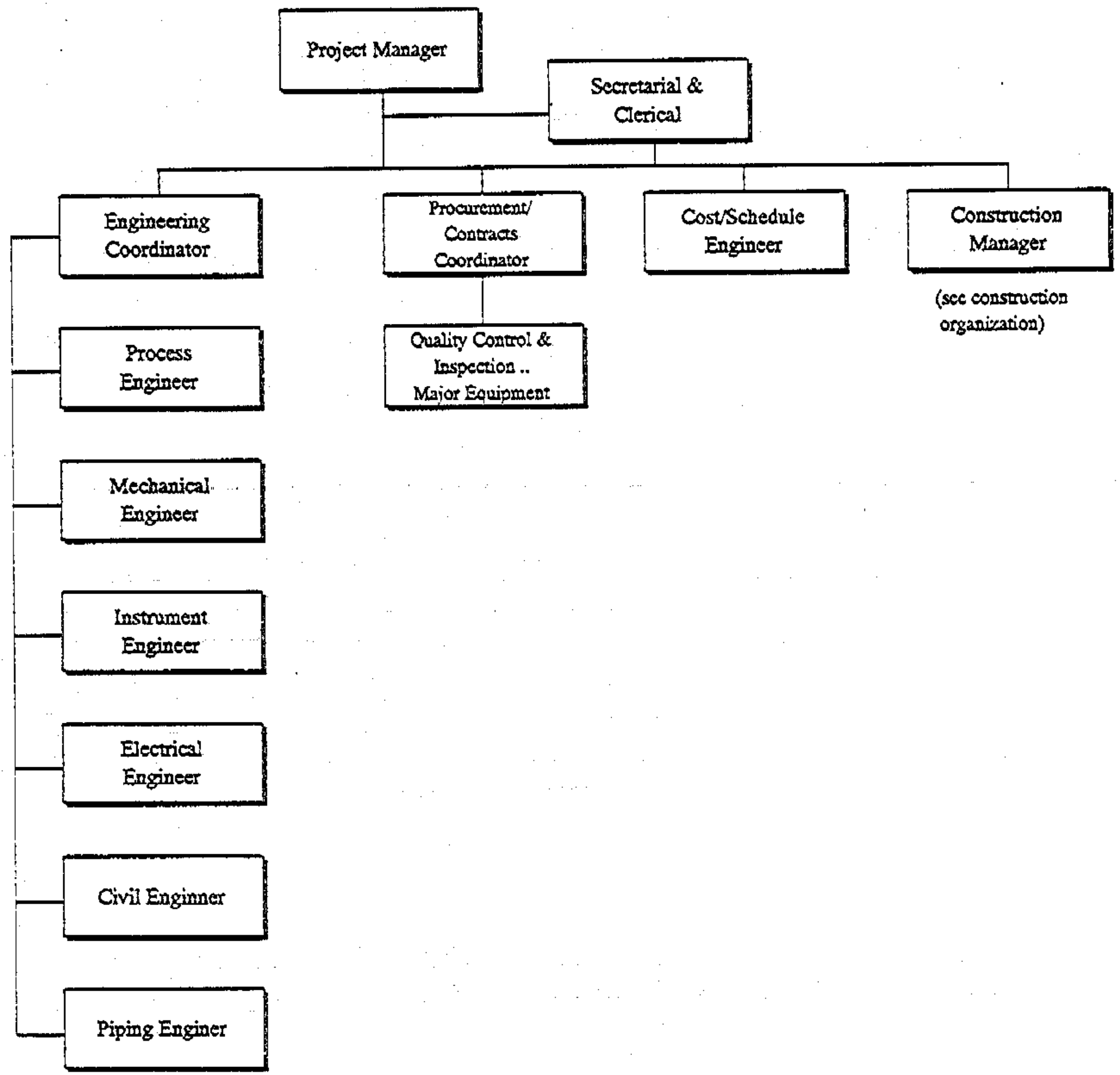
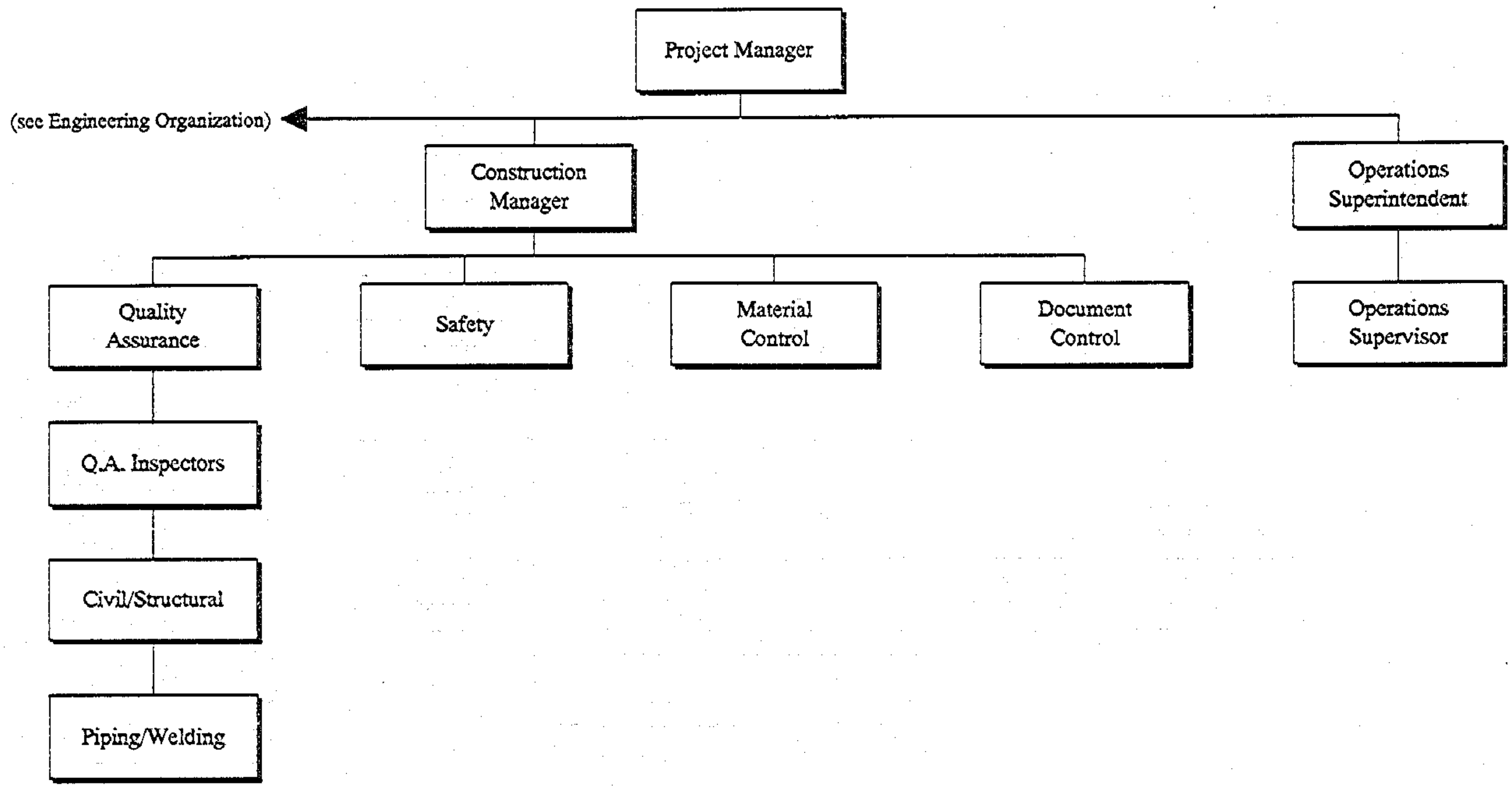


Figure 8.3-2 RECOMMENDED OWNER'S ORGANIZATION – CONSTRUCTION PHASE
MODERNIZATION OF NO.1 DISTILLATION UNIT



8.4 Staffing Requirements and Training Facilities and Programs

8.4.1 Staffing requirements

Since these projects are modernization, no additional man-power will be required after the completion of modernization. The staffing and organization are discussed in chapter 3 and chapter 5.

8.4.2 Training facilities

Since PPSA has been operating and maintaining the existing facilities for a long period of time, and this project involves only modernization of the facilities, no particular training will be required other than in the area of distributed control system (DCS).

With regard to DCS, it is quite helpful that the operational personnel be adequately trained on the system before the system is applied to the actual control of the facility. However, operators will not be required to be trained for the system configuration.

As the first stage, it is important that one or two persons from the refinery should attend the manufacturer's software configuration training courses for in-depth studies into the system's configuration. It is recommended that Personnel with a basic understanding of personal computers and the refinery process attend such courses.

Those personnel who attend the system configuration course shall train the operating persons. Training must be developed to meet the facility's specific DCS requirements. Therefore, it is also recommended to install the new DCS at as early stage as possible before precommissioning in the existing control room, so that operators will be accustomed to the operation of DCS on the actual configuration.

Operator training should include the following:

- General explanation of the system hardware
- Definition of terms associated with the DCS
- Explanation of the operational platform (the mechanical flow sheet graphics)
- How controllers and indicators are accessed
- How alarms are displayed and acknowledged
- How shutdown and start-up procedures are to be performed
- How to start and stop equipment with the system
- How to recognize system malfunctions

Typically, some one week courses at the facilities, with the DCS, is an effective method.

Chapter 9

Financial and Economic Evaluation and Overall Justification of the Project

Contents of Chapter 9

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Chapter 9 Financial and Economic Evaluation and Overall Justification of the Project

9.1 Financial Evaluation of the Projects for the Modernization of No.1 Crude Oil Distillation Unit(CDU) and Thermoelectric Power Plant

9.1.1 Review of financial status of PPSA

PPSA is not only the biggest refinery, but also the top industrial producer in Poland in terms of gross sales. The refinery has both fuel and petrochemical profiles. The company has an approximately 710 hectare plant site area and its total employees number about 8,500 including 1,368 technicians and engineers as of November, 1993.

PPSA's major corporate financial profile in recent three years is summarized as follows:

(Unit: 1,000 US$)

Item	1991	1992	1993
Fixed assets	554,016	442,876	459,523
Annual sales	2,098,237	2,551,187	2,447,021
Annual net profit	20,942	128,587	140,930

Source: PPSA
Note: Exchange rate used: 1991= Zl. 11,100/US$,
1992= Zl. 15,300/US$, 1993= Zl. 21,500/US$

The present Study is confined in its scope to the modernization of No.1 CDU which produces intermediate products fed to other plants for further treatment, and the Thermoelectric Power Plant which supplies utilities like electricity and steam to the whole complex.