2.9 Environment Situation of PPSA

2.9.1 Environmental administrative structures

The environmental administrative structures in Poland are divided into the following three levels of management.

(1) Central (National)
(2) Provincial
(3) Local (Town, village, commune)

PPSA is under direct supervision of a state inspectorate as well as a provincial inspector with regard to environmental management.
For implementation of environmental regulations, PPSA is first to abide by the national legislations, then to follow the regulations by the provincial and local authorities, which are commonly much more stringent taking into account the special local environmental circumstances.

The major activities of the state environmental protection inspectorate are to control emission of pollutants by taking individual measurements and through monitoring (usually parallel measurement and monitoring are conducted by the companies to be inspected for mutual data comparison), who also have authority to punish with infringement of fines against the environment violations or send a motion to the public prosecutor's office and ask for opening an inquiry.

They also calculate and collect fees and fines, control the observation of environmental regulations, prepare plans of tasks in the field of environmental protection in the province, including investments and the management of the provincial environmental protection fund.

If the enterprises emit the pollutants more than the allowable values into the air, the following penalty are imposed.

(1) Payment of fines (for the amount exceeding the defined quantities) which are ten times higher than normal fees.

(2) Close down of the plant or a part of it

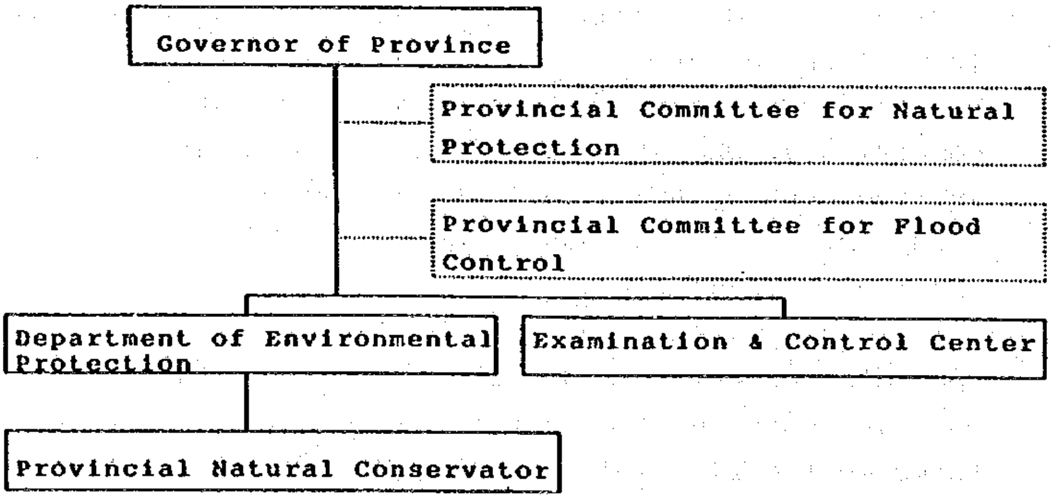
Since 1991, the environmental activities are reorganized on a double structure as shown in the followings.

(1) The chief inspector of environmental protection assisted by the office of the state environmental inspectorate.

(2) The provincial inspector of environmental protection assisted by the provincial environmental inspectorate.

Figure 2.9-1 shows organization of provincial environmental protection

Figure 2.9-1 ORGANIZATION OF PROVINCIAL ENVIRONMENTAL PROTECTION



Source: OECC

2.9.2 Legislation and regulations

(1) National legislation

The allowable concentrations and allowable downfall to the earth of polluting substances are legislated by the decree of Ministry of Environmental Protection, Natural Resources and Forestry, (Quality & emission standards).

(2) Provincial regulations

The allowable amount of the emitted substances is regulated by provincial government, (Emission standards).

Corporate bodies or people engaged in economic activities are obliged to obtain from the local provincial authority for environmental protection "Allowable emission values". The revised regulations will be enacted on 1994 and on and after 1998, in which the further reductions of allowable emission levels are projected.

The following tables show the agreements between PPSA and Plock province for allowable pollutant emissions and the real emission values including noise.

Table 2.9-1	General Agreement Between PPSA & Plock for Total Allowable Pollutant Emission Values
Table 2.9-2	Air Pollution Emission of Different Emission Sources of PPSA (1993)
Table 2.9-3	Facility-Wise Contribution to Emissions of PPSA (1993)
Table 2.9-4	Noise Limit and Emission Value in PPSA

Table 2.9-1 shows that SO_2, H_2S, benzene, methanol, aliphatic and aromatic H/C exceeded allowable emission values in respect to air and no infringement items except Phenol in respect to water in 1993.
Table 2.9-2 and Table 2.9-3 show pollutant emission quantities in each equipment and each emission ratio to total emission, so that the contribution to the environmental effects of each unit can be estimated in view of environmental management.

Table 2.9-1 GENERAL AGREEMENT BETWEEN PPSA & PLOCK FOR TOTAL ALLOWABLE POLLUTION EMISSION VALUES

(1) Air

(ton/year)

Pollutant	Allowable Emission Value		Real Emission Value		
	→end of 1993	Jan. 1.1994→	1991	1992	1993
SO_2	53,209	35,082	▨ 58,650.13	48.113.86	43.144.23
NO_2	9.108	7,857	5.404.52	5,867.28	6.616.39
CO	42,870	2,630	9,586.17	7.354.07	3.002.64
Dust	1,468	483	489.26	411.09	376.49
Silicon Dust	662	632	288.26	452.90	507.71
H_2S	101	19	83.84	65.36	48.95
Benzene	32	11	23.95	▨ 47.52	26.24
Ethylene Oxide	32	32	12.77	10.36	12.18
Cumene	16	16	NA	NA	▨ 30.74
Phenol	8	1.5	▨ 14.05	1.20	2.06
Toluene	44	37	10.47	29.75	35.12
Ethylene Glycol	61	60	31.66	18.99	18.37
Methanol	0.1	1	▨ 10.13	▨ 10.07	▨ 10.67
Ethylene+Propylene	975	990	NA	NA	718.54
CS_2	18	20	▨ 33.49	14.11	5.74
Aliphatic H/C	6.446	3.188	▨ 7.003.45	6.172.30	5.200.90
Aromatic H/C	309	288	▨ 846.19	▨ 784.32	▨ 1,019.26

(Note) Desulfurization unit for a feed line on FCC and for exhaust gas of Power Station will be installed in near future

▨ shows substances exceeding allowable emission value

(2) Water

1) Allowable and real Pollutant Emission Values in PPSA (1993)

	Item	Allowable Value		Real Value
		Winter season (11/1-3/31)	Summer season (4/1-10/31)	
1	Flow(m^3/d)	87,000	87,000	51,192
2	COD(mg/l)	230	210	122
3	SS (mg/l)	80	75	58
4	Phenol(mg/l)	0.3	0.2	0.02
5	Ether extract(mg/l)	16	14	3.8
6	pH	6.3-9.0	6.5-9.0	7.6-8.2

2) Allowable and Real Pollutant Emission Values of Industrial Sewage System-1 & 2 at Inlet of the Treatment System (1993)

	Sewage	Item	Allowable Value	Real value
1	Industrial sewage system-1	pH	6.8-8.7	5.6-9.8
		COD (mgO$_2$/l)	180-760	576
		Sulfides (mgS/l)	1.1-510	9.8
		Phenol (mg/l)	0.1-1.5	▨ 16.5
		Hydrocarbon(mg/l)	10-1847	137
		SS (mg/l)	60-409	139
		Total flow (m^3/h)	1300-2000	1148
2	Industrial sewage system-2	pH	7.2-9.0	6.2-10.2
		COD (mgO$_2$/l)	180-8600	2780
		Sulfates (mgS/l)	2.8-308	34
		Phenol (mg/l)	1.4-42	9.4
		Hydrocarbon(mg/l)	43-550	68.0
		SS (mg/l)	63-160	86
		Total flow (m^3/h)	250-320	248

Note) ▨ shows substances exceeding allowable emission value

Table 2.9-2 AIR POLLUTION SOURCES OF DIFFERENT EMISSION SOURCES OF PPSA (1993)

(ton/year)

	SO_2	NOx	CO	H_2S	CS_2	Dust	Total
1. Refinery Processes							
1.1 Fuels Operations							
Distillation unit I	1078.7	87.2	3.4	7.2			1,176.5
Distillation unit II	2094.7	214.2	30.4	7.9			2,347.2
Distillation unit III	2665.8	232.7	31.9	15			2,945.4
Distillation unit IV	626	60.6	6.8	3			696.4
Slop oil distill. unit	0.1	0.5	0.05	0.05			0.7
Cat. cracker unit I	383.8	204.8	577.2	1		180.1	1,346.9
Cat. cracker unit II	3360	778	1539			327.6	6,004.6
HF alkylation unit		1.7					1.7
Reformer unit I	416.9	46.4	10.7				474.0
Reformer unit II	571.7	10.3	33.8				615.8
Reformer unit III	560.3	3.8	28.6				592.7
Reformer unit IV	513.6	72.2	19.9				605.7
Arom. extraction unit	23.6	3.5	4.7				31.8
P-xylene unit	6.2	0.9	1.2				8.3
Sulphur recovery unit	738.3	2.8	25.8	10.7	5.7		783.3
1.2 Lube Oil Operations							
Futural extraction unit	255.5	38.3	25				318.8
Dewaxing unit							0.0
Hydro finishing unit	46.9	7	1.3				55.2
Asphalt blowing unit	40.4	2.5	64.2				107.1
2. Petrochemical Works							
Polyethylene units I+II							0.0
Polypropylene units I							0.0
Polypropylene units II							0.0
Ethylene oxide/Glycol unit I							0.0
Ethylene oxide/Glycol unit II							0.0
Ethylene cracker unit I		30	191.5				221.5
Ethylene cracker unit II	0.3	253.2	181.6				435.1
Phenol/Acetone unit							0.0
(Sub total 1+2)	(13,382.8)	(2,050.6)	(2,777.05)	(44.85)	(5.7)	(507.7)	(18,768.7)
3. Utilities							
Power plant	29392.8	4497.4	190.8			277.25	34,358.25
Cooling towers							0.0
Waste water treatment	349	60.5	37.4			99.2	546.1
4. Offsites							
Gasoline blending							0.0
Lube oil blending							0.0
Railway exp. ref. prod. & crude oil							0.0
Export tasc. ethylene							0.0
Olefin/LPG export							0.0
Pyrol. gasoline							0.0
Benzene/Butadiene		7.5					7.5
Sum	43124.6	6616	3005.2	44.85	5.7	884.15	53,680.55

Source: PPSA

Table 2.9-3 FACILITY-WISE CONTRIBUTION TO EMISSIONS OF PPSA(1993)

Area/Process	Contribution to emissions (%)				
	SO_2	NOx	CO	H_2S	Dust
1.1 Crude oil distillation 1	2.51	1.32	0.12	16.06	-
1.2 Crude oil distillation 2	4.86	3.24	1.02	17.62	-
1.3 Crude oil distillation 3	6.19	3.52	1.07	33.45	-
1.4 Crude oil distillation 4	1.46	0.92	0.23	6.69	-
2.1 Reformer 1	0.97	0.71	0.36	0.0	-
2.2 Reformer 2	1.33	0.16	1.13	0.0	-
2.3 Reformer 3	1.30	0.06	0.96	0.0	-
2.4 Reformer 4	1.19	1.1	0.67	0.0	-
3.1 FCC 1	0.89	3.1	19.21	2.23	20.37
3.2 FCC 2	7.8	11.76	51.22	0.0	37.06
4 Sulphur recovery unit	1.7	0.05	0.86	23.86	-
5 Waste water treatment plant	0.8	0.92	1.25	0.0	11.22
6.1 Ethylene cracker 1	0.0	0.46	6.38	0.0	-
6.2 Ethylene cracker 2	0.0	3.83	6.05	0.0	-
7 Other	0.9	0.95	3.12	0.09	-
8 Total process unit	31.9	32.1	93.65	100.0	
9 Power plant	68.1	67.9	6.35	0.0	31.35
10 Total PPSA	100.0	100.0	100.0	100.0	100.0

Source: PPSA

Note : Emission quantities of heavy metals in PPSA are as follows V:28.0, Ni:9.6, Cr:0.49, Pb:0.07, Cd:0.0043 (tons/year)

Table 2.9-4 NOISE LIMIT & EMISSION VALUE IN PPSA

(1)Distillation unit No.1

(Unit:dB)

	Measuring point	Evaluation of Noise		dB/A	
		Calculation	Standard	Actual	per STD
1	Control room	57	70	62	75
2	Cloak room	50	70	55	75
3	Dining room	52	70	57	75
4	Desalination unit	88	80	79	85
5	Start point of trench	72	80	77	85
6	Pump station	86	80	90	85
7	End point of trench	66	80	70	85
8	Leaching unit	64	80	69	85
9	Slop tank No.14	65	80	69	85
10	Slop tank No.2 & 4	63	80	68	85
11	Utility pump station	83	80	68	85
12	Switch station	64	80	69	85
13	Colums & racks	77	80	82	85
14	Foreman room	54	70	59	75
15	Exchangers & coolers	75	80	79	85
16	Heater Pc-1	96	80	101	85
17	Vacuum distillation	77	80	82	85
18	Heater Pc-2	92	80	97	85
19	Process pump station	86	80	91	85
20	Utility pump station	79	80	84	85

(2)Power plant & Water system-1

	Measuring point	Evaluation of Noise		dB/A	
		Calculation	Standard	Actual	per STD
1	Control room	58	70	63	75
2	Labour room	60	70	66	75
3	Ion exchangers	66	80	71	85
4	Waste neutralization	61	80	66	85
5	Laboratory	54	70	59	75
6	Regeneration,2.5mH	71	80	76	85
7	Heated tanks	84	80	89	85
8	Work shop	59	80	64	85
9	SWD hall,0mH	50	80	55	85
10	SUH hall,0mH	62	80	67	85
11	Cistern loading	57	80	62	85
12	SDW hall,3.2mH	85	80	90	85
13	Office room	53	80	58	85
14	Pumps & tanks	84	80	89	85
15	Heating	56	70	61	75

(3)Boiler unit of power plant

	Measuring point	Evaluation of Noise		dB/A	
		Calculation	Standard	Actual	per STD
1	Boiler No.1, 0mH	72	80	77	85
2	Ditto , 7mH	76	80	81	85
3	Ditto ,14mH	78	80	83	85
4	Ditto ,23mH	82	80	87	85
5	Boiler No.2, 0mH	72	80	77	85
6	Ditto 7mH	76	80	81	85
7	Ditto 14mH	78	80	83	85
8	Ditto 23mH	82	80	87	85
9	Boiler No.5, 0mH	71	80	76	85
10	Ditto 7mH	76	80	81	85
11	Ditto 14mH	76	80	81	85
12	Ditto 35mH	78	80	83	85
13	Boiler Burners,7mH	76	80	81	85
14	Ventilators&pumps,0mH	82	80	87	85
15	Cleaning stand	76	80	81	85
16	Pump station	80	80	85	85
17	Crane car	76	80	81	88
18	Communication levels	-	-	-	-

(4)Machine department

	Measuring point	Evaluation of Noise		dB/A	
		Calculation	Standard	Actual	per STD
1	Control room No.1	57	70	62	75
2	Control room No.2	59	70	64	75
3	Control room No.3	62	70	67	75
4	Control room No.4	62	70	67	75
5	Sound proof cabin,1&2	68	70	73	75
6	Sound proof cabin,3	72	70	77	75
7	Sound proof cabin,4	64	70	69	75
8	Sound proof cabin,5&6	82	70	87	75
9	Sound proof cabin,7	73	70	78	75

Source: PPSA

2.9.3 Waste water treatment system of PPSA

The existing system was installed and expanded in accordance to the then prevalent national and local regulations up to the current system as shown in the Figure 2.9-2.

Since the quality of waste water is closely related to the inlet water quality of the Vistula River, the current water quality of the river is shown in Table 5.5-4 and summarized in Table 2.9-5.

The outlet water quality after being treated by the water treatment system in PPSA, reportedly, has better quality than the water quality of the inlet water.

Figure 2.9-2 SCHEMATIC FLOW DIAGRAM OF
WASTE WATER TREATMENT FACILITY

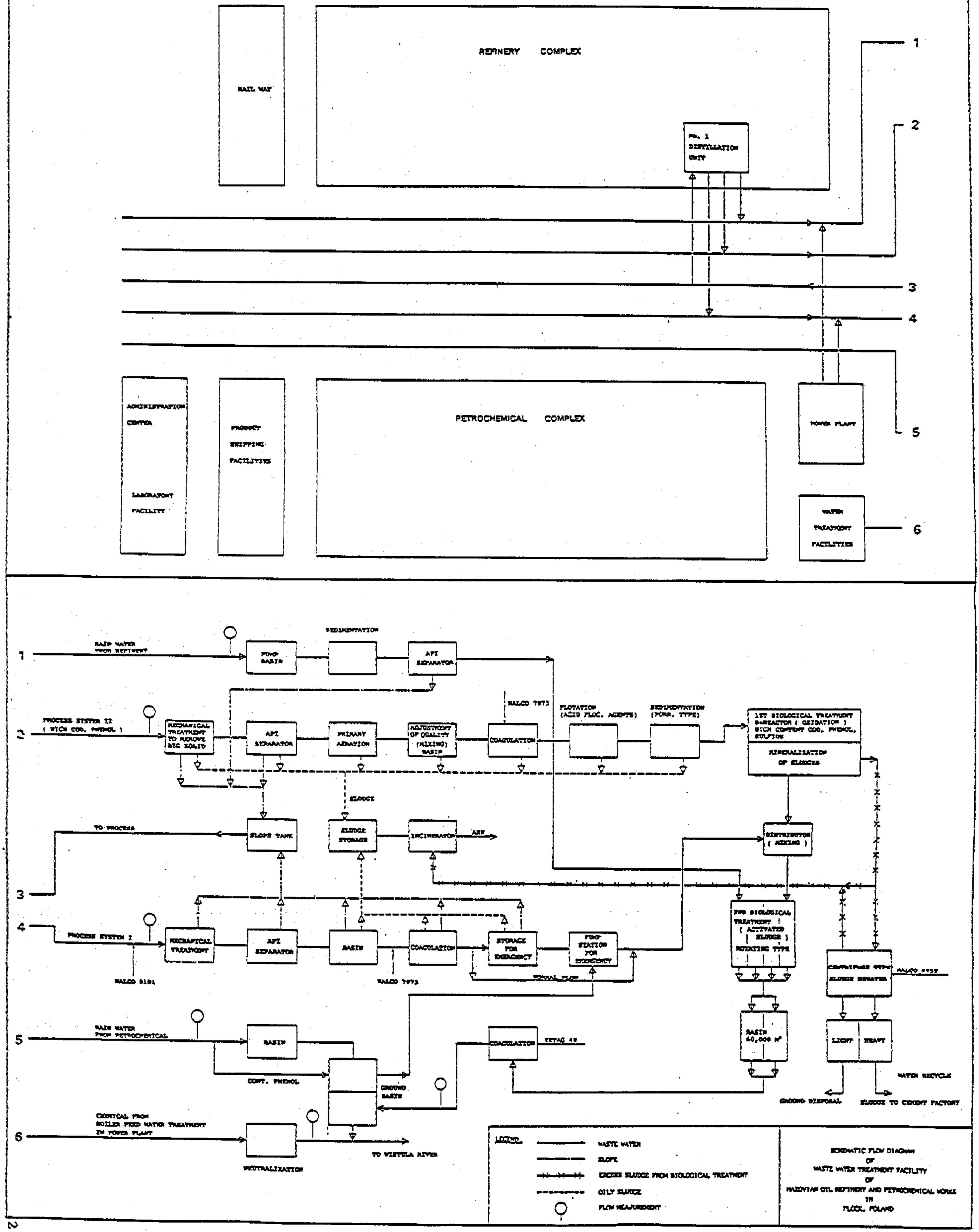


Table 2.9-5 INLET WATER QUALITY OF PPSA

Item	Unit	Inlet water quality		
		Minimum	Maximum	Average
Mudiness		13	55	36
Chromaticity	mgPt/l	19	66	35
pH		7.6	8.9	8.2
Total hardness	mVal/l	9.9	15.8	13.2
Ca	mg/l	66	116	91.5
Mg	mg/l	6.8	24.2	12.8
Fe	mg/l	0.225	0.85	0.56
Mn	mg/l	0.17	0.46	0.31
Na	mg/l	25	116	55.4
K	mg/l	3	5.7	4.4
Cl	mg/l	45	164	99.9
NH4	mg/l	0.13	5.9	1.73
COD (Cr)	mg/l	28	89.6	58.8
Oily substance	mg/l	0.15	1.1	0.45
SS	mg/l	15.3	36.9	25.2
Residue on evaporation	mg/l	355	702	468

Source: PPSA

2.9.4 Monitoring system

Since very near to PPSA there is Plock city in the south-east side as well as specially protected area in both side of the Vistula River in the south-west side, the environmental authority in Plock province imposes the strict environmental regulations on PPSA.

For the purpose of monitoring environmental conditions around PPSA, there are 10 monitoring points controlled and managed by PPSA and Plock province as shown in Figure 2.9-3, among them there are two automatic stations for the measurement of instantaneous pollution concentration connected by telephone cable to a central monitoring station as shown in Figure 2.9-4.

Average daily results of measurement of SO_2 were below allowable limit at all of the measuring points in 1992 and except No.4 location (Company's Dispensary) in 1993 as shown in Table 2.9-6 and average daily H_2S concentration sometimes exceed allowable standard value as shown in Table 2.9-7.

As shown in Table 2.9-6, 2.9-7 and Figure 2.9-6(1), the annual trend of environmental pollution in Plock city has shown steady improvement during these several years, and it is believed that all of the environmental quality standards including H_2S will be perfectly cleared in Plock city in the near future.

Table 2.9-6 AVERAGE DAILY SO_2 CONCENTRATION IN 1992 & 1993

No	Location	No. of Measurement			Measurement													
					0-10%NDS		10-20%NDS		20-50%NDS		50-75%NDS		75-100%NDS		<100%NDS		
		1990	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993	1990	1992	1993
1	Murzynowo	319	357	290	300	278	36	6	9	6	7	0	5	0	20	0	0
2	Chelpowo	244	360	294	292	237	54	34	12	22	2	1	0	0	0	0	0
3	Residential District	359	231	293	222	251	8	22	1	18	0	2	0	0	0	0	0
4	Company's Dispensary	358	359	355	261	247	69	39	28	54	1	9	0	3	5	0	3
5	Stara Biara	324	362	295	280	244	62	30	20	20	0	0	0	1	0	0	0
6	Trzepowo	358	258	295	234	252	19	27	5	16	0	0	0	0	0	0	0
7	Nieglosy	355	221		221		0		0		0		0		0	0	
8	Scoczewka	243	356	233	306	205	36	10	14	14	0	4	0	0	2	0	0
	Total	2570	2504	2055	2116	1714	284	168	89	150	10	16	5	4	27	0	3

(source) PPSA

(Note) NDS: Maximum allowable concentration by regulations
75 microgram/m³ for location 1&8
200 microgram/m³ for location 2-7

Table 2.9-7 AVERAGE DAILY H_2S CONCENTRATION IN 1990, 1992 & 1993

No	Location	No. of measurement			No. of trespass of NDS (%)		
		1990	1992	1993	1990	1992	1993
1	Chelpowo	244	359	295	13.5	6.7	8.1
2	Residential District	359	231	295	15.6	2.6	3.7
3	Company's Dispensary	358	360	357	15.6	2.2	5.3

(source) PPSA

(Note) NDS: Maximum allowable concentration by regulations
5 microgram/m³ for location 1&8

Figure 2.9-3 MONITORING POINTS FOR AIR POLLUTANTS AROUND PPSA

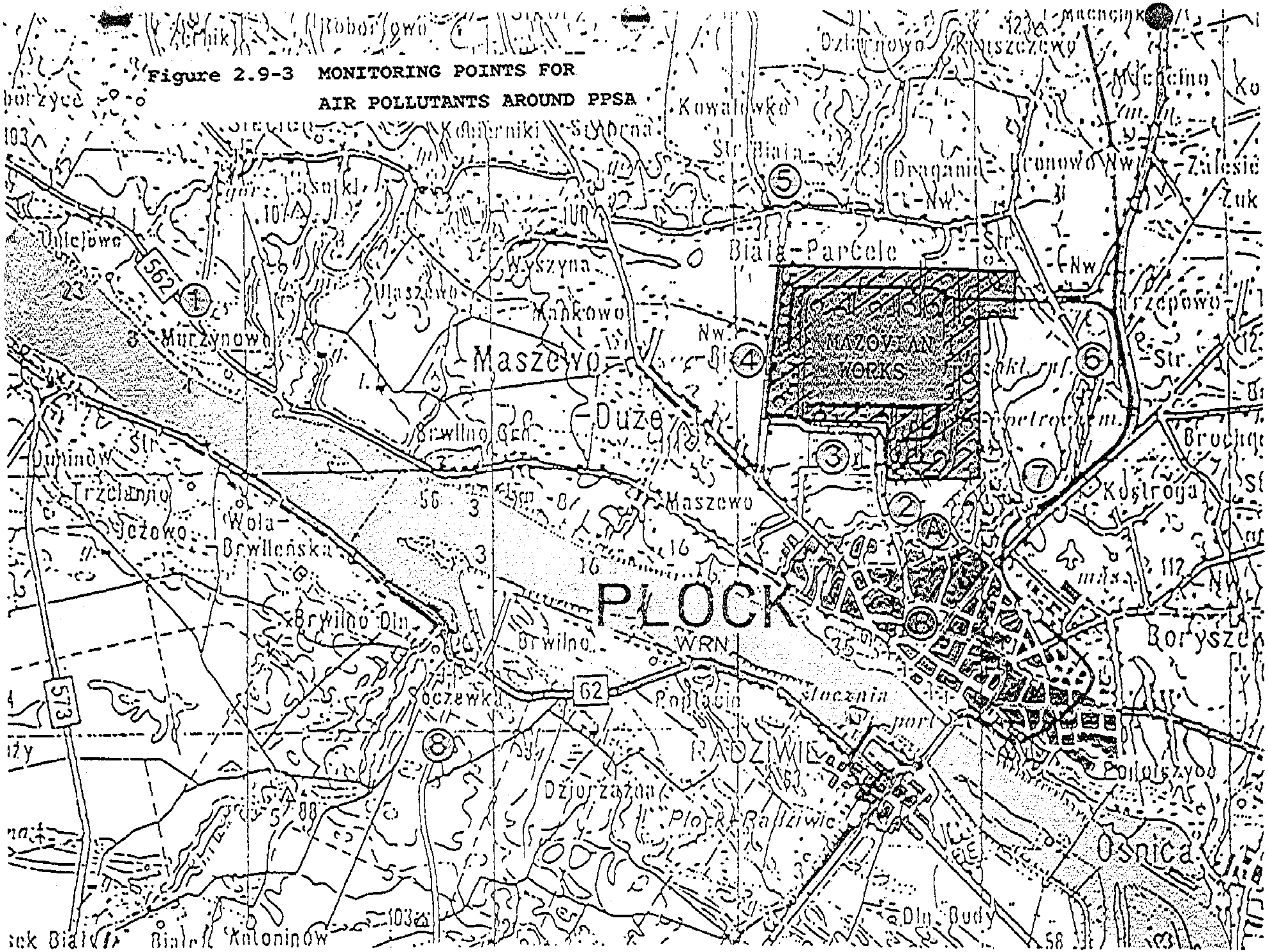
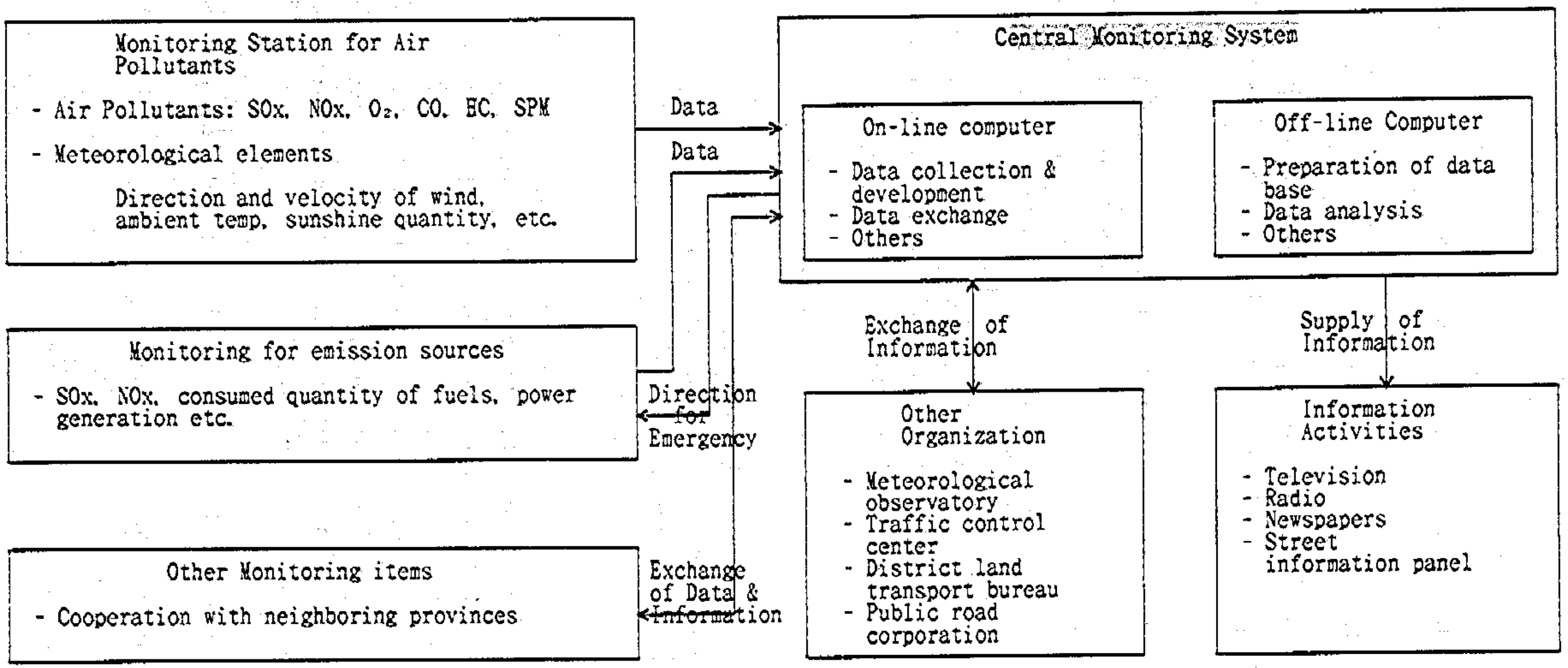


Figure 2.9-4 MONITORING SYSTEM FOR AMBIENT AIR



Source: PPSA

2.9.5 Environment measurement procedure

(1) SO_2

As for sampling methods, there are no problems on sampling position, collecting tube and duct in view of comparison with JIS.

On analyzing method, MADUR GA-60, an equipment made in Poland, is used. Although this method is good at measuring several items during the shorter time, it is necessary to confirm the accuracy of the measured values by conducting the parallel measurement either with manual analysis such as Titration Method or Absorption Method, or with continuous analysis by employing an equipment to be calibrated by standard gas.

In the case of JIS, the following methods are employed.

- Neutralization Titration Method
- Precipitation Titration Method
- Tubimetric Method

(2) NOx

As in the case of SO_2, there are no problems on sampling position, collecting tube and duct in view of comparison with JIS.
Regarding analyzing method, MADUR GA-60 is also used. Similar to the case of SO_2, it is necessary to confirm the accuracy of the measured values by employing either manual analysis or continuous analysis.

In the case of JIS, the following methods are employed.

- Zn-MEDA Method
- PDS Method

(3) CO

There are no problems on sampling position, collecting tube and duct in view of comparison with JIS.

MADUR GA-60 is also used for analyzing procedure.

It is also necessary to confirm the accuracy of the measured values by employing either manual analysis such as Gas-Chromatography or continuous analysis. Since GC-TCD is equipped in the laboratory, several times of parallel measurement using this equipment will be good enough to confirm accuracy of the measured values.

2.9.6 Environmental management system

Around the end of 1992, environmental evaluation and its protection action were the main subject for discussion on the board of PPSA. After detailed evaluation for environmental protection task and duty, they have decided the new organization consisting of Environment Inspection Section and Environment Protection Section as shown in Figure 2.9-5.

Duty of Environment Inspection Section is to evaluate influence of production units against environment, which will be conducted by direct measurement and analytical investigation, while Environment Protection Section assembles experts who are responsible for advancement in the following environmental protection.

- Air
- Soil and underground water
- Greens and waste management

Environment Protection Section is also responsible for preparing the balance sheets of economic outcome of environmental activities.

Table 2.9-8 shows 17.2 billion zl for fines of emission excess produced by PPSA in 1992, while fees are approx 93 billions in 1992, so that PPSA paid 110 billion zl. (¥550 million) as penalty for emission of pollutants.

The total quantity of pollution emission as well as pollutant per unit of crude oil in PPSA has a reducing trend as shown in Figure 2.9-6(1) & (2), accordingly with result of very slight increase of total fees as illustrated in Figure 2.9-7.

Table 2.9-8 FINES OF EMISSION EXCESS FOR PPSA

(1) Air

(Unit: Zloty)

No.	Unit	Amount		
		1990	1991	1992
1	FCC 1	17,314,379.3		
2	FCC 2	10,355,865.0	12,271,234,780	16,210.790.200
3	Reforming 1	-	804,427,488	494,151,800
4	Reforming 2	355.6	-	-
5	Reforming 3	5,161,612.0	-	-
6	Reforming 4	6,249,120.0	-	-
7	HF Alkylation	-	434,016	-
8	Phenol & Acetone	-	807,840	464,227,200
9	Power Plant	-	-	33,628,800
10	Noise	-	-	65,887,800
	Total	39,081,311.9	13,076,904,124	17,268,685,800

Source: PPSA

(2) Water

1990 : 210,297,600 Zl
1991 : 726,723,000 ZL

Figure 2.9-5 ORGANIZATION CHART OF ENVIRONMENTAL PROTECTION

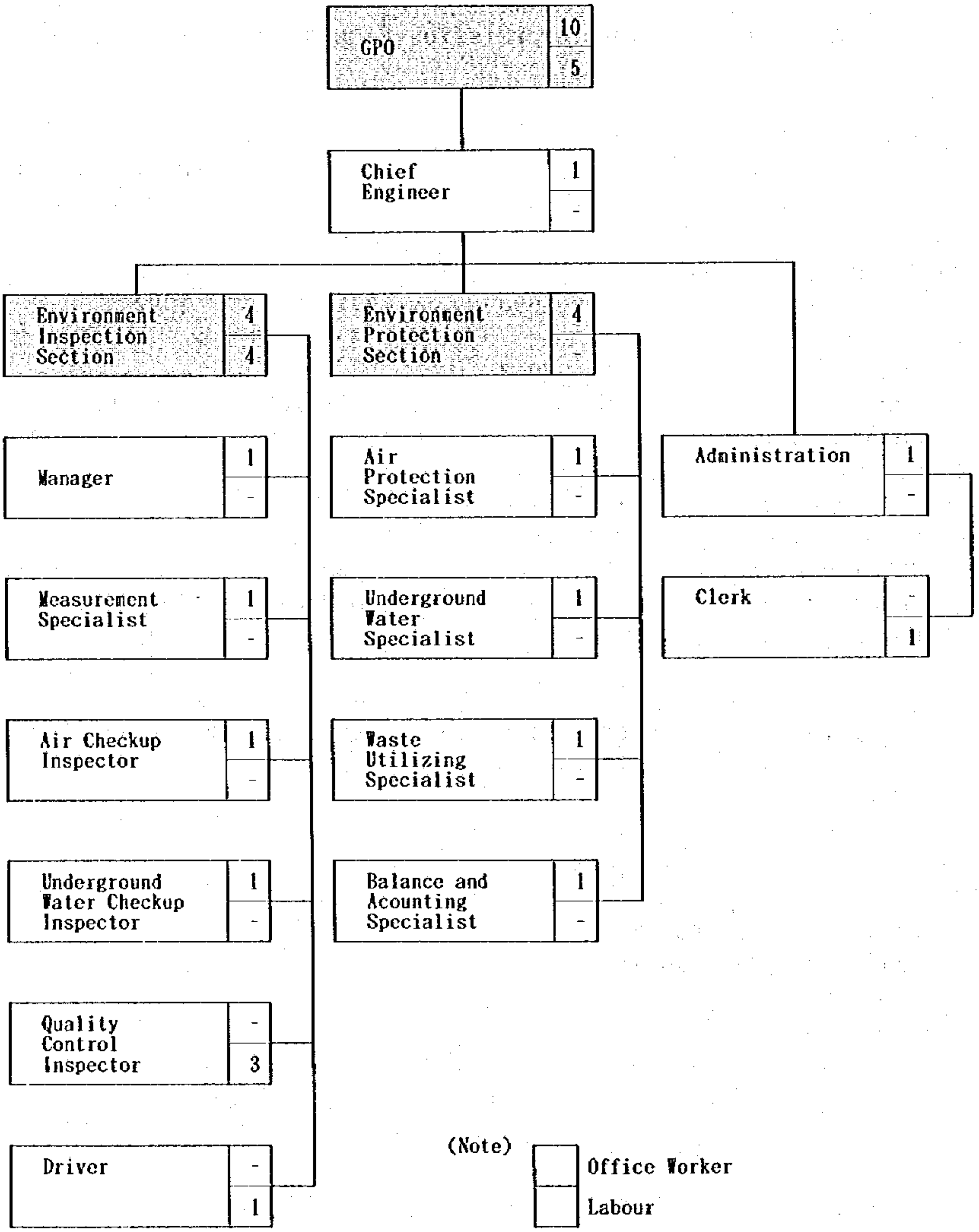
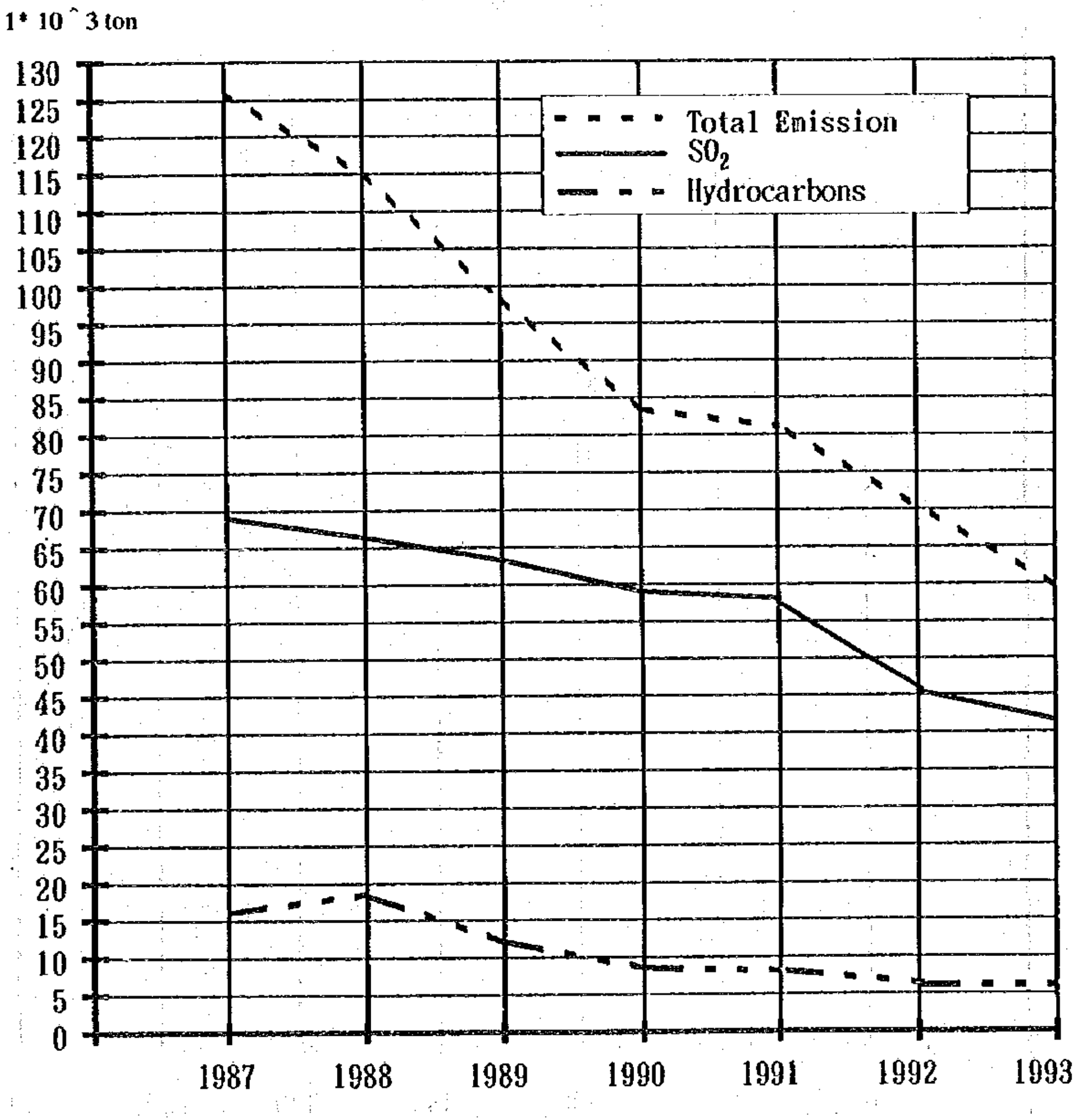
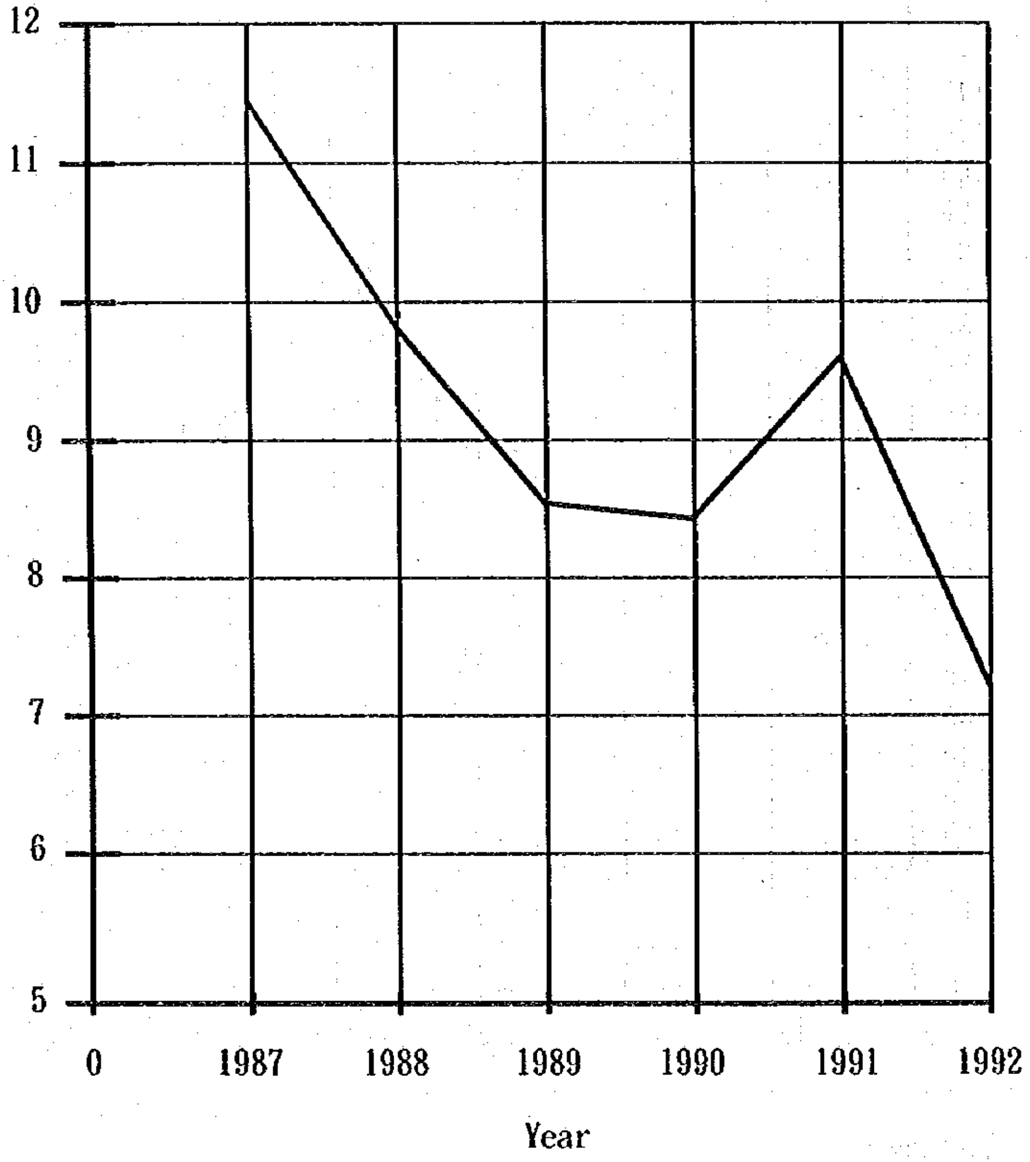


Figure 2.9-6(1) PLOCK REFINERY POLLUTION EMISSION



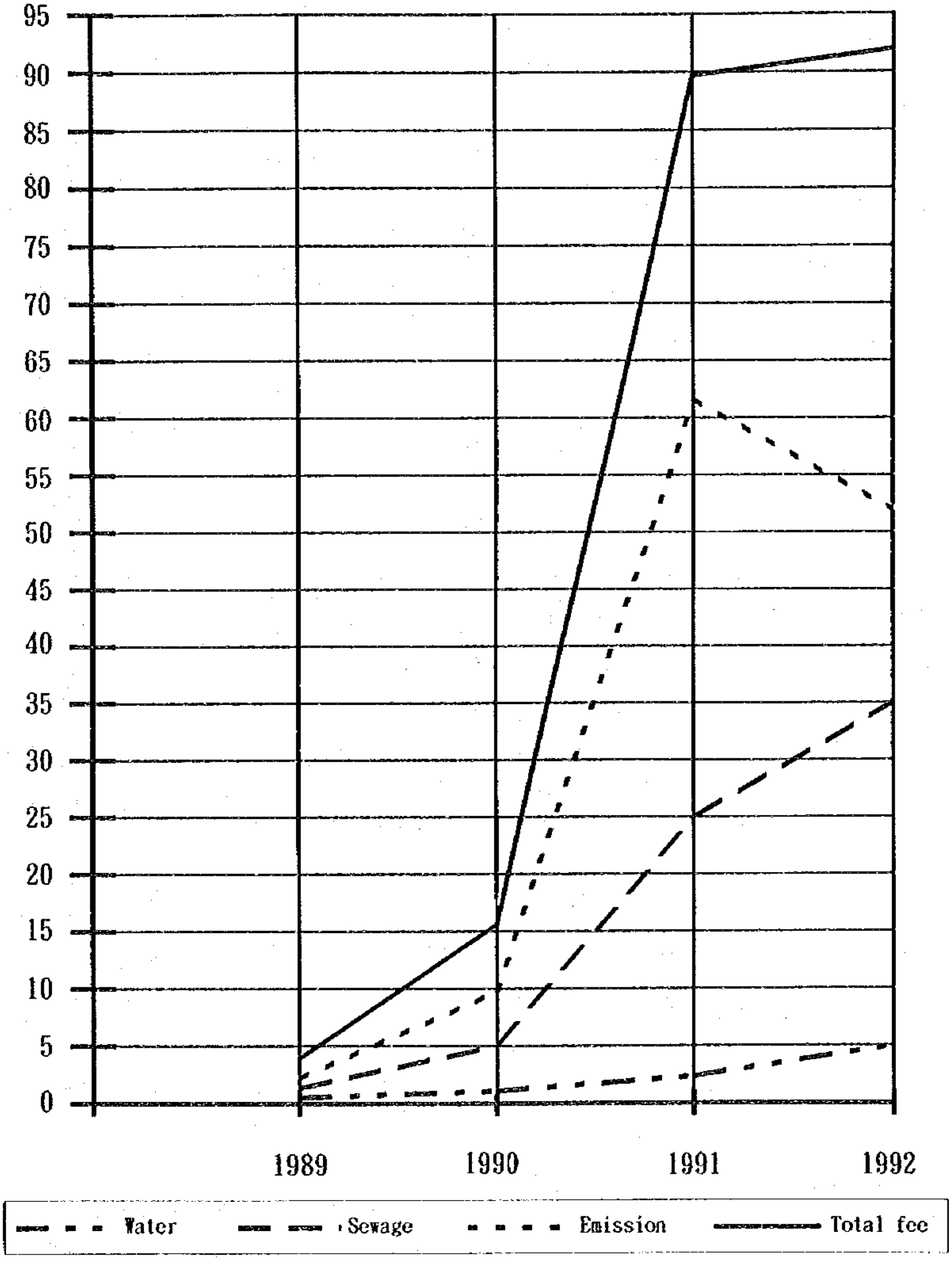
Source: PPSA

Figure 2.9-6(2) POLLUTION EMISSION INDEX, kg PER 1 ton OF PROCESSED CRUDE OIL



Source: PPSA

Figure 2.9-7 FEE FOR ENVIRONMENTAL CONSUMPTION



Source: PPSA

Values for 1992 are assumed only - there aren't data for 4th quarter

Chapter 3

Diagnostic Review of the No.1 Crude Oil Distillation Unit

Contents of Chapter 3

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Chapter 3 Diagnostic Review of the No.1 Crude Oil Distillation Unit

3.1 Outline of No.1 Crude Oil Distillation Unit and Modernization Plan of PPSA

3.1.1 Process of No.1 crude oil distillation unit (Refer to Figure 3.1-1)

(1) Throughput

No.1 crude oil distillation unit consists of No.1 atmospheric distillation unit and No.1 vacuum distillation unit which is designed to charge 100% Ural crude oil. The design throughput is 308 t/h.
However, No.1 atmospheric distillation unit can be charged 308 t/h by bypassing some atmospheric residue to No.1 vacuum distillation unit, which means the throughput of No.1 vacuum distillation unit is balanced to the throughput of 288 t/h of No.1 atmospheric distillation unit in case of no bypass.

(2) No.1 Atmospheric Distillation Unit

After being fed to heat exchangers where crude oil is heated by products, crude oil is fed to the desalters (Eh-1 and Eh-2) where salt contamination in the crude oil is reduced.
Thereafter, desalted crude oil is heated by heat exchangers and fed to the preflash column (W-1), where A10 containing gas, LPG and naphtha are extracted from the top of W-1.
A10 is fed to the other plant for further treatment.
Oil from the bottom of W-1 is heated by a heater (Pc-1) to the designated temperature and fed to the atmospheric distillation tower (W-2).
Products such as A11, A12, A13, A14, A15 and A16 are extracted from the W-2.
A12, A13, A14, A15 and A16 are fed to the stripper (W-3) to

adjust product properties, then run down to product tanks after passing through heat exchangers.

(3) No.1 Vacuum distillation unit

Bottom oil from W-2 is fed to the heater (Pc-2).
After being heated to the designated temperature, the bottom oil is fed to the vacuum distillation tower (W-7) which is maintained under vacuum.
Vacuum products such as P11, P12, P13 and P14 are extracted from the W-7.
P11 is distillated from the upper part of the W-7 and used as diesel oil for the lighter fraction and lubricant oil for heavier fraction.
P12, P13 and P14 are introduced to the stripper (W-8) to adjust product properties and stored in tanks as feed oil to the lubricant oil plant.

Bottom oil from W-7 is used as feed oil to the asphalt plant and as fuel oil in the refinery.

3.1.2 Current situation of waste water treatment (Refer to Figure 4.6-1)

The waste water is generated from the following equipment in No.1 crude oil distillation unit:

(1) Desalters (Eh-1 and Eh-2)

(2) W-1 overhead receiver (Od-1)

(3) W-2 overhead receiver (Od-2)

(4) W-7 overhead receiver (Od-8)

(5) Heat exchangers (During periodical maintenance)

(6) Blow down system

This waste water from the blow down system is connected to the refinery waste water treatment system I or to a slop tank (Zb-3).
Waste water recovered in Zb-3 is separated in the oil separator (Zm-1, Zm-2 and Zm-3) where water and oil are separated.
Water separated in the oil separator is fed to the refinery waste water treatment system I and the recovered oil is charged to the No.1 crude oil distillation unit.

The waste water is not treated in the area of No.1 crude oil distillation unit and connected to the refinery waste water treatment system II by underground pipe lines.
After being treated at the refinery waste water treatment unit, the water is discharged to the Vistula River.

3.1.3 Current situation of flue gas

Flue gas is generated from the following equipment in No.1 crude oil distillation unit:

(1) No.1 Atmospheric distillation unit heater (Pc-1)

(2) No.1 Vacuum distillation unit heater (Pc-2)

(3) No.1 Vacuum distillation tower overhead receiver (Od-8)

(4) Slop tank (Zb-3)

Isoflow type is applied for both Pc-1 and Pc-2 and each heater has its own independent stack.

Refinery gas together with component of heavy fuel oil without vanadium are used as fuel for both heaters.
No flue gas desulfurization plant for the heaters exists or is planned so far.

3.1.4 PPSA's Modernization plan of No.1 crude oil distillation unit

PPSA has a modernization plan as follows;

(1) Increase of No.1 vacuum distillation unit throughput up to the level of No.1 atmospheric distillation unit

(2) Construction of stabilization unit for A10 fraction

(3) Construction of rectification unit (Splitter)

(4) Decreasing of atmospheric distillation product number

(5) Improvement of heat exchange between product and crude oil

(6) Improvement of process heaters efficiency by means of utilization of flue gas heat for air preheating

(7) Improvement of vacuum fraction

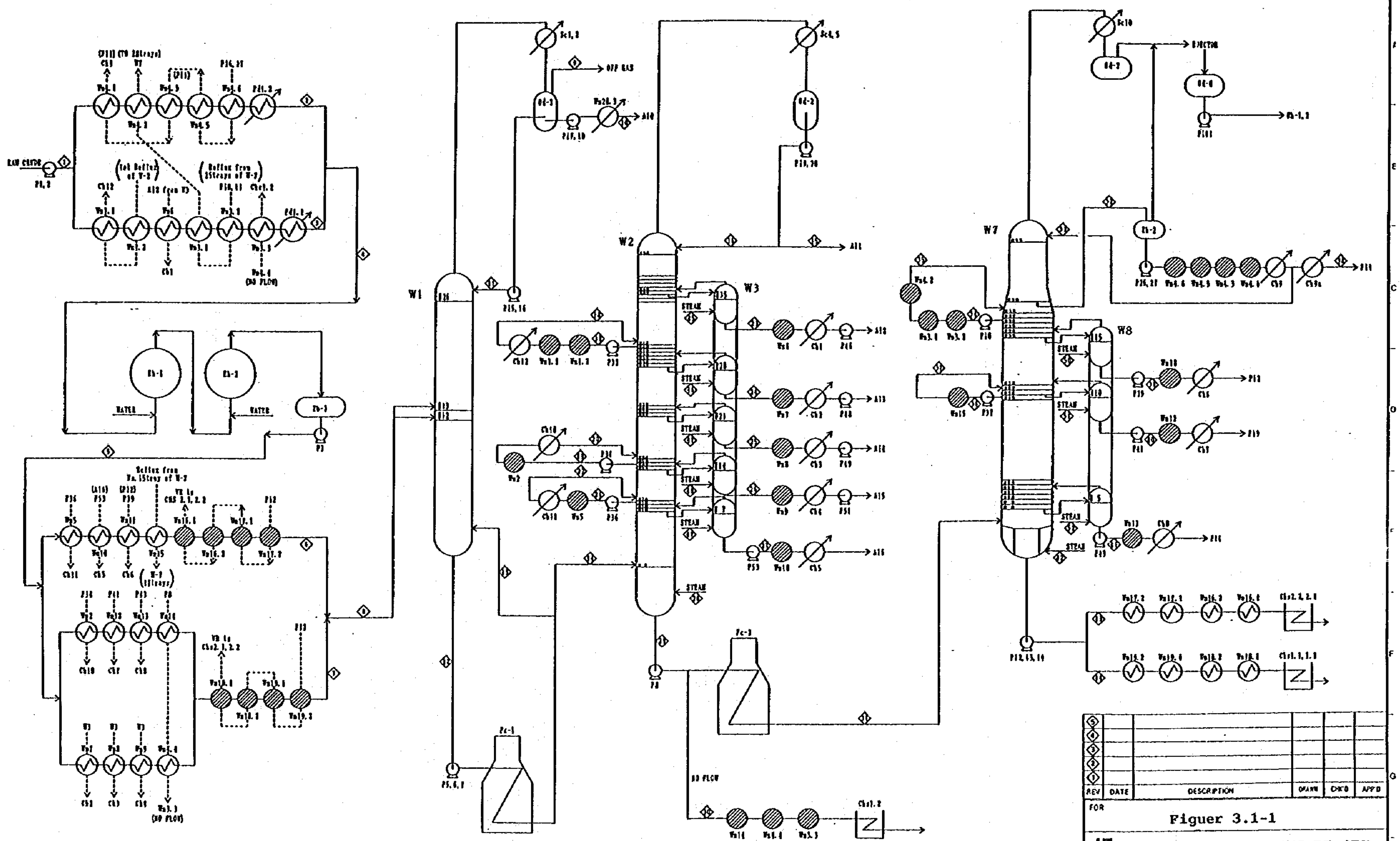
(8) Revamping of electrodehydrators

(9) Box water coolers liquidation

(10) The liquidation of Od-8 and Zb-3 emissions

(11) Application of DCS

The Refinery's modernization plan above shall be reflected in the JICA Team's study.
In addition to the refinery's original plan, Item (11)- application of DCS - was requested for the JICA Team to study during the first field survey.



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FOR

Figuer 3.1-1

IDEMITSU ENGINEERING CO., LTD.

TITLE
PFD OF NO.1 CRUDE OIL
(DISTILLATION UNIT IN)
MAZOVIAN REFINERY

DRAWN	SCALE	JOB NO.	
CHK'D	DATE	DWG NO.	3.1-5
APP'D			

3.2 Simulation of the Existing No.1 Crude Oil Distillation Unit

For diagnosing the existing No.1 crude oil distillation unit, it is necessary to know the operation conditions of No.1 crude oil distillation unit when it is operated as designed by charging the Ural crude oil.
For this purpose, a simulation model was designed by using a computer simulation program, PROCESS by inputting actual operation data, such as flow rate, temperature, pressure and analysis data of No.1 crude oil distillation unit collected on 26 November 1993 (hereinafter referred to as the DATA).

Many of the process plants in operation today have been designed and commissioned by using PROCESS.
PROCESS is presently installed on more than 250 in-house computers with a world-wide user base of over 800 companies.

3.2.1 Purpose of the simulation of the existing No.1 crude oil distillation unit

The design of a simulation model has the following purposes;

(1) to diagnose the operating conditions of No.1 crude oil distillation Unit.

(2) to design the simulation model after the modernization by inputting new conditions to be applied after the modernization.

3.2.2 Design of the simulation model of the existing No.1 crude oil distillation unit

(1) Base data used to design the simulation model

To design the simulation model of the existing No.1 crude oil distillation unit, the following data were applied:

1) PFD was drawn based on the current P & ID (Refer to Figure 3.1-1.)

2) Characteristics and properties of Ural crude oil (Refer to Tables 3.2-1 and 3.2-2)

3) Current products specification (Refer to Table 3.2-3)

4) Equipment Data (Refer to Table 3.2-4)

(2) Assumptions

In order to design the simulation model, the following assumptions were made:

1) Crude oil for the study shall be Ural crude oil only, of which characteristics and properties are indicated in Table 3.2-1 and 3.2-2.

2) There is no deterioration of the existing equipment and materials. Namely, the existing equipment and materials shall be able to continue mechanically sound operation with their design characteristics.

3) Amended operation DATA

Basically, all the DATA are inputted to the simulation model.
However, as discussed in Paragraph 3.3.2, all the DATA were reviewed and found that there are some discrepancies or

inconsistencies in the DATA.

The inputted data for the simulation model were amended where there is discrepancies or inconsistency in the DATA as explained below:

(Refer to Figure 3.3-1 as for the number.)

(a) Inlet and outlet temperature of heat exchangers located from P1 to Eh-1

* DATA inputted to the simulation program

-Temperature : P1 discharge (No.1)
Eh-1 inlet (No.5 and No.7)
Shell inlet of heating liquid

-Flow : Shell side of heating liquid

* Data obtained by the simulation program

-Overall Heat Transfer Coefficient of Heat Exchangers

-Outlet temperature of Heating Liquid

(b) Inlet and outlet temperature of heat exchangers located from Eh-2 to W-1

* DATA inputted to the simulation model

-Temperature : Eh-2 outlet (No.12)
W-1 inlet (No.18 and No.29)
Shell inlet of heating liquid

-Flow : Shell side of heating liquid

* Data obtained by the simulation model

Overall Heat Transfer Coefficient of Heat Exchangers

Outlet temperature of Heating Liquid

(c) Inlet and outlet temperature of coolers

There are some unreasonable DATA in temperatures for Ch-1 and Ch-7 (Outlet temperature is higher than the inlet one).

For the purpose of the feasibility study, the simulated temperatures for these coolers' inlets are used and the measured outlet temperature is used for simulation input.

(d) Analysis data for the distillation of W-1 and W-2 bottom oil

Regarding the analysis data of distillation of W-1 and W-2 bottom oil, it seems that these two oils have almost the same property if the test method for the distillation is the same. It never happens in this process.

Since the distillation data of W-2 bottom oil seemed to be based on the data of 10 mmHg of ASTM D 1160 while that of W-1 bottom oil seemed to be based on the data of 760 mmHg of ASTM D 1160, the distillation data of W-2 bottom oil was inputted to the simulation program based on the data of 10 mmHg of ASTM D 1160. As a result, the output of the simulation for the distillation of the other intermediate products is consistent with the analyzed distillation DATA.

Therefore, the distillation data of W-2 bottom oil is regarded as the data based on the 10 mmHg of ASTM D 1160.

During the third field survey, PPSA reported that both data were based on 10 mmHg of ASTM D 1160 and the both oils were sampled at the drain valves of the bottom oil level gauge of W-1 and W-2 since there are no proper sampling points. It is estimated that the similar analysis data would be obtained due to the such improper sampling.

During basic design, it is required to sample the two bottom oils at the right points and design a new simulation model.

(e) Flow of W-1 bottom oil

Flow rate of W-1 bottom oil to W-2 was 230 t/h by the DATA and 247.36 t/h by the calculation of the material balance.

The value obtained from the calculation of material balance (247.36 t/h) was applied for the simulation model.

4) Assumed data

Since there were some points which were not recorded on 26 November 1993, the following data were assumed and used as the data for the simulation model;

(a) The Bottom temperature of W-7

The Bottom temperature of W-7 was assumed to be 340°C and was obtained from the simulation model.

(b) The run down temperature of VR

The run down temperature of VR was assumed to be 130°C for fuel oil blend.

(c) Overall heat transfer coefficient (U value) for Wm-14, Wm-4.4 and Wm-3.3

Since there were no flow of W-2 bottom oil on 26 November 1993, it is impossible to calculate the U value.

U value of 251 x 10^3 $J/m^2 \cdot h \cdot {}^\circ C$ was assumed.

(d) Penetration of VR

The penetration of the VR does not indicate the definite value in the DATA. (Refer to Item 5.7.6 in Table 3.3-7.)

Therefore, the VR yield from W-7 was maintained as the same as it is now, that is, the penetration of VR is

the same as the present value.
The penetration of VR will be adjusted at the asphalt blowing unit as processing now.

3.2.3 Procedure for designing the simulation model of the current No.1 crude oil distillation unit

The following procedures are followed to build up the simulation model of the current No.1 crude oil distillation unit.

(1) Calculation of theoretical plate numbers of W-1, W-2 and W-7

Theoretical plate number of W-1, W-2 and W-7 is calculated by the simulation program until the simulated product properties becomes similar to the actual one analyzed on 26 November 1993.

(2) U value for the heat exchangers

Since there are discrepancies and inconsistencies in the DATA, it is impossible to use all the DATA for estimating U value for the heat exchangers.
Therefore, the operation data described in 3.2.2 is used.
For the run down temperature, the value of DATA was inputted to the simulation model.

3.2.4 The Result of the Simulation

The Result of the simulation is summarized in Table 3.2-5.

3.2.5 Evaluation of the simulation output

The simulation output is evaluated as follows:

(1) W-1 (Preflash column) overhead system pressure

There are unreasonable DATA in the pressure of the W-1 overhead system which means the pressure of Od-1 (W-1 overhead receiver) is higher than that of W-1 top.

The following DATA were inputted to simulate the pressure around W-1.

* Flow rate of A10
* Temperature of W-1 top
* Temperature of Od-1

The simulation results are shown in Table 3.2-6.

The simulated values seem to be more reliable because there is no reverse in the pressure of W-1 top and Od-1.

Table 3.2-6 COMPARISON OF THE DATA AND SIMULATED VALUES FOR W-1 OVERHEAD

	The DATA (MPa)	Simulated Values (MPa)
Od-1	0.29	0.17
W-1 Top	0.28	0.24
W-1 Bottom	0.37	0.25

(2) W-2 overhead system pressure

There are unreasonable DATA in the pressures of the W-2 overhead system.
If the temperature of Od-2 (W-2 overhead receiver) is 70°C and its pressure is 0.0 MPa as indicated in the DATA, theoretically, it is impossible to control the pressure of Od-2 because A11 fraction will vaporize completely.
Therefore Od-2 pressure is assumed to be 0.04 MPa by the simulation model which is more probable.
Table 3.2-7 shows the comparison of the DATA and simulated values.
Judging from the property of A11 Fraction, the simulated values seem to be more probable.

Table 3.2-7 COMPARISON OF THE DATA AND ESTIMATED VALUES FOR W-2 OVERHEAD

	The DATA (MPa)	Estimated Values (MPa)
Od-2	0.0	0.04
W-2 Top	0.014	0.051
W-2 Bottom	0.071	0.07

On 30 June 1994, the pressure of Od-2 was 0.03 MPa. It is impossible to compare these data simply because the operating conditions would have been different from that of 26 November 1993.
(No.1 crude oil distillation unit was periodically shut down in May/June 1994.)
The pressure would be influenced largely by the temperature of the cooling water used.

(3) The outlet temperature of Pc-1

1) The difference between the DATA and the simulation

The DATA indicates that Pc-1 outlet temperature is 330°C. However, the temperature of 320°C which was obtained by the simulation is more probable because of the following reasons:

(a) Gap between A16 and atmospheric residue(AR) (Refer to 3.5.1)

Table 3.2-8 shows the gap between A16 and AR.

Table 3.2-8 SIMULATED GAP BETWEEN A16 and AR

Pc-1 Outlet Temp.	320°C	330°C
Gap	-53°C	-22°C

The gap of -22°C in Table 3.2-8 is not realistic in W-2.

(b) Furthermore, when the outlet temperature of Pc-1 is 320°C, the simulation result for the distillation of 95% of A16 and 5% of AR are near to the actual analysis result.

2) Check of the temperature record

The outlet temperature of Pc-1 is a very important point because of its heat duty, namely, the throughput of the No.1 crude oil distillation unit (Refer to Table 3.2-9). Therefore, it was recommended to check the instrument for measuring outlet temperature of Pc-1.

During the second field survey, the accuracy of the thermocouple was checked and the result was as follows:

(a) The accuracy of the instrument
PPSA checked the accuracy of the thermocouple.
The temperature error was within 1°C.

(b) Review of the record sheet
PPSA and JICA Team reviewed the actual record sheet on 26 November 1993 on which the Pc-1 outlet temperature is recorded.
PPSA and JICA Team reached the conclusion that the outlet temperature of Pc-1 ranged from 319°C to 323°C. An error in reading the temperature would be the main cause for this.

Therefore the temperature of 320°C was applied for the outlet temperature of Pc-1 in the simulation model of the existing No.1 crude oil distillation unit.

Table 3.2-1 PROPERTIES OF URAL CRUDE OIL (1/2)

Analysis of Ural Crude Oil to be used for the Modernization Study of NO.1 Crude Unit and Vacuum Unit

DESCRIPTION	UNIT	VALUE
1. Density d^{20}_{4}		0.860
API		32.3
2. Water Content	Wt %	0.23
3. Chloride Contents	mg/l	13
4. Distillation		
IBP	°C	45
Evaporated at 100°C	Vol %	10.5
150°C		19.5
200°C		28.0
250°C		30.0
300°C		47.0
350°C		61.0
5. Sulfur Content	Wt %	1.39
6. H_2S Content(Dissolved)	Wt %	
at 20 °C		nil
50 °C		nil
7. Viscosity		
at 10°C		20.36
20°C		13.33
37.8°C		7.64
50°C		5.84
8. Freezing Point	°C	-15
9. Pour Point	°C	-12

Table 3.2-1 PROPERTIES OF URAL CRUDE OIL (2/2)

DESCRIPTION	UNIT	VALUE
10. Conradoson Carbon Residue	Wt %	3.80
11. Metal Content		
V	mg/kg	36
Ni		13
Fe		20
Na		2
K		below 0.5
Ca		below 0.5
12. Asphaltene	Wt %	1.21
13. Ash	Wt %	0.014
14. Wax Content	Wt %	2.57
Melting Point	℃	53
15. Acid Number	KOH/g	0.06
16. Reid Vapor Pressure	Pa (Kg/cm²)	392(0.4)
17. Watson K Factor		11.79

Table 3.2-2 TBP DISTILLATION OF URAL CRUDE OIL

	TBP ℃	Yield on Crude		Yield on Crude		Density D^{20}
		Wt %	Cum Wt %	Vol %	Cum Vol %	
0		1.52	1.52	2.28	2.28	0.557
1	20 - 32	1.43	2.95	1.93	4.21	0.614
2	32 - 62	1.51	4.46	1.93	6.14	0.650
3	62 - 72	1.58	6.04	1.93	8.07	0.683
4	72 - 87	1.64	7.68	1.91	9.98	0.715
5	87 - 95	1.65	9.33	1.92	11.90	0.715
6	95 - 110	1.68	11.01	1.90	13.00	0.737
7	110 - 120	1.69	12.70	1.93	15.73	0.730
8	120 - 132	1.71	14.42	1.91	17.64	0.748
9	132 - 145	1.72	16.14	1.90	19.54	0.756
10	145 - 155	1.74	17.08	1.91	21.45	0.761
11	155 - 167	1.74	19.62	1.93	23.38	0.775
12	167 - 178	1.76	21.38	1.94	25.32	0.778
13	178 - 190	1.80	23.18	1.97	27.29	0.787
14	190 - 201	1.82	25.00	1.96	29.25	0.798
15	201 - 214	1.84	26.84	1.96	31.21	0.807
16	214 - 225	1.86	28.70	1.97	33.18	0.811
17	225 - 236	1.87	30.57	1.97	35.15	0.817
18	236 - 248	1.88	32.45	1.96	37.11	0.824
19	248 - 260	1.90	34.35	1.95	39.06	0.836
20	260 - 271	1.91	36.26	1.96	41.02	0.838
21	271 - 283	1.92	38.18	1.95	42.97	0.846
22	283 - 295	1.92	40.10	1.95	44.92	0.847
23	295 - 306	1.93	42.03	1.96	46.88	0.848
24	306 - 317	1.94	43.97	1.96	48.84	0.852
25	317 - 328	1.95	45.92	1.95	50.79	0.858
26	328 - 339	1.96	47.60	1.94	52.73	0.860
27	339 - 351	1.96	49.84	1.92	54.65	0.876
28	351 - 363	1.98	51.82	1.93	56.58	0.8841
29	363 - 383	1.97	53.79	1.91	58.49	0.8884
30	383 - 398	1.97	55.76	1.90	60.39	0.8920
31	398 - 414	1.97	57.73	1.89	62.28	0.8958
32	414 - 430	1.98	59.71	1.89	64.17	0.9000
33	430 - 445	1.97	61.68	1.87	66.04	0.9047
34	445 - 460	1.97	63.65	1.86	67.90	0.9094
35	460 - 475	1.95	65.60	1.83	69.73	0.9145
36	475 - 486	2.00	67.60	1.87	71.60	0.9191
37	486 - 500	1.98	69.58	1.84	73.44	0.9236
38	500 - 516	2.01	71.59	1.06	75.30	0.9278
39	516 - 531	2.00	73.59	1.85	77.15	0.9315
40	531 - 552	2.02	75.61	1.86	79.01	0.9363
41	552 - 570	2.01	77.62	1.04	80.05	0.9404
42	> 570	22.38	100.00	19.15	100.00	1.0048

Table 3.2-3 CURRENT PRODUCT SPECIFICATION (1/2)

	USE	SPECIFICATION
(1)Gases	Refinery Fuel Gas	C_4 minimum
(2)LPG	Fuel for Home	C_1+C_2 content vol % max. 1.5 C_5 content vol % max. 0.5
(3)A_{10}		Distillation IBP min. 25 ℃ FBP max. 10 8 ℃
(4)A_{11}	①Reforming Feed	Distillation IBP 78.5 ± 5 ℃ FBP 148 ± 5 ℃
	②Pyrolysis Feed	Distillation IBP 78.5 ± 5 ℃ FBP 148 ± 5 ℃
(5)A_{12}	①Reforming Feed	Distillation IBP 130 ℃ FBP 190 ℃
	②Pyrolysis Feed (USE)	Distillation IBP 130 ℃ FBP 200 ℃
(6)A_{13}	Diesel Blend	Distillation FBP 220 ℃ max. (*) % vol evaporated at 200℃ 50 % Flash Point min. 55℃ Note: (*) Only for Pyrolysis
(7)A_{14}	Diesel Blend	Distillation IBP 180 ℃ min. Density at 20 ℃ 0.810– 0.835 g/cm³ Flash Point min. 66 ℃
(8)A_{15}	Diesel Blend	Density at 20℃ 0.830– 0.850 g/cm³ % vol evaporated at 350℃ min. 87
(9)A_{16}	Diesel Blend	Density at 20 ℃ 0.850– 0.870 g/cm³ % vol evaporated at 350 ℃ min. 80

Table 3.2-3 CURRENT PRODUCT SPECIFICATION (2/2)

	USE	SPECIFICATION
(10)P_{10}	NO SIDE CUT	
(11)P_{11}	Light Fraction Diesel Heavy Fraction Lublicant Oil	Density at 20 ℃ 0.880 – 0.895 g/cm^3 Distillation(ASTM-D 2887-78) FBP max. 460 ℃ Flash Point min. 120 ℃ Freezing Point max. +8 ℃
(12)P_{12}	Lublicant Oil	Flash Point min. 120 ℃ Distillation(ASTM-D 2887-78) FBP max. 460 ℃
(13)P_{13}	Lublicant Oil	Viscosity at 100℃ 10.5 – 12.5 mm^2 / s Density at 20 ℃ 0.910 – 0.925 g/cm^3 Flash Point min. 220 ℃ Freezing Point min. 37 ℃ Distillation(ASTM-D 2887-78) IBP min. 400 ℃ FBP max. 545 ℃ FBP-IBP max. 120 ℃
(14)P_{14}	Fuel Oil Blend	Flash Point 210 ℃
(15)Vacuum Residue (Use)	• Refinery Fuel Oil • Asphalt Plant	Softening Point R-B Method 43.6 – 46.5

Table 3.2-4 EQUIPMENT DATA (1/3)

1. Heaters

NO	Description	Pc-1	Pc-2
1	Duty Gj/h		
	– Product	150	50
	– Steam	1.9	3.6
2	Type	Cylinder / Vertical	
3	Diameter m	7.6	
4	Shell Height m	29.9	
5	Burners	Vertical 16 pieces	Vertical 8 pieces
6	Flow t/h	350 ~ 420	125~ 150
7	Stack Temperature ° C	350 ~ 500	320~ 450
8	Surface Area m^2		
	1)Radiation Section	860	310
	2)Convection Section		
	– Product	1,820	650
	– Steam	59	650

Table 3.2-4 EQUIPMENT DATA (2/3)

2. Heat exchangers

	Quantity	Unit Surface Area m²	Shell Diameter				Gross Baffle Spacing	Tube Side Pass Flow Number	Material
				Length (mm)	No	OD/ID			
Wm 1.1, Wm 1.2, Wm 3.1–Wm 3.3, Wm 4.1–Wm 4.6 Wm 5, Wm 9, Wm 10, Wm 11, Wm 12	17	280	1,000	6,000	632	24/20	460	6	Carbom Steel
Wm 6, Wm 7, Wm 8	3	136	700	6,000	308	24/20	300	4	Carbom Steel
Wm 13, Wm 14, Wm 15	3	181	800	6,000	408	24/20	300	4	Carbom Steel
Wm 16.1, Wm 16.2, Wm 17.1, Wm 17.2, Wm 18.1, Wm 18.2 Wm 19.1, Wm 19.2	8	193	1,000	4,500	584	24/20	450	6	Carbom Steel
Pd 1.1, Pd 1.2	2	280	1,000	6,000	632	24/20	-	6	Carbom Steel
Sc 3, Sc 4, Sc 5 Top Bottom	3	248 265	1,200 1,200	4,500 4,500	800 854	24/20 24/20	-	2	Carbom Steel
Sc 10	6	248 265	1,200 1,200	4,500 4,500	800 854	24/20 24/20	-	2	Carbom Steel
Ch 1 – 7, Ch 10 – Ch 12	10	136	700	6,000	308	24/20	300	4	Carbom Steel
Ch 8	1	71	500	6,000	160	24/20	240	2	Carbom Steel
Ch 9	1	181	800	6,000	108	24/20	300	4	Carbom Steel
Ch S Box Type Exchanger	4	230	6,720X 4,160 H= 2,900	5,000	140	108/100			Carbom Steel

Table 3.2-4 EQUIPMENT DATA (3/3)

3. Column

		W - 1 Preflah Column	W - 2 Atmospheric Distillation	W - 3 Stripper	W - 7 Vacuum Distillation	W - 8 Stripper
Tower Diameter	mm	3,700	4,500	1,200	8,000	1,500
Tray Spacing	mm	600	750	500	750	500
Tower Height	mm	31,505	52,700	-	38,362	-
Number of Trays		26	56	7 Trays x 5 Sections	33	5 Trays x 3 Sections
Feed Tray		12/13	6	-	4	

Table 3.2-5 HEAT & MATERIAL BALANCE SHEET(1/5) (26 NOVEMBER 1993)

	Flow No.	1	2	3	4	5	6	7	8	9	1 0	1 1	1 2
	Flow (kg/h)	270 000	135 000	135 000	270 000	270 000	270 000	270 000	270 000	640	22 000	(55 000)	407 360
	Temperature(℃)	5	104	101	102	96	197	195	192	55	55	55	247
	Pressure(MPa)	1.15	0.41	0.41	0.41	2.20	—	—	—	(0.17)	1.30	1.30	(0.25)
Distillation ℃	Method	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	—	ASTM D86	ASTM D86	D1160 760mmHg
	IBP	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	—	27	27	126
	5%	(61)	(61)	(61)	(61)	(61)	(61)	(61)	(61)	—	34	34	—
	10%	(98)	(98)	(98)	(98)	(98)	(98)	(98)	(98)	—	39	39	175
	30%	(222)	(222)	(222)	(222)	(222)	(222)	(222)	(222)	—	53	53	257
	50%	(336)	(336)	(336)	(336)	(336)	(336)	(336)	(336)	—	66	66	372
	70%	(446)	(446)	(446)	(446)	(446)	(446)	(446)	(446)	—	80	80	462
	90%	(553)	(553)	(553)	(553)	(553)	(553)	(553)	(553)	—	93	93	560
	95%	(578)	(578)	(578)	(578)	(578)	(578)	(578)	(578)	—	100	100	580
	FBP	—	—	—	—	—	—	—	—	—	102	102	98% 592
	Density @20 ℃ (g/cm³)	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	—	0.661	0.661	0.889
	Vis @100℃ (cSt)	—	—	—	—	—	—	—	—	—	—	—	5.45

※ ( ):simulation value

Table 3.2-5 HEAT & MATERIAL BALANCE SHEET(2/5) (26 NOVEMBER 1993)

Flow No.		13	14	15	16	17	18	19	20	21	22	23	24
Flow (kg/h)		(230 000)	247 360	(18 360)	7 600	65 000	65 000	63 000	63 000	58 500	22 000	12 000	18 000
Temperature(℃)		(320)	(320)	70	70	148	90	223	150	230	167	129	—
Pressure(MPa)		—	0.53	—	—	0.54	—	0.48	—	0.29	—	—	—
Distillation ℃	Method	D1160 760mmHg	D1160 760mmHg	ASTM D86	ASTM D86	—	—	—	—	—	—	ASTM D86	ASTM D86
	IBP	126	126	84	84	—	—	—	—	—	—	123	152
	5%	—	—	94	94	—	—	—	—	—	—	133	166
	10%	175	175	98	98	—	—	—	—	—	—	137	173
	30%	257	257	106	106	—	—	—	—	—	—	146	185
	50%	372	372	114	114	—	—	—	—	—	—	153	197
	70%	462	462	122	122	—	—	—	—	—	—	160	206
	90%	560	560	139	139	—	—	—	—	—	—	171	221
	95%	580	580	148	148	—	—	—	—	—	—	176	227
	FBP	98% 592	98% 592	153	153	—	—	—	—	—	—	185	237
Density @20 ℃ (g/cm³)		0.889	0.889	0.736	0.736	—	—	—	—	—	—	0.764	0.797
Vis @100℃ (cSt)		5.45	5.45	—	—	—	—	—	—	—	—	—	—

※ ( ):simulation value

Table 3.2-5 HEAT & MATERIAL BALANCE SHEET(3/5) (26 NOVEMBER 1993)

Flow No.		25	26	27	28	29	30	31	32	33	34	35	36
Flow (kg/h)		16 000	22 000	17 000	1 100	144 000	—	144 000	118 500	82 500	61 000	61 000	24 000
Temperature(℃)		201	245	271	330	300	—	391	152	76	280	83	322
Pressure(MPa)		—	—	—	0.48	0.071	—	0.15	—	—	0.68	—	0.22
Distillation ℃	Method	ASTM D86	ASTM D86	ASTM D86	—	D1160 10mmHg	—	D1160 10mmHg	ASTM D86	ASTM D86	—	—	—
	IBP	158	178	159	—	127	—	127	250	250	—	—	—
	5%	179	213	238	—	—	—	—	272	272	—	—	—
	10%	191	227	258	—	186	—	186	288	288	—	—	—
	30%	220	257	297	—	277	—	277	318	318	—	—	—
	50%	236	273	316	—	368	—	368	335	335	—	—	—
	70%	248	286	332	—	480	—	480	352	352	—	—	—
	90%	264	304	85% 350	—	88% 588	—	88% 588	372	372	—	—	—
	95%	271	314	—	—	—	—	—	380	380	—	—	—
	FBP	282	323	—	—	—	—	—	384	384	—	—	—
Density @20 ℃ (g/cm³)		0.820	0.836	0.856	—	0.860	—	0.860	0.877	0.877	—	—	—
Vis @100℃ (cSt)		—	—	—	—	3.7	—	3.7	2.23	2.23	—	—	—

※ ( ):simulation value

Table 3.2-5 HEAT & MATERIAL BALANCE SHEET(4/5) (26 NOVEMBER 1993)

Flow No.		37	38	39	40	41	42	43	44	45	46	47	48
Flow (kg/h)		24 000	36 000	15 000	30 000	10 000	2 500	22 000	31 000	0	0	0	0
Temperature(℃)		230	—	220	246	254	340	(340)	(340)	—	—	—	—
Pressure(MPa)		—	—	0.50	0.36	0.37	0.57	1.40	1.40	—	—	—	—
Distillation ℃	Method	—	ASTM D86	D1160 760mmHg	D1160 760mmHg	D1160 760mmHg		TBP 760mmHg	TBP 760mmHg	—	—	—	—
	IBP	—	250	372	398	412	—	(417)	(417)	—	—	—	—
	5%	—	272	388	422	435	—	(450)	(450)	—	—	—	—
	10%	—	288	402	442	475	—	(464)	(464)	—	—	—	—
	30%	—	318	422	462	506	—	(510)	(510)	—	—	—	—
	50%	—	335	432	475	532	—	(552)	(552)	—	—	—	—
	70%	—	352	442	498	552	—	(609)	(609)	—	—	—	—
	90%	—	372	452	520	572	—	(731)	(731)	—	—	—	—
	95%	—	380	462	532	585	—	(775)	(775)	—	—	—	—
	FBP	—	384	468	545	—	—	(832)	(832)	—	—	—	—
Density @20 ℃ (g/cm³)		—	0.877	0.901	0.914	0.938	—	0.958	0.958	—	—	—	—
Vis @100℃ (cSt)		—	2.23	5.26	9.61	18.6	—	—	—	—	—	—	—

※ ( ):simulation value

Table 3.2-5 HEAT & MATERIAL BALANCE SHEET(5/5) (26 NOVEMBER 1993)

Flow No.		49	50	51	52
Flow (kg/h)		0	0	0	0
Temperature(℃)		—	—	—	—
Pressure(MPa)		—	—	—	—
Distillation ℃	Method	—	—	—	—
	IBP	—	—	—	—
	5%	—	—	—	—
	10%	—	—	—	—
	30%	—	—	—	—
	50%	—	—	—	—
	70%	—	—	—	—
	90%	—	—	—	—
	95%	—	—	—	—
	FBP	—	—	—	—
Density @20 ℃ (g/cm³)		—	—	—	—
Vis @100℃ (cSt)		—	—	—	—

※ ( ):simulation value

HEATER DUTY(absorbed)

ITEM No	Pc-1	Pc-2
DUTY (GJ/h)	(123.80)	(41.13)

Table 3.2-9 HEAT DUTY FOR HEATERS

(Gj/h)

	Design	Present (26. Nov. 1993)		Present (Estimated)		Modernization
		270 t/h		308 t/h		308 t/h
		Pc-1 Outlet Temperature				
		320℃	330 ℃	320 ℃	330 ℃	330 ℃
Pc-1	150	123.8	133.04	141.2	151.8	144.8
Pc-2	50	41.13	—	46.9	—	40.0

3.3 Review of Current Condition of No.1 Crude Oil Distillation Unit

3.3.1 Evaluation for the design of No.1 crude oil distillation unit

(1) Imbalance in the throughput of No.1 atmospheric distillation unit and No.1 vacuum distillation unit

As described in 3.1.1, there is an imbalance in the throughput of No.1 atmospheric distillation unit and No.1 vacuum distillation unit. That is, in a case where the throughput of No.1 atmospheric distillation unit is over than 288 t/h, all the atmospheric residue can not be fed to No.1 vacuum distillation unit and some portion of the atmospheric residue shall be bypassed.
Although the bypassed atmospheric residue is used as fuel oil, it is preferable to produce a more profitable product without bypass flow.

(2) The number of side cut from the atmospheric distillation Tower (W-2)

At present there are six (6) side cuts including the overhead product(A11).
A clear answer as to why this is so could not be found by the site survey.
The usage of the six (6) side cuts are as follows;

A11 : Reforming feed, Pyrolysis feed
A12 : Reforming feed, Pyrolysis feed
A13 : Diesel blend
A14 : Diesel blend
A15 : Diesel blend
A16 : Diesel blend

It would appear that there is no justification for six (6) side cuts because the usage of the products from A13 to A16 is all the same, i.e., diesel oil blend. There is no reason to distillate 6 fractions because those fractions will then be blended in the tank.
Furthermore, additional train of pumps, heat exchangers and instruments will be required for the extra fractions.
Hence, unit costs will increase accordingly.

(3) Switching draw-off tray

The draw-off tray from the distillation tower (W-2) to the stripper (W-3) can be selected from three (3) trays.
The draw-off tray from the vacuum tower (W-7) to the stripper (W-8) can be selected among two (2) trays also.
Generally speaking, draw-off trays do not contribute to distillation, and such switching of draw-off trays is not common practice in distillation tower design.
The purpose of these switching trays seems to adjust the product quality. However, it is possible to adjust it by adjusting operation conditions such as the temperature and draw off flow of the product.

It is estimated that there will be no problem after the modernization because of the reduction of the number of products for No.1 atmospheric distillation unit and milder product specification for No.1 vacuum distillation unit.
Therefore, no modification work for these trays was planned in this feasibility study.

(4) Bottom recycle (quench line) of W-7

There is not a quench line at W-7 although the installation of the quench line is common practice for vacuum distillation unit design.

The purpose of the quench line is as follows:

(a) To prevent thermal cracking of the bottom oil.
(b) To increase NPSH of vacuum tower bottom pump.

Actually the penetration of the vacuum residue is not at the level that is expected. It is required to increase the bottom temperature of W-7 for improving the penetration.
In order to increase W-7 bottom temperature, it is required to raise Pc-2 outlet temperature.
According to PPSA's explanation, it was not possible to raise the W-7 bottom temperature because there would be a possibility of thermal cracking of the bottom oil and the outlet temperature of Pc-2 could not be raised.

In case when the Pc-2 outlet temperature is raised to meet the product specification of VR by installing a quench line, it is necessary to confirm that the heat duty of Pc-2 is within the design value during basic design.

In this feasibility study, as discussed in 3.2.2 of assumed data, no quench line will be installed because the yield of VR is maintained the same before and after the modernization, i.e., the penetration before and after is the same.

(5) Cooler inlet temperature in No.1 vacuum distillation unit

The inlet temperature of the products to the coolers (Ch-8, Chs 1.1, Chs 1.2, Chs 2.1 and Chs 2.2) ranged from 180°C to 210°C.
It is recommended that the inlet temperature of the products to the coolers be set at 150°C as a target in order to save energy.

(6) Usage of box water coolers

There are 2 box water coolers in No.1 crude oil distillation unit.
One is for cooling the W-2 bottom oil and the other is for W-7 bottom oil.

The box coolers at the W-2 bottom are used when the throughput of No.1 atmospheric distillation unit is over 288 t/h.
The measurement conducted on 26 November 1993 shows that the inlet temperature of the box water cooler for W-7 bottom oil was 200°C. Furthermore, there was no flow to the box cooler of W-2 bottom oil since the throughput of atmospheric distillation unit was 270 t/h.

These box water coolers are used only to heating water and this is not effective for recovering heat of the products. The heat of the bottom oil should be recovered by heat exchangers as much as possible and box water coolers are not recommended for use.

3.3.2 Review of Operation Control

In order to review the present condition of No.1 crude oil distillation unit, JICA team requested the DATA during stable operation.
PPSA collected the DATA on No.1 crude oil distillation unit from 9:00 to 10:00 on 26 November 1993 and submitted them to JICA Team.

The points where the operation data were collected are shown in Figure 3.3-1 and the the DATA are shown in the following Tables;

Table 3.3-1 Operation data of No.1 crude oil distillation unit (Pressure)
Table 3.3-2 Operation data of No.1 crude oil distillation unit (Flow)
Table 3.3-3 Operation data of No.1 crude oil distillation unit (Temperature)
Table 3.3-4 Operation data of No.1 crude oil distillation unit (Heat balance of furnaces)

And at the same time, No.1 atmospheric and No.1 vacuum distillation products were analyzed as shown in the following Tables:

Table 3.3-5 Analytical data of crude oil properties
Table 3.3-6 Analytical data of products of No.1 atmospheric distillation unit
Table 3.3-7 Analytical data of products of No.1 vacuum distillation unit

(1) Reliability of the DATA

Before taking the DATA of No.1 crude oil distillation unit, JICA Team requested verification of all instruments such as pressure gauges, thermometers and flow meters.
However, there were three points which were not recorded on 26 November 1993 because the instruments were out of order.

Also there are unjustifiable and inconsistent data as described below. All these were amended or assumed as described in 3.2.2 and 3.2.5, then inputted into the simulation model.

One of the important points which was not recorded is the bottom temperature of W-7. The temperature is the key to knowing the thermal decomposition of the bottom oil.

It is strongly recommended to repair such an important instrument as soon as possible after malfunction.

The real cause should be investigated and measures should be established with the cooperation of the operation section and the maintenance section.

1) Preheating of crude oil before feeding to desalters (from P1 to W-1)

Crude Oil is heated without any heater by passing through heat exchangers with products before being fed to W-1. Therefore, the temperature of the crude oil should be increased gradually as crude oil passes through the heat exchangers.
However, there are some points which are contradictory to the above rationale.

It is clear to see that the temperature cools down at some of the heat exchangers.
Therefore, it is recommended to seek for the real causes and to improve these for the modernization.

2) Outlet temperature of Wm 14 tube side

On 26 November 1993, no flow was confirmed in the shell side of Wm 14 because all the W-2 bottom oil was fed to the vacuum distillation unit.
However the crude oil was heated from 175°C to 262°C, although there was no flow of W-2 bottom oil.

PPSA explained that the instrument was out of order on that day during the second site survey.

3) Inlet and outlet temperature of Ch 1 and Ch 7.

The outlet temperatures of these coolers are higher than the inlet temperatures.
Refer to 3.2.2 for review.

(2) Review of operation conditions

1) Operation temperature of desalters

There are two desalters in series in No.1 atmospheric distillation unit to remove salts contained in crude oil.

According to the DATA, the inlet temperature of the first desalter was 102°C and the second desalter was 99°C.
At the same time, the inlet pressure for the first desalter was 0.41 MPa and the second desalter was 0.35 MPa.

The inlet temperature of the desalter is low, compared to the range of 120°C to 140°C which is commonly used in refineries at present.

It is reported that the reason why the inlet temperature can not be increased is because of a restriction of the design temperature of the insulation, a part of the electrical equipment, which is 105°C.

2) Pressure around W-1 over head

This is discussed in 3.2.5.

3) W-1 bottom oil flow to W-2

This is discussed in 3.4.2.

4) Oxygen content in the flue Gas from Heaters (Pc-1 and Pc-2)

Pc-1 and Pc-2 are natural draft and isoflow type heaters.
Both Heaters burn fuel oil and gas.
The DATA shows that the oxygen content in the flue gas from the Heaters is 9.5% and 6.83% respectively.
It is recommended to reduce the oxygen content to as low level as possible to save energy.

5) Flue gas temperature from heaters

The flue gas temperature of the heater were 310°C and 360°C respectively on 26 November 1993. The flue gas temperature reaches about 500°C in summer.
It is often the case that the preheating of combustion air is done by recovering the heat of the flue gas.
This should be studied further as one of the modernization plan.

6) Necessity of reducing offensive odor substance in sewage

Waste water is generated from such equipment as desalters, overhead receiver of preflash column and etc. in No.1 crude oil distillation unit as described in 3.1.2.
This waste water is transferred to the central waste water treatment unit through the sewer pipe lines, and the treated waste water is poured into Vistula River.

The waste water drain pipes from the equipment in No.1 crude oil distillation unit are connected to the sewer pipe lines by drip funnel.
There is a space between the end of the drain pipe and the drip funnel.
Offensive odor leaks from this space.
Since this odor will undermine the operator's health, some

measure should be taken.

7) Necessity of treatment of Od-8 and Zb-3 emissions

There is an offensive odor in the off gases from the vacuum over head receiver (Od-8) and slop tank (Zb-3).
Since this odor can be dangerous to the operator's health, it is required to treat these gases.
At the moment, these gases are introduced into Pc-1.
However these gases contain 90% of total H2S emission in No.1 crude oil distillation unit and it is not allowed to burn H_2S in the heater.
For reference, the total H_2S emission from No.1 crude oil distillation unit in 1993 was reported as 7.2 ton/year.

There is the same problem in No.2 crude oil distillation unit but the offensive gases are treated with caustic soda.
H_2S is absorbed by caustic soda and becomes Na_2S.
PPSA explained that this measure to use caustic soda is not available for No.1 crude oil distillation unit because of the limitation in the capacity of treating Na_2S solution.

(3) Review of the analysis DATA

1) Review of analysis DATA regarding the product quality

Refer to 3.5.

2) Reliability of analysis DATA of the flue gas from the heaters (Refer to Table 3.3-4)

Regarding the analysis DATA of the flue gas from the heaters, the following is pointed out;

- Composition analysis of fuel oil
  Total of the compositions are not 100%.
- Composition of flue gas analysis
  Total of the compositions are not 100%.
- SO_2 and NOx analysis for Pc-1 flue gas
  Content of SO_2 is too low (47 ppm).
  Content of NOx is too low (7 ppm).

PPSA explained that the reason why the total of the composition is not 100% is that there are some components which were not analyzed on 26 November 1993.

It is recommended that all the components of the gas should be analyzed once and confirm that there are not components which were not usually analyzed.

3.3.3 Review of product quality control

Review of product quality will be done in Section 3.5. Below are some recommendations for controlling product quality, although it is well known to PPSA.

(1) Review of the analysis report to be done by the operation section

There are some products in the DATA which do not meet the product specification.
The causes must be cleared up and countermeasures should be taken immediately to prevent the same mistakes.
The operation section should have the initiative for establishing the measure and should confirm that the measures taken are pertinent.

(2) Recommended practices

It is also important to confirm periodically that the sampling is performed correctly as described below.

1) When taking a sample,

(a) Confirm that the sampling point is correct and that the sample bottle or balloon is clean and not contaminated.

(b) The person who analyze the sample should check the test result during sampling whenever he can know the analyzed result with a portable type analyzer at the site.
If the result appears to be different when compared to the past data, he should repeat the analysis again.

2) When analysing a sample in the laboratory

Confirm the procedure for analyzing a sample. If there is no procedure for measuring a certain sample, it is recommended to prepare a procedure for analyzing the sample.

3) When reporting the result of analysis

Confirm that there are not any transcription mistakes.

4) When receiving the analysis data at the operation section

The operation section should check the analysis data by comparing the actual operation conditions every day.
If there are any data which has discrepancies or inconsistencies found in the analysis data, it is recommended to analyze again.

5) When taking action for a countermeasure

The operation section in cooperation with the relevant sections such as maintenance section and laboratory should take actions immediately to prevent the same kind of error from happening again.

6) After taking action

Analyze the sample again and confirm that the countermeasures are pertinent.

Table 3.3-1 OPERATION DATA OF NO.1 CRUDE OIL DISTILLATION UNIT (PRESSURE) (1/2)

1. Date : 26 November 1993
2. Time : 9:00 ~ 10:00
3. Crude Oil : URAL CRUDE OIL 100 %
4. Throughput

NO.1 Atmospheric Distillation Unit : 270 t/h

NO.1 Vacuum Distillation Unit : 144 t/h

6. Pressure (MPa)

Number	Press.	Number	Press.	Number	Press.	Number	Press.
1	S 0.11	12	0.29	22	0.48	34	–
	D 1.15	13	1.3	23	0.17	35	–
2	0.72	14	0.37	24	0.44	36	–
3	0.79	15	1.35	25	0.53	37	–
4	0.41	16	0.49 0.49 0.49 0.49 0.51	26	–	38	–
5	0.35			27	–	39	0.15
6	0.34			28	–	40	–
7	0.25	17	0.014	29	–	41	70mmHg (9.33 kPa)
8	2.2	18	0.0	30	–		
9	–	19	0.29	31	0.48	42	65mmHg (8.67 kPa)
10	–	20	0.54	32	0.071		
11	0.28	21	0.2	33	1.15	43	–

Table 3.3-1 OPERATION DATA OF NO.1
CRUDE OIL DISTILLATION UNIT (PRESSURE) (2/2)

Number	Temp.	Number	Temp.	Number	Temp.	Number	Temp.
44	—	53	—	62	—	71	—
45	0.68	54	0.9	63	—	72	0.31
46	—	55	0.5	64	—	73	0.03
47	0.22	56	0.36	65	—	74	0.22
48	—	57	0.37	66	—	75	0.12
49	—	58	0.57	67	—	76	0.61
50	-0.03	59	1.4	68	—	77	0.61
51	—	60	0.73	69	—	78	—
52	—	61	—	70	—		

Table 3.3-2 OPERATION DATA OF NO.1 CRUDE OIL DISTILLATION UNIT (FLOW)

1. Date : 26 November 1993

2. Time : 9:00 ～ 10:00

3. Crude Oil : URAL CRUDE OIL 100 %

4. Throughput

NO.1 Atmospheric Distillation Unit : 270 t/h

NO.1 Vacuum Distllation Unit : 144 t/h

6. Flow (t/h)

Number	Flow	Number	Flow	Number	Flow	Number	Flow
1	270	12	65	23	61	34	2.5
2	—	13	63	24	24	35	144
3	—	14	58.5	25	144	36	22
4	130	15	7.6	26	—	37	31
5	140	16	18	27	—	38	—
6	—	17	12	28	10	36+37	22+31
7	—	18	18	29	82.5	39	10
8	—	19	16	30	36	40	22
9	390	20	22	31	15	41	0.64
10	160	21	17	32	30	—	—
11	230	22	0	33	1.1	—	—

Table 3.3-3 OPERATION DATA OF NO.1
CRUDE OIL DISTILLATION UNIT (TEMPERATURE) (1/3)

1. Date : 26 November 1993
2. Time : 9:00 ~ 10:00
3. Crude Oil : URAL CRUDE OIL 100 %
4. Throughput

   NO.1 Atmospheric Distillation Unit : 270 t/h

   NO.1 Vacuum Distillation Unit : 144 t/h
5. Temperature (℃)

Number	Temp.	Number	Temp.	Number	Temp.	Number	Temp.
1	5	13	—	25	143	37	90
2	65	14	136	26	—	38	223
3	* 140	15	—	27	150	39	—
4	85	16	161	28	150	40	150
5	101	17	* 140	29	195	41	22
6	100	18	197	30	192	42	—
7	104	19	140	31	102	43	230
8	22	20	180	32	55	44	—
9	—	21	175	33	247	45	167
10	102	22	* 262	34	330	46	22
11	99	23	102	35	148	47	—
12	96	24	* 105	36	—	48	94

Table 3.3-3 OPERATION DATA OF NO.1 CRUDE OIL DISTILLATION UNIT (TEMPERATURE) (2/3)

Number	Temp.	Number	Temp.	Number	Temp.	Number	Temp.
49	70	65	27	81	–	95	–
50	130	66	–	82	391	96	230
51	182	67	201	83	*2	97	152
52	203	68	135	84	*2	98	76
53	245	69	72	85	*2	99	282
54	278	70	27	86	70, 67	100	318
55	350	71	–	87	*1	101	355
56	300	72	245	88	22	102	*1
57	129	73	145	89	27	103	220
58	* 40	74	58	90 EJECT. LINE	28, 44 42, 80 23, 26 35, 40	104	246
59	53	75	27			105	254
60	27	76	–			106	83
61	–	77	271	91	280	107	76
62	*1	78	105	92	–	108	27
63	110	79	49	93	83	109	–
64	63	80	27	94	322	110	* 130

Table 3.3-3 OPERATION DATA OF NO.1 CRUDE OIL DISTILLATION UNIT (TEMPERATURE) (3/3)

Number	Temp.	Number	Temp.	Number	Temp.	Number	Temp.
111	69	119	92	126 Two Trains	I 176	131	–
112	27	120	27		II 167	132	–
113	–	121	–	127 Two Trains	I 176	133	22
114	80	122	262		II 167	134	22
115	102	123	194	128 Two Trains	I 176	135	–
116	27	124	286		II 167	136	–
117	–	125	210	129	340	137	27
118	180	–	–	130	22	–	–

NOTE : (1) *1 means OUT OF ORDER.

(2) *2 means NO FLOW.

(3) Outlet Temperature of all Cooler is roughly 40 ℃ ~ 45 ℃ .

(4) * means OUT OF ORDER(PPSA informed during the second field survey).

(5) PPSA informed the new data collected on 26 November 1993 during the second field survey as follows:
No.4 : 101 ° C, No.6 : 104 ° C, No.20 : 152 ° C
No.62: 157 ° C, No.87: 42,35,37 ° C.

Table 3.3-4 OPERATION DATA OF NO.1 CRUDE OIL DISTILLATION UNIT (HEAT BALANCE OF FURNACE) (1/3)

1. Date : 26 November 1993
2. Time : 9:00 ～ 10:00
3. Crude Oil : URAL CRUDE OIL 100 %
4. Throughput
   - NO.1 Atmospheric Distillation Unit : 270 t/h
   - NO.1 Vacuum Distillation Unit : 144 t/h
5. Meteorological Condition
   - Temperature : -1.9 ℃
   - Atmospheric Pressure(Hecto-Pascal) : 1,026
6. Poperties of Fuel Oil

		PC-1	PC-2
6.1 Fuel Oil Consumption (Kg/h)		2,300	1,200
6.2 Fuel Oil Temperature (℃)		67	67
6.3 Specific Gravity (20 ℃)		1.002	1.002
6.4 Composition (wt %)	Carbon	87.65	87.65
	Hydrogen	7.15	7.15
	Sulfer	2.80	2.80
	Nytrogen(Ave.)	700 PPM	700 PPM
6.5 Lower Calorific Value (ASTM D-2382-83) (kcal/kg)		9,443	9,443

Table 3.3-4 OPERATION DATA OF NO.1 CRUDE OIL DISTILLATION UNIT (HEAT BALANCE OF FURNACE) (2/3)

7. Poperties of Fuel Gas

		PC-1	PC-2
7.1 Fuel Gas Consumption (Nm^3/h)		1,000	476
7.2 Fuel Gas Temperature (℃)		20	20
7.3 Composition (vol %)	CH_4	26.94	26.94
	C_2H_6	} 3.27	} 3.27
	C_2H_4		
	C_3H_8	2.99	2.99
	C_3H_6	1.74	1.74
	$i-C_4H_{10}$	1.47	1.47
	$n-C_4H_{10}$	1.39	1.39
	C_4H_8	0.36	0.36
	C_5	0.61	0.61
	H_2	50.70	50.70
	N_2	3.88	3.88
	H_2S	0.81	0.81
	CO	5.82	5.82
	CO_2	0.02	0.02
7.4 Lower Calorific Value(kcal/m^3)		8,516	8,516
7.5 Specific Gravity (Air= 1)		0.487	0.487

Table 3.3-4 OPERATION DATA OF NO.1 CRUDE OIL DISTILLATION UNIT
(HEAT BALANCE OF FURNACE) (3/3)

8. Poperties of Flue Gas from Furnaces

		PC-1	PC-2
8.1 Flue Gas Temperature (℃)		310	360
8.2 Flue Gas Composition (vol %)	CO_2	8.12	10.20
	CO	0.0	0.0
	O_2	9.5	6.83
	N_2	75.24	71.16
	NOX (vol ppm)	47	113
	SO_2 (vol ppm)	7	495

Table 3.3-5 ANALYTICAL DATA OF CRUDE OIL PROPERTIES (1/2)

1. Date : 26 November 1993
2. Time : 9:00 ~ 10:00
3. Crude Oil : URAL CRUDE OIL 100 %
4. Throughput
   NO.1 Atmospheric Distillation Unit : 270 t/h
   NO.1 Vacuum Distillation Unit : 144 t/h
5. Crude Oil Properties

	Crude Oil	Desalted Crude Oil
5.1 Density (20 ° C)	0.858	0.863
5.2 Cl^- Content Wt % (DIN 51576)	0.0027	< 0.0001
5.3 H_2O Content Wt % (ASTM D 9570) (DIN ISO 3733)	0.27	0.09
5.4 Conradson Carbon Wt % (ASTM D 189-81)	3.77	——
5.5 Freezing Point (° C)	- 18	——
5.6 Asphaltenes Wt %	1.6	——
5.7 Sulfur Wt %	1.47	——

Table 3.3-5 ANALYTICAL DATA OF CRUDE OIL PROPERTIES (2/2)

	Crude Oil
5.8 Impurities Wt % Indissoluble in Butane	0.003
5.9 Paraffin Wt %	2.5
5.10 TBP Distillation	
IBP	42 ° C
75 ° C	2 Vol %
150 ° C	14 Vol %
175 ° C	20 Vol %
200 ° C	26 Vol %
350 ° C	50 Vol %
520 ° C	76 Vol %

6 Waste Water from Desalter

6.1 pH	8.1
6.2 Hydrocarbon mg/l	28.44

Table 3.3-6 ANALYTICAL DATA OF PRODUCTS OF NO.1 ATMOSPHERIC DISTILLATION UNIT (1/3)

1. Date : 26 November 1993
2. Time : 9:00 ～ 10:00
3. Crude Oil : URAL CRUDE OIL 100 %
4. Throughput

   NO.1 Atmospheric Distillation Unit : 270 t/h

   NO.1 Vacuum Distillation Unit : 144 t/h
5. Products Properties of Gas

	Dry Gas
5.1 Hydrocabon Content (Vol %)	
C_1	2.54
C_2	10.27
C_3	39.04
C_4	29.47
C_5	7.89
H_2S	1.27
CO	9.38
CO_2	0.14
5.2 Specific Gravity (Air = 1)	0.874

Table 3.3-6 ANALYTICAL DATA OF PRODUCTS OF NO.1 ATMOSPHERIC DISTILLATION UNIT (2/3)

6. Products Properties of Oil

6.1 Distillation (ASTM D 86-67)

	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
IBP	27	84	123	152	158	178	159
5 %	34	94	133	166	179	213	238
10 %	39	98	137	173	191	227	258
20 %	41	102	142	181	209	243	279
30 %	53	106	146	185	220	257	297
50 %	66	114	153	197	236	273	316
70 %	80	122	160	206	248	286	332
90 %	93	139	171	221	264	304	350 (88 %)
95 %	100	148	176	227	271	314	--
FBP	102	153	185	237	282	323	--

6.2 Flash Point

(ASTM D 9371)

	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
° C	< 0	< 0	21	47	53	79	94

Table 3.3-6 ANALYTICAL DATA OF PRODUCTS OF NO.1 ATMOSPHERIC DISTILLATION UNIT (3/3)

6.3 Density

(ASTM D 941-83)

	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
g/cm³	0.661	0.736	0.764	0.797	0.820	0.836	0.856

6.4 Evapolation

	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
at 200 ° C	–	–	–	57	12	2	1
at 350 ° C	–	–	–	–	–	–	88

Table 3.3-7 ANALYTICAL DATA OF PRODUCTS OF NO.1 VACUUM DISTILLATION UNIT (1/5)

1. Date : 26 November 1993

2. Time : 9:00 ~ 10:00

3. Crude Oil : URAL CRUDE OIL 100 %

4. Throughput

   NO.1 Atmospheric Distillation Unit : 270 t/h

   NO.1 Vacuum Distillation Unit : 144 t/h

5. Products Properties of Oil

5.1 Distillation

ASTM	P_{11} D86-67	P_{12} D-1160	P_{13} D-1160	P_{14} D-1160
IBP	250	372	398	412
5 %	271	388	422	435
10 %	288	402	442	475
20 %	306	415	455	495
30 %	318	422	462	506
50 %	335	432	475	532
70 %	352	442	498	552
90 %	372	452	520	572
95 %	380	462	532	585
FBP	384	468	545	(Cracking)

Table 3.3-7 ANALYTICAL DATA OF PRODUCTS OF OF NO.1 VACUUM DISTILLATION UNIT (2/5)

5.2 Flash Point

(ASTM D 9317)

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
° C	141	205	237	260	—

5.3 Density at 20 ° C

(ASTM D 941-83)

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
g/cm^3	0.877	0.901	0.914	0.938	—

5.4 Freezing Point

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
° C	+6	+21	+27	+37	—

Table 3.3-7 ANALYTICAL DATA OF PRODUCTS OF NO.1 VACUUM DISTILLATION UNIT (3/5)

5.5 Viscosity at 100 ° C

(DIN 51560)

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
cSt	2.23	5.26	9.61	18.6	
° E	1.12	1.42	1.82	2.78	—

5.6 Softning Point (Rink and Ball Method) (DIN 1995)

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
	—	23	25	29	32

Table 3.3-7 ANALYTICAL DATA OF PRODUCTS OF NO.1 VACUUM DISTILLATION UNIT (4/5)

5.7 W-1 and W-2 Bottoms Oil

5.7.1 Distillation (ASTM D-1160)

° C	W-1 Bottoms Oil	W-2 Bottoms Oil
IBP	126	127
10 %	175	186
30 %	257	277
50 %	372	368
70 %	462	480
90 %	560	588 (88 %) (Cracking)
95 %	580	—
FBP	592 (98 %)	—

5.7.2 Specific Gravity at 20 ° C

	W-1 Bottoms Oil	W-2 Bottoms Oil
g/cm³	0.889	0.890

Table 3.3-7 ANALYTICAL DATA OF PRODUCTS OF NO.1 VACUUM DISTILLATION UNIT (5/5)

5.7.3 Freezing Point

	W-1 Bottoms Oil	W-2 Bottoms Oil
° C	-1	-4

5.7.4 Flash Point

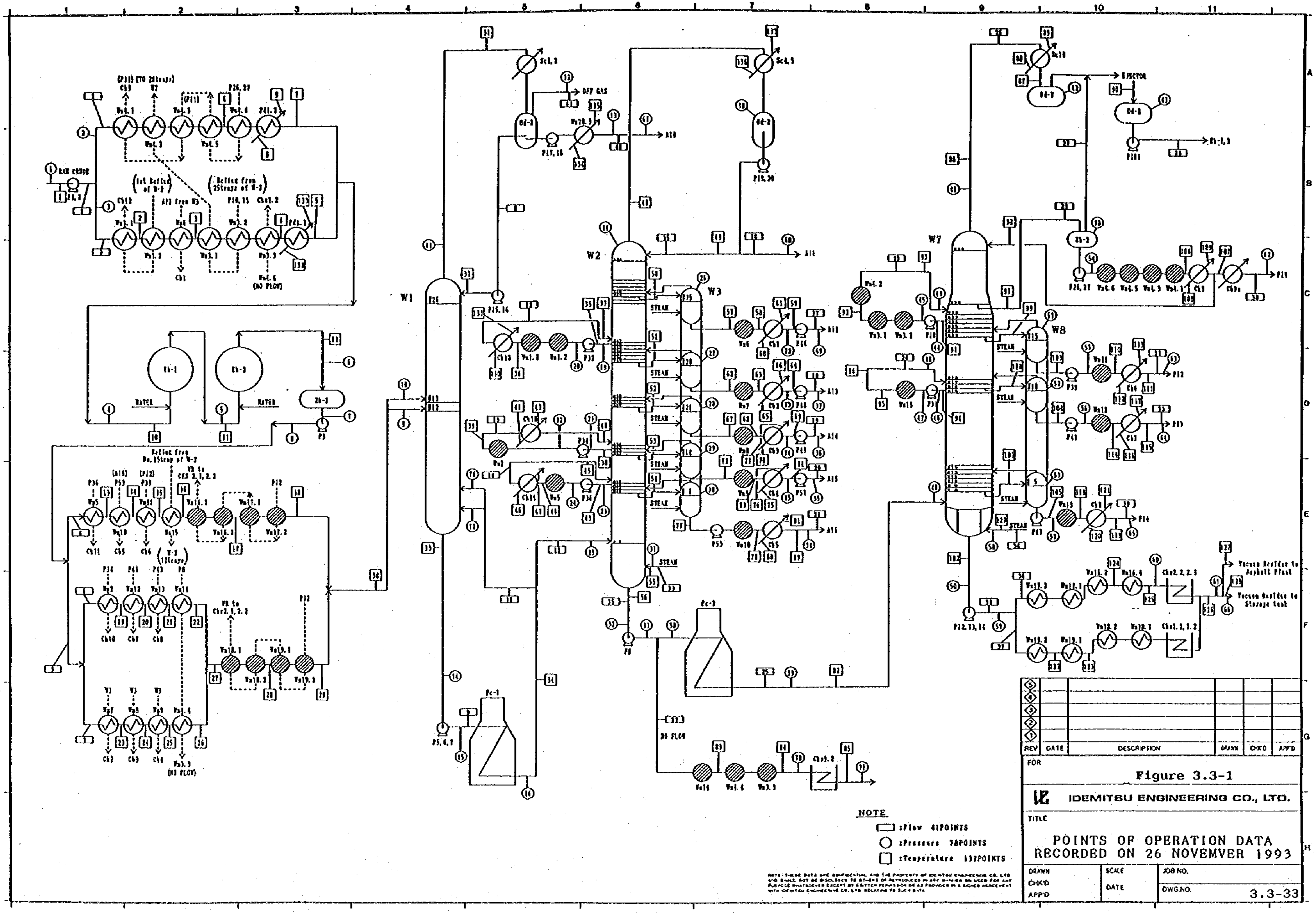
	W-1 Bottoms Oil	W-2 Bottoms Oil
° C	52	42

5.7.5 Viscosity at 100° C

	W-1 Bottoms Oil	W-2 Bottoms Oil
Cst	5.45	3.7
° E	1.43	1.26

5.7.6 Softning Point (Rink and Ball Method) (DIN 1995)

	W-1 Bottoms Oil	W-2 Bottoms Oil
	impossible	< 0



NOTE

▭ :Flow 41POINTS

○ :Pressure 78POINTS

□ :Temperature 133POINTS

NOTE: THESE DATA ARE CONFIDENTIAL AND THE PROPERTY OF IDEMITSU ENGINEERING CO., LTD AND SHALL NOT BE DISCLOSED TO OTHERS OR REPRODUCED IN ANY MANNER OR USED FOR ANY PURPOSE WHATSOEVER EXCEPT BY WRITTEN PERMISSION OR AS PROVIDED IN A SIGNED AGREEMENT WITH IDEMITSU ENGINEERING CO., LTD RELATING TO SUCH DATA

Figure 3.3-1

IDEMITSU ENGINEERING CO., LTD.

TITLE
POINTS OF OPERATION DATA
RECORDED ON 26 NOVEMVER 1993

DWG NO. 3.3-33

3.4 Review of Heat and Material Balance (at maximum throughput)

3.4.1 Heat balance

(1) Absorbed heat duty of heaters

Based on the simulation for the existing No.1 crude oil distillation unit, actual heat duties of heaters are calculated as shown in Table 3.2-9.

There is allowance in the heat duty of the heaters compared to the design value under the operation condition on 26 November 1993. The reason is the throughput of No.1 atmospheric and No.1 vacuum distillation unit was lower than the design values on that day.

It may be said that there is no problem with heat duty at this moment as long as the throughput is the same as that of the design and the outlet temperature of Pc-1 is kept at 320°C.

(2) Estimated fuel consumption for Pc-1

Estimated fuel consumption for Pc-1 obtained from the simulation model is more than the actual fuel consumption when the fuel consumption is calculated under the following conditions:

(a) The throughput of No.1 crude oil distillation unit : 308 t/h
(b) Heater efficiency : 60%
(c) Lower calorific value of fuel oil : 9,443 kcal/kg

Refer to Table 4.4-2 for the result.

Based on the actual fuel consumption for both Pc-1 and Pc-2 on 26 November 1993, the fuel oil consumption at the throughput of 308 t/h is estimated to be 5,513 kg/h, while the simulation result is 7,931 kg/h.
Refer to 3.6.1 for the estimated cause.

For this feasibility study, this calculated fuel consumption for the current No.1 crude oil distillation unit, 7,931 kg/h, will be used as a standard fuel consumption in order to evaluate the fuel reduction after the modernization.

3.4.2 Material Balance

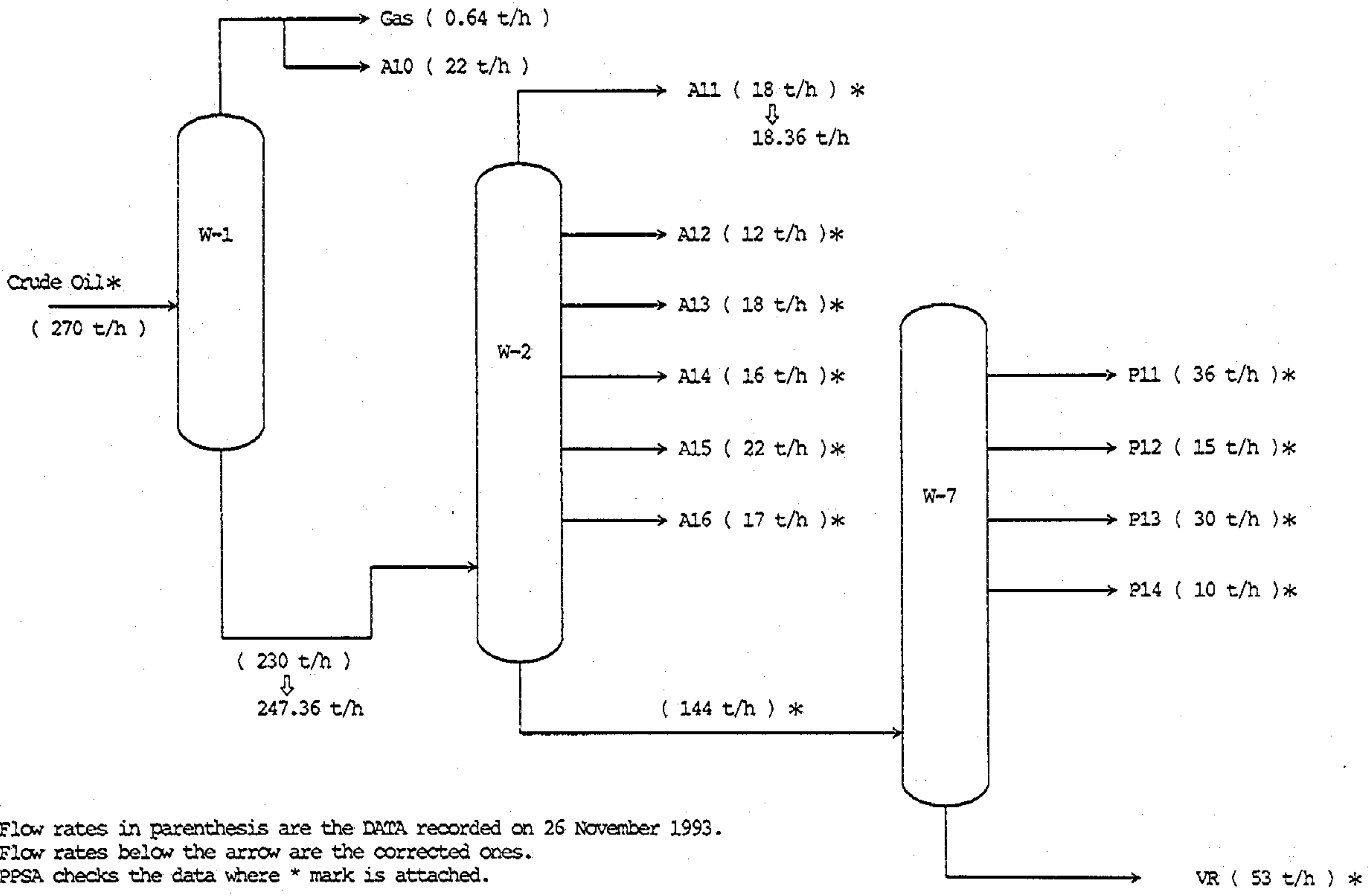
The material balance of No.1 crude oil distillation unit was calculated based on the DATA as shown in Figure 3.4-1.

There is an anomaly in the flow of W-1 bottom oil, i.e., the DATA indicates 230 t/h while the total of the fractions of W-2 is 247.36 t/h.

247.36 t/h is applied for the simulation because this is a more probable value.

During the second field survey, PPSA explained that the flow meter of W-1 bottoms oil is not correct and this flow has less meaning for the material balance.
PPSA also explained that the flows which are marked with a * in Figure 3.4-1 are checked everyday.

Figure 3.4-1 NO.1 CRUDE OIL DISTILLATION UNIT MATERIAL BALACNE
(26 NOVEMBER 1993)



Note
1. Flow rates in parenthesis are the DATA recorded on 26 November 1993.
2. Flow rates below the arrow are the corrected ones.
3. PPSA checks the data where * mark is attached.

3.5 Review of Product Quality and Specification

3.5.1 Product quality

(1) No.1 atmospheric distillation unit (Refer to Table 3.5-1)

1) Gap of products in No.1 atmospheric distillation unit

(a) Definition of gap

A Petroleum Product consists of a certain range of a continuous hydrocarbon fraction which is obtained by the distillation of crude oil. Therefore, it is required to distillate crude oil within the specification without any lighter or heavier fraction in the product.

In order to express the degree of the quality of the product in terms of distillation, the term "Gap" is used.
The gap of petroleum products is defined as follows:
The ASTM 5% distillation point of a product minus the ASTM 95% distillation point of the adjacent lighter product.

(b) Actual gap of the products

Confirmation of the gap based on the DATA is as shown Table 3.5-2.

Table 3.5-2 GAP OF PRODUCTS OF NO.1 ATMOSPHERIC DISTILLATION UNIT

ASTM 5% Point		-	ASTM 95% Point		=	Gap (°C)
A12	133°C		A11	148°C	=	-15
A13	166°C		A12	176°C	=	-10
A14	179°C		A13	227°C	=	-48
A15	213°C		A14	271°C	=	-58
A16	238°C		A15	314°C	=	-76

Usually, the gap of the lighter fractions is from +10°C to +20°C.
So, in this case the quality of the product in terms of distillation between A11 and A12 may be poor and also the gap for heavier products is poor.
The countermeasure is to increase the number of trays between each product in the atmospheric distillation tower.
Such out of standard fractions from No.1 atmospheric distillation unit does not affect quality of the final products from the refinery.
Because those fractions are only mixed with fractions from other atmospheric distillation unit.

2) Lower IBP than the specification for the products of atmospheric distillation unit

For the products of A11, A12, A13 and A14, IBP is out of the specification, i.e., lower than the specification.

At present, no stripping steam is used for the stripper in atmospheric distillation unit, even though there is stripping steam connection. (Refer to Figures 3.5-1 and 3.5-2)

3) IBP of A15 and A16

The IBP of A16 is 159°C but should be theoretically higher

than the IBP of A15.
However, IBP of A16 is lower than that of A15 according to the DATA.

4) Flash points of A13 and A14

Flash points of A13 and A14 are lower than the specification. This is related to the IBP of A13 and A14 which contains lighter fractions.

Injection of stripping steam will improve the flash points of A13 and A14.

5) Installation of a stabilizer and a splitter

At present, A10 from the overhead of W-1, which contains LPG, is transferred to the other unit where A10 is separated to naphtha and LPG together with A10 from the other unit.
However, A10 from No.1 crude oil distillation unit contains more sulfur than A10 from the other units. It is not good to contaminate the A10 from other units. In order to secure low sulfur A10, it is required to construct a stabilizer and a splitter in the area of No.1 crude oil distillation unit.

(2) No.1 vacuum distillation unit (Refer to Table 3.5-3)

1) W-1 bottom oil and W-2 bottom oil

(a) Flash point
The flash point of W-1 bottom oil is higher than W-2 bottom oil by 10°C.
Theoretically this should never happen.

Because the lighter fraction of W-1 bottom oil is vaporized in W-2, the flash point of W-2 bottom oil should be higher than that of W-1 bottom oil.

(b) Viscosity

The same situation as seen with the flash point is also observed for the viscosity.

Theoretically it also should never happen as in the case of flash point.

2) Specific gravity and freezing point of P11

The specific gravity of P11 is 0.877 which is out of the specification range of 0.880 to 0.895.

The actual freezing point of P11 is +6°C which is lower than the specification, + 8°C.

More draw-off of lighter portion of P12 to P11 will improve the specific gravity and freezing point.

3) FBP of P12

FBP of P12, 468°C does not satisfy the specification which is 460°C.

Since the flash point fully meets the specification, it is recommended that there be less draw-off of P12 as long as the freezing point satisfies the specification.

4) Quality of P13

According to the DATA, the following items do not meet the product specification:

- Freezing Point of +27°C, is out of the limit of the specification which sets minimum of +37°C.
- Specification of FBP- IBP ≤ 120°C is not satisfied, since actual FBP- IBP is 147°C.

- Viscosity of 9.61 does not meet the specification which has a range from 10.5 to 12.5 cSt (at 100°C).

3.5.2 Product specification (Current)

Refer to Table 3.2-3 for the current product specification.

(1) Flash point and FBP of P11 and P12

According to the current specification, the flash point and FBP of P11 and P12 are the same.
Judging from the location of the draw-off tray of P11 and P12, the flash point and FBP of P11 should be lower than that of P12.
This is verified by the actual analysis DATA.

This is not a problem now, because these products meet their present specifications.
However, it seems to be meaningless to specify the same flash point and FBP for different fractions.

3.5.3 Product specification (After the modernization)

Refer to Table 4.2-1 for the product specification to be applied after the modernization.

(1) Standard of the penetration of VR

ASTM D 1321 will be applied to measure the penetration of VR in the new specification.
ASTM D 1321 is used for paraffin Wax, therefore it is better to apply ASTM D 5.

At the second field survey, this turned out to be a simple mistake and PPSA had revised the standard to be applied for measuring penetration of VR to ASTM D 5.

3.5.4 Estimated product properties obtained by the simulation

All of the estimated product properties obtained by the simulation model for both No.1 atmospheric and No.1 vacuum distillation unit were reviewed by comparing with the new product specification to be applied after the modernization.

(1) Flash point of A13

According to the simulation, it is impossible to satisfy the specification of the flash point of A13 which is 80°C. The estimated value is 53°C because no kerosene fraction is withdrawn from the atmospheric distillation unit after the modernization.
It is estimated that the flash point of A13 will be out of the product specification because the IBP of A12 is 180°C. During the second field survey, PPSA explained that there is no problem because of the following reasons:

1) It is not necessary to withdraw kerosene fraction in No.1 atmospheric distillation unit because the other atmospheric distillation units can produce kerosene.

2) If there is a big problem in flash point of A13 during the operation after the modernization, the new product specification will be revised if necessary.

As a result, no revision of the product specification for the flash point of A13 is made and the flash point of A13 obtained by the simulation model was applied in this feasibility study.

(2) IBP of the products

Among the products which the IBP is to be adjusted by the stripper, A12 is the only one which the IBP is specified in the product specification after the modernization.
IBP of A12 almost meets the product specification by injecting stripping steam.

The stripper is regarded as a drum in this simulation model because there was no stripping steam injected on 26 November 1993.
After the modernization, this stripper is to be used without any modification in this feasibility study, although small quantity of stripping steam will be injected.
Therefore, it should be decided during basic design whether all the existing equipment located from the draw-off tray to the tank around the strippers can be used after the modernization by reviewing tray performance and hydraulic check. Necessary actions should be taken accordingly.

Table 3.5-1 COMPARISON OF PRODUCTS PROPERTIES OF NO.1 ATMOSPHERIC DISTILLATION UNIT WITH ITS SPECIFICATION (1/2)

1. Distillation

	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
IBP							
Actu.	27	84	123	152	158	178	159
Spec.	Min.25	78.5± 5	130	220	180	N.A	N.A
50 %							
Actu.	66	114	153	197	236	273	316
Spec.	N.A	N.A	N.A	200	N.A	N.A	N.A
70 % Actu.	80	122	160	206	248	286	332
Spec.	N.A	N.A	N.A	N.A	N.A	87 % 350	80 % 350
90 % Actu.	93	139	171	221	264	304	350 (88 %)
FBP							
Actu.	102	153	185	237	282	323	—
Spec.	< 108	148 ± 5	190	N.A	N.A	N.A	N.A

Table 3.5-1 COMPARISON OF PRODUCTS PROPERTIES OF NO.1 ATMOSPHERIC DISTILLATION UNIT WITH ITS SPECIFICATION (2/2)

2. Flash Point (° C)

	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
Actu.	< 0	< 0	21	47	53	79	94
Spec.	N.A	N.A	N.A	Min.55	66	N.A	N.A

3. Density (ASTM D 941-83) (g/cm³)

	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
Actu.	0.661	0.736	0.764	0.797	0.820	0.836	0.856
Spec.	N.A	N.A	N.A	N.A	0.810 ~ 0.835	0.830 ~ 0.850	0.850 ~ 0.870

Table 3.5-3 COMPARISON OF PRODUCTS PROPERTIES OF NO.1 VACUUM DISTILLATION UNIT WITH ITS SPECIFICATION (1/2)

1. Distillation

ASTM	P_{11} D86-67	P_{12} D-1160	P_{13} D-1160	P_{14} D-1160	Vacuum Residue
IBP Actu.	250	372	398	412	
Spec.	N.A	N.A	400	N.A	
FBP Actu.	384	468	545	—	—
Spec.	< 460	460	545	N.A	N.A
FBP-IBP <120	N.A	N.A	Actu. 147 Spec. 120	N.A	N.A

2. Flash Point (ASTM D 9317) (° C)

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
Actu.	141	205	237	260	—
Spec.	> 120	> 120	> 220	210	N.A

Table 3.5-3 COMPARISON OF PRODUCTS PROPERTIES OF NO.1 VACUUM DISTILLATION UNIT WITH ITS SPECIFICATION (2/2)

3. Density (ASTM D 941-83) (g/cm³)

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
Actu.	0.877	0.901	0.914	0.938	—
Spec.	0.880 ~ 0.895	N.A	0.910 ~ 0.925	N.A	N.A

4. Freezing Point (°C)

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
Actu.	+6	+21	+27	+37	—
Spec.	+8	N.A	> 37	N.A	—

5. Softning Point (Rink and Ball Method) (DIN 1995)

	P_{11}	P_{12}	P_{13}	P_{14}	Vacuum Residue
Actu.	—	23	25	29	32
Spec.	N.A	N.A	N.A	N.A	43.6 ~ 46.3

Figure 3.5-1 STEAM CONSUMPTION (0.7 MPa STEAM)

DATE : 26 NOVEMBER 1993

TIME : 09:00 ~ 10:00

PLACE : NO.1 CRUDE OIL DISTILLATION UNIT

STEAM CONSUMPTION : 9.4 t/h

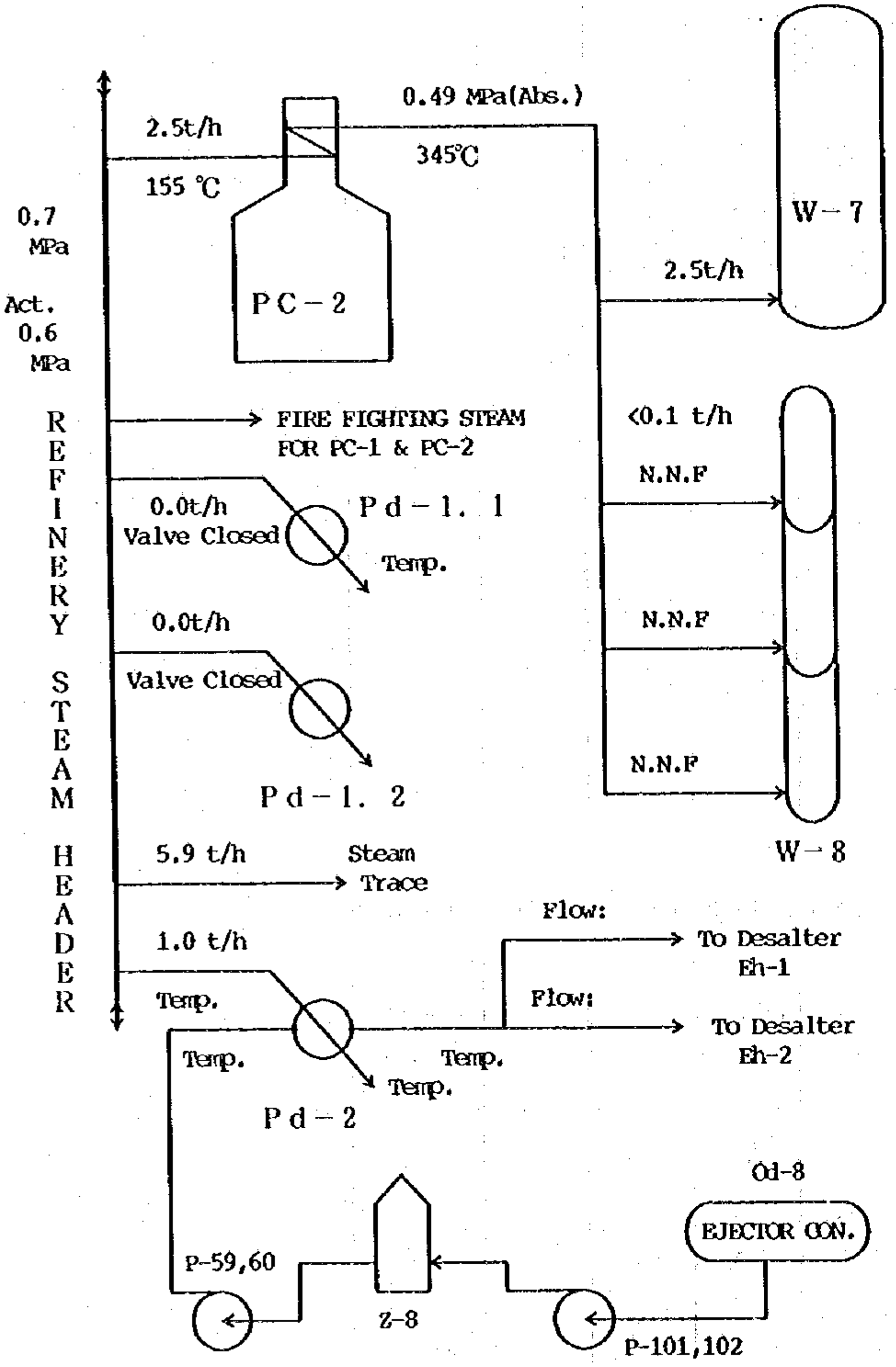


Figure 3.5-2 STEAM CONSUMPTION (1.3 MPa & 0.7 MPa STEAM)

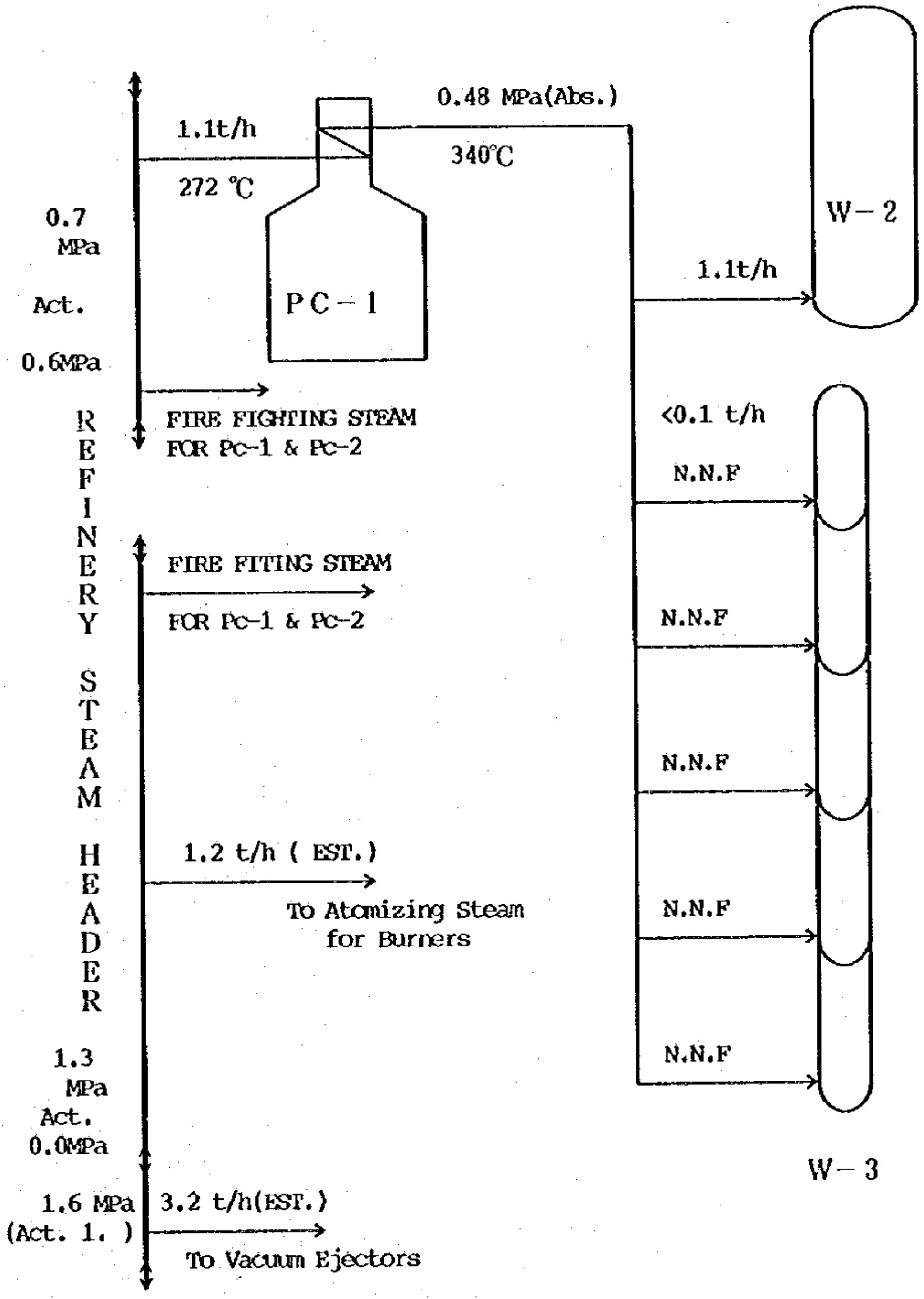
DATE : 26 NOVEMBER 1993

TIME : 09:00 ~ 10:00

PLACE : NO.1 CRUDE OIL DISTILLATION UNIT

STEAM CONSUMPTION : 1.3 MPa . t/h

0.7 MPa . t/h



3.6 Review of Fuel Efficiency in the Heating Furnace and of Energy Balance

3.6.1 Fuel efficiency in the heating furnace

Fuel efficiency in the heating furnace is calculated as follows:

(1) Pc-1

1) Fuel Consumption

Based on the DATA	126.6 Gj/h

2) Absorbed Heat Duty (Refer to Table 3.2-9)

Simulation of the existing Unit	123.8 Gj/h

3) Fuel Efficiency

$$\frac{123.8}{126.6} \times 100 = 97.8\%$$

4) Review of Fuel Efficiency of Pc-1

Judging from the excess air ratio, the Fuel Efficiency of 97.8% is incredible.
Actual fuel efficiency would be about 60 to 70% when considering the actual fuel efficiency of Pc-2.

5) Estimation of the cause of the high fuel efficiency

(a) Accuracy of the flow meters
During the second field survey, the accuracy of the flow instrument for fuel oil and fuel gas was confirmed.

According to the explanation by PPSA, the flow instruments were inspected in September and October of 1993, therefore, there should be no malfunction for these instruments.

(b) Overhead pressure of W-2

The pressure of W-2 would affect the fuel consumption, i.e., the lower the pressure of W-2, the smaller the fuel consumption.

In the simulation model, the pressure of W-2 was assumed to be higher than that of actual operation (Refer to Table 3.2-7). This means the estimated fuel consumption obtained from the simulation model would be more than the actual one.

This is one of the reason why the fuel efficiency is high.

(c) The wrong sampling place for W-1 bottom oil

As discussed in 3.2.2, it was reported that the W-1 bottom oil was sampled at the wrong place.

Through the above discussions, it is estimated that the unreasonable fuel efficiency would have been calculated by the difference with W-2 overhead pressure between the measured one and simulated one and wrong sample of W-1 bottom oil.

During basic design, it is recommended to simulate again by using more accurate actual data of W-2 overhead system and proper analysis DATA for W-1 bottom oil.

(2) Pc-2

1) Fuel Consumption

Based on the DATA	64.37 Gj/h

2) Absorbed Heat Duty (Refer to Table 3.2-9)

Simulation of the existing Unit 41.13 Gj/h

3) Fuel Efficiency

$$\frac{41.13}{64.37} \times 100 = 63.9\%$$

4) Review of Fuel Efficiency of Pc-2

This value is reasonable if the excess air ratio is taken into consideration.

3.6.2 Review of energy balance in No.1 crude oil distillation unit

Energy balance of No.1 crude oil distillation unit submitted by PPSA is shown in Figure 3.6-1.

Although the operation conditions when this energy balance was prepared should be confirmed, this energy balance would be prepared by the data at the maximum throughput because the atmospheric residue was bypassed from the vacuum unit.

(1) Heater efficiency

According to the Energy balance shown in Figure 3.6-1, the efficiency for Pc-1 and Pc-2 is as follows;

Pc-1 : (39,136.6 - 13,261.5) / 39,136.6 = 66.1%
Pc-2 : (23,735.2 - 7,634.9) / 23,735.2 = 67.8%

The above efficiencies are probable based on our

(2) Energy Balance for each section in Figure 3.6-1.

Each section in Figure 3.6-1, i.e., heat exchangers, coolers, column W-1, furnace Pc-1, column W-2, furnace Pc-2 and column W-7, should be balanced in terms of energy. Figure 3.6-2 is a simplified one of Figure 3.6-1.

Table 3.6-1 shows the summary of the energy balance in each section of Figure 3.6-2.
It is clear that energy in each section does not balance. Especially, energy input to furnace Pc-1 is 127,136.6 kW and energy output from furnace Pc-1 is 232,596.1 kW.

It is recommended that energy balance should be calculated carefully otherwise it would be difficult to review the energy balance by comparing with past data.

Table 3.6-1 ENERGY BALANCE IN EACH SECTION (kW)

Section	In	Out
Heat Exchangers	138,882.2	137,042.5
Coolers		
W-1	95,811.9	95,827.1
Pc-1	127,136.6	232,569.1
W-2	206,302.4	72,389.3
Pc-2	29,635.2	59,631.5
W-7	76,651	77,151

Figure 3.6-1 ENERGY BALANCE OF NO.1 CRUDE OIL DISTILLATION UNIT

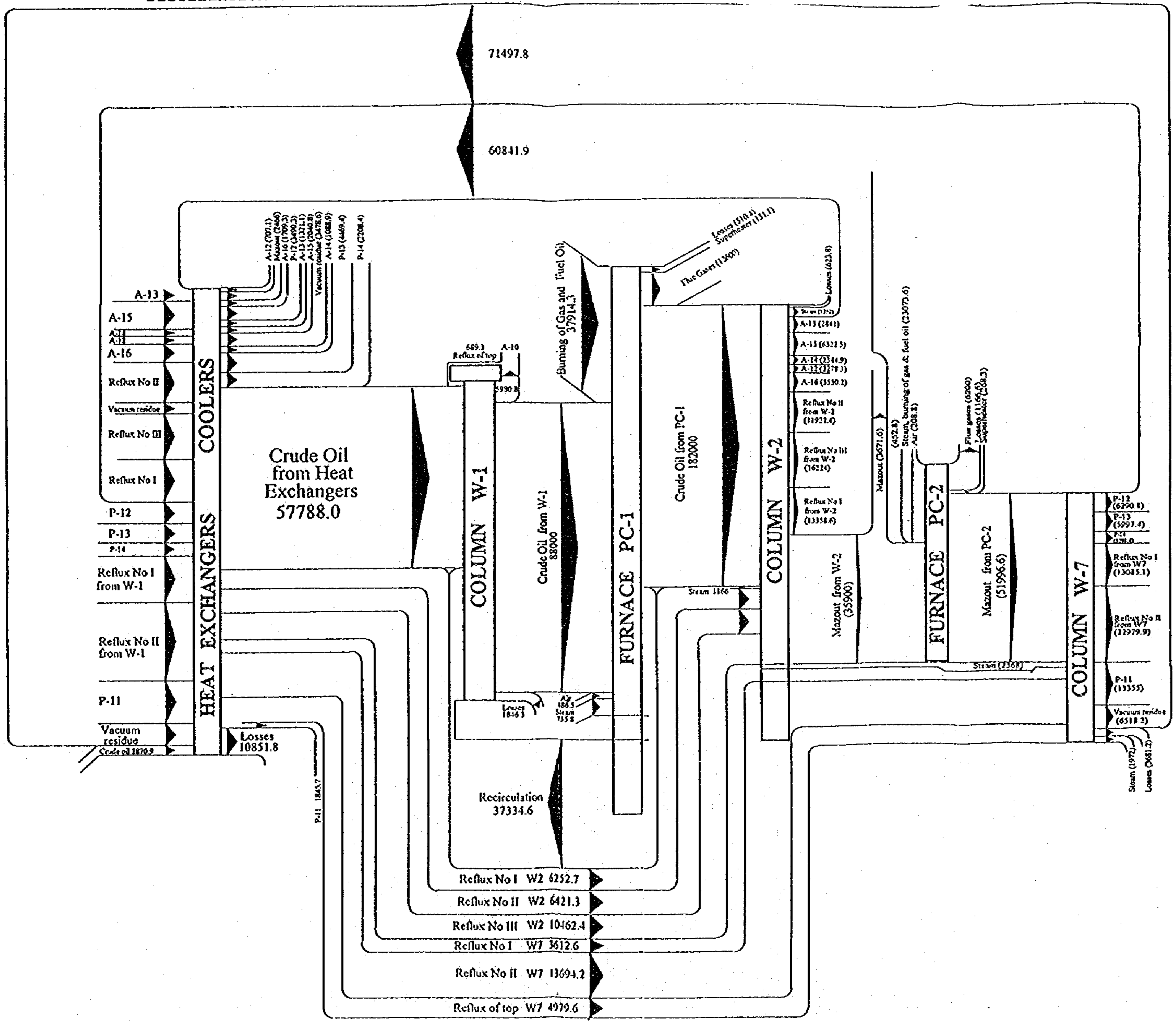
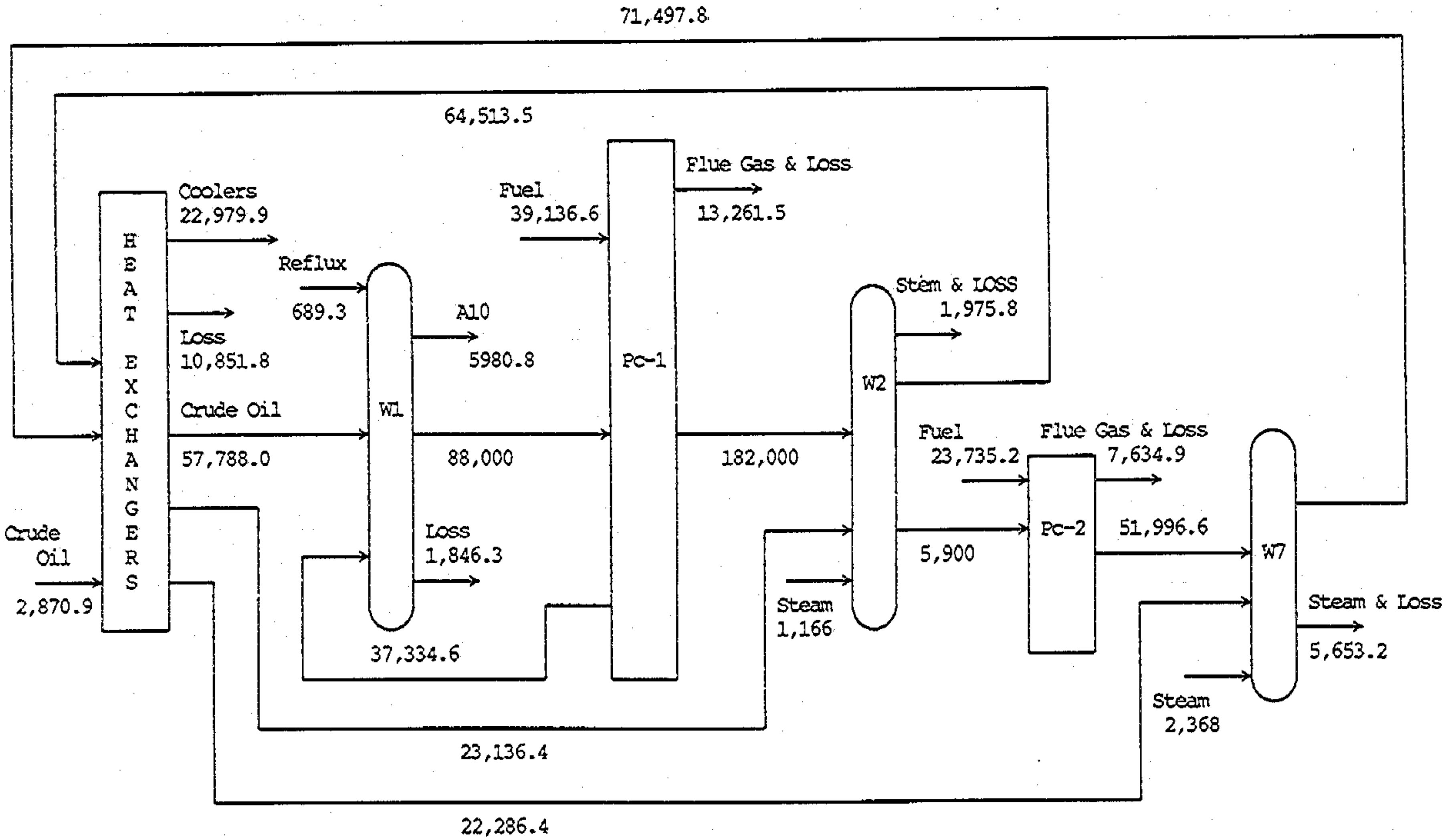


Figure 3.6-2 ENERGY BALANCE OF NO.1 CRUDE OIL DISTILLATION UNIT (1989)

Unit : kW



3.7 Review of Environmental Control Measures

As shown in Table 2.9-1, the pollutants emitted by PPSA which exceed the emission limits in 1993 are those of Phenol, Methanol and Aromatic HC, but substances directly related to No.1 crude oil distillation unit are SO_2 and HC as shown in Table 3.7-1.

SO_2 is emitted in flue gas of Pc-1 & Pc-2, while HC is escaped from open exits like an ejector into the atmosphere, seemingly resulting in the major cause of offensive odor together with small amount of leakage of H_2S.

3.7.1 Measures for reduction of SO_2 emission

(1) Current situation of SO_2 emission

SO_2 emission can be calculated by the following 3 methods.

1) Fuel consumption & sulfur content in fuel
2) Flue gas volume & SO_2 concentration in flue gas
3) Calculation based on heat balance sheet

Table 3.7-2 shows the calculated result by means of above 3 methods. Since there are big difference among the values, it is believed to be attributable to the errors in the measurement. Therefore, it is necessary for PPSA to improve the accuracy of measurement in order to have the same results with calculation.

The major assumptions for calculating SO_2 emission in accordance to the operating conditions set forth for collection of operation data conducted on 26 November, 1993 are as shown below (see Table 3.3-4 for details).

- Crude oil : Ural crude oil 100%
- Operation rate : 270 t/h in No.1 crude oil distillation unit

- Flue gas composition: The same as Table 3.3-4

Item	Pc-1	Pc-2
Fuel oil (Kg/h)	2,300	1,200
- Sulfur content (wt%)	2.80	2.80
- LHV (Kcal/Kg)	9,443	9,443
Fuel gas (Nm^3/h)	1,000	476
- H_2S content (Vol%)	0.81	0.81
- LHV ($Kcal/Nm^3$)	8,516	8,516
Excess air ratio	1.83	1.48
Dry flue gas (Nm^3/h)	Appx. 55,000	Appx. 22,300

- Flue gas composition: The same as Table 4.2-1

Item		Pc-1	Pc-2
Flue gas temperature (°C)		310	360
Flue gas composition (Vol%)	CO_2	8.12	10.20
	CO	0.0	0.0
	O_2	9.5	6.83
	N_2	75.24	71.16
	NOx (Vol ppm)	47	113
	SO_2 (Vol ppm)	7	495

Note: Emission values of NOx & SO_2 of Pc-1 are abnormally low. Calculated values of SO_2 are 557ppm for Pc-1 and 710ppm for Pc-2.

- Emission limit (1993) & real emission volume (1992): The same as Table 4.5-2

Item		Emission volume limit (Kg/h)	Real emission volume (Kg/h)
Pc-1	SO_2	56.6	97.9
	NOx	17.4	7.8
	CO	10.0	0.3
Pc-2	SO_2	20.3	50.6
	NOx	7.7	4.2
	CO	6.0	0.8

Note: "50.6" shows that emission volume exceeding the limit

- Heat balance : Refer to Table 3.6-1

(2) Measures for reduction of SO_2 emission

Measures for reduction of SO_2 emission can be generally considered as follows.

1) Measures by means of save-energy

Refer to Section 4.4. It is believed in particular that the effective measures for save-energy are reduction of excess air ratio as well as intensive heat recovery by installation of air preheater on the furnace and rearrangement of heat exchangers around the distillation unit.

2) Measures by use of low sulfur fuel

Fuels which are currently used are mainly vacuum residue with sulfur content of 2.8 wt% and off-gas to be generated in the refinery with H_2S content of 0.81 vol%. Accordingly, it can be expected to have SO_2 reduction effect in proportion to decreased sulfur content in fuel.

3) Installation of desufurization unit

Direct reduction of SO_2 content in flue gas can expected although large amount of investment is needed.

3.7.2 Measures for reduction of H_2S emission

Refer to Section 4.6.

3.7.3 Problems on environmental protection

Measures for environmental protection shall be established on the basis of correct understanding on emission volume of pollutants.

However, as shown in Table 3.7-2, it is not clear how to determine the correct value among the values in the table, since there are big difference in the values obtained by various methods.
The outcome of measurement or calculation might be different according to the mixed ratio of liquid and gas fuels, therefore SO_2 emission is to be calculated based on the average mixed ratio of fuels throughout a year.

SO_2 emission of Pc-1 as well as Pc-2 exceed the limit value in 1993 as shown in Table 3.7-1.
Therefore, taking into account the schedule that the national legislation for SO_2 emission limit will be far more strengthened on and after 1998, it is indispensable for PPSA to establish more effective measures for reduction of SO_2 emission as soon as possible.

In view of complying to the necessity of above countermeasures, PPSA has already prepared the medium and long term management plan to install an appropriate facility to cope with the environmental enactment.

Table 3.7-1 AIR POLLUTION LIMIT & EMISSION VALUE OF NO.1 CRUDE OIL DISTILLATION UNIT (1993)

Item	Emitter Symbol	Emitter Location	Emitter Dimension H(m)xD(m)	Pollutants	Emission Limit value (kg/h)	Emission Limit value (ton/y)	Emission value (kg/h)	Emission value (ton/y)
1	BEM 001	Pc-1	48.04x3.35	SO_2	56.58	282.9	97.92	711.3
				NO_x	17.42	87.1	7.8	56.8
				CO	10.00	50.0	0.3	2.2
				HC-aliph.	3.00	18.0	0.09	0.6
				HC-arom.	0.50	3.0	0.017	0.1
2	BEM 002	Pc-2	33.79x1.98	SO_2	20.31	101.5	50.58	367.4
				NO_x	7.74	38.7	4.18	30.4
				CO	6.00	30.0	0.76	1.1
				HC-aliph.	2.00	12.0	0.04	0.3
				HC-arom.	0.25	1.5	0.016	0.1
3	BEM 003	Od-8 Zb-3 Slop Tanks	26.00x0.11	HC-aliph.	44.0	348.4	9.0	64.6
				HC-arom.	1.00	7.9	-	-
				H_2S	1.50	11.9	1.0	7.2
4	BEM 004	Rv on Slop Tanks Zm-2.Zm-3	10.26x0.40	HC-aliph.	0.03	0.2	0.02	0.2
				HC-arom.	0.001	0.01	0.002	0.01
				H_2S	0.001	0.01	-	0.01
5	BEM 230	Rv on Slop Tank Zm-1	40.26x0.28	HC-aliph.	0.005	0.01	0.006	0.05
6	BEM 231	Rv on Solution Tank Zm-13	3.32x0.15	HC-aliph.	0.005	0.01	0.002	0.012
				HC-arom.	0.001	0.004	-	-
7	BEM 232	Rv on Fuel Oil Tanks Z-11.Z-12	3.04x0.15	HC-aliph.	0.025	0.09	0.002	0.012

(NOte) Emission limit : Effective on Dec. 31.1993

▨ shows substances exceeding permited limit

Table 3.7-2 CALCULATED EMISSION VALUES OF AIR POLLUTANTS (1993)

(270t/h throughput of crude oil)

(Unit: Kg/h)

Item		Emission limit by regulation	Current emission measured by PPSA	S02 emission calculated by fuel consumption			S02 emission calculated by heat balance		
		(1993)	(1993)	100% Oil	Mixed	100% gas	100% Oil	Mixed	100% gas
Pc-1	S02	56.6	97.9	179.3	151.9	82.1	292.3	247.6	133.9
	NOx	17.4	7.8						
	CO	10.0	0.3						
Pc-2	S02	20.3	50.6	91.2	78.2	41.8	97.0	83.2	44.5
	NOx	7.7	4.2						
	CO	6.0	0.8						

Item		S02 emission calculated by concentration
Pc-1	S02	1.1
	NOx	5.3
	CO	
Pc-2	S02	31.5
	NOx	5.2
	CO	

(Note)

-Mixed ratio between fuel oil and fuel gas is determined by each fuel consumption quantity as shown in Table 3.2-4.

-Values in the table are based on 270t/h throughput of crude oil

3.8 Review of Environmental Measurement and Monitoring System

3.8.1 Confirmation on sampling methods

There are no noticeable problems on sampling methods including location, position, collection tube, and duct when compared to JIS method except the following items.

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

(2) H_2S/RSH : For gathering samples, PVF (Polyvinyl Flvoridi) bag or vacuum glass flask are believed to be more appropriate for use

(3) HC-Alipha/Aroma : Air evacuated sampling bag made from PVF rather than use of diaphragm pump.

3.8.2 Confirmation on analysis procedures

(1) SO_2

The Polish equipment of MADUR GA-60 is employed, which has the advantage of measuring several elements at relatively shorter time. However, it is necessary to make confirmation on accuracy of the measured value by conducting parallel measurement by means of manual analysis like titration or absorption methods, or by means of continuous measuring equipment with self-proofreading system by using standard gas.

PPSA has assigned ENERGOPOMIAR corporation as outside contractor to conduct measurement and analysis on behalf of PPSA. In this company, UV absorption equipment is used as in the case of JIS, and is believed that this method gives the more accurate values.

UV absorption equipment has the higher reliability since calibration is made at each measurement by use of standard gas, and receives little influence of interference substances.

The analysis methods defined by JIS are as shown below.

- Neutralization Titration Method
- Precipitation Titration Method
- Tubimetric Method

(2) NOx

MADUR GA-60 is used. As mentioned in Item (1) above, it is requisite to confirm accuracy of the measured values by conducting parallel measurement by means of manual analysis like absorption method, or continuous measuring equipment with self-proofreading system by using standard gas.

ENERGOPOMIAR uses chemiluminescence equipment with standard gas made by internationally wellknown AGA corporation in ex-West Germany, leading to the higher reliability.
JIS adopts the following methods, either of them has high accuracy although some experiences are necessary to get familiar with these methods.

- Zn-NEDA Method
- PDS Method

(3) CO

MADUR GA-60 is used. It is necessary to confirm accuracy of the measured values by conducting parallel measurement by means of manual analysis with gas-chromatography or continuous measuring equipment with self-proofreading system by using standard gas.

Since PPSA has equipped with GC-TCD, several parallel measurements by use of GC-TCD will be good enough to confirm the accuracy of the measured values. The confirmation on the measured value was made by means of a gas detector tube with appropriate result.

(4) H_2S/RSH

No problem, since analysis is made by GC with FPD.

(5) HC-Alipha/Aroma

Analysis is made by GC with FPD.
(HP5890A-FID with Integrator)
No Problem is observed, since accurate operation is conducted with regard to preparation of standard gas, sample injection into GC, etc..

3.8.3 Emission values in flue gas

Emission values measured in flue gas of Pc-1 Furnace (BEM-001) are as shown below.

Item	MD MADUR GA-60	Gas detector	Brand name
O_2 (%)	10.23	17	No. 31
H_2S (ppm)	0	ND < (1)	4L
CO (ppm)	6	7	1L
SO_2 (ppm)	201	No measure't	5M
NO_2 (ppm)	5	ND < (2.5)	No. 10
NO (ppm)	64	No measure't	No. 10
CO_2 (%)	7.7	-	-
NOx (ppm)	70	No measure't	11L
RSH (ppm)	-	ND < (0.1)	70L
(ppm)	-	50	No. 140
(ppm)	-	ND < (2)	No. 120

(Note) ND: Not detected

3.8.4 Location for measurement in PPSA and the measured values

Refer to Table 3.7-1.

3.9 Review of Management System

No.1 crude oil distillation unit was reviewed in the aspects of operation and maintenance management. Mechanical- and process-related problems of No.1 unit are already treated in Section 3.3 to 3.7.

3.9.1 Operation Management

(1) organization

The organization chart of PPSA is shown in Figure 2.4-1. PR-3 is a production department of refinery responsible for production control in No.1, 2, 3 and 4 crude oil distillation units, and DRW-I section is in charge of production and partial maintenance management of No.1 crude oil distillation unit under the control of PR-3.

Organization of DRW-I section is given in Figure 3.9-1, which consists of a manager, a process engineer of PR-3 department for production management, each mechanical and electrical engineer in charge of maintenance planning and preparations for repair works, and shift workers for production of No.1 crude oil distillation unit.

(2) Working hours and costs of laborers

Operation of No.1 crude oil distillation unit is maintained by three eight-hour shifts of 7 members per shift, as shown in Tables 3.9-1 and 3.9-2.

Wages for rough classification of all job categories are given in Table 3.9-3 and the average basic wage of laborers working for No.1 crude oil distillation unit is 8.3×10^6 Zl/month as of October 1993.

(3) Operation Control

The number of employees of DRW-I section is 35 as of December 1993, including a process engineer of PR-3 department. Production is maintained by three eight-hour shifts. Figure 3.9-2, for example, shows structure of three eight-hour shifts for operation of a refinery in Japan. Its processing capacity of an atmospheric distillation unit is 100,000 barrels per stream day (BPSD), and a vacuum distillation unit 50,000 BPSD.

These are modern units with advanced instrumentation, so-called distributed control system (DCS), compared with obsolete facilities of No.1 crude oil distillation unit so that direct comparison of organization is not considered to be meaningful.
Employment of No.1 crude oil distillation unit, however, is considered to be admittedly oversized for operation of a 70,000 BPSD-scale atmospheric and vacuum distillation unit.

The following are possible causes to oversize the structure and need to be taken into consideration in case of restructuring of PPSA.

1) Crude oil refining plants comprise four units, and the processing capacity of each unit is relatively small scale of 70,000 BPSD-scale: this causes ineffectiveness in operation management of distillation units.

2) Location of No.1 crude oil distillation unit off No.2, 3 and 4 crude oil distillation units obstructs the unification of the units.

3) DRW-I, -II, -III and -IV sections are organized independently. This hinders the union of four sections or the establishment of the mutual support system for start-up, shutdown, and emergency operations.

The study of measures below is requisite to further effective employment of the personnel. It would be expected that implementation of the unit reconstruction below in addition to improvement of the above mentioned matters would optimize employment like that shown in Table 3.9-4.

4) Adoption of automatic emergency shutdown system.

5) Introduction of automatic control system like DCS.