3.9.2 Maintenance Management

(1) Organization

Centralized maintenance system has been adopted in the maintenance sector of PPSA, so that evaluation of the organization of the maintenance sector for No.1 crude oil distillation unit is difficult. Figure 3.9-3 is the organization chart of the entire maintenance sector of PPSA, named maintenance system, and Figure 3.9-4 that of the workshop MZB.
Maintenance system includes the following public organizations which are described later.

UDT (Government Inspection Organization)
ZDT (Local Inspection Organization)

Employment of the maintenance sector in 1993 is in total 2,832, comprising 586 staffs and 2,246 laborers, which accounts for 34% of all employees in PPSA. In accordance with the investigation report*1 of 1,376 Japanese manufacturers workers of the maintenance sector in the chemical industry in 1993 account for 11.3% of the total sum of the personnel for the maintenance and manufacture sectors and those in case of the coal and oil industry account for 23.9%.

Maintenance system is admittedly massive in contrast to the state of the Japanese industry, although the centralized maintenance system which can be organized in the relatively small number of employees has been employed in PPSA. Presumable causes are listed below:

*1: Japan Plant maintenance Association(1993) Investigation reports of actual state of maintenance in Japan.

1) Most of maintenance works in PPSA are carried out by inside labor forces except engineering design, manufacture of equipments, construction, and concentrated works of periodic maintenance during turnaround which are in principle depending upon outside labor forces.

2) Most of processing machinery of workshops is obsolete and complicated to be handled, and sophisticated works there require many hand skills. Hence the structure swells.

Referring to a complex of an oil refinery and petrochemical works in Japan, PPSA ordinarily has the huge maintenance sector nearly equal to the size of external workers required for maximum concentrated works of periodic maintenance during turnaround for a 300,000 BPSD-scale refinery. It is not possible to estimate appropriate employment for maintenance because of difficulties to grasp entire maintenance works in detail. Rough size of engagement to perform all maintenance works in PPSA by itself excluding maintenance during turnaround is provisionally estimated around the scale of 1,000 with reference to the complex in Japan cited above.

To develop its competitive power even up with the West European bloc in the condition of free market economy after introduction of the principle of competition, drastic restructuring of organization of the maintenance sector is essential. For this purpose it is judged to be disadvantageous in respects of technologies, assets, and economy for PPSA to implement all maintenance works by itself. Engineering works of the following natures in mechanical, electrical, instrumental, civil, construction, and software works should be studied to be isolated from current commission of the maintenance sector and relied on external engineering companies.

Engineering works:

a) requiring specific techniques and special-purpose machinery.
b) calling for expertises.
c) needing high-price facilities.
d) being low value added.
e) necessitating lots of manpower.

(2) Working hour and labor cost

Maintenance works are performed in two eight-hour shifts. Working hour of the personnel given in Table 3.9-5 is 178 hours a month and 2,136 hours a year.

In accordance with the investigation report*1 of 1,376 Japanese manufacturers working hour of the maintenance sector in the chemical industry in 1993 are reported to be 181 hours a month and 2,132 hours a year, and theses two figures are similar to those mentioned in the case of PPSA. Basically, maintenance works requiring lots of hands such as repair and assembly, welding, and machining are assigned to the first shift and only simple works like machining to the second shift in order to keep the higher efficiency of engineering works.

Average basic wages of laborers working for the maintenance sector are given in Table 3.9-6.

(3) Maintenance system

Maintenance system for effective works needs to comprise administrative sub-systems of maintenance technologies, maintenance works, materials, and budget, as shown in Figure 3.9-5.

Maintenance management system of the workshop MZB is also given in Figure 3.9-5. According to the job requests from mechanics of the production sector, persons of MZB responsible for control of works decide maintenance technologies and schedule, materials, budget, and outside engineering works requisite for preparation of an implementation plan. This plan is forwarded to a foreman and the foreman selects technicians to conduct works and makes a maintenance report for the record. Based on such reports results of works, materials, costs, and manpower spent are evaluated for feedback to planning.

Structure of each section belonging to MZB is actually similar to distributed maintenance system, although centralized maintenance system is adopted. This is likely to be ineffective. Hence restructuring of organization to substantially centralized maintenance system is required in order to improve efficiency of maintenance system. As explained above in the previous item (1), to achieve more effective maintenance works and optimize employment it should be necessary to separate implementation of maintenance works and procurement of materials from the responsibility of MZB and place their orders to control of maintenance technologies, schedule, budget, and evaluation of maintenance performance.

(4) Maintenance management

1) Maintenance policy

Basically planned maintenance (PM) appears to be applied. PM is a concept under which two types of maintenance are adopted premeditatedly for all equipments, i.e. preventive maintenance (PM) and breakdown maintenance (BM) in accordance with extent of their effects on administration of the enterprise in case of their failure.

Further study on shift of current maintenance system to the following should be important.

a) Concept
Shift of PM to corrective maintenance (CM) and maintenance prevention (PdM).

Current PM is the maintenance system only to repair to the original condition. On the contrary CM is the maintenance system highly motivated to improve maintainability and availability, and extend remnant life of equipment.

PdM is the maintenance system aimed at engineering design free of maintenance.

b) Time of maintenance
Application of PdM to PM to carry out maintenance before failure when evaluated to be feasible in technical and economical aspects.

Optimum time of maintenance can be determined by monitoring the condition of equipments.

c) Decision of maintenance time
Decision of optimum maintenance time by condition monitoring in addition to conventional procedures by experience, intuition, past records, and statistics.

It is essential for effective PdM to introduce condition monitoring of equipments which requires advanced diagnostic analysis technology. Diagnostic analysis technology includes all techniques to monitor the condition of facilities quantitatively and take measures against problems analyzed. At present there are few monitoring techniques applied in PPSA, such as vibration monitoring of rotating machinery. Introduction of advanced diagnostic analysis technology is greatly expected as a key for modification of existing maintenance system.

2) Periodic maintenance during turnaround

a) Schedule of periodic maintenance during turnaround
Periodic shutdown maintenance during turnaround is planned in detail for each equipment as schedule of shutdown. For vessels in this schedule, for example, maintenance works are divided into small parts like temporary work of scaffolding, cleaning, visual inspection, replacement of trays, commissioning, and detailed schedule for each part. In addition to schedule of shutdown, a maintenance program for each equipment is drawn as scope of work for repair, which describes specifications, codes to be applied as well as repair works, and supports schedule of shutdown.

b) Inspection regulated by laws
PPSA shall apply to the following official organizations for inspection of all equipments.

UDT: Government Inspection Organization
ZDT: Local Inspection Organization

ZDT functions as a branch office of UDT. ZDT and UDT have codes controlling plans and schedules of design, manufacturing, installation, operation, and maintenance of all equipments to be applied the codes in PPSA.

Basically, UDT has responsibilities for equipments operation pressure of which is 0.7 bar and over, and ZDT less than 0.7 bar. PPSA shall provide documents of newly installed equipments for application to ZDT. ZDT decides the ZDT or UDT code to be applied or non-code in accordance with pressure, temperature, and safety of equipment nature. Then, ZDT binds documents concerned and transfers a copy of a bookbinding of the equipment regulated by the UDT code to UDT. The original bookbinding is returned to PPSA and a copy of a bookbinding is kept at the ZDT office. Nondestructive inspection methods applied for equipment regulated by codes are selected by ZDT/UDT inspectors according to the ZDT/UDT codes and operation conditions of equipment. Visual inspection and pressure testing in those inspection methods is described in Table 3.9-7.
It is learned that visual inspection for internal side of vessels and tanks shall be carried our within three years.

c) Interval of periodic maintenance during turnaround Table 3.9-8 shows schedules and past records of operation, shutdown, and periodic maintenance time of No.1 crude oil distillation unit in the years of 1988 to 1992.

Periodic maintenance during outage in 1988 to 1992 was scheduled and implemented once a year and in 1993 and after planned every one and half years. The reasons why periodic maintenance was conducted once a year are explained as follows, but periodic maintenance interval of either one or one and half years seems to be excessively short.

i) Cleaning of heater and heat-exchanger tubes.
ii) Repair and replacement of machinery and parts.

The ZDT/UDT codes require visual inspection of internal side of equipments once in at least 3 years. Studies to extend the interval of periodic maintenance to more than two years toward the target of 3 years shall be required for reduction of maintenance works and optimization of employment.

d) Emergency maintenance

Only one emergency shutdown was reported in 1988 because of an outbreak of fire caused by leakage of hot oil from a mechanical seal of a pump P-3/4. The repair cost of equipments, electric machinery, and instrument due to this accident reportedly amounted to 6,094,238 Zl as losses.

3) Maintenance costs

Past records of maintenance costs in 1989 through 1993 are described in Table 3.9-9.

Table 3.9-10 [*2,*3] shows investigation results of maintenance costs, for example, of heavy industries, i.e. steel, ammonium sulphate, vinyl chloride, soda, rayon, sugar refining, and oil, held in U.S.A. in 1957 and in Japan in 1961 almost the same time when No.1 crude oil distillation unit was constructed. Ratio of maintenance costs to re-acquisition cost in the middle 50% companies in USA is 5.9% and in the case of Japan 7.2%. 1989 and 1990 would be years when lunatic fluctuation of inflation rate lasted and data of those years is not considered to be useful for comparison so that data of 1991, 1992 and 1993 is taken into consideration. Ratio of maintenance costs to re-acquisition cost is 11.3 to 14.8%, rather higher when compared to the cases of USA and Japan.

Definite indices useful for evaluation of maintenance records could not be found. Indices such as the following are required for control of maintenance to slash maintenance costs and improve efficiency of maintenance works; especially those which are unlikely to be affected largely by lunatic fluctuation of inflation rate need to be established.

i) Rate of maintenance costs to production.
ii) Rate of maintenance costs to trade.
iii) Ratio of maintenance costs to production cost.
iv) Ratio of maintenance costs to acquisition cost.

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

(4) Inventory control

Workshops control inventory as their responsibilities. Inventory control to support maintenance works done by the maintenance sector itself likely causes excess stores and then results in ineffective operation of maintenance costs.

As mentioned in the item 3.9.2 (1), in case of studies to restructure organization of the maintenance sector, modification of inventory control system should be requisite to dependence upon supply of materials from outside, reliable organizations except stocks of materials for emergency maintenance of critical equipments.

3.9.3 Education and training system

Qualification and employment necessary for each job position is regulated by bylaws of PPSA and there is the education and training system organized for this purpose. Education of outside workers is included in this system, as well. Outline of the system is as follows:

- Education and training system:

instruction for training of workers including safety rules, fire protection, environment protection, and permission of works.

(1) Introduction

(2) General description

(3) Primary training

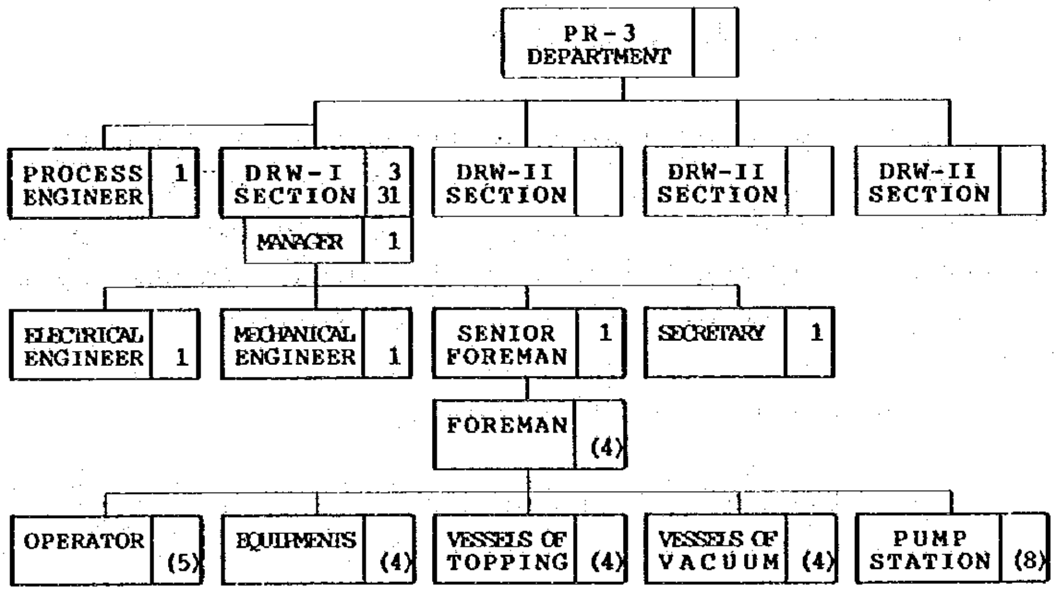
(4) Training of positions including all the subjects

(5) Some additional training to promote to higher level

(6) Some kinds of training for outside workers to implement works in refinery

(7) Some training course regarding safety, fire protection, etc.

Figure 3.9-1 ORGANIZATION CHART OF DRW-1 SECTION



* The upper figures show the number of staffs, the lower labourers, and ones in parentheses the number of shift workers.

Table 3.9-1 SHIFT OF EMPLOYEES FOR PRODUCTION OF NO.1 CRUDE OIL DISTILLATION UNIT

SHIFT	SYMBOL	NUMBER OF WORKERS	ON-DUTY TIME
1ST	①	7	06:00 - 14:00
2ND	②	7	14:00 - 22:00
3RD	③	7	22:00 - 06:00
OFF DUTY	○	7	-

Table 3.9-2 SCHEDULE FOR WORK ON THREE EIGHT-HOUR SHIFTS

SHIFT	DAY															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I	①	①	①	①	○	③	③	③	③	○	○	②	②	②	②	○
II	②	②	②	○	①	①	①	①	○	③	③	③	③	○	○	②
III	③	○	○	②	②	②	②	○	①	①	①	①	○	③	③	③
IV	○	③	③	③	③	○	○	②	②	②	②	○	①	①	①	①

Table 3.9-3 EMPLOYMENT

AS OF DECEMBER 1993

JOB POSITIONS	EMPLOYEES	AVERAGE SALARY/10^6 zl
UNIT MANAGEMENT	1	13.7
TECHNICIAN	4	12.3
OFFICE WORKER	1	6.0
INDUSTRIAL LABOURER	28	7.3
TOTAL	34	8.3

Figure 3.9-2 INSTANCE OF THREE EIGHT-HOUR SHIFT FOR PRODUCTION OF A JAPANESE REFINERY

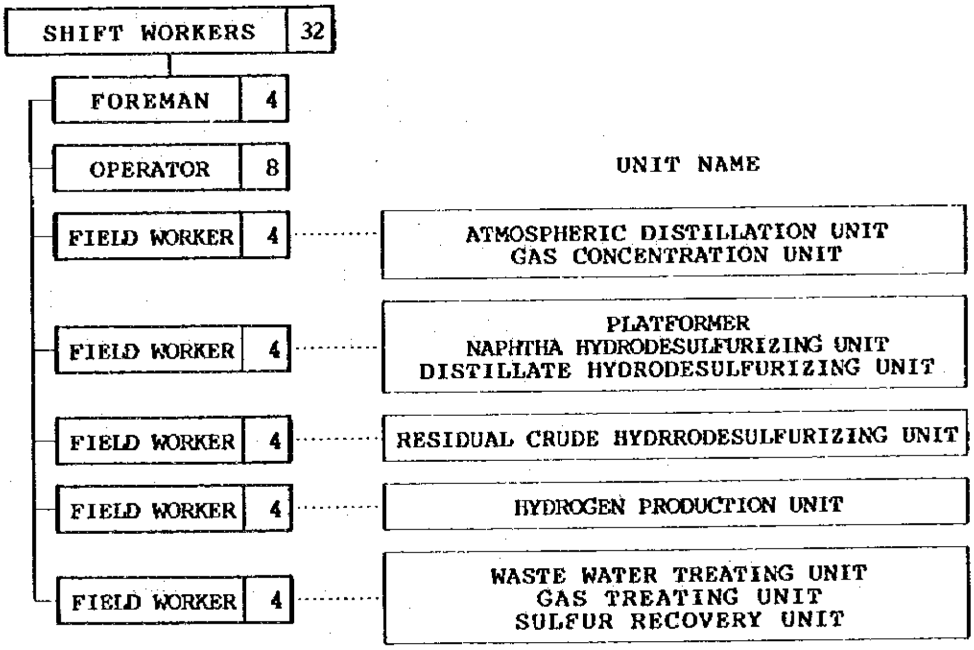


Table 3.9-4 EXPECTED OPTIMUM EMPLOYMENT AFTER STRUCTURAL AND ENGINEERING IMPROVEMENT

	CURRENT	AFTER IMPROVEMENT	DIFFERENCE
FOREMAN	4	4	0
OPERATOR	5	5	0
FIELD WORKER	20	8	12

Figure 3.9-3 ORGANIZATION CHART OF MAINTENANCE SYSTEM
AS OF NOVEMBER 1990

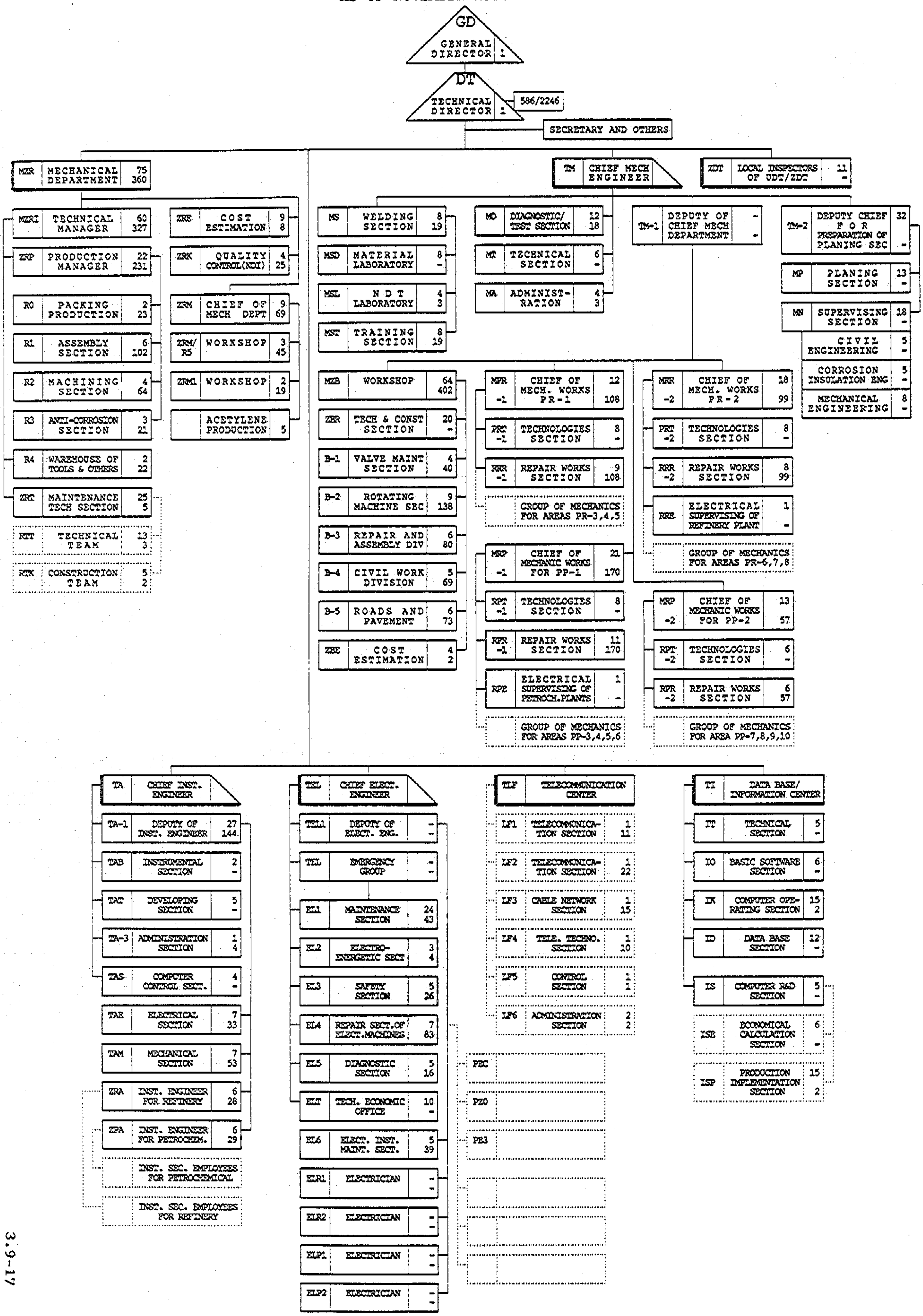


Figure 3.9-4 ORGANIZATION CHART OF WORKSHOP MZB

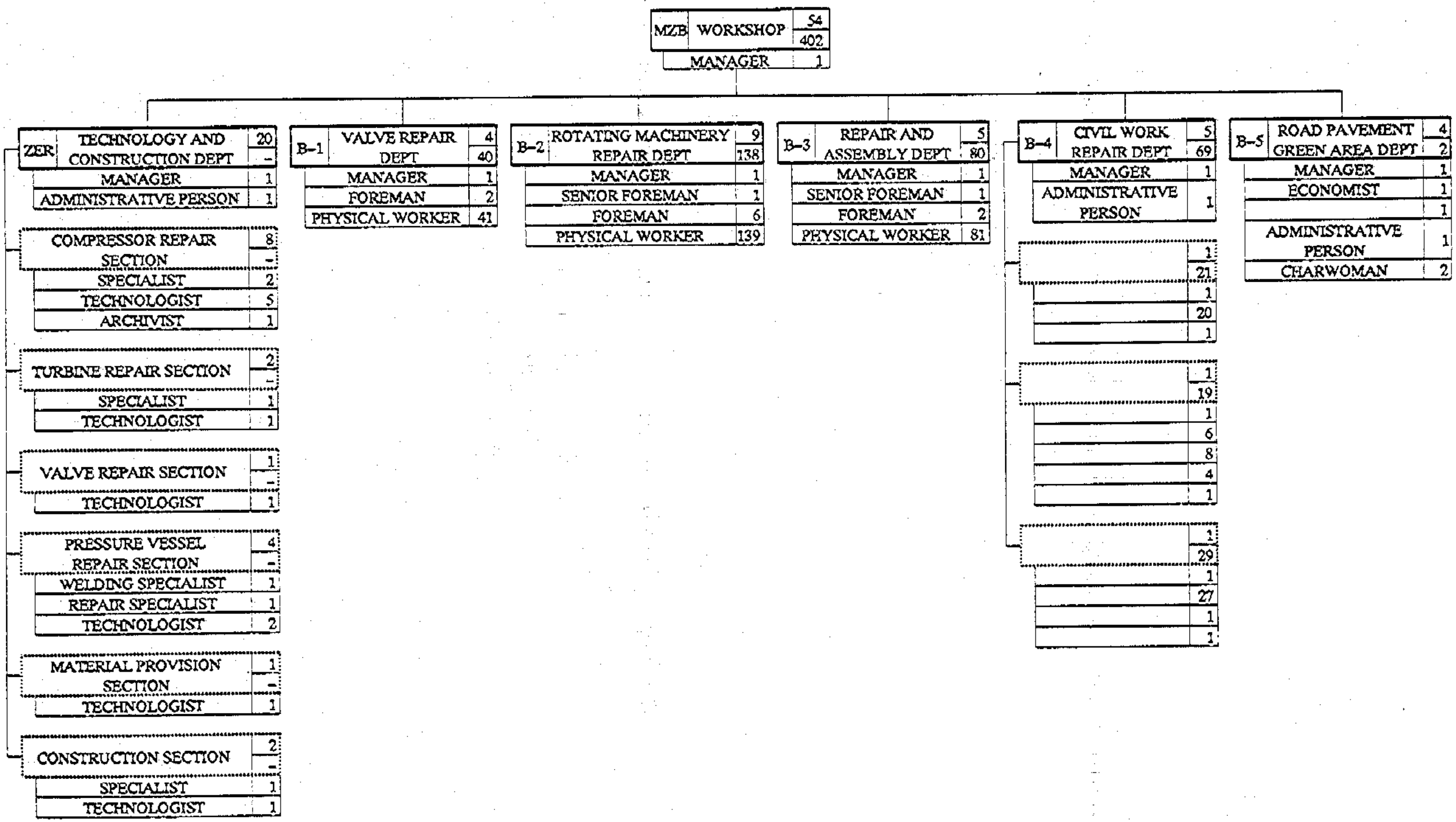


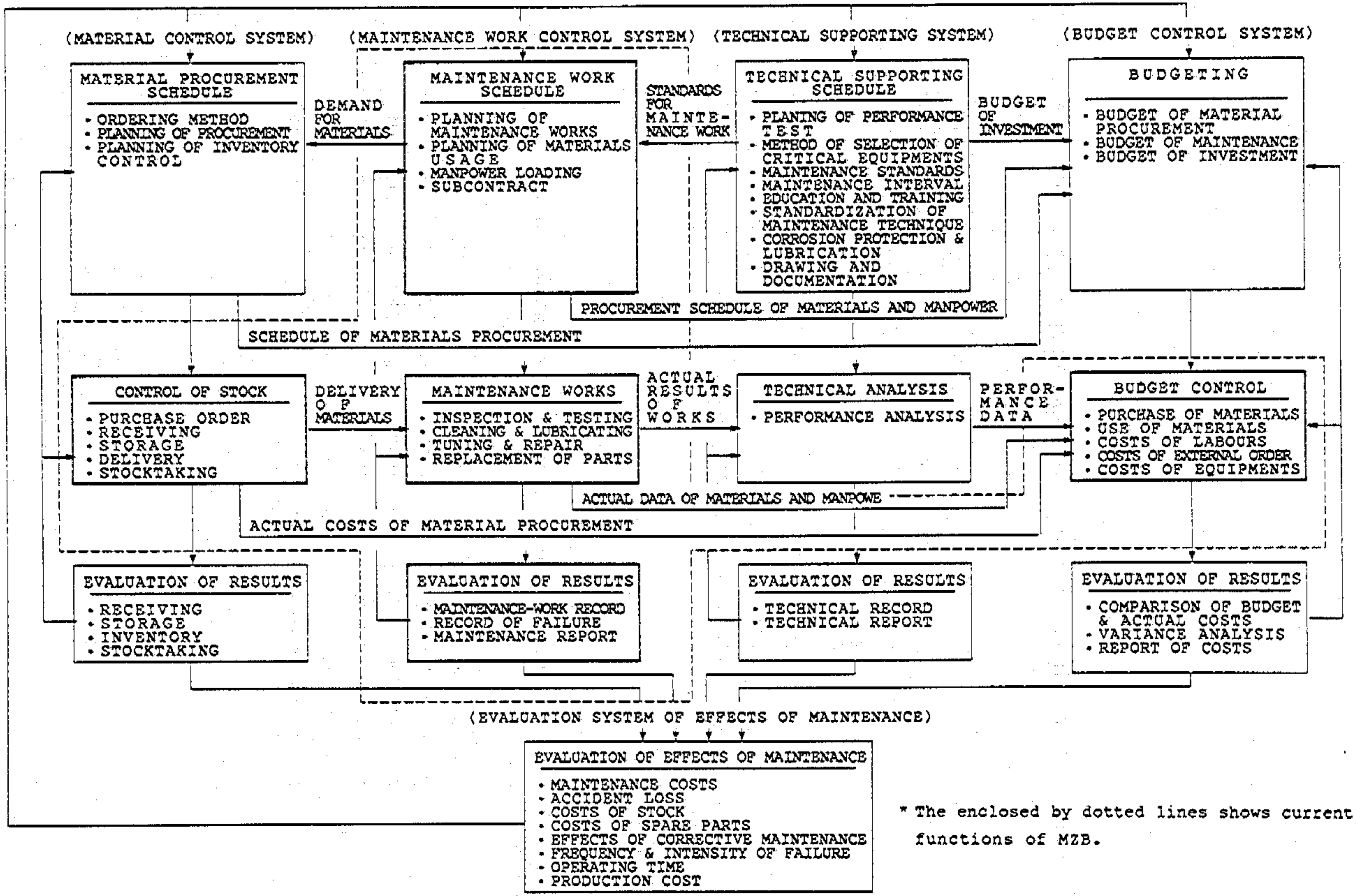
Table 3.9-5 WORKING HOUR FOR EMPLOYEES OF MAINTENANCE SECTOR

	DAY	MONTH	YEAR
WORKING HOURS (HOURS)	8	178	2136
SHIFT	WORKING TIME		
1 ST	06:00 - 14:00		
2 ND	14:00 - 22:00		

Table 3.9-6 WAGES OF EMPLOYEES FOR MAINTENANCE SECTOR

AVERAGE WAGES/10⁶ Zl	
HOUR	MONTH
0.06	10.68

Figure 3.9-5 TOTAL MAINTENANCE SYSTEM



* The enclosed by dotted lines shows current functions of MZB.

Table 3.9-7 INSPECTION OF EQUIPMENT REGULATED BY UDT/ZDT CODES

CODE	EQUIPMENT	INSPECTION INTERVAL		
		PRESSURE TEST	VISUAL TESTING	
		(DESIGN PRESSURE x 1.25)	INTERNAL	EXTERNAL
U D T	VESSEL	6 YEARS	3 YEARS	1 YEARS
	TANK	6 YEARS	3 YEARS	1 YEARS
	PIPELINE	6 YEARS	–	–
Z D T	VESSEL	6 YEARS	3 YEARS	1 YEARS
	TANK	6 YEARS	3 YEARS	1 YEARS
	PIPELINE	6 YEARS	–	–

Table 3.9-8 NUMBER OF OPERATION DAYS

YEAR		1988	1989	1990	1991	1992
PLANNED OPERATION DAYS	(DAYS)	118	334	311	338	324
PLANNED SHUTDOWN DAYS	(DAYS)	34	31	54	27	42
ACTUAL OPERATION DAYS	(DAYS)	88	349	311	315	324
ACTUAL SHUTDOWN DAYS	(DAYS)	277	16	54	50	42
ACTUAL SHUTDOWN OPERATION DAYS	(DAYS)	22	19	37	17	21
ACTUAL START-UP OPERATION DAYS	(DAYS)	3	4	3	2	12

Table 3.9-9 MAINTENANCE COSTS OF NO.1 CRUDE OIL DISTILLATION UNIT

YEAR		1989	1990	1991	1992	1993
a:PREVAILING VALUE	(x 10^6 zl)	2523	32922	92319	92319	93027
b:REAL COST OF MAINTENANCE	(x 10^6 zl)	1400	6883	10453	13650	10961
e:(b/a) x 100	(%)	55.4	20.9	11.3	14.8	11.8
h:($a/a_{PREVIOUS\ YEAR}$) x 100	(%)	-	1304.9	280.4	0.0	99.7

Table 3.9-10 MAINTENANCE COSTS OF FACILITIES IN HEAVY INDUSTRIES IN U.S.A. AND JAPAN

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

Chapter 4

Examination of Possiblities and Alternative Plans for Modernization of No.1 Crude Oil Distillation Unit

Contents of Chapter 4

Page

Contents of Table in Chapter 4

Page

Contents of Figure in Chapter 4

Chapter 4 Examination of Possiblities and Alternative Plans for Modernization of No.1 Crude Oil Distillation Unit

4.1 Summary of the Current Issues of No.1 Crude Oil Distillation Unit

Diagnostic review of No.1 crude oil distillation unit was done in Chapter 3 and the current issues of No.1 crude oil distillation unit needing to be solved were clarified. Since these issues are related to each other, it is necessary to arrange them into groups for study. Figure 4.1-1 shows the study items after summarizing the current issues. Namely, the current issues which were clarified in Chapter 3 are summarized in 14 items as follows:

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

(2) Construction of stabilization unit for A10 fraction

(3) Construction of splitter unit

(4) Decreasing the atmospheric distillation product number

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

(6) Improvement of process heaters efficiency
(The heat recovery of flue gas from heaters)

(7) Improvement of vacuum tower fractions

(8) Revamping of desalters

(9) Box water cooler liquidation

(10) Liquidation of Od-8 and Zb-3 emissions

(11) Application of DCS

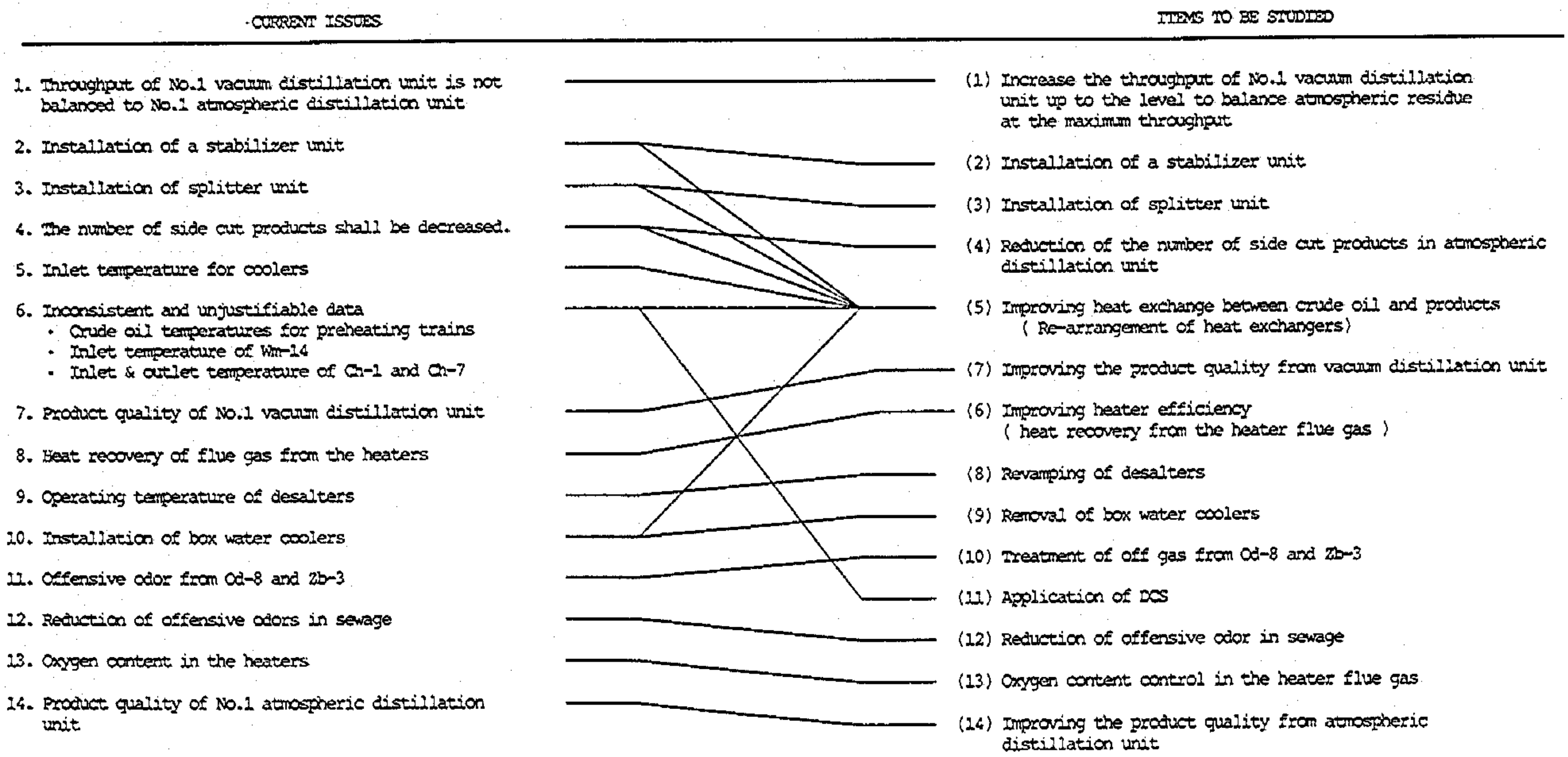
(12) Reducing offensive odor substance in sewage

(13) Control of oxygen content in the flue gas from heaters

(14) Improvement of atmospheric tower fractions.

Among the above items, items from (1) to (11) are involved in PPSA's modernization plan.

Figure 4.1-1 SUMMARY OF THE CURRENT ISSUES OF NO.1 CRUDE OIL DISTILLATION UNIT



4.2 Assumptions for the modernization

The following items are the assumptions for studying the modernization:

(1) Crude oil fed to No.1 crude oil distillation unit is Ural crude oil only of which properties are indicated in Tables 3.2-1 and 3.2-2.

(2) Product specification and the number of products from No.1 atmospheric and No.1 vacuum distillation unit are indicated in Table 4.2-1.
Product yields, product properties, etc. are estimated by using the simulation model which was designed in 3.2.
In this case, reforming feed case in Table 4.2-1 was applied for the products specification of A11 and A12 because this is more severe case than pyrolysis case. And operation case B in Table 4.2-1 was used for P11, P12 and P13 because operation case B contains more lighter fractions than operation A which means that it is more severe than operation case A from the stand point of heat recovery.

(3) The down stream of the No.1 crude oil distillation unit and also related facilities of utilities plants shall be sufficient to cope with the increased amount of fractions of No.1 crude oil distillation unit or capacities.

(4) 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.

(5) A new DCS system will be installed in the existing control room.

Table 4.2-1 FUTURE PRODUCT SPECIFICATION FOR NO.1 CRUDE OIL DISTILLATION UNIT (1/2)

	Use	Specification
(1) Gases	Refinery Fuel Gas	C_4 mininum
(2) LPG	Fuel for Home	$C_1 + C_2$ content vol % max. 1.5 C_5 content vol % max. 0.5
(3) R_{12}	① W-5 Columm in depenta-nization operation	Distillation (*1) IBP min. 25℃ FBP 85 ± 5℃ Loss+Residue max. 4 vol. %
	② W-5 Columm in dehexani-zation operation	Distillation (*1) IBP min. 25℃ FBP max. 80℃ C_4 content max. 4 wt% C_7 content max. 1 wt%
(4) R_{13}	① W-5 Columm in depenta-nization operation	Distillation (*1) IBP 78 ± 5℃ (1 50 vol. % recovered at 87℃ FBP 110 ± 5℃ 1) or $C_3 - C_5$ content 3 wt%
	② W-5 Columm in depenta-nization operation	Distillation (*1) IBP 80 ± 5℃ FBP 110 ± 5℃ C_6 content minimized
(5) A_{11}	① Reforming Feed	Distillation (*1) IBP 78 ± 5℃ FBP max. 110 ± 5℃
	② Pyrolysis Feed	Distillation (*1) IBP 78℃ FBP max. 180℃
(6) A_{12}	① Reforming Feed	Distillation (*1) IBP min. 130℃ FBP max. 180℃
	② Pyrolysis Feed	Distillation (*1) IBP min. 130℃ FBP max. 230℃
(7) A_{13}	Diesel Oil Blend	Distillation (*1) FBP max. 300℃ Flash Point (ASTM D 93) min. 80℃

Note: (*1) ASTM D 86

Table 4.2-1 FUTURE PRODUCT SPECIFICATION FOR NO.1 CRUDE OIL DISTILLATION UNIT (2/2)

(8) A_{14}	Diesel Oil Blend	% vol. evaporated at 350℃ Summer min. 85 Winter min. 90
(9) P_{10}	Diesel Oil Blend	Non Specificated
(10) P_{11}	Lubricating Oil	OPERATION A / B Distillation (*2) (TBP) % vol. evaporated at 300℃ max. 7 / max. 0.5 at 325℃ max. 20 / max. 3 at 350℃ 35–45 / max. 10 at 400℃ min. 90 / 45–60 at 450℃ – / min. 90 Viscosity at 100℃ (mm^2/S) 2.5–3.2 / 3.5–4.2
(11) P_{12}	Lubricating Oil	Distillation (*2) (TBP) % vol. evaporated at 300℃ max. 0.5 / max. 0.5 at 350℃ max. 6 / – at 400℃ 20–30 / max. 10–15 at 450℃ 80–85 / 45–60 at 500℃ min. 98 / 85–90 above 520℃ – / max. 15 Viscosity at 100℃ (mm^2/S) 5.0–5.6 / 6.9–7.3
(12) P_{13}	Lubricating Oil	Distillation (*2) (TBP) % vol. evaporated at 400℃ 6.5–8.0 / max. 0.5 at 450℃ 31–34 / max. 15 at 500℃ 73–79 / 45–50 above 525℃ 10–14 / 25–30 Viscosity at 100℃ (mm^2/S) 11.2–11.8 / 12.0–14.0
(13) P14	Fuel Oil Blend	Flash Point 210℃ / 210℃
(14) Vacuum Residue	• Refinery Fuel Oil • For Asphalt Plant	Penetration 1/10mm (ASTM D 5) max. 200 / max. 200 min. 120 / min. 120

Note: (*2) ASTM D 2887-78

4.3 Summary of the Study for the Modernization

The items for the modernization are studied one by one as described later. Here, the study results are summarized as follows:

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

When No.1 atmospheric distillation unit is operated according to the new product specification to be applied after the modernization, the total quantity of intermediate products will be increased.
Namely, even if the throughput of No.1 atmospheric distillation unit is at its maximum throughput which is 308 t/h, all of the atmospheric residue can be charged without any bypass flow to No.1 vacuum distillation unit.

4.3.2 Construction of stabilization unit for A10 fraction

It is necessary to construct a new stabilization unit for A10 fraction in No.1 crude oil distillation unit area. The heat source for the new reboiler is supplied by the heat of reflux in No.1 atmospheric distillation unit.

4.3.3 Construction of splitter unit

In order to produce new products which will meet the new product specification, a new splitter unit which separates stabilizer bottom oil to light and heavy naphtha must be constructed.
The heat source for the new reboiler is supplied by the heat of reflux in No.1 atmospheric distillation unit.

4.3.4 Decreasing the atmospheric distillation product number

The number of products of No.1 atmospheric distillation unit will be decreased from six to four.
Rearrangement of heat exchangers is required because of the variation in yield of the new four products and heat recovery to crude oil that exchanged the heat with the canceled two products.
This item is relating not only to 4.3.5 but also 4.3.2 and 4.3.3 in terms of heat supply for the new reboilers.

4.3.5 Improvement of heat exchange between products and crude oil (Rearrangement of heat exchangers)

Because of the transition of the temperature of crude oil in the preheat train and for more efficient heat recovery, rearrangement of the existing heat exchangers and installation of new heat exchangers were studied.
As a result, the fuel consumption was reduced compared to the calculated current fuel consumption although the heat supply to the new reboilers of the stabilizer and the splitter was secured.

4.3.6 Improvement of process heaters efficiency (The heat recovery of flue gas from heaters)

The flue gas heat from the heaters was recovered by modifying the heaters to the balanced type and installing new Jung Strom.
This is effective to reduce fuel consumption for saving energy generally. However, the final decision will be made depending on the result of the economic evaluation.

4.3.7 Improvement of vacuum tower fractions

The number of the product specifications to be applied after the modernization has been reduced. For example, the number of product specification for P11 (P10 after the modernization) is reduced from four to two and from five to two for P13 although there are no reductions for P12 and P14.
Therefore, judging from the simulation output, it is estimated that there are not any products which does not meet the product specification after the modernization.

However, the penetration of VR after the modernization was assumed to be the same value as before the modernization because analysis data of the penetration of VR under the current operation was not available.
The penetration will be adjusted by the asphalt blowing unit as is done now. Therefore, it is requested that the heat duty of Pc-2 and installation of quench line shall be reviewed in detail during basic design so that the penetration will be improved after the modernization.

4.3.8 Revamping of desalters

Since the current operating temperature of the desalters in the atmospheric distillation unit are lower by 30°C to 40°C than these generally operated in refineries, the performance was reviewed but it was concluded that the desalters can be used without any revamping after the modernization.

4.3.9 Box water cooler liquidation

In order to recover the heat which is wasted by heating the cooling water, a unit which has no box water coolers was studied. There will be no box water coolers in No.1 crude oil distillation unit after the modernization.

4.3.10 Liquidation of Od-8 and Zb-3 emissions

It is necessary to treat the off gas from Od-8 and Zb-3 because these gases contain H_2S. At present, these gases are burnt in Pc-2 which will not be allowed in the future. An amine treating unit was studied. However, it is expensive to construct the amine treating unit. Therefore, it is recommended to continue the burning of these gases in Pc-2 as being done now.

It was agreed at the third field survey that no amine treating unit will be planned and no cost will be estimated in this feasibility study.

4.3.11 Application of DCS

In addition to the instruments which were out of order, there were so many unjustifiable and inconsistent data which were collected on 26 November 1993.
Because of a shortage of spare parts as well as insufficient maintenance for the instrumentation, the application of DCS was studied.

4.3.12 Reducing offensive odor substance in sewage

There is an offensive odor which undermine the operator's health. A plan to seal the drip funnels is proposed to prevent offensive odor substance from being released to the atmosphere.

4.3.13 Control of oxygen content in the flue gas from heaters

Oxygen content in the flue gas from the heaters is rather high. Oxygen content control of 4% is proposed based on the guidelines which the Ministry of Industry and Trade in

Japan announced in 1992 for the heaters in refineries and the reduction of fuel oil consumption was estimated. This is effective to reduce fuel consumption for saving energy. However, the final decision will be made depending on the result of the economic evaluation.

4.3.14 Improvement of atmospheric tower fractions

It is necessary to improve IBP and the flash point for the atmospheric tower fractions. IBP and flash point are improved by injecting stripping steam which is not being injected now.
However, the flash point of A13 will not satisfy the product specification after the modernization.

Stripping steam is to be injected after the modernization, therefore, coalescers will be installed for the products from No.1 atmospheric distillation unit to remove water which is the condensation of stripping steam.

4.4 Evaluation of Alternative Design Possibilities for Saving Energy

4.4.1 Items to be applied to No.1 crude oil distillation unit for saving energy

Items to be applied to No.1 crude oil distillation unit are listed in Table 4.4-1.
Each item is explained briefly below.
It is recommended to study carefully before applying any of these methods.

(1) Control of oxygen content in the flue gas from heaters

It is necessary to supply the heaters with a larger volume of combustion air than the theoretical amount in order to maintain good combustibility.
The ratio of the actual amount of air divided by the theoretical amount of air is called the excess air ratio.
Decreasing the excess air ratio to as low as possible is effective for saving energy.

The oxygen content in the flue gas is controlled by adjusting the openings of the dampers of the heaters.

An oxygen content of four(4) vol. percent(%) in the flue gas is recommended at the maximum throughput.

The Ministry of Trade and Industry in Japan announced a guideline for the oxygen content in the flue gas from heaters in petroleum refinery in 1992.
It is stated as 4.2 vol. % regardless of the kind of fuel.

Since fuel oil and gas are used in the heaters of No.1 crude oil distillation unit, it may be possible to keep the oxygen content at 4 vol. %.

Four(4) vol. percent(%) should be regarded as a temporary target and it is recommended to decrease the oxygen content gradually in the future.

Subject to further study and economic evaluation, this is to be included in the modernization plan because this is one of the most effective measures for saving energy generally.

(2) Change in operating conditions of the distillation tower

1) Reduction of reflux ratio

It is often the case that the original design value of reflux ratio is applied for actual operation and the result is an excess reflux ratio.
Power used by the motors can be saved by reducing the reflux.
Usually the minimum reflux ratio is obtained in the actual plant operation by reducing the reflux. During reduction of the reflux ratio, product quality must be analyzed frequently and confirmed so that the product quality meets the product specification.

2) Reduction of the stripping steam flow

In the case of PPSA, stripping steam is not injected for W-3 and W-8 at present.
However, it is recommended to look for the optimum quantity of stripping steam in case the stripping steam were injected after the modernization.

In time, stripping steam will be reduced step by step as long as the product quality, especially IBP, meets the product specification.

3) Reduction of the pressure of the atmospheric distillation tower

The crude oil can be distilled with reduced fuel consumption as the pressure of the atmospheric tower is reduced.

Therefore it is desirable to operate the atmospheric tower at the pressure level as low as possible after checking the following items;

- The design pressure of the atmospheric tower and its related vessels and pumps
- The capacity of the tray in the atmospheric tower and condensers

(3) Rotating Machine

1) Impeller cut

It is common to design the pumps with certain allowance. Therefore, it is recommended to review the pump performance based on the actual operation data and to cut the impeller to the proper size in order that the power consumed by the pump may be reduced.

2) Inverter control

Inverter control can control the flow rate by changing the revolution of motors. As a result, energy consumed by valves or dampers at the discharge line of pumps can be saved.

(4) Effective use of the ejectors in the vacuum unit

1) Reduce the number of ejectors

It is often the case that ejectors are designed with some allowance and with plural trains.
Many cases have been observed without any troubles, even when the steam to one train of the ejectors has stopped.
If such a case can be expected, the quantity of steam and cooling water may be reduced.

With regard to the effective use of ejectors by reducing the number, it is recommended to consult with the manufacturer.

2) Optimization of the size of ejectors

In the case that too much allowance is projected in the capacity of the ejectors, there is an alternative way to change the ejectors to the proper size. However, this is not common practice in view of the cost for replacement.

(5) Utilization of flue gas heat for air preheating

This is to heat up the combustion air to reduce fuel consumed in the heater.
The existing heater will be modified from natural draft to balanced draft type by installing a forced draft fan, an induced draft fan and a Jung Strom.
Refer to 4.8.6 for the study.
This is part of the modernization plan of PPSA.

Subject to further study and economic evaluation, this is to be included in the modernization plan because this is an effective measure for saving energy generally.

(6) Decrease the heat loss from the wall of Heaters

The heat loss from the wall of heaters can be reduced by installing insulation such as ceramic fiber.

The effect can be estimated from the calculation of heat dissipation.

(7) Improving heat exchange between crude oil and products (Rearrangement of heat exchangers)

This is to recover the heat which the products have by means of the heat exchangers.
This is already planned by PPSA and is studied in 4.8.5.

(8) Improvement in heat transfer of heater tubes

Through long operation, the heat transfer of heater tubes decreases due to both the inside and outside fouling. Therefore, it is necessary to clean the heater tubes periodically.

Radiographic inspection is often applied to measure the thickness of the inside scale where visual inspection is not available.

(9) Repair of insulation and its cover

It is necessary to repair the area where insulation or its cover is broken as soon as possible. It is advisable not to leave it unattended since saving energy is an accumulation of such small matters.

Sometimes valves and flanges are insulated in an area where the operation temperature is high. In this case the attention should be paid to the elongation of bolts which may cause leakage of the internal fluid.

(10) Check of steam traps

In the case of out of order in steam traps, steam will be bled off.
This is a waste of steam and the load on the boiler water unit will be increased.
Maintenance of the steam trap is important.

(11) Heat transfer of heat exchangers

Heat exchangers in the atmospheric and vacuum distillation unit are apt to be fouled as the operation period becomes longer.

Accordingly, the overall heat transfer coefficient (U value) is to be calculated from time to time to check the degree of the fouling of the heat exchangers.

It is common to clean the tube bundle of heat exchangers during periodical shutdown to improve the heat transfer coefficient.

Some refineries where fouling is a severe problem inject anti-fouling additives into the crude oil to decelerate the fouling.
Anti-fouling additives, for example, such as AFTOL produced by Petrolite, Kuritop B 103 produced by Kurita and etc. are used with the injection rate of 5 to 30ppm for the crude oil throughput.

4.4.2 Fundamental policy of saving energy

It is recommended to begin saving energy with a plan which does not require any investment, i.e, changing operation conditions. A plan which requires a little investment is the next step. In the case where the operating conditions are changed, the operation conditions and its effect of No.1 crude oil distillation unit should be analyzed precisely and the product quality should be checked frequently.

4.4.3 Estimation of saving energy through the modernization

As explained in 4.4.1, there are many design possibilities for reducing energy consumption.
Subject to further study and economic evaluation, the following three items are to be incorporated in the modernization of No.1 crude oil distillation unit because generally these are effective for saving energy.

- Control of oxygen content in the flue gas from heaters
- Utilization of flue gas heat for air preheating
  (Installation of an air preheater)
- Utilization of product heat
  (Heat exchangers rearrangement)

(1) Assumptions for estimating saving energy

The following assumptions were made for estimating saving energy.

1) The present conditions

(a) The outlet temperature of Pc-1 is 320°C.

(b) The throughput of No.1 crude oil distillation unit is converted to 308 t/h.

(c) Simulated heat duty for heaters is applied.

(d) Heater efficiency is 60%.

(e) Lower calorific value of fuel oil is 9,443 kcal/h.

(f) Fuel oil is only used and its sulfur content is 2.8 wt%.

(g) Measured data of oxygen content in the flue gas from heaters are used for the estimation.
(Pc-1 : 9.5% ,2Pc-1 : 6.83%)

2) After the modernization

(a) Heat exchangers are rearranged as shown in Figures 4.8-1 and 4.8-2.
A stabilizer and a splitter units are newly installed and the heat sources for the reboilers of these units are supplied by the reflux heat in No.1 crude oil distillation unit.

(b) Heater efficiency is 60%.

(c) Lower calorific value of fuel oil is 9,443 kcal/h.

(d) Fuel oil is only used and its sulfur content is 2.8 wt%.

(e) Oxygen content in the flue gas from both heaters is 4 vol %.

(f) Air preheat system is installed as illustrated in Figure 4.8-3.

(2) Results of fuel oil saving after modernization

Refer to Table 4.4-2 for the estimated fuel oil saving after the modernization.

Total fuel oil saving is estimated to be 1,815.7 kg/h (7,931 - 6,115.3 kg/h).

Table 4.4-1 SAVING ENERGY ITEMS FOR NO.1 ATMOSPHERIC AND NO.1 VACUUM DISTILLATION UNIT (1/2)

[1] Reduction of Input Energy

	Saving Energy Item	Required Equipment or Action	Note
1.	Rationalization of excess air to Heater	1. Oxygen Analyzer 2. Remote and Autocontrol of Damper 3. Draft Gauge 4. Low NOx Burner 5. Minimization of Air Leak	Shut Down Sequence is Required.
2.	Rationalization of Distillation Tower		
(1)	Decrease Reflux Ratio		Check Product Quality
(2)	Reduce Stripping Steam Flow		Check Product Quality
(3)	Reduce Operation Pressure		
(4)	Overflash Monitor	Overflash Moniter	
3.	Rotating Machine	1. Impeller Cut 2. Inverter Control	
4.	Ejector	1. Size Down 2. Stop One(1) Train	
5.	Control of the Temperature of Cooler Outlet		Daily Operation

Table 4.4-1 SAVING ENERGY ITEMS FOR NO.1 ATMOSPHERIC AND NO.1 VACUUM DISTILLATION UNIT (2/2)

[2] Waste Heat Recovery

	Saving Energy Item		Required Equipment or Action	Note
1.	Utilization of Flue Gas Heat for Air Preheating	1.	Air Preheater	
		2.	Extension of Convection Section	
2.	Decrease the Heat Loss from Heater Wall	1.	Reinforcement of Insulation	
3.	Heat Recovery from Products	1.	Rearrangement of Heat-exchangers	
		2.	Extension of Heat-exchangers	
4.	Improvement of Heat Transfer of Heater Tubes	1.	Cleaning of Heater Tube (Inside & Outside)	
5.	Repair and Re-inforcement of Insulation			
6.	Maintenance of Steam Trap			
7.	Improvement of Heat Transfer of Heat Exchanger	1.	Cleaning of Heat Exchangers	
		2.	Injection of Antifoulant	

Table 4.4-2 ESTIMATION OF SAVING ENERGY (BASED ON CALCULATED HEAT DUTY & FUEL OIL)

	Present (26 Nov. 1993, Converted to 308 t/h)			After Modernization (308 t/h)		NOTE
	Actual Fuel Oil Consump.	Calculated Heat Duty	Fuel Oil Consumption	Calculated Heat Duty	Fuel Oil Consumption	
1. Calcutation						
Pc-1	3,653 kg/h	141.2 Gj/h (1	5,954 kg/h (2	144.8 Gj/h (3	6,106 kg/h (2	(1 : Outlet Temp. of Pc-1 is 320℃
						(2 : Heater Efficiency is assumed 60%
Pc-2	1,860 kg/h	46.9 Gj/h (1	1.977 kg/h (2	40.0 Gj/h (3	1,686 kg/h (2	
(Sub total)	(5,513 kg/h)	(188.1 Gj/h)	(7,931 kg/h)	(184.8 Gj/h)	(7,792 kg/h)	: Sulfur Content of Fuel Oil is 2.8 wt. %.
2. Moderniza-tion Plan						: Lower calorific Value is 9,443 kcal/kg
(1) Air Pre-Heater (4						(3 : Including Heat Duty for Stabilizer & Splitter (19.4 Gj/h = 818 kg/h as fuel oil)
Pc-1	——	——	——	——	- 924.5 kg/h	
Pc-2	——	——	——	——	- 255.3 kg/h	
(2) Decrease (4 O_2 %						(4 : O_2 % in Flue Gas is 4%
Pc-1	——	——	——	——	- 446.7 kg/h	
Pc-2	——	——	——	——	- 50.2 kg/h	
Total	5,513 kg/h	188.1 Gj/h	7,931 kg/h	184.8 Gj/h	6,115.3 kg/h	

4.5 Evaluation of Alternative Measures for Control of SO_2, NOx

4.5.1 Current situation for emission of SO_2 and NOx

(1) Actual measured value

Actual data collected on 26 November 1993 is indicated in Table 4.5-1.

Table 4.5-1 FLUE GAS TEMPERATURE AND COMPOSITION

		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)	2	495

(2) Evaluation of the DATA

1) NOx and SO_2 of Pc-1

The Data of NOx and SO_2 is unreliable judging from the Data of Pc-2.
Therefore, it is recommended to check the gas sampling method, the use and accuracy of the portable analyzer.

When the data seems to be inconsistent, resampling or re-analyzing should be done immediately under the same operating conditions.

2) Emission volume limit and current emission volume of flue gas.

Emission volume limit and current emission volume of flue gas is shown in Table 4.5-2.

Table 4.5-2 EMISSION VOLUME LIMIT AND EMISSION VOLUME OF FLUE GAS

		Emission Volume Limit (kg/h)	Current Emission Volume (kg/h) (*1)
Pc-1	SO_2	56.58	97.92
	NOx	17.42	7.8
	CO	10.00	0.3
Pc-2	SO_2	20.31	50.58
	NOx	7.74	4.18
	CO	6.0	0.16

Source: PPSA
Note : (*1) Actual record for the year of 1993

It is reported that these emission volume limits will become more stringent after 1 January 1994 (Refer to Table 2.9-1).

(3) Calculated SO_2 emission by fuel consumption

The current SO_2 Emission is calculated for reference to give a basis for the further discussion of reduction of SO_2 emission.
The calculated value is just a spot value so it is natural that there will be a difference between the calculated values and the reported data in Table 4.5-2.

1) Calculated SO_2 emission from Pc-1 on 26 November 1993

Calculated SO_2 emission
= Fuel Oil Consumption x Sulfur Content in Fuel Oil +
  Fuel Gas Consumption x Sulfur Content in Fuel Gas
= 2,300 kg/h x 0.028 x 64/32 +
  1,000 nm3/h x 0.0081 x 64/22.4
= 151.9 kg/h

This calculated value is different from the value of SO_2 emission in Table 4.5-2 which is 97.92 kg/h.

2) Calculated SO_2 Emission from Pc-2 on 26 November 1993

Calculated SO_2 emission
= Fuel Oil Consumption x Sulfur Content in Fuel Oil +
  Fuel Gas Consumption x Sulfur Content in Fuel Gas
= 1,200 kg/h x 0.028 x 64/32 +
  476 nm3/h x 0.0081 x 64/22.4
= 78.2 kg/h

This calculated value is different from the value of SO_2 emission in Table 4.5-2 which is 50.58 kg/h.

4.5.2 SO_2 reduction plan of PPSA

No de-NOx and de-NOx units for flue gas are planned for No.1 crude oil distillation unit at this moment.
Therefore, there is no way to reduce SO_2 emission except by reducing the fuel consumption while saving energy.

4.5.3 Calculated SO_2 emission in the flue gas

Here, current SO_2 emission before the modernization is calculated based on the simulation output.
There is a difference in fuel consumption between the actual one and the simulation output as discussed in 3.6.1.
Fuel consumption obtained from the simulation output is used in order to estimate the reduction of SO_2 emission before and after the modernization.

(1) Before modernization

1) Assumptions

Here, SO_2 emission reduction is estimated under the following assumptions;

The following assumptions are made:

- Heat duties from the simulation model are applied.
- Throughput : 308 t/h.
- Lower calorific value of fuel oil is 9,433 kcal/kg and sulfur content is 2.8 wt. %.
- Only fuel oil will be burnt for both Pc-1 and Pc-2.
- Heater efficiency : 60% for both Pc-1 and Pc-2
- The excess air ratio : Pc-1 1.83 (Oxygen content: 9.5%)
  Pc-2 1.48 (Oxygen content: 6.83%)

2) SO_2 emission from Pc-1

SO_2 emission
= 141.2 Gj/h / (9,433 kcal/kg x 4,185.5 x 0.6)
x 0.028 x 64/32
= 333.4 kg/h

3) SO_2 emission from Pc-2

SO_2 emission
= 46.9 Gj/h / (9,433 kcal/kg x 4,185.5 x 0.6)
x 0.028 x 64/32
= 110.7 kg/h

(2) After the modernization

Here, SO_2 emission reduction is estimated under the following assumptions;

1) Assumptions

- Stabilizer and Rectification unit are constructed as shown in Figure 4.8-1.
- Heat exchangers are re-arranged as shown in Figure 4.8-2.
- The excess air ratio : Pc-1 1.24 (Oxygen content: 4.0%)
  Pc-2 1.24 (Oxygen content: 4.0%)
  Recommended excess air ratio proposed by a burner vendor is 1.15. In such case, the maximum oxygen content in flue gas is to be reduced to 2.7%.
- Throughput : 308 t/h.
- Heat duties after the modernization obtained by simulation model are applied.
- Only fuel oil will be burnt for both Pc-1 and Pc-2.
- Lower calorific value of fuel oil is 9,443 kcal/kg and sulfur content is 2.8 wt. %.

- Heater efficiency : 60% for both Pc-1 and Pc-2
- The flue gas temperatures from Pc-1 and Pc-2 are assumed to be 400°C.
- The combustion air is heated from 120°C to 300°C by a Jung Strom.
  For the flow scheme of the installation of a Jung Strom, refer to Figure 4.8-3.

2) Estimated SO_2 emission with no oxygen content control in the flue gas from the heaters and no combustion air preheat after the modernization

(a) Pc-1

SO_2 emission
= 144.8 Gj/h / (9,433 kcal/kg x 4,185.5 x 0.6)
x 0.028 x 64/32
= 342.0 kg/h

(b) Pc-2

SO_2 emission
= 40.0 Gj/h / (9,433 kcal/kg x 4,185.5 x 0.6)
x 0.028 x 64/32
= 94.4 kg/h

3) Estimated SO_2 emission reduction by oxygen content control in the flue gas from the heaters after the modernization

(a) Pc-1
SO_2 emission = 446.7(2) x 0.028 x 64 / 22.4
= 25.0 kg/h

(b) Pc-2
SO_2 emission = 50.2(2) x 0.028 x 64 / 22.4
= 2.8 kg/h

Note: (2) Refer to Table 4.4-2.

4) Estimated SO_2 emission reduction by combustion air preheat after the modernization

(a) Pc-1
SO_2 emission = 924.5(2) x 0.028 x 64 / 22.4
= 51.8 kg/h

(b) Pc-2

SO_2 emission = $255.3^{(2)}$ 0.028 x 64 / 22.4
= 14.3 kg/h

Note: (2) Refer to Table 4.4-2.

(3) Summary

The result is shown in Table 4.5-3.

1) Estimated SO_2 emission reduction in No.1 crude oil distillation unit

(a) Comparison of SO_2 emission before and after the modernization at the throughput of 308t/h

SO_2 Emission will be reduced by 101.6 kg/h (444.1 kg/h - 342.5 kg/h).

(b) Comparison of SO_2 emission after the modernization with and without the oxygen control and air preheat

SO_2 Emission will be reduced by 93.9 kg/h (51.8 + 14.3 + 25.0 + 2.8 kg/h).

2) Conclusion

As long as a flue gas desulfurization plant is not installed, it is necessary to reduce sulfur content in the fuel oil in order to reduce SO_2 emission.
After the operation of the new CCR (Continuous Catalyst Regeneration Reformer), a larger quantity of fuel gas will be burnt in the heaters, which is effective in reducing SO_2 emission.

4.5.4 Reduction of emission of NOx

(1) Assumptions for estimation of NOx emission

As mentioned in 4.5.2, PPSA has no plan to construct a plant to remove NOx from flue gas. In this case, low-NOx burner would be better to use for the heaters.

Here, NOx emission is estimated under the following assumptions:

1) The throughput of No.1 crude oil distillation unit : 308t/h

2) Fuel consumption : Estimated fuel consumption obtained from the simulation model

3) Fuel oil and gas ratio : Fuel oil only

4) Nitrogen in the fuel oil : 1 wt. ppm.

5) Heater inside temperature : 800°C.

6) Burning calorific capacity of combustion chamber : 10^6 kcal/h.

7) Current situation

O_2 and NOx content in the flue gas recorded on 26 November 1993 are used.
That is,
Pc-1 : 9.5%, 113 ppm
Pc-2 : 6.83%, 113 ppm

However the DATA of NOx content for Pc-1 is not used because of its improbability so the data of Pc-2 is used.

8) After the modernization

(a) O_2 and NOx content in the flue gas
(NOx content in the flue gas is estimated based on data issued by a vendor.)
Pc-1 : 4.0%, 130 ppm
Pc-2 : 4.0%, 130 ppm
(b) A Jung Strom and related equipment are to be constructed, which means the temperature of combustion air is heated to 300°C before heater inlet.
(c) Rearrangement of heat exchangers is to be implemented.
(d) Stabilizer and Splitter are to be constructed.

(2) Estimated of NOx emission before the modernization

1) Pc-1

NOx emission
= (The amount of dry flue gas) x 0.000113 x 46 / 22.4
= 162,000 nm^3/h x 0.000113 x 46 / 22.4
= 37.6 Kg/h

2) Pc-2

NOx emission
= (The amount of dry flue gas) x 0.000113 x 46 / 22.4
= 47,000 nm^3/h x 0.000113 x 46 / 22.4
= 10.9 kg/h

(3) Estimated NOx emission after the modernization
(with oxygen control and air preheater)

1) Pc-1

NOx emission
= (The amount of dry flue gas) x 0.000130 x 46 / 22.4
= 101,000 nm^3/h x 0.000130 x 46 / 22.4
= 27.0 kg/h

2) Pc-2

NOx emission
= (The amount of dry flue gas) x 0.000130 x 46 / 22.4
= 30,000 nm^3/h x 0.000130 x 46 / 22.4
= 8.0 kg/h

(4) Summary

It is estimated that NOx emission will be reduced by 13.5 kg/h after the modernization.

This NOx emission is calculated based on the heat duty obtained from the simulation model. As explained in 3.6.1, the fuel consumption for Pc-1 calculated by simulation model is higher than the measured fuel consumption. Therefore the estimated NOx emission for Pc-1 shall be treated as a reference.

For the actual application of the low-NOx burner, it is recommended to re-calculate the estimated NOx emission by using the vendor's data since the performance may be different from vendor to vendor.

Table 4.5-3 ESTIMATION OF SO_2 EMISSION (BASED ON CALCULATED HEAT DUTY & FUEL OIL)

	Present (26 Nov. 1993, Converted to 308 t/h)			After Modernization (308 t/h)			NOTE
	Calculated Heat Duty	Fuel Oil Consumption	SO_2 Emission	Calculated Heat Duty	Fuel Oil Consumption	SO_2 Emission	
1. Calcutation							
Pc-1	(1 141.2 Gj/h	(2 5,954 kg/h	333.4 kg/h	(3 144.8 Gj/h	(2 6,106 kg/h	342.0 kg/h	(1 : Outlet Temp. of Pc-1 is 320℃
Pc-2	(1 46.9 Gj/h	(2 1,977 kg/h	110.7 kg/h	(3 40.0 Gj/h	(2 1,686 kg/h	94.4 kg/h	(2 : Heater Efficiency is assumed 60%
(Sub total)	(181.1 Gj/h)	(7,931 kg/h)	(441.1 kg/h)	(184.8 Gj/h)	(7,792 kg/h)	(436.4 kg/h)	: Sulfur Content of Fuel Oil is 2.8 wt. %.
2. Moderniza-tion Plan							: Lower calorific Value is 9,443 kcal/kg
(1) Air Pre-Heater (4							(3 : Including Heat Duty for Stabilizer & Splitter (19.4 Gj/h = 818 kg/h as fuel oil)
Pc-1	——	——	——	——	- 924.5 kg/h	- 51.8 kg/h	
Pc-2	——	——	——	——	- 255.3 kg/h	- 14.3 kg/h	
(2) Decrease (4 O_2 %							(4 : O_2 % in Flue Gas is 4%
Pc-1	——	——	——	——	- 446.7 kg/h	- 25.0 kg/h	
Pc-2	——	——	——	——	- 50.2 kg/h	- 2.8 kg/h	
Total	188.1 Gj/h	7,931 kg/h	444.1 kg/h	184.8 Gj/h	6,115.3 kg/h	342.5 kg/h	

4.6 Evaluation of Alternative Design Possibilities for Reducing Offensive Odor Substance in Sewage

4.6.1 Current flow scheme and waste water properties

Current flow scheme is shown in Figure 4.6-1 and waste water properties are shown in Table 4.6-1.

4.6.2 Countermeasures

There are three possible methods as illustrated below:

(1) Connecting the drip funnel and drain pipe of the vessel with a piece of pipe so that the offensive odor cannot escape.

This method has an advantage in that it does not cost too much.
Refer to the drawing "Seal of drip funnel" in Figure 4.6-2.

(2) Construction of a waste water stripping unit in No.1 crude oil distillation unit.

It is supposed that the source of the offensive oder is ammonia(NH_3), hydrogen sulfide(H_2S) and phenol.

Ammonia is not analyzed in Table 4.6-1. This shall be checked for designing a stripper tower.

This method is to construct a waste water stripping unit in No.1 crude oil distillation unit to remove NH_3, H_2S and phenol in the waste water which is the source of the offensive odor (Refer to Figure 4.6-2).

The waste water stripping unit can strip NH_3 and H_2S, however, it should be confirmed by a laboratory test whether this method is effective in reducing offensive odor substance in sewage since it is impossible to remove phenol by stripper.

It is not recommended to construct a waste water stripping unit for only one distillation unit because this is not economical.

(3) Construction of a waste water stripping unit for No.1 and No.2 crude oil distillation unit.

This method would involve construction of two(2) waste water stripping units for four(4) distillation units because the waste water stripping unit is an environmental prevention plant and at least one(1) plant should be in operation during the operation of the distillation unit. Therefore, there should be 2 waste water stripping units in the refinery.

When one(1) waste water stripping unit is shut down, the throughput of the four(4) distillation unit would have to be adjusted to treat all of the waste water in the refinery.

4.6.3 Recommendation

It is recommended to apply method (1) in Item 4.6.2 because of its low cost and simplicity.

During the second field survey, it was agreed to apply method (1) in Item 4.6.2 by PPSA because of its low cost cost and simplicity.

Table 4.6-1 PROPERTIES OF WASTE WATER FROM NO.1 CRUDE OIL DISTILLATION UNIT FOR THE YEAR 1993

No	Item	Unit	System I	System II
1.	pH	-	6.8 - 8.7	7.2 - 9.0
2.	Sulfide	mg/l	1.1 - 510	2.8 - 308
3.	Phenol	mg/l	0.1 - 1.5	1.0 - 42
4.	Suspended Solid	mg/l	60 - 109	63 - 160
5.	Hydrocarbon	mg/l	10 - 1,847	43 - 550
6.	COD	mg/l	180 - 760	180 - 8,600
7.	Flow Rate	m^3/h	8.5 - 20	8.5 - 84

Figure 4.6-1 WASTE WATER FLOW SCHEME SCHEME IN NO.1 CRUDE OIL DISTILLATION UNIT

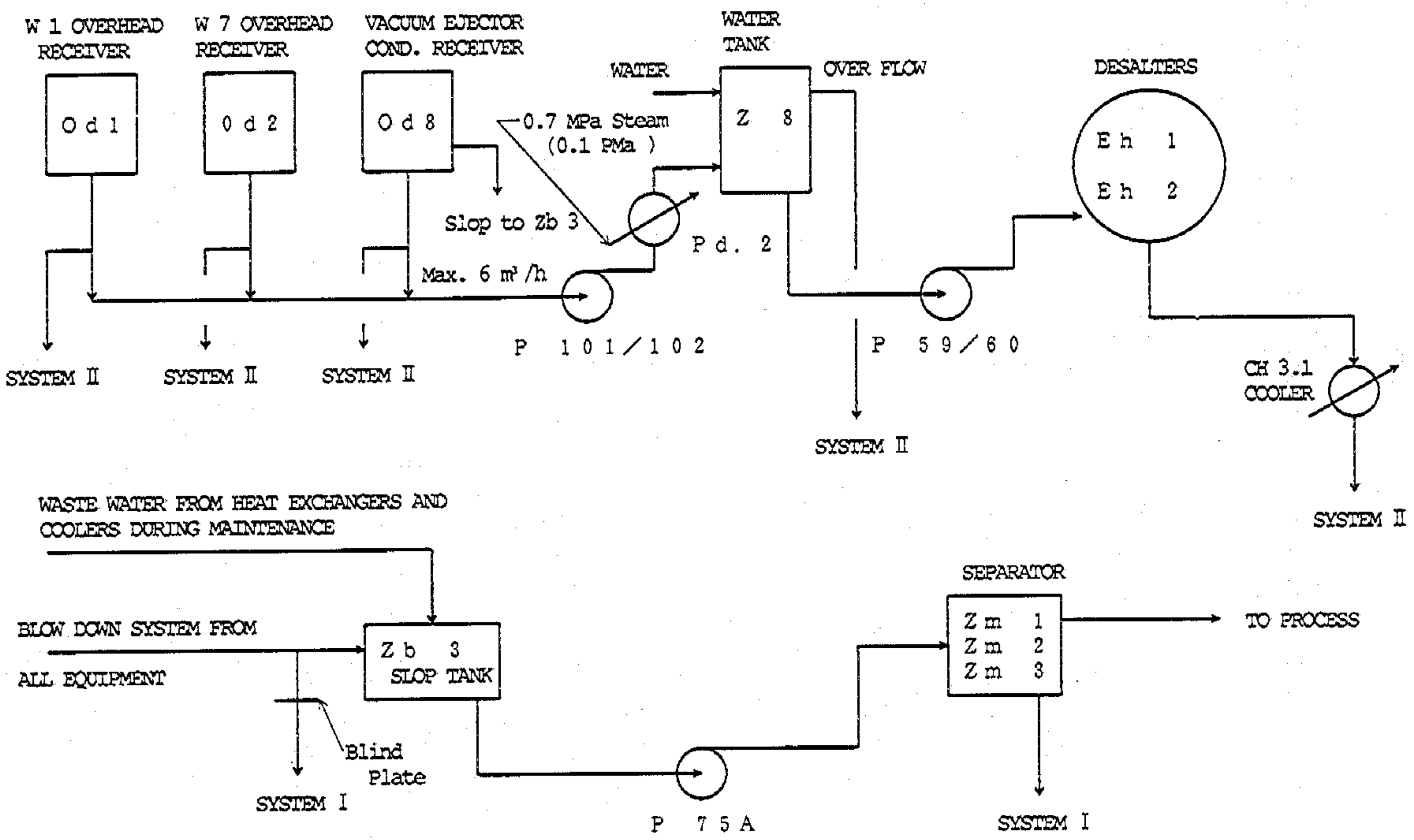
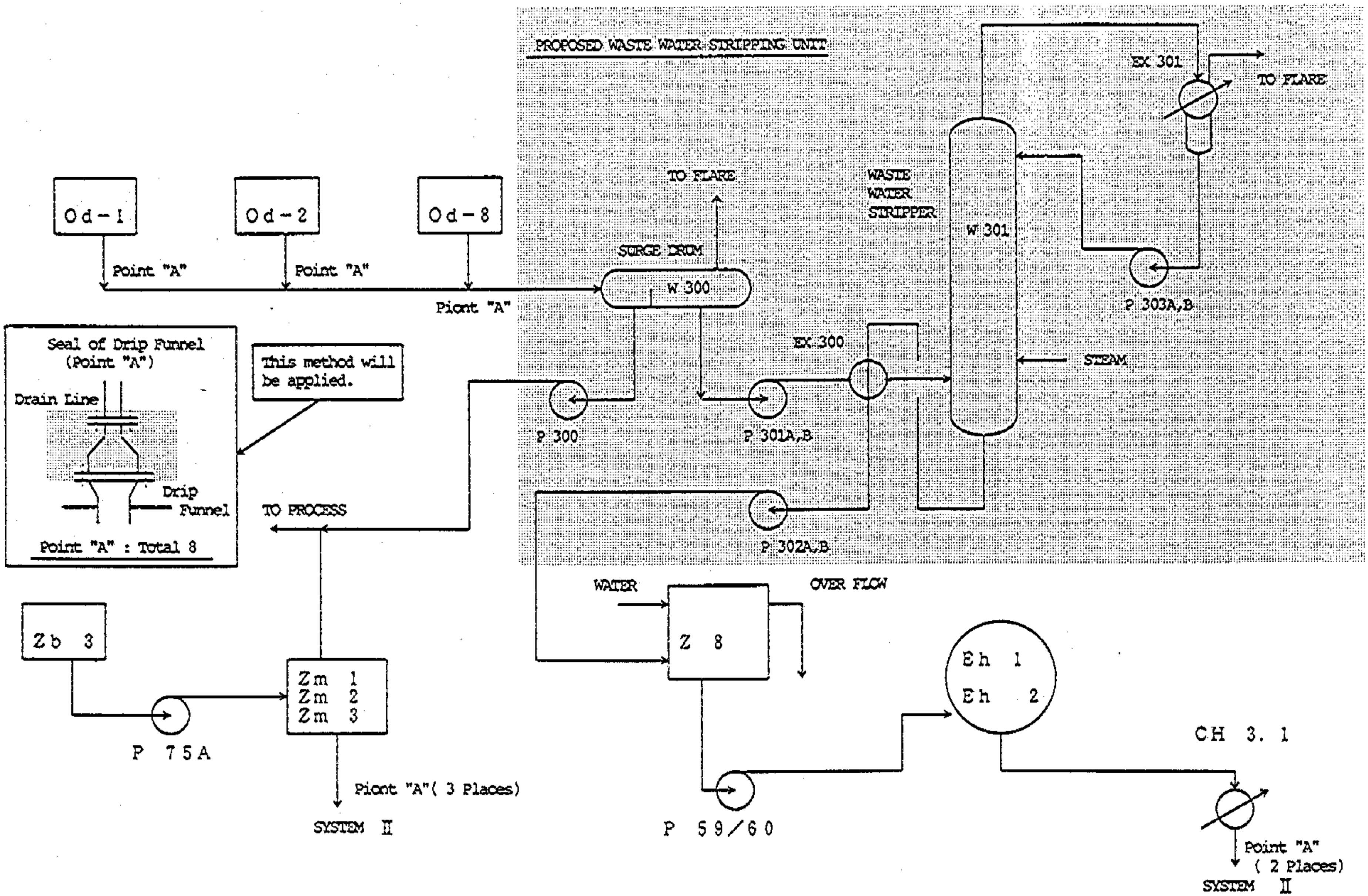


Figure 4.5-2 COUNTERMEASURE FOR REDUCING OFFENSIVE SUBSTANCES IN SEWAGE



4.7 Evaluation of Alternative Design Possibilities for Improving Product Quality

4.7.1 Current problems

The current problems regarding product quality were discussed in 3.5.
The problems are repeatedly listed in Table 4.7-1.

Table 4.7-1 CURRENT PROBLEMS FOR THE PRODUCTS

(1) Poor Gap between A11 and A12
(2) Low IBP from A11 to A14
(3) Lower IBP of A16 than A15
(4) Flash points of A13 and A14 do not meet the specification
(5) Unreasonable DATA in flash point and viscosity of W-1 and W-2 bottom oil
(6) Specific gravity and freezing point of P11 do not meet the specification.
(7) FBP of P12 does not meet the specification
(8) P13 does not meet the specification of FBP - IBP $\leq$ 120°C, freezing point and viscosity

4.7.2 Countermeasures

(1) Improving of the gap between A11 and A12

It is necessary to add more trays between A11 and A12. There are 12 trays at present. After the modernization, this will be improved because the number of trays between the two(2) fractions will be changed to 22 trays by the

reduction of the number of products and the gap will become + 12°C as indicated by the simulation.
For reference, the estimated gap after the modernization obtained by the simulation model is shown in Table 4.7-2.
As can be seen in the table, the gap is largely improved after the modernization.

Table 4.7-2 GAP OF PRODUCTS AFTER THE MODERNIZATION

ASTM 5% Point		-	ASTM 95% Point		=	Gap(°C)
A12	152°C		A11	142°C	=	10
A13	183°C		A12	171°C	=	12
A14	268°C		A13	284°C	=	-16

(2) Lower IBP than the product specification for A11, A12, A13 and A14

It is common to inject stripping steam to adjust the product properties, i.e., IBP.
It is reported that stripping steam is effective for adjusting IBP of hydrocarbons with boiling points below 260°C in many atmospheric distillation units(*1).
The literature cited introduces the example that a product with IBP 148.9°C and FBP 482.2°C was improved to a product with IBP 260°C, i.e., IBP was raised 111.1°C by injecting stripping steam.
Since IBP for A11, A12, A13 and A14 is below 260°C, improvement of IBP can be expected by injecting stripping steam.

Note: (*1) Penn Well Books (1985), Trouble Shooting Process Operations (2nd edition), Oklahoma, Norman P. Lieberman

During the second field survey, the following facts were reported:

At the beginning of the operation of No.1 crude oil distillation unit after the completion of construction, stripping steam was injected to the strippers and IBP cleared the present product specification.
However, because of the plugging of catalyst bed in the reactors and heavy corrosion in the plants down stream, the stripping steam injection was stopped.

Now, PPSA is seeking the necessary equipment, such as coalescer, for removing water in the products since adjusting IBP by injecting stripping steam is required to meet the product specification.
Installation of coalescers has been taken into consideration for this feasibility study.
One coalescer with two filters will be installed at the run down line to the tank for the products of A12, A13 and A14.

(3) Lower IBP of A16 than that of A15

Possible causes are estimated as follows:

(a) A mistake or error was made when sampling, analyzing and reporting.
(b) Something is wrong in the distillation tower. For example, contamination of lighter fraction into A16 due to a leak of a tray in the atmospheric distillation tower.
(c) Contamination of lighter fraction into A16 due to leakage in the heat exchanger, i.e., Wm 10.

PPSA explained during the second field survey that the sampling was taken mistakenly.

(4) Lower flash points than the product specification for A13 and A14

Flash points of A13 and A14 are lower than the product 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) Unreasonable DATA in flash point and viscosity of W-1 and W-2 bottom oil

There are unreasonable DATA in flash point and viscosity of W-1 and W-2 which theoretically never happens in a distillation unit.
Therefore, it is recommended to examine the following items:

1) Leakage of heat exchangers

It is possible that there is contamination of lighter fraction into W-2 bottom oil.

During periodical shut down, it is recommended to re-confirm that the inspection for leakage of the tubes and tube sheets of a heat exchanger was done completely.

2) Check the sampling point

It is possible if the sample was taken at the wrong sampling point.

At the second field survey, PPSA explained that the operator took the sample at the wrong sampling point since this sample is not taken during normal operation.
It is important to show the right sampling point to the operator in advance so that a wrong sample is not taken.

3) Check the procedure in laboratory

It is possible if the wrong sample was analyzed in the laboratory.
Mis-reading of the analyzed data and mis-transcription can be considered as a possible cause.
It is recommended to reconfirm the job flow procedures in the laboratory, from analysis up to reporting.

(6) P11 which does not satisfy the product specification of specific gravity and freezing point

Since current P11 contains much lighter fractions, more draw off of P11 will improve the properties.

(7) P12 which does not satisfy the product specification of FBP

FBP of P12, that is 468°C, does not satisfy the specification which is 460°C.
Since the flash point fully meets the product specification, it is recommended that there be less draw-off of P12 as long as the freezing point satisfies the product specification.

(8) P13 which does not satisfy freezing point, FBP-IBP $\leq$ 120°C and viscosity

In order to improve the freezing point, it is necessary to increase the draw-off of P13 and this is also effective to improve the specific gravity which is now 0.914 while the product specification is 0.925.
Increasing the draw-off is also effective for improving the viscosity.

However, from the stand point of the product quality of distillation, it will be impossible to increase the draw-off because the FBP is at the upper limit of the current product specification, 545°C.

Therefore, it is recommended to transfer the lighter portion of P13 to P12 and the heavier portion of P12 to P13. This means that P13 shall be a narrow cut product.

It should be noted that the freezing point and viscosity of P13 will become lower than the current values, which means a violation of the product specifications as in the case when the draw-off of P12 is reduced as explained in (7) of 4.7.2.

There are some practical measures as follows:
- To improve the gap of P12 and P13 by increasing the internal reflux in W-7. This can be done by raising a outlet temperature of Pc-2 or increasing the vacuum of W-7.
- To inject stripping steam to P13 stripper.
- To increase the number of trays between P12 and P13 for increasing theoretical number of trays or change to a high performance structured packing.

It is estimated that the above measures will not be required in the modernization plan because the product specification such as FBP-IBP $\leq$ 120, FBP max. 545°C and freezing point are not specified. This means that the product specification to be applied after the modernization becomes mild.

As the viscosity is not estimated in this feasibility study, reconfirmation of all the product properties shall be done by establishing a more accurate simulation model during basic design.

4.8 Study for Each Modernization Plan

The remaining items which were listed in 4.1 are studied below:

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

(1) Cause of the unbalance

According to PPSA's information, the cause of the imbalance is as follows:
Originally the throughput for both No.1 atmospheric distillation unit and No.1 vacuum distillation unit was the same (288 t/h). During design phase, the throughput of No.1 atmospheric distillation unit was increased to 308 t/h.
However, the throughput of No.1 vacuum distillation unit was not increased because no demand for the vacuum product was estimated at that time. Therefore, the imbalance was estimated from the beginning of the operation.

PPSA reported that efforts were made to increase the throughput of No.1 vacuum distillation unit, but the outlet temperature of Pc-2 could not be raised due to the limitation in the capacity of Pc-2.
However, it is not clear as to the real reason why the Pc-2 outlet temperature could not be raised.

During the second field survey, an engineer in charge of maintenance reported that decoking of the heater tube is performed every periodical shut down.

The real cause should be pursued and all the necessary measures should be taken during the basic design for the modernization.

(2) Absorbed heat duties for Pc-1 and Pc-2 after the modernization

Here, the absorbed heat duties for Pc-1 and Pc-2 are reviewed based on the simulation output to confirm whether the heaters have enough capacities after the modernization.

It is needless to say that more detailed review for burner capacities are required during basic design phase.

1) Absorbed heat duty of Pc-1

After the modernization, Pc-1 outlet temperature will be increased to 330°C, however, the absorbed heat duty is estimated to be 144.8 Gj/h which is lower than the design value, 150 Gj/h (Refer to Table 3.2-9).
Therefore, Pc-1 would have enough capacity for the throughput of 308t/h.

2) Absorbed heat duty of Pc-2

After the modernization, absorbed heat duty of Pc-2 is estimated 40 Gj/h which is lower than the design value, 50 Gj/h.
Therefore, Pc-2 also would have enough capacity for the maximum throughput after the modernization.

(3) Allowance for W-2 and W-7 at the maximum throughput after the modernization

As the next step, the required tower diameters for W-2 and W-7 are reviewed whether these towers have enough capacities for the maximum throughput after the modernization.

The internals are assumed to be valve trays with two passes for both W-2 and W-7.
During the basic engineering phase, it is required to check the tray capacities by using the tray performance charts.

1) W-2

After the modernization, the required tower diameter is 4.5 meters which is the same diameter as the existing W-2. Therefore, it is not necessary to replace W-2 with new one for the modernization.

2) W-7

After the modernization, the required tower diameter is 5.2 meters. Therefore, there is an allowance in W-7 since the actual tower diameter is 8 meters.
However, sealing of some trays would be required subject to the tray performance check.

(4) Conclusion

Subject to the further capacity check for the burners, the downcomer of the tower, pumps, heat exchangers, piping, etc., and hydraulic check and review of the design conditions to be conducted in the detailed engineering, there would be no imbalance in throughput between No.1 atmospheric and No.1 vacuum distillation unit from the stand point of the heat duty of heaters and the tower diameter.

4.8.2 Construction of stabilization unit for A10 fraction

(1) Outline of the unit (Refer to Figure 4.8-1)

This stabilizer is used to separate LPG by distillation from the A10 fraction.
The heat for the stabilizer reboiler is supplied by a reflux in No.1 atmospheric distillation unit because the heat capacity of the reflux is large enough and stable.
The stabilizer unit can be started after the starting of the reflux to No.1 atmospheric distillation unit.
If the reboiler heat source is supplied by a product of No.1 atmospheric distillation unit, the start up of the stabilizer will be delayed compared to the case in which the reboiler heat source is supplied by the reflux.

(2) Process flow diagram and weight and material balance

The process flow is a common one and a new reboiler is added for the new stabilizer.
The heat for the reboiler is supplied by the reflux of No.1 atmospheric distillation unit, i.e., without installing a heater.
The heat source (13.1 Gj/h) for the new reboiler of the stabilizer is secured by the rearrangement of heat exchangers.

(3) Pressure and temperature of the stabilizer

The overhead pressure of stabilizer receiver is set at 1.03 MPa in order to minimize the loss of LPG fraction (C3 + C4).
The feed temperature to the stabilizer is assumed 55°C which is the same as the operation condition collected on 26 November 1993. No methane fraction will be contained at this temperature of the stabilizer feed.

However two(2) ways of pressure control are provided in consideration of methane fraction contamination.
One way is pressure control by the condenser by-pass, another is off-gas control.

(4) The stabilizer tower specification

The stabilizer is a distillation tower which has 40 valve trays with a diameter of 1.9 meters.

4.8.3 Construction of rectification unit (The splitter unit)

(1) Outline of the unit (Refer to Figure 4.8-1)

The splitter is to be used to separate the bottom oil from the stabilizer into light and heavy fractions.

The heat for the splitter reboiler is supplied by the reflux to the atmospheric distillation unit for the same reasons as for the stabilizer unit.

Feed oil to the splitter is charged by the pressure of the stabilizer bottom, which means there is no stabilizer bottom pump. This is effective to minimize the cost investment and utility consumption.

(2) Process flow diagram

This is a usual distillation unit as a process.

The heat for the reboiler is supplied by the reflux of the atmospheric distillation unit, i.e., without installing a heater. The heat source (6.3 Gj/h) for the new reboiler of the splitter is secured by the rearrangement of heat exchangers.

(3) Pressure of the splitter overhead receiver

The pressure of the overhead receiver of the splitter is controlled by the volume of the off gas from the overhead receiver or split range control by feeding gas from another unit.
The overhead pressure of splitter receiver is set at 0.15 MPa which is the lowest pressure to be controlled by the off-gas from the overhead receiver.

(4) The splitter tower specification

The splitter is a distillation tower which has 24 valve trays with a diameter of 1.7 meters.

4.8.4 Reduction of atmospheric distillation product number

PPSA plans to reduce the number of products in the atmospheric distillation unit from six to four.
Four products in number are usual in an atmospheric distillation unit.

PPSA has prepared a new product specification to be applied for the modernization as well.

The simulation is conducted according to four products with new product specification, therefore, the number is reduced from six to four.

4.8.5 Improvement of heat exchange between products and crude oil (Rearrangement of heat exchangers)

(1) Relation for the other items to be studied together.

Since the following items for the modernization plan will affect the rearrangement of heat exchangers, these items will be studied concurrently.

(a) Construction of stabilizer and splitter
(Heat sources are needed for the reboilers of these units.)
(b) Reduction in product number of atmospheric distillation unit
(c) Removal of box water coolers

(2) Procedure for the improvement

Taking the above situation into consideration, a procedure for improving the heat exchange between products and crude oil, i.e., rearrangement of heat exchangers, should be established.
Refer to Table 4.8-1 for the procedure.

(3) Main principles for the improvement

For rearranging heat exchangers, the following principles are applied.

1) Minimization of investment costs.

2) Maximization of heat recovery.

The heat source of the new reboilers for stabilizer and splitter should be secured by this rearrangement of the heat exchangers without installing any additional heaters.

(4) Rearrangement of heat exchangers

1) Assumptions

In order to rearrange heat exchangers, the following assumption are made:

a) The inlet temperature for the desalters is set at 100°C (The existing desalters are to be used after the modernization).
b) Vacuum residue temperature going to tanks is set at 130°C and used for fuel oil blend.
c) Cooler inlet temperature is aimed about below 150°C for heat recovery.
Inlet temperature of W-1 feed oil will be increased as high as possible for reducing load of Pc-1.

2) Non-used equipment

(a) Wm-5 & Wm-2
Wm-5 & Wm-2 are replaced with new heat exchangers because reflux to W-2 was used as the heat source of the reboilers of the new stabilizer and splitter.
(b) Wm-6, Wm-8 and a part of W-3
Because the number of products was reduced from six to four, stripper and heat exchangers for these products become redundant.

3) Outline of rearrangement of heat exchanger

Because of the un-used heat exchanger, it is inevitable that the inlet temperature of Eh-1 and W-1 will decrease. In order to improve this situation, it is required to re-arrange heat exchangers to recover heat to crude oil with minimum cost investment as follows:

a) Heat recovery of VR by installing heat exchangers
b) Utilization of Wm-14, Wm-4.3 and Wm-3.3 which are not usually used.

4) Heat recovery from VR

Wm-5 and Wm-2 are re-used to recover the heat from vacuum residue.

The temperature of VR at the outlet of Wm-5 and Wm-2 is designed to be 130°C which is suitable for the fuel oil blend.
However, it is necessary to review the rearrangement of the heat exchangers in case VR is used in the boiler plant where the temperature of VR should be 180°C.

5) The Eh-1 inlet temperature

Due to the decreased draw-off rate of product P10 after the modernization compared to the current draw-off rate of product P11, the inlet temperature of Eh-1 will become lower than now.
Wm-3.3 is used down stream of Wm-4.6 and heat exchange is made with vacuum unit product P11 after the modernization. As for the heat exchanger Wm-6 at the other train up-stream of Eh-1, splitted flow of product A13 will be used.

Pd-1.1 and Pd-1.2 are used to maintain the inlet temperatures of the desalters.

6) Increase of the inlet temperature to W-1

In order to decrease the load of Pc-1, it is necessary to raise the inlet temperature of W-1 as high as possible. Wm-4.4 is used to heat crude oil by the shell side outlet flow from Wm-15 which is now 230°C.
The shell side flow of Wm-14 which usually had no flow is switched to the flow from the shell side of Wm-11. The location of Wm-14 is shifted up stream of Wm-12 and Wm-13 because the temperature of shell side flow of Wm-12 and Wm-

13 is lower than that of shell side flow of Wm-14 from Wm-11 shell side.
The inlet temperature of Pc-1 is increased from 192°C to 194°C after making all of these rearrangements which are effective in decreasing Pc-1 load.

(5) Result

1) Rearrangement of heat exchangers

As shown in Figure 4.8-2, heat exchangers will be rearranged.

This rearrangement of heat exchangers bases on the idea to reduce investment cost.
Therefore, this rearrangement of heat exchanger network may not be the optimum selection.

2) Heat source for the reboilers for new stabilizer and splitter is secured without any installation of heaters.

3) Effect of saving energy by the rearrangement of heat exchangers

As discussed in 4.4.3, fuel(as fuel oil) consumption will be decreased from 7,931 kg/h to 7,792 kg/h by the rearrangement of heat exchangers (The effect of fuel oil reduction of by oxygen content control in the flue gas and preheating combustion air are not included).
According to this result, it seems that the fuel reduction is not so much.
However, it should be understood that the fuel consumption after the modernization includes the heat for the two reboilers for the new stabilizer and the new splitter which amounts to 818 kg/h of fuel oil.

Refer to Table 4.4-2 as summary.

4.8.6 Improvement of process heater efficiency

In order to improve process heat efficiency, heat recovery from the flue gas to preheat the combustion air is studied below as part of the modernization plan.

(1) Measures to be studied

There are two(2) measures to be applied as shown below:

1) Installation of new tubes by the extension of the convection section of the heaters.

The combustion air is heated by passing through the tubes. In this case, strength calculation is required for the beams of the structures.
Even if the beam of the structure are strong enough according to the calculation, the actual strength is still questionable because No.1 crude oil distillation unit was constructed about 30 years ago.

2) Heat recovery by air preheater

The flue gas is fed to the Jung Strom through the duct where the heat of the flue gas is exchanged with combustion air.
In this case, an induced draft fan (IDF), a forced draft fan (FDF) and a steam preheater for minimizing low temperature corrosion are required in addition to the Jung Strom as main equipment.

It would be better to apply this measure for No.1 crude oil distillation unit because there is less retrofitting work of the existing heater compared to the other case.

Heat recovery by air preheating is to be applied in the modernization plan of No.1 crude oil distillation unit.

However, it is estimated that this plan will require investment and increased utility consumption.
Therefore, the decision for the implementation shall be made based on the economic evaluation.

(2) Outline of the air preheating system
(Refer to Figure 4.8-3)

Combustion air is heated by a steam preheater to 120°C (T_1).
This steam preheater is indispensable for preventing corrosion caused by sulfuric acid.
Combustion air heated up to 300°C (t_2) by Jung Strom is fed to the air chamber of the heaters.
Meanwhile, flue gas from the heaters is introduced to the Jung Strom by a newly installed duct and exhausted to the atmosphere after the heat exchange with combustion air.
An automatic emergency shut down sequence is required to stop this air preheating system safely in the case any one of the Jung Strom, IDF or FDF are stopped.

(3) Design of the Jung Strom

1) Flue gas inlet temperature to Jung Strom (t_1°C)
For the feasibility study, the Inlet temperature of the Jung Strom is assumed to be 400°C while the DATA indicate 320°C (compensated by flue gas volume). In summer, it is reported that the flue gas temperature is about 500°C.

2) Combustion air inlet temperature to Jung Strom (T_1°C)
120°C is recommended for preventing corrosion caused by sulfuric acid.
As observed in the power plant in PPSA, this temperature is

important for the long term operation.

3) Flue gas outlet temperature from Jung Strom (T_2°C)
This temperature is calculated using the following equation;

$$(T_1 + T_2) / 2 \geqq 180°C$$

Here, 180°C is the temperature described in API recommended practice 533 air preheat system for fired process heaters to which 30°C allowance is added, assuming 3% sulfur content in the fuel oil.
Since T_1 is 120°C, T_2 becomes 240°C.

(4) Saving fuel oil (At the throughput of 308 t/h)

The amount of reduction of fuel consumption is equal to the total heat of the combustion air which is required to heat up from +2°C to 300°C.
+2°C, which is the yearly average temperature in Plock, is adopted as the air temperature for the calculation of the steam consumption at the steam preheater.

1) Pc-1

$$73,500\ nm^3/h \times 0.313 \times \{300 - (2.0)\} \times \frac{28.8}{24.4} / 9,443\ kcal/kg$$
$$= 924.5\ kg/h$$

924.5 / 6,106 x 100 = 15.1%

2) Pc-2

$$20,300\ nm^3/h \times 0.313 \times \{300 - (2.0)\} \times \frac{28.8}{22.4} / 9,443\ kcal/kg$$
$$= 255.3\ kg/h$$

255.3 / 1,686 x 100 = 15.1%

As a result, a total of 1,179.8 kg/h of fuel oil will be saved by installing an air preheater after the modernization.

(5) Points to be studied during the basic engineering phase

The following points shall be studied in detail during the basic design phase:

1) Tube skin temperature in the heaters

Usually the tube skin temperature is increased by installing an air preheater. Therefore, it is necessary to confirm that the tube skin temperature is lower than the design temperature and shall be lower than the temperature to cause coking after installing the air preheater.

2) Bypass line of steam preheater and air preheater

The installation of this bypass line is necessary to keep the flue gas outlet temperature of the air preheater above the design temperature taking into consideration of the actual operation situation.

4.8.7 Improvement of vacuum tower fraction

Refer to 4.7 for the study.

4.8.8 Revamping of electrodehydrators (Desalter)

(1) Analysis data of crude oil and desalted crude oil

Analysis data of crude oil and desalted crude oil analyzed on 26 November 1993 is shown in Table 4.8-2.

Table 4.8-2 PROPERTIES OF CRUDE OIL AND DESALTED CRUDE OIL

	Crude Oil	Desalted Crude Oil
Cl^- Content (wt. ppm)	27	< 1
H_2O Content (wt. %)	0.27	0.09

Properties of waste water from the desalter are shown in Table 4.8-3.

Table 4.8-3 PROPERTIES OF WASTE WATER FROM DESALTER

pH	8.1
Hydrocarbon (mg/l)	28.44

The color of the waste water is white with tiny bubbles of air.
It is entrained during sampling and soon becomes transparent when it settles.

(2) Criteria for judging the performance of the desalter

The following criteria is applied to judge the performance of the desalters which are generally installed in series. Although only one spot data is available in this case, the DATA is regarded as typical because only one(1) kind of crude oil charged to No.1 atmospheric distillation unit, meaning that the operation condition can be expected to be very stable.

1) Salt content in the desalted crude oil is to be less than the larger of the following two values;

- less than 1% of the salt content of the crude oil or
- 2 ppm

2) Water content in the desalted crude oil is to be less than 0.2 vol. %

3) Oil content in the waste water from the desalter is to be less than 200 wt. %

(3) Evaluation of performance of the desalter

1) Salt content in the desalted crude oil

a) Criteria

1% of the salt content in the crude oil is obtained as follows:

27 wt. ppm as Cl^- x 0.01 = 27 x (23 + 35.5)/ 35.5
= 0.445 wt. ppm as NaCl

Accordingly, the criteria of less than 2 ppm is applied in this case.

b) Actual salt content in the desalted crude oil

1 wt. ppm as Cl^- = 1 x (23 + 35.5)/ 35.5
= 1.6 wt. ppm as NaCl

c) Judgement

Actual salt content in the desalted crude oil (1.6 wt. ppm) satisfies the criteria of less than 2 wt. ppm.

2) Water content in the desalted crude oil

Water content in the desalted crude oil is 0.09 wt% which is equivalent to 0.076 vol %.

0.09 wt. % ÷ 0.84 = 0.076 < 0.1 vol. %

This satisfies the criteria of less than 0.2 vol. %.

3) Oil content in the waste water from the desalter

Oil content in the waste water from the desalter is 28.44 mg/l which is less than 200 wt. ppm of the criteria.

As studied above, the performance of the current desalters meet all of the requirement of the criteria.

(4) Conclusion

It is concluded that it is not necessary to revamp the desalters because the current performance satisfies all of the criteria.

Therefore, the existing desalters are used as they are in the modernization plan.

4.8.9 Removal of box water coolers

(1) Plan of PPSA

PPSA has a plan to remove all the existing box coolers in order to save energy.

(2) The modernization plan

It is preferable not to waste the heat by heating cooling water.
Usually the heat of the product in the atmospheric and vacuum residue are recovered as much as possible so it is general practice that there be no box water coolers installed.

In the modernization plan, no water box cooler is installed in order to recover the heat as much as possible.

As for the PFD after the modernization, refer to Figure 4.8-2.

4.8.10 Treatment of Od-8 and Zb-3 emissions

(1) Alternative Plan

There are two methods which are commonly applied in refineries;

1) Amine Treating unit

2) Burning in a furnace

(2) Evaluation of the alternative methods

Amine treating is recommended because of the following reasons:

1) As explained by PPSA, it is not allowed to introduce the gas to a furnace.

2) Absorption by caustic soda is not available due to the limitation in the capacity for treating Na_2S solution.

3) There are so many amine treating units applied for vacuum overhead receiver off gas.

This was recommended based on PPSA's information during the second field survey that burning in a furnace is not allowed in the future.

(3) Outline of the amine treating unit

Refer to Figure 4.8-4.

1) Feed gas composition

PPSA provided a feed gas composition to be used for the feasibility study as shown in Table 4.8-4.

Table 4.8-4 FEED GAS COMPOSITION TO THE AMINE TREATING UNIT

GAS	CONTENT(vol. %)	GAS	CONTENT(vol. %)
C1 + C2	12.5	H_2	4.97
C3	8.76	N_2	22.57
C4	5.49	O_2	10.86
C5	4.76	CO	0.51
C6	4.48	CO_2	0.8
C7	3.69	H_2S	18.87
C8	1.74		

The point to be reviewed is the oxygen content in the feed gas. The oxygen content of 10.86 vol.% is too high compared to the actual data in the other vacuum distillation unit.
(Refer to Table 4.8-5)

As shown in Table 4.8-5, oxygen content in the gas from vacuum overhead receiver is less than 1 vol. % which the gas can be compressed by a compressor.
The oxygen content should be checked again more precisely before the basic design.

Table 4.8-5 EXAMPLE OF FEED GAS COMPOSITION IN OTHER VACUUM DISTILLATION UNIT

Unit A		Unit B	
H_2	4.1 vol %	H_2	4.3 vol %
N_2	2.6	N_2	1.7
O_2	0.8	O_2	0.3
CO	0.6	CO	3.4
CO_2	0.1	CO_2	0.4
H_2S	11.3	H_2S	18.7

If the oxygen content is more than 2 vol. %, the leakage of vacuum tower shall be suspected.

In this feasibility study, the oxygen content is regarded as less than 2 vol. %.
Regarding the off gas from Zb-3, it is required to seal the tank with nitrogen to prevent air entering into the off gas.

2) Gas compression section

The feed gas is compressed up to the necessary pressure and treated by amine solution.
In order to keep the suction pressure of the compressor positive, the spill back line should be installed.

3) Amine treating unit

An amine treating unit is to be constructed newly in the area of No.1 crude oil distillation unit. This is a general amine unit.
However, a line from the amine regenerator overhead

receiver to the sewer system should be checked again to see whether this line is required or not because this line is to be used in case of concentrating amine solution. This line is not included in this feasibility study because it was reported by PPSA that there is no such line in the existing amine treating unit.

4) H_2S rich gas from the amine regenerator

H_2S rich gas will be transferred to the existing sulfur recovery unit which is located 3 km away from No.1 crude oil distillation unit.
Therefore, the transfer line should be free drain with steam trace and insulation.

(4) Recommended method

Although an amine treating unit is to be constructed in this feasibility study, it is strongly recommended to burn the off gas in the furnace as PPSA is doing now because it is too expensive to construct the unit.

The construction of an amine treating unit and 3 km long H_2S rich gas line are not suitable for treating such a small amount of gas.

The off gas is burnt into the SO_2 gas which means no H_2S gas will be emitted from the furnace . In this case, however, sulfur content of the fuel for the furnace should be reduced a little to keep the total emission of SO_2 from the furnace.

It was agreed between PPSA and JICA team that no amine treating unit will be planned for the modernization during the third field visit in Ootober 1994.

4.8.11 Application of DCS

(1) Current situation

No.1 crude oil distillation unit is controlled by a pneumatic instrument system at present.
However, maintenance is often interfered with because of a lack of spare parts for this type of instrument system.
PPSA intends to replace it with a more effective control system, DCS, in the modernization plan.

(2) Reason for adopting DCS

The following are the reasons for adopting DCS:

1) Decrease the maintenance cost

2) Increase the accuracy of measurement

3) Application of advanced control

4) Improvement of operation supervision (by applying alarm function)

5) Improvement of process control
- Connection to a computer
- Operation performance control

(3) Methods for replacement

There are two methods to replace the existing instrument system as shown in Table 4.8-6.
Here, the existing transmitters are also to be replaced in

this feasibility study because of possible deterioration.

(4) Plant operation by using DCS

It is possible to control the unit in more advanced and more effective ways by using DCS.
It is also possible to answer the demand for complex process control by applying various kinds of software.
Typical examples are listed in Table 4.8-7.

(5) Matters to be considered for application of DCS

The following items should be taken into consideration in the application of DCS.

1) Education

Education and training is required for all the concerned persons as listed below.

(a) Operator
(b) Maintenance people
(c) System engineer

Before the start up of No.1 crude oil distillation unit after the modernization, all the people involved should be already accustomed to the operation of DCS.
It is preferable to attend the vendor's training course if possible.
For system engineers, it is necessary to attend an advanced course in addition to the training course for operators.

2) Budget control

For budget control, a detailed plan should be established not only for the process but also for the utility plant.

For example,

(a) Power Plant
- Revamping plan for the power plant
- Modification plans for incidental facilities caused by the replacement to DCS such as substation, control room, etc..
- Renovation of contracted power.

(b) Plan of buck up system
(c) Plan for advanced control items to be applied.
(d) Request from the stand point of air and water pollution prevention.
(e) Others

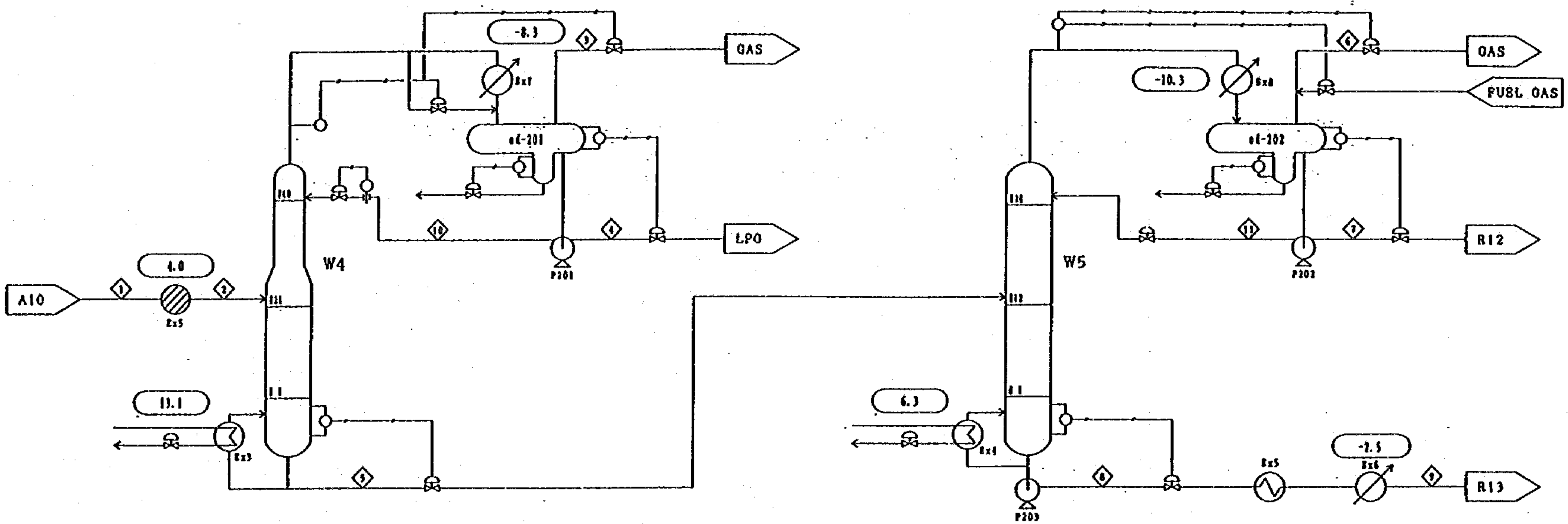
The above items should be fixed during basic design phase and there should not be any revisions after this.
If there are uncertain items left, it would be impossible to control the budget.

(6) Procedure for the application

As a first step, it is recommended to become accustomed to the DCS.
For this purpose, it is preferable to install DCS in the control room as early as possible so that operators could use DCS many times.

Table 4.8-1 PROCEDURE FOR IMPROVING HEAT EXCHANGER BETWEEN PRODUCT AND CRUDE OIL

Step	DESCRIPTION	NOTE
1	Estimate Properties of new Fraction from the Atmospheric Distillation Tower	• Properties of Crude Oil
2	Estimate Temperature of the Draw-off tray for each Fraction	• New Product Specification
3	Heat Source for the Reboilers for Stabilizer and Splitter ↓ Use heat source of W-2 Reflux	• Wm-2, Wm-5 Stop
4	Heat Balance of No.1 Unit ↓ Inlet Temperature of Eh-1 and W-1 become lower than now.	
5	Increase Eh-1 inlet temperature ↓ Replace Wm-3.3 to Wm-4.1 train to exchange with New P11	• Temperature and Flow of New P10 (corresponding to Ex-P11) become lower than now. • New pumps (P490 A, B) are required instead of P49 & P50.
6	Increase W-1 Inlet Temperature ↓ • Utilize Vacuum Residue Heat Source to Wm-2, Wm-5. • Re-use Wm-8, Wm-9 as Heat Exchangers with New Product A13. • Use Wm-14, Wm-4.4 to exchange with oil from Wm-11 and Wm-15 shell side outlet. • Wm-14 tube side is replaced to the down stream of Wm-2 tube side outlet.	• A13 flow becomes three(3) times more than before. • New pump (P510 A, B) is required instead of P51 & P52.
7	Liquidation of Vacuum Residue Box Cooler ↓ Install new Heat Exchanger (Ex-1 and Ex-2)	• The Eh-1 inlet temperature is increased to the level at which operation of Pd1.1 and no operation of Pd1.1 and Pd1.2 are not required.



FLOW NO.		1	2	5	7	8	9	11
FLOW RATE (kg/h)		25 096	←	20 828	7 252	13 576	←	20 476
TEMPERATURE (°C)		55	70	162	47	116	38	47
PRESSURE (MPa)		1.3	1.11	1.13	0.6	0.6	—	0.6
DISTILLATION (°C)	METHOD	ASTM D86	←	←	←	←	←	←
	IBP	-23	←	49	35	78	←	35
	5%	5	←	50	—	86	←	—
	10%	16	←	51	—	88	←	—
	30%	40	←	54	—	90	←	—
	50%	66	←	74	—	92	←	—
	70%	80	←	85	40	93	←	40
	90%	93	←	94	57	95	←	57
	95%	101	←	99	66	100	←	66
	FBP	102	←	102	80	103	←	80
DENSITY@20°C (g/cm³)		0.661	←	0.684	0.638	0.711	←	0.638

FLOW NO.		3	4	6	10
FLOW RATE (kg/h)		—	4 268	—	17 072
TEMPERATURE (°C)		38	38	47	38
PRESSURE (MPa)		1.03	1.7	0.15	1.7
COMPONENT (mol%)	C2	—	—	—	—
	C3	—	20.2	—	20.2
	iC4	—	18.4	—	18.4
	nC4	—	61.2	—	61.2
	iC5	—	0.2	—	0.2
	nC5	—	—	—	—
	cC5	—	—	—	—

HEAT DUTY (GJ/h)

REV	DATE	DESCRIPTION	DRWN	CHK'D	APP'D
5					
4					
3					
2					
1					

FOR

Figure 4.8-1

IDEMITSU ENGINEERING CO., LTD.

TITLE

PFD
STABILIZATION UNIT
OF MAZOVIAN REFINERY

DRAWN
CHK'D
APP'D
SCALE
DATE
JOB NO.
DWG NO. 4.8-27

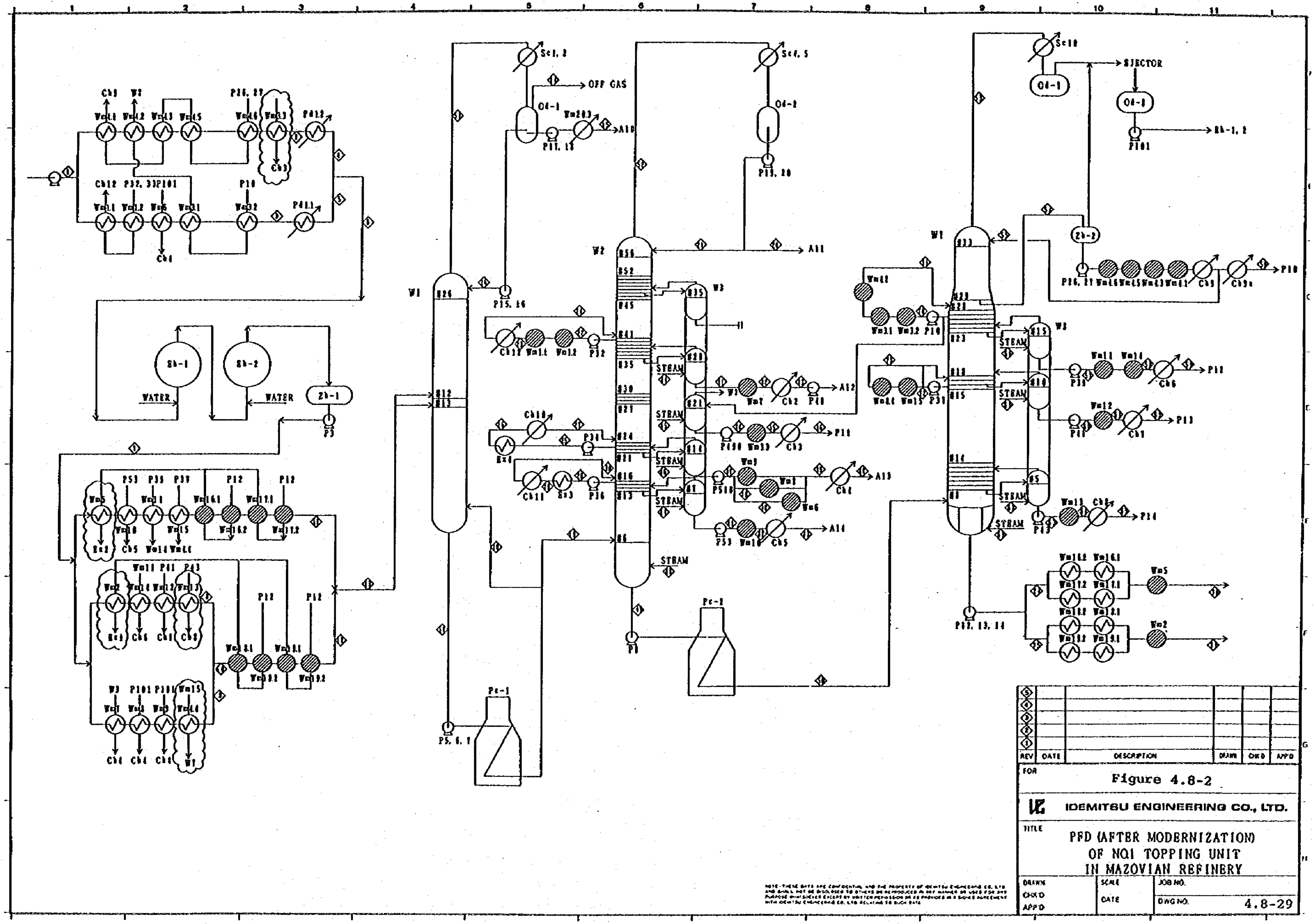

OFF GAS
EJECTOR
WATER
STEAM
IDEMITSU ENGINEERING CO., LTD.
REV
DATE
DESCRIPTION
DRWN
CHK'D
APP'D
FOR
TITLE
PFD (AFTER MODERNIZATION)
OF NO1 TOPPING UNIT
IN MAZOVIAN REFINERY
DRAWN
CHK'D
APP'D
SCALE
DATE
JOB NO.
DWG NO.
4.8-29
Figure 4.8-2

Figure 4.8-3 INSTALLATION OF AIR PREHEATER

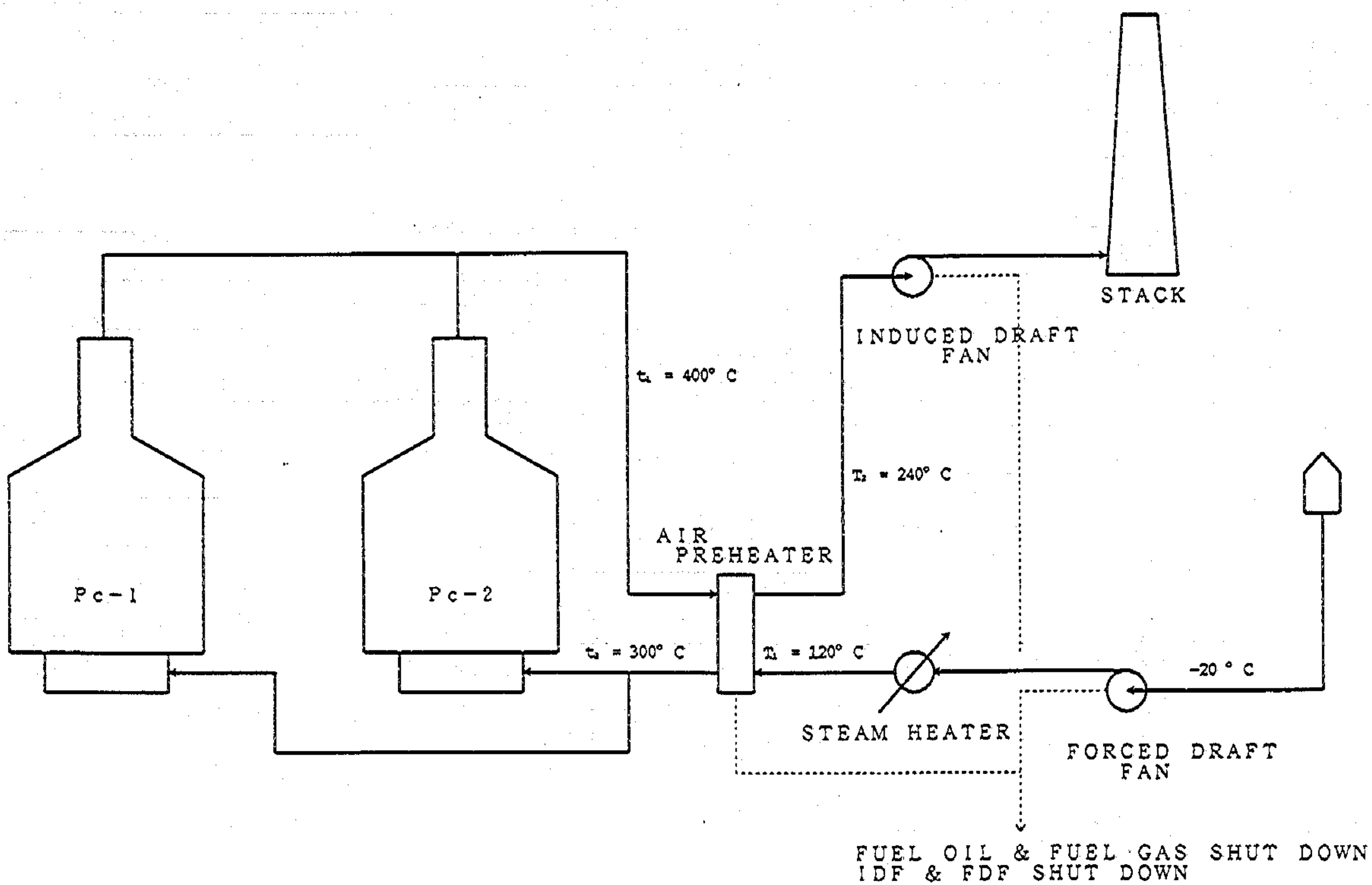
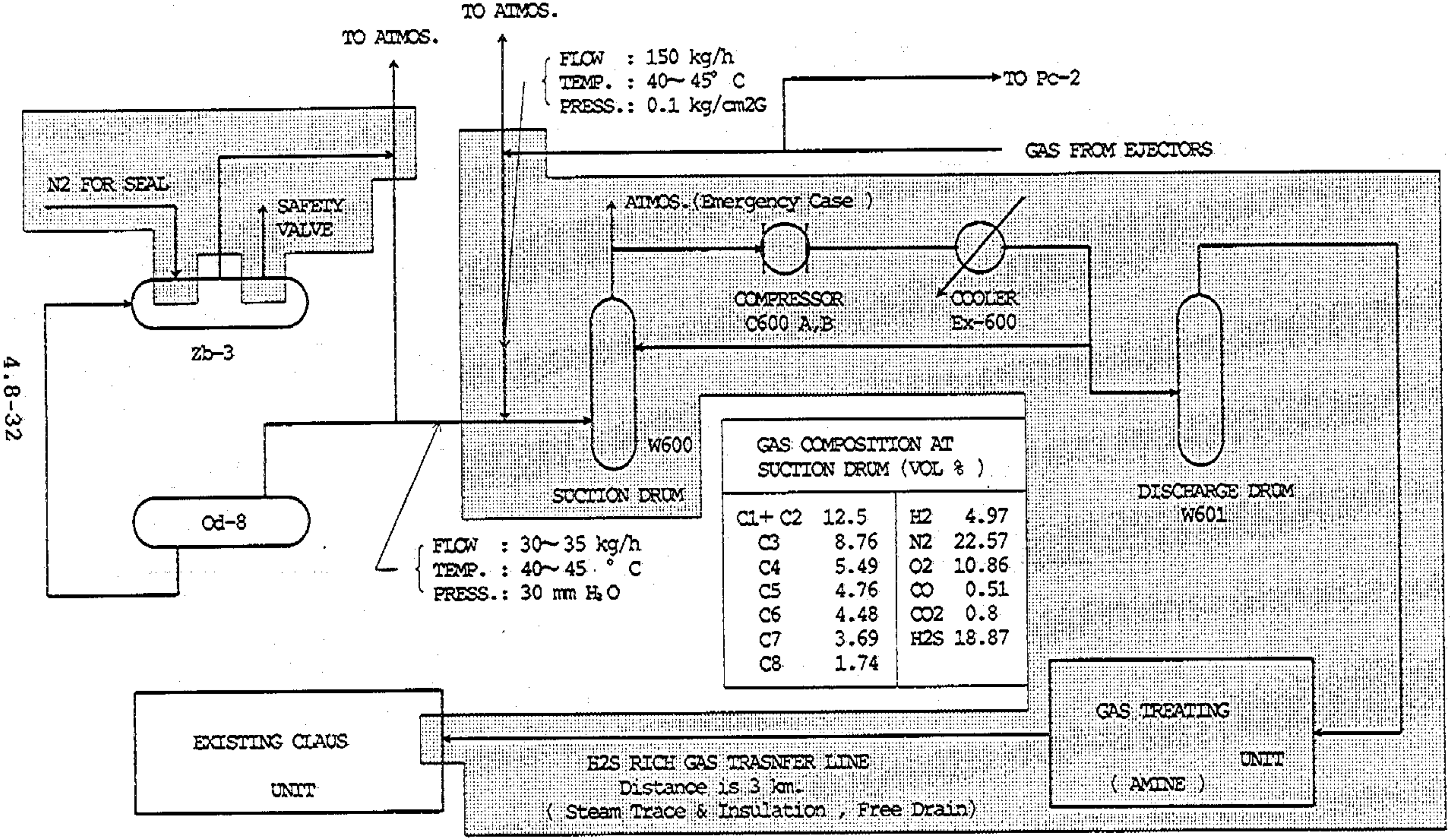


Figure 4.8-4 THE TREATMENT OF OD-8 AND ZB-3 EMISSIONS



GAS COMPOSITION AT SUCTION DRUM (VOL %)

C1+C2	12.5	H2	4.97
C3	8.76	N2	22.57
C4	5.49	O2	10.86
C5	4.76	CO	0.51
C6	4.48	CO2	0.8
C7	3.69	H2S	18.87
C8	1.74		

Table 4.8-6 REPLACEMENT OF INSTRUMENT SYSTEM

	Case 1 Re-Use of existing transmitter	Case 2 Replacement of existing transmitter
Outline	(1) Re-use of existing transmitters (2) Re-use of existing copper tube cable (3) Install PI and IP converters in the Control Room	(1) Re-placement of existing transmitters (2) Replacement of existing copper tube cable to electric cable
Main re-modeling	(1) Re-modeling of substation (Power plant) (2) Installation of constant voltage and constant frequency unit and uninterrupted power supply (3) Modification of control room (Lighting, partition, free-access and etc.,) (4) Remove existing instrument system	
Related work	(1) Installation of PI converters in control room and IP converters at site.	(1) Installation joint boxes in control room and at site. (2) Installation of cable duct and pit (3) Modification of connecting pipe (4) Installation of IP converter at site
Charact-eristics	(1) Decrease maintenance cost (2) Increased accuracy of Measurement (3) Improving operation supervision (Improving alarm function) (4) Improving operation control • Connection to computer • Operation performance control	(1) Decrease maintenance cost (2) Increased accuracy of measurement (3) Possibility for application of advanced control for saving energy (4) Improving operation supervision (Improving alarm function) (5) Improving operation control • Connection to computer • Operation performance control

Table 4.8-7 EXAMPLE OF APPLICATION OF DOC IN NO.1 CRUDE OIL DISTILLATION UNIT

Item	Description
1. Automation and saving manpower	Operation done by board man will be (1) Increase and decrease of throughput of the unit (2) Increase and decrease of heater outlet temperature (3) Smooth charge of atmospheric residue to vacuum unit (Minimize the fluctuation of the feed).
2. Product quality control	There are two ways to control product quality: One is to use automatic analyzer and the other is to use control algorithm. The latter case requires a lot of operation data, laboratory data and plenty of knowledge of distillation theory and will be applied for the following items: (1) Naphtha FBP (2) RVP of Stabilizer Bottoms Oil
3. Cascade control	(1) Stripping steam flow control according to throughput (2) Reflux control according to throughput
4. Saving energy	(1) Oxygen control in the flue gas (2) Outlet temperature control of each pass of heaters
5, Improved supervision	(1) Material balance supervision (2) Dew point supervision (3) Variation rate check by measuring increasing rate of heater inlet temperature (4) Flow check by output of instrument
6. Operation control	(1) Automatic preparation of daily reports (2) Accumulation of data (3) Preparation of the following performance information • Trend of temperature • Fouling of heat exchanger

4.9 Formation of Conceptual Design for an Appropriate Project for Modernization

4.9.1 Conceptual design of No.1 crude oil distillation unit after the modernization

The result of the conceptual design for No.1 crude oil distillation unit after the modernization is summarized in the following documents:

1) Figure 4.8-1 PFD-stabilization unit of Mazovian refinery

2) Figure 4.8-2 PFD (After modernization) No.1 crude oil distillation unit of PPSA

3) Table 4.9-1 Heat and material balance sheet (After modernization)

4.9.2 Summary of the material balance before and after the modernization

Figure 4.9-1 shows the material balance with current product specification before and after the modernization.

4.9.3 Estimated utility consumption after the modernization

The utility consumption after the modernization is estimated here.

(1) Assumption

Estimated utility consumption for newly installed equipment is based on the similar operation in Japan.
Since no detailed engineering was made for the estimated utility consumption, the value shall be used only for the feasibility study.

(2) Estimated utility consumption

Refer to Table 4.9-2 for the difference of the estimated utility consumption before and after the modernization of No.1 crude oil distillation unit.
According to this estimation, electric power is increased by about 1 MW which is mainly due to the installation of new FDF and IDF.
In this feasibility study, it is assumed that all the increased utilities can be supplied without any modification of the existing utilities facilities.
As for the electric power, it is expected that the existing substation has enough capacity for the increased electric power.

4.9.4 Retrofitting work

Refer to Annex 1 for the retrofitting work items and specifications.

4.9.5 For basic and detail design

As this modernization is the retrofitting work of the existing No.1 crude oil distillation unit, the simulation model was set up by inputting current operation data and analysis data. The operating conditions after the modernization will be estimated by inputting new conditions to the simulation model.

As discussed in Chapter 3, there were some unjustifiable, inconsistent and un-available data which had to be estimated or assumed when previously being inputted into the simulation model.

Therefore, this study shall be treated as a feasibility study only.

A more accurate simulation model should be set up by using more accurate operation data and analysis data for basic and detail design.

Since this modernization is retrofitting work of the existing unit, all the equipment should be checked again to see whether it is able to be used after the modernization during basic and detail design.
The following items should especially be checked in detail:

- Capacity of accumulator tray of all the towers
- Hydraulic check of pipe line from accumulator tray to pump for all the products (including strippers)
- Check of tray performance for all of the towers
- Hydraulic check of all pipe lines
- Check whether the existing pumps can be used after the modernization
- Check whether the existing towers, vessels and heat exchangers can be used after the modernization
- Check of the capacity of the heaters, including burner capacity

Table 4.9-1 HEAT & MATERIAL BALANCE SHEET (AFTER MODERNIZATION)

(1/7)

Flow No.		1	2	3	4	5	6	7	8	9	10	11	12
Service		raw crude	Pd-1.2 inlet	Pd-1.1 inlet	Pd-1.2 outlet	Pd-1.2 outlet	Desalter inlet	Desalter outlet	crude Wm13 out	crude Wm4.4out	crude Wm18.1in	crude Wm 17.2 out	crude Wm 19.2 out
Flow (kg/h)		308 000	154 000	154 000	154 000	154 000	308 000	308 000	77 000	77 000	154 000	154 000	154 000
Temperature(℃)		5	95	92	100	100	100	96	182	155	169	193	194
Pressure(MPa)		1.15	0.41	0.41	0.41	0.41	0.41	2.2	—	—	—	—	—
Distillation ℃	Method	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg
	IBP	2	2	2	2	2	2	2	2	2	2	2	2
	5%	61	61	61	61	61	61	61	61	61	61	61	61
	10%	98	98	98	98	98	98	98	98	98	98	98	98
	30%	222	222	222	222	222	222	222	222	222	222	222	222
	50%	336	336	336	336	336	336	336	336	336	336	336	336
	70%	446	446	446	446	446	446	446	446	446	446	446	446
	90%	553	553	553	553	553	553	553	553	553	553	553	553
	95%	578	578	578	578	578	578	578	578	578	578	578	578
	FBP	—	—	—	—	—	—	—	—	—	—	—	—
Density @20 ℃ (g/cm³)		0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860

Table 4.9-1 HEAT & MATERIAL BALANCE SHEET (AFTER MODERNIZATION)

(2/7)

	Flow No.	13	14	15	16	17	18	19	20	21	22	23	24
	Service	W1 inlet	W1 off gas	A10 product	A10 reflux	W1 bottom	Pc-1 to W1 bt'm	W2 feed	A11 product	A11 reflux	P32 dis'	Ch12 inlet	Ch12 outlet
	Flow (kg/h)	308 000	730	25 096	50 000	486 174	204 000	282 174	24 447	98 400	86 000	86 000	86 000
	Temperature(°C)	194	55	55	55	247	330	330	57	57	127	86	86
	Pressure(MPa)	—	0.29	1.3	—	0.37	—	—	—	—	0.54	—	—
Distillation °C	Method	TBP 760mmHg	TBP 760mmHg	ASTM D86	ASTM D86	D1160 760mmHg	D1160 760mmHg	D1160 760mmHg	ASTM D86	ASTM D86	—	—	—
	IBP	2	2	-35	-35	152	152	152	91	91	—	—	—
	5%	61	61	25	25	165	165	165	95	95	—	—	—
	10%	98	98	33	33	178	178	178	100	100	—	—	—
	30%	222	222	41	41	257	257	257	109	109	—	—	—
	50%	336	336	66	66	372	372	372	116	116	—	—	—
	70%	446	446	79	79	462	462	462	124	124	—	—	—
	90%	553	553	94	94	559	559	559	134	134	—	—	—
	95%	578	578	100	100	580	580	580	142	142	—	—	—
	FBP	—	—	102	102	591	591	591	150	150	—	—	—
	Density @20 °C (g/cm³)	0.860	0.860	0.664	0.664	0.888	0.888	0.888	0.742	0.742	—	—	—

Table 4.9-1 HEAT & MATERIAL BALANCE SHEET (AFTER MODERNIZATION) (3/7)

Flow No.		25	26	27	28	29	30	31	32	33	34	35	36
Service		P35 dis'	Ch10 inlet	Ch10 outlet	P36 dis'	Ch11 inlet	Ch11 outlet	A12 Wm7 inlet	A12 Ch2 inlet	A12 Ch2 outlet	P11 Wm3. 3 inlet	P11 Ch3 inlet	P11 Ch3 outlet
Flow (kg/h)		75 000	75 000	75 000	64 000	64 000	64 000	9 722	9 722	9 722	36 000	36 000	36 000
Temperature(℃)		168	135	100	253	180	180	138	107	63	264	175	—
Pressure(MPa)		0.48	—	—	0.44	—	—	—	—	—	—	—	—
Distillation ℃	Method	—	—	—	—	—	—	ASTM D86	ASTM D86	ASTM D86	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg
	IBP	—	—	—	—	—	—	128	128	128	294	294	294
	5%	—	—	—	—	—	—	152	152	152	336	336	336
	10%	—	—	—	—	—	—	153	153	153	348	348	348
	30%	—	—	—	—	—	—	154	154	154	373	373	373
	50%	—	—	—	—	—	—	155	155	155	395	395	395
	70%	—	—	—	—	—	—	158	158	158	418	418	418
	90%	—	—	—	—	—	—	165	165	165	446	446	446
	95%	—	—	—	—	—	—	171	171	171	463	463	463
	FBP	—	—	—	—	—	—	180	180	180	480	480	480
Density @20 ℃ (g/cm^3)		—	—	—	—	—	—	0.770	0.770	0.770	0.891	0.891	0.891

Table 4.9-1 HEAT & MATERIAL BALANCE SHEET (AFTER MODERNIZATION) (4/7)

Flow No.		37	38	39	40	41	42	43	44	45	46	47	48
Service		A13 P101 dis	A13 Wm6 inlet	A13 Ch4 inlet	A13 Ch4 outlet	A14 P53 dis'	A14 Ch5 inlet	A14 Ch5 outlet	W3(A12) steam	W3(P11) steam	W3(A13) steam	W3(A14) steam	W2 btm steam
Flow (kg/h)		65 721	20 000	65 721	65 721	27 973	27 973	27 973	70	—	150	30	2 400
Temperature(℃)		190	190	129	58	272	180	49	330	—	330	330	330
Pressure(MPa)		—	—	—	—	—	—	—	0.48	—	0.48	0.48	0.48
Distillation ℃	Method	ASTM D86	ASTM D86	ASTM D86	ASTM D86	ASTM D86	ASTM D86	ASTM D86	—	—	—	—	—
	IBP	152	152	152	152	202	202	202	—	—	—	—	—
	5%	183	183	183	183	268	268	268	—	—	—	—	—
	10%	190	190	190	190	283	283	283	—	—	—	—	—
	30%	211	211	211	211	303	303	303	—	—	—	—	—
	50%	231	231	231	231	315	315	315	—	—	—	—	—
	70%	251	251	251	251	327	327	327	—	—	—	—	—
	90%	274	274	274	274	354	354	354	—	—	—	—	—
	95%	284	284	284	284	367	367	367	—	—	—	—	—
	FBP	300	300	300	300	392	392	392	—	—	—	—	—
Density @20 ℃ (g/cm^3)		0.811	0.811	0.811	0.811	0.834	0.834	0.834	—	—	—	—	—
Vis @100℃ (cSt)		FL.Pt 51 ℃	FL.Pt 51 ℃	FL.Pt 51 ℃	FL.Pt 51 ℃	—	—	—	—	—	—	—	—

Table 4.9-1 HEAT & MATERIAL BALANCE SHEET (AFTER MODERNIZATION)

(5/7)

Flow No.		49	50	51	52	53	54	55	56	57	58	59	60
Service		W2 btm oil	W7 feed	W1 top	W2 top	W7 top	P10 to Zb-2	P10 to W7	P10 product	P12 Wm11 inlet	P12 Ch6 inlet	P12 Ch6 outlet	P13 Wm12 inlet
Flow (kg/h)		154 311	154 311	75 826	122 847	2 550	92 075	85 000	12 075	26 000	26 000	26 000	9 886
Temperature(°C)		309	391	103	93	76	116	55	83	316	167	69	350
Pressure(MPa)		0.071	0.15	0.24	0.05	70mmHg	—	—	—	0.5	—	—	0.36
Distillation °C	Method	D1160 760mmHg	D1160 760mmHg	—	—	—	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg
	IBP	276	276	—	—	—	254	254	254	326	326	326	388
	5%	342	342	—	—	—	258	258	258	382	382	382	435
	10%	374	374	—	—	—	267	267	267	400	400	400	452
	30%	463	463	—	—	—	298	298	298	436	436	436	483
	50%	561	561	—	—	—	324	324	324	456	456	456	503
	70%	673	673	—	—	—	345	345	345	475	475	475	523
	90%	802	802	—	—	—	368	368	368	508	508	508	547
	95%	883	883	—	—	—	380	380	380	518	518	518	552
	FBP	952	952	—	—	—	394	394	394	522	522	522	558
Density @20 °C (g/cm³)		0.900	0.900	—	—	—	0.863	0.863	0.863	0.912	0.912	0.912	0.929
Vis @100°C (cSt)		—	—	—	—	—	—	—	—	—	—	—	—

Table 4.9-1 HEAT & MATERIAL BALANCE SHEET (AFTER MODERNIZATION) (6/7)

	Flow No.	6 1	6 2	6 3	6 4	6 5	6 6	6 7	6 8	6 9	7 0	7 1	7 2
	Service	P13 Ch7 inlet	P13 Ch7 outlet	P14 Wm13 inlet	P14 Ch8 inlet	P14 Ch8 outlet	W8(P12) steam	W8(P13) steam	W8(P14) steam	W7 steam	P10 dis'	Wm4.2 to W7	P37 to Wm15
	Flow (kg/h)	9 886	9 886	10 000	10 000	10 000	—	50	—	2 500	61 000	61 000	24 000
	Temperature(℃)	164	102	357	210	92	—	340	—	340	264	107	350
	Pressure(MPa)	—	—	—	—	—	—	0.57	—	0.57	0.68	—	0.22
Distillation ℃	Method	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	—	—	—	—	—	—	—
	IBP	388	388	345	345	345	—	—	—	—	—	—	—
	5%	435	435	421	421	421	—	—	—	—	—	—	—
	10%	452	452	447	447	447	—	—	—	—	—	—	—
	30%	483	483	488	488	488	—	—	—	—	—	—	—
	50%	503	503	512	512	512	—	—	—	—	—	—	—
	70%	523	523	535	535	535	—	—	—	—	—	—	—
	90%	547	547	556	556	556	—	—	—	—	—	—	—
	95%	552	552	582	582	582	—	—	—	—	—	—	—
	FBP	558	558	615	615	615	—	—	—	—	—	—	—
	Density @20 ℃ (g/cm³)	0.929	0.929	0.933	0.933	0.933	—	—	—	—	—	—	—
	Vis @100℃ (cSt)	—	—	FL.Pt 210℃	FL.Pt 210℃	FL.Pt 210℃	—	—	—	—	—	—	—

Table 4.9-1 HEAT & MATERIAL BALANCE SHEET (AFTER MODERNIZATION) (7/7)

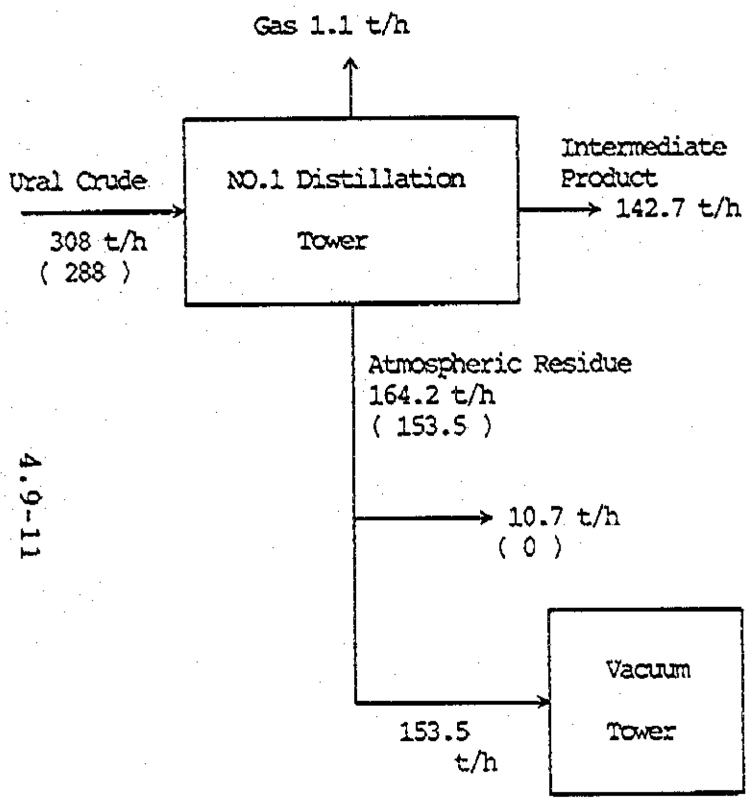
Flow No.		73	74	75	76	77	78
Service		Wm4.4 to W7	VR to Wm 16/17	VR to Wm 18/19	VR from Wm 5	VR from Wm 2	A13 Wm6 inlet
Flow (kg/h)		24 000	30 175	30 175	30 175	30 175	20 000
Temperature(℃)		259	345	345	130	130	190
Pressure(MPa)		—	1.4	1.4	—	—	—
Distillation ℃	Method	—	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	TBP 760mmHg	ASTM D86
	IBP	—	429	429	429	429	152
	5%	—	468	468	468	468	183
	10%	—	485	485	485	485	190
	30%	—	522	522	522	522	211
	50%	—	549	549	549	549	231
	70%	—	612	612	612	612	251
	90%	—	748	748	748	748	274
	95%	—	807	807	807	807	284
	FBP	—	876	876	876	876	300
Density @20 ℃ (g/cm^3)		—	0.957	0.957	0.957	0.957	0.811
Vis @100℃ (cSt)		—	—	—	—	—	FL.Pt 51 ℃

HEATER DUTY(absorbed)

ITEM No.	Pc-1	Pc-2
DUTY (GJ/h)	144.8	40.0

Figure 4.9-1 MODERNIZATION PLAN OF NO.1 CRUDE OIL DISTILLATION UNIT

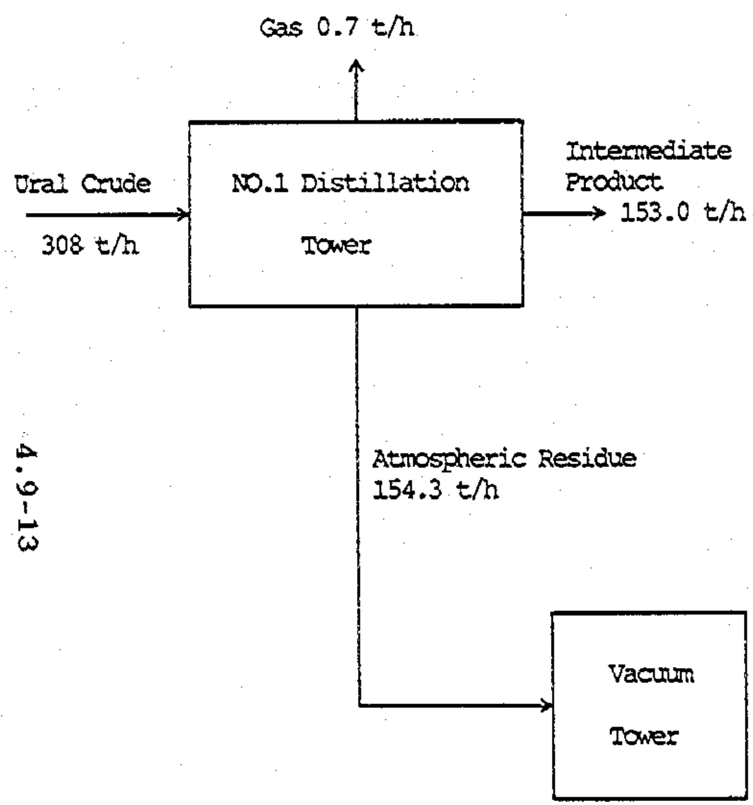
1. Before Modernization



Intermediate Products	Specification	Product Quantity (t/h)	Remarks
Gas	—		
Full range Naphtha (A10)	IBP min. 25° C FBP max. 180° C	25	
Light Naphtha (A11)	IBP 78.5 ± 5° C FBP 148 ± 5° C	20.9	IBP:Out of Spec. Gap:Not Satisfactory
Heavy Naphtha (A12)	IBP 130 ° C FBP 190 ° C	13.6	IBP:Out of Spec. Gap:Not Satisfactory
Kerosene (A13)	FBP 220 ° C % vol. evaporated at 200 ° C - 50 Flash Point < 55 °	20.5	IBP:Out of Spec. FP :Out of Spec.
Light Gas Oil (A14)	IBP 180 ° C Density 0.81 ~ 0.835 Flash Point < 66 °	18.2	IBP:Out of Spec. FP :Out of Spec.
Gas Oil (A15)	Density 0.83 ~ 0.850 % vol. evaporated at 350 ° C - 87	25.1	Lower than IBP of A16
Heavy Gas Oil (A16)	Density 0.85 ~ 0.870 % vol. evaporated at 350 ° C - 80	19.4	
Atmospheric Residue	—	164.2	

Intermediate Products	Specification	Product Quantity (t/h)	Remarks
Gas Oil (P11)	FBP < 460 ° C Density 0.88 ~ 0.895 Flash Point > 120° C Freezing Point < 8° C	41.0	Specific Gravity: Out of Spec.
Gas Oil (P12)	FBP < 460 ° C Flash Point > 120° C	17.1	FBP : Out of Spec.
Gas Oil (P13)	Density 0.91 ~ 0.925 Viscosity 10.5~ 12.5 mm²/s Flash Point > 220° C Freezing Point <37° C IBP > 400 ° C FBP < 545 ° C FBP-IBP ≦ 120° C	34.2	Vis : Out of Spec. FBP-IBP : Out of Spec.
Gas Oil (P14)	Flash Point < 210° C	11.4	
Vacuum Residue	Penetration (Softening Point R-B Method) 43.6 ~ 46.5	60.4	Penetration : Out of Spec.

2. After Modernization



Intermediate Products	Specification	Product Quantity (t/h)	Remarks
Gas	—		
LPG	C1+C2 < 1.5 vol. % C5 < 0.5 vol. %	4.3	
Light Naphtha (R12)	IBP > 25° C FBP 85 ± 5° C	7.2	
Light Naphtha (R13)	IBP 78 ± 5° C 50vol.% recovered at ° C 87 FBP 110 ± 5° C	13.6	
Light Naphtha (A11)	IBP 78 ± 5° C FBP < 150° C	24.5	
Heavy Naphtha (A12)	IBP < 130° C FBP < 180° C	9.7	
Light Gas Oil (A13)	FBP < 300° C Flash Pont > 80° C	65.7	FP : Out of Spec.
Heavy Gas Oil (A14)	% vol. evaporated at 350 ° C Summer > 85 winter > 90	28.0	
Atmospheric Residue	—	154.3	

Intermediate Products	Specification	Product Quantity (t/h)	Remarks
Gas Oil (P10)		12.0	
Gas Oil (P11)	% vol. evaporated at 300 ° C < 0.5 325 ° C < 3 350 ° C < 10 400 ° C 45 – 60 450 ° C > 90 Vis. at 100 ° C 3.5 – 4.2	36.0	
Gas Oil (P12)	% vol. evaporated at 300 ° C < 0.5 350 ° C — 400 ° C max. 10 – 15 450 ° C 45 – 60 500 ° C 85 – 90 above 520° C < 15 Vis. at 100 ° C 6.9 – 7.3	26.0	
Gas Oil (P13)	% vol. evaporated at 400 ° C < 5 450 ° C < 15 500 ° C 45 – 50 above 520° C 25 – 30 Vis. at 100 ° C 12.0 – 14.0	9.9	
Gas Oil (P14)	Flash Point 210° C	10.0	
Vacuum Residue	Penetration 120 — 200 (ASTM D 1321)	60.4	The same as value before Modernization

Table 4.9-2 DIFFERENCE OF ESTIMATED UTILITIES' CONSUMPTION BEFORE AND AFTER THE MODERNIZATION OF NO.1 CRUDE OIL DISTILLATION UNIT

ITEM NUMBER	FUEL OIL (kg/h)	ELECT-RICITY (kw)	STEAM (t/h)	COOLING WATER (t/h)	NOTE
(1) Heaters					• Including Saving Energy Items (Air Preheating and O_2 Control).
Pc-1	-1,371.2				• Lower calorific value of fuel oil : 9,443 kcal/kg
Pc-2	-305.5				• Minus means decrease of consumption.
(2) Stabilizer & Splitter					
P-210 A,B		1.5			- One pump operation.
P-202 A,B		1.5			- One pump operation.
P-203 A,B		1.1			- One pump operation.
(3) Re-arrangement of H.E					
Pumps		182.5			- One pump operation.
Ex-6				40	
Ex-7				130	
Ex-8				165	
Stripping Steam			4.5(0.7 MPa)		W-2, W-3, W-7, W-8
Pd-1.1 & Pd-1.2			4.0(1.7 MPa)		14kg/cm²G(205 ° C)
(4) Air Preheat					
Jung Strom		2.2			• Current utility consumption informed by PPSA
Soot Blower		0.2			-Electric Power:1,501 kwh
Steam Air Heater			7.8(1.7 MPa)		-Instrument air: 234 nm³/h
Forced Fan		500			-Steam (1.7 MPa): 5.447 t/h -Steam (0.6 MPa):14.580 t/h
Induced Fan		400			(including steam for steam trace- 6 t/h)
(5) Removal of existing pumps					
P-46		-9.6			Information from PPSA
P-49		-16.0			Information from PPSA
P-51		-30.0			Information from PPSA
(6) DCS		25			
	-1,676.7	1,058.0	16.3	335	