(1) The objective factories under the present survey are all located in Sfax city and the total volume of waste water discharged from the objective factories is limited. If the scope of waste water treatment is expanded to the entire city, an increase in volume of waste water will necessitate an expansion of ONAS plant which is out of the scope under the present study.

(2) A waste water treating process applied at ONAS sewage treatment plant is a biodegradable method which can treat organic compounds such as BOD and COD, but cannot dispose fluorine (F) from SIAPE or chrome (Cr) from SMCP. Therefore, it is a prerequisite to remove such substances as F and Cr at the respective factory before waste water is flown into ONAS sewage treatment plant.

4.2 Preconditions for Planning Waste Water Treatment by Factory

4.2.1 SIAPE

Items concerning water quality which are problems in Sampling Spots SPE-20 are pH, Cd, F, COD, BOD, Fe, SO4 and P.

Therefore, waste water from these factories is systematically classified to the following four categories.

I. Waste water from TSP scrubbers - 44 m^3/hr

This effluent is low in pH value and contains a high concentration of F, Cl and SO4.

II. Waste water from generators and boilers - 18 m^3/hr

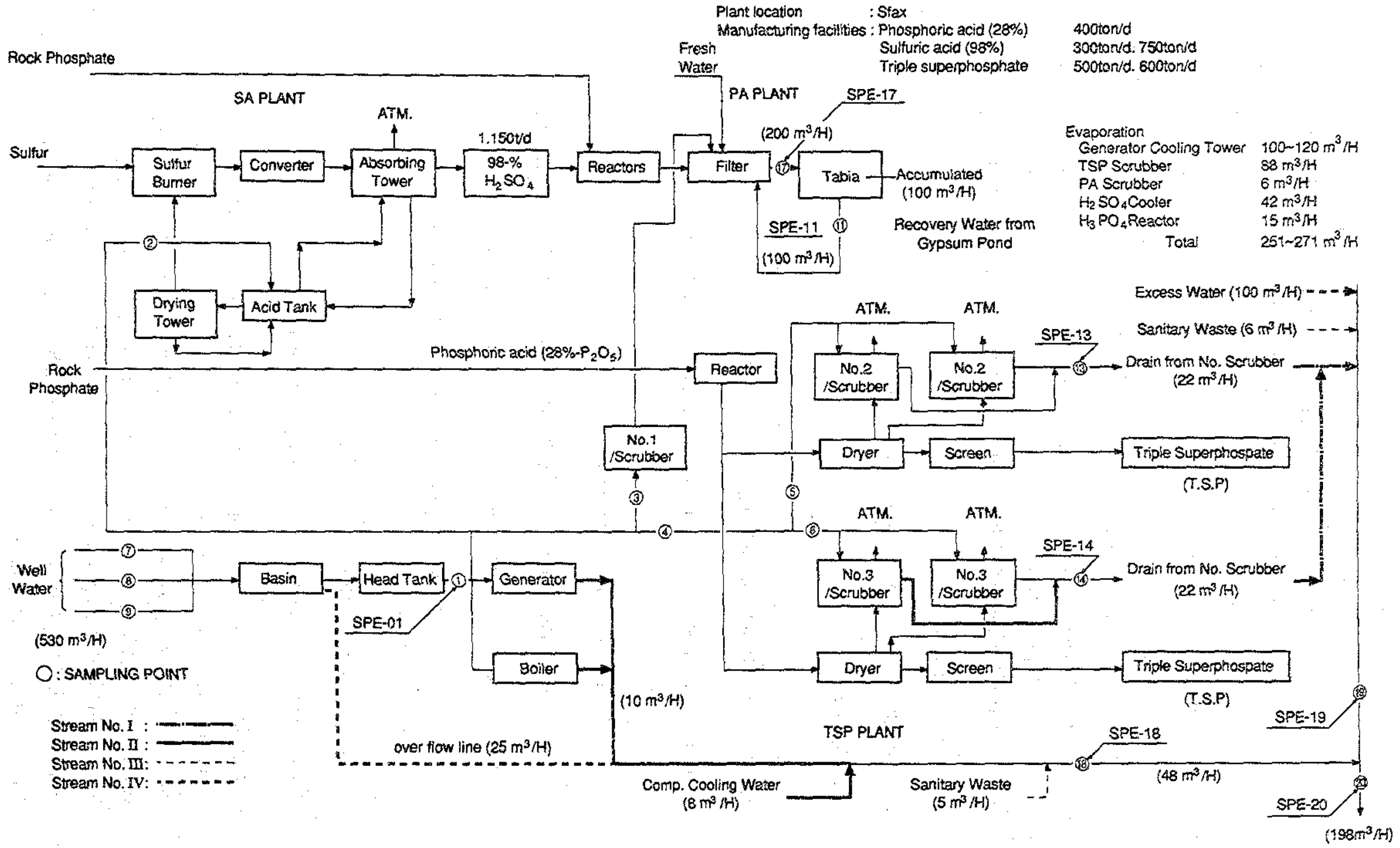
Waste water from generators and boilers contains COD, Fe and are high in the concentration of Cl and SO_4

III. Waste water from daily livings - 11 m^3/hr

IV. Excessive water and overflows - 125 m^3/hr

Fig. V-3 shows a flow sheet for the above-stated conditions I to IV. Waste water from daily livings mentioned in III above is to be released to ONAS plant and excessive water and overflows mentioned in IV above will be excluded from our considerations as water from wells is released to the plant. Well water SPE-1 contains 940 mg/l and 930 mg/l of SO4. This well water is, however, to be limited for use or used for dilution, because SO4 contained is below 1000 mg/l of the INNORPI emission standard for waste water to be released into the sea area.

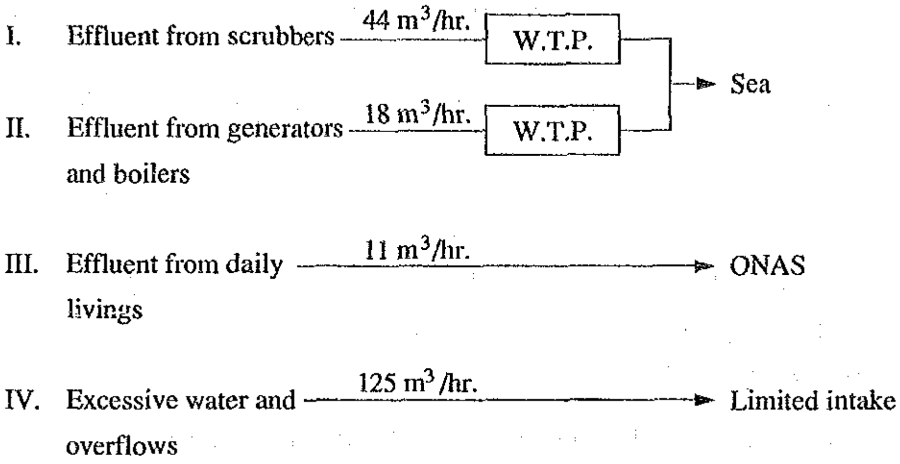
Fig. V-3 Grouping for Streame of Waste Water (SIAPE)



Plant location : Sfax
Manufacturing facilities : Phosphoric acid (28%) 400ton/d
Sulfuric acid (98%) 300ton/d. 750ton/d
Triple superphosphate 500ton/d. 600ton/d

Evaporation	
Generator Cooling Tower	100~120 m^3/H
TSP Scrubber	88 m^3/H
PA Scrubber	6 m^3/H
H_2SO_4Cooler	42 m^3/H
H_3PO_4Reactor	15 m^3/H
Total	251~271 m^3/H

Therefore, only waste water in Stream I and II will be included for our considerations.



Whereas "W.T.P." above means "Waste water treating plant".

Measured values for the quality of effluent under I and II are as as shown in Table V-11. However, those values should be modified when countermeasures for ehaust gas as mentioned later must be taken, as the given values have not taken such countermeasures into account.

Table V-11 Quality of Waste Water (SIAPE)

		FLOW m³/Hr	PH	COD mg/l	F mg/l	Fe mg/l	Cd mg/l	P mg/l	Cl mg/l	SO4 mg/l
I	Effluent from TSP scrubbers	44	1.1-1.6	276	5848	3.36	0.018	108	3700	1125
II	Effluent from generators and boilers	18		150	4.2	2	0.01	0.1	3100	1800

The effluent is assumed to be released into the sea area, and the standards to be applied are as follows:

Case 1B :	Tentative standard proposed by Japan
Case 2B and 3B:	Tentative standard proposed by Tunisia and INNORPI standard (Case 2B and Case 3B are the same).

We will consider to return the treated effluent to the filtration process at the phosphoric acid plant.

4.2.2 SNDP

As mentioned in Chapter III, various reconstruction works are taking place and countermeasures for waste water treatment are under planning in SNDP plant. Upon completion of the reconstruction works, remarkable improvement of the water quality is anticipated. Therefore, no case of waste water treatment will be set up as for SNDP plant.

4.2.3 UPOTS

Waste water of UPOTS taken up for this study is margin. Applicable items with respect to the mergin quality are N-HEX, phenol, COD, kj-N, K, P, C1, and SO4. COD and K are particularly high in concentration.

Values to be studied and standard values of each case are shown in Table V-12. The margin waste water volume from UPOTS is about 50m3/day. The treatment facilities will handle this waste water together with margin of other companies in consideration of the scale merits, so that the waste water volume becomes to be 1,000 m3/day for 100 days a year. The target treatment values are based on the tentative standard proposed by Japan of case 1A, tentative standard proposed by Tunisia of case 2A and INNORPI standard of case 3A. The treated water is discharged to ONAS.

Table V-12 Designed Quality of Margin

FLOW m3/D	COD mg/l	N-HEX mg/l	PHENOL mg/l	Kj-N mg/l	K mg/l	P mg/l	Cl mg/l	SO4 mg/l	EC ms/cm
1000	190000	300	5	920	10000	2300	8900	3050	35

Flow of 1000 m^3/D is exhausted 100 days a year.

4.2.4 SIOS-ZITEX

The broblematic water quality items for SIOS-ZITEX are Ph, SS, COD, N-HEX, Cl and SO4.

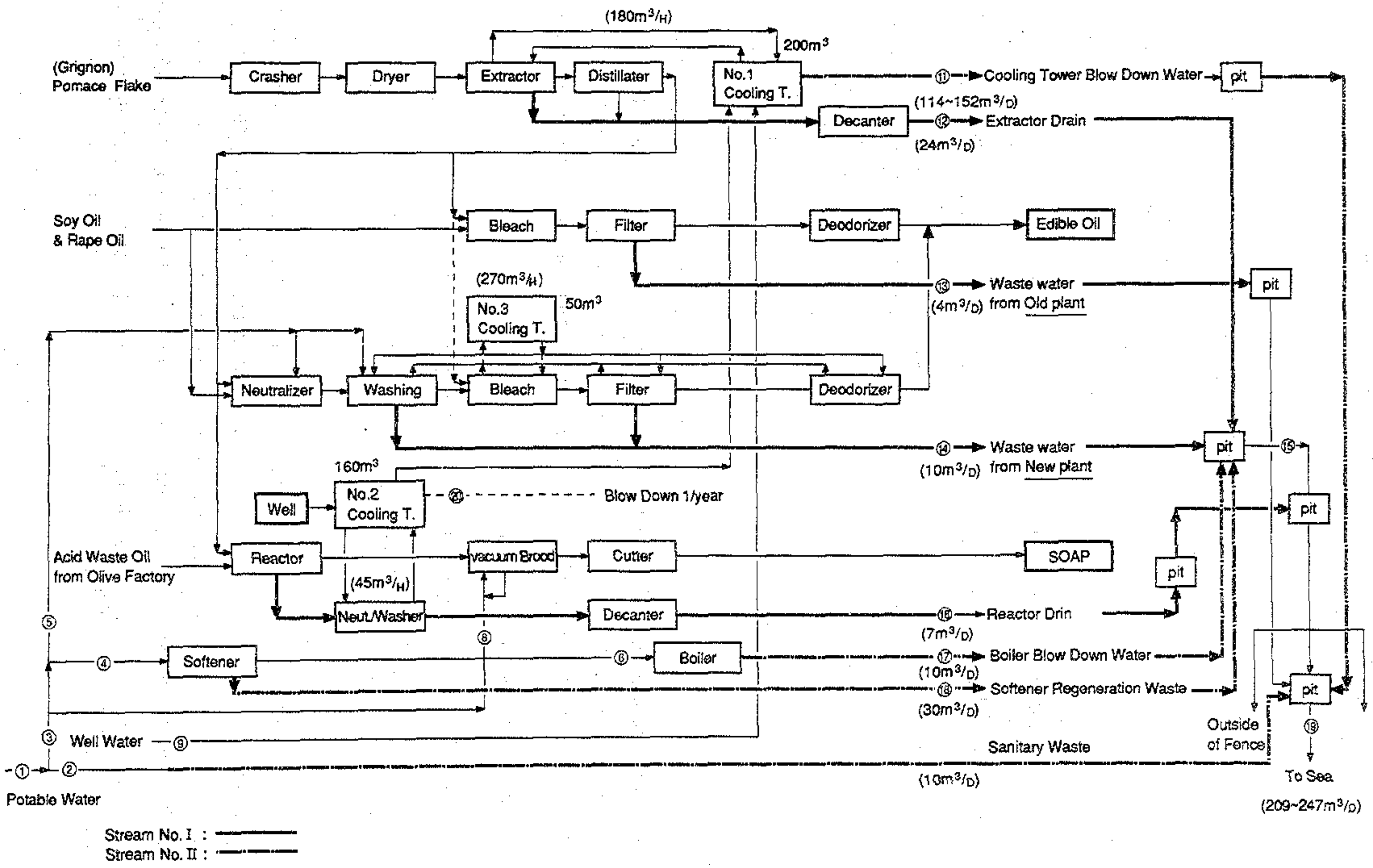
Waste water from the factory have to be effectively treated by dividing it into waste water of high COD concentration and the one of low COD concentration.

For this purpose flow of waste water will comprise two lines as shown in Fig. V-4. The contents of these two lines are as follows:

I. Waste water from extraction, refining, and soap processes (high COD concentration)

II. Cooling water, boiler, softener, and living waste water (low COD concentration)

Fig. V-4 Grouping for Stream of Waste Water (SIOS-ZITEX)



Mean values of quality of various waste water in the stream I and II obtained from primary and detailed analytical values are summarized in Table V-13.

Table V-13 Quality of Waste Water (SIOS-ZITEX)

			FLOW m^3/D	COD mg/l	Cl mg/l	SO$_4$ mg/l	EC mS/cm
STREAM NO.	SAMP. NO.						
I	SZT-12	Extraction	24	1865	3750	3250	16.25
	SZT-13	Old purification system	4	61919	1400	240	8.7
	SZT-14	New purification system	10	21843	11500	1030	32
	SZT-16	Soap	7	18733	10150	8350	45.9
		Confluence I	45	14267	6259	3282	
II	SZT-11	Cooling tower	152	300	3236	2158	17.4
	SZT-17	Boiler	10	600	6585	7892	46.7
	SZT-18	Softener	30	130	300	360	2.6
		Effluent from daily livings	10	1000	300	360	
		Confluence II	202	324	2820	2086	

Values of Cl and SO4 contained in effluents from cooling water or boilers were reckoned taking account of the ratio of well water and city water assumed from electric conductivity. COD values of effluent from daily livings were obtained by taking 1000 mg/l of the inflow standard value at ONAS plant. Values for Cl and SO4 are based on the city water.

Selected cases are as follows:

Case 1A: Tentative standard proposed by Japan (ONAS)

Case 2A: Tentative standard proposed by Tunisia (ONAS)

Case 3B: INNORPI standard for discharge to the sea

A plan for rationalizing the process to recover glycerol from a soap manufacturing plant is shown in Volume IV. With this rationalization, COD of effluent from the soap manufacturing plant will be reduced, and the water discharge will be increased from 7 m^3/day to 8m^3/day. This case will be included in our consideration as Case 4A based on the tentative standard proposed by Japan. The quality of waste water in this case is shown in Table V-14.

Table V-14 Quality of Waste Water after Improvement of Production Process (SIOS-ZITEX)

		FLOW m^3/D	COD mg/l	Cl mg/l	SO_4 mg/l
I	Confluence I	46	12214	6259	3282
II	Confluence II	202	324	2820	2086

4.2.5 SATHOP

Similar to the case of SIOS-ZITEX, waste water from the system including extraction process where COD is generally high, the purification process and the soap process is referred to as Group I, and any other waste water incoming from cooling water, boilers, softener and daily livings is referred to as Group II. Fig. V-5 is a flow sheet of waste water classified as Groups I and II. The effluent quality determined at SIOS-ZITEX was adopted for effluent of Group I, because the primary analysis is not carried out at SATHOP. Likewise, the quality of effluent from boilers and softener determined at SIOS-ZITEX was adopted for the effluent quality at SATHOP.

Blow down water from cooling tower flown into the well changed the effluent point to waste water and values for SO4 were calculated from electric conductivity. The effluent quality are shown in Table V-15.

Case 4 is taking rationalization of the production facilities into account, as was done in the case of SIOS-ZITEX. The quality of waste water for Case 4 is shown in Table V-16.

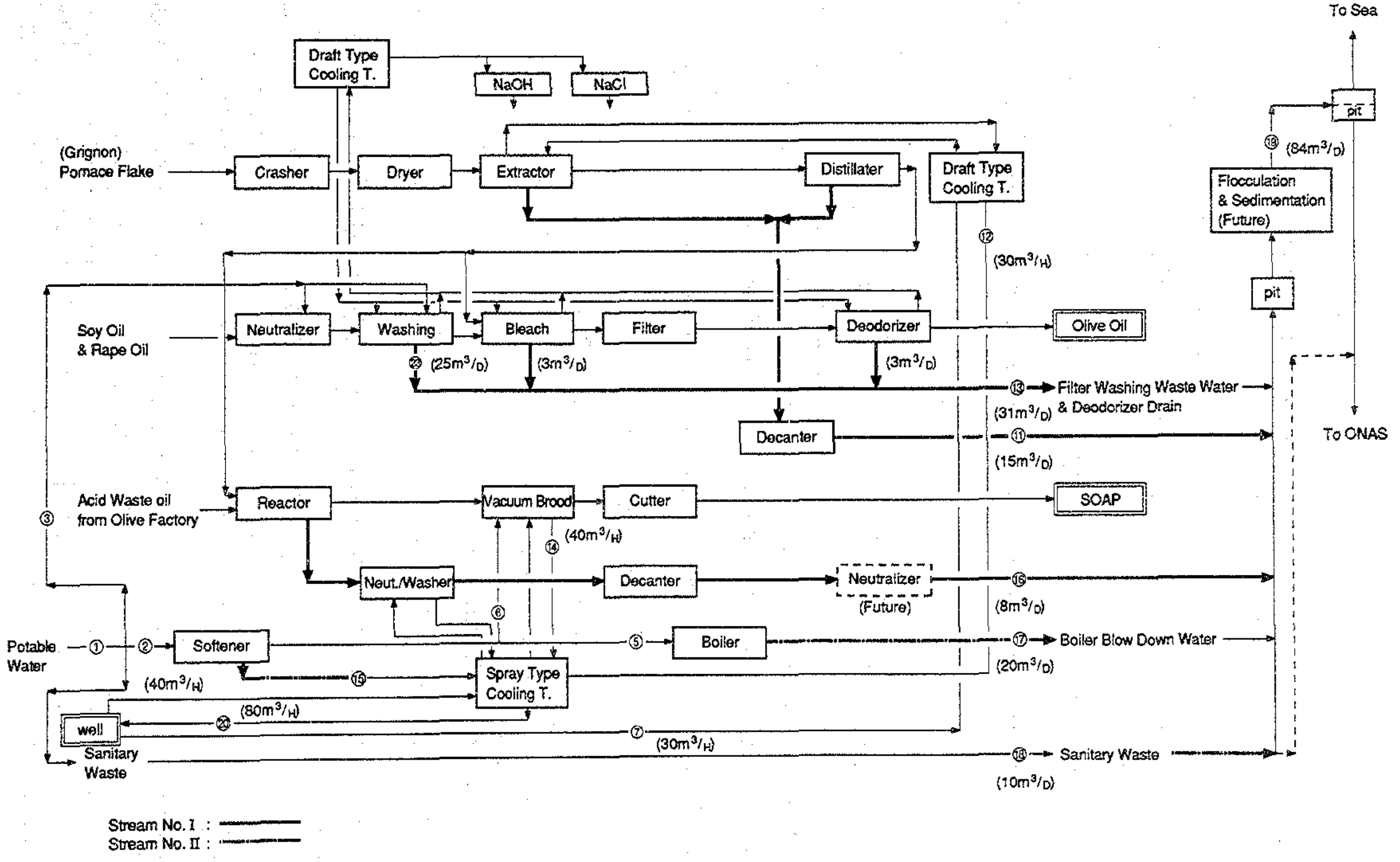
Table V-15 Quality of Waste Water (SATHOP)

STREAM NO.	SAMP. NO.		FLOW m^3/D	COD mg/l	Cl mg/l	SO_4 mg/l	EC mS/cm
I	SZT-12	Extraction	15				
	SZT-13	purification system	31				
	SZT-16	Soap	8				
		Confluence I	54	14267	6259	3282	
II	SZT-11	Cooling tower	80	300	11000	3550	17.4
	SZT-17	Boiler	20	600	6585	7892	46.7
	SZT-18	Softener	30	130	300	360	2.6
		Effluent from daily livings	10	1000	300	360	
		Confluence II	140	356	7312	3259	

Table V-16 Quality of Waste Water after Improvement of Production Process (SATHOP) - Case 4A

		FLOW m^3/D	COD mg/l	Cl mg/l	SO_4 mg/l
I	Confluence I	55	12692	6259	3282
II	Confluence II	140	356	7312	3259

Fig. V-5 Grouping for Stream of Waste Water (SATHOP)



4.2.6 SMCP/TMC

Waste water at SMCP and TMC will be treated together. The followings are taken into account for the quality of waste water.

(1) As fluctuations of the COD value in the primary analyses and detailed analyses of effluent is remarkably large at SMCP, the COD value of time based analyses is adopted.

(2) COD values of effluent at TMC are the mean values in the primary analyses.

(3) Values of T-N, NH3-N and Cr in effluent at SMCP are values obtained by detailed analyses.

(4) Values of Cl and SO4 were reckoned from electric conductivity.

Problematic items concerning the effluent quality at SMCP and TMC are COD, N-HEX, T-N, NH3-N, Cr, Cl and SO4. The concentrations of respective water quality items are shown in Table V-17. The volume of effluent is assumed to be 300 m3/day as shown in Volume III in consideration of future expansion of facilities.

The planned waste water standard comprises the following four cases;

Case 1A: Tentative standard proposed by Japan (ONAS)

Case 2A: Tentative standard proposed by Tunisia (ONAS)

Case 3A: INNORPI standard (ONAS)

Case 3B: INNORPI standard (SEA)

Table V-17 Quality of Waste Water (SMCP/TMC)

	FLOW m^3/D	COD mg/l	N-HEX mg/l	T-N(Kj) mg/l	NH3-N mg/l	T-Cr mg/l	EC mS/cm	Cl mg/l	SO$_4$ mg/l
SMCP	26.4	4372	378	834	580	358	12.2	2000	1800
TMC	13.3	7055	-	-	-	-	22.7	3200	3836
SMCP + TMC	39.7	4372	251	555	386	318		2400	3480
Values to be studied	300	4372	251	555	386	318		2400	3480

4.2.7 STS

Problematic items of effluent at STS are COD, Cl and SO4.

Effluent at STS is classified to 3 Groups - namely, Stream I being wastewater of high COD from the dyeing process at STS-13, 14 and 15, Stream II being wastewater from softener regeneration at STS-21 which contains highly concentrated salt, and Stream III being wastewater from other sources than those mentioned in other Groups. The flow sheet of classified waste water at STS is shown in Fig. V-6 and the quality of waste water at STS is shown in Table V-18.

Fig. V-6 Grouping for Stream of Waste Water (STS)

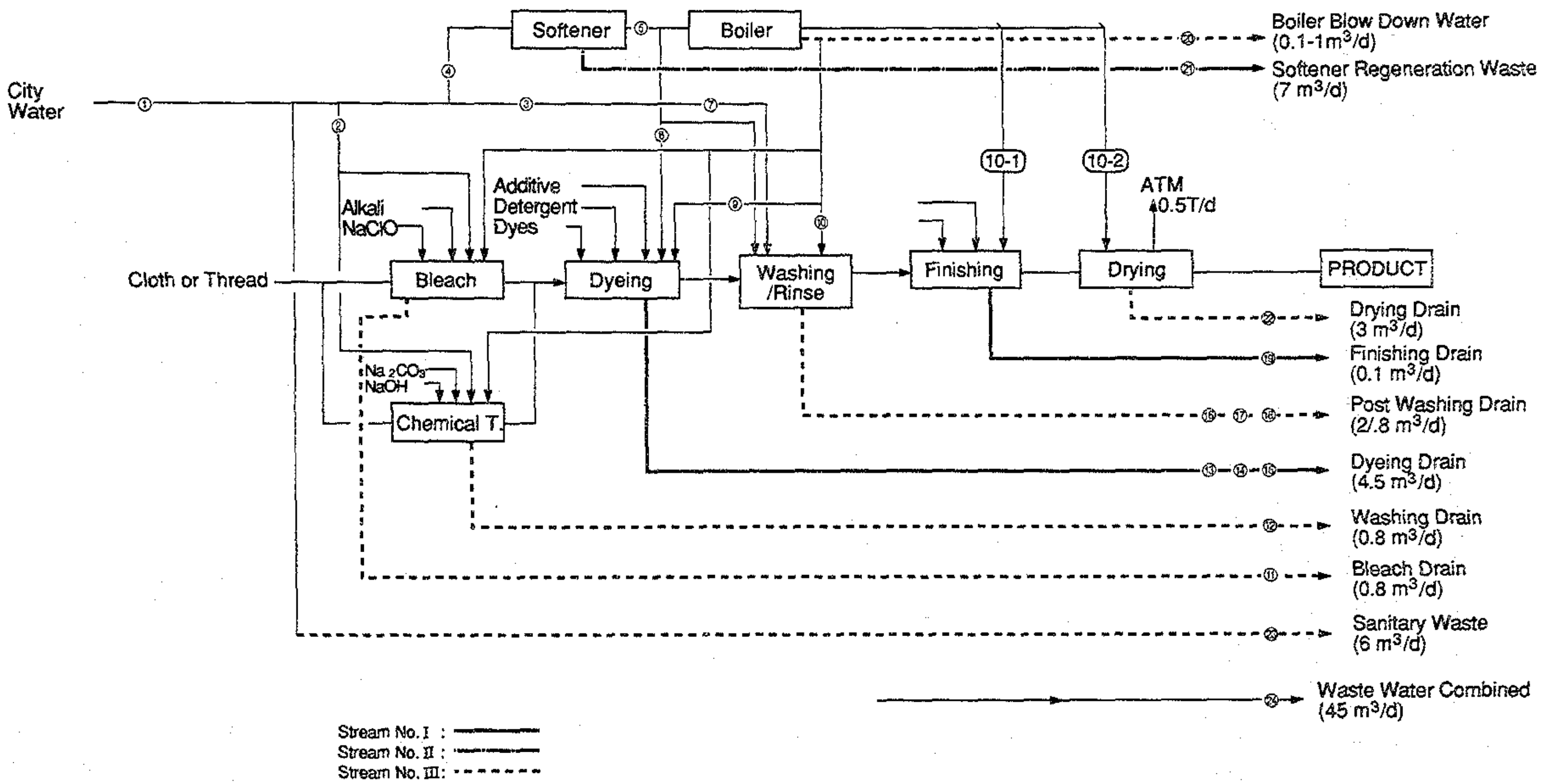


Table V-18 Quality of Waste Water (STS)

STREAM NO.	SAMP. NO.	FLOW m^3/D	COD mg/l	Cl mg/l	SO_4 mg/l	EC mS/cm
I	STS-13, 14, 15, 19	4.6	26276	1133	5476	19
II	STS-21	7.0	282	4800	5800	34.5
III	Other sources than mentioned above	33.4	504	363	595	

4.2.8 ONAS

Waste water flown into ONAS plant does not satisfy INNORPI standard at present with respect to COD, BOD and SS, as already mentioned in Volume III. When waste water from the selected factories of this study is added to the existing incoming flow, situations at ONAS plant will be worsened. Therefore, our planning will include remodeling of the existing waste water treatment facilities so that they can satisfy teh emission standard of INNORPI for sea area, taking the additional inflow into account. The remodeling plan of ONAS waste water treatment facilities should essentially take account of all other existing enterprises in addition to the selected factories of this study. However, our remodeling plan for ONAS plant will consider available values of waste water from the selected factories only, basing on tentative standard proposed by Japan of Case 1A, and values of COD, BOD and SS for living wastewater from SIAPE plant were based on design values of ONAS inflowing waste water.

Table V-19 Increases of Pollutant Load at ONAS by Accepting Inflows of Waste Water from the Selected Factories

		FLOW m^3/D	COD mg/l	BOD mg/l	SS mg/l	Cl mS/cm	SO_4 mg/l
New inflow	SIAPE living wastewater	264	1000	390	350	360	300
	UPOTS MARGIN	685	2000	800	800	4160	1460
	SIOS-ZITEX	247	2000	800	800	3047	2304
	SATHOP	153	2000	800	800	7019	3265
	SMCP/TMC	300	2000	800	800	2400	3480
	STS	45	2000	800	800	1132	1904
	Sum	1694	1844	736	730	3272	1935
Existing inflow	1991.6-1992.6 AVE.	19554	878	439	334	1026	429 (EC)
Total inflow		21248	955	463	366	1205	549
	Designed standard of quality for inflowing waste water	20300	900	390	350		
	INNORPI standard of quality for inflowing waste water		1000	400	400	700	400

As apparent from the table, an increase of total inflow to ONAS plant is in the vicinity of 9%, which is exceeding the designed inflow but is well below the maximum daily flow of 32,000m^3, as mentioned in Volume III. In this increase of incoming effluent, an increase of COD is about 9% that is below the inflow standard for ONAS plant. An increase of BOD is about 5% which will exceed the inflow standard by about 16%. An increase of SS is about 10%, which is below the inflow limit.

With regard to salts such as Cl and SO4, data measured from the existing facilities are already above values stipulated in INNORPI standard. At this time, Cl will be increased by 19% and SO4 by 28%. However, with regard to salts, the effluent standard for SO4 is 1,000 mg/l, while a total increase is only 549 mg/l which will not require treatment. Under such circumstances, we have only to consider removal of COD, BOD and SS.

VOLUME VI

STUDY OF EXHAUST GAS TREATMENT TECHNIQUE AND PRECONDITIONS FOR PLANNING

VOLUME VI STUDY OF EXHAUST GAS TREATMENT TECHNIQUE AND PRECONDITIONS FOR PLANNING

1. Outline of Combustion Technique

Combustion is an oxidation reaction whereby light is emitted by temperature increase. To burn a material, the fuel and oxidant are required. The oxidant is the air as gas in most cases, and the fuel can be in the state of gas, liquid, or solid. At present, the energy for our consumption is obtained by combustion of fossil fuel. In recent years, importance of the combustion technique is recognized from the limited existence of the fossil fuel and from the requirement to restrict the pollution resulting from the combustion. To study this problem, the fundamentals of combustion are explained below.

1.1 Combustion

Combustion is a reaction of a combustible material to generate an oxide by acting on oxygen in the air, where light emission is caused by the generation of oxidation heat.

The combustibles that perform the combustion reaction are called the fuel, which consist of carbon, hydrogen, etc.. Oxidation reaction of these items constitutes the main combustion. The followings show the oxidation reaction formulas of carbon and hydrogen:

$$C + O_2 \rightarrow CO_2 + 97{,}800 \text{ kcal/kmol}$$

$$H_2 + \frac{1}{2} O_2 \rightarrow H_2O + 57{,}800 \text{ kcal/kmol}$$

The reaction heat generated at such reactions increases the temperature of the combustible to 500°C or more, where a visible light is emitted. Then, the phenomenon called combustion is the state where the heat generation and diffusion are balanced to each other to continue the reaction.

For many types of material, the combustion will not start unless the temperature reaches a certain degree. However, once it starts, temperature of other areas in the combustible also reaches the required degree to start the combustion. Thus the combustion will continue as long as the combustible and oxidant exist.

Solid fuels such as coal and charcoal burn at a constant speed in a furnace, because the combustion is maintained by the air supplied by convection. Under such condition, the combustion speed is controlled by the speed of air supply. To increase the combustion speed to increase the furnace temperature, the air supply speed must be increased by forced ventilation.

Liquid fuel burns in a form of gaseous combustion by the liquid evaporation. The gas generated by the evaporation is rapidly mixed with the air by being diffused. The combustible gas mixed with the air becomes explosive by generating a rapid combustion speed. However, explosion does not occur in the actual combustion, because the fuel (gas or liquid) is supplied at a constant speed from the burner.

1.2 Fuels

Fuel is a material used for generating light, heat, and power by combustion. Fuel is classified by the gaseous, liquid, and solid states. Each of these states has the following features:

(1) Gaseous fuel

① With a high combustion efficiency, gaseous fuel enables a complete combustion with a trace amount of excess air without generating soot.

② Many gaseous fuels contain no sulfur, and no SO_2 is generated in the combustion exhaust gas.

③ Generates little ash and no smoke or soot.

④ Combustion can be controlled easily.

⑤ Working efficiency is high.

(2) Liquid fuel

① With a high calorific value, liquid fuel enables easy storage and transportation.

② Can be purchased at a constant quality.

③ Less smoke or soot issues compared with the coal combustion, but combustion of heavy oil may generate some smoke and soot.

④ Heavy oil contains sulfur, and generates SO_2 by combustion.

⑤ While little ash is generated, some metal oxide in the ash may cause trouble.

(3) Solid fuel

① Fuel that mankind used for the first time.

② Contains inorganic ash so that the treatment of the combustion ash is required.

③ Because of the handling and storage troubles, its ratio in the fuel consumption is being decreased.

1.3 Conditions of Combustion

(This section describes the liquid and solid fuels used at the selected factories for the study.)

1.3.1 Combustion Air Quantity

(1) Logical quantity of air

The air is required for the combustion, and the minimum air quantity logically required for the combustion is called logical air quantity. To obtain the precise logical air quantity, check the fuel composition and use the following equation for the calculation:

$$A_o = \frac{1}{0.21}\left\{\frac{22.4}{12}c + \frac{22.4}{4}\left(h - \frac{o}{8}\right) + \frac{22.4}{32}s\right\}$$

A_o : Logical air quantity required for combustion of 1 kg fuel (Nm^3/kg)

c : Weight (kg) of carbon contained in 1 kg fuel

h : Weight (kg) of hydrogen contained in 1 kg fuel

o : Weight (kg) of oxygen contained in 1 kg fuel

s : Weight (kg) of sulfur contained in 1 kg fuel

(2) Required air quantity

When fuel is burnt in a combustion device, supply of only the air in the logical air quantity will not be enough to cause a complete combustion. In the actual combustion, therefore, the air is supplied in larger quantity than the logical level.

The following formula shows the relationship between the logical air quantity and the actually supplied air quantity:

$$A = mA_o \ (m > 1.0)$$

A : Actually supplied quantity of the air

m : Air ratio

The air ratio varies with the fuel type or combustion method. The table below shows the air ratio generally considered to be adequate.

Table VI-1 General Air Ratio

Combustion method	Oil burner	Moving fire grate	Hand firing fire grate
Value of m	1.1–1.4	1.3–1.6	1.5–2.0
CO_2 (%)	8–20	11–14	8–20

1.3.2 Combustion Gas Quantity

By the complete fuel combustion, the carbon content in the fuel is changed into carbon dioxide, the hydrogen content into steam, and the sulfur content into sulfurous acid gas, and the nitrogen (and oxygen) remaining in the air is exhausted as a combustion gas. At this time, the combustion gas containing steam is called wet gas, and the one with condensed steam is called dry gas.

There are two conceptual methods of calculating the combustion gas as follows:

① Attention is directed to the fact that the burning combustible component reacts to oxygen to generate the combustion gas.

② Attention is directed to the volume increase after the combustion (because fuel volume before the combustion is negligible compared with the air quantity).

Based on the above concept, the wet combustion gas can be calculated by the following formula:

$$G = (m - 0.21)Ao + 1.867c + 11.2h + 0.8n + 0.7s + 1.24W \ (Nm^3/kg) \quad (1)$$

$$G = mAo + 5.6h + 0.7o + 0.8n + 1.24w \ (Nm^3/kg) \quad (2)$$

The dry combustion gas can be calculated by the following formula:

$$G' = (m - 0.21)Ao + 1.867c + 0.8n + 0.7s \ (Nm^3/kg) \quad (3)$$

$$G' = mAo - 5.6h + 0.7o + 0.8n \ (Nm^3/kg) \quad (4)$$

Where, the symbols indicate the followings:

G: Combustion gas,

Ao: Logical air quantity,

m: Air ratio,

c, h, n, s, w: Carbon, hydrogen, nitrogen, sulfur, water content in the fuel

2. Outline of Exhaust Gas Treatment Technique

Pollutions arising by combustion of fuels are particles of soot, sulfur oxides and nitrogen oxides in general.

The method of controlling air pollution by inhibiting emission of such polluants can be classified into four categories as quoted below.

(1) Improvement of fuels:

Improving fuels or converting to non-pollution fuels

(2) Appropriate controls of fuel combustion

(3) Installing appropriate pollution-preventive facilities

(4) Lowering the pollutional density on the ground level (landing concentration) by utilizing atmospheric diffusion such as adoption of high chimneys

Generaration of pollutants such as particles of soot, sulfur oxides and nitrogen oxides and exhaust gas treating methods will be explained hereunder.

2.1 Particles of Soot

2.1.1 Generation

Particles of soot are carbon particles contained in the combustion gas and a carbon particle layer adhering to the walls of equipment contacted by the combustion gas. Their generation process depends on the fuel types and the flame characteristics. The fuel type in particular largely affects the generation of particle of soot, with the general tendency described below.

① The larger C/H ratio of the fuel generates more particles of soot.

② The hydrocarbon types are arranged below in the order of generation ease.

Naphthalene > benzene > olefin > paraffin

③ Among the hydrocarbon types, compounds with side chain are more prone to be generated than those with straight chain.

(1) Particles of soot in liquid fuel

Combustion of atomized liquid fuel is similar to diffused combustion of gaseous fuel, because the atomized oil drops are first evaporated to be burnt after they are mixed in the air supplied from the periphery. Therefore, carbon particles are formed in the flames, so that very little residual particles of soot is resulted when sufficient combustion air is supplied. However, in heavy oil combustion, some coke may remain after the oil drops were evaporated. This depends on the atomized size of the oil drops, and an inferior atomization generates the particles of soot.

(2) Particles of soot in solid fuel

On the solid fuel such as coal and charcoal, combustion (including gasification) occurs on the surface by contacting the air. This means the combustion occurrence by the air going through the fuel particles. At this time, any unbalance between the fuel layers and air flow paths may cause a partial air shortage, resulting in the generation of particles of soot.

2.1.2 Prevention Technique

To prevent the generation of particles of soot, the combustion must be controlled to suppress the generation, and the equipment must be constructed to prevent the generated particles of soot from being exhausted to outside.

(1) Generation control

To prevent the generation, the fuel and air supply must be balanced well. For this, the following countermeasures are considered on the liquid and solid fuels respectively:

1) Liquid fuel

① Optimize the burner atomization.

② Note the air supply method for the combustion.

③ Optimize the relationship between the flame shape and the combustion chamber

④ Use a fuel of good quality with little ash content.

2) Solid fuel

① For a hand firing operation, note the method of fuel supply.

(Supply the fuel by dividing it alternately to the left and right against the combustion surface. Or diffuse the fuel thinly over the whole surface.)

② Perform the fuel supply and ash disposal quickly to avoid the temperature reduction in the furnace.

③ Use a fuel of good quality with little ash content.

(2) Dust collector equipment

It is important to remove the particles of soot at the generation source area. For this, the dust collector must be installed after the combustion equipment so that the particles of soot can be removed before exhaustion to the open air.

The dust collector is described below.

1) Dust collection by gravitation

Gravitation of the particles of soot is utilized to cause a plain sedimentation for separation and collection.

2) Dust collection by inertia

Inertia of the particles of soot is utilized for the separation and collection, by causing a collision of the gas containing particles of soot against obstacles or a rapid change of its direction.

3) Dust collection by centrifugal force

The gas containing particles of soot is given a turning motion to separate the particles of soot by utilizing the centrifugal force on them.

4) Dust collection by washing

Liquid (chiefly water) is used to wash the gas containing the particles of soot, to separate and collect the particles of soot.

5) Dust collection by filtration

It is generally called bag filter. For the filtering material, cotton, woolen textile, synthetic fibers, glass fiber, etc. are used.

6) Dust collection by electricity

High DC voltage is applied to cause corona discharge between the discharge pole and particles collection pole. The particles of soot in the gas generated thereby are charged by colliding with the ion generated at the time of corona discharge, and are attracted to the particles collection pole for separation.

7) Dust collection by sound wave

Particles of soot in gas are concentrated into large grains by ultrasonic wave pressure, and are separated using such device as a cyclone separator.

Table VI-2 summarizes these features of various dust collectors.

2.2 Sulfur oxide (SOx)

2.2.1 Generation

SO_2 and SO_3 are pointed out to be problems as the sulfur oxide. Their main generation source are the combustion equipment of fuels including sulfur (example: heavy oil combustion equipment) and sulfuric acid manufacturing plant. In case a combustion equipment is a generation source, the generated quantity is proportional to the sulfur quantity contained in the fuel to be used.

2.2.2 Prevention Technique

To control the sulfur oxide, there are methods such as conversion into a low sulfur fuel, desulfurization of heavy-oil, desulfurization of flue gas to remove the sulfur oxide from the exhaust gas. Out of these methods, this section outlines the desulfurization of flue gas which is divided into a wet method and dry method. Table VI-3 shows the main processes.

The wet method washes the exhaust gas by using aqueous solution containing chemicals to remove the sulfur oxide. Although this method requires an additional heating to prevent white smoke of the exhaust gas from being issued after the washing, it is widely applied to actual equipment because of its high desulfurization effect and flexibility to follow the load fluctuation.

Particularly for the alkali absorption method, aqueous solution of such items as milk of lime, caustic soda, sodium sulfite, ammonium, etc. are used. This method removes the sulfur oxide by absorption, and has many records of actual use, since the sulfur oxide can be utilized as gypsum, ammonium sulfate, sulfuric acid, etc.

Controls of sulfur oxides are not made by concentratin control at the exhaust outlet like as former mentioned particles of soot, but are made by regulating the maximum concentration on the ground level (landing concentration) calculated with atmospheric diffusion formula.

Therefore installing tall chimneys to reduce the polltional concentration on ground level are also carried out.

Table VI-2 Features of Dust Collector

	Main type	Applied Grain diameter (μ)	Treated gas speed (m/sec)	Pressure loss (mmAq)	Dust collecting efficiency (%)	Remarks
Dust collection by gravity	Sedimentation chamber	> 50	Ordinary: 3 m/sec or less	5 to 10	Low	
Dust collection by inertia	Commutation type (looper type) Collision type (Calder-Fox type)	> 50 > 5	Blow-out speed to collision plate: 15 to 30 m/sec	Approx. several ten mm Aq. (50 to 60 mm Aq) < 100	Midium	• Size can be more compact than the gravitation sedimentation chamber. • Simplified inertia dust collector has little pressure loss, and efficient as a pre-duster for a high-performance dust collector.
Dust collection by centrifugal force	Tangent line type cyclone Axial flow type cyclone Multitype cyclone Wet type cyclone Mechanical centrifugal type dust collection	> 5 0.5 to 100 0.1 to 50	6 to 20 10 to 20 12 to 18	Tangent line type: 100 to 200 Axial flow type: 60 to 120 50 to 250 Power consumption: Equivalent to 50 to 250 mm Aq	70 to 98 70 to 95 70 to 95	• Multitype cyclone of axial flow type is widely used as a pre-duster for electric dust collector. • Wet type cyclone sprays water inside the cyclone to increase the collection effect.
Dust collection by washing	Packed tower	1 to 100	3 to 8	50 to 150	50 to 60	Water use: 2 to 6 litres/m³
	Spray type	1 to 100	2 to 12	30 to 75	40 to 55	1 to 4
	Orifice scrubber	0.05 to 50	30 to 50	350 to 500	80 to 85	1 to 2
	Cyclone scrubber	0.2 to 50	15 to 35	50 to 300	70 to 90	0.5 to 1
	Venturi scrubber	0.05 to 50	30 to 100	250 to 900	90 to 99	0.7 to 1.2
	P	0.5 to 50	3 to 8	50 to 350	50 to 70	1 to 4
Dust collection by filtration	Bag type By filter type: Cylinder type Flat plate type By brush-off method: Hammering type Adverse wind type High-frequency vibration type	> 0.1	0.5 to 4	50 to 150	99+	• Not suitable for wet powder dust or high-temperature gases. • Temperature for general use: Usually, 100°C is a maximum temperature and a glass cloth applied with silicon treatment can be used up to 300°C
Dust collection by electricity	For general industrial use: General type Dry type Wet type Half-wet type For air cleaning: Two-stage type	> 0.05	0.5 to 3	5 to 20	99+	• Two-stage type is widely spread for its little generation of ozone and nitrogen suboxide, which are generated in large quantity by the one-stage type. • One-stage type is commonly called a Cottrell precipitator.
Dust collection by sound waves		> 10	Not related	Depends on the type of dust collector on the subsequent stage	High	• Suitable for such dust as carbon black and several types of hume which are super minute particle at the beginning of generation with high concentration characteristics.

Table VI-3 Main Methods of Desulfurization of Flue Gas

Method	Process	Name	Absorbent	Byproduct
Dry method	Activated charcoal method	Gas/steam separation method Washing operation method	Activated charcoal	Concentrated sulfuric acid Gypsum and dilute sulfuric acid
	Manganese method	Active manganese oxide method	Active manganese oxide powder	Ammonium sulfate
Wet method	Alkali absorption method	Caustic soda method Collection method by sulfite soda Anhydrous sulfite soda method Glauber's salt method Sulfite soda gypsum method (double alkali method) Wellman-Lord method	Sulfite soda and acidic sulfite soda	Aqueous solution of Glauber's salt: discharge Sulfite soda solution Anhydrous sulfite soda Anhydrous Glauber's salt Gypsum Concentrated sulfuric acid
		Ammonium absorption method Ammonium absorption - sulfur recovery method Ammonium gypsum method	Ammonium sulfite	Ammonium sulfate or gypsum Sulfur Gypsum
		Lime gypsum method	Lime slurry	Gypsum
	Sulfuric acid absorption method	Dilute sulfuric acid method	Dilute sulfuric acid	Gypsum
	Magnesium absorption method	Chemico system MgO method Grillo method	Magnesia slurry MgO + MnO slurry	Concentrated sulfuric acid, aqueous solution of sulfuric acid magnesium Concentrated sulfuric acid

2.3 Nitrogen Oxide (NOx)

2.3.1 Generation

Among the nitrogen oxides mainly, NO and NO_2 are problems of air pollution. The generation sources of these items are roughly divided into a combustion equipment as a fixed generation source, and automobiles, etc. as a moving source. NO is the main nitrogen oxide generated by combustion, whereas NO_2 covers only less than 10% of such generation. Nitrogen oxide is divided into thermal NOx and fuel NOx, and the air pollution is largely affected by the former one.

Thermal NOx is generated by a reaction of nitrogen in the air to excessive oxygen at a high temperature.

Fuel NOx is the one which was changed into NO by combustion from originally an organic nitrogen compound such as pyridine and quinoline. The ratio of conversion into NO from the nitrogen compound contained in the fuel is about 20 to 60%, while depending on the combustion condition.

2.3.2 Prevention Technique

To control the nitrogen oxides, the following methods are available: improvements of combustion such as conversion of fuel, improvement of conditions or method of combustion, and modification of combustion chamber. Another method is denitration of flue gas to remove the nitrogen oxide in the exhaust gas. As the object of denitration of flue gas is NO which is little reactive, removal of NO is technically fairly difficult. Therefore, a dry contact reduction decomposition method using ammonium as the reducing agent has only been in practice.

The present mainstream in the nitrogen oxide control are methods of combustion improvement which are listed in Table VI-4.

Table VI-4 Control Technique of Nitrogen Oxide During Combustion

Control countermeasure	Technical description	Problem
1. Conversion of fuels	Coal → heavy oil → kerosine and gas oil → gaseous fuel	Equipment updating and fuel supply system
2. Improvement of combustion conditions	Reduction of air ratio, homogeneous mixing of air and fuel,reduction of load on combustion chamber, reducton of preheated air temperature, etc.	Generation of particles of soot, CO_2, and unburnt hydrocarbon Reduction of thermal efficiency and output
3. Device of combustion method	Low NOx concentration, burner (mixing acceleration, flame division, recirculation, stepwise combustion) Stepwise combustion (two-stage combustion, thick-flame combustion) Exhaust gas circulation (10 to 20%, reduction of combustion temperature) Water spray (reduction of combustion temperature)	Ditto
4. Modification of combustion chamber type	Opposed firing → tangential firing (reduction of flame temperature) Fluidized bed combustion (reduction of combustion temperature, and NOx decomposition)	Large scale modification of equipment

3. Introduction of Air Pollution Control Law in Japan

3.1 Basic Law for Environmental Pollution Control

Japanese laws concerning environmental pollutions are constituted mainly by the Basic Law for Environmental Pollution Control.

The main concept of this law is to clarify the basic attitude of the government to the environmental pollution control, and its content is constitued with the purpose of the Basic Law, the definition of "Environmental pollution", responsibilities of enterprises, the government and local public organizations, basic matters of the policies concerning environmental pollution controls, provisions concerning the bearing of expenses and the financial measures, provisions of the environmental standard, and development of the comprehensive plan for the environmental pollution controls.

However, the stress is plan on the basic attitude rather than on the concrete measures. Concrete measures concerning the air are provided in the Air Pollution Control law independently. Principal parts of the Basic Law for Environmental Pollution Control are given here as follows:

(1) Definition of the "Environmental pollution"

"Environmental pollution" is defined as giving harzards to the human health or the living environment, and comprises the following seven items, that is, air pollution/ Water pollution/Soil pollution/Noise/Vibration/Subsidence of the ground/Offensive smell.

(2) Responsibilities of enterprises, the government and local public organizations

This is a provisions clarifying responsibilities of enterprises, the government and local autonomies for the environmental pollution control.

However, with a premise that the main cause of environmental pollution are activities of the enterprises, this law places more stresses on the responsibilities of enterprises than those of the government and local autonomies.

It provides that the government has to establish and implement the basic and comprehensive policies for the environmental control, while the local autonomies have a right to establish their policies in accordance with the government policies plus their own more severe additional policies.

(3) Environmental standard

Environmental standard values are provided as the target for improving the whole areal environmental pollutions resulting from polymerization and accumulation of pollutants discharged from individual factories and business companies.

In the environmental standard concerning air pollution, four substances - sulfur dioxide, carbon monoxide, suspending substances and photochemical oxidant are designated as air pollutants and their standard values are as follows:

Sulfur dioxide : Daily average of hourly values ≤0.04 ppm, Hourly value ≤0.1 ppm

Carbon monoxide : Daily average of hourly values ≤10 ppm
Average of hourly values for 8 hours ≤20 ppm

Suspended particulate matter : Daily average of hourly values ≤0.10 mg/m^3
Hourly value ≤0.20 mg/m^3

Photochemical oxidant : Hourly value ≤0.06 ppm

On the other hand, the emission standard specifying the allowable limit of pollutant discharged from individual factories and business companies are stipulated into Air Pollution Control Law.

(4) Subsidizing measures

Various subsidizing measures are taken for financial and taxational systems by government.

1) Financial measures

① Special loans by Small Business Finance Corp. and People's finance Corp.

② Loans by the Small and Medium Enterprise Modernization Funds

③ Loans and construction works transfer by Environmental Pollution Control Service Corporation

④ Loans by the Small and Midium Enterprise Business Corp.

⑤ Financing by Japan Developement Bank

2) Taxational measures

① National taxes	:	Special depreciation to environmental pollution control facilities
② Local taxes	:	Reduction of real estate tax on environmental pollution control facilities

3.2 Air Pollution Control Law

Air Pollution Control Law provides concreate measures for air pollution controls coping with basic attitudes of the government provided in the Basic Law for Environmental Pollution Control. The systems under this law is in Fig. VI-1.

What should be noted about this law is that power to implement the policies for environmental pollution controls is given to the local autonomies (Governors of metropolis and each prefecture).

Major provisions are as follows:

① Establishing the additional effluent standard and the regulation for the total quanty of pollutant

② Authorization for installing facilities which cause environmental pollutions and issuance of orders for modifications of the plan.

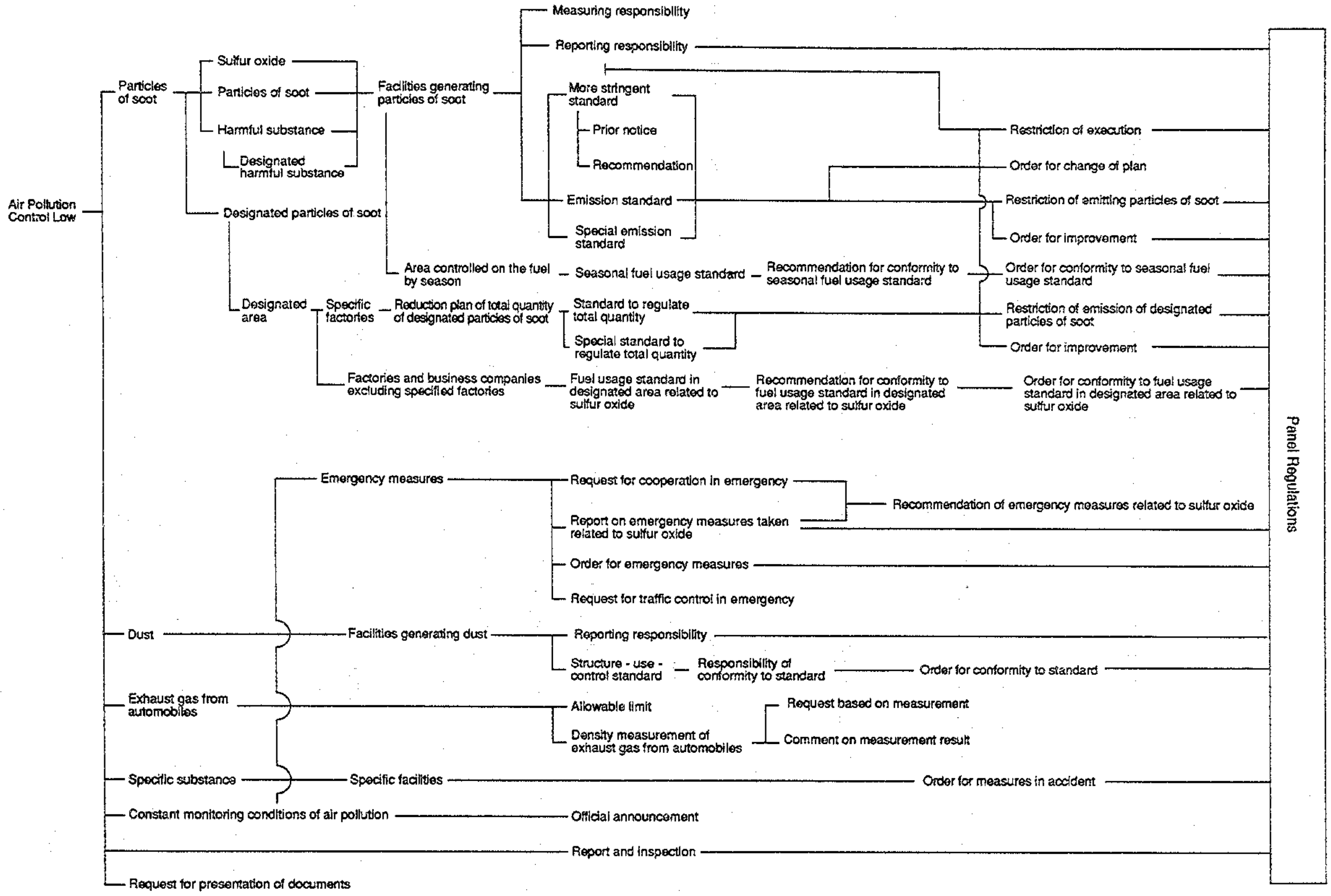
③ Issuing orders for modifying or restricting the use of the existing facilities

④ Establishing the standard for use of fuels

⑤ Authority for taking necessary actions in case of emergency

This section outlines the points related to the study concerning the objective, substances to be controlled, and control standard of the Air Pollution Control Law.

Fig. VI-1 System Diagram of Air Pollution Control Law



(1) Object

It is to control the emission of particles of soot from factories and companies places, and specify the allowable limit of exhaust gas from automobiles to protect people's health from the air pollution thus maintaining the living environment. It is also the object of the Law to specify the responsibility of entrepreneurs to protect the victims.

(2) Substances to be controlled

Substances to be controlled by this law are as follows:

1) Particles of soot

① Sulfur oxide generated from combustion of fuel and other substances

② Particles of soot generated from combustion of fuel or other substances or use of electricity as the heat source

③ Harmful substances generated from combustion, synthesis, decomposition, or other process of substances

- Cadmium and its compound
- Chlorine and hydrogen chloride
- Fluorine, hydrogen fluoride, silicon fluoride
- Lead and its compound
- Nitrogen oxide

2) Dust

Substances generated and scattered as a result of crushing, selecting, and other mechanical processing or accumulation of materials

3) Exhaust gas from automobiles

Carbon monoxide, hydrocarbon, lead compound, nitrogen oxide and particle-like substances generated along running of automobiles

4) Specifically designated substances

There are 28 kinds of substances such as ammonia, phenol and pyridine which are likely to cause pollution by accidents during chemical treatments like synthesis.

(3) Standard for regulation

Among various substances controlled by the laws, the emission standard is applied to sooty smokes as follows:

1) Emission standard of particles of soot

It is a standard to be conformed to by the person responsible for the emission, who is subject to penalty or order for improvement against the violation.

The emission standard is divided into three kinds which are a general, special, and more stringent aerial standards, becoming severer in this order.

Basically different concepts are adopted to establish the emission standard for sulfur oxides and particles of soot. That is to say, the standard for landing concentration (controls by k value - Details are mentioned in the following paragraph)is applied to sulfur oxides, while the concentration controls at the outlet is applied to particles of soot.

① Emission standard of sulfur oxide

Emission of sulfur oxide is regulated by K value which is based on a completely different concept from the concentration regulations on other substances. The object of the sulfur-oxide regulation is to adopt the Sutton's diffusion formula based on the idea that "the maximum concentration of pollutant on the ground is proportional to the quantity of the pollutant emission, and is in inverse proportion to the square of effective chimney height and the wind velocity." Thus, the regulation intends to reduce the emission effect on the ground by increasing the chimney height according to the quantity of emitted sulfur oxide. The allowable quantity of emitting the sulfur oxide is calculated by using the following equation:

$q = K \times (10)^{-3} \times (He)^2$

where, q : Quantity of sulfur oxide (m^3/h)

K : Constant depending on the area

He : Effective chimney height (m)

The emission standard is common to all facilities, but varies with the area. Presently, K value is classified into 16 stages from 3.0 to 17.5.

Thus, the relationships between K value and the maximum landing concentration of pollutant are shown in Table VI-5.

The sulfur oxide control by K values is limited to diffusing sulfur oxide into the air and is not necessarily sufficient to inhibit the areawide total discharge.

Therefore, in such particular areas where achievement of the environmental pollution control by K-values only seems difficult, measures under a regulation for the total quantity is implemented.

② Emission standard of particles of soot

Particles of soot is controlled by regulating the concentration at the outlet of the facilities accoring to the scale and kind (55 Kinds) of facilities.

Table VI-5 K Values and Landing Concentration

Rank	K Value	Landing concentration (ppm)	Objective area	
1	3.00	0.005	Special area in Tokyo, etc.	6 area
2	3.50	0.006	Chiba, Ichihara etc.	21 area
3	4.00	0.007	Sapporo	1 area
4	4.50	0.008	Kagoshima etc.	4 area
5	5.00	0.009	Toyama, Takaoka etc.	3 area
6	6.00	0.010	Hachinohe etc.	9 area
7	6.42	0.011	Hachioji etc.	3 area
8	7.00	0.012	Sendai etc.	6 area
9	8.00	0.014	Asahikawa etc.	8 area
10	8.76	0.015	Akita etc.	8 area
11	9.00	0.015	Kawagoe, Urawa etc.	6 area
12	10.00	0.017	Shizuoka etc.	4 area
13	11.50	0.020	Katsuta etc.	15 area
14	13.00	0.022	Kurume etc.	6 area
15	14.50	0.025	Kumamoto etc.	20 area
16	17.50	0.030	Other areas	

③ Emission standard of harmful substances

The control of ordinary harmful substances like nitrogen dioxide, etc. is made by regulating the concentration at the outlet as is in a case of particles of soot. For nitrogen dioxide, the standard is determined according to the kind (74 kinds) and the type of facilities.

For other harmful substances, the standard is determined by the kind of substances and the type of facilities.

(4) Controlling measures

When a person or an enterprise that exhaust sooty smoke violates or is likely to violate the emission standard, or when an emergency such as rapid advance of the air polution arises, the local autonomy (metropolitan or prefectual governor) can take such measures as mentioned below by its athority.

① Penal codes for violators against the emission standard

Those who violated the emission standard shall be subjected to a fine or an imprisonment (Direct penalty).

② Order of improvement

To an owner of the facilities which are not emitting at present but likely in the future to emit sooty smoke which violates the emission standard, the local authonomy can issue an order to improve the structure of the facilities and the method of use, or if necessary, to temporarily suspend operations (Prevention).

③ Control on use of fuels

The local autonomies can provide the standard for use of fuels at the sulfur oxides emitting facilities installed at the specific areas in connection with controls of sulfur oxide emission,and can order to comply with the standard.

④ Measures to be taken in emergency

In case an emergency has arisen as the result of heavy air pollution and subsequent serious damages to the human health or environment, the local autonomies are responsible for informing so to the general public, and can order to a person or enterprise emitting sooty smoke to reduce the quantity of or the concentration of the sooty smoke or restrict use of such sooty smoke generating facilities.

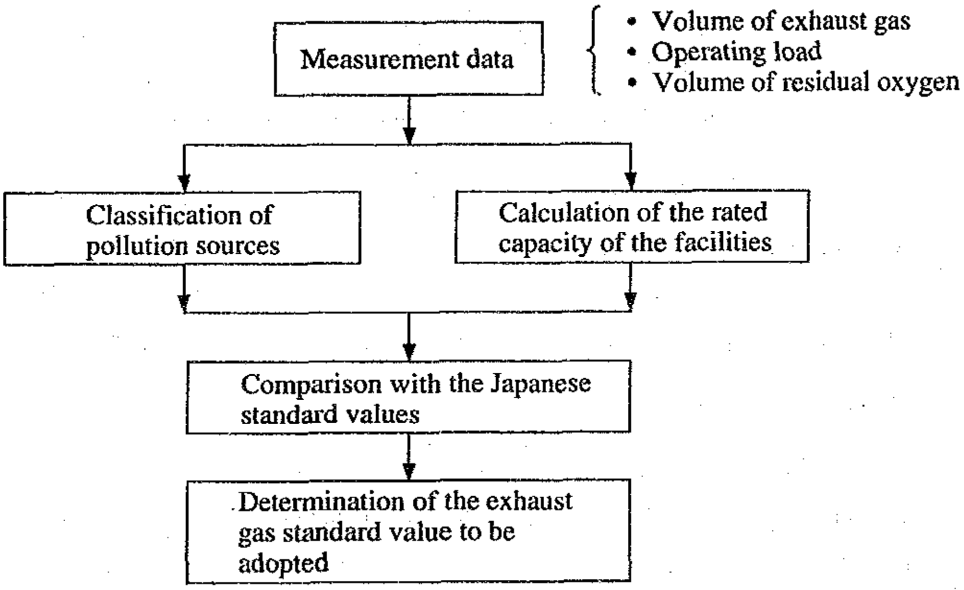
4. Setting of Target Emission Standard of Particles of Soot

(1) Preconditions

In Tunisia, there is no law related to the exhaust gas regulations, and one seems to be in preparation. Basically, the law for such regulations must be established by confirming the relevant technical level within the country. For the study, however, the technical confirmation of the whole Tunisia is so difficult that the regulation values presently effective in Japan will be applied for the future study.

Establishing the emission standard was proceeded with the procedure as shown in Fig. VI-2.

Fig. VI-2 Emission Standarrd Establishing Procedure



According to the Japanese rules, the regulation values are fixed according to the type and scale of each facility. By such rules, the selected facilities of the study can be classified as follows:

Name of Facility	Facility for study
- Liquid combustion boiler	STS-51/52
	SZT-57
	SPE-66
- Solid combustion boiler	SZT-54/55/56
	STP-53

- Drying furnace	SZT-51/52/53 STP-51/52 SPE-57/59/62/64
- Phosphoric acid reaction facility	SPE-54
- Phosphoric acid fertilizer manufacturing facility and incidental facilities	SPE-55 to 53
- Inorganic chemicals manufacturing and calcinating furnace	SPE-51/53

For some facility scales, the specification could not be checked because the equipment used in the objective factories was too old. Thus, the rated exhaust gas quantity was calculated from the one measured by the field survey, and the result was used as the scale of each equipment.

The rated exhaust gas quantity was calculated by the following formula:

$$Q_0 = \frac{Q1}{R} \times \frac{21 - O_1}{21 - O_2} \times 100$$

where, Q_0 : Rated exhaust gas quantity (Nm^3/h)

Q_1 : Exhaust gas quantity at measurement time (Nm^3/h)

R : Equipment load at measurement time (%)

O_1 : Concentration of residual oxygen at measurement time (%)

O_2 : Concentration of residual oxygen at normal operation (%)

The emission standards of particles of soot, nitorgen oxide and fluorine were established from the above results.

Emission standard for sulfur oxide was based on the K-value system.

As this emission standard is the first standard in Tunisia, the most gentle value of 17.5 is considered to be desirable to make the established standard value observed.

(2) Establishment of Emission Standard

The emission standard was established based on the preconditions as mentions above.

The emission standard for each substance is as follows:

-Particles of Soot : 0.20 to 0.40 g/Nm^3 (convertible into residual oxygen concentration)

-SOx : K value regulated to K = 17.5

-NOx : 230 to 650 ppm(convertible into residual oxygen concentration)

-F : 10 to 15 mg/Nm^3

The above values vary with the type and capability of each facility, except sulfur oxide.

Standard values for each facility are shown in Table VI-6.

According to the Japanese standard, a facility below a certain scale shall be exempted from the regulation. The criteria to determine the applicability or exemption are listed below by the facility names and scales, with the equipment capacity (rated capacity) of each facility.

Facility name	Scale	
- Boiler:	Heating surface area	: 10 m^2 or more,
	In terms of heavy-oil combustion rate	: 50 *l*/h or more
- Calcinating furnace:	Raw material treatment rate	: 1 ton/h or more
- Drying furnace:	Grate area	: 1 m^2 or more,
	In terms of heavy-oil combustion rate	: 50 *l*/h or more
- Facility of phosphatic fertilizer manufacture:	Raw material treatment rate	: 80 kg/h or more,
	In terms of heavy-oil combustion rate	: 50 *l*/h or more

Table VI-6 Proposal of Emission Standard of Exhaust Gas

							S O x	N O x			Particele of Soot		F
Factory Name	Sampling Point	Equipment Measured	Exhaust Gas Measured Nm3／h	Operation Load %	Concentration of Residual Oxygen %	Scale of Rated Exhaust Gas Nm3／h	K Value	Objective Equipment	Standard Value ppm	Residual Oxygen %	Standard Value g／Nm3	Residual Oxygen %	Standard Value mg／Nm3
S T S	STS-51	H.Oil Boiler	1,230	50	11.0	1,447	17.5	Liqiud Fuel Boiler	250	4.0	0.30	4.0	
S T S	STS-52	Oil Heater	350	50	8.2	527		Liqiud Fuel Boiler	250	4.0	0.30	4.0	
SIOS-ZITEX	SZT-51	Grignon dryer	10.000	100	19.9	2.200		Drying Furnace	250	16.0	0.40	0s	
	SZT-52	Grignon dryer	9.130	100	20.3	1.278		Drying Furnace	250	16.0	0.40	0s	
	SZT-53	Grignon dryer	9.400	100	19.9	2,068		Drying Furnace	250	16.0	0.40	0s	
	SZT-54	Grignon Boiler	7,830	100	15.7	2,767		Solid Fuel Boiler	480	6.0	0.40	6.0	
	SZT-54	Grignon Boiler	9.500	100	15.2	3.673		Solid Fuel Boiler	480	6.0	0.40	6.0	
	SZT-55	Grignon Boiler	1.540	100	18.7	236		Solid Fuel Boiler	480	6.0	0.40	6.0	
	SZT-56	Grignon Boiler	3.570	100	17.8	762		Solid Fuel Boiler	480	6.0	0.40	6.0	
	SZT-57	H.Oil Boiler	1,240	50	8.0	1,896		Liqiud Fuel Boiler	250	4.0	0.30	4.0	
SATHOP	STP-51	Grignon dryer	3.100	100	15.4	3.472		Drying Furnace	250	16.0	0.40	0s	
	STP-52	Grignon dryer						Drying Furnace	250	16.0	0.40	0s	
	STP-53	Gri. H.Oil Boiler	26.900	88	15.4	12,100		Solid Fuel Boiler	480	6.0	0.40	6.0	
	STP-53	Gri. H.Oil Boiler	23,300	83	14.8	11,603		Solid Fuel Boiler	480	6.0	0.40	6.0	
S I A P E	SPE-51	750 SA Absorber	107.000	100	9.2	180.371		Calcinating Furnace	250	14.0	0.30	0s	
	SPE-52	750 Pump Tank	240	100	18.1	99			- - -	14.0	- - -		
	SPE-53	300 SA Absorber	31,000		11.7			Calcinating Furnace	250	14.0	0.40	0s	
		300 SA Absorber	34.000	100	12.6	40.800		Calcinating Furnace	250	14.0	0.40	0s	
	SPE-55	PA Scrubber Out	34.800	100	20.0	5.800		Fusion Furnace(equivalent)	650	15.0	- - -		10
	SPE-57	500TSP Scrubber Out	50.300	100	18.6	24,144		Drying Furnace	250	16.0	0.20	0s	15
	SPE-59	500TSP Scrubber Out	43.400	100	17.7	28,644		Drying Furnace	250	16.0	0.20	0s	15
	SPE-60	TSP Main Reactor	4.200	100	12.0	6.300		Fusion Furnace(equivalent)	650	15.0	- - -		15
	SPE-62	600TSP Scrubber Out	61.200	100	16.5	55.080		Drying Furnace	250	16.0	0.20	0s	15
	SPE-64	600TSP Scrubber Out	64,100	100	18.3	34,614		Drying Furnace	250	16.0	0.20	0s	15
	SPE-65	TSP Sub Reactor	2.610	100	19.4	696		Fusion Furnace(equivalent)	650	15.0	- - -		15
	SPE-66	H.Oil Boiler	9,500	15	14.6	23,843	17.5	Liqiud Fuel Boiler	190	4.0	0.20	4.0	

By the field survey, the rated capacity of each equipment could not be grasped precisely. Therefore, it was calculated through estimation by calculating the rated exhaust gas quantity from the operation load at the time of measuring the exhaust gas. From the results, some items of the equipment capacity are excluded from application of the aforesaid standard. Treating measures for all facilities will be developed in this report.

However, considerations on the small scale of facilities as stated above will be necessary in Tunisia, if the environmental pollution control law is provided in the future.

5. Preconditions for Exhaust Gas Treatment Plan

(1) Capacity of facilities

The assumed gas exhaust standard was compared with the analyzed results of exhaust gas. Based on the results, the equipment and substances exceeding the standard are classified by fuel as shown in the table below.

Table VI-7 Source of Exhaust Gas Exceeding the Standard Value by Fuel

Fuel	Particles of Soot	SOx	NOx	F
Heavy oil	STS-51, STS-52, SZT-57 SPE-57, SPE-59, SPE-62, SPE-64, SPE-66		SZT-57 SPE-66	SPE-57, SPE-59 SPE-62, SPE-64
Grignon	SZT-54, SZT-55, SZT-56, STP-51, STP-53			
Others	SPE-51, SPE-52	SPE-51, SPE-53		SPE-55, SPE-60 SPE-65

As shown above, concerning the SIAPE factories, by the characteristics of their products, sulfur oxide is emitted from the sulfuric acid factory, and fluorine compounds from the factories of phosphoric acid and TSP. Since both of them exceed the standard values, some countermeasures are required.

From other factories, particles of soot are emitted exceeding the standard value so that the equipment requires the countermeasures.

The capacity of exhaust gas treatment facilities was established under the following conditions.

① Crude oil boilers and drying furnaces have a capacity 5% higher than the aforementioned rated capacity.

② The residual oxigin of grignon boiler was settled to be 5% at the time when rated capacity was calculated.

But when capacity of exhaust gas treatment facilities were calculated, it's residual oxigin was settled to be 12% by applying the waste combusion furnace, and 5% was added to it in cosideration of surplus rate.

③ PA and TSP scrubbers at SIAPE are operated with neggative loading to prevent generating dust.

Therefore, the capacity of treating facilities was increased by 5% of the measured gas volume, as the gas volume on exhaust gas measurement includes the air leaked in.

The scrubbers of TSP were handled as treating facilities of 500 ton line and 600 ton line each

Table VI-8 shows the capacity of treating facilities and removable substances calulated with the above-mentioned conditions.

Due to the limited time for the survey and for operational conveniences of the plants, not all of the exhaust gas emitting facilities at the soap manufacturing plants at SIOS-ZITEX and SATHOP could be measured.

Therefore, for the facilities of which measurements were not available, values obtained at the facilities having the similar operating conditions were quoted.

Table VI-8 Capacity of Exhaust Gas Treating Facilities

Factory Name	Sampling Point	Equipment Measured	Treatment Capacity m3／h	Measuring Data				SOx	NOx		Particele of Soot		F
				SOx Nm3／h	NOx ppm	Dust mg／Nm3	F mg／Nm3	Calculated Value(K=17.5) Nm3／h	Standard Value ppm	Residual Oxygen %	Standard Value mg／Nm3	Residual Oxygen %	Standard Value mg／Nm3
STS	STS-51	H.Oil Boiler	1.500			2.040			250	4.0	300	4.0	
STS	STS-52	Oil Heater	600			1.328			250	4.0	300	4.0	
SIOS-ZITEX	SZT-54	Grignon Boiler	4.800			7.925			480	6.0	400	6.0	
	SZT-54	Grignon Boiler	6.400			8.017			480	6.0	400	6.0	
	SZT-55	Grignon Boiler	1.800			12.391			480	6.0	400	6.0	
	SZT-56	Grignon Boiler	1.300			3.375			480	6.0	400	6.0	
	SZT-57	H.Oil Boiler	2.000		411	1.700			250	4.0	300	4.0	
SATHOP	STP-51	Grignon dryer	3.600			1.360			250	16.0	400	0s	
	STP-53	Gri. H.Oil Boiler	21.000			964			480	6.0	400	6.0	
	STP-53	Gri. H.Oil Boiler	21.000			1.476			480	6.0	400	6.0	
SIAPE	SPE-51	750 SA Absorber	190.000	439		770		98	250	14.0	300	0s	
	SPE-53	300 SA Absorber		65				32	250	14.0	400	0s	
		300 SA Absorber	43.000	55				33	250	14.0	400	0s	
	SPE-55	PA Scrubber Out	37.000				1.510		650	15.0	- - -		10
	SPE-57	500TSP Scrubber Out	98.000			290	154		250	16.0	200	0s	15
	SPE-59	500TSP Scrubber Out				310	130		250	16.0	200	0s	15
	SPE-62	600TSP Scrubber Out	130.000			1.110	1.250		250	16.0	200	0s	15
	SPE-64	600TSP Scrubber Out				1.000	400		250	16.0	200	0s	15
	SPE-66	H.Oil Boiler	25.000		262	372			190	4.0	200	4.0	

Consequently, the capacity of exhaust gas treating facilities at the soap manufacturing plants were assumed to be as follows:

SZT-54		3600 Nm³/h
SZT-55		1800 Nm³/h
SZT-56	1300 x 3 units	3900 Nm³/h
SZT-57	2000 x 3 units	6000 Nm³/h
STP-51		3600 Nm³/h
STP-52		3600 Nm³/h (Data mesured at STP-51 was quoted.)
STP-53		21000 Nm³/h

Table V-9 lists as "Determination of emission standards" the results of comparison between the measured values of exhaust gas analysis and the assumed emission standard. In the table, the item marked "O" shows conformity within the standard and the item marked "X" shows excess over the standard. In the final report, the equipment with mark "X" shall be object to study of countermeasures.

Table VI-9 Determination of Gas Emission Standard (1/3)

FACTORY	STS		SIOS - ZITEX							
SAMPLING POINT	STS-51	STS-52	SZT-51	SZT-52	SZT-53	SZT-54	SZT-54	SZT-55	SZT-56	SZT-57
SAMPLING DATE	JUL/7/92	JUL/7/92	JUL/13/92	JUL/13/92	JUL/13/92	JUL/14/92	OCT/1/92	JUL/15/92	JUL/14/92	JUL/15/92
FACILITY	BOILER	BOILER	R. KILN	R. KILN	R. KILN	BOILER	BOILER	BOILER	BOILER	BOILER
FUEL	H. OIL	H. OIL	GRIGNON	GRIGNON	GRIGNON	GRIGNON	GRIGNON	GRIGNON	GRIGNON	H. OIL
Emission Standards										
Dust mg/Nm3	300	300	400	400	400	400	400	400	400	300
Residual Oxygen %	4	4	Os	Os	Os	6	6	6	6	4
SOx K Value	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
NOx ppm	250	250	250	250	250	450	450	450	450	250
Residual Oxygen %	4	4	16	16	16	6	6	6	6	4
Stack										
Actual Height m	10	10	15	15	15	30	30	20	30	15
Effective Height m	10	10	15	15	15	33.2	34.4	20	31.8	15
Diameter m	0.32	0.23	0.95	0.95	0.95	0.9	0.9	0.52	0.9	0.39
Type(with roof Y/N)	Y	Y	Y	Y	Y	N	N	Y	N	Y
GAS VOLUME										
ACTUAL m3/h	2870	720	13100	11500	12000	12400	16100	2020	6250	1860
WET GAS Nm3/h	1370	380	11000	9830	10200	8280	10100	1670	3850	1370
DRY GAS Nm3/h	1230	350	10000	9130	9400	7830	9500	1540	3570	1240
H2O %	10.5	7.9	8.8	7.1	8.2	5.5	5.6	7.7	7.2	9.4
GAS TEMP. ℃	298	248	52	46	48	137	163	58	170	99
CO2 %	7.8	11.6	0.3	0.3	0.9	4.9	4.8	1.8	2.6	10.0
O2 %	11.0	8.2	19.9	20.3	19.9	15.7	15.2	18.7	17.8	8.0
DUST mg/Nm3	1200	1000	43	160	100	2800	3100	1900	720	1300
O2 conv. mg/Nm3	2040	1328	43	160	100	7925	8017	12391	3375	1700
Valuation	×	×	○	○	○	×	×	×	×	×
SOx ppm	560	900	<11	<11	<11	<11	21	<11	<11	1000
SOx (K=17.5) Nm3/h	1.75	1.75	3.94	3.94	3.94	19.28	20.76	7.00	17.67	3.94
SOx (Calc.) Nm3/h	0.69	0.32	----	----	----	----	0.20	----	----	1.24
Valuation	○	○	○	○	○	○	○	○	○	○
NOx ppm	170	180	<12	<12	22	46	63	22	55	290
(O2 Content) %	6.6	8.0	19.9	20.3	19.9	15.4		18.0	17.6	9.0
O2 conv. ppm	201	235	----	----	100	123	45	110	243	411
Valuation	○	○	○	○	○	○	○	○	○	×

Table VI-9 Determination of Gas Emission Standard (2/3)

FACTORY	S A T H O P				SIAPE(H2SO4)				SIAPE(H3PO4)	
SAMPLING POINT	STP-51	STP-52	STP-53	STP-53	SPE-51	SPE-52	SPE-53	SPE-53	SPE-54	SPE-55
SAMPLING DATE	SEP/11/92		SEP/11/92	OCT/1/92	SEP/24/92	SEP/23/92	SEP/24/92	SEP/30/92	SEP/29/92	SEP/29/92
FACILITY	R. KILN	R. KILN	BOILER	BOILER	750-ABSORB	CIRC. TANK	300-ABSORB	300-ABSORB	SCRUB. IN	SCRUB. OUT
FUEL	GRIGNON	GRIGNON	GRI./OIL	GRIGNON	---	---	---	---	---	---
Emission Standards										
Dust mg/Nm3	400		400	400	300		300	300		---
Residual Oxygen %	Os		6	6	Os		Os	Os		
SOx K Value	17.5		17.5	17.5	17.5	17.5	17.5	17.5		17.5
NOx ppm	250		480	480	250	---	250	250		650
Residual Oxygen %	16		6	6	14	14	14	14		15
F mg/Nm3										10
Stack										
Actual Height m	10		30	30	50	10	35	35		20
Effective Height m	10		41	42	75	10.1	43	43		31
Diameter m	0.57		0.9	0.9	1	0.2	1.19	1.19		1.46
Type(with roof Y/N)	Y		N	N	N	N	N	N		N
GAS VOLUME										
ACTUAL m3/h	4410		43800	42100	135000	300	41600	45600	75100	75200
WET GAS Nm3/h	3770		28500	25000	107000	240	31100	34000	58800	58600
DRY GAS Nm3/h	3100		26900	23300	107000	240	31000	34000	34800	34800
H2O %	17.9		5.6	6.7	0.1	0.5	0.1	0.2	40.8	40.5
GAS TEMP. ℃	46		147	186	73	73	92	92	77	77
CO2 %	5.6		5.6	4.2	0	0	0	0	6.4	6.3
O2 %	15.4		15.4	14.8	9.2	18.1	11.7	12.6	19.8	20.0
DUST mg/Nm3	1360		360	610	770	700	230	110	30	60
O2 conv. mg/Nm3	1360		964	1476	770	700	230	110	30	60
Valuation	×		×	×	×	×	○	○		
SOx ppm	7		110	38	4100	3300	2100	1620		
SOx (K=17.5) Nm3/h	1.75		29.59	30.18	98.08	1.80	31.89	32.99		
SOx (Calc.) Nm3/h	0.02		2.96	0.89	438.70	0.79	65.10	55.08		
Valuation	○		○	○	×	○	×	×		
NOx ppm	19		16	30	11	<10	<10	<10		
(O2 Content) %	15.4		15.4	17.6	17.6					
O2 conv. ppm	17		43	132	23					
Valuation	○		○	○	○					
TOTAL MIST mg/Nm3									47700	7000
kg/h									1660	244
H2SO4 MIST mg/Nm3					250	630		140	700	170
kg/h					27	0.2		5	24	5.9
H3PO4 MIST mg/Nm3									40	22
kg/h									1	1
F COMPOUND mg/Nm3									3900	1510
kg/h									136	53
Valuation										×
F MIST mg/Nm3									330	62
kg/h									11	2

Table VI-9 Determination of Gas Emission Standard (3/3)

FACTORY	S I A P E (TSP)										(BOILER)
SAMPLING POINT	SPE-56	SPE-57	SPE-58	SPE-59	SPE-60	SPE-61	SPE-62	SPE-63	SPE-64	SPE-65	SPE-66
SAMPLING DATE		SEP/17/92	SEP/18/92	SEP/18/92	SEP/16/92	SEP/14/92	SEP/14/92	SEP/15/92	SEP/15/92	OCT/21/92	OCT/28/92
FACILITY	TSP500-IN	TSP500-OUT	TSP500-IN	TSP500-OUT	TSP-MAIN	TSP600-IN	TSP600-OUT	TSP600-IN	TSP600-OUT	TSP-SUB	E.G/BOILER
FUEL	H.OIL	H.OIL	H.OIL	H.OIL		H.OIL	H.OIL	H.OIL	H.OIL	---	H.OIL
Emission Standards											
Dust mg/Nm3		200		200	---		200		200	---	200
Residual Oxygen %		Os		Os			Os		Os		4
SOx K Value		17.5		17.5	17.5		17.5		17.5	17.5	17.5
NOx ppm		250		250	650		250		250	650	190
Residual Oxygen %		16		16	15		16		16	15	4
F mg/Nm3		15		15	15		15		15	15	
Stack											
Actual Height m	10	30		30	20		30		30	20	25
Effective Height m	10	42		39	21		48		45	21	30
Diameter m	0.57	1.31		1.31	0.8		1.5		1.5	0.53	0.8
Type(with roof Y/N)	Y	N		N	N		N		N	N	N
GAS VOLUME											
ACTUAL m3/h		76800	93100	64200	6300	119000	115000	121000	108000	3540	16700
WET GAS Nm3/h		62200	63700	52900	5100	79900	84700	79800	85400	2960	10300
DRY GAS Nm3/h		50300	50300	43400	4200	57900	61200	60900	64100	2610	9500
H2O %		19.1	21.0	17.9	18.3	27.5	27.8	23.7	24.9	11.9	7.7
GAS TEMP. ℃		64	130	58	66	138	98	145	73	53	169
CO2 %		2.0	2.4	2.3	46.0	3.0	2.5	2.3	2.2	2.0	4.2
O2 %		18.6	17.6	17.7	12.0	15.9	16.5	18.5	18.3	19.4	14.6
DUST mg/Nm3		290	580	310	890	1220	1110	580	1000	30	140
O2 conv. mg/Nm3		290	580	310	890	1220	1110	580	1000	30	372
Valuation		×		×			×		×		×
SOx ppm		220	400	260	1100	560	550	400	520	135	800
SOx (K=17.5) Nm3/h		30.2		27.0	7.9		40.7		36.0	7.6	15.7
SOx (Calc.) Nm3/h		10.5		11.3	4.6		33.7		33.3	0.4	7.6
Valuation		○		○	○		○		○	○	○
NOx ppm											108
(O2 Content) %											14
O2 conv. ppm											262
Valuation											×
TOTAL MIST mg/Nm3		---		1500			---		---		
kg/h				65.1							
H2SO4 MIST mg/Nm3											
kg/h											
H3PO4 MIST mg/Nm3				91							
kg/h				3.9							
F COMPOUND mg/Nm3		154	1850	130	33	1780	1250	1540	400	33	
kg/h		7.7	93.1	5.6	0.1	103.1	76.5	93.8	25.6	0.1	
Valuation		×		×	×		×		×	×	
F MIST mg/Nm3				64							
kg/h				2.8							

VOLUME VII

FACILILTIES AND IMPLEMENTATION PLAN

VOLUME VII FACILITIES AND IMPLEMENTATION PLAN

1. Decision of Waste Water Treatment Processes

When deciding waste water treatment processes, considerations should be given to the volume of waste water to be treated, its quality, treatment characteristics of processes, construction expense, maintenance and control expenses, and other conditions.

Treatment processes are compared below with respect to the following 3 water-quality items selected for the study of this time.

1.1 Suspended Materials (SS, Suspended BOD, COD, Oil)

Large-size admixtures of suspended materials can be treated by screening, natural precipitation or other methods. Fine suspended materials or colloidal materials (metallic and non-metallic) are usually treated by adding flocculant for coagulation or floatation under pressure. When the waste water concentration is not so high, sand filtration may provide a powerful means.

Comparison among coagulation, floatation under pressure and sand filtration processes are shown in Table VII-1.

Table VII-1 Comparison of Suspended Material and Suspended BOD and COD Removal Processes

	Coagulation	Floatation under pressure	Sand filtration
1. Treatment characteristics			
Applicability to high-concentration waste water	High	High	Low
Quality of treated water	Good	Slightly bad	Good
2. Construction expense	Slightly expensive	Cheap	Cheap
3. Maintenance			
Chemical and power expenses	Low	Slightly high	Low
Easiness of operation control	Easy	Slightly difficult	Slightly difficult
4. Installation area	Large	Small	Small

Coagulation method is employed for the selected factories this time because of the stable quality of treated water and maintenance efficiency regarding the fluorine removal of SIAPE and high concentration COD removal of SIOS-ZITEX, SATHOP, CMCP, and STS.

1.2 Treatment of Organic Matter

It can be said that the organism treatment method is the most suitable to treat organic matters represented by COD and BOD. Organism treatment processes are broadly classified into aerobic and anaerobic ones, each of which have distinctive characteristics. Aerobic processes are classified into activated sludge method and lagoon method and are compared with the anaerobic methods below.

The anaerobic treatment has been used mainly as a part of the sludge treatment processes. Recently, studies on this method has progressed and are now applied also at low concentration. Actual results, however, are still not enough.

Comparison is shown in Table VII-2.

Table VII-2 Comparison of Organic Matter Treatment Processes

	Aerobic treatment		Anaerobic treatment
	Activated sludge method	Lagoon	
1. Treatment characteristics			
Applicability to high-concentration waste water	Below medium concentration	Below medium concentration	Applicable
Quality of treated water	Good	Good	Slightly bad
2. Construction expense	Expensive	Cheap	Slightly expensive
3. Maintenance			
Power expenses	High	Low	Low*
Easiness of operation control	Slightly difficult	Easy	Difficult
4. Installation area	Medium	Large	Medium

* As methane gas is generated, it is possible to recover energy.

Organism treatment is applied to the selected factories this time as the treatment after the coagulation process. Activated sludge method is employed for this purpose for the reason of the stability of the treated water. Since the concentration of organic matters in the margin treatment is very high, however, the anaerobic process is used before the activated sludge process.

1.3 Treatment of Salt

Salt (Cl and SO_4, in the case of this time) contained in water is removed. Usually salt is removed for the purpose of obtaining useful substances in the water. For instance, salt is removed from sea water to obtain drinking water or from waste water to recover valuable matter in it. It is rare to remove salt from waste water only for the purpose of discharging it.

This time, salt removal process is considered because of the regulation on salt in the tentative standard proposed by Tunisia and INNORPI standard. Salt can be removed by reverse osmosis film or ion exchange method or by evaporation. Comparison among them is shown in Table VII-3.

Table VII-3 Comparison of Salt Treatment Processes

	Reverse osmosis method	Ion exchange method	Evaporation method
1. Treatment characteristics			
Applicability to high concentration waste water	High	Low	High
Quality of treated water	Good	Good	Slightly bad
2. Construction expense	Expensive	Expensive	Expensive
3. Maintenance			
Consumables, chemicals, power	High	High	High
Operation control easiness	Difficult	Difficult	Difficult
4. Other problems	Generation of concentrated water	Generation of large volume of regenerated water	

In the case of this time, since the salt concentration of the waste water is high and treated water requires stability, the reverse osmosis film method is adopted. However, the reverse osmosis film has a significant problem that concentrated water is generated. When using the reverse osmosis film for the purpose of recovering useful matters, it presents no problem when obtaining drinking water from the sea water since the concentrated solution can be discharged into the sea. When any other valuable matters are to be recovered, the concentrated water is the desired object and therefore there is no problem.

On the contrary, when waste water is treated, concentrated water cannot be discharged. Therefore, this time, volume and concentration of concentrated water are specified for each factory and not included in the treatment. Only the method of disposal is described as follows:

(1) Incineration

Incineration means to evaporate moisture contents. Both construction and fuel expenses are high.

(2) Abondonment

Abandonment to desert or TABIA. Not final method, however, because of the permeation underground.

2. Decision of Exhaust Gas Treatment Processes

2.1 Classification of Treatment Facilities

Facilities requiring improvements are described in Volume VI, Chapter 5. They are classified as follows based on exhaust gas generation sources.

① Exhaust gas from production facilities

② Exhaust gas from burning facilities

- Using solid fuel
- Using liquid fuel

Since exhaust gas generation conditions are different in above ① and ②, applicable treatment methods are described for each condition.

2.2 Treatment of Exhaust Gas from Production Process (SIAPE)

(1) Sulfuric acid plant

Discharge of sulfur oxides such as SO_2, SO_x, etc. is restricted as the result of the change from the SCSA to DCDA method.

1) SO_2 conversion

The converter comprises 4 catalyzer layers. They are divided into two parts when used. Each part is provided with an absorption process, one of which is the current one.

SO_2 gas from existing waste heat boilder enters the first catalyzer layer from the top of the converter and about 60% is converted to SO_3.

The gas from the first layer enters the existing super heater, heat recovered and then enters the second layer. In the second layer, about 86% of SO_2 is converted. Reaction heat here is removed with the hot gas heat exchanger which is newly provided.

The gas enters the third layer from the hot gas heat exchanger, where about 94% of SO_2 is converted to SO_3.

The reaction heat in the third layer is cooled with the cold gas heat exchanger and No.1 economizer and then supplied to the intermediate absorption unit in about 170°C. The intermediate absorption unit is the existing one.

The gas from the intermediate absorption unit is heated through the cold gas heat exchanger and hot gas heat exchanger and enters the fourth catalyzer layer. In the fourth layer, SO_2 more than 99.7% is converted to SO_3.

The gas from the converter enters the final absorption unit, is heat recovered and dischared into the air.

2) Existing equipment and new equipment

Existing facilities have been sufficiently repaired to be adopted to the DCDA method so that the sulfuric acid plant will be operated satisfactorily. In addition, the catalyzer system is replaced with new one.

When the SCSA method is changed to the DCDA method, it should be investigated whether the existing air blower can be used or not.

This respect shall be in accordance with detailed design for remodeling. When the SCSA method and DCDA method are compared with each other, the SO_2 concentration is higher in the DCDA method and as the result, gas volume is smaller in this method. Therefore, even if the pressure loss of equipment increases, the existing blower is generally applicable from the view point of the performance of the blower.

(2) Phosphoric acid plant

The current spray type scrubber is replaced with a scrubber of higher cleaning efficiency.

The new scrubber is of the same type as the new exhaust gas scrubber of the TSP plant.

The scrubber is designed so that exhaust gas from the subreactor and main reactor can be collectively treated.

The existing exhaust gas supply fan to the scrubber can be continuously used.

Cleaning water from the planned scrubber is used for the filtration process as now.

(3) TSP plant

1) According to the analysis result of the current exhaust gas condition, the values specified here as follows are not satisfied about fluorine and dust.

Dust $\leq$ 200 mg/Nm^3

Fluorine $\leq$ 15 mg/Nm^3

Exhaust gas treatment is designed based on above values.

The scrubber being operated now in SIAPE is of the water spray type with a simple structure. Generally high cleaning efficiency is not secured with this type, though it varies depending on the L/G (cleaning liquid volume/treated gas volume) ratio. Therefore, a scrubber of better gas-liquid contact property should be employed.

It was determined for this purpose to employ a scrubber equivalent to the TCA unit (Turblent Contact Absorber in Japan) for the following reasons:

(1) Not clogged with dust when treating gas containing dust

(2) Good gas-liquid contact

(3) Relatively small gas pressure loss

(4) Easy operation

(5) Easy repair

The basic flow is designed almost the same as now. Quality of water discharged from the scrubber is as follows:

Water volume: 44 m^3/hr.

F: 9900 mg/*l*

2) Basic structure of scrubber

This scrubber is basically of the spray type. In order to improve the gas-liquid contact, multiple filling steps are provided. Steps are partitioned with a grid, which is properly filled with plastic balls (like ping-pong balls). When exhaust fume is blown into the scrubber from its bottom, the plastic balls filled in each step are violently moved. By passing cleaning liquid through the balls, efficient gas-liquid contact is attained.

Inside of each step is always in flowing condition during operation to prevent clogging of the scrubber inside with dust.

2.3 Treatment of Exhaust Gas from Burning Facilities

Burning exhaust fume treatment method is considered in the following procedure:

① Fuel containing no pollution source is used.

② Complete combustion should be attained.

(For this purpose, current situation of burning facilities and burning control technique should be grasped and efforts should be made to improve them.)

③ Treatment of discharged gas

When considering the exhaust gas treatment through above procedure, it is desirable to convert the fuel used currently such as heavy oil containing grignon and sulphur (3%) to low-sulfur heavy oil or natural gas fuel of low pollution. However, since converting the fuel requires an enormous sum of expense, national promotion is desired to realize it.

The process ② is the most feasible as the provisional means. It begins with grasping the capability of facilities now in use and their features.

Fuel facilities measured by this study are classified into two groups as follows:

- Solid fuel burning facilities
- Liquid fuel burning facilities

In Sfax, solid fuel (grignon) is used. Solid fuel facilities and their burning control are described below. Selection of exhaust fume treatment method is also described.

(1) Solid fuel burning facilities

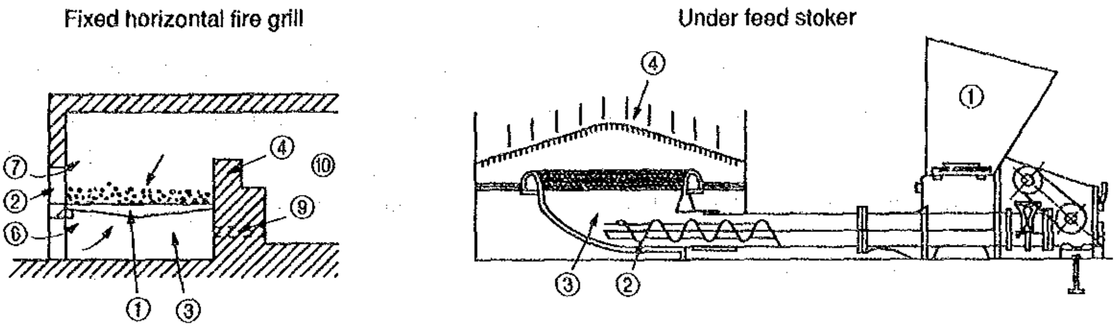
Generally, solid fuel is represented by coal and coke. In Sfax, residue after extracting olive oil is discharged as grignon and used as fuel in the factory.

Grignon has heat generation rate of about 4,000 - 5,000 kcal/kg under absolute dry condition. Moisture at the time of burning is about 15 - 25% like rice hulls or, residue of sugar cane (bagasse).

Generally, the fire grill burning method is used for solid fuel. Fire grill burning methods are classified into fixed fire grill burning and mechanical fire grill burning methods based on the operation methods. They are also classified into manual burning and mechanical burning methods based on the fuel supply methods.

Burning facilities used on the site comprise a fixed horizontal fire grill of manual burning method and under feed stoker. Schematic diagram of each method is shown in Fig. VII-1.

Fig. VII-1 Solid Fuel Burning Facilities



Fixed horizontal fire grill

① Fire grill
② Fuel hole
③ Ash reservoir
④ Fire bridge
⑥ Fire layer
⑥ Primary air
⑦ Secondary air
⑧ Burning chamber
⑨ Secondary air conditioning
⑩ Secondary burning chamber

Under feed stoker

① Hopper
② Screw
③ Primary air
④ Fire layer

1) Manual burning system

An upper feed fire layer is formed on the fire grill and there is a fire bridge on its inner side. The fire bridge prevents the fuel sprinkled on the fire layer from flying excessively inwardly and at the same time gives radiant heat to the fuel. Primary air for burning is introduced from under the fire grate by natural ventilation or forcing ventilation. When required, the fuel hole is opened or ventilation port is provided separately to introduce secondary air.

Generally, area of the firebed for which manual burning is possible is said to be about 2.5m^2. Fuel supply rate per hour for the total fire grate area is called fire grate area load. It is about 100 - 150 kg/m^{2}h for general solid fuel.

2) Under feed stoker system

Fuel in the hopper is pushed up over the fire grill by the rotations of the screw and supplied to the lower side of the fire layer. Air for burning is sent to under the fire grill and supplied to the fire layer from the ventilation port of the fire grate in parallel to the fuel and burnt.

In this system, movement of fire and air flow in the layer are reversed. With fuel hard to fire and fuel of small particle diameter, ventilation is often uneven, causing imperfect burning. Therefore, selection of fuel is important.

Generally, calorific volume of fuel used for the under feed stoker is more than 5,000 kcal/kg. In such a case, the fire grill area load is about 200 - 300 kg/m^{2}h.

(2) Burning control

Burning control means very usual control such as effective use of fuel suitable to facilities. When controlling burning conditions, it is important that personnel in charge on the site uses has an original idea and enthusiasm. Cooperation of the manager for improvement is also necessary. When such a cooperative system is established, improvement of heat efficiency and pollution prevention should be realized.

Cautions to be taken on the site for the burning control are described below.

1) Means to burn well

① Supply of fuel

With solid fuel, burning on the fire grate is apt to be uneven or one-sided. Burning condition in the furnace often fluctuates. As the result, fuel-air ratio becomes improper, causing black smoke. Therefore, alternate burning, manual burning or other proper methods should be attempted according to the conditions.

② Care of fire layer

In the case of fixed fire grill, the fire layer becomes increasingly thicker so that ventilation becomes unsatisfactory. The fire layer should be sometimes broken and equalized. If the fire layer becomes thicker furthermore, ash below the fire layer should be scraped out, which is called "furnace exchange". Since the fire power decreases during this process, it is important to finish it quickly.

③ Overload burning

Overload which requires generation of excessive and supplies much fuel may generate particles of soot.

In order to prevent such a condition, heat generation may be tried to some extent by intensifying ventilation and using preheating air. Basically, however, calory used and facilities' capability should be ballanced for proper burning.

2) Facilities

① Mechanical burning

Generally, with a mechanical burning method, fuel is continuously fed, burning efficiency is good, and generation of particles of soot can be reduced.

In the mechanical type boilder in SIOS-ZITEX the standard value of this study was exceeded. It should be improved from the basic data such as blowing of the required volume of air to the inside of the furnace, volume of fuel fed to the capacity of the facilities, etc.

② Use of measuring instruments

In order to judge the burning condition scientifically, collecting basic data is important.

In many factories selected for this study, operation relies upon experience and sense and only pressure gauges are used for steam generated. Existing measuring instruments are not sufficiently checked or adjusted.

For the control of burning operation, draft meters, various concentration meters, various flow rate meters and gas analysis meters should be provided to judge the burning condition based on the data.

③ Auxiliary burner and after burner

Particles of soot generated from solid burning facilities covered by this study should satisfy the standard values when burnt completely.

Major reason of incomplete burning is supposed that excessive air enters the burning chamber, decreases the temperature in the furnace and promotes the generation of particles of soot. To keep the in-furnace temperature, attaching an auxiliary burner or after burner to prevent particles of soot can be also considered.

④ Integration of chimney

The chimney has relation with burning. In order to diffuse exhaust gas, a larged chimney is used as far as possible instead of multiple chimneys provided for each facility. In Sfax, there is a large chimney in the plant to which several boilers are connected. No dumper is seen between boilers connected and flue. Therefore, if all boilers are not operated under constant conditions and if any boiler stops or is subjected to changes in the load, it gives influence on burning of other boilders. Therefore, if no dumper is provided, adverse influence to others is unavoidable even though diffusion of exhaust gas is effected with one tall chimney.

3) Others

① Standardization of work

Burning requires certain conditions. Particularly, many works to burn solid fuel requires skill or experience such as care of fire layer. Even when workers are changed, it is important to burn without causing pollution under required burning conditions. For this purpose, work standards should be established using the above-described measuring instruments so that anybody can perform same works.

② Rationalization of use of heat

Burning facilities generate heat source required in the factory. The burning facility department cannot cope with the pollution prevention by itself. The burning facilities should be desirably operated under certain load because of the efficiency and operating conditions. Therefore, it should be considered to satisfy such conditions throughout the factory.

③ Selection of fuel

As described above, factories selected for this study use solid (grignon) and liquid (heavy oil) fuels. Particles of soot and SOx contained in these fuels sometimes exceed standard values.

These fuels have been continuously used according to commercial practice. However, as pollution consciousness of the neighboring habitants is improved or low pollution fuel becomes easy to obtain as the result of promoted energy policy of the nation, exchanging the fuel to the one low pollution energy - from solid fuel to liquid fuel, for instance, gas fuel or electricity should be considered. It was heard in the field study that conversion of fuel to natural gas is being planned in Sfax. If it is realized, most of pollution problems due to air contamination from fixed generation source of particles of soot and SOx will be solved.

2.4 Method of Treatment of Exhaust Gas from Burning Facilities

For exhaust gas from burning facilities, it is particles of soot in most cases that requires treatment. Sometimes NOx exceeds standard values. As described above, generation of these two items should be able to be remarkably reduced by keeping a proper burning control. For instance, operating load on the boiler (SPE-66) used for power generation of SIAPE when the exhaust gas is measured was 15%. Generally, the burner is adjusted so that proper burning is carried out with the load on the boilder at 60 - 80%. Oxygen concentration in the exhaust fume from the same boiler was 14.6%, slightly high among heavy oil burning boilers. Thus, it is doubtful whether this boiler burner is properly adjusted. Even if it is adjusted, the capacity of facilities and operating load are unbalanced, resulted in a situation that particles of soot, etc. are easily generated. Burning control should be improved in the future. Treatment method of particles of soot is proposed here.

(1) Selection of particles of soot treatment method

As a system to treat particles of soot in exhaust gas, an electric dust collector (E.P), bag filter and cyclone are usually selected.

Features of each unit are described in Volume VI, Chapter 2.

Comparison of these soot treatment facilities are shown in Table VII-4 to help decision of treatment methods.

Table VII-4 Comparison of Particles of Soot Treatment Facilities

	Electric dust collector	Bag filter	Cyclone
1. Treatment characteristics			
Dust collection efficiency	High	Medium	Low
2. Construction expense	High	Medium	Low
3. Maintenance			
Operating expense	Medium	High	Low
Easiness of operation control	Medium	Medium	Low
4. Installation area	Large	Large	Small

Based on total judgment of the soot characteristics (the particle diameter is supposed to be more than 10 μ from generation of soot by imperfect burning of solid fuel) obtained from the result of comparison of above facilities, a cyclone (including multiple system) is recommended for the treatment facilities.

3. Plan for Facilities

3.1 Summary

Facilities are planned based on the assumption of the plan described in Volumes IV, V and VI and decision of processes described in Volume VII.

In the assumption for the waste water treatment plan in Volume V, cases are classified based on discharge standards for each factory. In this Volme VII, only the cases 1A, 1B, 2A and 2B are referred to. Treatment methods, sum of cost of facilities, etc. of other cases are described in the ANNEX.

Summayr of treatment methods are as shown in the block flow sheet, represented by abbreviations as follows:

CA : coagulation

BT : aerations tank for biological treatment

ST : sedimentation tank

SF : sand filtration

MF : membrane filtration

RO : reverse osmosis film unit

(Note: Other treatment methods not presented by abbreviations are described every time.)

Exhaust fume treatment facilities of the common type were selected for factories. Approximate dimensions are shown in a list in the paragraph about SIAPE.

3.2 SIAPE

3.2.1 Plan for Waste Water Treatment Facilities

Performance of the exhaust fume treatment facilities in the TSP plant should be improved. Therefore, the assumption of the waste water quality as described in Volume V is changed as follows. Dimensions after the change are shown in Table VII-5.

Table VII-5 Quality of Waste Water after Change (SIAPE)

		FLOW m^3/Hr	PH	COD mg/*l*	F mg/*l*	Fe mg/*l*	Cd mg/*l*	P mg/*l*	Cl mg/*l*	SO_4 mg/*l*
I	Waste water from TSP scrubber	44	1.1 - 1.6	276	9900	3.36	0.018	108	3700	1125
II	Waste water from generator and boiler	18		150	4.2	2	0.01	0.1	3100	1800

Problem items of the waste water of above I and II systems are as follows:

I Stream: case 1B: PH, COD, F, Fe, Cd

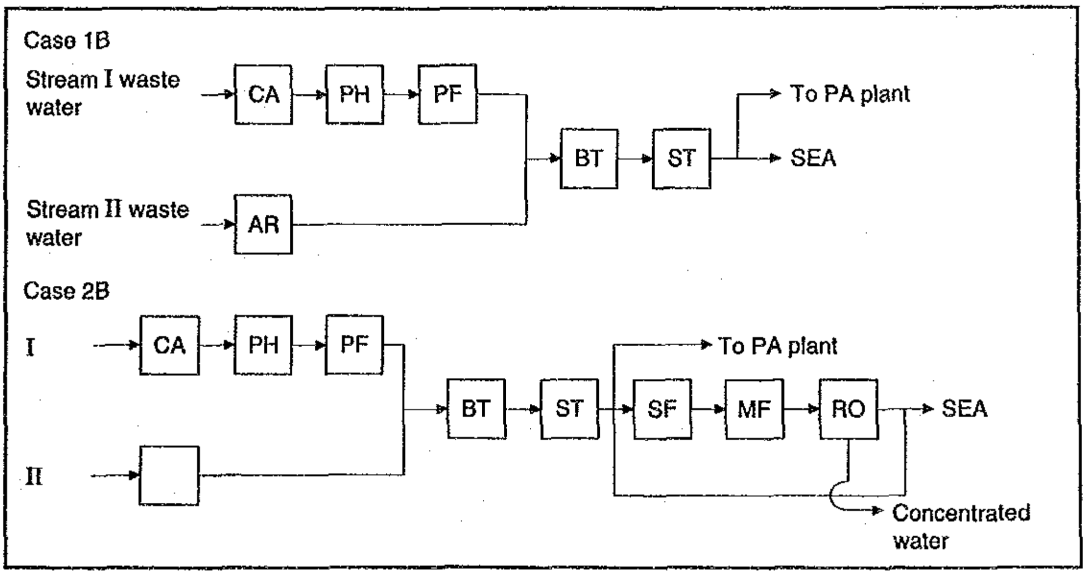
case 2B: P, SO_4 in addition to above ones

II Stream: case 1B: COD, Fe, Cd

case 2B: P, SO_4 in addition to above ones

Treatment block flow is shown in Table VII-6.

Table VII-6 Block Flow Sheet (SIAPE)



CA: Coagulation tank - lime is added to increase the PH and remove F

PH: PH adjustment - HCl is added and neutralize the PH increased by lime

PF : Filtering agent of absorbent agent composing mainly potassium tertiary phosphate $Ca_3(PO_4)_2$ mixed with sand passed through to remove very small volume of F

AR: aeration tank - Fe is oxidated by air seasoning to be trivalent Fe

BT: aeration tank for biological treatment - removal of organic substances

After the organism treatment, the waste water can be returned to the filtering process of the phosphoic acid plant. However, volume to the reverse osmosis film of the subsequent process was planned not to return the water to filtering process.

The reverse osmosis film was planned since SO_4 is restricited by the standard of discharge to the sea. It becomes unnecessary if the regulation is discontinued.

Concentrated water generated by the reverse osmosis film is as follows:

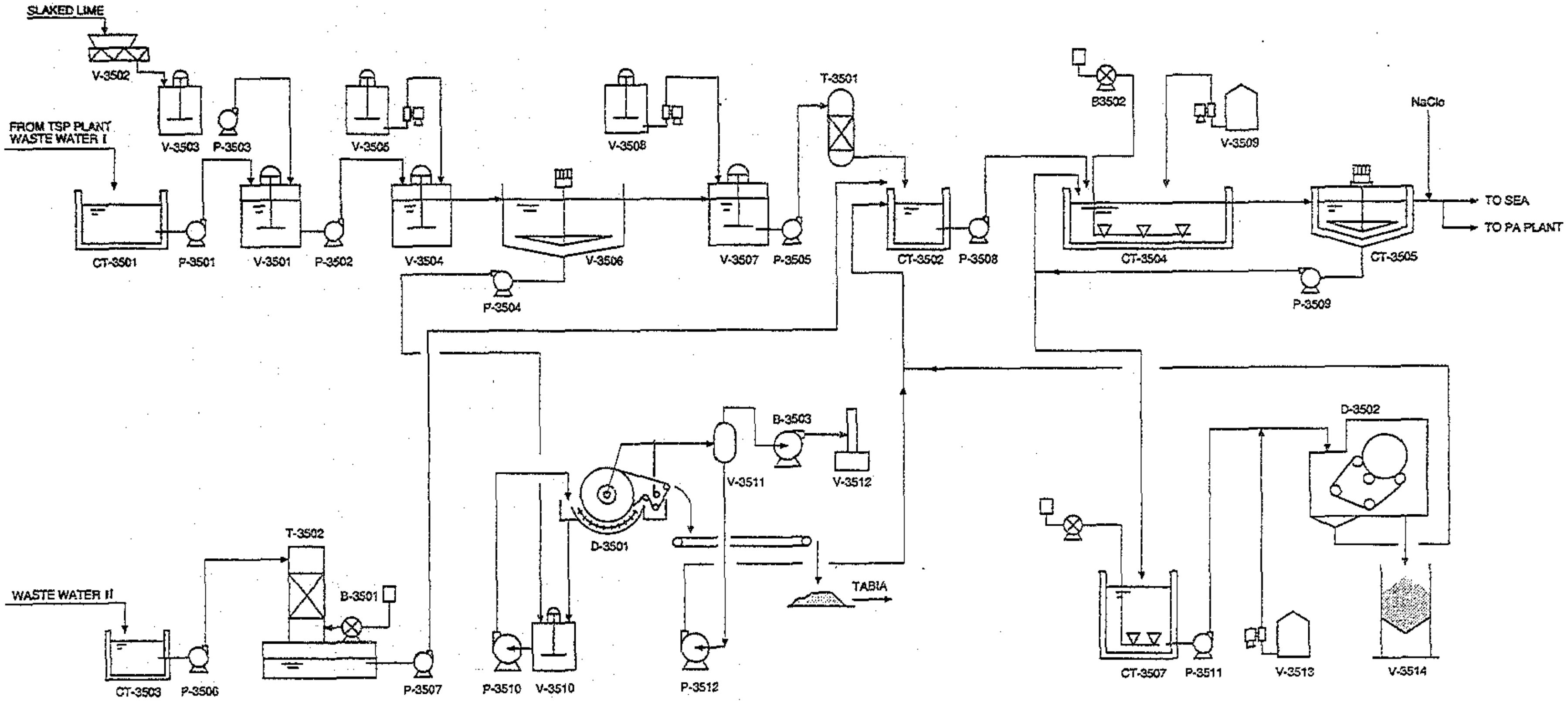
Concentrated water: Water volume 8.5 m^3/hr

SO_4 condensation about 5,000 mg/*l*

Flow sheet and arrangement are shown in Fig. VII-2, 3, 4 and 5.

List of equipment is shown in Table VII-7 and 8.

Fig. VII-2 Flow Sheet of Waste Water Treatment Facilities (SIAPE 1B)



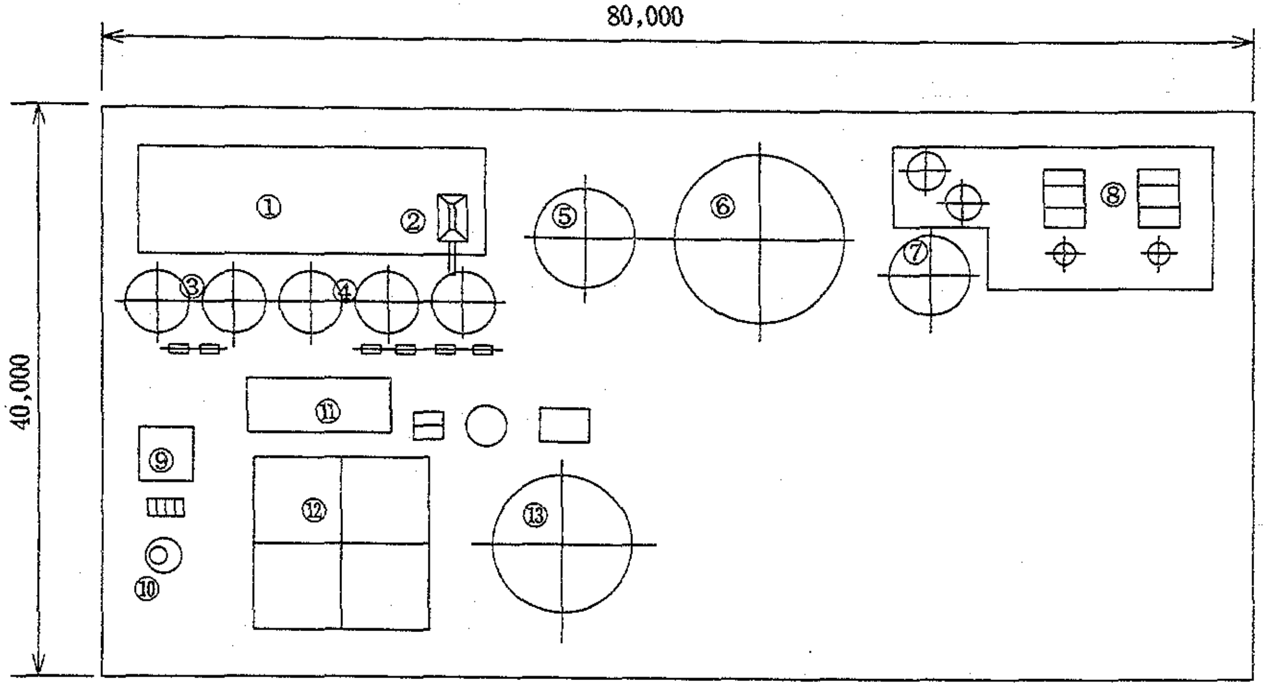
P-3501	WASHED WATER PUMP
P-3502	SLURRY PUNP
P-3503	LIME MILK PUMP
P-3504	SLUDGE PUMP
P-3505	ABSORBER FEED PUMP
P-3506	WASTE WATER PUMP
P-3507	OXIDIZED WATER PUMP
P-3508	AERATION TANK FEED PUMP
P-3509	RETURN SRUDGE PUMP
P-3510	SLUDGE FEED PUMP (1)
P-3511	SLUDGE FEED PUMP (2)
P-3512	FILTRATE PUMP

V-3501	NEUTRALIZER
V-3502	LIME HOPPER
V-3503	LIME MILK TANK
V-3504	MIXING HEAD TANK
V-3505	POLYMER TANK
V-3506	THICKENER
V-3507	RECOVERED WATER TANK
V-3508	HCl TANK
V-3509	CO (NH2) 2 TANK
V-3510	SLUDGE TANK (1)
V-3511	SEPARATOR
V-3512	SILENCER
V-3513	POLYMER TANK
V-3514	CAKE HOPPER

CT-3501	WASHED WATER TANK
CT-3502	TREATED WATER TANK
CT-3503	WASTE WATER TANK
CT-3504	AERATION TANK
CT-3505	SEDIMENTATION TANK
CT-3507	SLUDGE TANK (2)

T-3501	ABSORPTION TOWER
T-3502	OXIDATION TOWER
D-3501	MUD FILTER
D-3502	BELT PRESS
B-3501	OXIDATION BLOWER
B-3502	AERATION BLOWER
B-3503	VACUUM PUMP

Fig. VII-3 Plot Plan of Waste Water Treatment Facilities (SIAPE 1B)

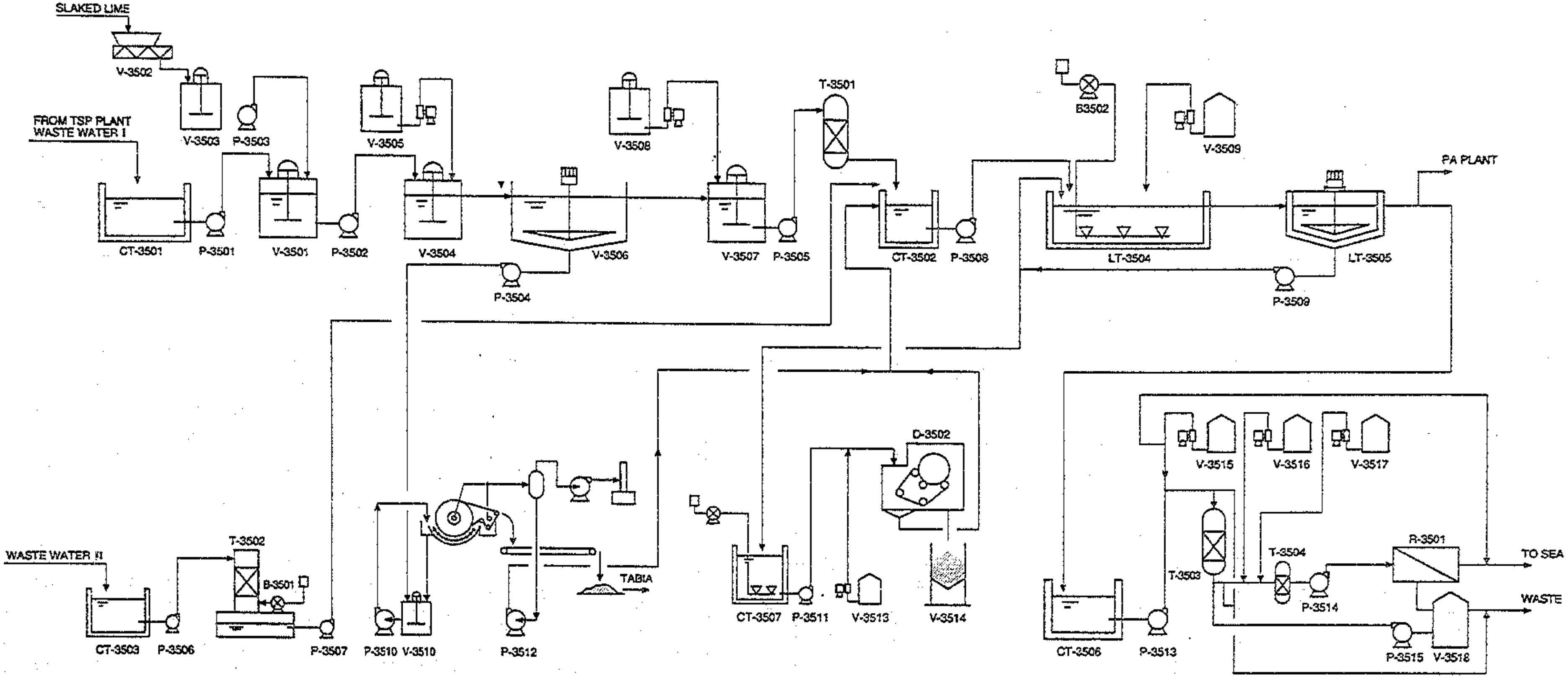


① LIME STONE STORAGE HOUSE
② LIME HOPPER
③ WASHED WATER TANK
④ NEUTRALIZATION TANK
⑤ RECOVERED WATER TANK
⑥ THICKENER
⑦ SLUDGE TANK
⑧ DEWATERING HOUSE
⑨ WASTE WATER TANK
⑩ OXIDATION TOWER
⑪ BLOWER HOUSE
⑫ AERATION TANK
⑬ SEDIMENTATION TANK

Table VII-7 Main Equipment List (SIAPE 1B)

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks
1	F TREATMENT PLANT			
	CT-3501	WASHED WATER TANK	1	90 m^3 R.C + RL
	V-3504	MIXING HEAD TANK	1	2 m^3 CS + RL AGITATER 1.5 kW
	V-3501	NEUTRALIZAITON TANK	1	45 m^3 CS + RL AGITATER 3.7 kW
	V-3506	THICKNER	1	14 mϕ CS + RL RAKE 2.2 kW
	T-3501	ADSORPTION TOWER	1	20 m^3 CS
	V-3507	RECOVERED WATER TANK	1	100 m^3 CS + RL
	CT-3502	TREATED WATER TANK	1	90 m^3 R.C + RL
	V-3502	LIME HOPPER	1	45 m^3 CS
	V-3503	LIME MILK TANK	1	3 m^3 CS
	V-3505	POLYMER TANK	1	4 m^3 PUMP 0.2 kW AGITATER 1.5 kW
	V-3508	HC1 TANK	1	4 m^3 PUMP 0.2 kW
	P-3503	LIME MILK PUMP	1+1	1.5 kW
	P-3501	WASHED WATER PUMP	1+1	3.7 kW
	P-3502	SLURRY PUMP	1+1	2.2 kW
	P-3504	SLUDGE PUMP	1	3.7 kW
	P-3505	ADSORBER FEED PUMP	1+1	3.7 kW
	P-3508	AERATION FEED PUMP	1+1	3.7 kW
2	OXYDATION TREATMENT PLANT			
	CT-3503	WASTE WATER TANK	1	9 m^3 R.C
	T-3502	OXIDATION TOWER	1	800ϕ x 3500H CS
	P-3506	WASTE WATER PUMP	1+1	0.75 kW
	B-3501	OXIDATION BLOWER	1	1.5 kW
3	BIOLOGICAL TREATMENT PLANT			
	CT-3504	AERATION TANK	4	126 m^3 R.C
	CT-3505	SEDIMENTATION TANK	1	9000ϕ R.C RAKE 0.4 kW
	B-3502	AERATION BLOWER	1+1	15 m^3/min. x 22 kW
	V-3509	CO (NH2)2 TANK	1	4 m^3 PUMP 0.1 kW
	P-3509	RETURN SLIDGE PUMP	1	3.7 kW
4	MUD DEWATERING PLANT			
	V-3510	SLUDGE TANK (1)	1	45 m^3 C.S AGITATER 3.7 kW
	D-3501	MUD FILTER	2	28 m^2
	V-3511	SEPARATOR	2	1000 mmϕ
	V-3512	SILENCER	2	1000 mmϕ
	P-3510	SLUDGE FEED PUMP	2+1	8 m^3/Hr 1.1 kW
	P-3512	FILTRATE PUMP	2	8 m^3/Hr 1.1 kW
	B-3503	VACUUM PUMP	2	2000 m^3/Hr 55 kW
5	SLUDGE DEWATERING PLANT			
	CT-3507	SLUDGE TANK (2)	1	10 m^3 R.C BLOWER 0.4 kW
	D-3502	BELT PRESS	1	0.5 m WIDTH 2.2 kW
	V-3514	CAKE HOPPER	1	CS
	V-3513	POLYMER TANK	1	4 m^3 PUMP 0.2 kW AGITATER 1.5 kW
	P-3511	SLUDGE PUMP	1+1	2.2 kW

Fig. VII-4 Flow Sheet of Waste Water Treatment Facilities (SIAPE 2B)



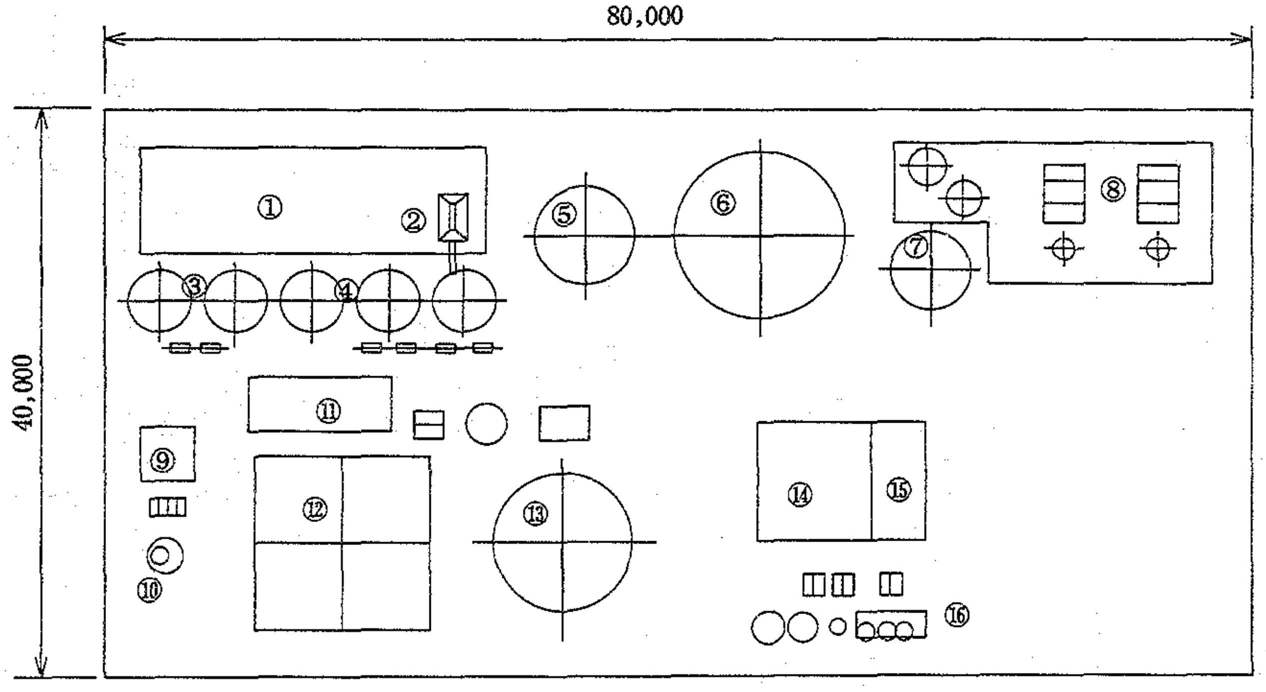
P-3501	WASHED WATER PUMP
P-3502	SLURRY PUMP
P-3503	LIME MILK PUMP
P-3504	SLUDGE PUMP
P-3505	ABSORBER FEED PUMP
P-3506	WASTE WATER PUMP
P-3507	OXIDIZED WATER PUMP
P-3508	AERATION TANK FEED PUMP
P-3509	RETURN SRUDGE PUMP
P-3510	SLUDGE FEED PUMP (1)
P-3511	SLUDGE FEED PUMP (2)
P-3512	FILTRATE PUMP
P-3513	FILTER FEED PUMP
P-3514	BOOSTER PUMP
P-3515	BACK WASH PUMP

V-3501	NEUTRALIZER
V-3502	LIME HOPPER
V-3503	LIME MILK TANK
V-3504	MIXING HEAD TANK
V-3505	POLYMER TANK
V-3506	THICKENER
V-3507	RECOVERED WATER TANK
V-3508	HCl TANK
V-3509	$CO(NH_2)_2$ TANK
V-3510	SLUDGE TANK (1)
V-3511	SEPARATOR
V-3512	SILENCER
V-3513	POLYMER TANK
V-3514	CAKE HOPPER
V-3515	NaClO TANK
V-3516	SCALE INHIVITER TANK
V-3517	HCl TANK
V-3518	BRINE TANK

CT-3501	WASHED WATER TANK
CT-3502	TREATED WATER TANK
CT-3503	WASTE WATER TANK
CT-3504	AERATION TANK
CT-3505	SEDIMENTATION TANK
CT-3506	RECEPTION TANK
CT-3507	SLUDGE TANK (2)

T-3501	ABSORPTION TOWER
T-3502	OXIDATION TOWER
T-3503	SANDFILTER
T-3504	CARTRIDGE FILTER
D-3501	MUD FILTER
D-3502	BELT PRESS
R-3501	RO FILTER
B3501	OXIDATION BLOWER
B3502	AERATION BLOWER
B3503	VACUUM PUMP

Fig. VII-5 Plot Plan of Waste Water Treatment Facilities (SIAPE 2B)



① LIME STONE STORAGE HOUSE
② LIME HOPPER
③ WASHED WATER TANK
④ NEUTRALIZATION TANK
⑤ RECOVERED WATER TANK
⑥ THICKENER
⑦ SLUDGE TANK
⑧ DEWATERING HOUSE
⑨ WASTE WATER TANK
⑩ OXIDATION TOWER

⑪ BLOWER HOUSE
⑫ AERATION TANK
⑬ SEDIMENTATION TANK
⑭ RECEPTION TANK
⑮ BRINE TANK
⑯ RO FILTER

Table VII-8 Main Equipment List (SIAPE 2B) - 1/2

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks		
1	F TREATMENT PLANT					
	CT-3501	WASHED WATER TANK	1	90 m^3	R.C + RL	
	V-3504	MIXING HEAD TANK	1	2 m^3	CS + RL	AGITATER 1.5 kW
	V-3501	NEUTRALIZAITON TANK	1	45 m^3	CS + RL	AGITATER 3.7 kW
	V-3506	THICKNER	1	14 mϕ	CS + RL	RAKE 2.2 kW
	T-3501	ADSORPTION TOWER	1	20 m^3	CS	
	V-3507	RECOVERED WATER TANK	1	100 m^3	CS + RL	
	CT-3502	TREATED WATER TANK	1	90 m^3	R.C + RL	
	V-3502	LIME HOPPER	1	45 m^3	CS	
	V-3503	LIME MILK TANK	1	3 m^3	CS	
	V-3505	POLYMER TANK	1	4 m^3	PUMP 0.2 kW	AGITATER 1.5 kW
	V-3508	HC1 TANK	1	4 m^3		PUMP 0.2 kW
	P-3503	LIME MILK PUMP	1+1	1.5 kW		
	P-3501	WASHED WATER PUMP	1+1	3.7 kW		
	P-3502	SLURRY PUMP	1+1	2.2 kW		
	P-3504	SLUDGE PUMP	1	3.7 kW		
	P-3505	ADSORBER FEED PUMP	1+1	3.7 kW		
	P-3508	AERATION FEED PUMP	1+1	3.7 kW		
2	OXYDATION TREATMENT PLANT					
	CT-3503	WASTE WATER TANK	1	9 m^3	R.C	
	T-3502	OXIDATION TOWER	1	800ϕ x 3500H	CS	
	P-3506	WASTE WATER PUMP	1+1	0.75 kW		
	B-3501	OXIDATION BLOWER	1	1.5 kW		
3	BIOLOGICAL TREATMENT PLANT					
	CT-3504	AERATION TANK	4	126 m^3	R.C	
	CT-3505	SEDIMENTATION TANK	1	9000ϕ	R.C	RAKE 0.4 kW
	B-3502	AERATION BLOWER	1+1	15 m^3/min. x 22 kW		
	V-3509	CO (NH2)2 TANK	1	4 m^3		PUMP 0.1 kW
	P-3509	RETURN SLIDGE PUMP	1	3.7 kW		
4	RO PLANT					
	CT-3506	RECEPTION TANK	1	30m^3	R.C	
	T-3503	SAND FILTER	2	2000ϕ		
	T-3504	CARTRIGE FILTER	1 set	CARTRIGE TYPE		
	R-3501	RO FILTER	1 set	SPIRAL TYPE 200ϕ x 60 ELEMENTS		
	V-3518	BRINE TANK	1	30 m^3	R.C	
	V-3515	NaC1O TANK	1	4 m^3		PUMP 0.2 kW
	V-3516	INHIVITER TANK	1	4 m^3		PUMP 0.2 kW
	V-3517	HC1 TANK	1	4 m^3		PUMP 0.2 kW
	P-3513	FILTER FEED PUMP	1+1	3.7 kW		
	P-3514	BOOSTER PUMP	1+1	55 kW		
	P-3515	BACK WASH PUMP	1	5.5 kW		

Table VII-8 Main Equipment List (SIAPE 2B) - 2/2

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks
5	MUD DEWATERING PLANT			
	V-3510	SLUDGE TANK (1)	1	45 m^3 C.S AGITATER 3.7 kW
	D-3501	MUD FILTER	2	28 m^2
	V-3511	SEPARATOR	2	1000 mmϕ
	V-3512	SILENCER	2	1000 mmϕ
	P-3510	SLUDGE FEED PUMP	2+1	8 m^3/Hr 1.1 kW
	P-3512	FILTRATE PUMP	2	8 m^3/Hr 1.1 kW
	B-3503	VACUUM PUMP	2	2000 m^3/Hr 55 kW
6	SLUDGE DEWATERING PLANT			
	CT-3507	SLUDGE TANK (2)	1	10 m^3 R.C BLOWER 0.4 kW
	D-3502	BELT PRESS	1	0.5 m WIDTH 2.2 kW
	V-3514	CAKE HOPPER	1	CS
	V-3513	POLYMER TANK	1	4 m^3 PUMP 0.2 kW AGITATER 1.5 kW
	P-3511	SLUDGE PUMP	1+1	2.2 kW

3.2.2 Exhaust Gas Treatment Facilities

Preconditions of the exhaust gas treatment facilities in SIAPE are as shown in the table below:

Table VII-9 Preconditions of Exhaust Gas Treatment Facilities (SIAPE)

	Treatment method	Treatment facility capacity (Nm^3/h)	Exhaust gas property			
			SOx Nm^3/h	NOx ppm	DUST mg/Nm^3	F mg/Nm^3
1. Sulfuric acid plant	DCDA method					
750 ton/D		190,000	439		770	
300 ton/D		43,000	65			
2. Phospharic acid plant	Wet type scrubber	37,000				1,510
3. TSP plant	Wet type scrubber					
500 ton/D		89,000			310	154
600 ton/D		130,000			1,100	1,250
4. Boiler	Multi-cyclone	25,000		262	372	

(1) Sulfuric acid plant

Exhaust gas flow sheet and layout in the sulfuric acid plant are shown in Fig. VII-6 and 7 and the list of those equipment in 750 and 300 tons in Table VII-10. If the SCSA is changed to DCDA, the sulfur recovery rate is improved from 98 to 99.7% and therefore, volume of sulfur to be used is anticipated to decrease by 5.3 tons/day.

Fig. VII-6 Flow Sheet of DCDA Method (SA Plant)

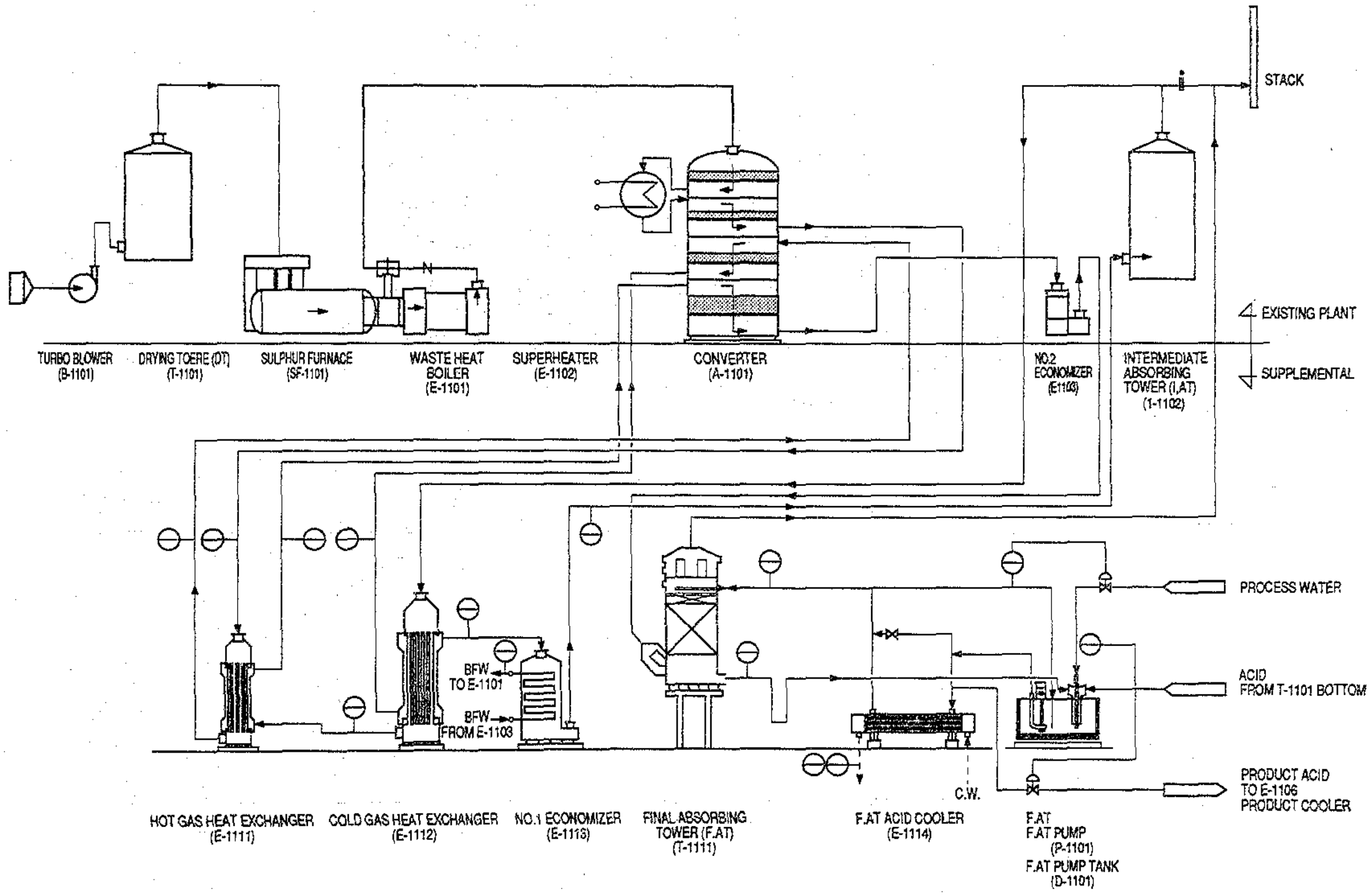


Fig. VII-7 Plot Plan of DCDA Method (SA Plant)

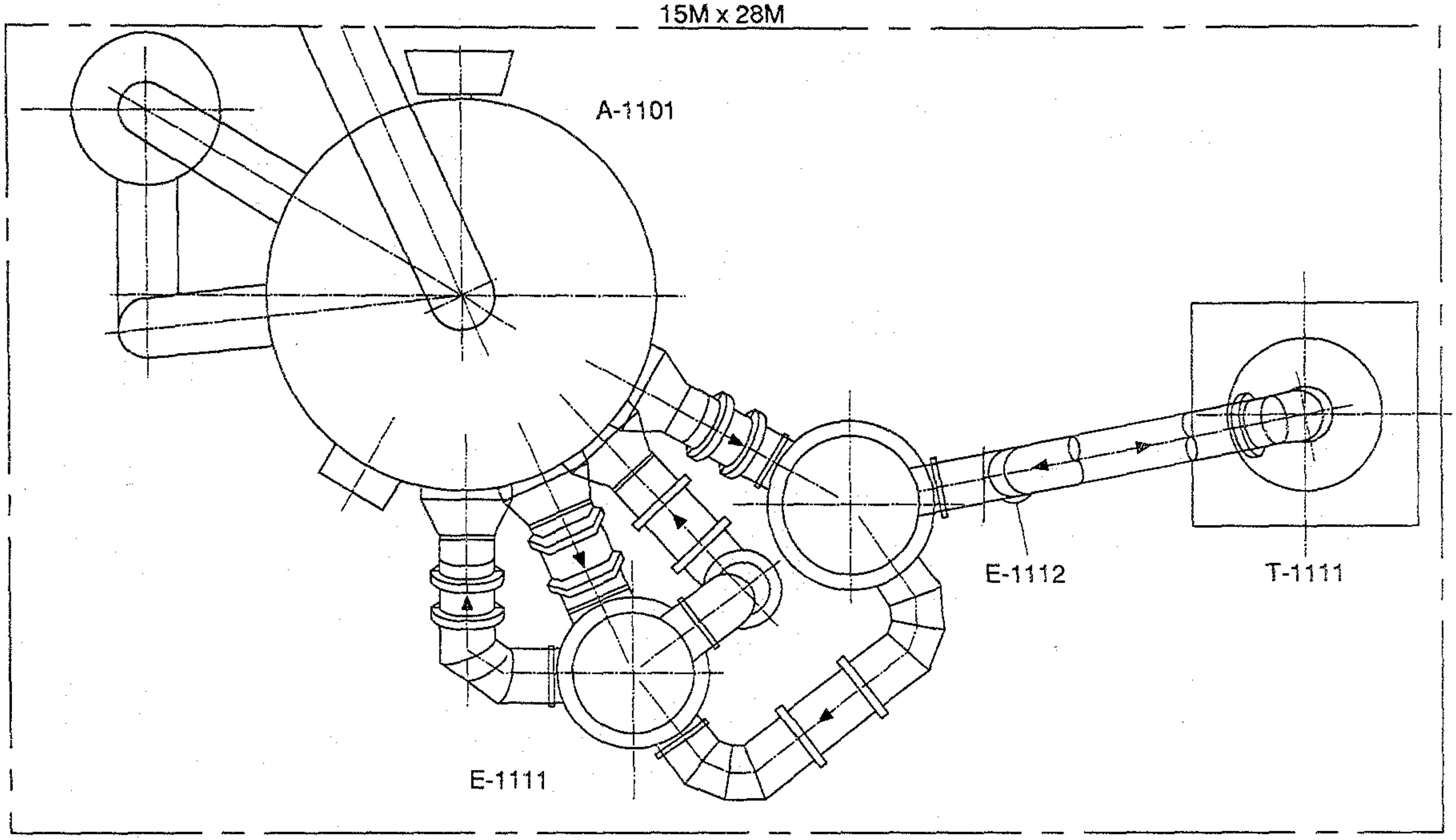


Table VII-10 Main Equipment List (SA Plant)

Equip. No.	Name of Equipment	No. of REQ'D	Type	Remarks	
				750 ton	300 ton
A-1101	CONVERTER	1	VERTICAL CYLINDRICAL	EXISTING	EXISTING
E-1111	HOT GAS HEAT EXCHANGER	1	VERTICAL, SHELL & TUBE	960 m^2, 3mϕ	380 m^2, 1.9 mϕ
E-1112	COLD GAS HEAT EXCHANGER		VERTICAL, SHELL & TUBE	1400 m^2, 3mϕ	560 m^2, 1.9 mϕ
E-1113	NO.1 ECONOMIZER		VERTICAL FIN	FIN TUBE 2700 m^2 FIN 570 m^2	1100 m^2 230 m^2
E-1114	F.A.T. ACID COOLER	1	AP COOLER	56 m^2, 800ϕ	23m^2, 500ϕ
P-1111	F.A.T. PUMP	1		400 m^3/H, 75 kW	160 m^3/H, 30 kW
T-1111	FINAL ABSORBIC TOWER	1	VERTICAL CYLINDRICAL	4800ϕ	3000ϕ
D-1111	F.A.T. PUMP TANK	1	VERTICAL CYLINDRICAL	4500ϕ	2900ϕ

(2) Phosphoric acid plant

Exhaust gas treatment flow sheet in the phosphoric acid plant is shown in Fig. VII-8 and list of equipment is in Table VII-11. cleaning waste water is used in the filtering process.

Table VII-11 Main Equipment List (PA plant)

EQUIP. NO.	NAME OF EQUIPMENT	NO. OF REQ'D	REMARKS
A-2101A/B	CIRC. PUMP	1 + 1	CENTRIFUGAL 6.6 m³/min × 18 m, FC + RL
T-2101	PA SCRUBBER	1	TCA 37000 Nm³/H, 2700ϕ × 12.6 mH

(3) TSP plant

Exhaust gas in the TSP plant is treated with a scrubber provided for each system of 500/600 tons. Gas after treated is combined together and discharged from the chimney. Waste water used for cleaning (44 m³/month) is treated with a lime neutralization system.

Exhaust gas treatment flow sheet and layout in the TSP plant are shown in Fig. VII-9 and 10 and the list of the equipment in Table VII-12.

Table VII-12 Main Equipment List (TSP Plant)

Equip. No.	Name of Equipment	No. of REQ'D	Remarks
K-3301	EXHAUST GAS FAN	1	TURBO, 178,000 Nm³/H x 400 mm Aq, 400 kW
P-3301A, B	CIRC. PUMP	1+1	CENTRIFUGAL, 17m³/min., 150 kW
T-3301	SCRUBBER	1	TCA, 4500ϕ x 19.1 mH 4 STEPS
S-3401	STACK	1	SELF STAND, 2500ϕ x (38 + 19.5) m
K-3401	EXHAUST GAS FAN	1	SAME AS K-3301
P-3401	CIRC. PUMP	1	SAME AS P-3301
T-3401	SCRUBBER	1	SAME AS T-3301

Fig. VII-8 Flow Sheet Exhaust Gas Scrubbing (PA Plant)

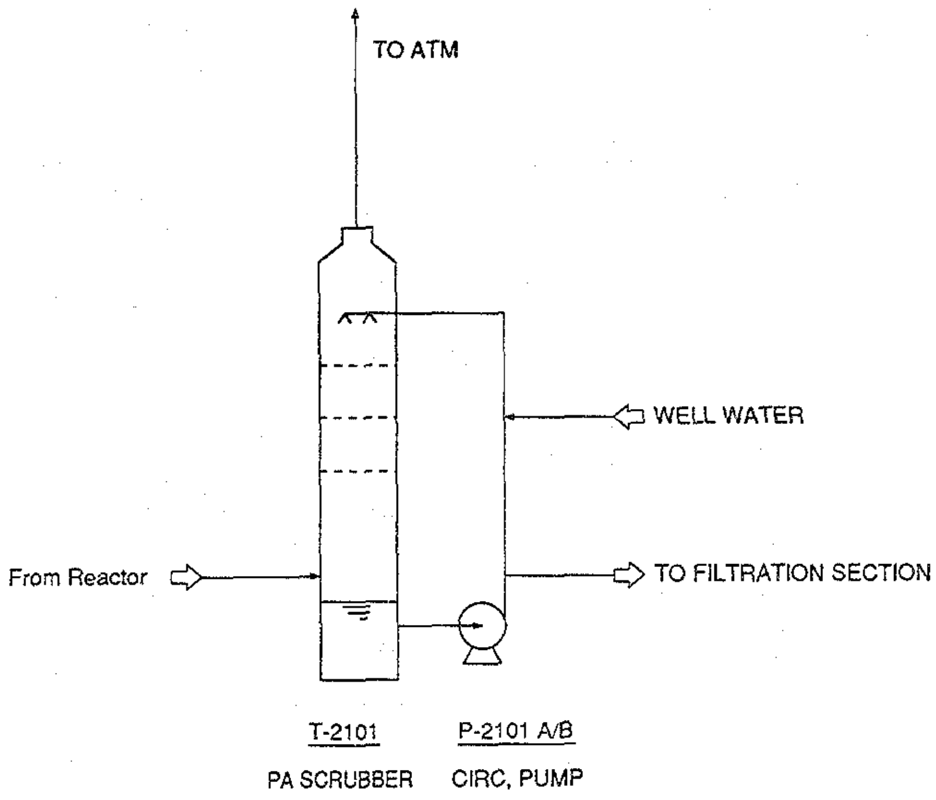


Fig. VII-9 Flow Sheet of Exhaust Gas Scrubbing (TSP Plant)

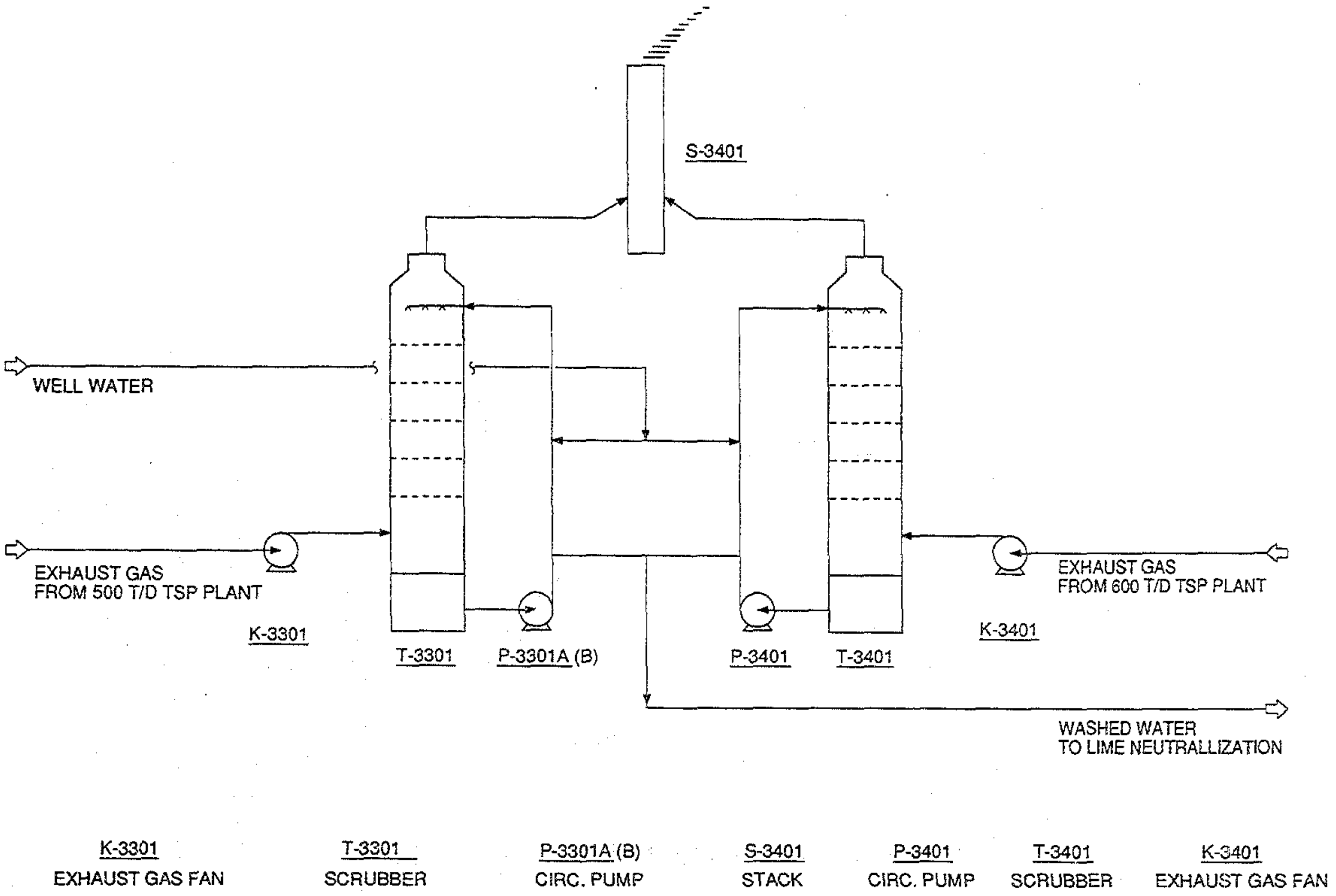
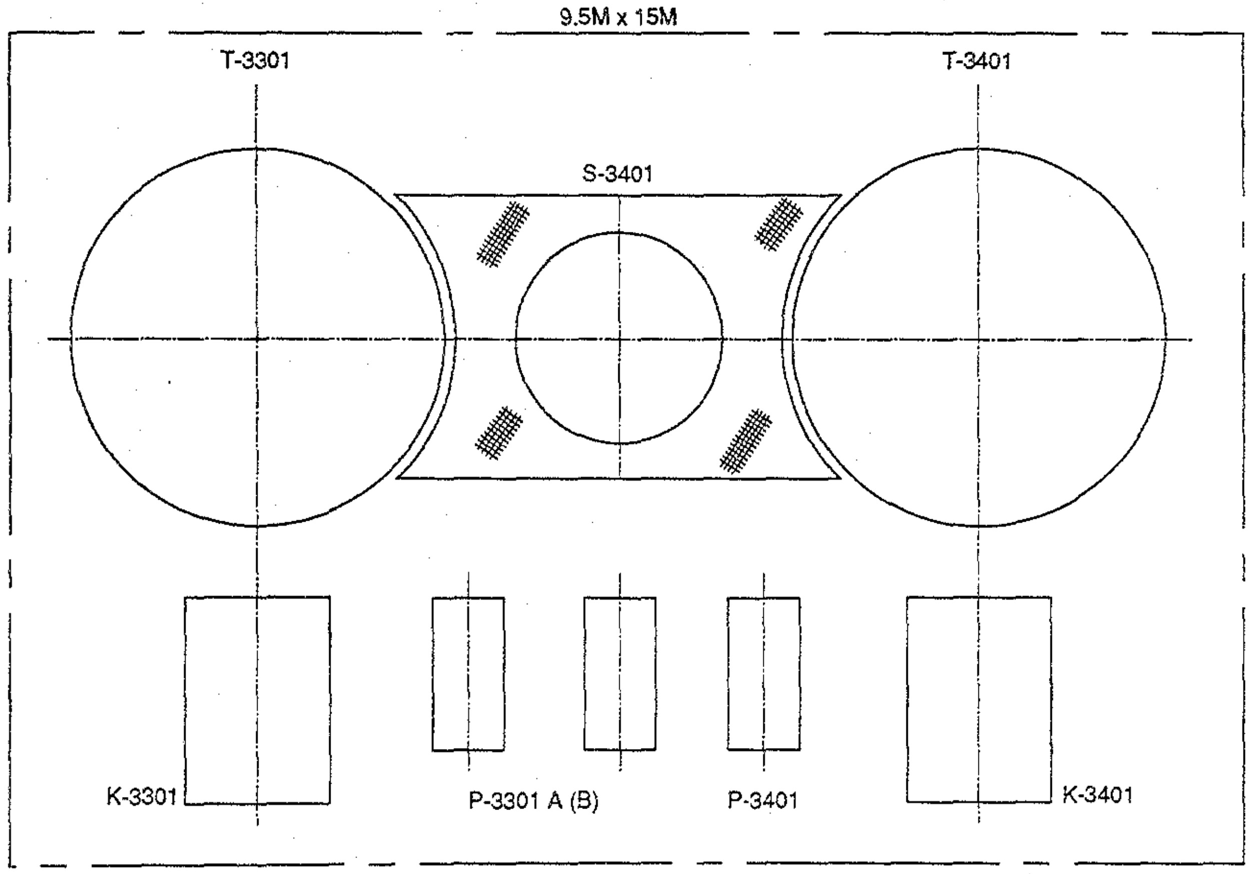


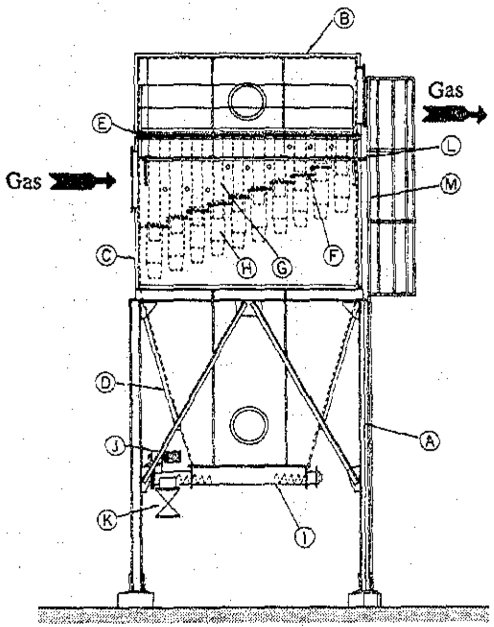
Fig. VII-10 Plot Plan of Exhaust Gas Scrubbing Facilities (TSP Plant)

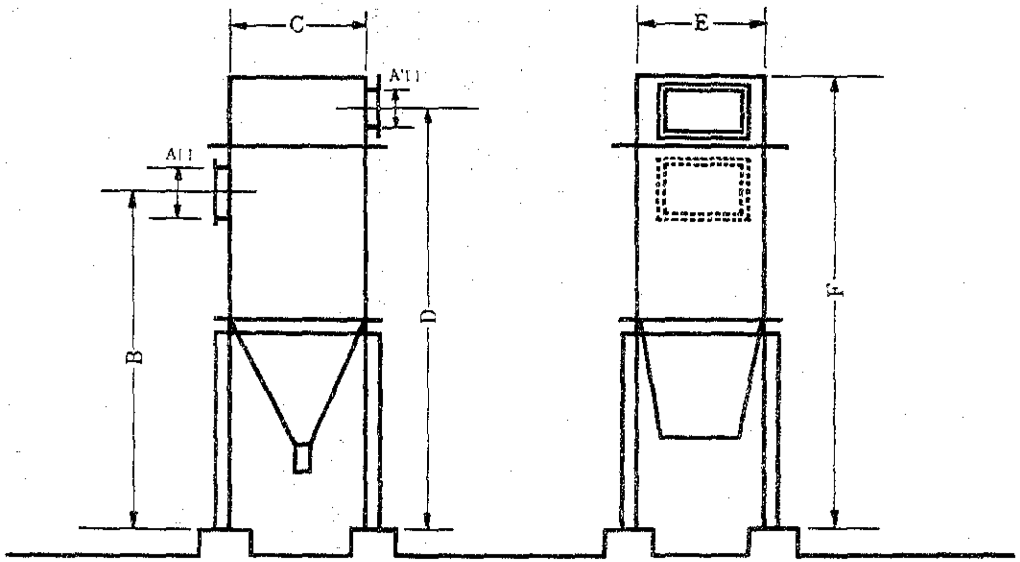


(4) Boiler

Multi-cyclone system is used for treatment of boiler waste gas (SPA-60). This system is applied also to other factories. List and approximate dimensions are shown in Table VII-13.

Table VII-13 Main Dimensions of Multi Cyclone





Factory	Sampling Point	Gas Volume (m3/Hr)	Lines x Stages of Multi Cyclone	Dimensin of cyclone (m/m)							Remarks
				A□	A'□	B	C	D	E	F	
SIAPE	SPA-60	25,000Nm3/H	7x6	500x1850	650x1300	4700	1940	5700	2200	6250	
SIOS-ZITEX*	SZT-54	3600NM3/H	3x2	250x650	250x500	3400	700	3800	1000	4350	
	SZT-55	1800Nm3/H	2x2	250x350	200x400	3200	700	3600	700	4150	
	SZT56	3900Nm3/H	3x3	300x600	300x600	3650	1000	4350	1000	4750	
	SZT-57	6000Nm3/H	4x3	300x950	350x700	3650	1000	4350	1300	4750	
SATHOP	STP-51	3600Nm3/H	3x2	250x650	250x500	3400	700	3800	1000	4350	
	STP-52	3600Nm3/H	3x2	250x650	250x500	3400	700	3800	1000	4350	
	STP-53	21,000Nm3/H	7x6	500x1850	650x1300	4700	1940	5700	2200	6250	
STS	STS-51	1500 Nm3/H	2 x 2	250 x 350	200 x 400	3200	700	3600	700	4150	
	STS-52	600 Nm3/H	2 x 1	200 x 300	200 x 350	3000	500	3500	700	4000	

3.3 UPOTS

Water quality of margin of UPOTS to be treated is as shown in Table VII-14.

Table VII-14 Quality of Margin Waste Water

FLOW m^3/D	COD mg/*l*	N-HEX mg/*l*	PHENOL mg/*l*	Kj-N mg/*l*	K mg/*l*	P mg/*l*	Cl mg/*l*	SO_4 mg/*l*	EC ms/cm
1000	190000	300	5	920	10000	2300	8900	3050	35

Flow 1000m^3/D is discharged for 100 days a year.

The major problem of margin is that the volume of waste water discharged varies depending on seasons. The waste water is discharged for 100 days a year. In order to treat the waste water continuously through the year, a reservoir with capacity of 100,000m^3 for a year is necessary. The pond for margin near ONAS which is now used for abondoning the waste water is used for this purpose and subsequent treatment is continuously carried out. This reservoir will be provided with a surface aeration system for aerobic treatment and reduction of water volume by evaporation. But the post treatment will be planned on the assumption that both COD and water volume do not reduce.

The next major problem is very high COD concentration. Organic matter expressed by COD will be treated by biological treatment.

Treatment of margin is a world-wide problem. Studies on biological treatment are being promoted in various countries. Anaerobic treatment saves energy and can recover energy since CH_4 gas is generated. It has been attracting attention recently and its studies are advancing. Particularly studies related with foods have advanced and actually plants are being operated in sugar making and starch factories. However, treatment of margin is still at the stage of studies and no actual plant is being operated.

In the study of this time, aerobic treatment after anaerobic treatment is being planned from the view point of energy saving.

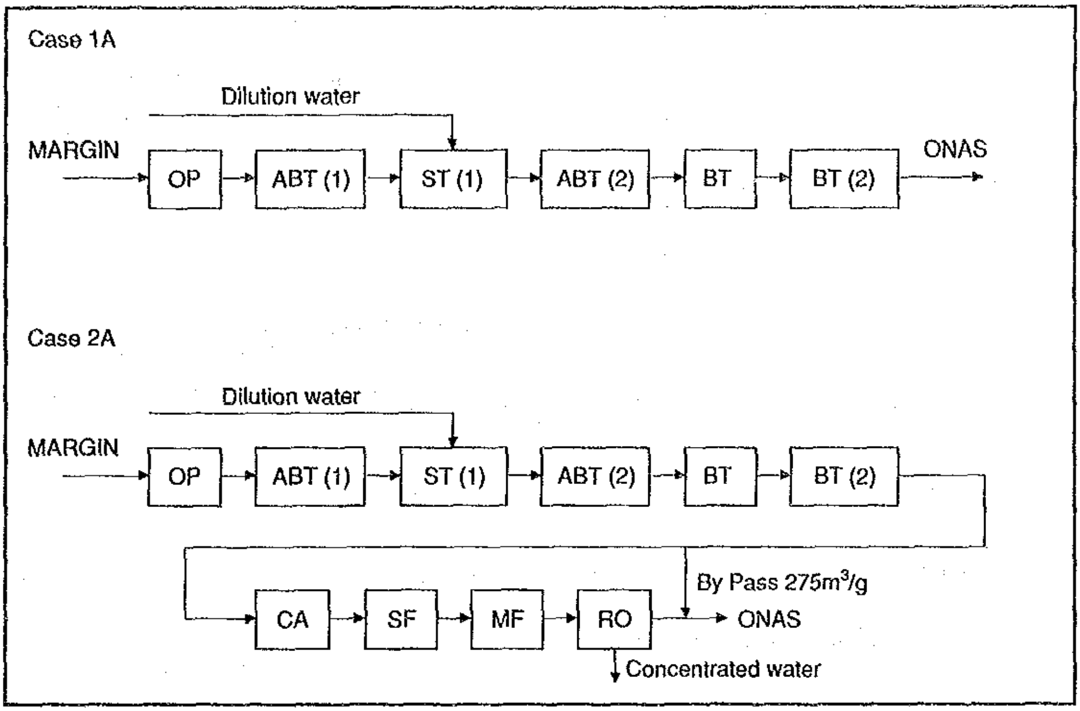
Anaerobic treatment is divided into two stages. The first stage is acid fermentation.

Before entering the methane fermentation tank of the second stage, diluted water is added, bacteria is separated, returned to the acid fermentation tank of the first stage and the waste water is trated in the methane fermentation tank.

For the case 2A, reverse osmosis film is provided to satisfy the standard flow into ONAS.

Block flow sheet is shown in Table VII-15.

Table VII-15 Margin Block Flow Sheet



OP : reservoir - store margin for a year. Existing pond is used.

ABT1: acid fermentation tank - used to ferment acid of organic substances

ST1 : After diluting by water, sediment and separate the bacteria.

ABT2: methane fermentation tank - organic acid is dissolved by methane bacteria for methane fermentation. The model is UASB (Upflow Anaerobic Sludge Blanket). Methane gas generated is used to heat waste water. Excessive methane gas is generated.

BT : aeration tank for biological treatment

ST2 : sedimentation tank of activated sludge method

Part of the methane gas generated in the methane fermentation tank is used to heat the waste water. Rest of the gas can be used as energy. Specifications of the usable gas are as follows:

Gas volume: 12,500 Nm^3/D

Methane content: about 75%

Methane gas calorific volume: 8,500 kcal/Nm^3

Usable calory: about 80,000,000 kcal/D

Method of using the calory is not included in the plan of this time but the following uses can be considered:

1. Gas power generation
2. Fuel used in plant e.g. boiler in SIAPE
3. Energy for evaporation of reverse osmosis concentrated water

Diluting water is required for separating bacteria after acid fermentation. Treated water in ONAS or water from well is used. Water volume used: 411 m^3/day

Concentrated water of reverse osmosis film of case 2

Water volume: 82 m^3/day

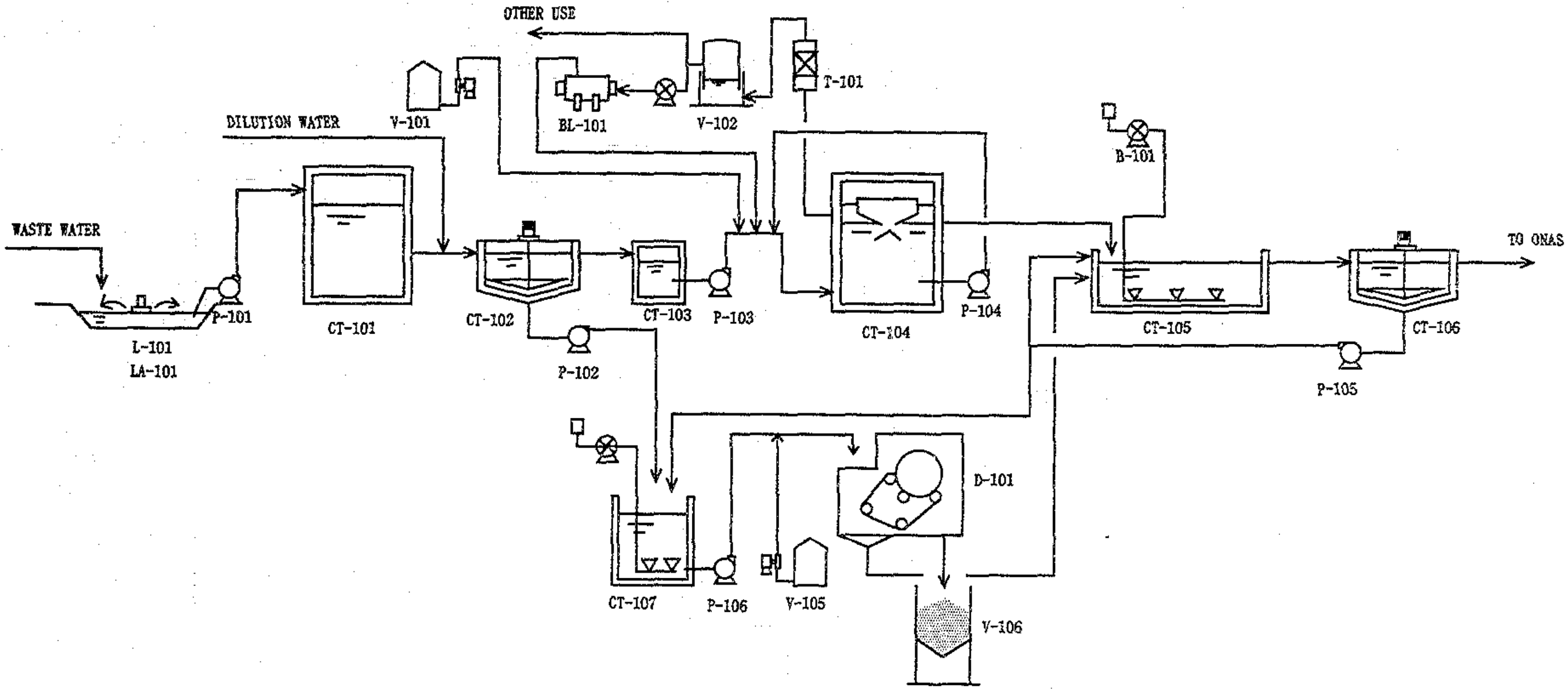
Cl concentration: about 20,000 mg/l

SO_4 concentration: about 6-700 mg/l

Detailed flow sheet and layout are shown in Fig. VII-11, 12, 13 and 14 and list of equipment in Table VII-16, and 17.

As described above, margin is treated mainly by the anaerobic microorganism treatment method. Though the anaerobic treatment has been used for a long time, it is used only in special cases since response is slow. Recently, energy recovery by methane gas generated has been reexamined and a method of treating in a short time by increasing the volume of microorganism are being studied. The UASB method is one of such methods. However, the anaerobic treatment involves many elements and operation is difficult. In addition, the UASB method has only a short history and only a small number of study reports have been released. Therefore, If it is applied for the treatment of margin, collecting data sufficiently by basic studies will be important.

Fig. VII-11 Flow Sheet of Margin Treatment Facilities (UPOTS 1A)



P-101 WASTE WATER PUMP
P-102 SLUDGE DRAWING PUMP
P-103 FERMENTER FEED PUMP
P-104 RECYCLE PUMP
P-105 RETURN SLUDGE PUMP
P-106 SLUDGE FEED PUMP
P-107 SLUDGE DROWING PUMP
P-108 FILTER FEED PUMP
P-109 BOOSTER PUMP
P-110 BRINE PUMP

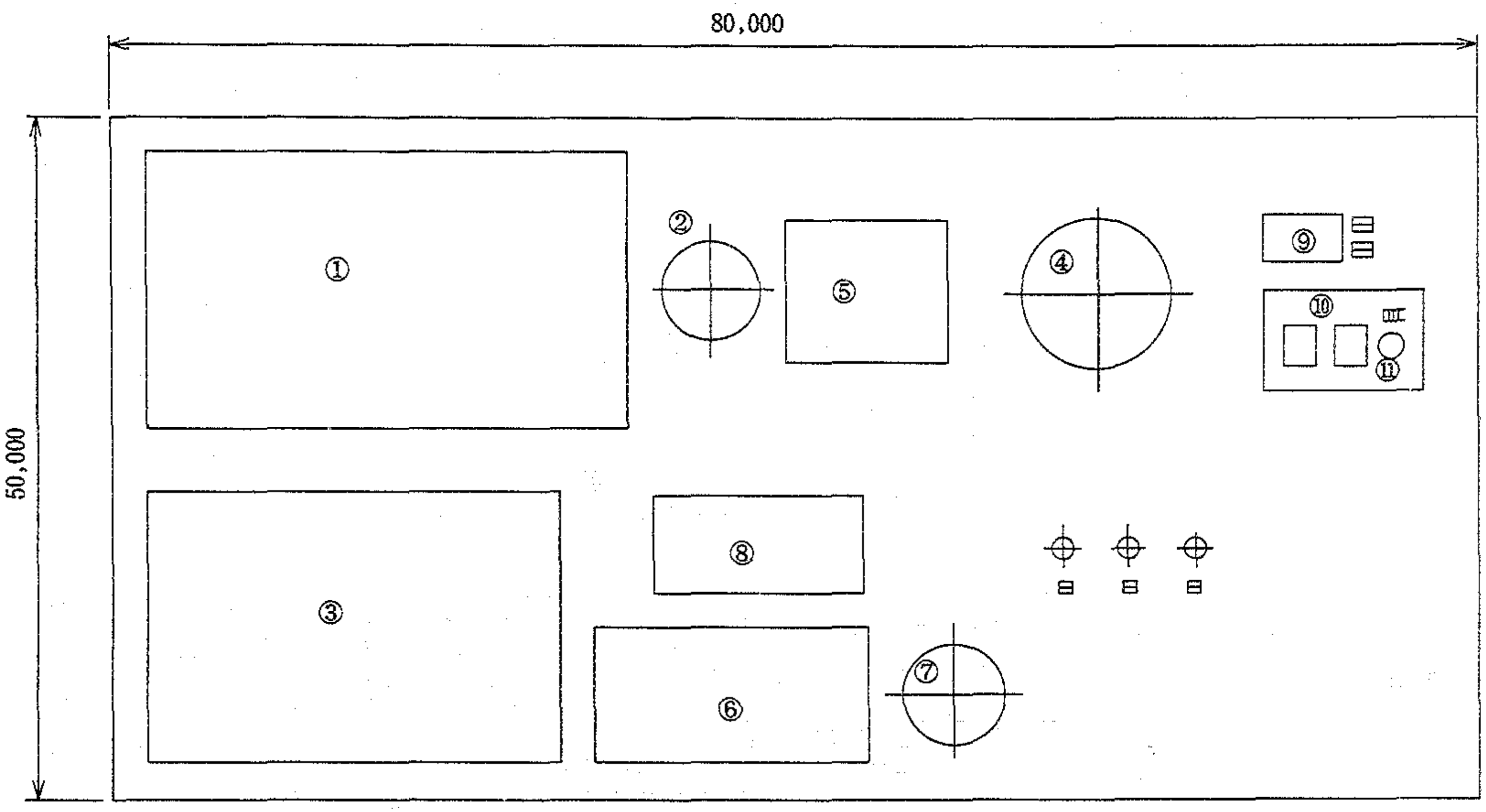
V-101 NaOH TANK
V-102 GAS HOLDER
V-105 POLYMER TANK
V-106 CAKE HOPPER
V-107 MIXING HEAD TANK
V-108 COAGULATION TANK
V-109 SEDIMENTATION TANK
V-110 ALUM TANK
V-111 NaOH TANK
V-112 POLYMER TANK

V-113 NaClO TANK
V-114 INHIVITER TANK
V-115 HCl TANK
V-116 BRINE TANK

CT-101 ACID FERMENTER
CT-102 SEPARATION TANK
CT-103 RECEPTION TANK
CT-104 METHANE FERMENTER
CT-105 AERATION TANK
CT-106 SEDIMENTATION TANK
CT-107 SLUDGE HOLDING TANK
CT-108 RECEPTION TANK

L-101 LAGOON
BL-101 BOILER
T-101 DESULFUR TANK
B-101 AERATION BLOWER
D-101 BELT PRESS
LA-101 LAGOON AERATOR

Fig. VII-12 Plot Plan of Margin Treatment Facilities (UPOTS 1A)

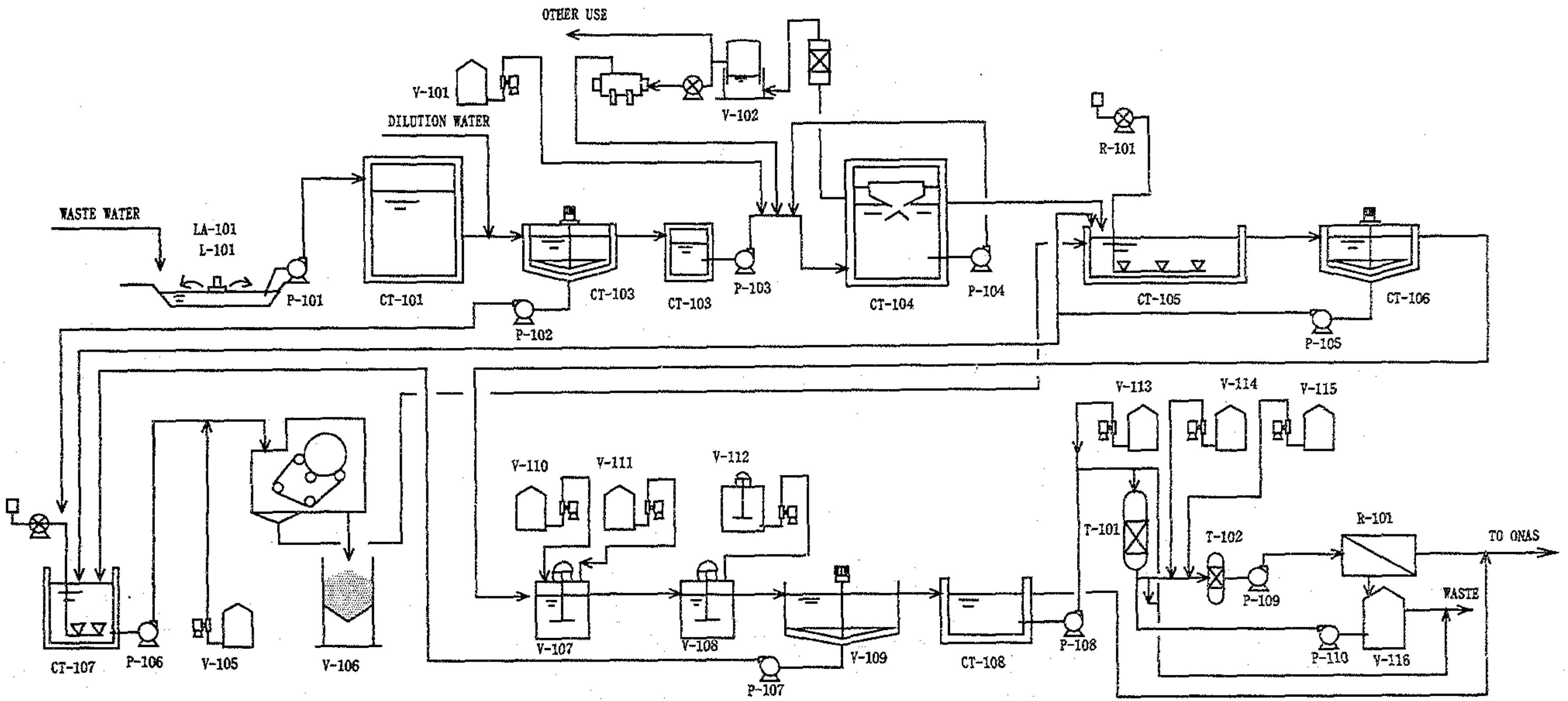


① ACID FERMENTATION TANK
② SEPARATION TANK
③ METHANE FERMENTATION TANK
④ GAS HOLDER
⑤ BOILER HOUSE
⑥ AERATION TANK
⑦ SEDIMENTATION TANK
⑧ BLOWER HOUSE
⑨ SLUDGE HOLDING TANK
⑩ BELT PRESS
⑪ POLYMER TANK

Table VII-16 Main Equipment List (UTOPS 1A)

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks
1	ANAEROBICAL TREATMENT PLANT			
	CT-101	ACID FERMENTER	1	4500 m^3 RC
	CT-102	SEPARATION TANK	1	7 mf RC
	CT-104	METHANE FERMENTER	1	5200 m^3 RL
	V-102	GAS HOLDER	1	5700 m^3 RC WATER SEAL
	CT-103	RECEPTION TANK	1	100 m^3 RC
	V-101	NaOH TANK	1	4 m^3 PUMP 0.1kW
	T-101	DESULFUR TANK	1	DRY TYPE
	BL-101	BOILER	1	HOT WATER TYPE
	P-101	WASTE WATER PUMP	1+1	1.5 kW
	P-102	SLUDGE DRAWING PUMP	1	2.2 kW
	P-103	FERMENTER FEED PUMP	1+1	2.2 kW
	P-104	RECYCLE PUMP	1	3.7 kW
	LA-101	LAGOON AERATOR	3	11 kW
2	AEROBIC TREATMENT PLANT			
	CT-105	AERATION TANK	1	435 m^3 RC
	CT-106	SEDIMENTATION TANK	1	7.0 m^2 RL RAKE 0.2 kW
	B-101	AERATION BLOWER	2+1	45 kW
	P-105	RETURN SLUDGE PUMP	1+1	2.2 kW
3	SLUDGE DEWATERING PLANT			
	CT-107	SLUDGE HOLDING TANK	1	20 m^3 RC
	D-101	BELT PRESS	2	1 m WIDTH 3.7 kW
	V-106	CAKE HOPPER	1	5 m^3 CS
	V-105	POLYMER TANK	1	4m^3 PUMP 0.2 kW AGITATER 0.4 kW
	P-106	SLUDGE FEED PUMP	1+1	1.5 kW

Fig. VII-13 Flow Sheet of Margin Treatment Facilities (UPOTS 2A)



P-101	WASTE WATER PUMP
P-102	SLUDGE DRAWING PUMP
P-103	FERMENTER FEED PUMP
P-104	RECYRCLE PUMP
P-105	RETURN SLUDGE PUM
P-106	SLUDGE FEED PUMP
P-107	SLUDGE DROWING PUMP
P-108	FILTER FEED PUMP
P-109	BOOSTER PUMP
P-110	BRINE PUMP

V-101	NaOH TANK
V-102	GAS HOLDER
V-105	POLYMER TANK
V-106	CAKE HOPPER
V-107	MIXING HEAD TANK
V-108	COAGULATION TANK
V-109	SEDIMENTATION TANK
V-110	ALUM TANK
V-111	NaOH TANK
V-112	POLYMER TANK

V-113	NaClO TANK
V-114	INHIVITER TANK
V-115	HCl TANK
V-116	BRINE TANK

CT-101	ACID FERMENTER
CT-102	SEPARATION TANK
CT-103	RECEPTION TANK
CT-104	METHAN FERMENTER
CT-105	AERATION TANK
CT-C06	SEDIMENTATION TANK
CT-107	SLUDGE HOLDING TANK
CT-108	RECEPTION TANK

L-101	LAGOON
BL-101	BOILER
T-101	DESULFER TANK
B-101	AERATION BLOWER
D-101	BELT PRESS
T-101	SAND FILTER
T-102	CARTRIGE FILTER
R-101	RO FILTER
LA-101	LAGOON AERATOR

Fig. VII-14 Plot Plan of Margin Treatment Facilities (UPOTS 2A)

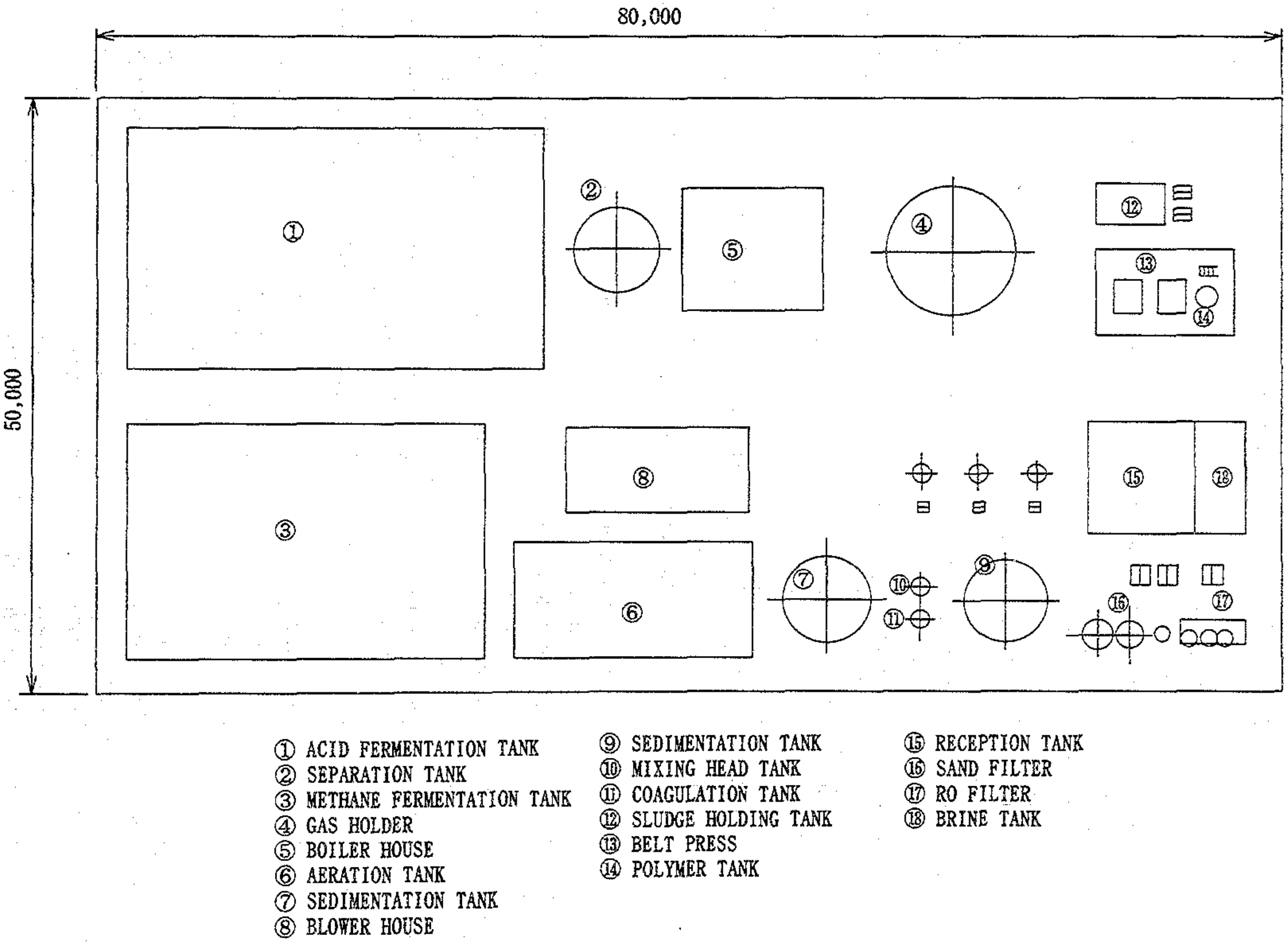


Table VII-17 Main Equipment List (UTOPS 2A) - 1/2

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks
1	ANAEROBICAL TREATMENT PLANT			
	CT-101	ACID FERMENTER	1	4500 m^3 RC
	CT-102	SEPARATION TANK	1	7 mf RC
	CT-104	METHANE FERMENTER	1	5200 m^3 RL
	V-102	GAS HOLDER	1	5700 m^3 RC
	CT-103	RECEPTION TANK	1	100 m^3 RC
	V-101	NaOH TANK	1	4 m^3 PUMP 0.1kW
	T-101	DESULFUR TANK	1	DRY TYPE
	BL-101	BOILER	1	HOT WATER TYPE
	P-101	WASTE WATER PUMP	1+1	1.5 kW
	P-102	SLUDGE DRAWING PUMP	1	2.2 kW
	P-103	FERMENTER FEED PUMP	1+1	2.2 kW
	P-104	RECYCLE PUMP	1	3.7 kW
	LA-101	LAGOON AERATOR	3	11 kW
2	AEROBIC TREATMENT PLANT			
	CT-105	AERATION TANK	1	435 m^3 RC
	CT-106	SEDIMENTATION TANK	1	7.0 m^2 RL RAKE 0.2 kW
	B-101	AERATION BLOWER	2+1	45 kW
	P-105	RETURN SLUDGE PUMP	1+1	2.2 kW
3	COAGULATION TREATMENT PLANT			
		WASTE WATER TANK	1	30 m^3 RC
	V-107	MIXING HEAD TANK	1	2.5 m^3 CS AGITATER 2.2 kW
	V-108	COAGULATION TANK	1	5.0 m^3 CS AGITATER 5.5 kW
	V-109	SEDIMENTATION TAN	1	7.0 mϕ RL RAKE 0.4 kW
	V-110	ALUM TANK	1	4 m^3 PUMP 0.1 kW
	V-111	NaOH TANK	1	4 m^3 PUMP 0.1 kW
	V-112	POLYMER TANK	1	4 m^3 PUMP 0.2 kW AGITATER 1.5 kW
		WASTE WATER PUMP	1+1	0.2 kW
4	RO PLANT			
	CT-108	RECEPTION TANK	1	20 m^3 RC
	T-101	SAND FILTER	1	2.0 mϕ
	T-102	CARTRIGE FILTER	1 set	CARTRIGE TYPE
	R-101	RO FILTER	1 set	SPIRAL TYPE 200ϕ x 28 ELEMENTS
	V-116	BRINE TANK	1	10 m^3 RC
	V-113	NaClO TANK	1	1 m^3 PUMP 0.1 kW
	V-114	INHIVITER TANK	1	1 m^3 PUMP 0.1 kW
	V-115	HCl TANK	1	1 m^3 PUMP 0.1 kW
	P-108	FILTER FEED PUMP	1+1	2.2 kW
	P-109	BOOSTER PUMP	1+1	37 kW
	P-110	BACK WASH PUMP	1	2.2 kW

Table VII-17 Main Equipment List (UTOPS 2A) - 2/2

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks
5	SLUDGE DEWATERING PLANT			
	CT-107	SLUDGE HOLDING TANK	1	20 m³ RC
	D-101	BELT PRESS	2	1 m WIDTH 3.7 kW
	V-106	CAKE HOPPER	1	5 m³ CS
	V-105	POLYMER TANK	1	4m³ PUMP 0.2 kW AGITATER 0.4 kW
	P-106	SLUDGE FEED PUMP	1+1	1.5 kW

3.4 SIOS-ZITEX

(1) Waste water treatment

When discussing the quality of water of SIOS-ZITEX, subjects causing problems are COD for the case 1A and Cl and SO_4 are added to them for the case 2A.

Assumptions of Volume V are shown in Table VII-18. In this table, waste water from extraction, refining, and soap processes are indicated as I and the waste water from cooling tower, boiler and softener and living waste water as II.

Table VII-18 Quality of Waste Water (SIOS-ZITEX)

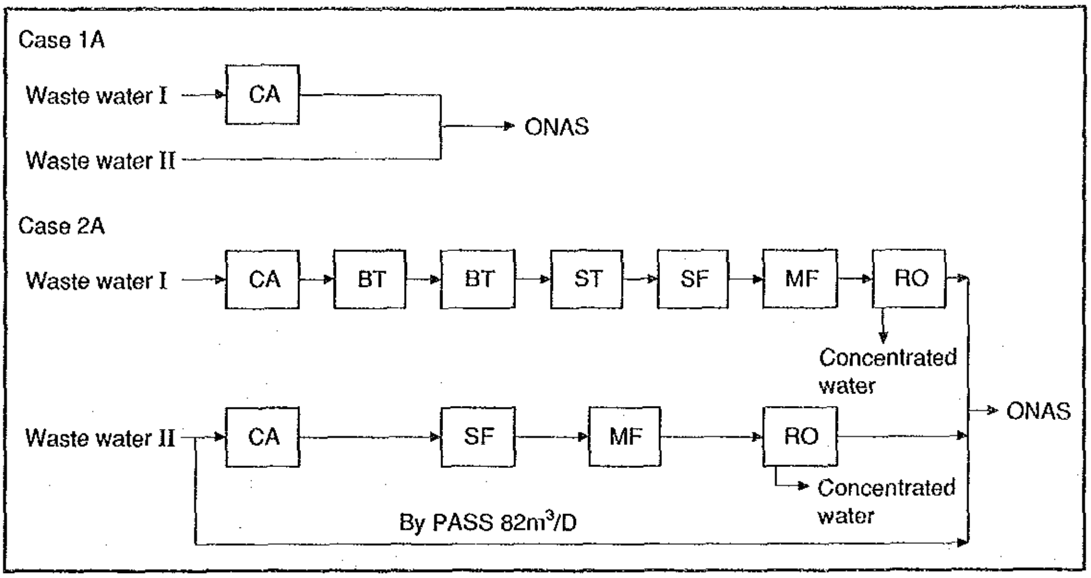
STREAM NO.	FLOW m^3/D	COD mg/*l*	Cl mg/*l*	SO_4 mg/*l*
I	45	14267	6259	3282
II	202	324	2820	2086

In the case 1A, standard values can be attained by removing COD from the waste watr I by the coagulation method and flowing it to ONAS together with the waste water II.

In the case 2A, after treating the waste water II by coagulation method, reverse osmosis treatment is carried out for Cl and SO_4.

Block flow sheet is shown in Table VII-19.

Table VII-19 Block Flow Sheet (SIOS-ZITEX)



As shown in the above block flow sheet, extensive facilities are required for the case 2A because of the regulation on salt. Concentrated water generated by the reverse osmosis film is as follows:

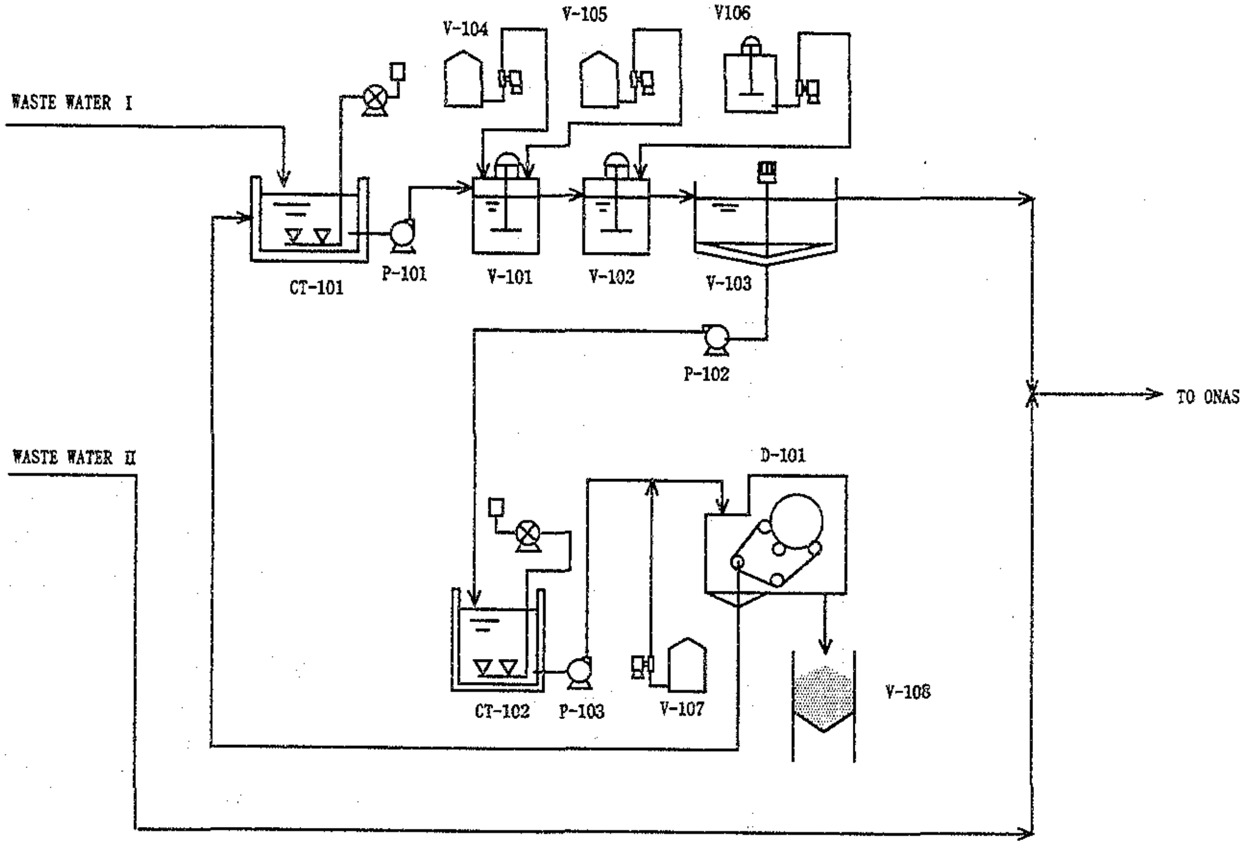
	Water volume	Cl concentration	SO4 concentration
Waste water of Stream I	11 m³/D	24,000 mg/l	12,500 mg/l
Waste water of Stream II	30 m³/D	11,000 mg/l	8,000 mg/l
Total	41 m³/D	14,500 mg/l	9,300 mg/l

Detailed flow sheet and layout are shown in Fig. VII-15, 16, 17, and 18 and the equipment specifications in Table VII-20 and 21.

(2) Exhaust gas treatment

Four multi-cyclones as follows were planned for exhaust gas treatment. Capacity and No. of cyclones of each facility are as follows and major dimensions are shown in Table VII-13.

Fig. VII-15 Flow Sheet of Waste Water Treatment Facilities (SIOS-ZITEX 1A)



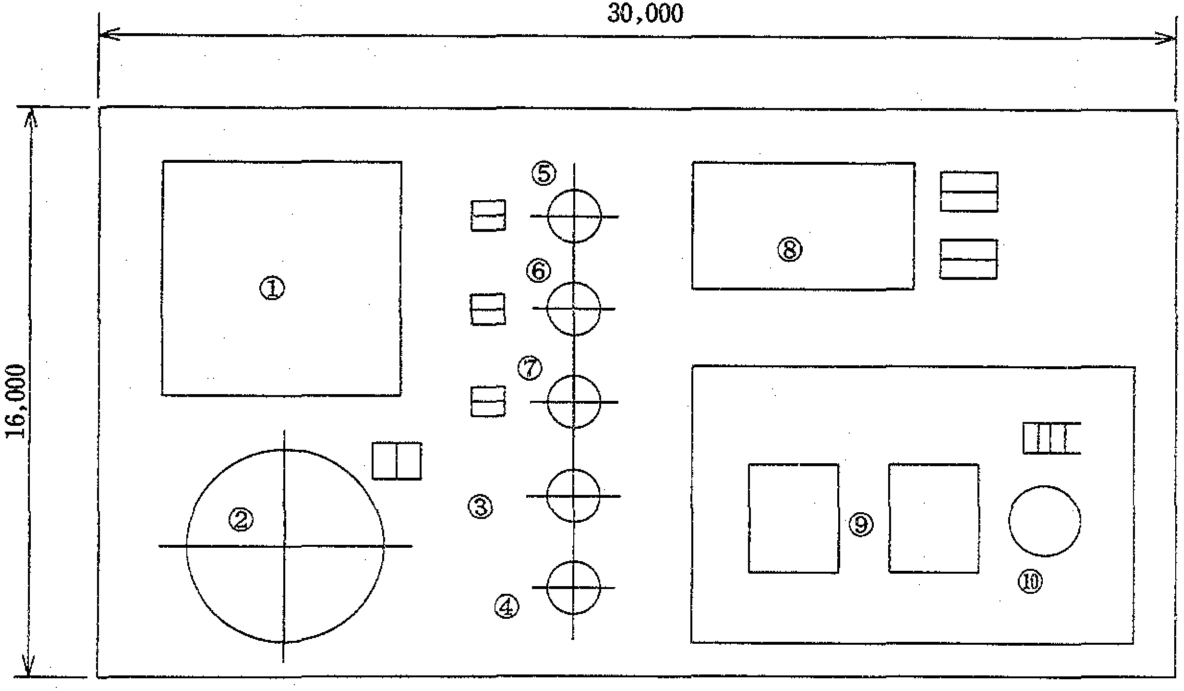
P-101 WASTE WATER PUMP
P-102 SLUDGE DRAWING PUMP
P-103 SLUDGE FEED PUMP

V-101 MIXING HEAD TANK
V-102 COAGULATION TANK
V-103 SEDIMENTATION TANK
V-104 ALUM TANK
V-105 NaOH TANK
V-106 POLYMER TANK
V-107 POLYMER TANK
V-108 CAKE HOPPER

D-101 BELT PRESS

CT-101 WASTE RECEPTION TANK
CT-102 SLUDGE HOLDING TANK

Fig. VII-16 Plot Plan of Waste Water Treatment Facilities (SIOS-ZITEX 1A)

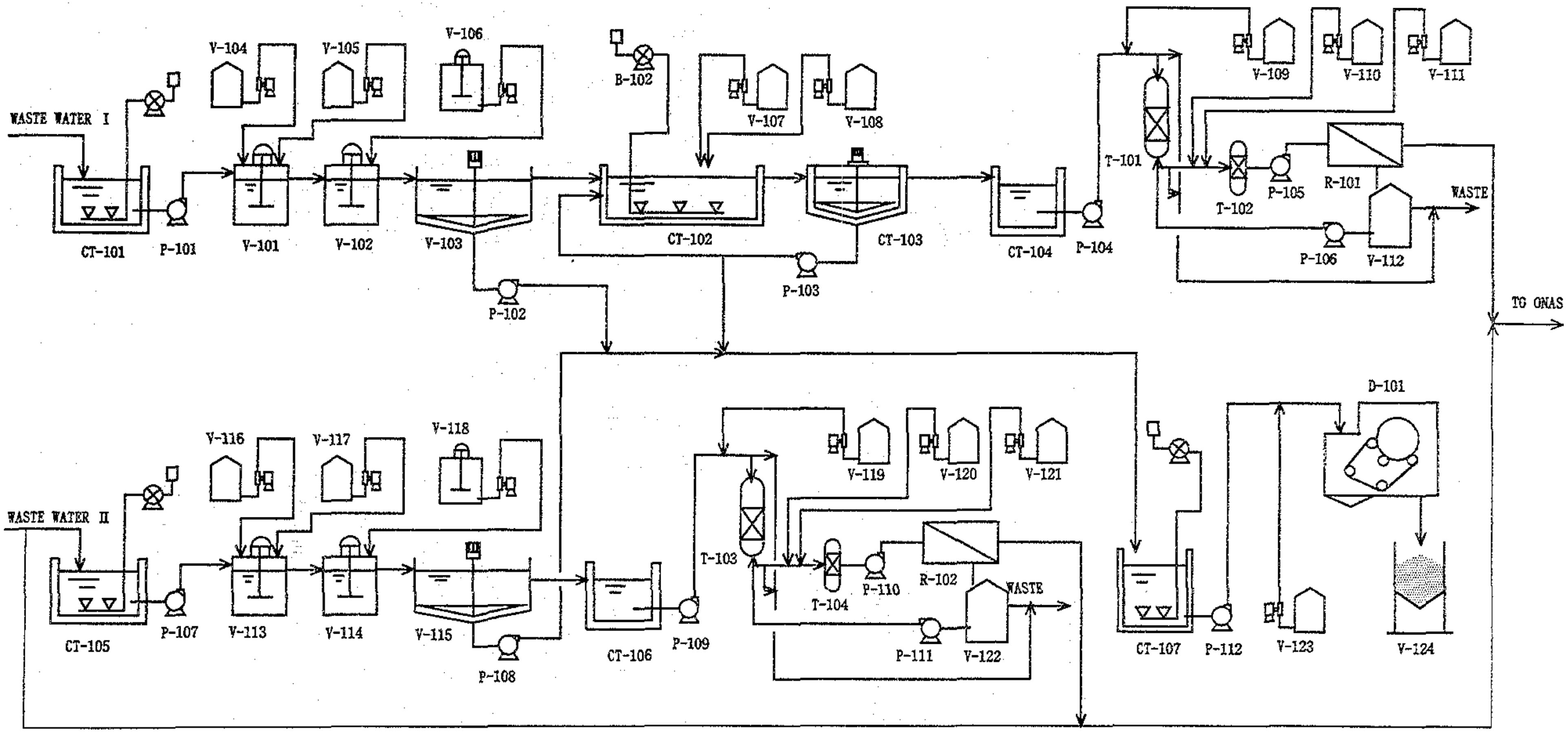


① WASTE WATER TANK
② SEDIMENTATION TANK
③ MIXING HEAD TANK
④ COAGULATION TANK
⑤ ALUM TANK
⑥ NaOH TANK
⑦ POLYMER TANK
⑧ SLUDGE HOLDING TANK
⑨ BELT PRESS
⑩ POLYMER TANK

Table VII-20 Main Equipment List (SIOS-ZITEX 1A)

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks		
1	COAGULATION TREATMENT PLANT					
	CT-101	WASTE WATER TANK	1	50 m³	RC	
	V-101	MIXING HEAD TANK	1	0.5 m³	CS	AGITATER 0.4 kW
	V-102	COAGULATION TANK	1	0.5 m³	CS	AGITATER 0.4 kW
	V-103	SEDIMENTATION TANK	1	1 m²	RC	RAKE 0.2 kW
	V-104	ALUM TANK	1	1 m³		PUMP 0.1 kW
	V-105	NaOH TANK	1	1 m³		PUMP 0.1 kW
	V-106	POLYMER TANK	1	1 m³		PUMP 0.1 kW
	P-101	WASTE WATER PUMP	1+1	0.2 kW		
	P-102	SLUDGE DRAWING PUMP	1+1	0.2 kW		
2	SLUDGE DEWATERING PLANT					
	CT-102	SLUDGE HOLDING TANK	1	10 m³	RC	BLOWER 0.2 kW
	D-101	BELT PRESS	2	1 m	WIDTH	3.7 kW
	V-108	CAKE HOPPER	1	30 m³	CS	
	V-107	POLYMER TANK	1	2 m³	PUMP 0.2 KW	AGITATER 0.4 kW
	P-103	SLUDGE PUMP	1+1	0.2 kW		

Fig. VII-17 Flow Sheet of Waste Water Treatment Facilities (SIOS-ZITEX 2A)



P-101 WASTE WATER PUMP
P-102 SLUDGE DROWING PUMP
P-103 RETURN SLUDGE PUMP
P-104 FILTER FEED PUMP
P-105 BOOSTER PUMP
P-106 BACK WASH PUMP
P-107 WASTE WATER PUMP
P-108 SLUDGE DRAWING PUMP
P-109 FILTER FEED PUMP
P-110 BOOSTER PUMP PUMP
P-111 BACK WASH PUMP
P-112 SLUDGE FEED PUMP

V-101 MIXING HEAD TANK
V-102 COAGULATION TANK
V-103 SEDIMENTATION TANK
V-104 ALUM TANK
V-105 NaOH TANK
V-106 POLYMER TANK
V-107 CO(NH2)2 TANK
V-108 H3PO4 TANK
V-109 NaOCl TANK
V-110 SCALE INHIVITER TANK
V-111 HCl TANK
V-112 BRINE TANK

V-113 MIXING HEAD TANK
V-114 COAGULATION TANK
V-115 SEDIMENTATION TANK
V-116 ALUM TANK
V-117 NaOH TANK
V-118 POLYMER TANK
V-119 NaClO TANK
V-120 SCALE INHIVITER TANK
V-121 HCl TANK
V-122 BRINE TANK
V-123 POLYMER TAK
V-124 CAKE HOPPER

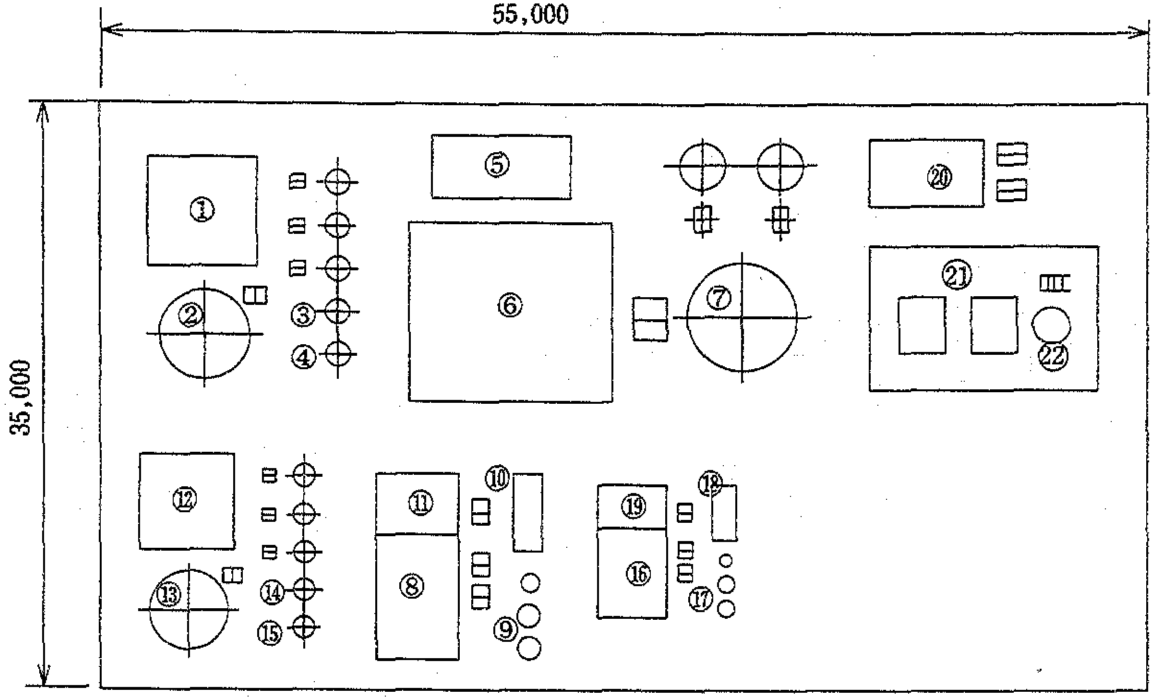
CT-101 WASTE WATER TANK
CT-102 AERATION TANK
CT-103 SEDIMENTATION TANK
CT-104 RECEPTION TANK
CT-105 WASTE WATER TANK
CT-106 RECEPTION TANK
CT-107 SLUDGE HOLDING TANK

T-101 SAND FILTER
T-102 CARTRIGE FILTER
T-103 SAND FILTER
T-104 CARTRIGE FILTER

R-101 RO FILTER
R-102 RO FILTER
D-101 BELT PRESS

B-102 AERATION BLOWER

Fig. VII-18 Plot Plan of Waste Water Treatment Facilities (SIOS-ZITEX 2A)



① WASTE WATER TANK
② SEDIMENTATION TANK
③ MIXING HEAD TANK
④ COAGULATION TANK
⑤ BLOWER HOUSE
⑥ AERATION TANK
⑦ SEDIMENTATION TANK
⑧ RECEPTION TANK
⑨ SAND FILTER
⑩ RO FILTER
⑪ BRINE TANK
⑫ WASTE WATER TANK
⑬ SEDIMENTATION TANK
⑭ MIXING HEAD TANK
⑮ COAGULATION TANK
⑯ RECEPTION TANK
⑰ SAND FILTER
⑱ RO FILTER
⑲ BRINE TANK
⑳ SLUDGE HOLDING TANK
㉑ BELT PRESS
㉒ POLYMER TANK

Table VII-21 Main Equipment List (SIOS-ZITEX 2A) - 1/2

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks		
1	COAGULATION TREATMENT PLANT					
	CT-101	WASTE WATER TANK	1	50 m^3	RC	
	V-101	MIXING HEAD TANK	1	0.5 m^3	CS	AGITATER 0.4 kW
	V-102	COAGULATION TANK	1	0.5 m^3	CS	AGITATER 0.4 kW
	V-103	SEDIMENTATION TANK	1	2 m^2	RC	RAKE 0.1 kW
	V-104	ALUM TANK	1	1 m^3		PUMP 0.1 kW
	V-105	NaOH TANK	1	1 m^3		PUMP 0.1 kW
	V-106	POLYMER TANK	1	1 m^3		PUMP 0.1 kW
	P-101	WASTE WATER PUMP	1+1	0.2 kW		
	P-102	SLUDGE DRAWING PUMP	1+1	0.2 kW		
2	BIOLOGICAL TREATMENT PLANT I					
	CT-102	AERATIN TANK	1	300 m^3	RC	
	CT-103	SEDIMENTATION TANK	1	5.0 m^2	RC	RAKE 0.1 kW
	B-102	AERATIN BLOWER	1+1	15 kW		
	V-107	CO (NH2)2 TANK	1	1 m^3		PUMP 0.1 kW
	P-103	RETURN SLUDGE PUMP	1	0.2 kW		
3	RO PLANT I					
	CT-104	RECEPTION TANK	1	15 m^3	RC	
	T-101	SAND FILTER	2	1000ϕ		
	T-102	CARTRIGE FILTER	1 set	CARTRIGE TYPE		
	R-101	RO FILTER	1set	SDIRAL TYPE 200ϕ x 4 ELEMENTS		
	V-112	BRINE TANK	1	4 m^3	RC	
	V-109	NaClO TANK	1	1 m^3		PUMP 0.1 kW
	V-110	INHIVITER TANK	1	1 m^3		PUMP 0.1 kW
	V-111	HCl TANK	1	1 m^3		PUMP 0.1 kW
	P-104	FILTER FEED PUMP	1+1	0.2 kW		
	P-105	BOOSTER PUMP	1+1	2.2 kW		
	P-106	BACK WASH PUMP	1	0.4 kW		
4	SLUDE DEWATERING PLANT					
	CT-107	SLUDEGE HOLDING TANK	1	10 m^3	RC	BLOWER 0.2 kW
	D-101	BELT PRESS	2	1 m	WIDTH	3.7 kW
	V-124	CAKE HOPPER	1	30 m^3	CS	
	V-123	POLYMER TANK	1	1 m^3	PUMP 0.1 kW	AGITATER 0.2 kW
	P-112	SLUDGE PUMP	1+1	0.2 kW		
5	COAGULATION TREATMENT PLANT II					
	CT-105	WASTE WATER TANK	1	150 m^3	RC	
	V-113	MIXING HEAD TANK	1	1.0 m^3	CS	AGITATER 0.4 kW
	V-114	COAGULATION TANK	1	1.0 m^3	CS	AGITATER 0.4 kW
	V-115	SEDIMENTATION TANK	1	20 m^2	RC	RAKE 0.1 kW
	V-116	ALUM TANK	1	1 m^3		PUMP 0.1 kW
	V-117	NaOH TANK	1	1 m^3		PUMP 0.1 kW
	V-118	POLYMER TANK	1	1 m^3		PUMP 0.1 kW
	P-107	WASTE WATER PUMP	1+1	0.2 kW		

Table VII-21 Main Equipment List (SIOS-ZITEX 2A) - 2/2

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks
6	RO PLANT II			
	CT-106	RECEPTION TANK	1	15 m^3 RC
	T-103	SAND FILTER	1	1200ϕ
	T-104	CARTRIGE FILTER	1 set	CARTRIGE TYPE
	R-102	RO FILTER	1 set	SPIRAL TYPE 200ϕ x 10 ELEMENTS
	V-122	BRINE TNAK	1	4 m^3 RC
	V-119	NaClO TANK	1	1 m^3 PUMP 0.1 kW
	V-120	INHIVITER TANK	1	1 m^3 PUMP 0.1 kW
	V-121	HCl TANK	1	1 m^3 PUMP 0.1 kW
	P-109	FILTER FEED PUMP	1+1	0.2 kW
	P-110	BOOSTER PUMP	1+1	5.5 kW
	P-111	BACK WASH PUMP	1	0.4 kW

• SZT-54	3,600 Nm^3/H	3 × 2
• SZT-55	1,800 Nm^3/H	2 × 2
• SZT-56	3,900 Nm^3/H	3 × 3
• SZT-57	6,000 Nm^3/H	4 × 3

Note: There are 2 boilers of the same capacity for SZT- 56 and 57 respectively in addition to the one measured and therefore the cyclone capacity is 3 times the value calculated from the measured value.

3.5 SATHOP

(1) Waste water treatment

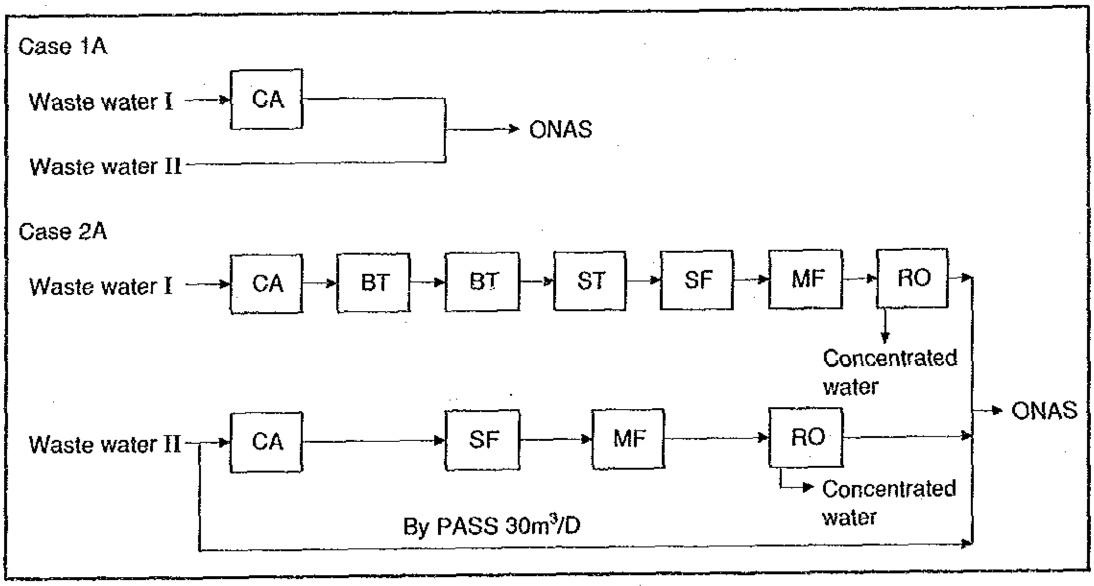
As in the case of SIOS-ZITEX, quality of waste water is shown in Table VII-22.

Table VII-22 Quality of Waste Water (SATHOP)

STREAM NO.	FLOW m^3/D	COD mg/l	Cl mg/l	SO_4 mg/l
I	54	14267	6259	3282
II	140	356	7312	3259

Block flow of each case is shown in Table VII-23

Table VII-23 Block Flow Sheet (SATHOP)



Concentrated water generated from RO is as shown below:

	Water volume	Cl concentration	SO_4 concentration
Waste water of Stream I	14 m^3/D	24,000 mg/*l*	13,000 mg/*l*
Waste water of Stream II	28 m^3/D	28,000 mg/*l*	13,000 mg/*l*
Total	42 m^3/D	27,000 mg/*l*	13,000 mg/*l*

Detailed flow sheet and layout are shown in Fig. VII-19, 20, 21 and 22, and list of equipment in Table VII-24 and 25.

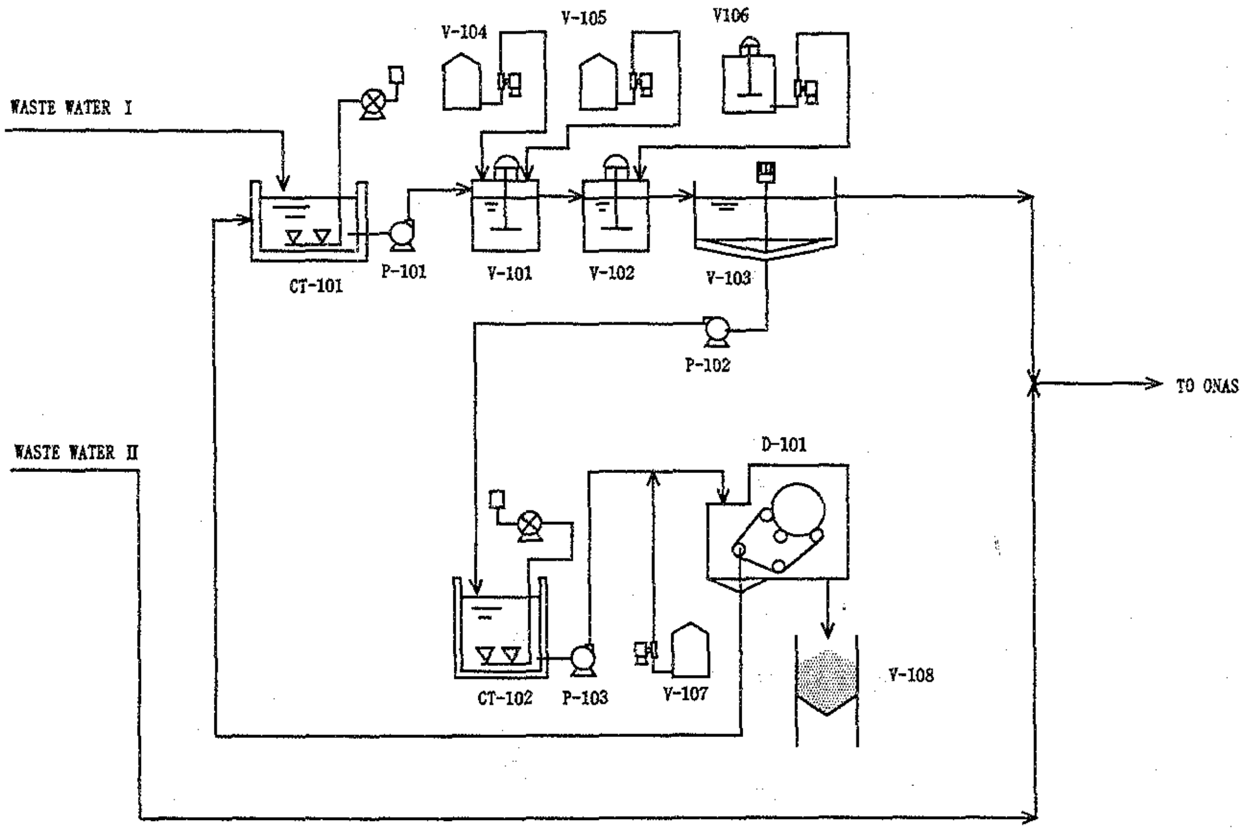
(2) Exhaust gas treatment

It was planned that exhaust gas from 2 dry furnaces and boiler is treated with a multi-cyclone.

Capacity and number of cyclones of each facility are shown below. Major dimensions are shown in Table VII-13.

• STP-51	3,600 Nm^3/H	3 × 2
• STP-52	3,600 Nm^3/H	3 × 2
• STP-53	21,000 Nm^3/H	7 × 6

Fig. VII-19 Flow Sheet of Waste Water Treatment Facilities (SATHOP 1A)



P-101 WASTE WATER PUMP
P-102 SLUDGE DRAWING PUMP
P-103 SLUDGE FEED PUMP

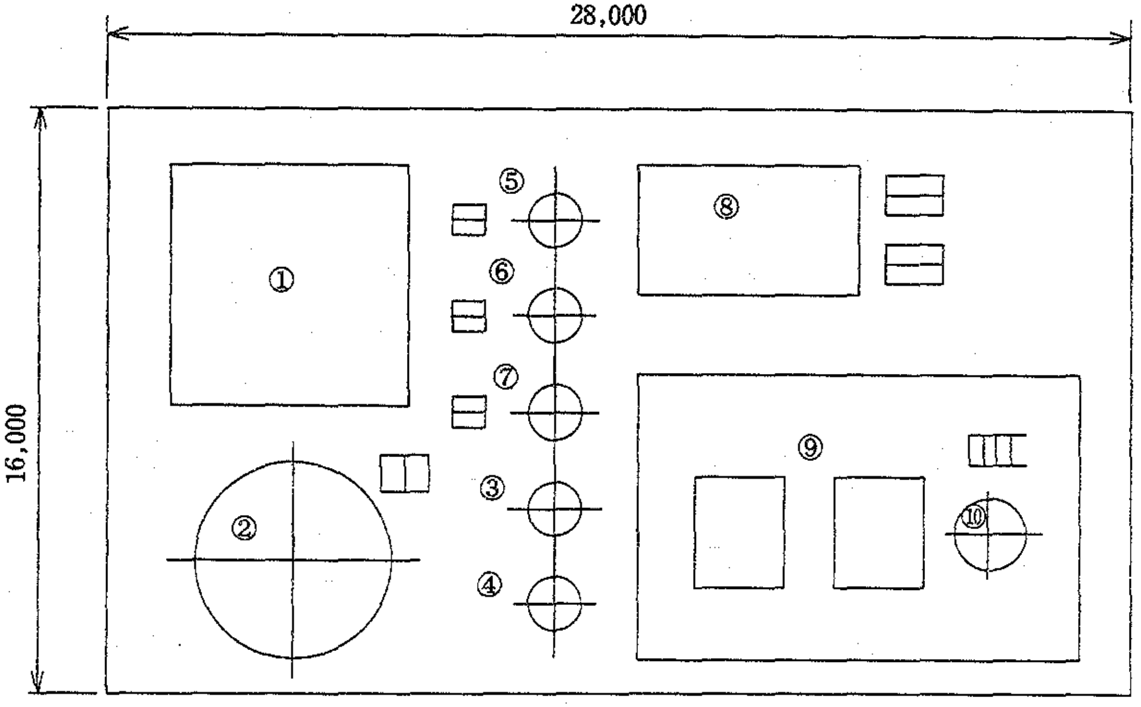
V-101 MIXING HEAD TANK
V-102 COAGULATION TANK
V-103 SEDIMENTATION TANK
V-104 ALUM TANK
V-105 NaOH TANK
V-106 POLYMER TANK
V-107 POLYMER TANK
V-108 CAKE HOPPER

D-101 BELT PRESS

B-102 AERATION BLOWER

CT-101 WASTE WATER TANK
CT-102 SLUDGE HOLDING TANK

Fig. VII-20 Plot Plan of Waste Water Treatment Facilities (SATHOP 1A)

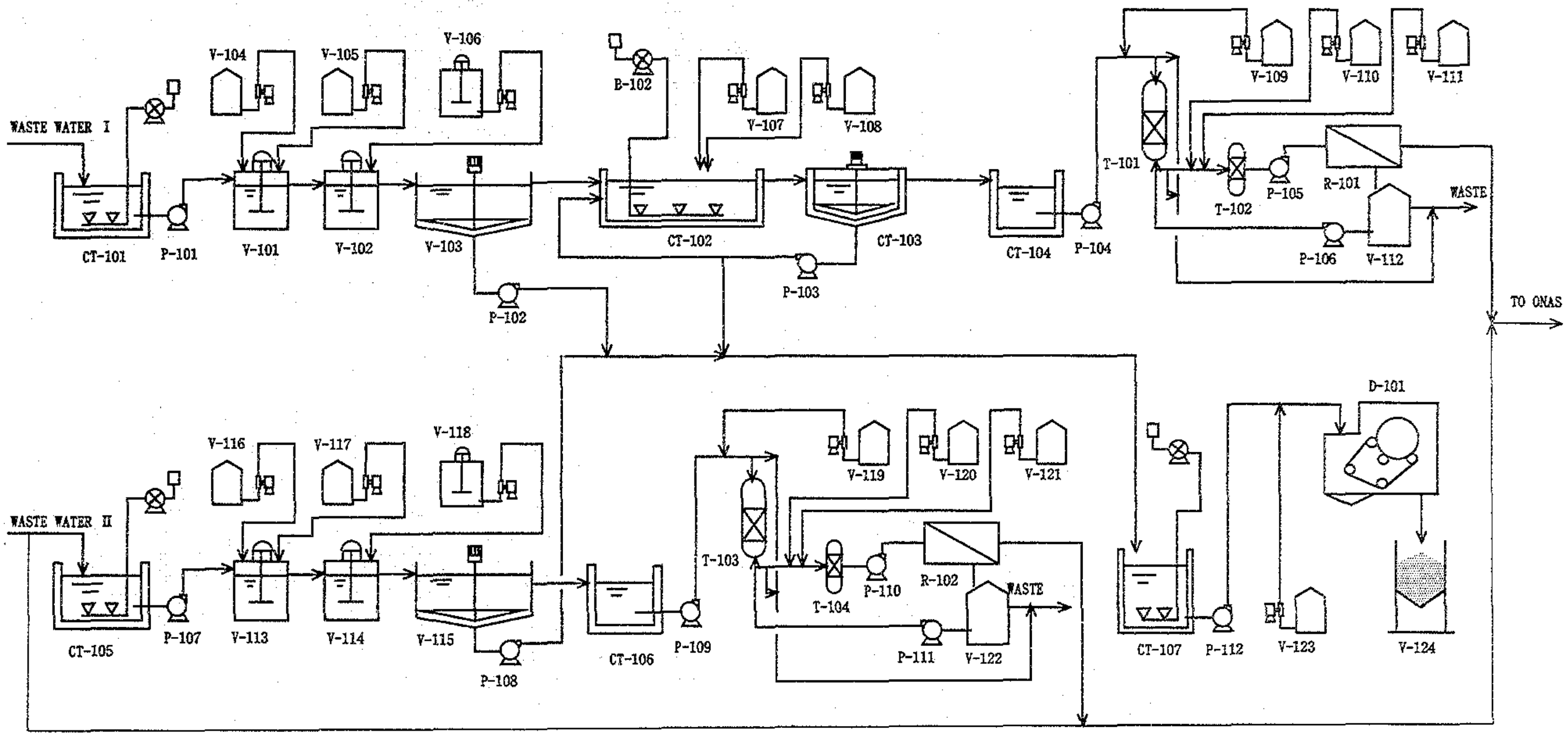


① WASTE WATER TANK
② SEDIMENTATION TANK
③ MIXING HEAD TANK
④ COAGULATION TANK
⑤ ALUM TANK
⑥ NaOH TANK
⑦ POLYMER TANK
⑧ SLUDGE HOLDING TANK
⑨ BELT PRESS
⑩ POLYMER TANK

Table VII-24 Main Equipment List (SATHOP 1A)

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks		
1	COAGULATION TREATMENT PLANT					
	CT-101	WASTE WATER TANK	1	50 m^3	RC	
	V-101	MIXING HEAD TANK	1	0.4 m^3	CS	AGITATER 0.4 kW
	V-102	COAGULATION TANK	1	0.4 m^3	CS	AGITATER 0.4 kW
	V-103	SEDIMENTATION TANK	1	2.3 m^2	RC	RAKE 0.2 kW
	V-104	ALUM TANK	1	1 m^3		PUMP 0.1 kW
	V-105	NaOH TANK	1	1 m^3		PUMP 0.1 kW
	V-106	POLYMER TANK	1	1 m^3		PUMP 0.1 kW
	P-101	WASTE WATER PUMP	1+1	0.2 kW		
	P-102	SLUDGE DRAWING	1+1	0.2 kW		
2	SLUDGE DEWATERING PLANT					
	CT-102	SLUDGE HOLDING TANK	1	10 m^3	RC	BLOWER 0.2 kW
	D-101	BELT PRESS	2	1 m	WIDTH	3.7 kW
	V-108	CAKE HOPPER	1	30 m^3	CS	
	V-107	POLYMER TANK	1	2 m^3	PUMP 0.2 KW	AGITATER 0.4 kW
	P-103	SLUDGE PUMP	1+1	0.2 kW		

Fig. VII-21 Flow Sheet of Waste Water Treatment Facilities (SATHOP 2A)



P-101 WASTE WATER PUMP
P-102 SLUDGE DROWING PUMP
P-103 RETURN SLUDGE PUMP
P-104 FILTER FEED PUMP
P-105 BOOSTER PUMP
P-106 BACK WASH PUMP
P-107 WASTE WATER PUMP
P-108 SLUDGE DRAWING PUMP
P-109 FILTER FEED PUMP
P-110 BOOSTER PUMP PUMP
P-111 BACK WASH PUMP
P-112 SLUDGE FEED PUMP

V-101 MIXING HEAD TANK
V-102 COAGULATION TANK
V-103 SEDIMENTATION TANK
V-104 ALUM TANK
V-105 NaOH TANK
V-106 POLYMER TANK
V-107 CO(NH2)2 TANK
V-108 H3PO4 TANK
V-109 NaOCl TANK
V-110 SCALE INHIVITER TANK
V-111 HCl TANK
V-112 BRINE TANK

V-113 MIXING HEAD TANK
V-114 COAGULATION TANK
V-115 SEDIMENTATION TANK
V-116 ALUM TANK
V-117 NaOH TANK
V-118 POLYMER TANK
V-119 NaClO TANK
V-120 SCALE INHIVITER TANK
V-121 HCl TANK
V-122 BRINE TANK
V-123 POLYMER TAK
V-124 CAKE HOPPER

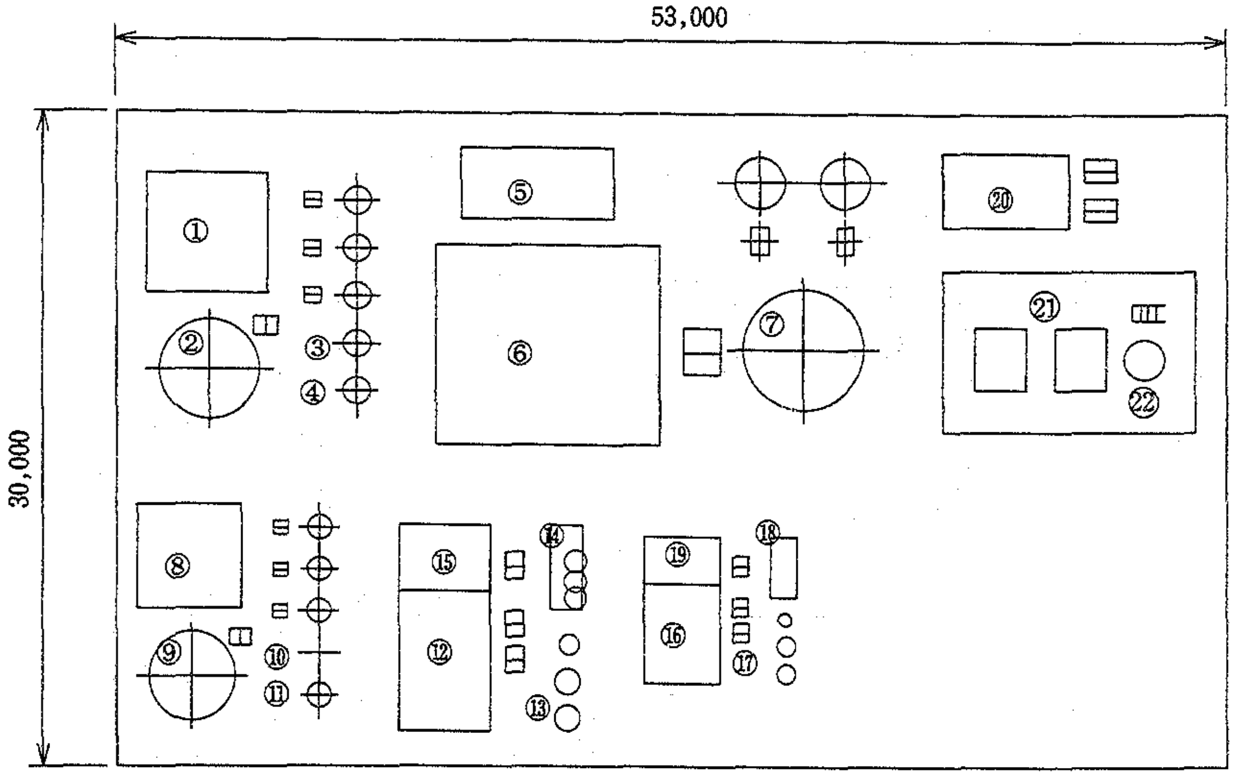
CT-101 WASTE WATER TANK
CT-102 AERATION TANK
CT-103 SEDIMENTATION TANK
CT-104 RECEPTION TANK
CT-105 WASTE WATER TANK
CT-106 RECEOTION TANK
CT-107 SLUDGE HOLDING TANK

T-101 SAND FILTER
T-102 CARTRIGE FILTER
T-103 SAND FILTER
T-104 CARTRIGE FILTER

R-101 RO FILTER
R-102 RO FILTER
D-101 BELT PRESS

B-102 AERATION BLOWER

Fig. VII-22 Plot Plan of Waste Water Treatment Facilities (SATHOP 2A)



① WASTE WATER TANK
② SEDIMENTATION TANK
③ MIXING HEAD TANK
④ COAGULATION TANK
⑤ BLOWER HOUSE
⑥ AERATION TANK
⑦ SEDIMENTATION TANK
⑧ RECEPTION TANK
⑨ SAND FILTER
⑩ RO FILTER
⑪ BRINE TANK
⑫ WASTE WATER TANK
⑬ SEDIMENTATION TANK
⑭ MIXING HEAD TANK
⑮ COAGULATION TANK
⑯ RECEPTION TANK
⑰ SAND FILTER
⑱ RO FILTER
⑲ BRINE TANK
⑳ SLUDGE HOLDING TANK
㉑ BELT PRESS
㉒ POLYMER TANK

Table VII-25 Main Equipment List (SATHOP 2A) - 1/2

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks
1	COAGULATION TREATMENT PLANT			
	CT-101	WASTE WATER TANK	1	50 m^3 RC
	V-101	MIXING HEAD TANK	1	0.4 m^3 CS AGITATER 0.4 kW
	V-102	COAGULATION TANK	1	0.4 m^3 CS AGITATER 0.4 kW
	V-103	SEDIMENTATION TANK	1	2.3 m^2 RC RAKE 0.2 kW
	V-104	ALUM TANK	1	1 m^3 PUMP 0.1 kW
	V-105	NaOH TANK	1	1 m^3 PUMP 0.1 kW
	V-106	POLYMER TANK	1	1 m^3 PUMP 0.1 kW
	P-101	WASTE WATER PUMP	1+1	0.2 kW
	P-102	SLUDGE DRAWING PUMP	1+1	0.2 kW
2	BIOLOGICAL TREATMENT PLANT I			
	CT-102	AERATIN TANK	1	360 m^3 RC
	CT-103	SEDIMENTATION TANK	1	5.6 m^2 RC RAKE 0.1 kW
	B-102	AERATIN BLOWER	1+1	18.5 kW
	V-107	CO (NH2)2 TANK	1	1 m^3 PUMP 0.1 kW
	V-108	H3P04 TANK	1	1 m^3 PUMP 0.1 kW
	P-103	RETURN SLUDGE PUMP	1	0.2 kW
3	RO PLANT I			
	CT-104	RECEPTION TANK	1	18 m^3 RC
	T-101	SAND FILTER	2	800ϕ
	T-102	CARTRIGE FILTER	1 set	CARTRIGE TYPE
	R-101	RO FILTER	1set	SDIRAL TYPE 200ϕ x 4 ELEMENTS
	V-112	BRINE TANK	1	5 m^3 RC
	V-109	NaClO TANK	1	1 m^3 PUMP 0.1 kW
	V-110	INHIVITER TANK	1	1 m^3 PUMP 0.1 kW
	V-111	HCl TANK	1	1 m^3 PUMP 0.1 kW
	P-104	FILTER FEED PUMP	1+1	0.2 kW
	P-105	BOOSTER PUMP	1+1	2.2 kW
	P-106	BACK WASH PUMP	1	0.4 kW
4	SLUDE DEWATERING PLANT			
	CT-107	SLUDEGE HOLDING TANK	1	10 m^3 RC BLOWER 0.2 kW
	D-101	BELT PRESS	2	1 m WIDTH 3.7 kW
	V-124	CAKE HOPPER	1	23 m^3 CS
	V-123	POLYMER TANK	1	1 m^3 PUMP 0.1 kW AGITATER 0.2 kW
	P-112	SLUDGE PUMP	1+1	0.2 kW

Table VII-25 Main Equipment List (SATHOP 2A) - 2/2

No.	Equip. No.	Name of Equipment	No. of REQ'D	Remarks	
5	COAGULATION TREATMENT PLANT II				
	CT-105	WASTE WATER TANK	1	100 m^3 RC	
	V-113	MIXING HEAD TANK	1	0.8 m^3 CS	AGITATER 0.4 kW
	V-114	COAGULATION TANK	1	0.8 m^3 CS	AGITATER 0.4 kW
	V-115	SEDIMENTATION TANK	1	4.6 m^2 RC	RAKE 0.1 kW
	V-116	ALUM TANK	1	1 m^3	PUMP 0.1 kW
	V-117	NaOH TANK	1	1 m^3	PUMP 0.1 kW
	V-118	POLYMER TANK	1	1 m^3	PUMP 0.1 kW
	P-107	WASTE WATER PUMP	1+1	0.2 kW	
	P-108	SLUDGE DRAWING PUMP	1+1	0.2 kW	
6	RO PLANT II				
	CT-106	RECEPTION TANK	1	20 m^3 RC	
	T-103	SAND FILTER	1	1100ϕ	
	T-104	CARTRIGE FILTER	1 set	CARTRIGE TYPE	
	R-102	RO FILTER	1 set	SPIRAL TYPE 200ϕ x 10 ELEMENTS	
	V-122	BRINE TNAK	1	9 m^3 RC	
	V-119	NaClO TANK	1	1 m^3	PUMP 0.1 kW
	V-120	INHIVITER TANK	1	1 m^3	PUMP 0.1 kW
	V-121	HCl TANK	1	1 m^3	PUMP 0.1 kW
	P-109	FILTER FEED PUMP	1+1	0.2 kW	
	P-110	BOOSTER PUMP	1+1	5.5 kW	
	P-111	BACK WASH PUMP	1	0.4 kW	