2. Review of the Current Wastewater Treatment and Reclamation Systems

2.1 Evaluation and Problems Concerning the Current Systems

The outlines of the present wastewater treatment plants are as described in "1.5 Conditions of Wastewater Treatment Plants".

It is also described above that there are no plating factories which perform wastewater reclamation, and in any of the central wastewater treatment plants in the 1st Estate Section and the 2nd Estate Section, wastewater reclamation is not done. Therefore, in this chapter, an evaluation of the central wastewater treatment plants will be made and some problems with them will be extracted.

The facilities in each central wastewater treatment plant of this plating industry estate comprise three systems: a system to receive wastewater discharged from each factory after being classified as three, (1) cyanide wastewaters, (2) chrome wastewaters and (3) acid-alkali wastewaters and treat them to be harmless; a system to remove organic substances such as COD, BOD, etc. remaining in the treated water; and a system to remove heavy metals in the form of chelate compounds which might remain in trace amounts after treatment.

For the sludge generated by wastewater treatment, a system which dehydrates the sludge and carries the dehydrated cake to the outside for entrusted disposition is adopted.

The wastewater treatment plant is a rational one which treats the overall wastewaters of the plating industrial estate safely and discharges the treated water finally to the public sewage system.

CN → Decomposition →
Cr → Reduction →　　　Dewatering → Disposal
H·OH → Neutralization → Sedimentation → Rapid Filter
→ Activated Carbon → Ion Exchange resin → Chelate Resin → Effluent

However, the wastewater treatment plant treats not only wastewaters discharged from plating factories located in the plating industrial estate, but also it is operated as an industrial waste treatment plant which receives wastewaters transported by tank lorry from plating factories located outside the plating industrial estate and treats and disposes of them for a consideration. Therefore, there are problems in the operation and maintenance of the wastewater treatment plant by the operators who have to address wastewater quantity and quality variations appropriately.

With the above-mentioned situations in mind, problems in the present wastewater treatment facilities will be extracted, and some fundamental ones of them will be described below.

(1) Receiving of wastewaters

Although scrupulous care is taken by most plating factories located in the plating industrial estate in discharging wastewaters, it seems that classified discharge of wastewaters is not done adequately in some factories. Cyanide washing and chrome washing are done in the same washing tank in some factories, and, water spilled over the floor is not separated in some factories, showing that classified discharge of wastewaters is not adequate. The fact that among many factories of the plating industrial estate some such factories exist is the problem unique to the wastewater treatment in the early plating industrial estates which was frequently seen also in Japan.

A. Classification of wastewaters

Based on the results of analysis of samples taken from each wastewater tank in the wastewater treatment plant in the visiting survey at the site, the following problems are pointed out.

a. The wastewater in the cyanide tank has to have alkaline pH, but it is as low as 2.07 in the wastewater treatment plant of the 1st Estate Section and 1.84 in the wastewater treatment plant of the 2nd Estate Section. However, 6-valent chromium is not detected.

b. Cyanide is detected in the wastewater of the chrome wastewater tank, 170 mg/l in the wastewater treatment plant of the 1st Estate Section and 113 mg/l in the wastewater treatment plant of the 2nd Estate Section.

c. Cyanide is detected in the acid-alkali wastewater tank, 127 mg/l in the wastewater treatment plant of the 1st Estate Section and 116 mg/l in the wastewater treatment plant of the 2nd Estate Section. However, 6-valent chromium is not detected.

From the foregoing, it is shown that classification of waste waters is not done adequately. The probable causes are as follows:

a. As is reported in "1.6 Other Related Conditions", the same washing tank is used in common for different wastewater systems in some plating factories. This is a problem prior to wastewater classification.

b. Classification of wastewaters is not done adequately by each factory before being discharged.

c. The wastewater received as industrial waste for treatment is already a mixture of various wastewaters.

d. The wastewater is received as industrial waste in an improper receiving tank by mistake or because of the proper receiving tank being full.

From the fact that the wastewater in the cyanide wastewater tank has an acidic pH, it is estimated that much acid wastewater is mixed. If the wastewater in the cyanide wastewater tank has pH on the acid side because of acidic wastewater being mixed, cyanide compounds in the wastewater are decomposed to generate harmful gases very dangerously. Moreover, if a cyanide wastewater is mixed in a chromium wastewater, or a cyanide wastewater is mixed in an acid-alkali wastewater, it is anticipated that the mixture wastewater can be treated only insufficiently in this wastewater treatment plant. Such a situation is reflected on the results of analysis on the samples taken from each treatment process of the wastewater treatment plant. For example, heavy metals such as copper, nickel and zinc and cyanide are detected in the sedimentation tank. Final discharge under this condition is not permissible, and retreatment is necessitated. This will lead to an increased treatment cost and also interfere with treating other wastewaters in time. Therefore, the operator in charge of operation and maintenance is given a serious problem to treat them properly.

B. Receiving of Wastewaters for Industrial Waste Treatment Business

S Co., Ltd. receives wastewaters of plating factories located outside the plating industrial estate and treats them in the wastewater treatment plant as an industrial waste treatment business. It seems that there is a problem in the way the wastewaters are received.

At the early time, wastewater analysis was made when the wastewater was received and how to treat in the wastewater treatment plant was fully investigated. Subsequently, however, it is naturally expected that the wastewater quantity and quality of plating factories would have been varied. Moreover, there is a possibility that classification would not be done adequately.

In the practice of industrial waste treatment enterprises in Japan, wastewaters brought in to be treated are analyzed each time, and only after the treatability is confirmed, these wastewaters are received.

Even in this central wastewater treatment plant, it is essential to receive wastewaters into the tank only after their composition is analyzed. This is because there is a possibility that any substances whose treatment with this wastewater treatment plant is difficult are contained or any other different wastewaters are mixed. If it is attempted without removing these substances to treat the wastewater, the treated water quality may not be satisfactory. Moreover, by confirming the concentration, it is possible to realize proper treatment cost.

C. Wastewater tanks

For each kind of wastewaters, one receiving tank is provided. From each plating factory surveyed by visiting, the bath liquor is discharged although the frequency of bath liquor renewal is as low as about once a year. The bath liquor to be discharged is degraded, but its concentration is high. Therefore, if this liquor is discharged, the wastewater concentration in the tank rapidly rises. Then, in the wastewater treatment plant, quantities of chemicals to be fed in the treatment processes such as neutralization, oxidation, reduction, etc. are increased, and if the pump capacities are not sufficient, incomplete treatment may result.
If concentrate acid and alkali wastewaters are discharged simultaneously into the acid-alkali wastewater tank, then much neutralization heat will be generated dangerously. Moreover, there is a possibility of the tank being damaged.

(2) Wastewater treatment system

If any unsatisfactories exist in the wastewater treatment system, it will cause incomplete wastewatger treatment.

A. Treatment of cyanide complexes
Cyanide complexes of nickel and cyanide complexes of iron are not treated in this wastewater treatment system.
a. Cyanide complexes of nickel
Cyanide complexes of nickel can be decomposed with sodium hypochlorite, but the reaction is very slow (24 hours).
Therefore, it is necessary to take care not to allow them to be mixed in the continuous treatment system. Nickel and, cyanide are detected in the sedimentation tank of the waste water treatment plant in the 1st Estate Section. It is esti mated that nickel is in the form of cyanide complexes. If cyanide complexes of nickel are mixed, the

wastewater should be treated separately without using this continuous treatment system.

b. Cyanide complexes of lion

Cyanide complexes of iron can hardly be decomposed with sodium hypochlorite. They cannot be removed completely by adsorption on chelate risins. When cyanide treatment is unsatisfactory in the plating wastewater treatment process, cyanide complexes of iron are detected frequently. The probable cause is that raw material iron fallen in the plating tank is eluted to form cyanide complexes of iron which are then dragged out into the plating wastewater. If cyanide complexes of lion are mixed, the wastewater should be treated separately without using this continuous treatment system, or a unit operation for that purpose should be added to this treatment system.

B. pH meter in the chrome reduction tank

In the chrome reduction tank, a pH meter should be installed together with an ORP meter.

The oxidation-reduction potential (concentration) and the hydrogen ion concentration are measured. As the reducing agent is added in the wastewater, pH is also varied. Therefore, in order to control (on-off) the addition of the reducing agent in terms of the ORP value, it is necessary to keep pH constant. This requires pH control.

C. Addition of aluminum sulfate

In the case of this wastewater treatment system, the wastewater containing heavy metals is introduced first into the neutralization tank where alkali treatment is done so that heavy metals are precipitated as hydroxide. In the following reaction tank, aluminum sulfate and calcium hydroxide are added. The probable reason is to improve the coagulability.

For aluminum to form hydroxide, it is proper that pH is nearly in the neutral range. Flocs of formed aluminum hydroxide improve the coagulability of the plating sludge which is liable to be fine particles. However, if pH is lowered with the sludge contained, heavy metals which were precificated as hydroxides might be redissolved. In this respect, a safer

system will be such that, following the solid-liquid separation in the sedimentation tank, aluminum sulfate is again added for solid-liquid separation. The addition of aluminum sulfate increases sludge generation.
However, the actual wastewater treatment processes are different in many points from the theoretical, and if good treated water quality is obtained with co-precipitation, there will be no specific problems to be taken up.

D. pH meter in the water monitoring tank
While the treated water is being discharged, the water monitoring tank does not serve for monitoring. It is necessary to store the treated water in a tank so that it can be observed visually and to install a pH meter to monitor and record the pH value.

E. Separate treatment of non-electroplating liquor, etc.
The non-electroplating liquor sometimes has a high COD concentration ammonia. It is proper that this wastewater should not be mixed with general wastewaters, but be treated separately. The same applies to the wastewater containing chelating agents.

(3) Facilities

In this wastewater treatment plant, at the beginning, various tanks and unit apparatus were arranged in a rational way in the narrow area, but as the time lapses, it seems that various tanks were added too crowdedly. This trend is seen in the wastewater treatment plant of the 1st Estate Section.

The wastewater treatment plant involves chemical dissolution and other works, and therefore, the control panel, together with the dehydrator room, etc., should be installed preferably in a separate room.

For the ease of operation and safety of the workers, it is also important to secure passways and stepways with hand rails.

The wastewater tanks are constructed as underground tanks with manholes for effective utilization of the area in the estate section.

Changes will also be necessary to this construction which facilitate water level confirmation, crack checking, tank cleaning, etc. by the workers.

(4) Operation

The workers working in the operation of the wastewater treatment plant face many difficult problems in the plant operation because of severe variations in water quantity and quality of the wastewaters received.

It seems that the workers are forced to spend their time in coping with the treatment of wastewaters of which treatment is entrusted from outside, retreatment of wastewaters which were incompletely treated, etc. in addition to the normal operation.

It is the present state that various wastewater tanks and reaction tanks for various wastewaters are cleverly managed so as to treat the total quantity of wastewaters in any way. As a matter of course, substitute reaction tanks have no control apparatus enough for such management. The operation in this case will possibly lead to incomplete treatment. Moreover, under these circumstances, the number of workers engaged in the wastewater treatment cannot but be larger than that necessary for stable operation. Radical measures considering the characteristics of the industrial waste treatment business are to be taken.

(5) Maintenance

It is seen sometimes that the sensor of the ORP meter installed in the reaction tank is defective. It is the essential rule of the maintenance to replace the defective sensor before it interferes with normal treatment.

Now, electrodes which are hardly corroded with fluorine are available. It is preferable to use them.

2.2 Proposal for the Improvement of the Current Systems

The treatment system of the present central wastewater treatment plant is a rational one, and extracted problems are caused mainly by the discharge of incompletely classified waste-waters and the operating method of facilities.

Plating wastewaters are one of the industrial wastewaters which should be treated with most scrupulous care. Moreover, wastewaters of the plating industrial estate are overall waste-waters comprising various wastewaters discharged from many plating factories, and their properties are very complicated. In addition, since the same wastewater treatment plant is also used for the industrial waste treatment business, advanced technology is required.

From the foregoing, the central wastewater treatment plant as the receiving side requests the following prerequisites. Not only in the plating factories located in the plating industrial estate, but also in the plating factories located outside the plating industrial estate, wastewaters should be discharged after being classified and their sources of discharge should be clearly identified.

Plating factories are small enterprises and have no sufficient money to spare in Korea, as well as in Japan and Europe and America.

Considering the present state mentioned above, improvement plans to address the extracted points by making use of the existing facilities will be proposed.

(1) Consolidation of the laboratory

With the objectives of receiving of wastewaters, confirming of wastewater treatability, and research and development of wastewater treatment technology and plating technology, the laboratory should preferably be consolidated as follows.

1) Collection of data concerning the composition of wastewa ters by kinds and treatment technology
2) Installation of automatic analyzers
   Common: pH meter, ORP meter, conductivity meter, absorption-

metry meter, etc.

Heavy metals: Atomic absorptionmetry meter, inductively coupled plasma-atomic emission spectroscopy (ICP) analyzer

Anion: Ion chromatography

Cyanide: Cyanide automatic analyzer (capable of confirming of complexes)

3) Training of engineers

(2) Improvement of wastewater tanks

1) Separation of acid-alkali wastewater tanks into acid wastewater tanks and alkali wastewater tanks

2) Installation of high concentration wastewater tanks for each kind of wastewaters, or division of existing tanks

High concentration wastewaters should be treated at a small rate together with low concentration wastewaters, or must be utilized effectively for neutralization of alkali wastewaters.

(3) Treatment of wastewaters containing cyanide complexes of iron

With the present wastewater treatment system, it cannot be expected to treat cyanide in the wastewaters containing cyanide complexes of iron.

It is desirable to add a treatment operation using the zinc white method after the present cyanide decomposition process.

For the principles, conditions, etc. of this treatment, refer to "V. Guidelines for Wastewater Treatment and Reclamation".

(4) Addition of some functions to batch reaction tanks

The batch reaction tank (mixing treatment tank) should be improved as follows: pH meter, ORP meter, etc. should be installed; in addition to the present flow diagram comprising sodium hydroxide, sodium hypochlorite, sulfuric acid and high polymer coagulant, it should be possible to feed reducing agents such as calcium hydroxide, inorganic coagulant, sodium sulfite, etc. and other oxidizing agents; and heating should be applicable, so as to cope with treatment of wastewaters which otherwise should be treated separately and recovery of resources.

Treatment to be covered is as follows. For the principles of treatment, conditions of treatment, etc., refer to the guidelines mentioned later.

1) Treatment of plating bath liquors containing cyanide complexes of nickel
2) Treatment by coagulation and sedimentation of cleaning liquors and stripping liquors containing heavy metal complexes
3) COD oxidation treatment by the Fenton method of non-electroplating liquors, and coagulation treatment of phosphorus
4) Treatment of fluoborate
5) Treatment of organic solvent containing wastewaters and chelate containing wastewaters and treatment of COD and BOD by the powdered activated carbon adsorption method
6) Ferrite formation of heavy metals
7) Recovery of EDTA from cleaning liquors and stripping liquors containing EDTA

(5) Automation

1) Installation of water level meters in the wastewater tanks
   To indicate water level and be operated jointly with on-off pump operation.
2) To be operated jointly with high polymer coagulant feed pump and storage pump.
3) Installation of graphic panels which display the present state.

Table 2.2.1. shows the improvement and problems of the current systems mentioned above.

Table 2.2.1. Points at issue and retoem measure for the current system

Items	Points at Issue	Proposal for the improvement
Receaving of wastewater	the discharge of incompletely classified waste water	1) education of workers 2) surprise Check 3) consolidation of the laboratory · collection of data concerning the composition of wastewater · installation of automatic analyzers · training of engineers 4) enforcement of wastewater analysis from the industrial waste treatment business point
Wastewater treatment system	the incompletly classified wastewater tanks	1) separation of acid-alkali wastewater tank into acid wastewater tank and alkali wastewater tank 2) installation of high concentration wastewater tanks for each kind of wastewaters
	impossible system for treatment of wastewaters containing cyanide complexes of iron	1) addition a treatment unit process by the zinc white after cyanide decomposition process
	lack of a pH meter in the chrome reduction tank	1) installation of a pH meter operated jointly with on-off chemical feed pump operation
	lack of a pH meter in the water momitoring tank	1) installation pf a pH meter with record meter in the water momitoring tank
	incomplete automation	1) installation of water level meter tn the wasteater tanks 2) to be operation jointly with high polymer coagulant feed pump storage pump 3) installation of graphic panels which display the present state
Facilities	unsuitable installation of control panel	1) the control panel should be installed preferably in a separate room
	security	1) passways and stepways with hand rails
	lack of construction of storage tank	1) comstructtion facilitate water level confirmation, crack checking, tank cleaning by the workers
	addition of some functions to batch reaction tanks	1) add functions to treat high concentrate wastewater, wastewater containig complexes, fluoborate, organic matters, and to recover EDTA, and use it as ferrite formation process
Operation and maintenance	lack of equipments and consciousness for waste service	1) add to control apparatus 2) carry out the above items
	incomplete maintenance	1) repair 2) collection new technology and new manufactured goods

3. Determination of the Optimum Systems

Industrial estate of S Co. is adopted as a typical example of Korean plating industrial estates. Then, the actual states of its central wastewater treatment plant is surveyed and problems concerning the current system are pointed out.

Though, this survey is a case study of plating industrial estate, it is looking upon as a model of the estate, and optimum systems of the central wastewater treatment plant are determined for the model estate.

3.1 Basic Policies

Selection criteria for optimum system are shown in Table 3.3.1.

(1) The optimum system for wastewater treatment plants will be defined as most economical wastewater treatment system which satisfied pollution related regulations now in effect or expected to be in effect , in Korea. Conceptual design and economic feasibility studies will be carried out on Case-1 and Case-2.

(2) the optimum system for reclamation plants will be defined as most economical system which produces reclaimed water having a quality equal to or better than that of tap water in use. A conceptual design and economic feasibility study will be carried out on Case-3, Case-4 and Case-5 will be reviewed as references.

Table 3.1.1. Criteria for the Selection of the Most Effective System

Case \ Treatment Levels	Existing Standards	High Reduction of COD	Closed system
Wastewater treatment only	CASE－1 ◎	CASE－2 ◎	×
Wastewater treatment and recycling	CASE－3 ◎	CASE－4 ○	CASE－5 ○

Note) ◎ ; Will be selected ○ ; Studied for reference
× ; Will not be selected

The section of the plating industrial estate which was selected for the optimum system study is the 2nd Estate Section. The reasons for this selection are as follows. The 1st Estate Section and the 2nd Estate Section are approximately the same in the number, contents and scale of plating factories located therein and in the central wastewater treatment plant; the 2nd Estate Section is arranged in more compact; about the 2nd Estate Section, more abundant information was furnished; and the 2nd Estate Section treats a smaller quantity of industrial wastes and the present state can be grasped more easily.

The basic policies for this study are as follows:

A. The study for the optimum system will on be limited to central wastewater treatment and reclamation of wastewaters from plating factories located in the estate section, excepting the industrial waste treatment business which is run by S Co., Ltd. at present.
B. Each plating factory has a small working area and it is impossible for each plating factory to have its own wastewater treatment equipment or reclamation equipment. Therefore, wastewaters to be treated will be overall wastewaters of the plating industrial estate.
C. The wastewater quantity and quality to be treated will be estimated from the data obtained by the visiting survey and the various data in Japan.

First, it will be assumed that wastewaters are discharged after being completely classified and the wastewater quantity and quality at that time will be determined and be taken as the present wastewaters. Then, it will be assumed that wastewater quantity reducing measures have been taken and wastewaters are discharged after being classified as high concentration wastewaters discharged when the plating liquor is renewed and as the present washing wastewaters, and the wastewater quantity and quality at that time will be determined and be taken as wastewaters after wastewater quantity reducing measures have been taken. The study for the wastewater treatment system will be made using these wastewaters. Further, washing wastewaters when the counter-current multi-stage washing system is adopted in the washing process will be classified as the semi-high concentration wastewaters and washing wastewaters. These wastewaters will be taken as wastewaters after the counter-current multi-stage washing system, and the reclamation system will be studied using this wastewaters.

D. In order to give generality to the optimum system to be proposed, the local peculiarity of the 2nd Estate Section will be ignored and the place of installation of the treatment facilities will be within Inchon City.

E. In economic calculation of construction cost, running cost, etc., standard prices in Korea taking the installation place into account will be adopted.

3.2 Measures for the Reducion of Wastewater Quantity

3.2.1 Conditions of Water Usage

Table 3.2.1. shows the conditions of water usage in the 10 factories. In this area, there are no facilities for industrial water supply and tap water supply is only the water source available.

These factories are very small in scale; they have an average of 9 employees and an average of 160 m^2 floor areas, and their water consumption is only 4-10 m^3 per day (6 m^3 per day on the average).

Nearly all of the water consumption is used for washing the products in the production processes. Cooling water is used in two factories (No.1 and No.3) out of the 10 factories, but in both cases, it is recycled through the cooling tower and the quantity of make-up water is small. Moreover, each factory of this industrial estate occupies a room of one same building and use toilets, dining rooms, etc. in common. The individual factories use little domestic water and miscellaneous water.

The products are washed in all cases by dipping them in a water tank because their size is small. Most of the water tanks as small as about 10-100 liters.

As shown in Table 3.2.2., the washing system is mostly of multi-stage type using 2-3 water tanks. The "Stored water washing" system where washing water is not run but is stored in the water tank is used mainly, and the "Running water washing" system where the washing water is run during washing is adopted only in two factories.

The water in the washing tank used in the "Stored water washing" system is renewed 1-2 times a day, but it seems that the renewal criteria (such as water quality, number of cycles of washing, quantity of objects to be washed) are defined clearly in few cases. On the other hand, even in the "Running water washing" system, it is hardly considered that the flow of water is strictly controlled, and there is a high probability that excess water will be consumed.

Table 3.2.1 The conditions of water usage in the surveyed factories

Factory No.	Kind of plating process	Working area m^2	No. of workers	Water usage m^3/d	Water usage other than washing water
1	Alumite	96	8	4	Cooling water of refrigerator is recycled by C.T. (ca. 20RT)
2	Cu, Ni, Cr, Cr(B)	220	11	7	
3	Zn, Cu, Ni, Cr, Cr(B)	116	11	6	C.T. (ca. 10RT) is used for cooling of electrolytic tank.
4	Zn perkarizing	198	11	10	Boiler(300kg/h) is used.
5	Cu, Ni, Cr, Cr(B)	182	5	5	
6	Cu, Ni, Cu+Zn, Cr	231	16	5	
7	Ni, Au, Ag	155	10	4	
8	Ni, Au, Ag	130	14	7	
9	Cu(chemica & electrolytic)	170	3	7	
10	Cu(printed circuit)	99	4	6	
		1,597	93	61	

Note : (B) shows Brack chrome plating
: C.T. shows cooling tower

Table 3.2.2 Washing systems of the surveyed factories

Factory No.	Water usage m^3/d	No. of washing process	Flow system	No. of stages	No. of washing tanks	Note
1	4	5	Stored	Multi	400 1x 5	
2	7	5	〃	〃	15～16	
3	6	5	〃	〃	ca. 15	
4	10	3	Flow		single 2, multi 1	Automatic
5	5	8	Stored	Multi	ca. 20	
6	5	5	Flow	〃	17	
7	4	4	〃	〃	50 1x3stagesx4systems	Pure water is used for washing
8	7	6	Stored	〃	ca. 30	
9	7	5	〃	〃		
10	6	9	〃	〃		

Apart from washing water, cooling water is used in two factories as described before. In Factory No.1, chilled water is used for cooling the alumite processing tank, and cooling water is used for cooling the refrigerator to make that chilled water. In Factory No.3, cooling water is used for cooling the plating processing tank. In both cases, the water is recycled through the cooling tower as described before.

Different from alumite treatment, electroplating does not generate too much heat and rarely requires cooling. Therefore, in the future as before, it is hardly considered that cooling water is used in quantities in these factories.

For these factories, the make-up water consumption per employee (specific water consumption) is calculated as follows.

Maximum 2.3, minimum 0.31 and average 0.66
(in m^3 per day per capita)

According to the industrial statistics regarding Japanese factories having 30 or more employees each (1990), the specific water consumption in the electroplating industry is 2.48 m^3 per day per capita which is considerably larger than the value shown in Table 3.2.1.

The probable causes are as follows:

A. In the Japanese industrial statistics, the number of employees per factory is 65; the scale is markedly larger than that of the factories in this survey.
B. In the factories which are large in scale, automatic equipment is introduced normally and productivity is markedly increased. While, in the factories in this survey, manual operation is dominant and productivity is very low.
C. According to the survey data on Japanese five factories having 10 or less employees each, the specific water consumption is 1.66 on the average, significantly lower than that in the industrial statistics given above.

From the foregoing, it is considered that the difference between the data for the surveyed factories and the Japanese industrial statistics is the difference in productivity caused by the difference in factory scale, and it is caused not because the water consumption in the surveyed factories is small but because the number of employees is large for the scale of production.

3.2.2 Basic Conceptions

(1) General

The method of reducing the wastewater quantity suited for a particular factory differs greatly depending on the method of water usage at that factory. In the case of plating factories, water usage is mainly washing as described before. Therefore, this section will discuss the case of washing water. The following features of washing water may be considered:

A. It is used mainly for washing the products, and therefore, its quantity and quality largely affect the quality of the product.
B. Wastewater contains various contaminants produced by washing, and therefore, it is contaminated usually to a considerable degree. In many cases, the water quality determines the water quality of the entire factory's wastewater.

Because of these features, reducing the wastewater quantity in the case of washing water is very difficult as compared with the case of indirect cooling water or air conditioning water whose wastewater is little contaminated. The major methods for wastewater reduction are listed below.

A. Complete implementation of water usage control
B. Adoption of counter-current multi-stage washing system
C. Adoption of cascade use
D. Adoption of automatic water supply system for washing tank
E. Use of hand control valve

These methods will be described below.

(2) Basic Method of Reducing the Washing water

1) Complete implementation of water usage control

This is the most fundamental factor. Its method differs much or less with the conditions of each factory, but in general, can be summarized into the following three points.

A. Complete consciousness of water saving: This aims at complete water saving from the aspect of man's consciousness. It is difficult from the aspect of discipline alone. And it needs education of water saving ,it may be little effective unless the "Working standards" described in C. below have not been established.

B. Accurate estimation of the water consumption: It is the basis for water usage control to know the flow of water at every point of water usage accurately. However, it is impossible to install a flowmeter at every such point, and therefore, it becomes necessary to estimate the water flow by any other convenient means. These means are as follows.
   a. Estimating from the pipe diameter and the velocity of flow
   b. Estimating from the water flow vs. valve opening relationship
   c. Receiving the running water in a container and measuring its quantity
   d. Installing a simple weir in the open conduit to measure the quantity of water

C. Preparation of working standards regarding the water consumption: The quantity of washing water required for a particular washing process should be determined from the appropriate working conditions for that washing process, and the workers should be instructed to observe it as the working standard. By this measure, it can be avoided that too much water is used. It is very difficult, however, to prepare these working standards and it will be necessary to start anywhere possible.

2) Adoption of the counter-current multi-stage washing system

In this system, the product to be washed moves in the direction counter to the flow of washing water. This system cannot be realized in a single tank alone, and necessarily becomes a multi-system comprising two or more tanks. Fig. 3.2.1. shows its principles.

The water consumption in the counter-current multi-stage washing system is very small as compared with that in the single-tank system. Fig.3.2.2. compares the water consumption required for the same washing effect between the single-tank and the counter-current multi-stage washing system.

As will be seen from Fig.3.2.2., the two-tank arrangement already saves water by 70-90 % as compared with the single-tank arrangement, but further increasing the number of tanks serves little for increasing the water saving effect.

3) Cascade use

In the case of cascade use, the drainage from a process is used directly in another process, and so on. The drainage from indirect cooling is little contaminated and its temperature is high, so that it is highly suitable for use as washing water. This method does require no special equipment and its running cost is low, and wherever applicable, it can be very effective. Fig.3.2.3 shows its principles.

4) Automatic water supply system for washing tank

This system automatically adjusts water supply to the water washing tank as the water quality in the tank varies, so as to keep it constant.

As the index showing the water quality, the concentration of salts dissolved by washing in the tank is preferable, but it cannot be measured easily. In stead, the conductivity which is nearly proportional to this concentration is used.

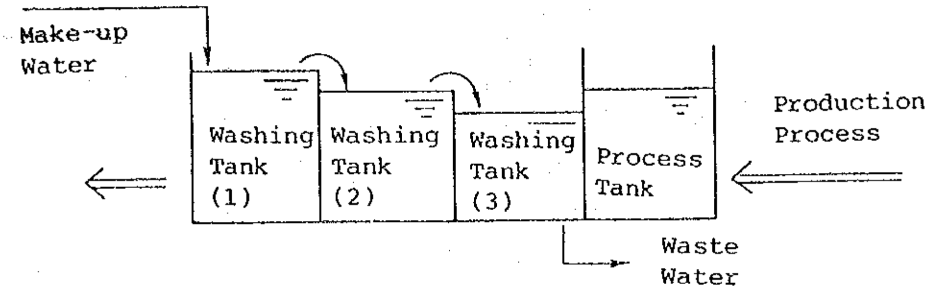

Fig. 3.2.1 Counter current multistage washing system

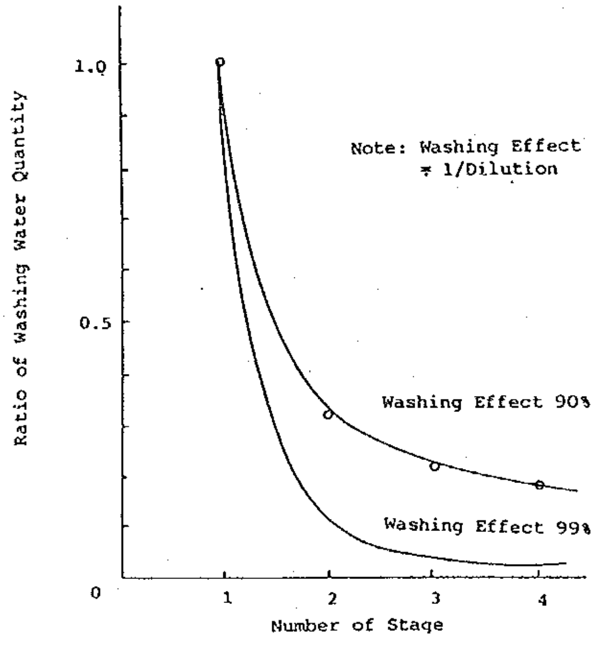

Fig. 3.2.2 Water quantity ratio in counter-current multistage washing system

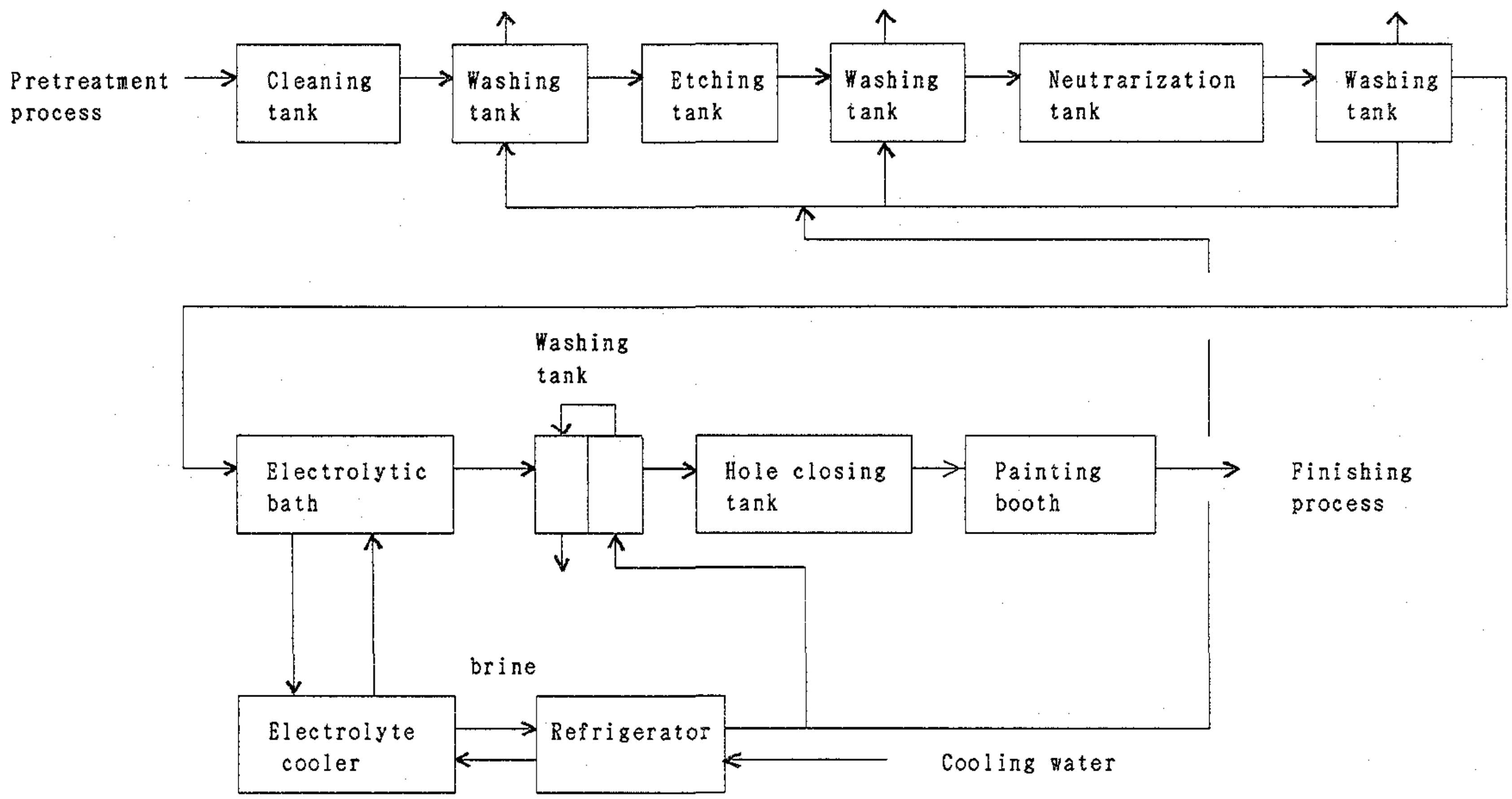

Fig. 3.2.3 An example of cascade system in alumite process

The conductivity sensing element is put in the water washing tank. This mechanism functions as follows. As the conductivity rises with increasing contamination of the washing wastewater, an electromagnetic valve opens to start water supply. And, as the conductivity lowers with diluting contamination, the electromagnetic valve closes to stop water supply.

In the case of plating factories, this system can be considerably effective even if it is installed to the single water washing tank, but the highest effect is obtainable when it is installed in the final stage of the counter-current multi-stage washing system. Fig.3.2.4. shows its example.

5) Hand control valve

This valve is mounted at the end of the water spray hose, so that the discharge and stop of water from the hose can be manipulated at its end without using the master cock. In many cases, this valve does flow regulation in addition to the water discharge and stop.

For the manipulation at the hose end, it is required that the valve should have such characteristics as light weight, easy operation, freedom from breakage, etc. Various types are available on market. An example shown in Fig.3.2.5. satisfies most of the above requirements.

(3) Reuse of wastewater

In addition to the techniques described in (2)-(6) above, a measure greatly effective in reducing the wastewater quantity is to reuse wastewater. However, the wastewater from cleaning is normally contaminated as described before, and its reuse requires somewhat advanced treatment, such as activated carbon adsorption, ozone treatment, reverse osmosis treatment, etc. and hence, a high treatment cost. Therefore, this item will be discussed only for the case of centralized treatment plants, and will not be discussed for the individual factories.

(4) Others

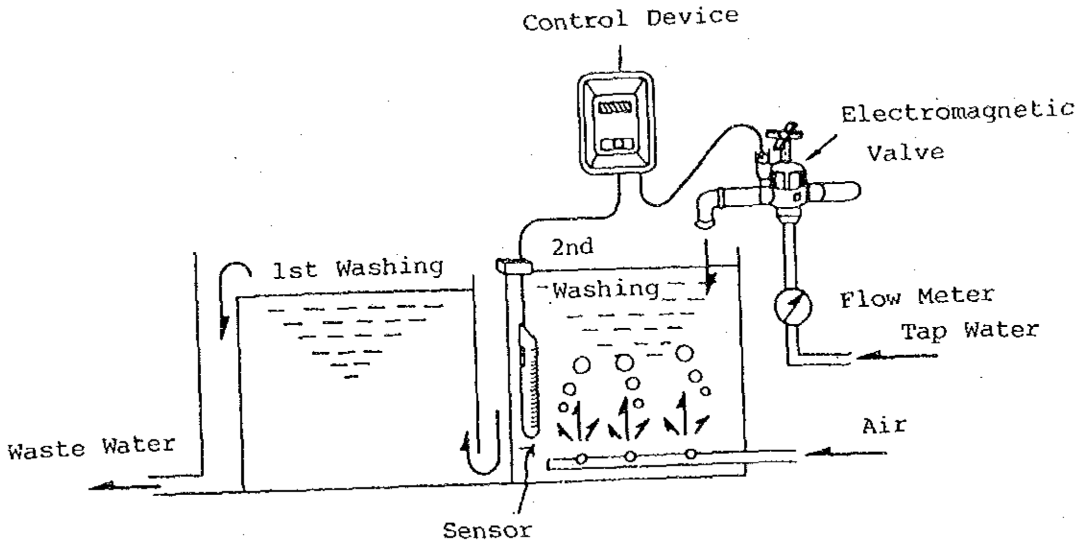

Fig. 3.2.4 Automatic water supply system

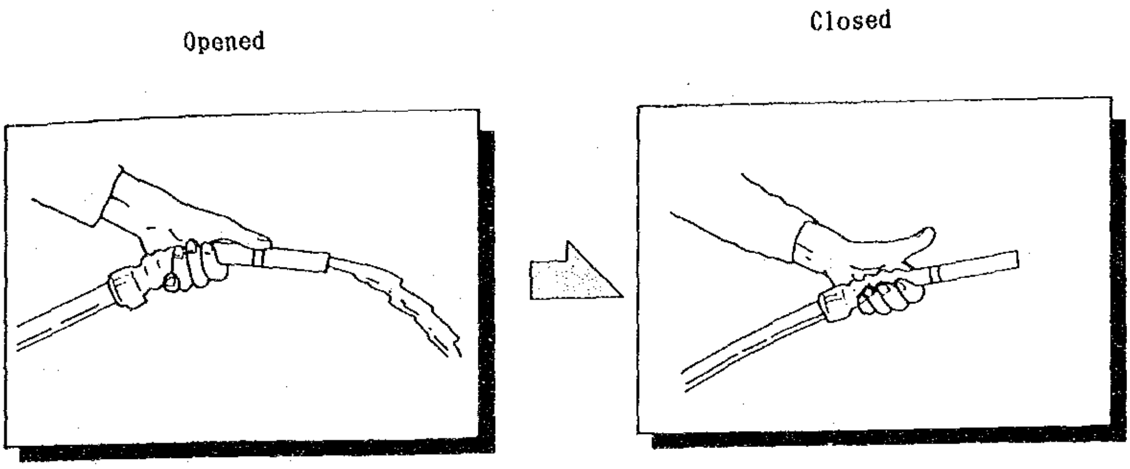

Fig. 3.2.5 An example of hand control valve

For reducing the wastewater quantity, various measures as mentioned in (2)-(7) of this section may be applicable, and the most important among them is B. "Accurate estimation of the water consumption" in (2). Without this, other techniques can be implemented in no way. And, once the water consumption is estimated accurately, it is very easy to study appropriate methods of reducing the wastewater quantity.

3.2.3 Concrete Measures

As mentioned before, the surveyed factories are very small in scale, and it is very difficult to show the details of water usage in the individual factories clearly. For this reason, in this section, concrete measures for the individual factories will not be shown and regarding A.-E. shown in (1) of 3.2.2, applicable forms of wastewater quantity reduction will be discussed for all the factories together.

(1) Complete implementation of water usage control

In each of the surveyed factories, tap water supply is only the water source available. The pipe diameter is about 25 mm in general. There is only one water tap. Near the pipe end, a water meter (integrating flowmeter) is provided. With this meter, the integrated value of water consumption can be known, but it is difficult to know the instantaneous flow rate. However, since the factory is small in scale and its water consumption is small, it is almost impossible to provide a flowmeter at every point of water use.

A relatively practicable method of water usage control will be to install at the outlet of the water tap a flowmeter capable of measuring the instantaneous flow rate, such as an area flowmeter (rotameter).

By this means, the water consumption at least at a certain point of time is known and it becomes possible to monitor whether the water consumption is proper or not for the working conditions at that point of time.

However, for this means to be applicable, it is necessary, as described above, to have the working standard concerning the water consumption prepared for each washing process.

Even such a degree of water usage control will make it possible to realize a considerable wastewater quantity reduction possible as compared with the present rough control method.

This type of flowmeter is relatively inexpensive (200-300 thousand wons or so) and its installation is also easy. It may be used sufficiently in the surveyed factories.

(2) Adoption of the counter-current multi-stage washing system

In the surveyed factories, with a few exceptions, the multi-stage system on washing method is adopted as shown in Table 3.2.2. The "Stored water washing" system is used in most cases, and the "Running water washing" system is used only in very few cases.

Even the "Stored water system" washing can be considerably effective for water saving, but the water in the water tank is degraded of its quality with the lapse of time and requires early replacement. Therefore, it cannot be said the effect of water saving of this system is not necessarily sufficient.

If the "Stored water washing" tank being used at present is improved into a "Running water washing" system of at least two-stage counter-current type and the water flow is controlled well, then considerably effective water saving, that is, wastewater quantity reduction, may be accomplished.

However, adopting the counter-current system involves the following problems.

A. Because of the very confined space, it is considerably difficult to arrange the counter-current washing tanks in a way to insure good working efficiency.
B. As described before, the water supply tap is provided only at one place, and it is difficult to supply water therefrom to each water washing tank continuously because it may require

many pipings to be installed on the limited floor surface.

C. The single tank which has been used conventionally can be moved easily and its application can also be changed easily. In contrast, the counter-current multi-stage washing tank, once installed, cannot be moved easily, nor its application can be changed. Thus, the flexibility in working is lost.

The counter-current multi-stage washing tank is made normally of synthetic resin (such as PVC) and is not too expensive. Therefore, if it is improved successively by solving the above problems one by one, it seems that this system will be applicable even in the present narrow area.

(3) Cascade use

As the cascade use, it is the easiest and most effective way to use the drainage from indirect cooling for the use of washing as mentioned above. However, since cooling water is rarely used in the surveyed factories, this method cannot find any place of application. In the two factories where cooling water is used, the cooling tower has already been installed for recycling use, and so, there is no need for cascade use.

(4) Automatic water supply system for washing tank

This system is applicable to either single tanks or multi-stage tanks as described before. However, since it is rather too expensive to install many units (about 80 thousand yen each in Japan), its application is difficult where there are many water washing processes for the water consumption as in the surveyed factories.

This equipment is suitable for larger factories.

(5) Hand control valve

In the surveyed factories, water supply to water washing tanks, etc. is done not through fixed pipings, but frequently by means of long hoses of movable type. In such cases, it is effective for the purpose of water saving to install a hand control valve at the hose end.

Such valves are priced at about 5 thousand yen each in Japan and will be sufficiently usable.

(6) The realizable amount of wastewater quantity reduction

It is difficult to discuss for the individual factories concretely that to what degrees the wastewater quantity can be reduced by the methods (1)-(5).

However, based on the data obtained through hearings, observations, etc. by the visiting survey and the experience obtained through many factory surveys in the past, an overall study has been made and it is considered that if the methods (1), (2) and (5), and especially (2) and (3) are implemented, the present wastewater quantity can be reduced by 20-30 % sufficiently.

The realizable amount of wastewater quantity reduction is considerable (40-60 m^3 per day) for the industrial estate as a whole, but may be only small for the individual factories. Therefore, unless each of these factories recognizes the circumstances well and makes efforts for itself to save water even to a small degree, the wastewater quantity reduction of the whole would not be achievable.

3.2.4. Setting of The Effluent Characteristics of the Present Wastewater

Based on the date obtained by the visiting survey, the effluent characteristics of overall wastewater from the plating industrial estate will be defined as follows. It is assumed that wastewater quantity reducing measures such as classified discharge of wastewaters by concentrations, complete implementation of water usage control, mounting of hand control valve, etc. and pollution load reducing measures such as drag-out reduction, have been taken.

A. The overall wastewater quantity from the plating industrial estate will be 200 m^3/day.

B. Plating liquor renewal wastewater will be discharged separately from washing wastewaters. The quantity of plating liquor renew wastewaters will be assumed as 2% of the above-mentioned wastewater quantity and it will be added to the overall wastewater quantity.

C. Acid-alkali wastewaters are discharged without separation.D. As is carried out in the plating industrial estate at present, the 1st washing tank will be used as the recovery tank and its wastewater will not be discharged but be used for bath preparation.

E. Wastewater from the 2nd and subsequent washing tanks will be discharged.

F. When classified discharge is completely realized, effluent characteristics of wastewater are assumed as shown in Table 3.2.3.

G. When highly concentrated plating liquor wastes and washing wastewater are separately discharged, the effluent character istics of wastewater mentioned in F. above will be assumed as shown in Table 3.2.4.

3.2.5 Setting of the Effluent Characteristics of the Wastewaters

When the wastewater quantity reduction by the countercurrent

Table 3.2.3. Condition of Water using in Plating Factory

ITEMS	CN Wastewater	Cr Wastewater	H・OH Wastewater
Quantity (m^3/d)	67	62	71
pH	10.2	2.6	2.5
COD (mg/ℓ)	370	240	300
SS (mg/ℓ)	320	210	270
n-Hex (mg/ℓ)	8	—	10
CN (mg/ℓ)	18	—	—
T-Cr (mg/ℓ)	—	100	—
Fe (mg/ℓ)	2	—	30
Zn (mg/ℓ)	30	25	25
Cu (mg/ℓ)	10	40	35
Ni (mg/ℓ)	—	—	25
Pb (mg/ℓ)	—	1	10
Al (mg/ℓ)	—	—	10
Cr^{6+} (mg/ℓ)	—	100	—
F (mg/ℓ)	—	—	10
T-N (mg/ℓ)	—	—	10
T-P (mg/ℓ)	—	20	20
TRICHLOROETHYLENE (mg/ℓ)	—	—	—
TETRACHLOROETHYLENE (mg/ℓ)	—	—	—

Table 3.2.4. Washing Water Ratio on Counter Current Maltistage Washing

ITEMS	CN Wastewater		Cr Wastewater		H·OH Wastewater		
	RINSE	CONC.	RINSE	CONC.	H·OH RINSE	H CONC.	OH CONC.
Quantity (m^3/d)	67	1.4	62	1.2	71	0.7	0.7
pH	10.2	12.2	2.6	0.3	2.5	0.3	13.0
COD (mg/ℓ)	37	3,700	24	2,400	40	4,000	4,000
SS (mg/ℓ)	10	100	10	100	10	1,000	1,000
n-Hex (mg/ℓ)	8	5	—	—	10	10	1,000
CN (mg/ℓ)	100	10,000	—	—	—	—	—
T-Cr (mg/ℓ)	—	—	100	10,000	—	—	—
Fe (mg/ℓ)	2	200	—	—	30	3,000	30
Zn (mg/ℓ)	30	3,000	10	1,000	25	2,500	25
Cu (mg/ℓ)	10	1,000	—	—	35	3,500	35
Ni (mg/ℓ)	—	—	—	—	10	1,000	10
Pb (mg/ℓ)	—	—	—	—	10	1,000	10
Al (mg/ℓ)	—	—	—	—	10	1,000	10
Cr^{6+} (mg/ℓ)	—	—	100	10,000	—	—	—
F (mg/ℓ)	—	—	—	—	10	1,000	10
T-N (mg/ℓ)	—	—	—	—	10	1,000	10
T-P (mg/ℓ)	—	—	20	2,000	20	2,000	20
TRICHLOROETHYLENE (mg/ℓ)	—	—	—	—	—	—	—
TETRACHLOROETHYLENE (mg/ℓ)	—	—	—	—	—	—	—

multi-stage washing has been carried out by improving the water washing system as described below, the wastewater quantity will be reduced.

A. The 2nd washing tank will be batchwise operated. The wastewater from this tank is called "semi-high concentration wastewater" and will be discharged after being classified.The quantity of the semi-high concentration wastewater will be assumed as 40% of the present wastewater quantity, and the pollution load will occupy 90% of the present pollution load.

B. The 3rd and subsequent washing tanks will be the countercurrent multi-stage washing tanks. The wastewater from these tanks is called "washing wastewater" and will be reclaimed separately. The quantity of the washing wastewater will be assumed as 60% of the present wastewater quantity, and the pollution load will occupy 10% of the present pollution load.

3.3 Determination of the Optimum Wastewater Treatment System

3.3.1 Wastewater Quantity and Quality

On the assumption that wastewaters are completely classified and the high concentration wastewater discharged when the plating liquor is renewed is separately discharged from the present washing wastewaters, the wastewater quantity and quality will be determined as shown in Table 3.2.4.

3.3.2 Treated Water Quality

In accordance with the effluent standards in Korea, the treated water quality will be determined as shown in Table 3.3.1.

3.3.3 Determination of the Optimum System

(1) Wastewater treatment system satisfying the present effluent standards

Of the plating wastewater treatment systems, the one which is most positive and is most inexpensive regarding the construction and treatment costs is what follows. This is also most widely used.

A. Harmful substances are made harmless.
   Cyanide is oxidized with sodium hypochlorite. It is decom posed into nitrogen and carbon dioxide. hexavalent chromium is reduced with sodium sulfite or the like to trivalent chromium.
B. An iron-cyanide complex treatment process is added.
C. Heavy metals, aluminum, fluorine and phosphorus are removed by coagulation-sedimentation treatment.
D. Acid and alkali are neutralized.
E. COD and BOD, caused by organic substances, are removed by coagulation-sedimentation treatment.

Table 3.3.1. Quality of Treated Water

Items (unit)		Effluent Standards
BOD	(mg/ℓ)	30
COD	(mg/ℓ)	130 (40) *-1
SS	(mg/ℓ)	30
pH	(mg/ℓ)	5 ~ 9
n－Hex (mineral oil)	(mg/ℓ)	5
n－Hex (plant oil)	(mg/ℓ)	30
Phenols	(mg/ℓ)	3
CN	(mg/ℓ)	1
T－Cr	(mg/ℓ)	2
Fe	(mg/ℓ)	10
Zn	(mg/ℓ)	5
Cu	(mg/ℓ)	3
Cd	(mg/ℓ)	0.1
Hg	(mg/ℓ)	0.005
Org－P	(mg/ℓ)	1
As	(mg/ℓ)	0.5
Pb	(mg/ℓ)	1
Cr^{6+}	(mg/ℓ)	0.5
Mn	(mg/ℓ)	10
F	(mg/ℓ)	15
PCB	(mg/ℓ)	0.003
Trichloroethylene	(mg/ℓ)	0.3
Tetrachloroethylene	(mg/ℓ)	0.1
T－N	(mg/ℓ)	60
T－P	(mg/ℓ)	8

*－1 Standards on Advanced Treatment

F. Heavy metals which are present in trace amounts in the effluent from the coagulation-sedimentation treatment process are removed by adsorption on chelate resins.

G. High concentration wastewaters such as plating liquor are separately stored in the wastewater storage tank, from which they are added at a small rate to the washing wastewater of the same system to be treated.

The iron-cyanide treatment process is generally not incorporated. However, taking the results of the visiting survey into account and from the viewpoint of treating the overall wastewaters from the plating estate, this process will be added. For the principles of this treatment, refer to "V. Guidelines for Wastewater treatment and Reclamation".

Since aluminum is contained in the wastewater, pH adjustment to weak alkalinity is necessary for the coagulation-sedimentation treatment of heavy metals. Therefore, there is a possibility that heavy metals to be removed as hydroacid s remain ions. Moreover, it is anticipated that complexed heavy metals may exist, and in order to remove them, the system must have a chelate resin tower installed following the coagulation-sedimentation treatment process.

Fig.3.3.1. shows the flow diagram of the wastewater treatment system satisfying the present effluent standards.

(2) Advanced treatment system

In the case of the wastewater treatment systems satisfying the present effluent standards, almost all COD sources remaining in the effluent from the coagulation-sedimentation treatment process are organic substances. These organic substances as pollutants are generated by oils, etc. released in the cleaning process and additives contained in the bath liquor. For the removal of these organic substances, activated carbon adsorption is most widely used.

On the other hand, in those plating factories which perform manufacture of printed circuit boards and plating of plastics,

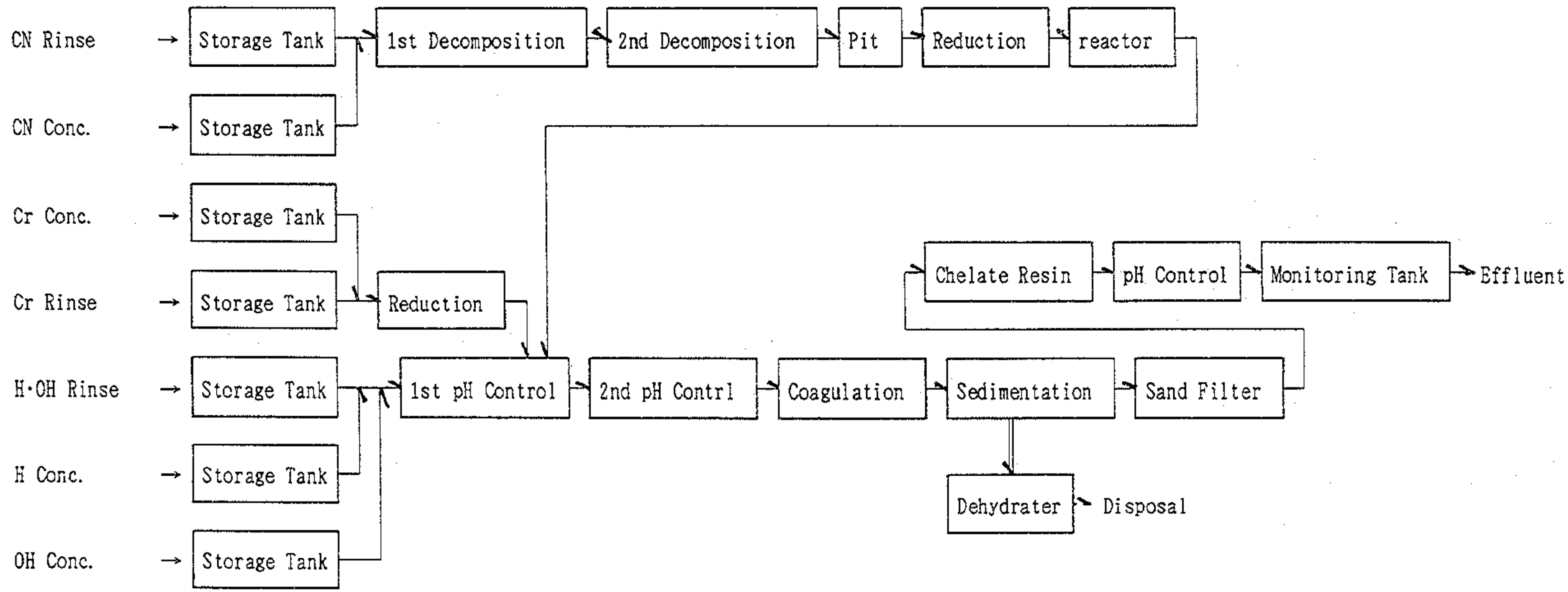

Fig. 3.3.1. Flow-Diagram of the Treatment System Satisfying the Present Effluent Standards

chemical plating is done, and from these factories, wastewaters containing reducing agents of inorganic and organic substances are discharged. These reducing agents are measured as COD.

In general, concentrate wastewaters are added at a small rate to the washing wastewaters to be treated, or are separately treated and disposed of. Washing wastewaters to be discharged as such are reduced in concentration by reduction measures and have no problems in most cases.

From the foregoing, the following system will be adopted.

A. The wastewater treatment system satisfying the present effluent standards will be added with an activated carbon adsorption tower before the chelate resin tower.

Fig.3.3.2. shows the flow diagram of the advanced wastewater treatment system.

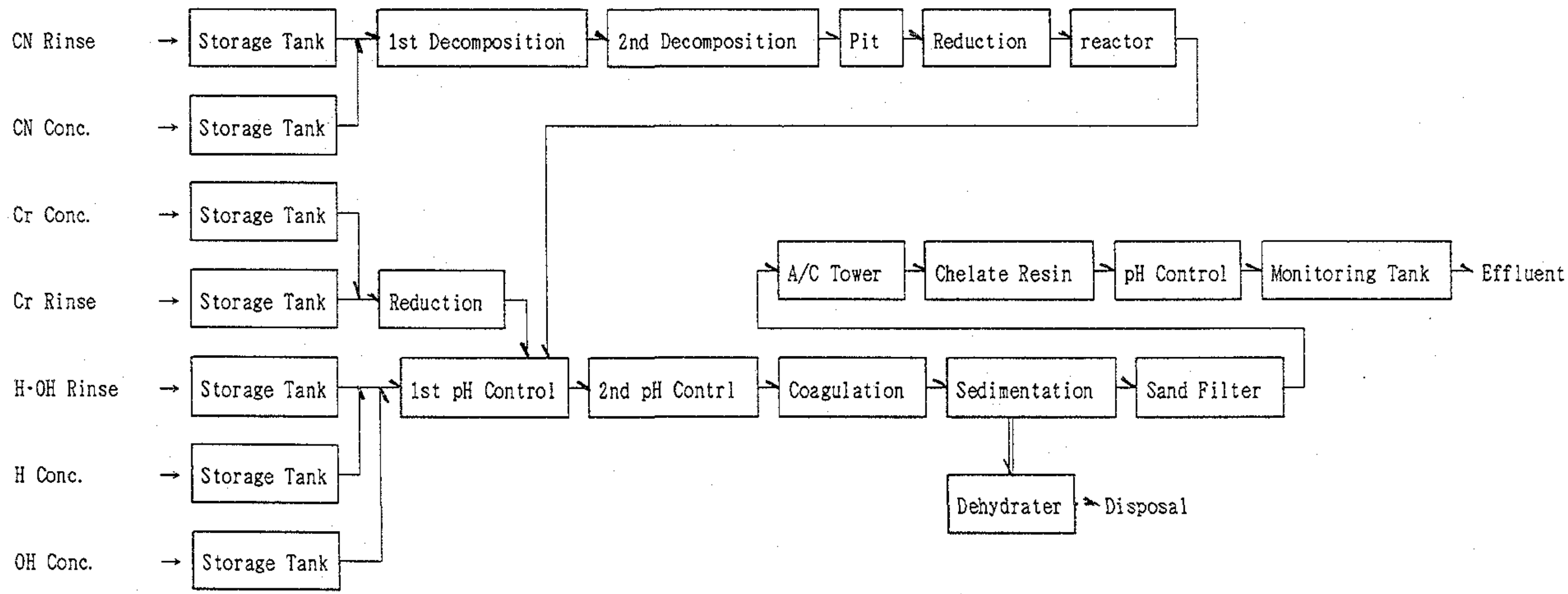

Fig. 3.3.2. The Flow-Diagram of the Advanced Treatment System

3.4 Determination of the Optimum Reclamation System

3.4.1 Wastewater Quantity and Quality

Classification of wastewaters was completely carried out as shown in Table 3.2.3 and then, wastewaters were classified as high concentration wastewaters discharged when the bath liquor was renewed and present washing wastewaters as shown in Table 3.2.4.

Then, the wastewater quantity and quality on the assumption that the washing wastewaters are discharged after being classified as semi-high concentration wastewaters and washing wastewaters by adopting the counter-current multi-stage washing system in the washing process will be defined as shown in Table 3.4.1.

3.4.2 Treated Water Quality

The treated wastewater quality will be as shown in Table 3.3.1.

The reclaimed water quality will be better than 20 uS/cm in conductivity.

3.4.3 Determination of the Optimum System

(1) Combination of the Reclamation System and the Wastewater Treatment System Satisfying the Present Effluent Standards

A. Wastewaters to be reclaimed

Washing wastewaters from the 3rd washing tank and subsequent counter-current multi-stage washing tanks will be reclaimed. Washing wastewaters will be classified as acid-alkali washing wastewater, chrome washing wastewater and cyanide washing wastewater.

B. Wastewaters to be treated

a. Bath liquor renewal wastewaters

Bath liquor renewal wastewaters will be classified as acid

Table 3.4.1. The Characteristics of Total Wastewater after counter current maltistage

ITEMS	CN Wastewater		Cr Wastewater		H·OH Wastewater	
	RINSE	SEMI CONC.	RINSE	SEMI CONC.	RINSE	SEMI CONC.
Quantity (m^3/d)	40.2	26.8	42.6	24.8	37.2	28.4
pH	9.2	11.2	3.6	1.6	3.5	1.5
COD (mg/ℓ)	6	83	3	54	8	10
SS (mg/ℓ)	2	225	1	23	2	3
n-Hex (mg/ℓ)	1	18	—	—	2	3
CN (mg/ℓ)	17	225	—	—	—	—
T-Cr (mg/ℓ)	—	—	15	225	—	—
Fe (mg/ℓ)	1	5	—	—	6	8
Zn (mg/ℓ)	5	68	1	23	5	6
Cu (mg/ℓ)	2	23	—	—	7	9
Ni (mg/ℓ)	—	—	—	—	2	3
Pb (mg/ℓ)	—	—	—	—	2	3
Al (mg/ℓ)	—	—	—	—	2	3
Cr^{6+} (mg/ℓ)	—	—	15	225	—	—
F (mg/ℓ)	—	—	—	—	2	3
T-N (mg/ℓ)	—	—	—	—	2	3
T-P (mg/ℓ)	—	—	3	45	4	5
TRICHLOROETHYLENE (mg/ℓ)	—	—	—	—	—	—
TETRACHLOROETHYLENE (mg/ℓ)	—	—	—	—	—	—

high concentration wastewater, alkali high concentration wastewater, chrome high concentration wastewater, and cyanide high concentration wastewater.

b. Semi-high concentration wastewater from the 2nd washing tank Semi-high concentration wastewaters will be classified as acid-alkali semi-high concentration wastewater, chrome high concentration wastewater, and cyanide high concentration wastewater.

c. Regeneration wastewater of ion exchange resins

C. Reclaimed wastewater quantity

a. The wastewater quantity to be treated for the purpose of reclamation will be 60 % of the present wastewater quantity.

However, the wastewater quantity to be recovered as reclaimed water, less the regeneration water for ion exchange resins, will be 50 % of the present wastewater quantity.

If the dilute wastewater such as washing water after reduction measures being taken is to be reclaimed, a method using ion exchange resins for removing salts containing heavy metals in the wastewater is widely used.

Among ion exchange resin towers, the 1st tower is a single bed tower containing strong cation exchange resin only and the 2nd tower is a two-bed tower containing weak anion exchange resin and strong anion exchange resin. The water in treatment is applied in up-flow and the water for resin regeneration is applied in down-flow.

A comparison of this treatment system using ion exchange resins with the conventional systems is as follows. The treated water quality is 2-10 uS/cm in conductivity in the present system and 10-50 uS/cm in the conventional systems, and the chemical consumption for resin regeneration is reduced to 1/2 in the present system of that in the conventional system. Owing to such advantages, wastewater reclamation has come to wide use.

Fig.3.4.1 shows the flow diagram of the reclamation system and the wastewater treatment system satisfying the present efflu-

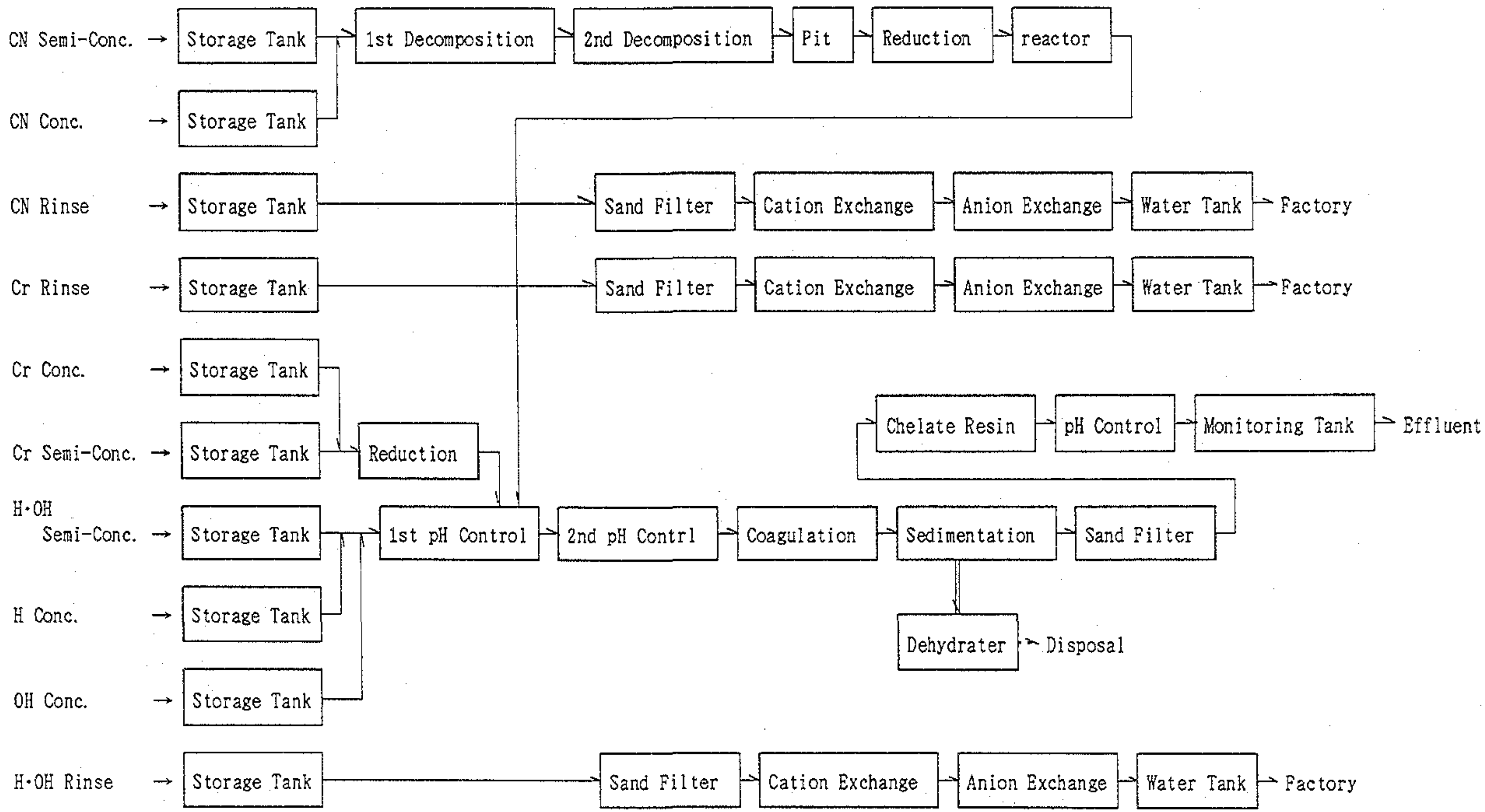

Fig. 3.4.1. The Flow-Diagram of the Reclamation System and the Treatment System Satisfying the Present Effluent Stadards

ent standards.

(2) Combination of the reclamation system and the advanced wastewater treatment system

Likewise in the advanced wastewater treatment system, an activated carbon adsorption tower will be installed before the chelate resin tower in the combination of the reclamation system and the wastewater treatment system satisfying the present effluent standards.

Fig.3.4.2. shows the flow diagram of the reclamation system and the advanced wastewater system.

(3) Closed wastewater system

Wastewater quantity reducing measures to be taken in adopting the closed wastewater system will be as follows.

A. As is practiced in the plating industrial estate at present, the 1st washing tank will be used as the recovery tank and the wastewater will be not discharged, but used for bath preparation.

B. The 2nd washing tank will be operated batchwise. The wastewater from this tank is called "semi-high concentration wastewater" and will be separately discharged and disposed of.
The wastewater quantity will be 10 % of the present wastewater quantity, and the pollution load will occupy 90 % of the present pollution load.

C. The 3rd and subsequent washing tanks will be counter-current multi-stage tanks. The wastewater is called "washing wastewater" and be separately reclaimed.
The wastewater quantity will be 90 % of the present wastewater quantity, and the pollution load will occupy 10 % of the present pollution load.
In comparison with the combination of the reclamation system and the wastewater treatment system satisfying the present

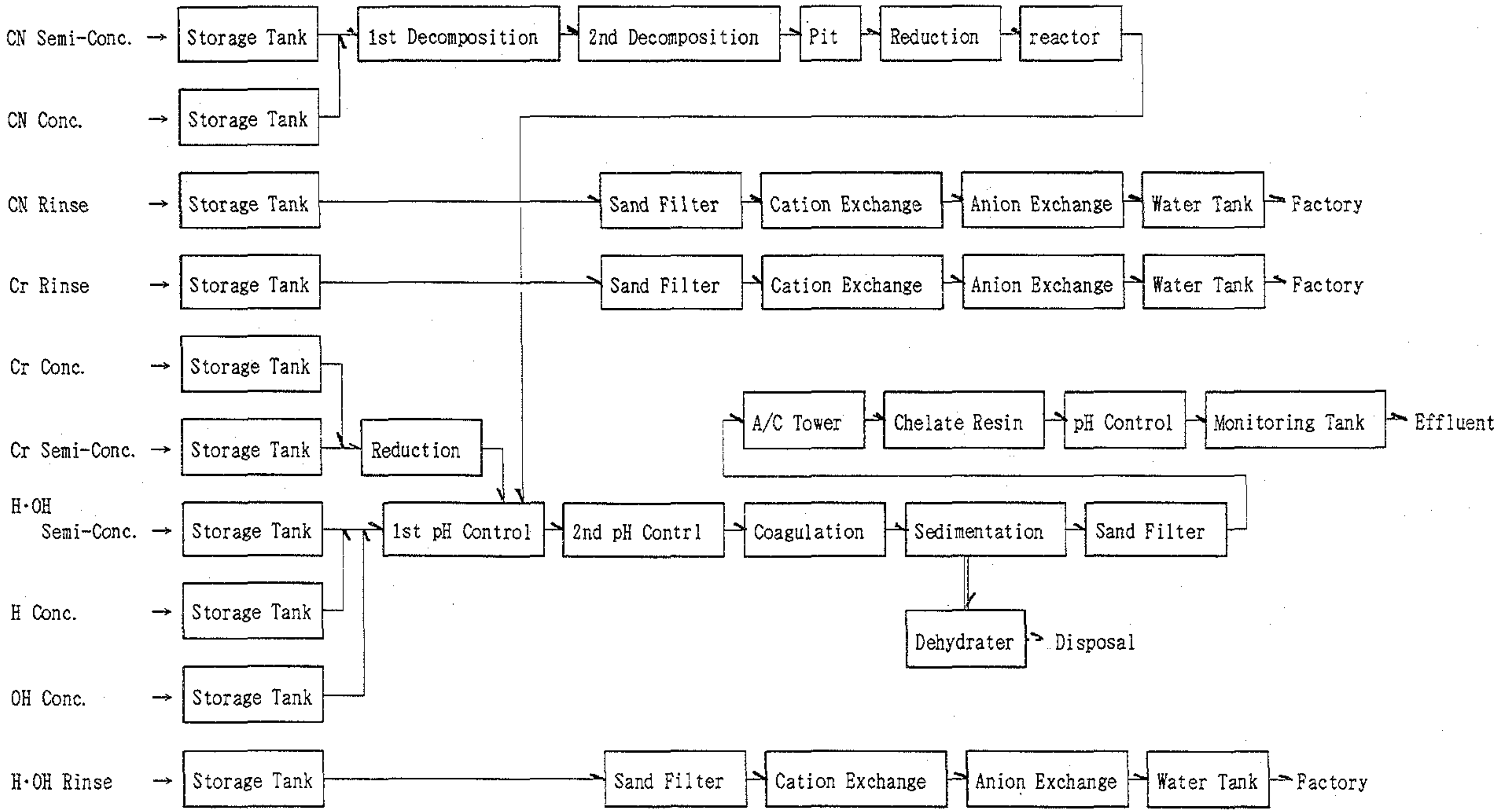

Fig. 3.4.2. The Flow-Diagram of the Combination of the Reclamation System and the Advanced Wastewater Treatment System

effluent standards, this system is different in the following points.

a. Chelate resin treatment is excluded.
b. Heavy metals, fluorine and phosphorus are treated by coagulation treatment only.
c. COD and BOD, caused by organic substances, are treated by coagulation treatment only.
d. The total quantity of effluents from coagulation treatment is filtered through a dehydrator.
e. The filtrate from the dehydrator is concentrated by an evaporator, and then, the salt in the concentrate is dried to solid in the drum drier.

Fig.3.4.3. shows the flow diagram of the closed wastewater treatment system.

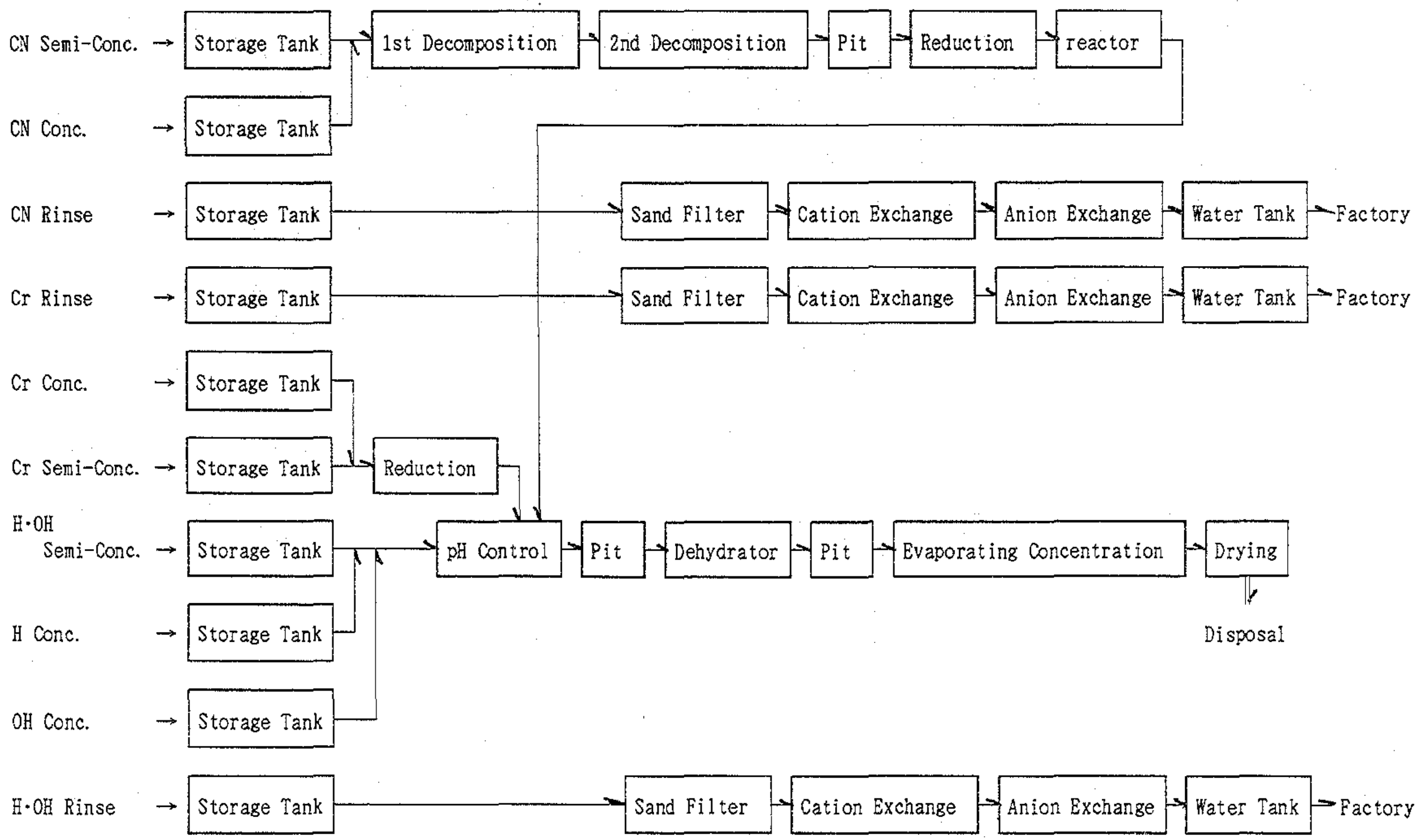

Fig. 3.4.3. The Flow-Diagram of the Reclamation System and the Closed Wastewater System

3.5 Conceptional Design of the Optimum Systems

3.5.1 Assumptions

The conceptual design will be carried out on the following assumptions.

A. The cost for purchase of the construction site shall be excluded.

B. The works for the following shall be excluded: water and wastewater piping from the plating industrial estate to the central treatment plant, spare parts, piling at the construction site, ground improvement, removal of surplus soils, treated water piping from the central treatment plant to the destination of final discharge, building-up of roads outside the site, gardening, fencing, primary power supply, and outdoor lighting. The works for heat insulation and indoor lighting shall be included so that the equipment may have the generality as such in Korea.

C. Wastewater receiving tanks shall have double construction to prevent secondary accidents due to cracking, etc.

D. Sludges shall be dehydrated to the cake having water content 80 % or below and shall be disposed of as industrial wastes outside the estate.

E. Wastewater treatment shall be continuous and be operated automatically.

F. The operating time of the facilities shall be 8 hours/day.

G. Regeneration of ion exchange resins shall be done by a automatic system.

H. Electric power supply for drive shall be 220 V, 50 Hz, and electric power supply for control shall be 110 V, 50 Hz.

I. Chemicals, with the exception of sulfuric acid (75 %) and hydrochloric acid (35 %), shall be obtained as powder.

J. The period of construction shall be one year.

3.5.2 The Treatment System satisfying the Present Effluent Standards (Case 1)

(1) Outlines of the system

A. Flow sheet

Fig.3.5.1 shows the flow sheet of the treatment system satisfying the present effluent standards.

B. Layout

Fig.3.5.2 shows the layout of the treatment system satisfying the present effluent standards (excepting the portion of two activated carbon adsorption towers).

C. Treated quantity

Chrome concentrate wastewater: 1.2m^3/day
Chrome washing wastewater: 62m^3/day
Acid concentrate wastewater: 0.7m^3/day
Alkali concentrate wastewater: 0.7m^3/day
Acid-alkali washing wastewater: 71m^3/day
Cyanide concentrate wastewater: 1.4m^3/day
Cyanide washing wastewater: 67m^3/day

(2) Conceptual design

A. Setting of process conditions

Table 3.5.1. shows the process set conditions.

Table 3.5.1. Process Condition

Division		Process Condition
Waste water Treatment	1st Treatment	CN Decomposition ; Alkali-Chlorine Cr^{6+} reduction ; Chemical Recuction Heavy Metal Treatment ; Coagulation-Sedimentation Acid Alkali Treatment ; Neutralization
	2nd Treatment	Ion Exchange
Sludge Treatment		Filter press

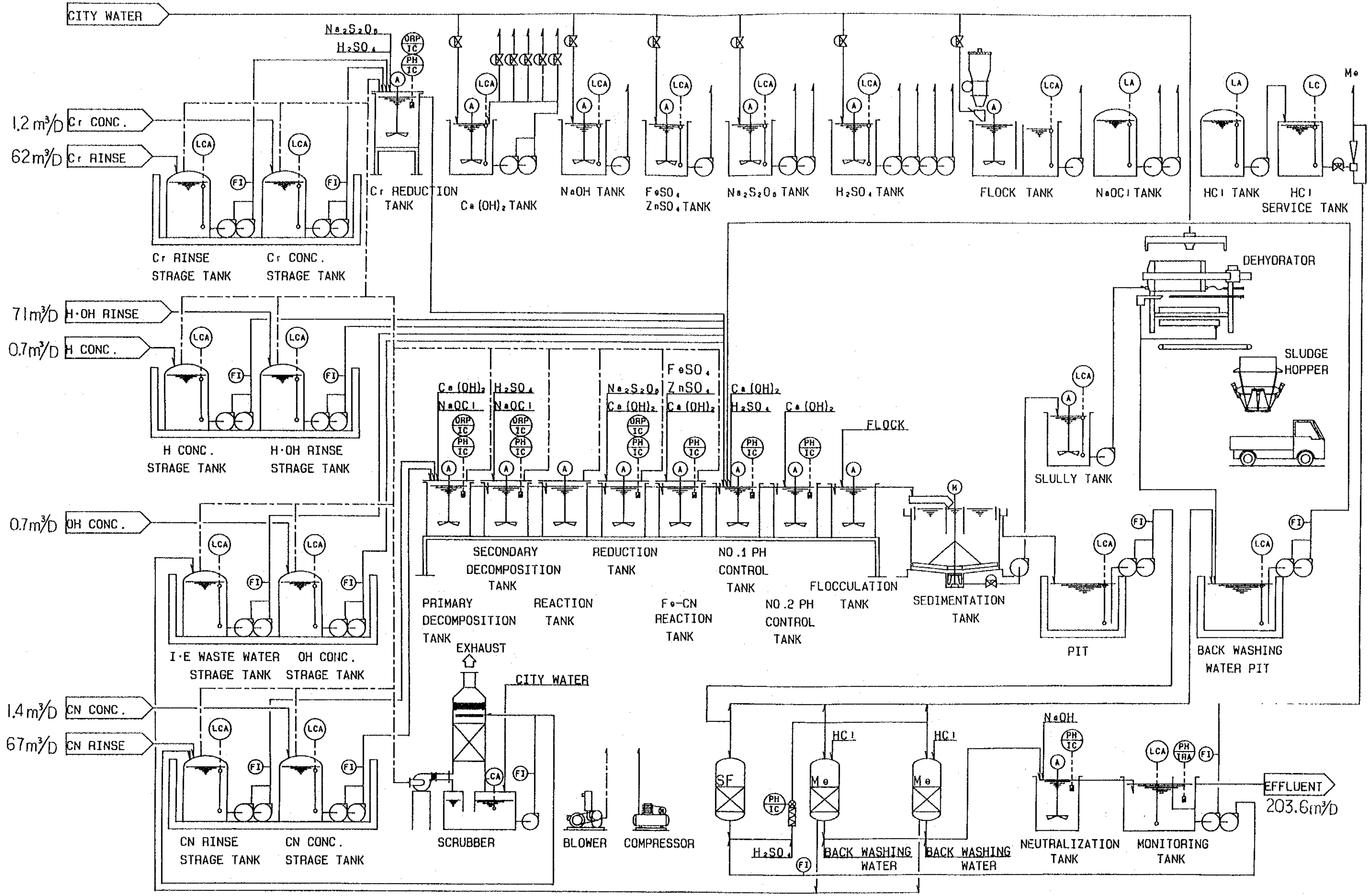

Fig. 3. 5. 1 FLOWSHEET CASE-1

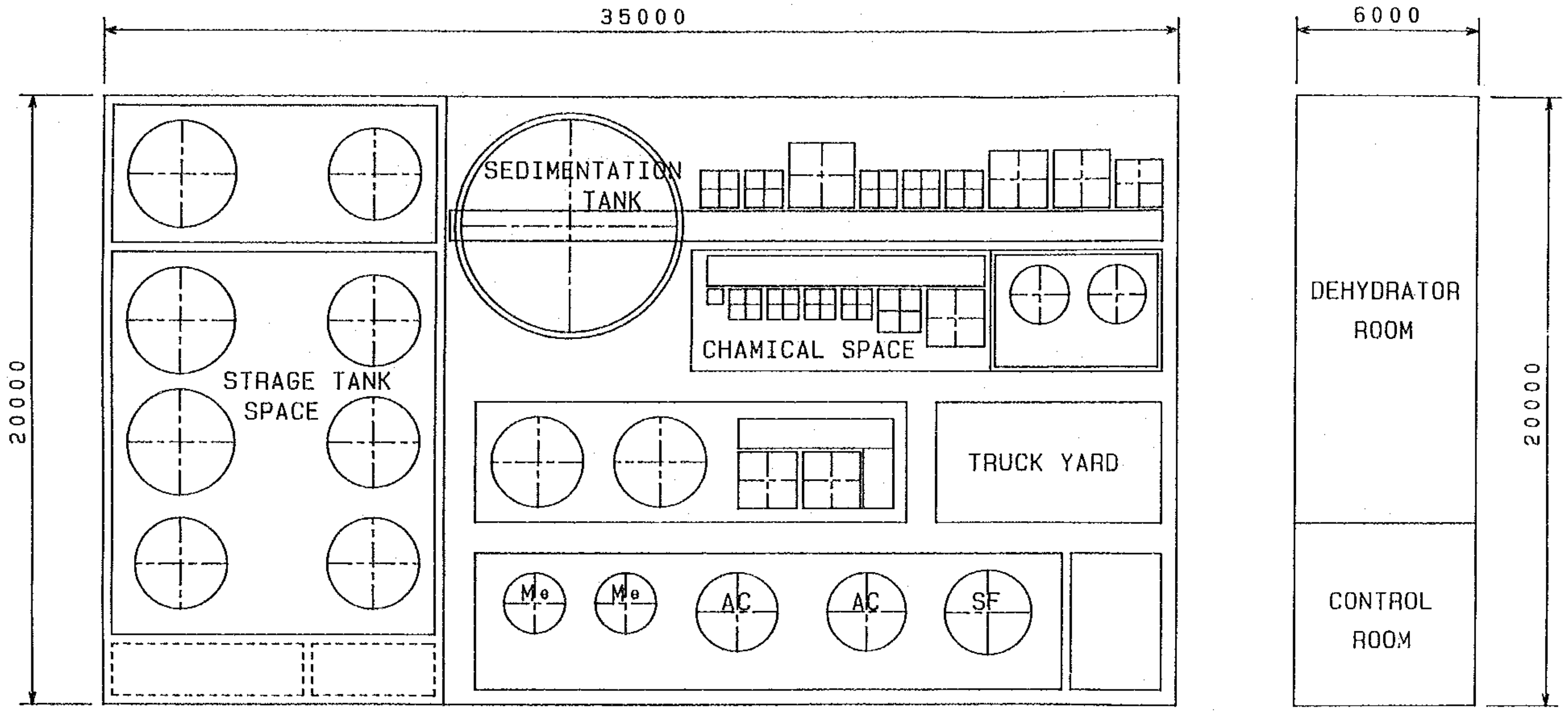

fig. 3. 5. 2 LAYOUT CASE-2

B. Equipment specifications

Table 3.5.2. shows the equipment list (excepting the portion of two activated carbon adsorption towers).

3.5.3 The Advanced Treatment System (Case 2)

A. Flow sheet

Fig.3.5.3. shows the flow sheet of the advance treatment system.

B. Layout

Fig.3.5.2. shows the layout of the advanced treatment system (also serviceable for Case 1).

C. Treated quantity

Chrome concentrate wastewater: $1.2m^3$/day
Chrome washing wastewater: $62m^3$/day
Acid concentrate wastewater: $0.7m^3$/day
Alkali concentrate wastewater: $0.7m^3$/day
Acid-alkali washing wastewater: $71m^3$/day
Cyanide concentrate wastewater: $1.4m^3$/day
Cyanide washing wastewater: $67m^3$/day

A. Setting of process conditions

Table 3.5.3. shows the process set conditions.

Table 3.5.3. Process Condition

Division		Process Condition
Waste water Treatment	1st Treatment	CN Decomposition ; Alkali-Chlorine Cr^{6+} reduction ; Chemical Recuction Heavy Metal Treatment ; Coagulation-Sedimentation Acid Alkali Treatment ; Neutralization
	2nd Treatment	Ion Exchange
	Advanced Treatment	Activated Carbon
Sludge Treatment		Filter press

Table 3.5.2. List of equipment (Case-1 & Case-2)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
1	Cr RINSE STRAGE TANK	1	FRP	CAPACITY 30m³	LCA
	PUMP	2	PVC	50/40A×200ℓ/min×20m^H×1.5kw	1 SPARE
				FLOW METER	
2	Cr CONC STRAGE TANK	1	FRP	CAPACITY 40m³	LCA
	PUMP	2	PVC	25A×6ℓ/min×3kg/cm²×0.2kw	1 SPARE
3	H CONC STRAGE TANK	1	FRP	CAPACITY 40m³	LCA
	PUMP	2	PVC	50/40A×200ℓ/min×20m^H×1.5kw	1 SPARE
4	H·OH RINSE STRAGE TANK	1	FRP	CAPACITY 30m³	LCA
	PUMP	2	PVC	50/40A×200ℓ/min×20m^H×1.5kw	1 SPARE
				FLOW METER	
5	I·E WASTE WATER STRAGE	1	FRP	CAPACITY 30m³	LCA
	TANK				
	PUMP	2	PVC	25A×6ℓ/min×3kg/cm²×0.2kw	1 SPARE
6	OH CONC STRAGE TANK	1	FRP	CAPACITY 40m³	LCA
	PUMP	2	PVC	25A×6ℓ/min×3kg/cm²×0.2kw	1 SPARE
7	CN RINSE STRAGE TANK	1	FRP	CAPACITY 30m³	LCA
	PUMP	2	FC	50/40A×200ℓ/min×17m^H×1.5kw	1 SPARE
				FLOW METER	
8	CN CONC STRAGE TANK	1	FRP	CAPACITY 40m³	LCA
	PUMP	2	PVC	25A×6ℓ/min×3kg/cm²×0.2kw	1 SPARE

Table 3.5.2. List of equipment (Case-1 & Case-2) (continued)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
9	Cr REDUCTION TANK	1	SS+R/L	CAPACITY 1.5m³	
	AGITATER	1	SS+R/L	VERTICAL TYPE 0.75kw	
	PH CONTROLLER	1		DIPING TYPE	
	ORP CONTROLLER	1		DIPING TYPE	
10	PRIMARY DECOMPOSITION	1	SS+R/L	CAPACITY 1.5m³	
	TANK				
	AGITATER	1	SS+R/L	VERTICAL TYPE 0.75kw	
	PH CONTROLLER	1		DIPING TYPE	
	ORP CONTROLLER	1		DIPING TYPE	
11	SECONDARY DECOMPOSITION	1	SS+R/L	CAPACITY 8m³	
	TANK				
	AGITATER	1	SS+R/L	VERTICAL TYPE 1.5kw	
12	REDUCTION TANK	1	SS+R/L	CAPACITY 1.5m³	
	AGITATER	1	SS+R/L	VERTICAL TYPE 0.75kw	
	PH CONTROLLER	1		VERTICAL TYPE 0.75kw	
	ORP CONTROLLER	1		VERTICAL TYPE 0.75kw	
13	FE·CN REACTION TANK	1	SS+R/L	CAPACITY 1.5m³	
	AGITATER	1	SS+R/L	VERTICAL TYPE 0.75kw	
	PH CONTROLLER	1		VERTICAL TYPE 0.75kw	
	ORP CONTROLLER	1		VERTICAL TYPE 0.75kw	
14	CONTROL TANK	1	SS+R/L	CAPACITY 6m³	
	AGITATER	1	SS+R/L	VERTICAL TYPE 2.2kw	
	PH CONTROLLER	1		VERTICAL TYPE 2.2kw	
	ORP CONTROLLER	1		VERTICAL TYPE 2.2kw	

Table 3.5.2. List of equipment (Case-1 & Case-2) (continued)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
15	CONTROL TANK	1	SS+R/L	CAPACITY $6m^3$	
	AGITATER	1	SS+R/L	VERTICAL TYPE 2.2kw	
	PH CONTROLLER	1		VERTICAL TYPE 2.2kw	
	ORP CONTROLLER	1		VERTICAL TYPE 2.2kw	
16	FLOCCULATION TANK	1	SS	CAPACITY $3m^3$	
	AGITATER	1	SUS-304	VERTICAL TYPE 0.75kw	
17	SEDIMENTATION TANK	1	SS	$7000\phi \times 3000^H$	
	PUMP	1	FC+R/L	$40A \times 100\ell/min \times 10m^H \times 1.5kw$	
18	PIT	1	RC	CAPACITY $40m^3$	LCA
	PUMP	1	FC	$80A \times 700\ell/min \times 25m^H \times 5.5kw$	1 SPARE
				FLOW METER	
19	SAND FILTER	1	SS	$2800\phi \times 2000^H$	
20	PH CONTROLLER	1			
21	Me TOWER	2	SS+R/L	$2000\phi \times 2000^H$	
22	NEUTRALIZATION TANK	1	SS+R/L	CAPACITY $6m^3$	
	AGITATER	1	SS+R/L	VERTICAL TYPE 2.2kw	
	PH CONTROLLER	1		DIPING TYPE	

Table 3.5.2. List of equipment (Case-1 & Case-2) (continued)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
23	MONITORING TANK	2	FRP	CAPACITY $30m^3$	LCA
	PH RECOEDER	1		DIPING TYPE	
	PUMP	1	FC	150/125A×$4m^3$/min×$23m^H$×22kw	
				FLOW METER	
	PUMP	1	FC	80/65A×$1m^3$/min×$28m^H$×7.5kw	
				FLOW METER	
24	BACK WASHING WATER PIT	1	RC	CAPACITY $60m^3$	LCA
	PUMP	2	FC	40A×150ℓ/min×$15m^H$×2.2kw	1 SPARE
				FLOW METER	
25	SLULLY TANK	1	SS	CAPACITY $5m^3$	LCA
	AGITATER	1	SUS-304	VERTICAL TYPE 1.5kw	
	PUMP	1	FC	100ℓ/min×$35m^H$×3.7kw	
26	DEHYDRATOR	1		FILTER PRESS TYPE	
				CAPACITY 260ℓ	
27	SLUDGE HOPPER	1	SS	CAPACITY $2m^3$	
28	SCRUBBER	1	PVC	$30m^3$/min	
29	BLOWER	1	FC	50A×$0.9m^3$/min×4500mmAq×2.2kw	
30	COMPRESSOR	1	FC	145ℓ/min×$9.9kg/cm^2$×1.5kw	
31	$Ca(OH)_2$ TANK	1	SS	CAPACITY $6m^3$	LCA
	AGITATER	1	SUS-304	VERTICAL TYPE 1.5kw	
	PUMP	2	FC+R/L	40A×100ℓ/min×$20m^H$×2.2kw	

Table 3.5.2. List of equipment (Case-1 & Case-2) (continued)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
32	NaOH TANK	1	SS	CAPACITY 200ℓ	LCA
	AGITATER	1	SUS-304	PORTABLE TYPE 0.1kw	
	PUMP	1	PVC	15A×0.1ℓ/min×10kg/cm²×0.2kw	
33	$FeSO_4 \cdot ZnSO_4$ TANK	1	SS+R/L	CAPACITY 1m³	LCA
	AGITATER	1	SS+R/L	PORTABLE TYPE 0.4kw	
	PUMP	1	PVC	15A×0.5ℓ/min×10kg/cm²×0.2kw	
34	$Na_2S_2O_5$ TANK	1	SS+R/L	CAPACITY 1m³	LCA
	AGITATER	1	SS+R/L	PORTABLE TYPE 0.4kw	
	PUMP	1	PVC	15A×1.7ℓ/min×10kg/cm²×0.2kw	
	PUMP	1	PVC	15A×1.7ℓ/min×10kg/cm²×0.2kw	
35	H_2SO_4 TANK	1	SS+R/L	CAPACITY 1m³	LCA
	AGITATER	1	SS+R/L	PORTABLE TYPE 0.2kw	
	PUMP	1	PVC	15A×0.5ℓ/min×10kg/cm²×0.2kw	
	PUMP	1	PVC	15A×0.1ℓ/min×10kg/cm²×0.2kw	
	PUMP	1	PVC	15A×1.7ℓ/min×10kg/cm²×0.2kw	
	PUMP	1	PVC	15A×0.5ℓ/min×10kg/cm²×0.2kw	
36	FK-Flock TANK	1	SS	CAPACITY 1m³	LCA
	AGITATER	1	SUS-304	PORTABLE TYPE 0.4kw	
	HOPPOR	1		CAPACITY 30ℓ FEEDER 0.06kw	
	PUMP	1	PVC	25A×6ℓ/min×3kg/cm²×0.2kw	
37	NaOCl TANK	1	FRP	CAPACITY 6m³	LA
	PUMP	1	PVC	25A×2.8ℓ/min×5kg/cm²×0.2kw	
	PUMP	1	PVC	15A×0.5ℓ/min×10kg/cm²×0.2kw	

Table 3.5.2. List of equipment (Case-1 & Case-2) (continued)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
38	HCl TANK	1	FRP	CAPACITY $6m^3$	LA
	PUMP	1	PP	$40A \times 100\ell/min \times 6m^H \times 0.4kw$	
39	HCl SERVICE TANK	1	SS+R/L	CAPACITY $2.5m^3$	LC
				EJECTOR	
40	CONTROL PANEL	1			

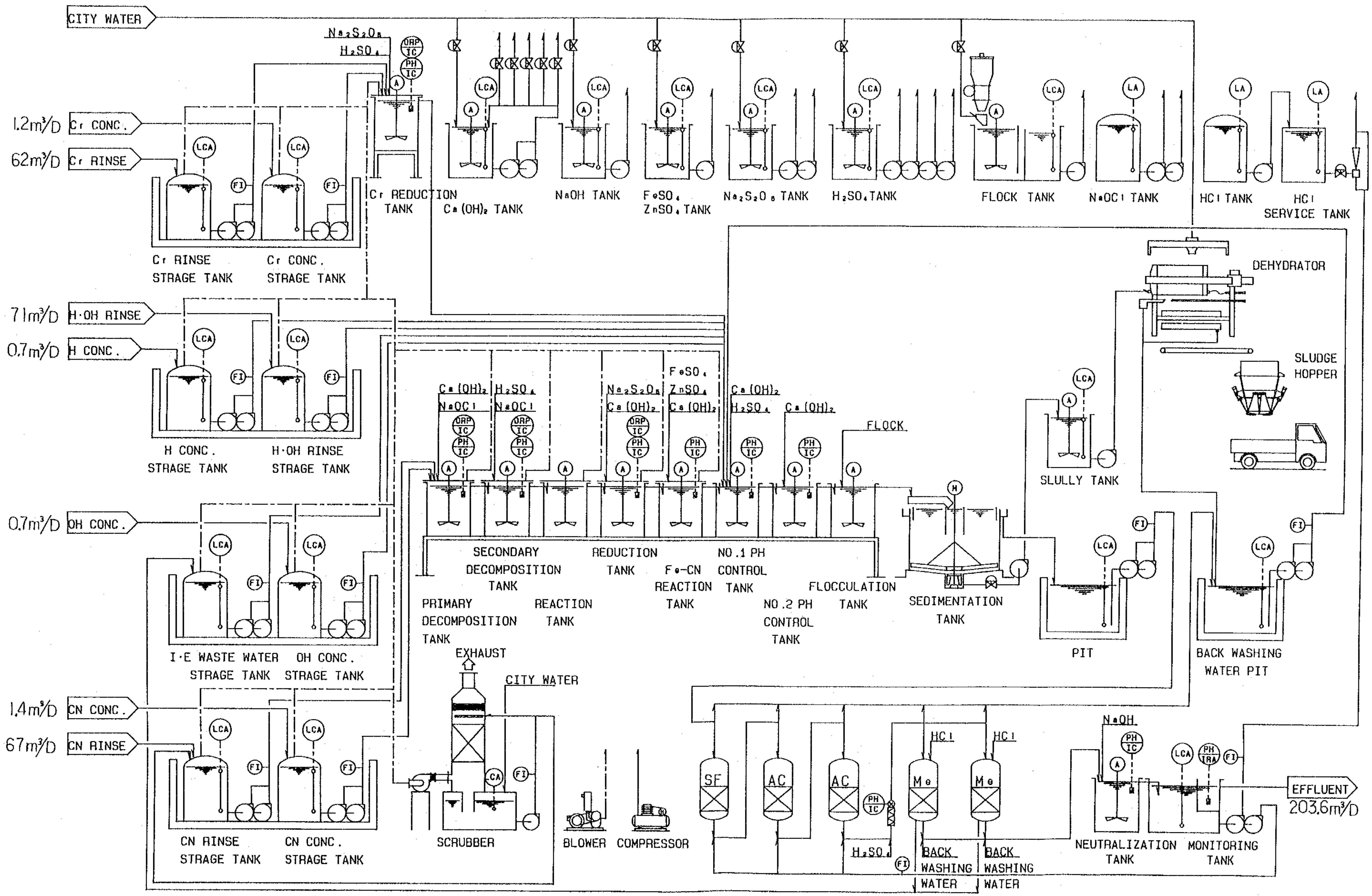

fig. 3. 5. 3 FLOWSHEET CASE-2

B. Equipment specifications

Table 3.5.2. shows the equipment list (also serviceable for Case 1).

3.5.4 A Combination of the Reclamation System and the System Satisfying the Present Effluent Standards (Case 3)

A. Flow sheet

Fig.3.5.4. and Fig.3.5.5. show the flow sheets of the reclamation system and the treatment system satisfying the present effluent standards, respectively.

B. Layout

Fig.3.5.6. shows the layout of the reclamation system and the treatment system satisfying the present effluent standards (excepting the portion of two activated carbon adsoption towers).

C. Treated quantity

(Wastewater treatment)

Chrome concentrate wastewater: $12m^3$/day

Chrome semi-concentrate wastewater: $24.8m^3$/day

Chrome ion exchange resin regeneration wastewater: $0.9m^3$/day

Acid concentrate wastewater: $0.7m^3$/day

Alkali concentrate wastewater: $0.7m^3$/day

Acid-alkali semi-concentrate wastewater: $28.4m^3$/day

Acid-alkali ion exchange resin regeneration wastewater: $12.6m^3$/day

Cyanide concentrate wastewater: $1.4m^3$/day

Cyanide semi-concentrate wastewater: $67m^3$/day

Cyanide ion exchange resin regeneration wastewater: $0.9m^3$/day

(Reclamation)

Chrome washing wastewater: $42.6m^3$/day

Acid-alkali washing wastewater: $37.2m^3$/day

Cyanide washing wastewater: $40.2m^3$/day

(2) Conceptual design

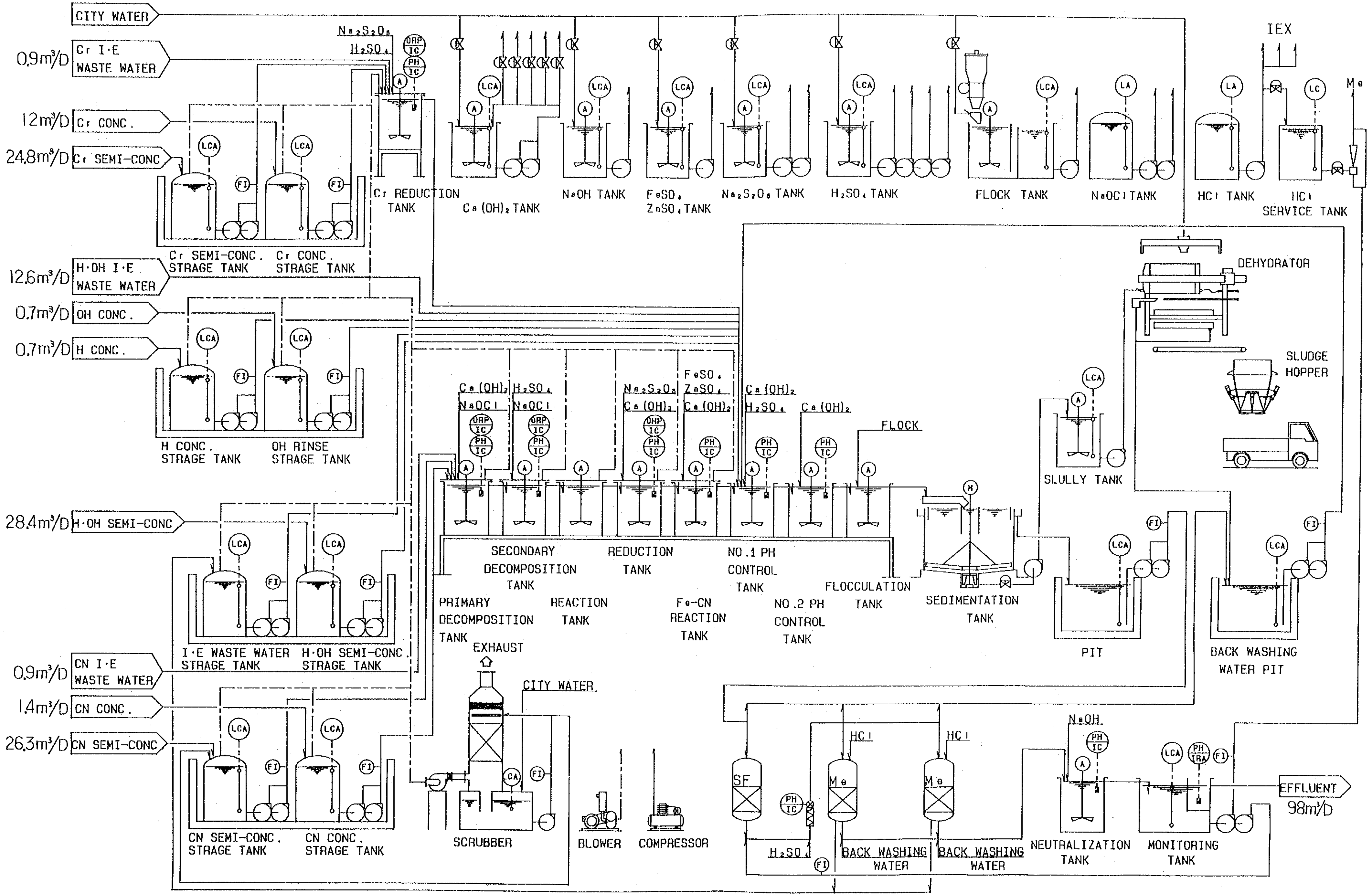

fig. 3. 5. 4 FLOWSHEET CASE-3

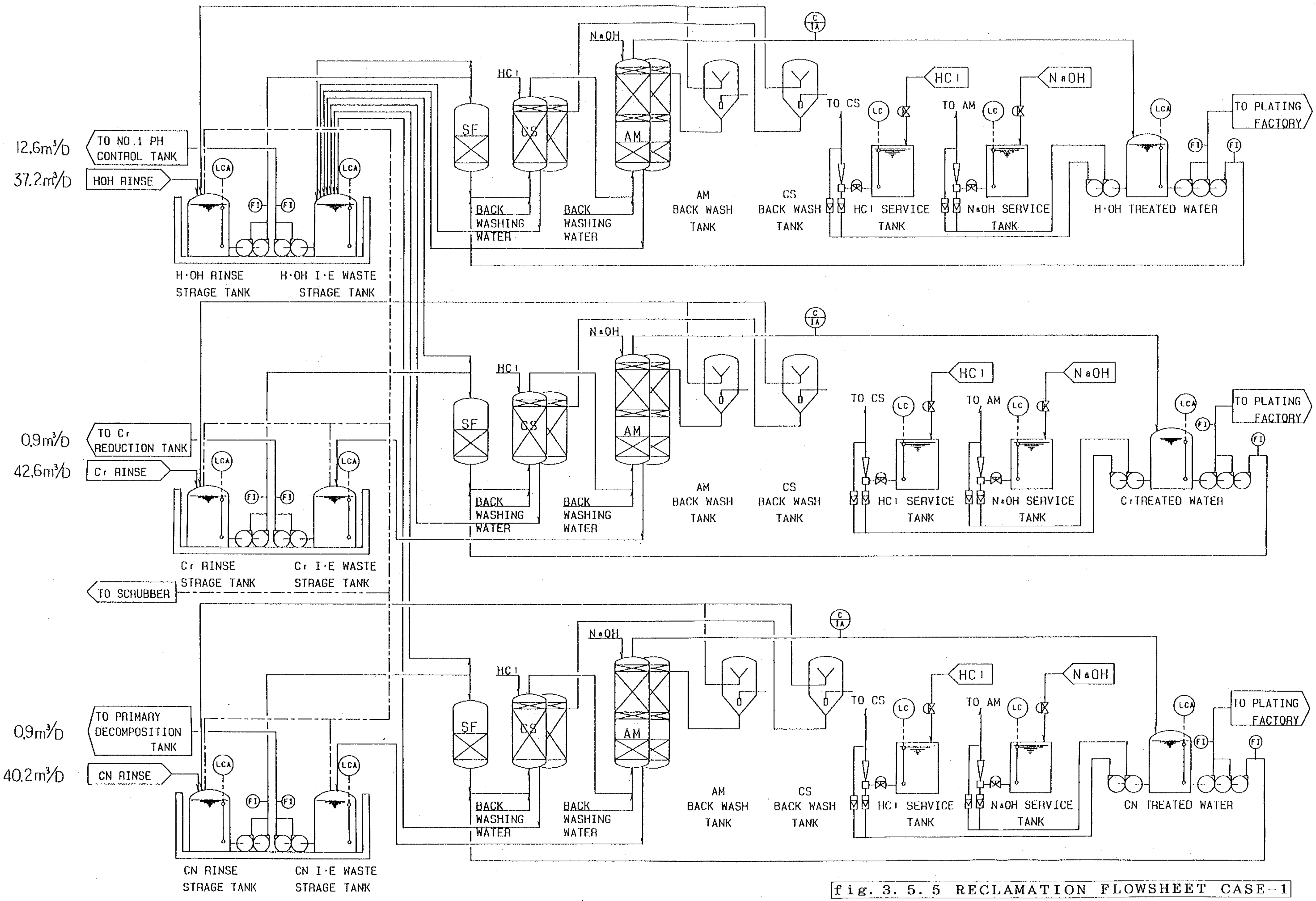

fig. 3. 5. 5 RECLAMATION FLOWSHEET CASE-1

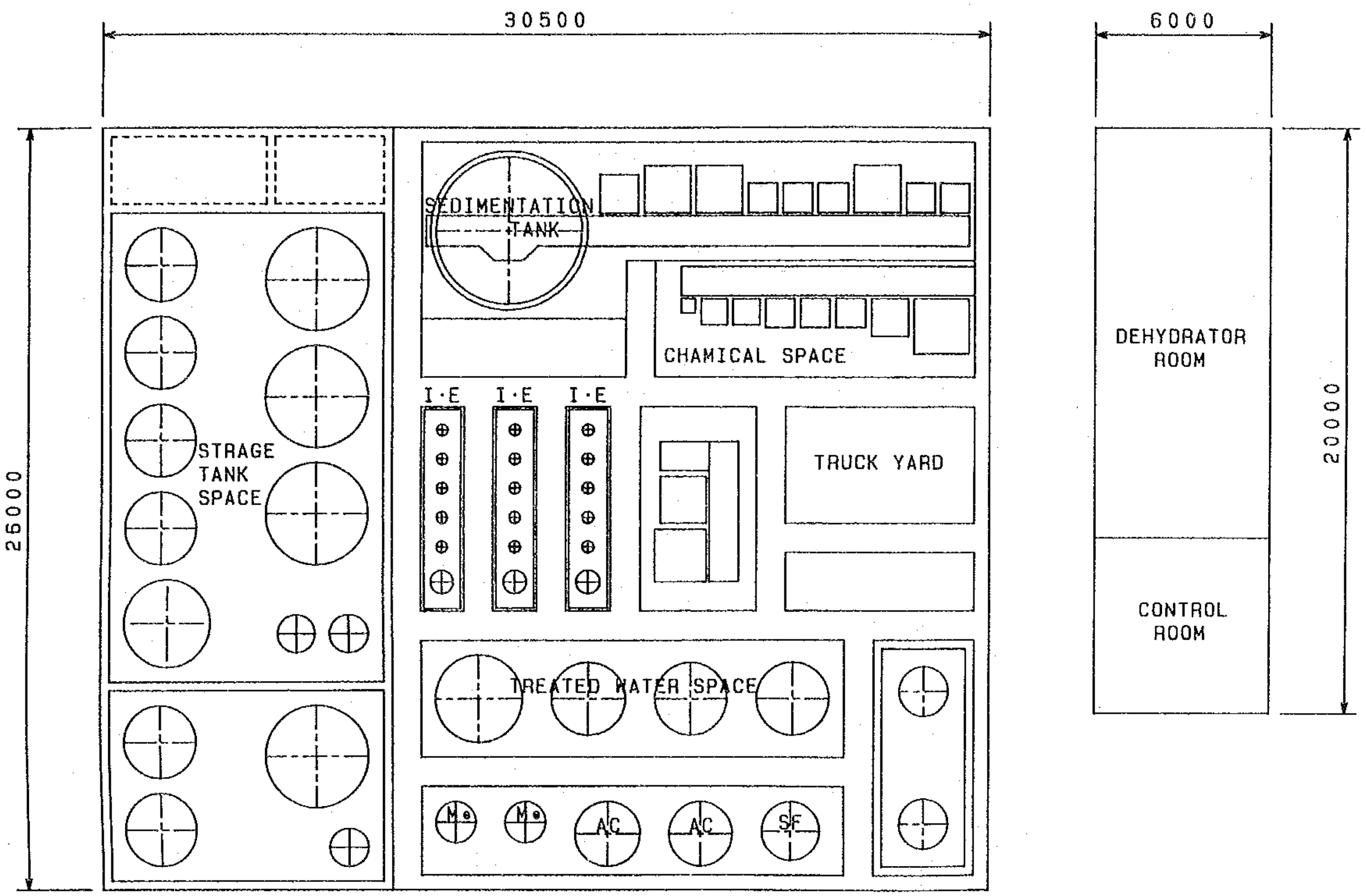

fig. 3. 5. 6 LAYOUT CASE-3

A. Setting of process conditions

Table 3.5.4. shows the process set conditions.

Table 3.5.4. Process Condition

Division		Process Condition
Waste water Treatment	1st Treatment	CN Decomposition ; Alkali-Chlorine Cr^{6+} reduction ; Chemical Recuction Heavy Metal Treatment ; Coagulation-Sedimentation Acid Alkali Treatment ; Neutralization
	2nd Treatment	Ion Exchange
Recycling Process		Ion Exchange
Sludge Treatment		Filter press

B. Equipment specifications

Table 3.5.5. shows the equipment list.

3.5.5 A Combination of the Reclamation System and the Advanced Wastewater Treatment System (Case 4)

A. Flow sheet

Fig.3.5.7. shows the flow sheet of the reclamation system and the advanced wastewater treatment system.

B. Layout

Fig.3.5.6. shows the layout of the reclamation system and the advanced wastewater treatment system (also serviceable for Case 3).

C. Setting of process conditions

Table 3.5.6. shows the process set conditions.

Table 3.5.6. Process Condition

Division		Process Condition
Waste water Treatment	1st Treatment	CN Decomposition ; Alkali-Chlorine Cr^{6+} reduction ; Chemical Recuction Heavy Metal Treatment ; Coagulation-Sedimentation Acid Alkali Treatment ; Neutralization
	2nd Treatment	Ion Exchange
	Advanced Treatment	Activated Carbon
Recycling Process		Ion Exchange
Sludge Treatment		Filter press

Table 3.5.5. List of equipment (Case-3 Recycling system)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
1	H·OH RINSE STRAGE TANK	1	FRP	CAPACITY 15m³	LCA
2	H·OH I·E WASTE WATER	1	FRP	CAPACITY 2m³	LCA
	STRAGE TANK				
3	H·OH SAND FILTER	1	SS+R/L	800ϕ ×2000^H	
4	H·OH CS TOWER	2	SS+R/L	400ϕ ×1500^H	
5	H·OH AM TOWER	2	SS+R/L	350ϕ ×3000^H	
6	H·OH CS BACK WASH	1	SS	400ϕ ×1000^H	
7	H·OH AM BACK WASH TANK	1	SS	350ϕ ×600^H	
8	H·OH HCl SERVICE TANK	1	PVC	CAPACITY 50ℓ	LC
9	H·OH NaOH SERVICE TANK	1	PVC	CAPACITY 50ℓ	LC
10	H·OH TREATED WATER	1	FRP	CAPACITY 15m³	LCA
11	Cr RINSE STRAGE TANK	1	FRP	CAPACITY 15m³	LCA
12	I·E WASTE WATER STRAGE	1	FRP	CAPACITY 2m³	LCA
	TANK				
13	SAND FILTER	1	SS+R/L	800ϕ ×2000^H	
14	CS TOWER	2	SS+R/L	400ϕ ×1500^H	

Table 3.5.5. List of equipment (Case-3 Recycling system) (continued)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
15	AM TOWER	2	SS+R/L	350φ×3000^H	
16	CS BACK WASH TANK	1	SS	400φ×1000^H	
17	AM BACK WASH TANK	1	SS	350φ×600^H	
18	HCl SERVICE TANK	1	PVC	CAPACITY 50ℓ	LC
19	NaOH SERVICE TANK	1	PVC	CAPACITY 50ℓ	LC
20	TREATED WATER	1	FRP	CAPACITY 15m³	LCA
21	CN RINSE STRAGE TANK	1	FRP	CAPACITY 15m³	LCA
22	I·E WASTE WATER STRAGE	1	FRP	CAPACITY 2m³	LCA
	TANK				
23	SAND FILTER	1	SS+R/L	800φ×2000^H	
24	CS TOWER	2	SS+R/L	400φ×1500^H	
25	AM TOWER	2	SS+R/L	350φ×3000^H	
26	CS BACK WASH TANK	1	SS	400φ×1000^H	
27	AM BACK WASH TANK	1	SS	350φ×600^H	
28	HCl SERVICE TANK	1	PVC	CAPACITY 50ℓ	LC

Table 3.5.5. List of equipment (Case-3 Recycling system) (continued)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
29	NaOH SERVICE TANK	1	PVC	CAPACITY 50ℓ	LC
30	TREATED WATER	1	FRP	CAPACITY $15m^3$	LCA

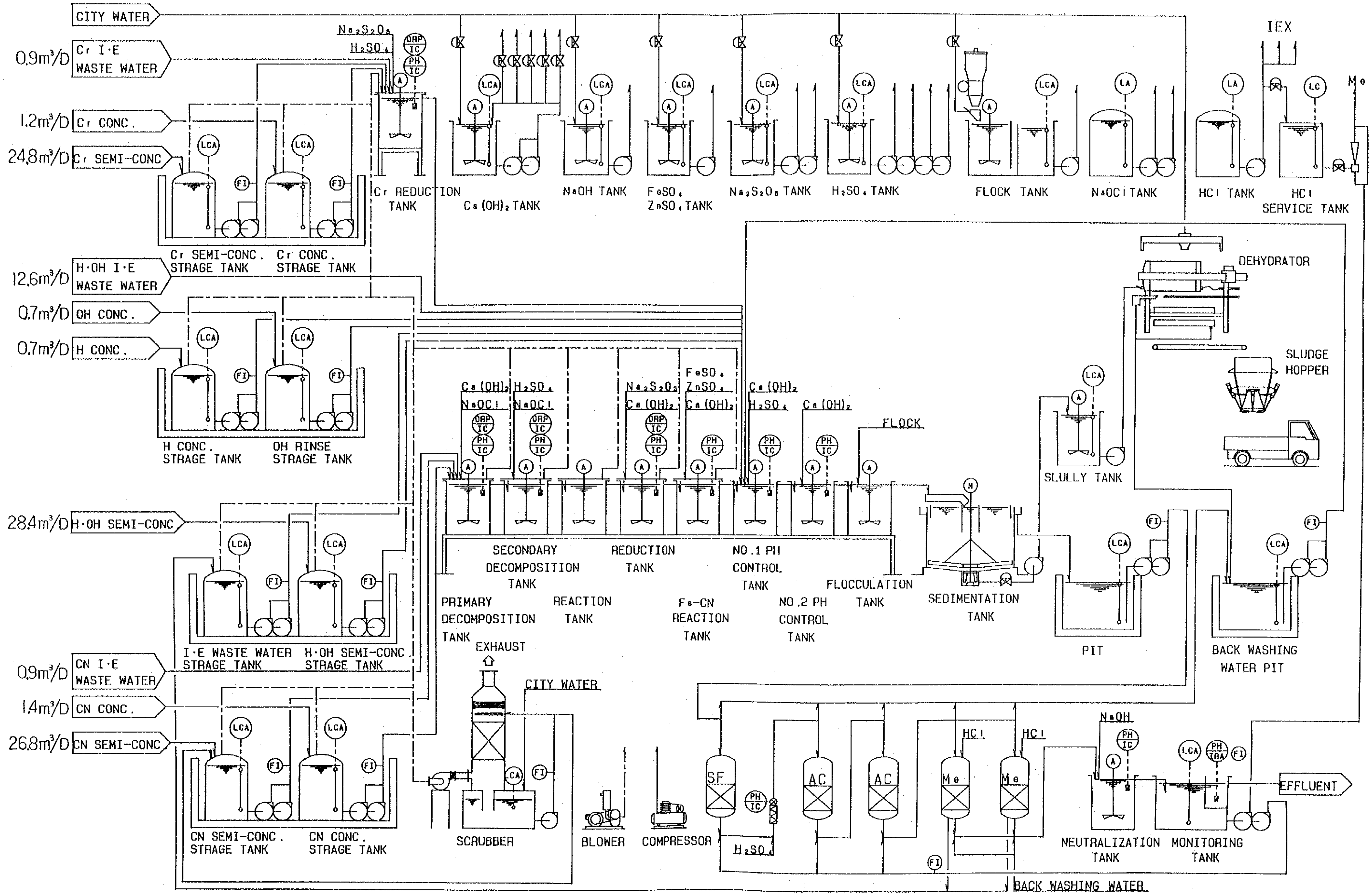

fig. 3. 5. 7 FLOWSHEET CASE-4

3.5.6 The Reclamation System and the Closed Wastewater System (Case 5)

A. Flow sheet

Fig.3.5.8. and Fig.3.5.9. show the flow sheets of the reclamation system and the closed wastewater system, respectively.

B. Setting of process conditions

Table 3.5.7 shows the process set conditions.

Table 3.5.7. Process Condition

Division		Process Condition
Waste water Treatment	1st Treatment	CN Decomposition ; Alkali-Chlorine Cr^{6+} reduction ; Chemical Recuction Heavy Metal Treatment ; Coagulation-Sedimentation Acid Alkali Treatment ; Neutralization
	2nd Treatment	Ion Exchange
Recycling Process		Ion Exchange
Sludge Treatment		Filter press
Desalination Procedd		Concentration ; Evaporating Concentration Drying ; Drum Dryer

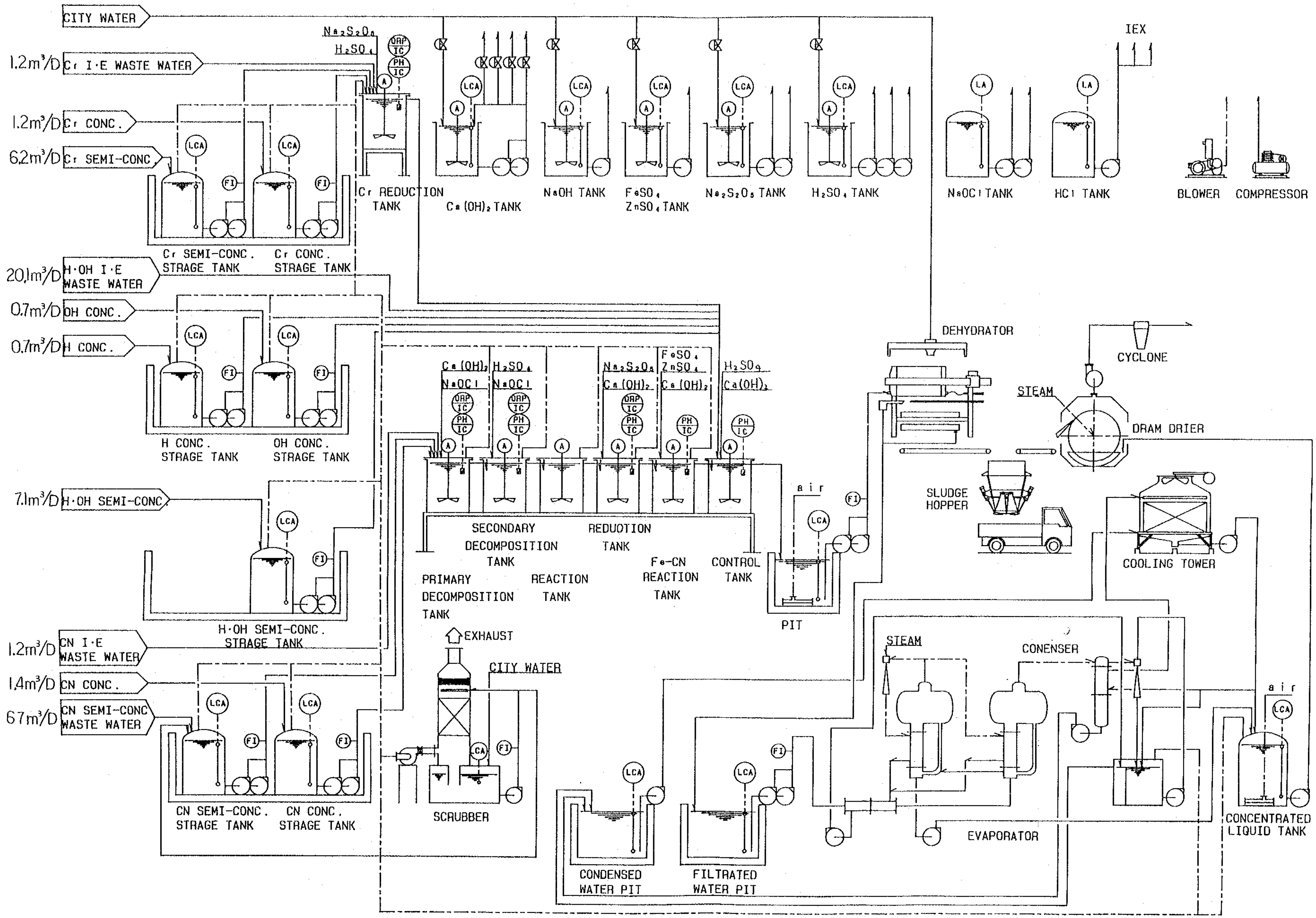

fig. 3. 5. 8 FLOWSHEET CASE-5

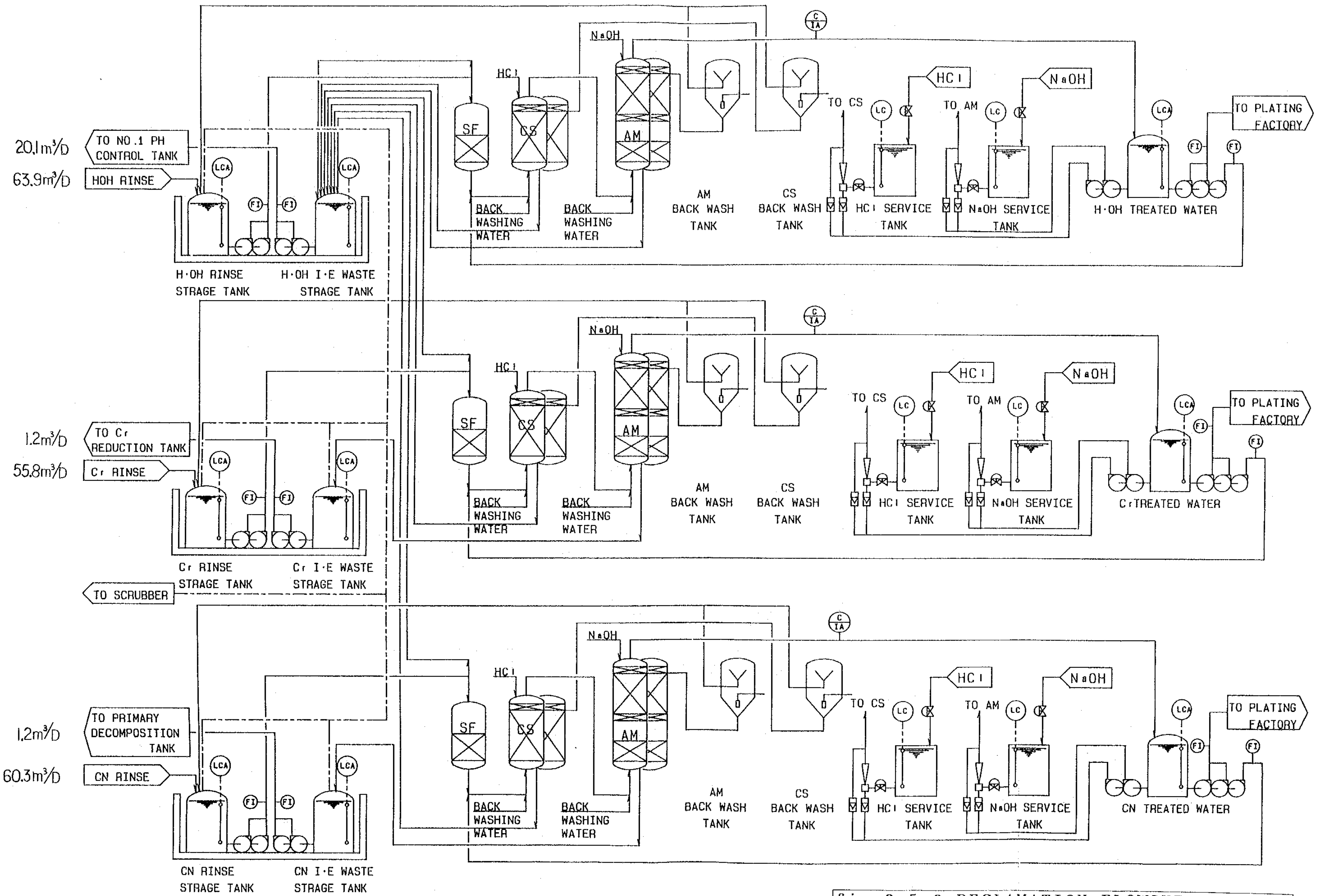

fig. 3. 5. 9 RECLAMATION FLOWSHEET CASE-5

3.6 Economic Feasibility of the Optimum Systems

3.6.1 Construction Cost

The following cost calculation are based on 1992 prices.

Table 3.6.1. shows the construction cost of a treatment system satisfies the present effluent standards (Case-1), an advanced COD component treatment system (case-2) and a combination of the reclamation system and the wastewater treatment system satisfying the present effluent standards.

The construction cost of a combination of the reclamation system and the advanced COD component treatment system, called Case 4, is about 1466 million wons, and that of the closed wastewater treatment system called Case 5 is about 314 million wons.

Table 3.6.1. Items of Construction Cost

(Million Won)

	CASE-1	CASE-2	CASE-3
(1) Civil & Architectural Work	—	—	—
(2) Machinery & Equipments	276	295	322
(3) Electrical Work	553	595	834
(4) Piping Work	60	64	70
(5) Test Working & Others	30	30	40
(Sub-total)	919	979	1,266
(6) The others	138	147	190
(Total)	1,057	1,126	1,156
Plottage (m^2) ( ) ; occupied for Control Room	820 (120)	820 (120)	913 (120)

3.6.2 Operation Cost

Table 3.6.2. shows details of unit prices of utilities such as chemicals used and labor costs for the calculation of operation costs.

表3.6.2. Unit Cost of Chemicals

ITEM	CONDITION	COST
1. $Ca(OH)_2$	100% (solid)	100 Won/kg
2. NaOH	100% (solid)	500 Won/kg
3. $FeSO_4 \cdot 7H_2O$	100% (solid)	210 Won/kg
4. $ZnSO_4 \cdot 7H_2O$	100% (solid)	450 Won/kg
5. $Na_2S_2O_5$	100% (solid)	1,250 Won/kg
6. H_2SO_4	100% (liquid)	85 Won/kg
7. Polymer Coagulant	100% (solid)	8,930 Won/kg
8. NaOCl	12% (liquid)	115 Won/kg
9. HCl	35% (liquid)	90 Won/kg
10. Activated Carbon	100% (solid)	1,600 Won/kg
11. Civil Water		450 Won/m^3
12. Cost of Sludge Disposal		100 Won/kW
13. Power		60 Won/kW
14. Steam		2,240 Won/t
15. Man Power	Manager Engineer Worker	23,000 million Won/y 16,000 million Won/y 11,000 million Won/y
(1) one year = 300 days		

Next, Table 3.6.3. shows daily consumption of each of the above items for each Case, 1 through 5.

Table 3.6.4. shows operation costs of foe Cases 1 through 3 clasified as (1) Chemicals, (2) City Water, (3) Electric Power,(4) Sludge Disposal and (5) Labor.

Similarly, the operation cost for Case 4 is about 143.6 million won per year and about 152.2 million won for Case 5.

Table 3.6.3. Unit cost of chemicals

ITEM		Case-1	Case-2	Case-3	Case-4	Case-5
1. $Ca(OH)_2$		136.4 kg/d	136.4 kg/d	136.4 kg/d	136.4 kg/d	136.4 kg/d
2. NaOH		16.9 kg/d	16.9 kg/d	16.9 kg/d	16.9 kg/d	16.9 kg/d
3. $FeSO_4 \cdot 7H_2O$		2 kg/d	2 kg/d	2 kg/d	2 kg/d	2 kg/d
4. $ZnSO_4 \cdot 7H_2O$		4.2 kg/d	4.2 kg/d	4.2 kg/d	4.2 kg/d	4.2 kg/d
5. $Na_2S_2O_5$		92.9 kg/d	92.9 kg/d	92.9 kg/d	92.9 kg/d	92.9 kg/d
6. H_2SO_4		21.9 kg/d	21.9 kg/d	21.9 kg/d	21.9 kg/d	21.9 kg/d
7. Polymer Coagulant		0.4 kg/d	0.4 kg/d	0.4 kg/d	0.4 kg/d	0.4 kg/d
8. NaOCl		1,309 kg/d	1,309 kg/d	1,309 kg/d	1,309 kg/d	1,309 kg/d
9. HCl		67.5 kg/d	67.5 kg/d	67.5 kg/d	67.5 kg/d	67.5 kg/d
10. Activated Carbon			61.5 kg/d		61.5 kg/d	
11. Civil Water		5 m^3/d	5 m^3/d	5 m^3/d	5 m^3/d	5 m^3/d
12. Cost of Sludge Disposal		430 kg/d	430 kg/d	430 kg/d	430 kg/d	430 kg/d
13. Power		480 kW/d	480 kW/d	480 kW/d	480 kW/d	480 kW/d
14. Steam						20 t/d
15. Man Power	Manager	0.5 Man/d	0.5 Man/d	0.5 Man/d	0.5 Man/d	0.5 Man/d
	Engineer	0.5 Man/d	0.5 Man/d	0.5 Man/d	0.5 Man/d	0.5 Man/d
	Worker	1 Man/d	1 Man/d	1 Man/d	1 Man/d	1 Man/d

表3.6.4. Operation Cost

(Million Won)

	CASE-1	CASE-2	CASE-3
(1) Chemicals	88.2	117.7	90.8
(2) City Water	0.7	0.7	0.7
(3) Electrical Power	7.2	7.2	8.6
(4) Sludge Disposal	12.9	12.9	12.9
(Sub-total)	109.0	138.5	113.0
(5) Labor	30.5	30.5	30.5
(Total)	139.5	169.0	143.5
Unit Water (Won/m^3)	2,325	2,817	2,392

3.7 Matters to be Considered for the Determination of the Optimum System

For selecting the optimum system, it is necessary to review the plating processes in each plating factory and study for rational water usage and pollution load reducing measures. Therefore, material balance of the plating industrial estate concerning water and wastewater should be prepared. It is important to study for wastewater treatment and reclamation taking into account the future plans of the plating industrial estate about the water quality, effluent standards for final discharge, wastewater treatment cost, tap water supply cost, etc.

When the optimum system is selected and implemented, it is essential that each plating factory located in the plating industrial estate should be well familiarized with the principles, design conditions, etc. of the optimum system.

That is, when each plating factory discharges wastewaters, it is essential that classification of wastewaters is positively carried out. Even if one of these plating factories does not follow it, wastewater treatment may become impossible. In the case of the wastewater reclamation equipment, if the wastewater as the raw water for reclamation contains a high concentration wastewater component, the reclamation cost becomes very high. This is a problem. When the reclamation equipment uses ion exchange resins, it is economical that the salt concentration in the wastewater should be below 1 epm (ion equivalent).

If any plating factory uses cleaning liquors, stripping liquors, etc. containing chelating agents, or uses non-electroplating liquors when COD treatment is difficult with ordinary treatment systems, it is rational that the plating liquor should be discharged at a small rate when it is renewed, or batchwise treatment should be applied separately.

Although the proposed optimum system is operated by automation operation, the operating conditions should be found by the operators in the field. Various chemicals are used in oxidation of cyanides, reduction of chromium or neutralization of heavy metals. The equipment operation should be done with minimum consumptions of these chemicals. To this end, it is important to determine set values of pH, ORP, chemical feed rates, etc. properly through the daily operation and control.

Reclaimed water is recycled water, and therefore, unexpected substances such as additives to the plating liquor may be accumulated in it. In order to avoid these accumulated substances from affecting the finishing of plating, it is necessary to take care from time to time. A portion of the recycled water should be discharged for use in dissolving the chemicals to be fed into each reaction tank or the chemicals to be used for regeneration of ion exchange resins, and tap water be supplied as make-up water.

In the water analysis of the wastewater to be received, wastewater to be finally discharged and the reclaimed water, necessary analytical items should be selected in addition to those specified in the effluent standards. This is because the water quality is represented by the analytical items.

Daily reports, weekly reports, monthly reports, yearly reports, etc. for the treatment facilities should be kept, as they may be useful in solving any problem arising from operation and/or maintenance of the central wastewater treatment plant.

Next, Table 3.6.3. shown daily consumption of each above items for each Case, 1 through 5.

Table 3.6.4. shows operation costs for Cases 1 through 3 classified as (1) Chemicals (2) City Water, (3)Electric Power (4) Sludge Disposal and (5) Labor.

Similarly, the operation cost for Case 4 is about 143.6 million won per year and about 152.9million eon for Case 5.

4 Financial and Economic Analysis

4.1 Total Capital Requirements and Operating Costs

4.1.1 Major Assumptions for Estimation

(1) Date for base cost estimation

This financial analysis is made on a fixed-price basis at the end of 1992. Thus, all of investment costs are also estimated at the price level of that time.

(2) Utilization of local currency

Total capital requirements and operating costs are assumed to be secured from local financing sources. Therefore, in this study, the foreign portion is not due in consideration for cost estimation. Won is used as the standard currency. Japanese yen is converted into won by the following fixed exchange rate, if needed.

One won = 0.157 Japanese yen

4.1.2 Items of Capital Investment

The estimated capital requirement covers following items.

(1) Plant construction cost
(2) Preoperational expenses
(3) Interest during construction

Land acquisition cost is optionally included for the financial analysis in the sub-section below although this cost is excluded from the costs estimation according to the Inception Report.

4.1.3 Plant Construction Cost

Plant construction costs are shown in Table 4.1.1 for only three cases, which are defined in Chapter 3. (The system for waste water treatment with the treatment level of existing standards is defined as Case 1. The system for waste water treatment with the treatment level of high reduction of COD is as Case 2. The system for waste water treatment and recycling with the treatment level of existing standards is as Case 3.) The details of costs estimation are also shown in Chapter 3.

Table 4.1.1 Construction Cost

Unit: million won

	Case 1	Case 2	Case 3
Civil and architectural work	-	-	-
Machinery and equipments	317	339	370
Electrical work	636	679	959
Piping work	69	74	81
Total	1,022	1,091	1,410

4.1.4 Preoperational Expenses

As preoperational expenses, cost in test runs is estimated. This cost covers initial charge of utilities and relevant consumables such as chemicals and spare parts for replacements, which are required during the test operation. The estimated costs are 34.5 million won for Case 1 and Case 2, and 46.0 million won for Case 3.

4.1.5 Interest during Construction

Interest during construction is calculated on the debt portion of disbursed capital expenditures (long term loan) for the period from such disbursement time through the end of completion date of the plant. The capital expenditures in the debt portion are assumed to be disbursed at two times equally. The first half is disbursed at the beginning of the year and the second half is scheduled to be disbursed at the middle of the year. As a result, the total amount of interest during construction is 39 million won for Case 1, 42 million for Case 2, and 54 million for Case 3. The interest rate is 7 percent in year.

4.1.6 Total Capital Requirements

Total capital requirements are summarized in Table 4.1.2. Optionally, the land acquisition cost is included in the table. This cost is assumed to be 451 million won for Case 1 and Case 2 at 820 m^2 and 502 million won for Case 3 at 913 m^2. These amounts are based on the actual purchase price of the plating industrial estate in Inchon City. Unit price is set at 550,000 won per m^2.

Table 4.1.2 Total Capital Requirements

Unit: million won

	Case 1	Case 2	Case 3
Construction cost	1,022	1,091	1,410
Preoperational expenses	35	35	46
Interest during construction	39	42	54
Total (1)	1,096	1,168	1,510
Land acquisition cost	451	451	502
Total (1)+Land acquisition cost	1,547	1,619	2,012

4.1.7 Operating Costs and Expenses

(1) Variable operating cost

This cost covers chemicals, water, utility (electricity) and disposal cost of sludge are included. The cost is summarized in Table 4.1.3. Details are discussed in Section 6 of Chapter 3.

(2) Fixed operating cost

Fixed operating cost consists of labor cost and maintenance cost. Labor cost is assumed to be 30.5 million won per year for each case. Details are shown in Chapter 3.

On the other hand, annual maintenance cost is estimated as 1.0 percent of the construction costs through out the project life period. The cost is summarized in Table 4.1.3.

Table 4.1.3 Operating Costs

Unit: million won

	Case 1	Case 2	Case 3
Variable operating cost			
Chemicals	88.2	117.7	90.8
Water	0.7	0.7	0.7
Utility (electricity)	7.2	7.2	8.6
Disposal cost of sludge	12.9	12.9	12.9
Sub-total	109.0	138.5	113.0
Fixed operating cost			
Labor cost	30.5	30.5	30.5
Maintenance costs	10.6	11.3	14.6
Sub-total	41.1	41.8	45.1
Total	150.1	180.3	158.1

4.2 Financial Analysis

4.2.1 Basic Assumptions and Premises

For the purpose of the financial calculations, the following basic premises are applied.

(1) Project life and plant operation

(a) Project life ; construction period : 1 year
; operating period : 15 years
(b) Implementation body : Non-profit industrial cooperative
(c) Waste water treatment capacity : 60,000 m^3 per year
(d) Volume of recycling water : 30,000 m^3 per year (Case 3)
(d) Annual operating days : 300 days
(e) Annual operating hours : 2,400 hours (8 hours per day)

(2) Escalation of costs and prices

All costs and prices used in the financial analysis are assumed to be fixed in the end of 1992, and no escalation factors are applied.

(3) Corporate income tax

Corporate income tax will be imposed at a rate of 10 % of taxable income. This preferential rate is provided to an operator of environment protection facilities under the regulation.

(4) Depreciation and amortization

Depreciable assets are assumed to be depreciate as follows.

(a) Mode : Declining balance method
(b) Period : 15 years
(c) Salvage value : 10 percent

Also, interest during construction are amortized for five years in the declining balance method.

4.2.2 Financial Plan

(1) Debt-Equity ratio

Total capital requirements and operating costs are assumed to be financed locally. An equity portion is assumed to be 30 percent for the total capital requirements. On the other hand, a portion by a long term loan is assumed to be 70 percent of them.

Unit: million won

	ratio	Case 1	Case 2	Case 3
Equity	30%	329	350	453
Debt (long term loan)	70%	767	817	1,057
Total	100%	1,096	1,168	1,510

(2) Financing sources

A long term loan is assumed to be available from the Environmental Management Corporation and other the public funds. Since the maximum amount of the loan for the environmental protection facilities, which is operated by an industrial cooperative, from the Environmental Management Corporation is 500 million won, the loan from other public funds will be needed.

(3) Financing terms for long term loan

Financing terms for long term loan are assumed as follows. These terms are based on the Environmental Management Corporation's loan conditions.

Amount of loan	:	as shown in the above table
Interest rate	:	7 percent per year
Grace period	:	3 years
Installment period	:	7 years
Installment term	:	equally divided in 7 years

(4) Financing terms for short term loan

Whenever a deficiency in the annual cash flow arises during the operating period, a short term loan from local financing institutions (commercial bank or others) is assumed to be made available at an annual interest rate of 12 percent. The full amount will be repaid in the year subsequent to the year when the loan is made.

4.2.3 Method of Financial Analysis

(1) Fixed profitability

In this financial analysis, emphasis is laid on whether or not the price of the discharged fee of waste water calculated based on the fixed level of Financial Internal Rate of Return on Investment (FIRROI) is viable. This means the price level of the fee is calculated in order to attain the target FIRROI. The applied rate is 10 percent.

The rationale in this method is as follows.

(a) Revenue for the implementation body is only the discharged fee of waste water from individual plating factories. That is to say that the profitability of the cooperative depends on the price level of the fee.

(b) The price level of discharged fee of waste water is not totally controlled by the government. Therefore, the price level is not decided as the exogenous factor.

(c) Since this project is a conceptual design, it is worth to show the viable price level of the discharged fee rather than the profitability.

(d) The fixed rate at 10 percent is mainly based on the interest rate of the preferential loan to private industries by public institutions. This rate is applied because the implementation body is assumed to be a non-profit cooperative although the rate is below the market rate in local commercial banks (12 - 13 percent per year).

(2) Internal Rate of Return (IRR) as applied indicators

In this analysis, two types of IRR are applied. One is Financial Internal Rate of Return on Investment (FIRROI) and the other is Financial Internal Rate of Return on Equity (FIRROE).

FIRROI is an indicator of the profitability in the total investment of the project. The total capital requirements except interest during construction, revenue, and operating costs in cash flow statements are components for calculating this indicator. The interest and repayment of debt is not included.

FIRROE, on the other hand, indicates the profitability of invested own funds (equity) in the project. Thus, this rate depends on financing conditions (interest, repayment amount and so on) as well as the total capital requirements, revenue, and operating costs.

4.2.4 Results of Financial Analysis

(1) Projected price of the discharged fee

The levels of the discharged fee in order to attain the target FIRROI (10.0 %) for three cases are shown below. The levels of the fee for the case with land acquisition cost are also presented.

	Case 1	Case 2	Case 3
FIRROI	10.00	10.00	10.00
FIRROE	12.02	12.04	12.02
Price of Fee (won per m^3)	**4,763**	**5,415**	**5,750**
FIRROI	10.00	10.00	10.00
(cases with Land Acquisition Cost)			
Price of Fee (won per m^3)	**5,751**	**6,165**	**6,588**

According to the interview to "S" company at plating industrial estate in Inchon City, the discharged fee from individual factories is about 13-14 thousand won per m^3 in 1992. When compared with this price level, the projected fee levels are rather low.

(2) Financial projections

Based on the above assumptions and conditions, the following financial projections are prepared for three cases.

(a) Income Statements
(b) Cash Flow Statements
(c) Production Cost Statements

Income statements and Cash Flow Statements are shown in Table 4.2.1 - Table 4.2.3. Production cost statements are shown in Table 4.2.4 - Table 4.2.6.

According to the cash flow statements, the implementation body can retain the cash increase of approximately 125 million won per year for Case 1, 130 million won for Case 2 and 170 million won for Case 3 respectively from 10th year to 15th year. Therefore, if the levels of the fee (revenue) can be changed in accordance with "one year budget" basis, the unit price levels of the fee (per m^3) can be decreased from 4,763 to 2,680 for Case 1, 5,415 to 3,250 for Case 2, and 5,750 to 2,920 for Case 3, respectively, in 10th - 15th years.

The cash flow statements do not show the needs of the short term loan. Conditions of long term debt (3 year's grace period and 7 year's installment) could hedge the shortage of cash.

Based on the production cost statements, the averages of unit production cost are 3,925 won per m^3 for Case 1, 4,523 won per m^3 for Case 2 and 4,597 won per m^3.

Table 4.2.1 Income Statements and Cash Flow Statements for Plating Industries Waste Water Treatment Plant (Case I)

INCOME STATEMENTS

Unit: million Won

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OPERATING INCOME		286	286	286	286	286	286	286	286	286	286	286	286	286	286	286
OPERATING EXPENSES		310	284	263	246	235	218	208	199	193	187	181	178	173	169	167
VARIABLE OPERATION COST		109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
FIXED OPERATION COST		41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
DEPRECIATION & AMORTIZATION		160	134	113	96	85	67	58	49	43	37	31	28	22	19	17
DEPRECIABLE FIXED ASSETS		145	125	107	92	79	67	58	49	43	37	31	28	22	19	17
INTEREST DURING CONSTRUCTION		14	9	6	4	6	0	0	0	0	0	0	0	0	0	0
OPERATING PROFIT(GROSS PROFIT)		-24	2	23	40	51	68	77	87	93	99	105	108	113	116	118
NON-OPERATING EXPENSES		54	54	54	46	38	31	23	15	8	0	0	0	0	0	0
INTEREST ON LONG TERM DEBT		54	54	54	46	38	31	23	15	8	0	0	0	0	0	0
INTEREST ON SHORT TERM DEBT		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET PROFIT BEFORE TAX		-78	-52	-31	-6	12	38	54	71	85	99	105	108	113	116	118
CORPORATE TAX		0	0	0	0	1	4	5	7	9	10	11	11	11	12	12
NET PROFIT AFTER TAX (RETAINED EARNINGS)		-78	-52	-31	-6	11	34	49	64	77	89	95	97	102	105	106

CASH FLOW ANALYSIS

Unit: million Won

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SOURCES																
CASH GENERATED	0	82	82	82	90	96	101	107	113	120	126	125	125	124	124	124
PROFIT AFTER TAX	0	-78	-52	-31	-6	11	34	49	64	77	89	95	97	102	105	106
DEPRECIATION AND AMORTIZATION	0	160	134	113	96	85	67	58	49	43	37	31	28	22	19	17
FINANCIAL RESOURCES	1,096	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EQUITY(SHARE CAPITAL)	329	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LONG TERM DEBT	767	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHORT TERM DEBT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOURCES TOTAL	1,096	82	82	82	90	96	101	107	113	120	126	125	125	124	124	124
USES																
FIXED CAPITAL EXPENDITURE	1,096	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON-DEPRECIABLE ASSETS	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEPRECIABLE FIXED ASSETS	1,023	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INTEREST DURING CONSTRUCTION	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEBT SERVICES	0	0	0	110	110	110	110	110	110	110	0	0	0	0	0	0
REPAYMENT OF LONG TERM DEBT	0	0	0	110	110	110	110	110	110	110	0	0	0	0	0	0
REPAYMENT OF SHORT TERM DEBT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USES TOTAL	1,096	0	0	110	110	110	110	110	110	110	0	0	0	0	0	0
CASH INCREASE (OR DECREASE)	0	82	82	-28	-20	-14	-8	-2	4	10	126	125	125	124	124	124
BEGINNING CASH BALANCE	0	0	82	164	136	116	103	95	92	96	106	232	357	482	606	730
ENDING CASH BALANCE	0	82	164	136	116	103	95	92	96	106	232	357	482	606	730	854

Table 4.2.2 Income Statements and Cash Flow Statements for Plating Industries Waste Water Treatment Plant (Case 2)

INCOME STATEMENTS

Unit: million Won

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OPERATING INCOME		325	325	325	325	325	325	325	325	325	325	325	325	325	325	325
OPERATING EXPENSES		351	323	301	282	271	252	242	233	226	220	213	210	204	201	199
VARIABLE OPERATION COST		139	139	139	139	139	139	139	139	139	139	139	139	139	139	139
FIXED OPERATION COST		42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
DEPRECIATION & AMORTIZATION		170	143	121	102	91	72	62	52	46	39	33	29	24	21	19
DEPRECIABLE FIXED ASSETS		155	133	115	98	84	72	62	52	46	39	33	29	24	21	19
INTEREST DURING CONSTRUCTION		15	10	6	4	7	0	0	0	0	0	0	0	0	0	0
OPERATING PROFIT(GROSS PROFIT)		-26	2	24	43	54	73	82	92	99	105	112	115	121	124	126
NON-OPERATING EXPENSES		57	57	57	49	41	33	25	16	8	-0	-0	-0	-0	-0	-0
INTEREST ON LONG TERM DEBT		57	57	57	49	41	33	25	16	8	-0	-0	-0	-0	-0	-0
INTEREST ON SHORT TERM DEBT		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET PROFIT BEFORE TAX		-83	-55	-33	-6	13	40	58	76	91	105	112	115	121	124	126
CORPORATE TAX		0	0	0	0	1	4	6	8	9	11	11	12	12	12	13
NET PROFIT AFTER TAX (RETAINED EARNINGS)		-83	-55	-33	-6	12	36	52	68	82	95	101	104	109	112	113

CASH FLOW ANALYSIS

Unit: million Won

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SOURCES																
CASH GENERATED	0	87	87	87	96	102	108	114	121	127	134	133	133	133	132	132
PROFIT AFTER TAX	0	-83	-55	-33	-6	12	36	52	68	82	95	101	104	109	112	113
DEPRECIATION AND AMORTIZATION	0	170	143	121	102	91	72	62	52	46	39	33	29	24	21	19
FINANCIAL RESOURCES	1.168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EQUITY(SHARE CAPITAL)	350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LONG TERM DEBT	817	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHORT TERM DEBT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOURCES TOTAL	1.168	87	87	87	96	102	108	114	121	127	134	133	133	133	132	132
USES																
FIXED CAPITAL EXPENDITURE	1.168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON-DEPRECIABLE ASSETS	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEPRECIABLE FIXED ASSETS	1.092	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INTEREST DURING CONSTRUCTION	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEBT SERVICES	0	0	0	117	117	117	117	117	117	117	0	0	0	0	0	0
REPAYMENT OF LONG TERM DEBT	0	0	0	117	117	117	117	117	117	117	0	0	0	0	0	0
REPAYMENT OF SHORT TERM DEBT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USES TOTAL	1.168	0	0	117	117	117	117	117	117	117	0	0	0	0	0	0
CASH INCREASE (OR DECREASE)	0	87	87	-29	-21	-14	-9	-2	4	11	134	133	133	133	132	132
BEGINNING CASH BALANCE	0	0	87	175	146	124	110	101	99	103	113	248	381	514	647	779
ENDING CASH BALANCE	0	87	175	146	124	110	101	99	103	113	248	381	514	647	779	911

Table 4.2.3 Income Statements and Cash Flow Statements for Plating Industries Waste Water Treatment Plant (Case 3)

INCOME STATEMENTS

Unit: million Won

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OPERATING INCOME		345	345	345	345	345	345	345	345	345	345	345	345	345	345	345
OPERATING EXPENSES		378	343	314	290	275	251	238	226	217	209	200	196	189	185	182
VARIABLE OPERATION COST		113	113	113	113	113	113	113	113	113	113	113	113	113	113	113
FIXED OPERATION COST		45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
DEPRECIATION & AMORTIZATION		220	185	156	132	117	93	80	68	59	51	42	38	31	27	24
DEPRECIABLE FIXED ASSETS		200	172	148	127	109	93	80	68	59	51	42	38	31	27	24
INTEREST DURING CONSTRUCTION		20	13	8	5	8	0	0	0	0	0	0	0	0	0	0
OPERATING PROFIT(GROSS PROFIT)		-33	2	31	55	70	94	107	119	128	136	145	149	156	160	163
NON-OPERATING EXPENSES		74	74	74	63	53	42	32	21	11	0	0	0	0	0	0
INTEREST ON LONG TERM DEBT		74	74	74	63	53	42	32	21	11	0	0	0	0	0	0
INTEREST ON SHORT TERM DEBT		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NET PROFIT BEFORE TAX		-107	-72	-43	-8	17	52	75	98	117	136	145	149	156	160	163
CORPORATE TAX		0	0	0	0	2	5	7	10	12	14	14	15	16	16	16
NET PROFIT AFTER TAX (RETAINED EARNINGS)		-107	-72	-43	-8	15	46	67	88	105	123	130	134	140	144	147

CASH FLOW ANALYSIS

Unit: million Won

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SOURCES																
CASH GENERATED	0	113	113	113	124	132	140	148	156	165	173	172	172	171	171	171
PROFIT AFTER TAX	0	-107	-72	-43	-8	15	46	67	88	105	123	130	134	140	144	147
DEPRECIATION AND AMORTIZATION	0	220	185	156	132	117	93	80	68	59	51	42	38	31	27	24
FINANCIAL RESOURCES	1,510	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EQUITY(SHARE CAPITAL)	453	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LONG TERM DEBT	1,057	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHORT TERM DEBT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOURCES TOTAL	1,510	113	113	113	124	132	140	148	156	165	173	172	172	171	171	171
USES																
FIXED CAPITAL EXPENDITURE	1,510	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON-DEPRECIABLE ASSETS	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEPRECIABLE FIXED ASSETS	1,410	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INTEREST DURING CONSTRUCTION	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEBT SERVICES	0	0	0	151	151	151	151	151	151	151	0	0	0	0	0	0
REPAYMENT OF LONG TERM DEBT	0	0	0	151	151	151	151	151	151	151	0	0	0	0	0	0
REPAYMENT OF SHORT TERM DEBT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USES TOTAL	1,510	0	0	151	151	151	151	151	151	151	0	0	0	0	0	0
CASH INCREASE (OR DECREASE)	0	113	113	-38	-27	-19	-11	-3	5	14	173	172	172	171	171	171
BEGINNING CASH BALANCE	0	0	113	226	188	160	142	130	127	132	146	319	492	664	835	1,006
ENDING CASH BALANCE	0	113	226	188	160	142	130	127	132	146	319	492	664	835	1,006	1,177

Table 4.2.4 Production Cost Statements for Plating Industries Waste Water Treatment Plant (Case 1)

Unit: million Won (unless otherwise designated)

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) PRODUCTION (m3/year)		60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000
(2) VARIABLE OPERATING COST		109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
(3) FIXED OPERATING COST		41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
(4) CASH COST TOTAL:(2)+(3)		150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
(5) UNIT CASH COST: (4)/(1);won per m3		2.501	2.501	2.501	2.501	2.501	2.501	2.501	2.501	2.501	2.501	2.501	2.501	2.501	2.501	2.501
(6) DEPRECIATION & AMORTIZATION		160	134	113	96	85	67	58	49	43	37	31	28	22	19	17
(7) OPERATING EXPENSES:(2)+(3)+(6)		310	284	263	246	235	218	208	199	193	187	181	178	173	169	167
(8) INTEREST ON LONG TERM DEBT		54	54	54	46	38	31	23	15	8	0	0	0	0	0	0
(9) INTEREST ON SHORT TERM DEBT		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(10)TOTAL PRODUCTION COST		363	338	317	292	273	248	231	214	201	187	181	178	173	169	167
(11)UNIT PRODUCTION COST:(10)/(1): (won per m3)		6.056	5.627	5.281	4.863	4.556	4.137	3.856	3.575	3.345	3.115	3.012	2.961	2.876	2.825	2.791

* Average of Unit Production Cost for 15 years
3.925 won per m3

(Percentage of components)

Unit: percent

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) VARIABLE OPERATING COST		30.00	32.28	34.40	37.36	39.88	43.91	47.11	50.82	54.31	58.33	60.31	61.35	63.16	64.31	65.09
(2) FIXED OPERATING COST		11.30	12.16	12.96	14.08	15.03	16.54	17.75	19.15	20.46	21.98	22.72	23.11	23.80	24.23	24.53
(3) DEPRECIATION & AMORTIZATION		43.92	39.64	35.69	32.79	31.06	27.18	25.19	22.88	21.40	19.70	16.97	15.54	13.04	11.46	10.38
(4) INTEREST ON LONG TERM DEBT		14.78	15.91	16.95	15.78	14.03	12.36	9.95	7.15	3.82	0.00	0.00	0.00	0.00	0.00	0.00
(5) INTEREST ON SHORT TERM DEBT		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(6) TOTAL PRODUCTION COST		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.2.5 Production Cost Statements for Plating Industries Waste Water Treatment Plant (Case 2)

Unit: million Won (unless otherwise designated)

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) PRODUCTION (m3/year)		60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000
(2) VARIABLE OPERATING COST		139	139	139	139	139	139	139	139	139	139	139	139	139	139	139
(3) FIXED OPERATING COST		42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
(4) CASH COST TOTAL:(2)+(3)		180	180	180	180	180	180	180	180	180	180	180	180	180	180	180
(5) UNIT CASH COST: (4)/(1):won per m3		3.004	3.004	3.004	3.004	3.004	3.004	3.004	3.004	3.004	3.004	3.004	3.004	3.004	3.004	3.004
(6) DEPRECIATION & AMORTIZATION		170	143	121	102	91	72	62	52	46	39	33	29	24	21	19
(7) OPERATING EXPENSES:(2)+(3)+(6)		351	323	301	282	271	252	242	233	226	220	213	210	204	201	199
(8) INTEREST ON LONG TERM DEBT		57	57	57	49	41	33	25	16	8	-0	-0	-0	-0	-0	-0
(9) INTEREST ON SHORT TERM DEBT		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(10)TOTAL PRODUCTION COST		408	380	358	331	312	285	267	249	234	220	213	210	204	201	199
(11)UNIT PRODUCTION COST:(10)/(1): (won per m3)		6.797	6.339	5.970	5.523	5.196	4.750	4.450	4.150	3.905	3.659	3.550	3.496	3.405	3.350	3.314

* Average of Unit Production Cost for 15 years
4.523 won per m3

(Percentage of components)

Unit: percent

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) VARIABLE OPERATING COST		33.96	36.42	38.67	41.79	44.43	48.60	51.87	55.62	59.12	63.08	65.02	66.04	67.80	68.91	69.66
(2) FIXED OPERATING COST		10.24	10.98	11.66	12.60	13.40	14.65	15.64	16.77	17.83	19.02	19.61	19.91	20.44	20.78	21.00
(3) DEPRECIATION & AMORTIZATION		41.77	37.56	33.70	30.81	29.07	25.28	23.30	21.04	19.57	17.90	15.37	14.05	11.76	10.32	9.33
(4) INTEREST ON LONG TERM DEBT		14.03	15.04	15.97	14.80	13.11	11.47	9.18	6.56	3.49	0.00	0.00	0.00	0.00	0.00	0.00
(5) INTEREST ON SHORT TERM DEBT		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(6) TOTAL PRODUCTION COST		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.2.6 Production Cost Statements for Plating Industries Waste Water Treatment Plant (Case 3)

Unit: million Won (unless otherwise designated)

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) PRODUCTION (m3/year)		60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000
(2) VARIABLE OPERATING COST		113	113	113	113	113	113	113	113	113	113	113	113	113	113	113
(3) FIXED OPERATING COST		45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
(4) CASH COST TOTAL:(2)+(3)		158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
(5) UNIT CASH COST: (4)/(1):won per m3		2.634	2.634	2.634	2.634	2.634	2.634	2.634	2.634	2.634	2.634	2.634	2.634	2.634	2.634	2.634
(6) DEPRECIATION & AMORTIZATION		220	185	156	132	117	93	80	68	59	51	42	38	31	27	24
(7) OPERATING EXPENSES:(2)+(3)+(6)		378	343	314	290	275	251	238	226	217	209	200	196	189	185	182
(8) INTEREST ON LONG TERM DEBT		74	74	74	63	53	42	32	21	11	0	0	0	0	0	0
(9) INTEREST ON SHORT TERM DEBT		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(10)TOTAL PRODUCTION COST		452	417	388	353	328	293	270	247	228	209	200	196	189	185	182
(11)UNIT PRODUCTION COST:(10)/(1): (won per m3)		7.535	6.943	6.467	5.890	5.466	4.890	4.502	4.115	3.797	3.480	3.339	3.269	3.151	3.081	3.034

* Average of Unit Production Cost for 15 years
4.597 won per m3

(Percentage of components)

Unit: percent

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) VARIABLE OPERATING COST		24.99	27.13	29.12	31.98	34.45	38.51	41.83	45.77	49.59	54.11	56.40	57.61	59.76	61.13	62.08
(2) FIXED OPERATING COST		9.97	10.82	11.61	12.75	13.74	15.36	16.68	18.25	19.78	21.58	22.49	22.97	23.83	24.38	24.75
(3) DEPRECIATION & AMORTIZATION		48.68	44.30	40.20	37.33	35.69	31.72	29.75	27.41	25.99	24.31	21.11	19.41	16.41	14.49	13.17
(4) INTEREST ON LONG TERM DEBT		16.36	17.76	19.07	17.94	16.11	14.41	11.74	8.56	4.64	0.00	0.00	0.00	0.00	0.00	0.00
(5) INTEREST ON SHORT TERM DEBT		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(6) TOTAL PRODUCTION COST		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

4.2.5 Ratio Analysis

The results of conventional ratio analysis are shown in Table 4.2.7 - Table 4.2.9. The definitions of financial performance indicators are summarized below.

(a) Profit on Sales Revenue :

Net profit (after tax) / Operating income (Revenue)

(b) Profit on Equity :

Net profit (after tax) / Equity

(c) Debt Service Coverage Ratio :

(Net profit+Depreciation+Interest)/(Repayment+Interest)

(d) Break Even Revenue (B.E.R, Profit) :

B.E.R = (FOC + DP + Interest)/ (1 - (VC / Revenue))
B.E.P = B.E.R / Revenue

(e) Break Even Revenue (B.E.R, Cash) :

B.E.R = (FOC + Repayment + Interest)/ (1 - (VC / Revenue))
B.E.P = B.E.R / Revenue

where,

B.R.P = Break Even Point Ratio
FOC = Fixed Operating Cost
VC = Variable Operating Cost
DP = Depreciation and Amortization

Table 4.2.8 Ratio Analysis for Plating Industries Waste Water Treatment Plant (Case 2)

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Profit on Sales Revenue (%)	-	-27.15	-18.14	-10.88	-2.09	3.92	11.82	17.14	22.45	26.80	31.15	33.08	34.04	35.65	36.62	37.26	15.44
Profit on Equity (%)	-	-23.60	-15.77	-9.46	-1.82	3.41	10.27	14.89	19.51	23.29	27.07	28.75	29.59	30.99	31.83	32.39	13.42
Debt Service Coverage Ratio	-	2.53	2.53	0.83	0.87	0.91	0.94	0.98	1.03	1.08	-	-	-	-	-	-	-
Break Even Revenue (Profit)	-	411	370	336	295	266	225	198	171	148	126	116	111	103	98	94	205
B.E.P. Ratio (%)	-	143.90	129.33	117.59	103.38	92.96	78.77	69.22	59.68	51.87	44.05	40.58	38.85	35.96	34.22	33.07	71.56
Break Even Revenue (Cash)	-	153	153	330	318	306	293	281	268	256	66	66	66	66	66	66	184
B.E.P. Ratio (%)	-	53.61	53.61	115.61	111.27	106.93	102.59	98.25	93.91	89.57	23.23	23.23	23.23	23.23	23.23	23.23	64.32

Note: Unit of Break Even Revenue is million won.

Table 4.2.7 Ratio Analysis for Plating Industries Waste Water Treatment Plant (Case 1)

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Profit on Sales Revenue (%)	-	-25.52	-17.06	-10.25	-2.00	3.65	11.06	16.04	21.03	25.10	29.18	31.00	31.90	33.41	34.32	34.93	14.45
Profit on Equity (%)	-	-23.67	-15.82	-9.50	-1.86	3.38	10.25	14.88	19.50	23.29	27.07	28.75	29.59	30.99	31.84	32.40	13.41
Debt Service Coverage Ratio	-	2.53	2.53	0.83	0.87	0.91	0.94	0.98	1.03	1.09	-	-	-	-	-	-	-
Break Even Revenue (Profit)	-	469	422	383	336	302	255	224	193	167	141	130	124	115	109	105	232
B.E.P. Ratio (%)	-	144.48	129.73	117.86	103.49	92.94	78.59	68.93	59.28	51.38	43.48	39.97	38.21	35.29	33.53	32.36	71.30
Break Even Revenue (Cash)	-	173	173	376	362	348	333	319	305	291	73	73	73	73	73	73	208
B.E.P. Ratio (%)	-	53.10	53.10	115.73	111.35	106.97	102.58	98.20	93.81	89.43	22.40	22.40	22.40	22.40	22.40	22.40	63.91

Note: Unit of Break Even Revenue is million won.

Table 4.2.9 Ratio Analysis for Plating Industries Waste Water Treatment Plant (Case 3)

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Profit on Sales Revenue (%)	-	-31.04	-20.75	-12.46	-2.43	4.44	13.46	19.53	25.60	30.56	35.53	37.73	38.84	40.67	41.78	42.51	17.60
Profit on Equity (%)	-	-23.65	-15.81	-9.49	-1.85	3.38	10.25	14.88	19.50	23.28	27.06	28.74	29.58	30.98	31.82	32.38	13.40
Debt Service Coverage Ratio	-	2.53	2.53	0.83	0.87	0.91	0.94	0.98	1.03	1.08	-	-	-	-	-	-	-
Break Even Revenue (Profit)	-	504	451	409	357	320	268	234	199	171	142	130	124	113	107	103	242
B.E.P. Ratio (%)	-	146.17	130.86	118.53	103.61	92.66	77.76	67.73	57.71	49.50	41.30	37.66	35.83	32.79	30.97	29.75	70.19
Break Even Revenue (Cash)	-	177	177	402	386	370	354	339	323	307	67	67	67	67	67	67	216
B.E.P. Ratio (%)	-	51.31	51.31	116.39	111.83	107.28	102.72	98.17	93.61	89.05	19.42	19.42	19.42	19.42	19.42	19.42	62.55

Note: Unit of Break Even Revenue is million won.

4.2.6 Sensitivity Analysis

Sensitivity analysis is conducted in two ways. The first one is to see the variation of the discharged fee (revenue) through fluctuating the construction cost and the operating cost on condition that FIRROI keeps at 10 percent. These results are shown in Table 4.2.10 and Fig.4.2.1. According to the results, the operating cost is more sensitive than the construction cost in Case 1 and Case 2. On the other hand, the construction cost is more sensitive in Case 3.

Table 4.2.10 Sensitivity Analysis (1) (FIRROI = 10 %)

Unit: won per m^3

	Construction Cost	Operating Cost
(Case 1)		
-20	4,311	4,263
-10	4,537	4,514
0 (Base)	4,763	4,763
+10	4,990	5,014
+20	5,216	5,264
(Case 2)		
-20	4,932	4,814
-10	5,174	5,114
0 (Base)	5,415	5,415
+10	5,655	5,715
+20	5,896	6,015
(Case 3)		
-20	5,127	5,223
-10	5,439	5,488
0 (Base)	5,750	5,750
+10	6,062	6,014
+20	6,374	6,277

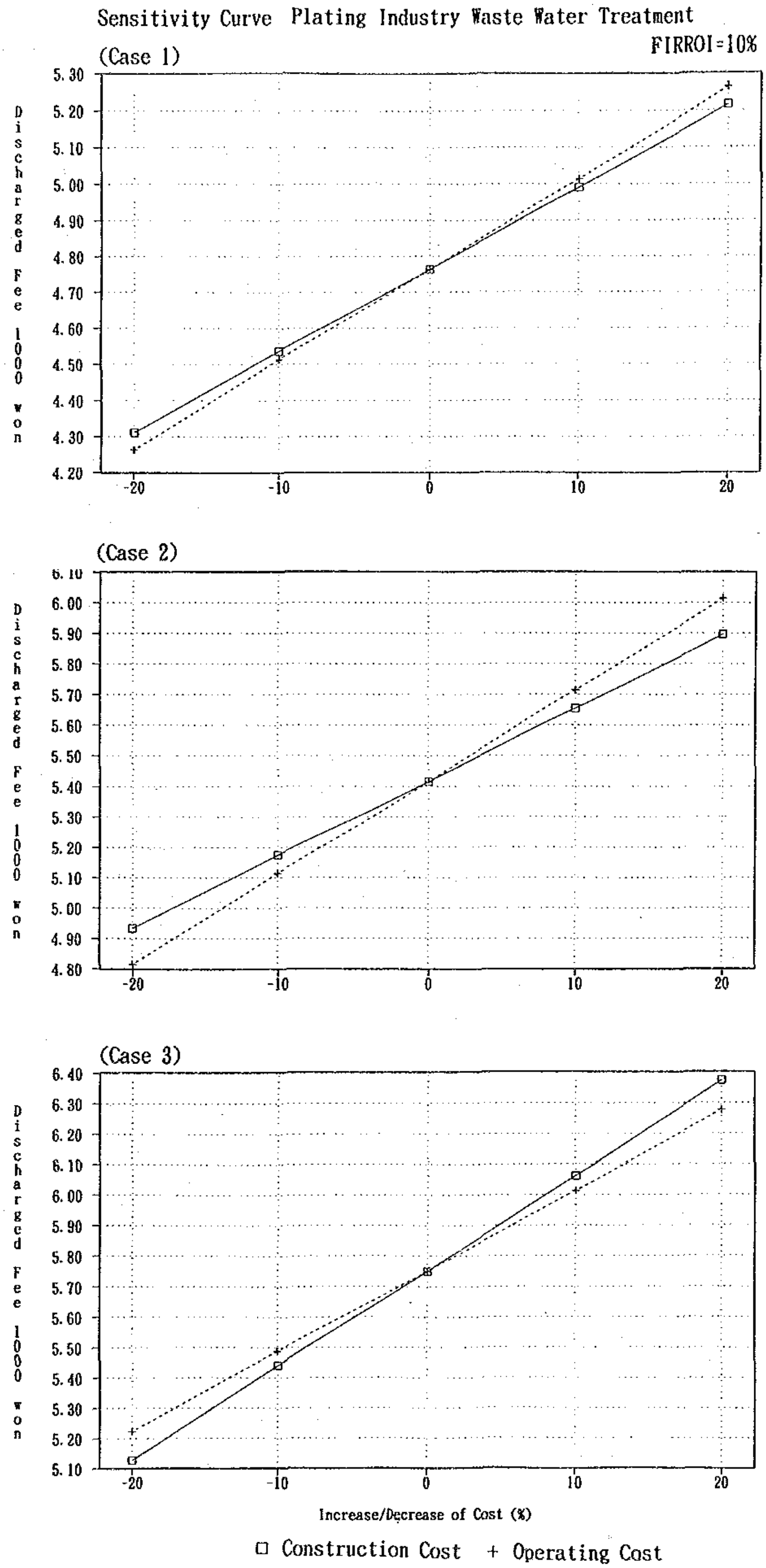

Fig.4.2.1 Sensitivity Analysis (1)

Another way to analyze sensitivity is to see the variation of FIRROI through fluctuating construction cost, operating cost and revenue. The results are shown in Table 4.2.11 and Fig. 4.2.2. The most sensitive factor to influence FIRROI is the variation of the revenue (operating income). A ten percent drop in revenue will cause 3.64%, 3.89%, and 3.17% decrease of FIRROI for Case 1, Case 2 and Case 3, respectively. The increase of the operating cost also influences FIRROI in Case 2 in particular.

Table 4.2.11 Sensitivity Analysis (2)

Unit: percent(FIRROI)

	Construction Cost	Operating Cost	Revenue
(Case 1)			
-20	13.99	13.54	2.33
-10	11.80	11.80	6.36
0 (Base)	10.00	10.00	10.00
+10	8.46	8.12	13.38
+20	7.14	6.17	16.58
(Case 2)			
-20	14.00	13.98	1.76
-10	11.81	12.03	6.11
0 (Base)	10.00	10.00	10.00
+10	8.47	7.89	13.60
+20	7.15	5.66	17.01
(Case 3)			
-20	13.99	12.73	3.38
-10	11.80	11.38	6.83
0 (Base)	10.00	10.00	10.00
+10	8.46	8.57	12.97
+20	7.15	7.10	15.80

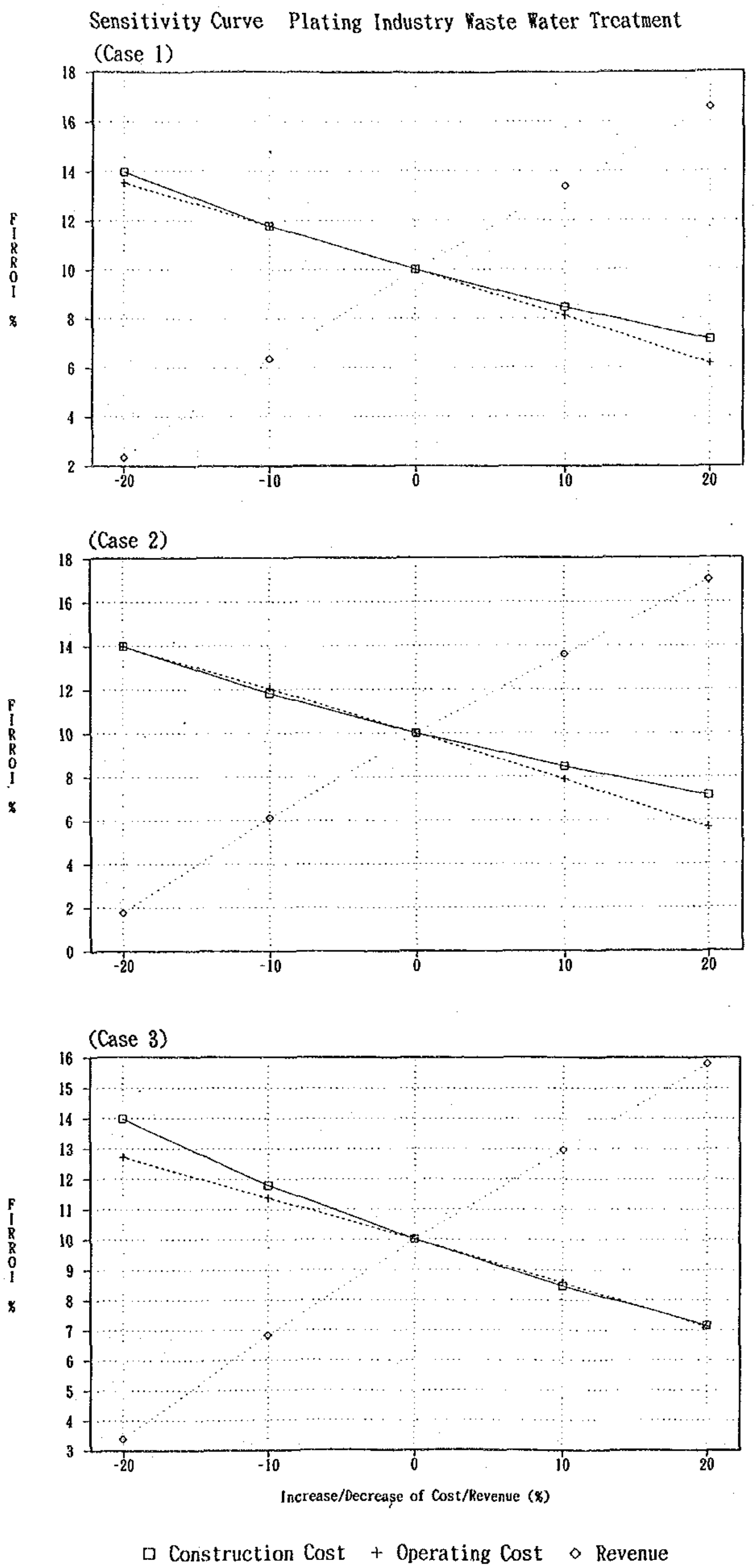

Fig.4.2.2 Sensitivity Analysis (2)

4.3 Economic Analysis

Whereas financial analysis focuses primarily on market prices and cash flows, economic analysis should include the benefits and the costs of the effects that the project have on the environment.

However, the direct loss or damage to the environment in the Study Areas and the vicinity is not seen in this project because this is a conceptional design. As a result, the benefits based on market values can not been identified quantitatively except recycling water produced in Case 3. In this economic analysis, therefore, the introduction of generally applicable methods, the benefits of recycling water in Case 3 and the qualitative socio-economic impacts are discussed. The Economic Internal Rate of Return (EIRR) is not calculated.

4.3.1 Generally Applicable Techniques for the Analysis[1]

Three sets of valuation techniques using market prices, which are those of straightforward benefit-cost analysis, are used in common in the economic analysis on the environmental project. The first one deals with changes in production and the value of output. The second one is the loss of earnings approach. And, the third one is the opportunity cost approach.

The techniques using changes in productivity are direct extensions of traditional benefit-cost analyses. Physical changes in production are valued using market prices for inputs and outputs. (example: Untreated effluent, with a high BOD content, polluted waters and then affected the productivity of a downstream fishery.)

The "loss of earning" technique is to estimate the lost earnings and medical costs that result from the environmental damage caused by a project. (example: an urban water supply project which reduces the incidence of diarrhea)

The opportunity cost approach is based on the concept that the

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1.The contents of this sub-section is mainly relied on "Economic Analysis of the Environmental Impacts of Development Projects" by the Asian Development Bank in 1986.

cost of using resources for unpriced or unmarketed purposes can be estimated by using the forgone income from other uses of the resources as a proxy. This approach is a way of the measuring the "cost of preservation". (example: preserving land for a national park rather than harvesting its tree for timber)

4.3.2 Benefits of recycling water

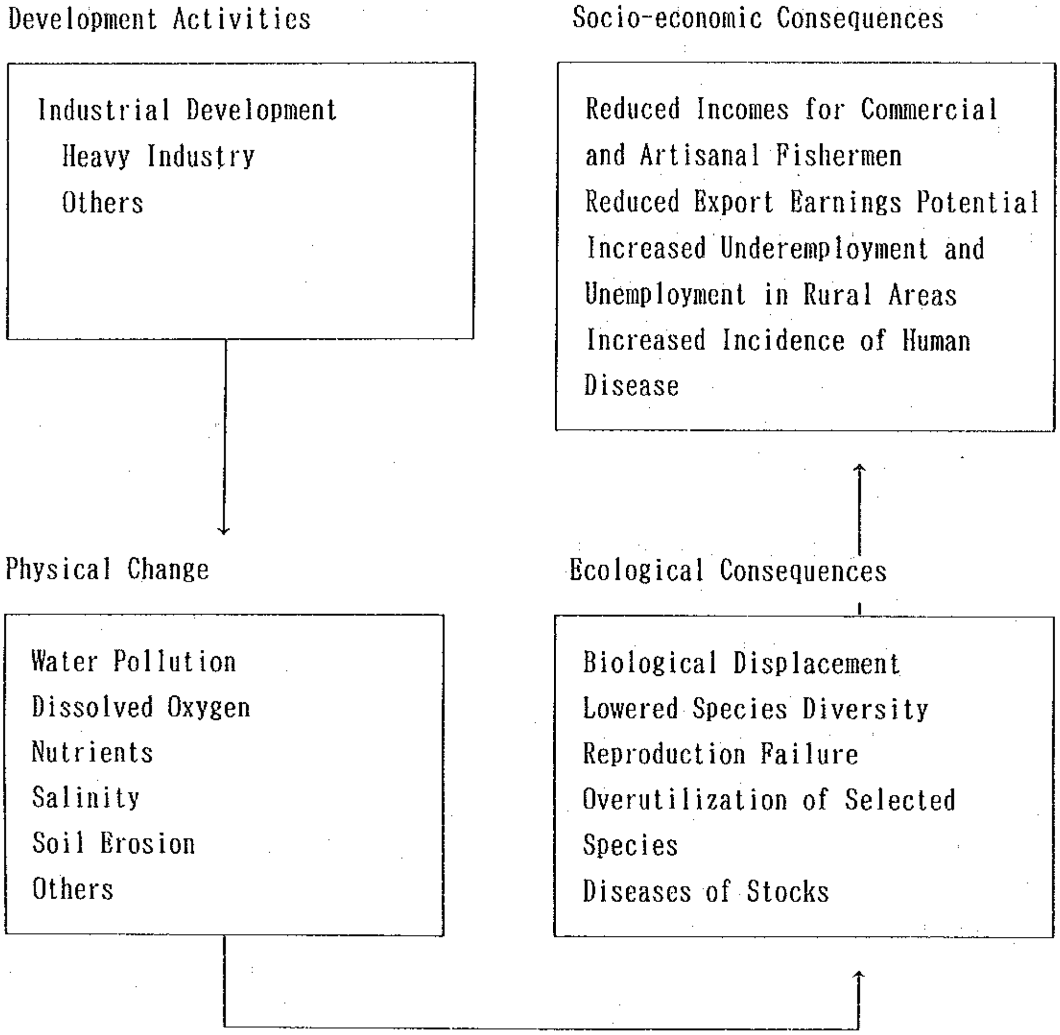
In Case 3, 30,000 m^3 of recycling water is annually produced. This recycling water is the benefit under the change-in-production approach, which is discussed before. The benefits from the recycling water are calculated based on the alternative resource saved by avoiding the needs to provide clean water (presumably least costly). This means that the production costs on the equal amount of water supply is the benefit for recycling water. Since the unit cost of water supply is 268 won per m^3 according to the data for water production in Inchon area, the total savings (benefits) amount to 8.05 million won per year although this is very small compared with the total cost for the treatment plant. Since recycling water is not produced from Case 1 and Case 2, the savings for these two cases can not be calculated. .

4.3.3 Socio-economic Impact Consideration

Industrial development (such as plating industrial estate) in general tends to cause the damage to the environment through the linkages. The development causes physical changes in water, air, soil and so on in terms of temperature, dissolved oxygen, nutrients, salinity, siltation, solid wastes and so on. These changes result in ecological changes such as biological displacement, change in species composition, lowered species diversity, reproduction failure, and so on. Then, these have the socio-economic consequences such as reduced incomes for fishermen and farmers through the reduction of the productivity, increased underemployment and unemployment, and increased incidence of human disease. These linkages are shown in Fig. 4.3.1.

Specifically CN, Cu, Cr^{+6} and other heavy metals in the waste water from plating industries may cause the following environmental effects.

(a) Fish and other animals in the water near the plating industrial estate may be contaminated by poisonous heavy metals and incidence of human disease may be increased through a



Note: This diagram is mainly transformed from Table 1 in "Economic Analysis of the Environmental Impacts of Development Projects" published by ADB in 1986.

Fig. 4.3.1 Linkage between Development Activities and their Consequences food cycle.

(b) The water supplies used both by people and by animals may be contaminated and the cost may be incurred in replacing the water from other sources.

(c) Additional water-treatment measures (including sewerage) may be needed by downstream users.

Therefore, the proposed project on the waste water treatment plant for plating industries is highly valuable in terms of protection of the environment, although a "with-and-without-project framework" is not simply applied to this project since the Korean Government has stringent standards for effluents.