THE KINGDOM OF SAUDI ARABIA

# STUDY REPORT ON REVERSE OSMOSIS BRINE REJECT TREATMENT IN THE CITY OF RIYADH

MARCH 1981

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

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# PREFACE

In response to the request of the Government of the Kingdom of Saudi Arabia, the Japanese Government decided to conduct a study on the Reverse Osmosis brine treatment Project in the City of Riyadh and entrusted the study to the Japan International Cooperation Agency (J.I.C.A.). The J.I.C.A. sent to Saudi Arabia a survey team headed by Mr. Masaru Ikai from September 27th to October 12th, 1980.

The team exchanged views with the officials concerned of the Saudi Arabian Government and conducted a field survey in the Riyadh area. After the team returned to Japan, further studies were made and the present study report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

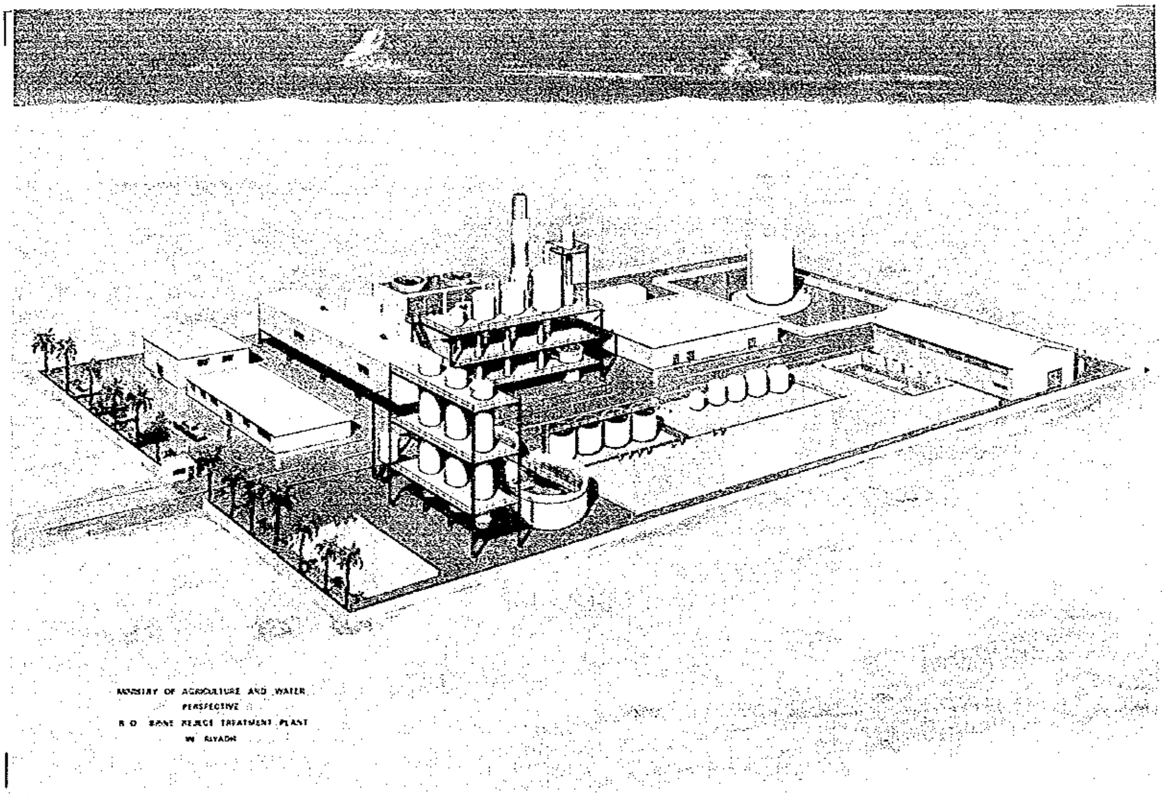
I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Saudi Arabia for their kind cooperation extended to the team.

March, 1981

Keisuke Arita

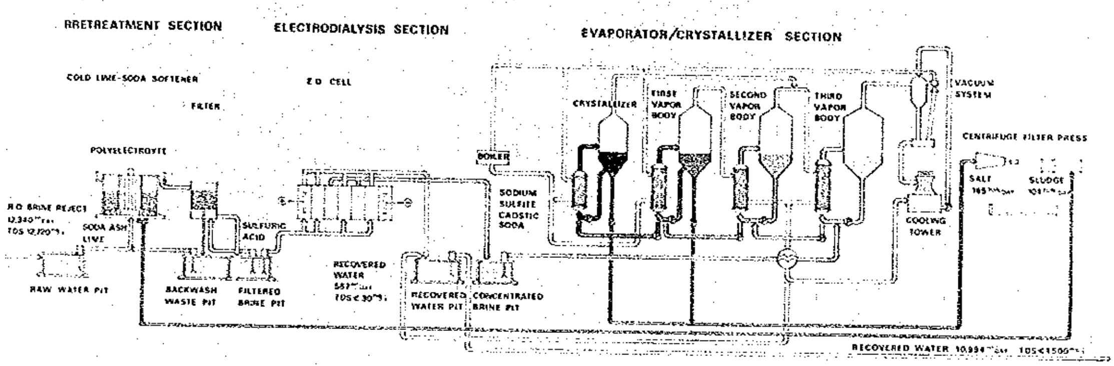
Keisuke Arita
President
Japan International Cooperation Agency

## C O N T E N T S




# معمل معالجة المياه الفائضة بالرياض
# لوزارة الزراعة والمياه

MINISTRY OF AGRICULTURE AND WATER
SIMPLIFIED FLOW CHART
R. O. BRINE REJECT TREATMENT PLANT
IN RIYADH




# معمل معالجة المياه الفائضة بالرياض

# لوزارة الزراعة والمياه

## 1. Summary

This study report was prepared by the Japan International Cooperation Agency (JICA) in response to a request from the Ministry of Agriculture and Water of the Government of the Kingdom of Saudi Arabia (MOAW) to solve certain problems concerning the disposal of brine reject which would be produced following the completion of reverse osmosis (RO) plants in the three water treatment plants (Malez, Manfouha and Shemessy) in the city of Riyadh.

One method was selected by MOAW from the methods described in the Interim Report prepared by the Japanese team sent by JICA for an on-the-spot survey.

The method, called an integrated plant, has numerous advantages compared to the others in capital investment, operation, number of workers, etc. The integrated plant consists of several process facilities: pretreatment and electrodialysis facilities, evaporator/crystallizer and required auxiliary facilities.

A brief outline of the integrated plant is as follows:

Capacity: 12,340 $m^3/d$ of brine reject of 12,720 mg/l in TDS

Recovered water: 11,281 $m^3/d$ of 1,500 mg/l in TDS

Extracted solid waste: 269 ton/d

Capital investment cost: US$58,650,000 on full turn-key basis

Fuel and chemical consumption: US$6,064,000 per year (365 days, 8,000 hours of operation)

Required area: 15,200 $m^2$ (160 m x 95 m)

The above capital cost does not include brine-gathering systems as it has been decided that MOAW would conduct study and construction of the transportation systems of RO brine reject.

This report consists of a conceptual design of the integrated plant, an estimate of utility and chemical consumption and direct operation costs, operating personnel, capital investment cost, project schedule and attachments.

The attachments are the Annex to the Minutes of Meetings between MOAW and the Japanese site survey team and the related reports.

## 2. Abbreviations, Definitions of Terms and Units

Abbreviations, definitions of terms and units used in this report are as follows:

### 2.1 Abbreviations

(1) ED: Electrodialysis process

(2) RO: Reverse Osmosis process

(3) MOAW: The Ministry of Agriculture and Water of the Government of the Kingdom of Saudi Arabia

(4) JICA: Japan International Cooperation Agency

(5) JIS: Japanese Industrial Standards

(6) TDS: Total dissolved solids

(7) DC: Direct current

### 2.2 Definitions of Terms

(1) "Three Ro Plants": the three RO plants at Manfouha, Shemessy and Malez in the city of Riyadh

(2) "Integrated Plant": the independent plant to be constructed to treat brine reject from the Three RO Plants

(3) "Brine Reject": the concentrated brine produced at the Three RO Plants

(4) "Recovered Water": the water which is produced by the Integrated Plant

(5) "Battery Limit": the battery limits shown on the drowing "Plot Plan" in section 7.7 of this report.

### 2.3 Units

(1) mm: Millimeter

(2) cm: Centimeter

(3) m: Meter

| | | |
|---|---|---|
| (4) | km: | Kilometer |
| (5) | $cm^2$: | Square Centimeter |
| (6) | $m^2$: | Square meter |
| (7) | $m^3$: | Cubic meter |
| (8) | l: | Liter |
| (9) | kl: | Kiloliter |
| (10) | mg: | Milligram |
| (11) | kg: | Kilogram |
| (12) | ton: | Metric ton |
| (13) | h: | Hour |
| (14) | d: | Day |
| (15) | y: | Year (365 days) |
| (16) | A: | Ampere |
| (17) | Hz: | Hertz |
| (18) | V: | Volt |
| (19) | KW: | Kilowatt |
| (20) | KV: | Kilovolt |
| (21) | Kcal: | Kilocalorie |
| (22) | RPM: | Revolution per Minute |
| (23) | °C: | Centigrade |

## 3. Introduction

This feasibility study has been carried out at the request of the Government of the Kingdom of Saudi Arabia for a method of disposing of Brine Reject from the Three RO Plants at Malez, Manfouha and Shemessy, which has been installed to treat ground water pumped up from deep wells in the city of Riyadh.

In order to cope with the demand for fresh water by the increasing population of the Riyadh area, the Government of the Kingdom of Saudi Arabia have decided to supply potable water from aquifers at 1,200 to 1,500 meters below the surface.

The ground water from the aquifers has high values in hardness, sulfate ions and total dissolved solids, and is supplied as potable water after treatment by a lime-soda process which is mainly aimed at softening the water at the existing Malez, Manfouha and Shemessy Water Treatment Plants.

As a result of studies by MOAW, a new method containing the RO process was adopted to improve the quality of the potable water.

Improvements in the quality of the water supplied will be attained by the RO plants, but the disposal of concentrated brine that is rejected by the RO plants raises new problems; that is, the Three RO Plants require the installation of adequate facilities to treat and dispose of the Brine Reject effectively in order ot facilitate the practical operation of the RO plants.

For the purpose of solving this serious problem, a Japanese study team was organized by JICA in September, 1980, and the JICA sent a site survey team to Riyadh from September 26 to October 13, 1980.

The site survey team proposed several methods of disposing of the Brine Reject in two reports (Tentative Report [Document No. SAJ/RO-101] and Interim Report [Document No. SAJ/RO-102]) to MOAW during their stay in Riyadh.

The latter was prepared on the basis of MOAW data and suggestions. It contains the idea of an integrated plant to treat all Brine Reject from all of the Three RO Plants and five other ideas on treating Brine Reject separately in each water treatment plant.

On November 29, 1980, MOAW requested the Japanese Government to draw up a final report on the lines of the Integrated Plant with auxiliary facilities.

The Integrated Plant described in the following sections is based on a unified plan which clarifies the ideas involved in the disposal method selected for the Brine Reject. In the Integrated Plants, the Brine Reject is processed to produce Recovered Water and solid waste. The volume of Recovered Water is the largest compared to the other methods. The Recovered Water is an excellent water resource, and the solid waste can be disposed of easily due its smaller volume compared to the solution.

The Brine Reject gathering systems are not included in the following conceptual design, as it has been decided that MOAW would conduct study and construction.

## 4. Principles of the Study

The Integrated Plant has been studied on the basis of the following principles:

(1) The water recovered should be as much as possible.

(2) The Recovered Water should be usable for irrigation. recharge, industry and other purposes.

(3) The Integrated Plant should not produce any aqueous waste, only solid waste.

(4) Only fuel and chemicals should be supplied to the Integrated Plant. Utilities, such as electric power, water and steam should be produced by the Integrated Plant itself.

(5) The Integrated Plant should be an independent plant containing all necessary auxiliary facilities.

(6) The Integrated Plant should be more economical in construction and operation costs than three separate plants.

(7) The design of the Integrated Plant should be simple to provide ease of operation and maintenance.

(8) The Integrated Plant should be designed to operate continuously for 8,000 hours a year (365 days) with a shutdown once a year for periodic inspection, maintenance and repair work.

(9) The Integrated Plant should not be provided with a full stand-by process train. However, the process train should be provided with stand-by mechanical equipment, such as pumps, required for continuous operation and for daily maintenance.

## 5. Basic Study Data

Basic data for the study of the Integrated Plant is as follows:

### 5.1 Volume of Brine Reject to be treated

| | |
|---|---|
| from the Malez Plant | 2,230 $m^3/d$ |
| from the Manfouha Plant | 6,800 $m^3/d$ |
| from the Shemessy Plant | 3,310 $m^3/d$ |
| Total | 12,340 $m^3/d$ |

The flow of Brine Reject is assumed to be continuous and drastic fluctuations in the flow rate are not anticipated.

### 5.2 Analysis of Brine Reject

| | | |
|---|---|---|
| Sodium | (as $Na^+$) | 3,520 mg/l |
| Calcium | (as $Ca^{++}$) | 160 mg/l |
| Magnesium | (as $Mg^{++}$) | 470 mg/l |
| Chloride | (as $Cl^-$) | 3,120 mg/l |
| Fluoride | | 0 |
| Bicarbonate | | 0 |
| Sulfate | (as $SO_4^{--}$) | 3,350 mg/l |
| Silica | (as $SiO_2$) | 85 mg/l |
| Phosphate | (as $PO_4$) | 20 mg/l |
| TDS | | 12,720 mg/l |
| pH | | 5 - 6 |
| Temperature | | 30°C |

Note: (1) Analytical data was provided by MOAW.

(2) Analytical methods conform to the Standard Methods for the Examination of Water and Waste Water (14th Edition), APHA-AWWA-WPCF.

5.3 Projected Quality of Recovered Water

(1) Dilute water from the ED section

TDS 1,500 mg/l or less

(2) Steam Condensate from the Evaporator/Crystallizer section

TDS 30 mg/l or less

5.4 Brine Reject Supply and Recovered Water Delivery Conditions

(1) Supply pressure of the Brine Reject at the Battery Limits of the Integrated Plant 0.3 $kg/cm^2G$

(2) Delivery pressure of the Recovered Water at the Battery Limits of the Integrated Plant 3 $kg/cm^2G$

Note: It is assumed that the Brine Reject will be pumped from the Three RO Plants to the Integrated Plant.

5.5 Plant Location

The Integrated Plant will be located near the existing Manfouha Sewage Treatment Plant in the city of Riyadh.

5.6 Site Conditions

5.6.1 General

It is assumed that site is sufficiently flat that land preparation and leveling work will not be required and that there are no aboveground or underground obstacles to construction.

5.6.2 Soil Bearing Capacity 20 $ton/m^2$

5.6.3 Seismic Factor None

## 5.7 Meteorological Data

### 5.7.1 Ambient Temperature

| | |
|---|---|
| Minimum | -5.6°C |
| Maximum | 47.7°C |

### 5.7.2 Relative Humidity

| | |
|---|---|
| Winter | 100 - 6% |
| Summer | 68 - 2% |

### 5.7.3 Rainfall

| | |
|---|---|
| Daily maximum | 51.5 mm/d |
| Annual minimum | 21.6 mm/y |
| Annual maximum | 176.6 mm/y |

### 5.7.4 Wind Velocity

| | |
|---|---|
| Maximum | 32 km/h |

### 5.7.5 Evaporation Rate

| | |
|---|---|
| Average | 2,890 mm/y |

## 5.8 Fuel and Chemicals Conditions

### 5.8.1 Fuel

Light diesel oil

Heat Value: 10,280 kcal/kg

Specific Gravity: 0.82 - 0.85

Delivery: by tank lorry

Unit Price: 21 US$/kl

### 5.8.2 Chemicals

| | | Type | Purity | Delivery | Unit Price at site (US$/ton) |
|---|---|---|---|---|---|
| (1) | Calcium Hydroxide ($Ca(OH)_2$) | Powder | > 72% as CaO | 1 $m^3$ container bag | 82 |
| (2) | Sodium Carbonate ($Na_2CO_3$) | Powder (Heavv) | > 99% | 1 $m^3$ container bag | 312 |
| (3) | Polyelectrolyte | Powder | 100% | 20 kg paper drum | 6,363 |
| (4) | Sodium Sulfite ($Na_2SO_3$) | Granular | > 67% | 25 kg paper bag | 857 |
| (5) | Sulfuric Acid ($H_2SO_4$) | Liquid | > 98% | tank lorry | 318 |
| (6) | Caustic Soda (NaOH) | Flake | > 99% | 25 kg paper bag | 380 |
| (7) | Hydrochloric Acid (HCl) | Liquid | 35% | tank lorry | 100 |

## 5.9 Technical Codes & Standards

In general, JIS codes and standards are applied to this study.

Manufacturer's standards, however, are also applied to special equipment.

Analytical methods for water conform to the Standard Method for Examination of Water and Waste Water (14th Edition), APHA-AWWA-WPCF.

## 6. Scope of Study

This study covers the conceptual design, estimates of utility and chemical consumption, capital investment cost, direct operating costs, operational personnel and overall project schedule for the Integrated Plant.

### 6.1 Items Included

The following facilities and works inside the Battery Limits of the Integrated Plant, as shown on the drawing "Plot Plan" in Section 7.7, are included.

#### 6.1.1 Process Plant with Instrumentation, Piping and Structure

(1) Cold lime-soda softeners

(2) Filter units

(3) ED units

(4) Evaporator/crystallizer units

(5) Chemical feed units

(6) Sludge dehydration units

#### 6.1.2 Auxiliary Facilities

(1) Brine reject storage

(2) Recovered Water storage and transfer pumps

(3) Fuel oil system

(4) Boiler and power generator for processing use

(5) Diesel power generator for utility use

(6) Buildings with air conditioning, lighting, furniture, etc.

1) Control building

2) Power station

3) Warehouse

4) Guard box

5) ED building

6) Perimeter fence and gates

7) Drainage system

8) Road and pavement

9) Parking lot

10) Lighting system

11) Telecommunication system

12) Fire hydrant system

13) Drinking water system

### 6.1.3 Construction Work

(1) Site grading work

(2) Civil engineering work

(3) Architectural work

(4) Fabrication and erection work

(5) Piping work

(6) Instrumentation work

(7) Electrical work

(8) Painting and insulation work

### 6.1.4 Indirect Work

(1) Project management

(2) Engineering work

(3) Procurement and delivery of equipment and materials

(4) Temporary work

(5) Insurances related to construction

(6) Construction supervision work

(7) Pre-commissioning work and performance test to be

conducted by MOAW operating personnel under the supervision of the contractor

6.2 Items Excluded

The following facilities and works are excluded from this study:

(1) Gathering and transportation system for Brine Reject from the Three RO Plants to the Battery Limits of the Integrated Plant

(2) Transportation pipeline for Recovered Water outside the Battery Limits

(3) Transportation and permanent dump facilities for solid waste and sludge

(4) Transportation facilities for operating personnel

(5) Catering facilities for operating personnel

(6) Laboratory

(7) Dormitory for operating personnel

(8) Landscaping

(9) All other facilities and works outside the Battery Limits of the Integrated Plant

(10) Site selection and land aquisition

(11) Commissioning and training of MOAW operating personnel

# 7. Conceptual Design

## 7.1 Outline of the Integrated Plant

The Integrated Plant consists of the following:

(1) Pretreatment Section

(2) Electrodialysis (ED) Section

(3) Evaporator/Crystallizer Section

(4) Auxiliary Facilities

The Integrated Plant has the capacity to process 12,340 $m^3/d$ of brine reject from the Three RO Plants, and to produce approximately 11,000 $m^3/d$ of Recovered Water for irrigation and other purposes and approximately 270 ton/d of solid waste for disposal.

### 7.1.1 Pretreatment Section

The pretreatment section employs a cold lime-soda softening process to remove calcium and silica from the Brine Reject in order to prevent scale formation on the ED membranes.

### 7.1.2 ED Section

The ED Section recovers low-salinity water from the softened brine and also concentrates the softened brine in order to reduce the volume of water to be evaporated in the evaporator/crystallizer section.

Approximate 85% of the volume of brine can be recovered as dilute water; at the same time, the volume of water sent to the evaporator/crystallizer section is reduced to approximate one-seventh of its previous volume.

### 7.1.3 Evaporator/Crystallizer Section

The evaporator/crystallizer section employs a triple-effect forced-circulation system. The concentrated brine is evaporated and salts dissolved in the brine are crystallized as solid waste.

The solid waste is sent by trucks to a permanent dump site outside the Integrated Plant.

Steam condensate around 40,000 $m^3/d$ from the evaporator is used as boiler feed, cooling tower makeup, utility and process water, and the remaining approximately 570 $m^3/d$ of high purity water produced by the evaporator is sent to the Recovered Water pit.

### 7.1.4 Auxiliary Facilities

The main auxiliary facilities are the boiler plant, steam turbine power generator, diesel engine power generator, cooling tower and water storage pits.

This combination of ED and evaporator/crystallizer is the most suitable technique for the Brine Reject treatment.

This technique has been developed in Japan for producing table salt from sea water and has been in commercial use for over ten years.

The following technical improvements have been made in this technique:

(1) High-conductivity and high-permselectivity ED membrane

(2) Large-scale, high-efficiency ED unit

(3) Anti-scale formation technique for the evaporator

(4) Anti-corrosion materials for the high temperature brine

With these improvements, efficient production of table salt from sea water has been attained with lower energy consumption.

Salt production plants using this process combination have been operated successfully.

## 7.2 Process Description

### 7.2.1 Pretreatment Section

The pretreatment section consists of two cold lime-soda softeners, four sand filters, two filter presses for sludge dewatering and chemicals storage and feeders.

The cold lime-soda softening process is designed to remove calcium salts, magnesium salts and silica contained in the Brine Reject and which cause scale formation on the ED membranes.

Preliminary beaker tests on the Brine Reject softening were carried out during the site survey in September - October 1980.

The test results are shown on the next page :

| | Brine Reject | Test No.1 | Test No.2 |
|---|---|---|---|
| Chemicals Feed Rate - mg/l | | NaOH 2,000<br>$NaCO_3$ 500 | $Ca(OH)_2$ 1,600<br>$Na_2CO_3$ 2,500 |
| pH | 3.7 | 12.3 | 11.5 |
| Ca mg/l(as $Ca^{++}$) | 540 | 6.7 | 3.2 |
| $SiO_2$ mg/l | 107 | 28.4 | 10.8 |
| TDS mg/l | 12,200 | 11,900 | 11,200 |

This results indicated that a cold lime-soda softening process would provide sufficient water quality for the ED process, although a combined process of cold lime softening and cation exchange was proposed in the Tentative Report.

(1) Cold lime-soda Softeners

Two cold lime-soda softeners, with a capacity of 280 $m^3$/h each, are normally operated in parallel.

At the softener inlets, sufficient amounts of lime slurry, soda ash solution and poly-electrolyte solution are injected into the Brine Reject.

Calcium and magnesium salts contained in the Brine Reject react with the injected chemicals in the reaction chambers of the softeners and are converted to insoluble calcium hydroxide and magnesium hydroxide which are precipitated in the precipitation chambers of the softeners.

Silica is also precipitated together with magnesium hydroxide. The softened brine overflows from the top of the softeners into the filters.

The settled sludge is collected by rake to the center of the softener and pumped to the filter presses for dewatering.

(2) Sand Filters

The sand filters are designed to remove residual suspended solids from the softened brine.

Four sand filters, with a capacity of 135 $m^3/h$ each, are normally operated in parallel.

While one of the sand filters is being backwashed, the remaining three filters are capable of filtering the full water flow.

The filtered brine is sent to the ED section via the filtered water pit.

The filters are automatically backwashed periodically using air and filtered brine.

The backwash waste water is sent back to the softener inlets for retreatment via a backwash waste pit.

(3) Chemicals Storage and Feeding System

The chemicals storage and feeding system consist of chemicals silos for lime and soda ash storage, chemicals tanks and chemicals injection pumps.

Three chemical silos have a total storage capacity for one week's normal operation.

Lime and soda ash are measured by dry chemical feeders and fed by pumps into the Brine Reject as a slurry.

The poly-electrolyte is dissolved in water and fed by controlled volume reciprocating pump.

The chemical feeding rates are manually set to correspond with the water flow rate and water quality.

(4) Filter Press

The sludge from the softeners is dehydrated by the filter presses.

Two filter presses are provided and the sludge charging, pressing and discharging cycles are carried out in sequence.

The dehydrated sludge is dropped directly from the filter presses to a sludge yard for temporary storage and then sent out by trucks to permanent dump site outside the Integrated Plant.

The volume of dehydrated sludge is approximate 104 ton/d.

### 7.2.2 Electrodialysis (ED) Section

The filtered brine from the pretreatment section is treated by the ED units to produce dilute water and concentrated brine.

The volume of the brine is reduced to approximately one-seventh of that of the Brine Reject by the ED units and the recovery rate for dilute water is around 85%.

Four Model DS-V* ED units are installed in the ED section. Each unit comprises four blocks of ED stacks which have one pair of electrodes, 400 pairs of ion-exchange membranes and 400 pairs of dilution and concentration chambers in each stack.

As design basis, 511 $m^3/h$ of the filtered brine is supplied to the ED section. Around 435 $m^3/h$ of the filtered brine is continuously fed to the dilute pit and the remainder is fed to the concentrate pit. The diluted and concentrated liquors are recycled to the ED units and all units are operated in parallel.

DC electricity is applied to the units by the constant voltage method and estimated average voltage is around 420 V. Although the electric current to the units is varied with the temperature of the brine, the estimated average value is around 1,900 A/unit.

During normal operation, around 435 $m^3/h$ of the dilute water, with less than 1,500 mg/l of TDS, is discharged from the dilute pit to the Recovered Water pit. And around 76 $m^3/h$ of

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* To make rather clear explanation, a specific model is used.

concentrated brine, with around 75,700 mg/l of TDS, is sent to the evaporator/crystallizer section after being used as the electrode rinse liquor.

The results of ED are: approximately 85% of the softened brine is recovered as dilute water and around 90% of the solid content of the brine is accumulated in the concentrated brine.

During normal operation, filtered brine is continuously supplied to the pits by the automatic flow rate control system, and dilute water is discharged from the dilute pit at approximately same flow rate as the filtered brine is supplied.

Overflow from the concentrate pit is supplied to the electrode rinse pit and recycled to the electrode chambers of the units.

To prevent the scale formation in the concentration and cathode chambers, small amounts of acid are injected into the filtered brine.

Overflow from the electrode rinse pit is sent to the evaporator section after neutralization of the excess acid with caustic soda and the reduction of free chlorine generated in the anode chambers of the units with sodium sulfite.

The DC voltage is automatically regulated within desired range and amperage to the ED units is adjusted within desired range accordingly.

There is no need to readjust voltage or amperage for the units during steady-state operation.

When the flow rate or pressure of the liquor deviates outside the designed range, warnings are given to indicate the fact for manual adjustment of the flow conditions. If there is an extraordinary deviation in the flow conditions, such as might be caused by extreme failure of pumps or other equipment, an interlock circuit detects the phenomena and all equipment is shutdown immediately.

Thus, there is no need for frequent inspections of the equipment during normal operation.

In so far as the pretreatment of the Brine Reject is performed properly, there is no need for frequent maintenance of the ED units. However, very small amounts of suspended matter will deposit in the ED units during long-term operations. Special chemical cleaning, using oxidizing and reducing agents and detergents, is necessary once or twice a year. Maintenance on the other equipment is performed according to a predetermined maintenance schedule.

When disassembling the ED units, each ED stack is disassembled separately after replacement with a spare stack.

### 7.2.3 Evaporator/Crystallizer Section

In the evaporator/crystallizer section, water is evaporated from the concentrated brine from the ED section. Various salts dissolved in the brine are crystallized and discarded as solid waste. This section consists of triple-effect evaporators with a crystallizer, and centrifuges for dewatering the salts. The evaporators and the crystallizer are of the forced circulation type to avoid scale formation on the surface of the heating tubes.

The exhaust steam from the power generator is utilized as the heat source for the first heater and the crystallizer heater.

The concentrated brine from the ED section is fed to triple-effect evaporators with a crystallizer by the backward flow. First, the brine is fed to the third vapor body through the pre-heater where the brine is heated by the condensate from the second and the third heaters. Next, it flows through the second vapor body, the first vapor body and finally the crystallizer. The results of evaporation is the crystallization of the dissolved salts into a mixed salt slurry in the first vapor body and the crystallizer. This mixed salt slurry is sent to the centrifuge feed tank. In this tank, the slurry is thickened and fed to a continuous push-type centrifuge. The dehydrated mixed salts from the centrifuge are discarded as solid waste. The water from the centrifuge is fed back to the crystallizer.

In addition, a part of the mother liquor is discarded from the crystallizer to avoid scale formation. This mother liquor is rich in magnesium chloride at high temperature and the discarded magnesium chloride crystallizes into crystal by cooling.

At the same time, the condensate from the first heater and the crystallizer heater is returned to the boiler. The condensate from the second and the third heaters is used as process water and makeup water for the boiler and the cooling tower after it is cooled with the feed brine in the pre-heater. The vapor from the third vapor body is cooled in the direct condenser with circulating cooling water. Non-condensable gases from the vapor body are discharged by means of a vacuum system which consists of a two-stage steam ejector.

The evaporator/crystallizer are shutdown a few times a year for cleaning by water and chemicals.

During the shutdown, the concentrated brine from the ED section is stored in a 1,000 $m^3$ concentrate pit in order to maintain the continuous operation of the pretreatment and ED sections.

165 ton/d of dehydrated salts are discarded from the centrifuges and sent out by trucks to a permanent dump site outside the Integrated Plant.

### 7.2.4 Auxiliary Facilities

The major auxiliary facilities are described below:

(1) Boiler and Steam Turbine Power Generator

A package-type boiler with a capacity of 45 kg/-$cm^2$ and 60 $m^3/h$ is provided.

High pressure steam from the boiler is supplied to a steam turbine power generator with a capacity of 8,000 KVA.

The steam turbine power generator supplies electric power for the main process equipment, including the ED units.

The low-pressure exhaust steam from the steam turbine is supplied to the evaporator/crystallizer section for heating.

(2) Diesel Engine Power Generator

Two diesel engine power generators are provided to produce electric power for process control, lighting, utilities, and the start-up and shut-down operations of the Integrated Plant.

The diesel engine power generators have a capacity of 625 KW each. Normally one is in operation and the other is in stand-by.

(3) Fuel System

The fuel system consists of a 1,000 kl oil storage tank and fuel pumps.

Light diesel oil is supplied by tank lorry to the oil storage tank and pumped to the boiler and the diesel engines.

(4) Cooling Tower

A cooling tower with a capacity of 2,000 $m^3/h$ is provided to supply cooling water to all process equipment and utility facilities.

Steam condensate from the evaporator/crystallizer is supplied to the cooling tower as makeup water.

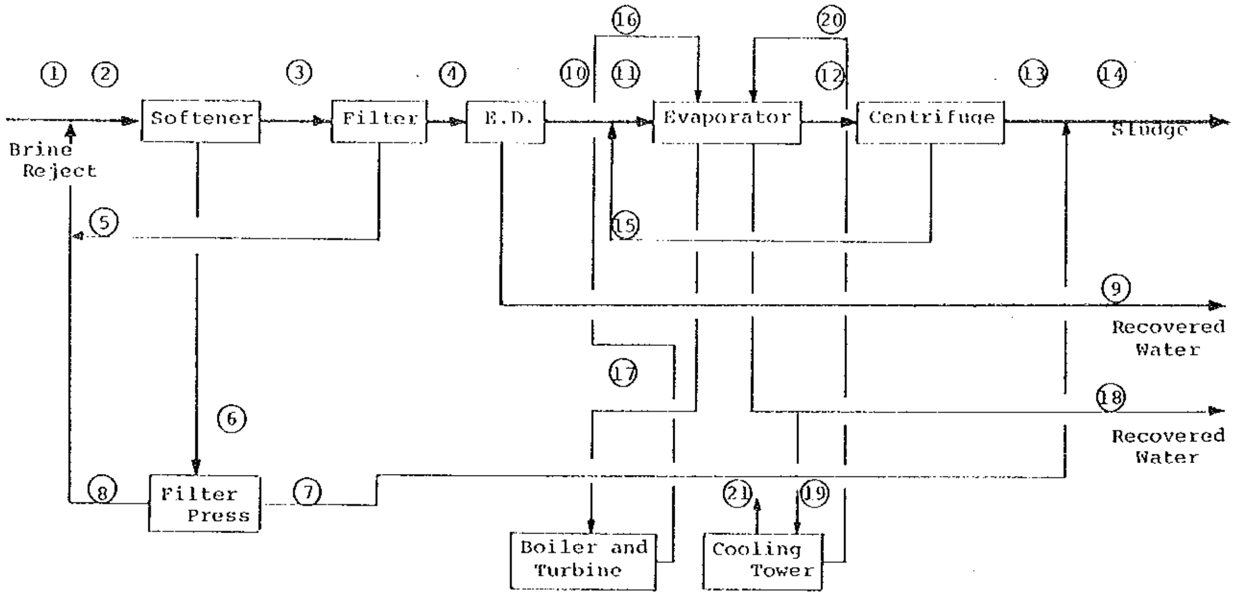
(5) Water Storage pit

Two 500 $m^3$ water storage pits are provided for receiving the Brine Reject and storing the Recovered Water.

## 7.3 Water Balance

A rough water balance for the Integrated Plant is shown on the attached drawing.

A total of 11,281 $m^3/d$ of water is recovered from the Brine Reject and 269 ton/d of solid waste is produced.




| No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name of Flow | Brine | Brine | Softened Brine | Filtered Brine | Backwash waste | Slurry | Sludge | Filtrate | Recov'd Water | Conc. Brine | Conc. Brine |
| $H_2O$ ton/d | 12,340 | 13,288 | 13,007 | 12,267 | 740 | 281 | 73 | 208 | 10,427 | 1,840 | 2,017 |
| Solids ton/d | - | - | - | - | - | 31 | 31 | - | - | - | - |
| TDS mg/l | 12,720 | - | - | 12,630 | - | - | - | - | 1,500 | 75,700 | - |

| No. | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|
| Name of Flow | Slurry | Salts | Sludge | Water from Centri-fuge | Steam | Conden-sate | Recov'd Water | Conden-sate | Cooling Water | Evaporation Loss |
| $H_2O$ ton/d | 203 | 26 | 99 | 177 | 790 | 790 | 854 | 39,360 | 38,400 | 1,200 |
| Solids ton/d | 139 | 139 | 170 | - | - | - | - | - | - | - |
| TDS mg/l | - | - | - | - | - | < 10 | < 30 | < 30 | - | - |

Rough Water Balance Sheet for the Integrated Plant

## 7.4 Process Flow Scheme

The process flow scheme for the Integrated Plant is shown on the attached drawing No. SAJ/RO-101.

The drawing shows all process equipments and controls.

## 7.5 Major Equipment List

Major process equipment and auxiliary facilities for the Integrated Plant are listed in the attached list.

1. Pretreatment Section

| Item | No. Req'd | Capacity | Type | Remarks |
|---|---|---|---|---|
| Cold Lime-Soda Softener | 2 | 280 $m^3/h$ x 2 | 14,000$^{\phi}$ Cylindrical Precipitator with Rake | Concrete/Carbon Steel |
| Sand Filter | 4 | 135 $m^3/h$ x 4 | 4,800$^{\phi}$ Cylindrical, Double Layer Gravity Filter Automatic Backwashing | Carbon Steel with Epoxy Coating |
| Filter Press | 2 | 12 $m^3/h$ | Automatic | |
| Chemical Silo | 3 | 250 $m^3$ x 3 | Cylindrical, with dry Chemical Feeder and Pneumatic Loading System | Carbon Steel |
| Raw Water Pit | 1 | 500 $m^3$ | Semi-underground, with Pumps | Concrete |
| Filtered Water Pit | 1 | 600 $m^3$ | Semi-underground, with Pumps | Concrete |
| Backwash Waste Pit | 1 | 300 $m^3$ | Semi-underground, with Pumps | Concrete |

2. Electrodialysis Section

| Item | No. Req'd | Capacity | Type | Remarks |
|---|---|---|---|---|
| Electrodialysis Unit | 4 | 130 $m^3/h$ x 4 | Model DS-V Membrane: Selemion CMV/AMV 1600 Pairs/Unit | |
| Dilution/ Concentration/ Electrode Rinse Pit | 1 | 360 $m^3$ | Semi-underground, with Pumps | Concrete with Epoxy Lining |

| Service | No. Req'd | Capacity | Type | Remarks |
|---|---|---|---|---|
| Rectifier with Transformer | 4 | 1,000 KVA | 460 V x 2,050 A | |
| **3. Evaporator/Crystallizor Section** | | | | |
| First Vapor Body | 1 | | 4,500 ø Cylindrical | SUS 316 Clad |
| Second Vapor Body | 1 | | 4,500 ø Cylindrical | SUS 316 Clad |
| Third Vapor Body | 1 | | 6,000 ø Cylindrical | SUS 316 Clad |
| Crystallizer | 1 | | 2,300 ø Cylindrical | Monel Clad |
| Pre-Heater | 1 | | Plate Type | Titanium |
| Crystallizer Heater | 1 | | Shell and Tube | Cupronickel/ Monel Clad |
| First Heater | 1 | | Shell and Tube | Aluminium Brass/ SUS 316 Clad/ Carbon Steel |
| Second Heater | 1 | | Shell and Tube | Aluminium Brass/ SUS 316 Clad |
| Third Heater | 1 | | Shell and Tube | Aluminium Brass/ SUS 316 Clad |
| Vacuum System | 1 | | Two-Stage Ejector and Direct Condenser | SUS 304/Carbon Steel |

| Service | No. Req'd | Capacity | Type | Remarks |
|---|---|---|---|---|
| Hot Well | 1 | | 4,000 ∅ Cylindrical | Carbon Steel |
| Centrifuge Feed Tank | 1 | | 3,600 ∅ Cylindrical | SUS 316L Clad |
| Centrifuged water Tank | 1 | | 2,500 ∅ Cylindrical | SUS 316L Clad |
| Blow Tank | 2 | | 4,500 ∅ Cylindrical | |
| Centrifuge | 1 + 1 | | Continuous Push-Type | Carbon Steel SUS 316L |
| Concentrate Pit | 1 | 1,000 $m^3$ | Semi-underground, with Neutralizing Equipment and Pumps | Concrete |

4. Auxiliary Facilities

| Service | No. Req'd | Capacity | Type | Remarks |
|---|---|---|---|---|
| Boiler | 1 | 70 $m^3/h$ x 45 $kg/cm^2$ | Packaged Water Tube-Type | |
| Steam Turbine Power Generator | 1 | 8,000 KVA | Basket-Type | |
| Diesel Engine Power Generator | 1 + 1 | 625 KW | 3.3 KV, 60 Hz, 9,000 RPM | |
| Cooling Tower | 1 | 2,000 $m^3/h$ | Cross Flow-Type | |
| Oil Storage Tank | 1 | 1,000 kl | 10,600∅ Cone Roof-Type | Carbon Steel |

| Service | No. Req'd | Capacity | Type | Remarks |
|---|---|---|---|---|
| Steam Condensate Tank | 2 | 140 $m^3$ | for Boiler Feed Water | Carbon Steel |
| | | 330 $m^3$ | for Cooling Tower Makeup and Utility Water | |
| Recovered Water Pit | 1 | 500 $m^3$ | Semi-underground, with Pumps | Concrete |
| Instrument Air System | 1 + 1 | 150$Nm^3/h$ 7 $kg/cm^2$ | Reciprocating Compressor with Air Dryer and Air Receiver | |

## 7.6 Plan of Buildings

Buildings for the Integrated Plant are described below. The plans for the control and ED buildings are shown, as examples, on the attached drawings Nos. SAJ/RO-102, -103, -104 and -105.

(1) Control Buildings

14 x 25 m, 350 $m^2$

Reinforced concrete, with air conditioner and utility facilities

(2) Electrodialysis (ED) Building

14.5 x 33 m, 478.5 $m^2$

Steel structure, asbestos cement sheet wall and roof with spot air conditioner and overhead traveling crane

(3) Power Station

28 x 19 m, 532 $m^2$

Reinforced concrete

1) Switch gear room with air conditioner

2) Generator room with ventilator and overhead traveling crane

(4) Warehouse

14 x 10 m, 140 $m^2$

Reinforced concrete, with air conditioner

(5) Guard Box

4 x 3 m, 12 $m^2$

Reinforced concrete, with air conditioner

## 7.7 Required Plot Area

The plot plan of the Integrated Plant is shown on the attached drawing No. SAJ/RO-106.

An area of 15,200 $m^2$ is required.

## 7.8 Single-Line Diagram

A single-line diagram of the electric power distribution system for the Integrated Plant is shown on the attached drawing No. SAJ/RO-107.

The steam turbine power generator normally supplies electric power to the process equipment.

The diesel engine power generator supplies electric power for process control, lighting and utility use as well as for the start-up and shutdown operations of the Integrated Plant.

## 8. Estimates of Utility and Chemical Consumption and of Direct Operating Cost

The utility and chemical consumptions are estimated on the Basic Study Data described in Section 5 and 8000-hour annual operation.

| Utility, Chemical and Consumable | Annual Consumption | Unit Price (US$) | Annual Cost (US$) |
|---|---|---|---|
| Lime | 6,580 ton | 82/ton | 540,000 |
| Soda Ash | 11,105 ton | 312/ton | 3,465,000 |
| Poly-electrolyte | 8 ton | 6,363/ton | 51,000 |
| Sulfuric Acid | 143 ton | 318/ton | 45,000 |
| Caustic Soda | 117 ton | 380/ton | 45,000 |
| Sodium Sulfite | 80 ton | 857/ton | 69,000 |
| Hydrochloric Acid | 16 ton | 100/ton | 2,000 |
| Light Diesel Oil | 73,600 kl | 21/kl | 1,546,000 |
| ED Membranes | 640 Pairs | 190/Pair | 121,000 |
| Other Consumables | - | - | 180,000 |
| Total Direct Operating Cost | | | 6,064,000 |

Unit Treatment Cost

Brine Reject Base 1.5 US$/$m^3$ of brine

Recovered Water Base 1.6 US$/$m^3$ of water

9. Estimate of Operating Personnel

A total of 54 operating personnel are required for the normal operation of the Integrated Plant excluding drivers and laborers for transporting the solid waste.

| | | | |
|---|---|---|---|
| 1) | Manager | 1 x 1 shift | 1 |
| 2) | Engineers | | |
| | Mechanical | 2 x 1 shift | 2 |
| | Electrical | 2 x 1 shift | 2 |
| | Chemical | 1 x 1 shift | 1 |
| 3) | Operators | | |
| | Chief Operators | 2 x 4 shifts | 8 |
| | Operators | 7 x 4 shifts | 28 |
| 4) | Laborers | | |
| | Skilled Laborers | 2 x 1 shift | 2 |
| | Common Laborers | 7 x 1 shift | 7 |
| 5) | Other | | |
| | Clerical Staff | 1 x 1 shift | 1 |
| | House Boy | 2 x 1 shift | 2 |
| | | Total | 54 |

## 10. Estimate of Capital Investment Cost

The estimate is based on the Basic Study Data in Section 5, Scope of Study in Section 6 and current market prices. The estimate is intended for use in defining the size of the project, but not for budgetary purposes.

Cost escalator scale is not considered in the estimate.

(1) Direct Costs

1) Supply of Materials and Equipment

(A) Pretreatment Section

(B) ED Section

(C) Evaporator/Crystallizer Section

(D) Auxiliary and Common Facilities

| | | |
|---|---|---|
| Sub-total | 28,840,000 | US$ |

2) Field Construction Work

(A) Installation, piping, painting and insulation work

(B) Electric and instrumentation work

(C) Civil engineering and building work including bulk materials

| | | |
|---|---|---|
| Sub-total | 14,990,000 | US$ |
| Direct Costs Total | 43,830,000 | US$ |

(2) Indirect Work

1) Engineering fee

2) Other expenses including:

Temporary facilities, construction equipment, transportation and insurance, field office expenses, precommissioning expenses and home office expenses

| | | |
|---|---|---|
| Sub-total | 14,820,000 | US$ |
| Grand Total | 58,650,000 | US$ |

## 11. Estimate of Project Schedule

Over-all project schedules for the Integrated Plant is studied for two cases of contracting method as follows:

(1) Separate Contracting Method

The engineering contractor and the construction contractor are selected in separate bids.

(2) Single Contracting Method

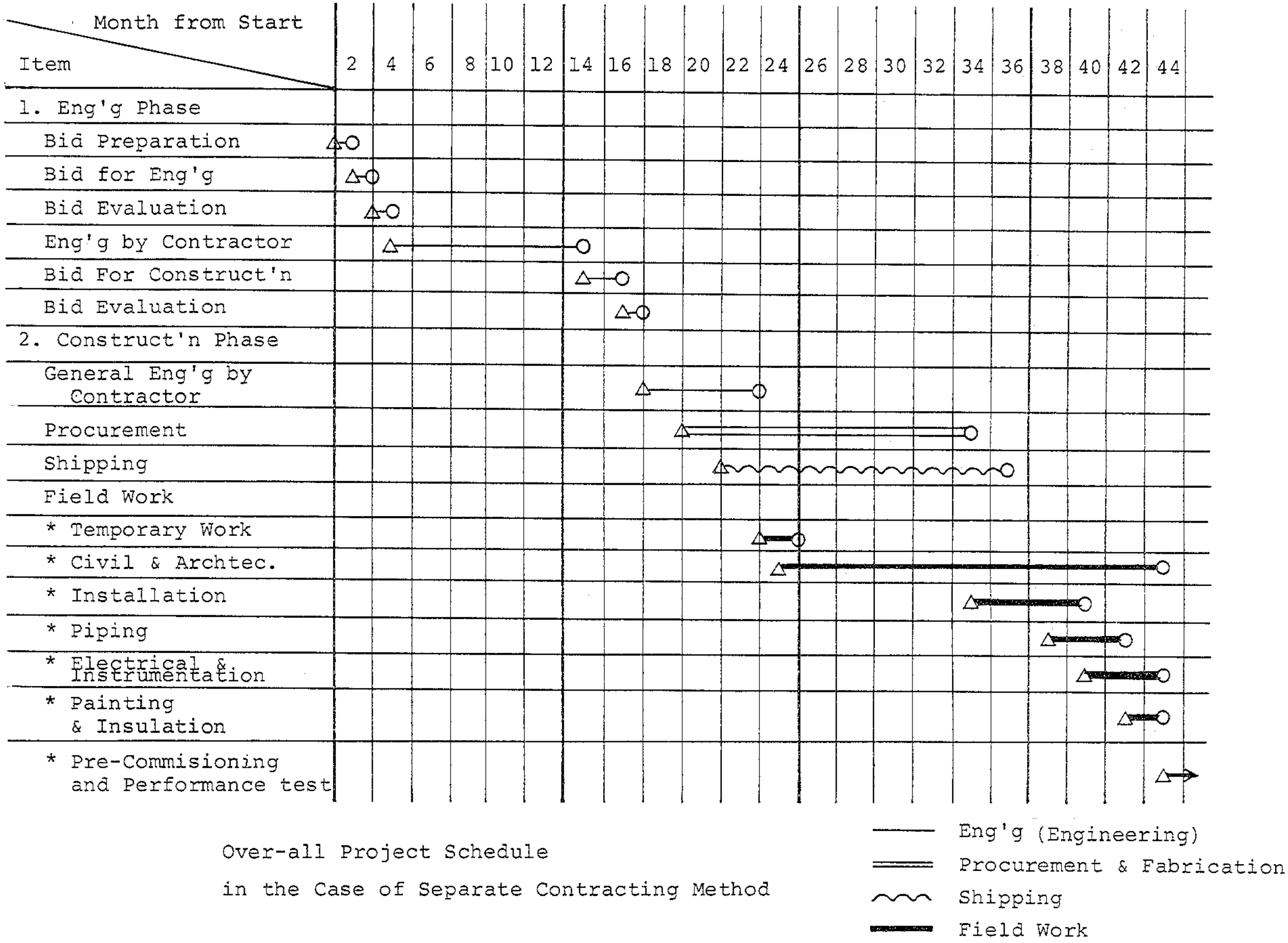
An engineering and construction contractor is selected in a single bid.

The single contracting method will resulting shorter time schedule than the separate contracting method will.

Over-all project schedule sheets for the both methods are attached.

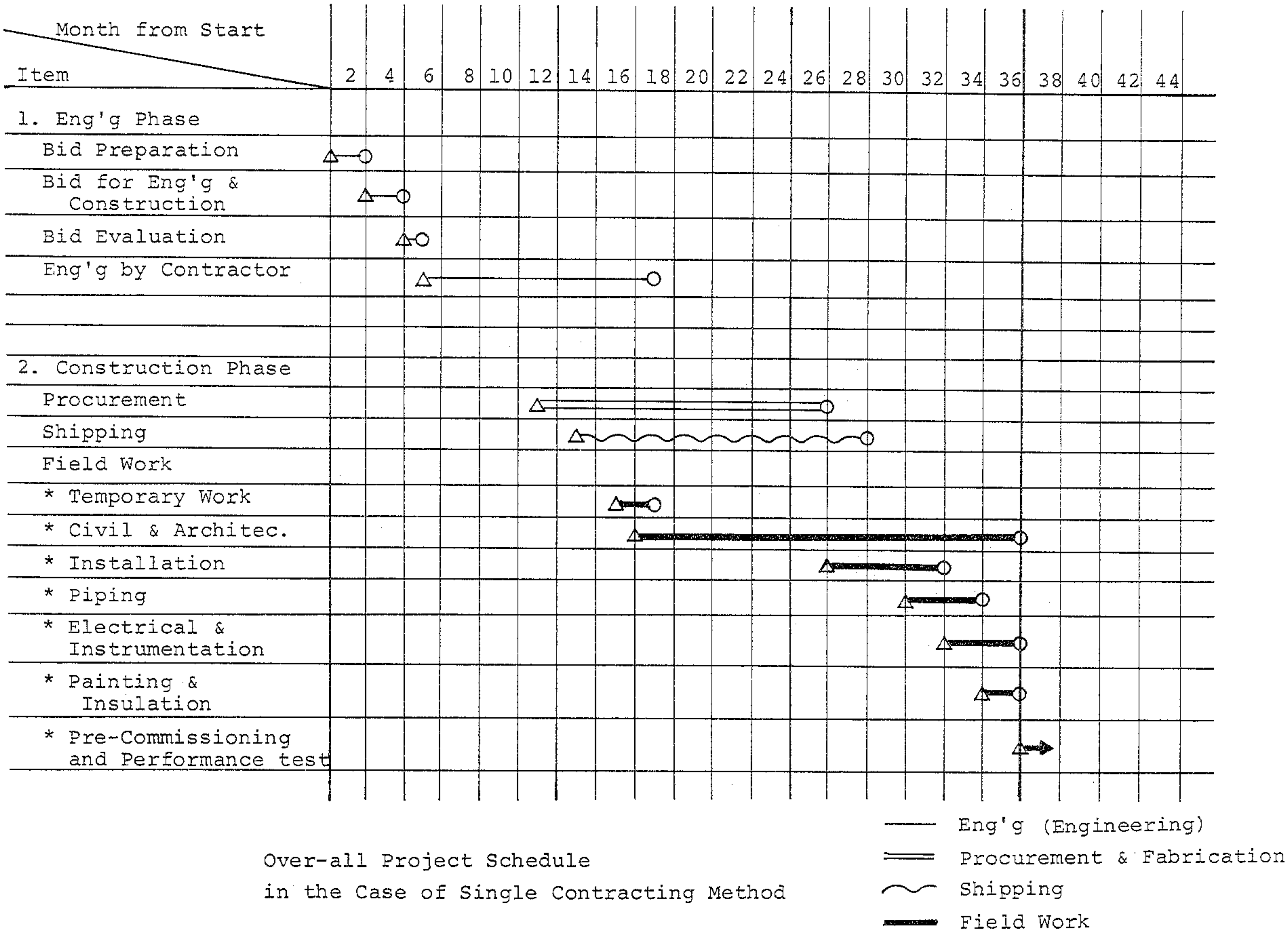
The single contracting method will resulting shorter time schedule than the separate contracting method will.

Over-all project schedule sheets for the both methods are attached.




Over-all Project Schedule

in the Case of Separate Contracting Method




Over-all Project Schedule
in the Case of Single Contracting Method

## 12. Remarks

1) Capital Investment Cost

The Integrated Plant studied in this report will offer less investment cost and more ease of operation and maintenance than the three separate plants discussed in the Interim Report.

However, construction costs and difficulties in construction of the Brine Reject pipelines from the three existing water treatment plants to the Integrated Plant should also be considered in the final decision.

2) Temperature of the Brine Reject

In this study, it is assumed that the Brine Reject pipelines will be laid underground and that the brine temperature will not increase during transportation.

If there is a possibility that the brine temperature will exceed 40°C, a cooling tower should be provided before the ED section.

3) Chemical Consumption

The chemical consumption for the cold lime-soda softeners is calculated on the basis of the results of the preliminary tests conducted during the site survey. For establishing optimum chemicals feed conditions, further tests will be required.

4) Transportation of Solid Waste

Transportation of the solid waste is considered by trucks in this report on the assumption that a permanent solid waste dump site will be located at a distance from the Integrated Plant site.

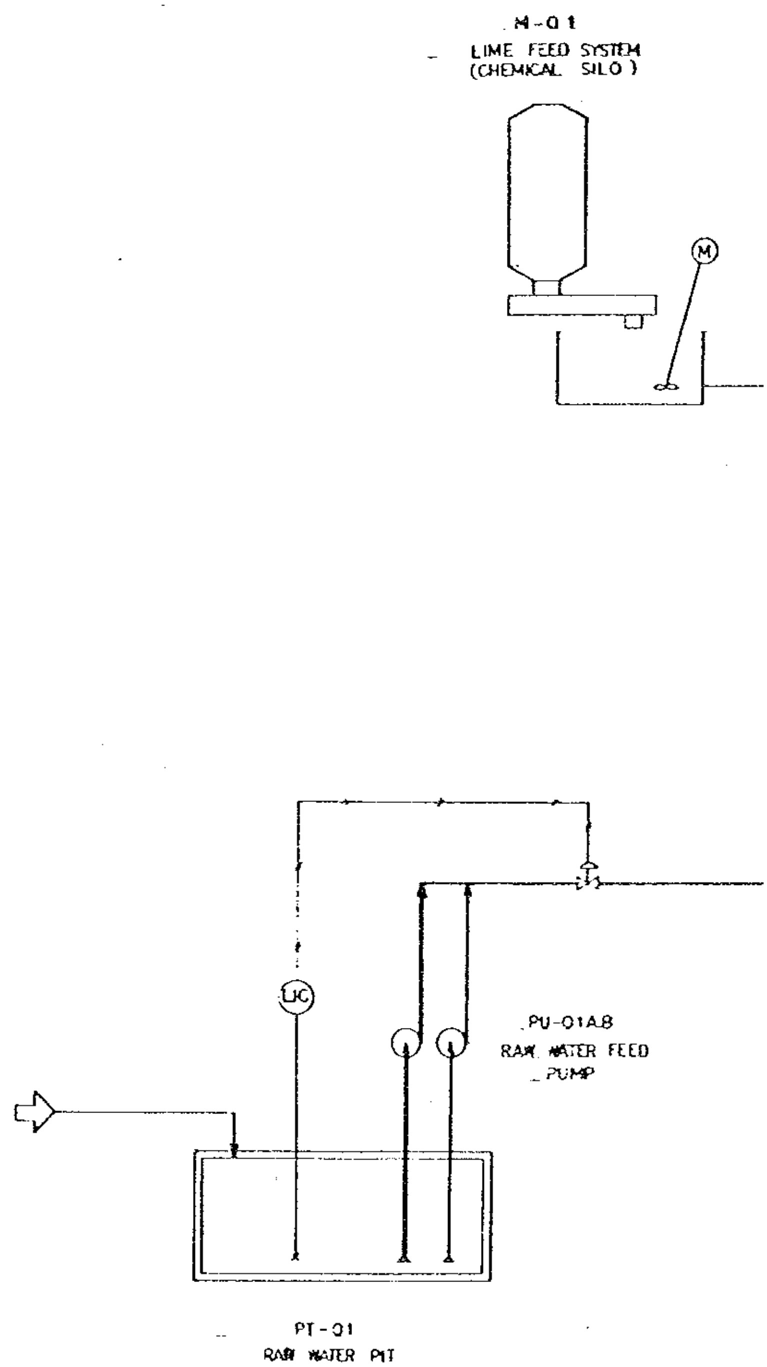
If the permanent solid waste dump site could be located beside the Integrated Plant site, a conveyer system should be studied.

5) Diesel Engine Power Generators

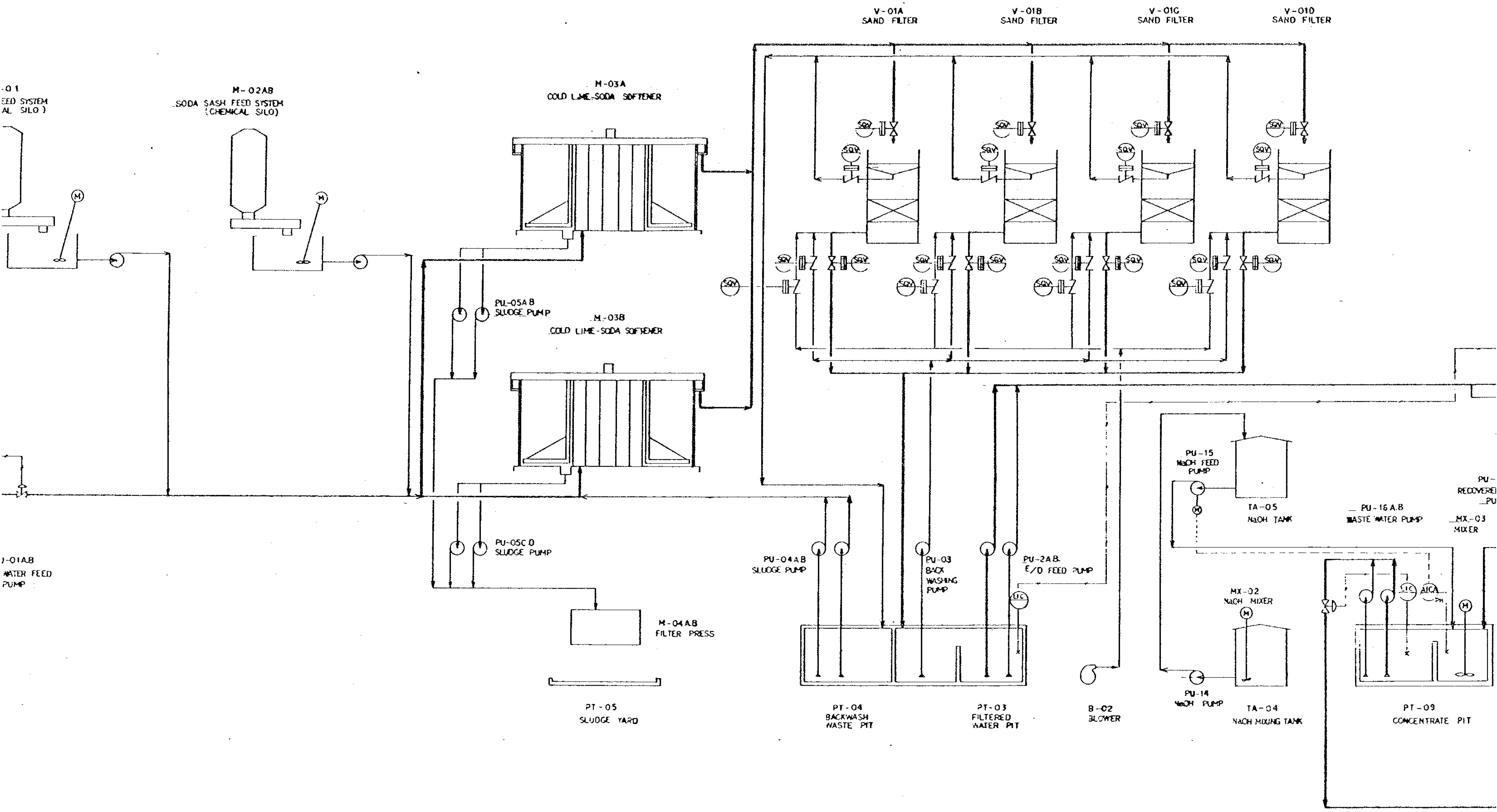
If public electric power is easily available at the Integrated Plant site, the diesel engine power generators could be replaced with the public electric power source.

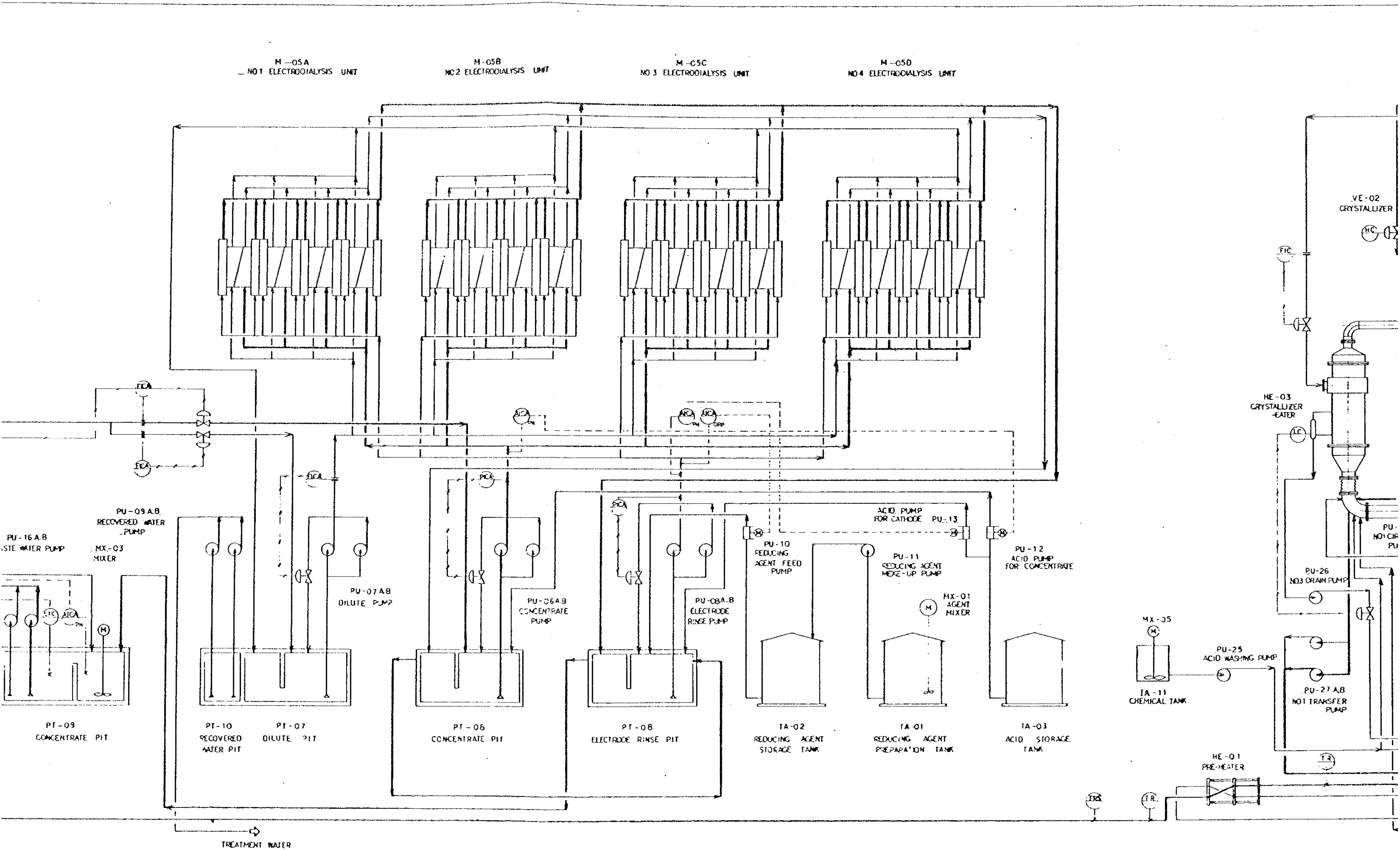
6) There is no boiler feed water at the initial start-up of the Integrated Plant, although steam condensate is supplied from the evaporators as boiler feed water during normal operation.

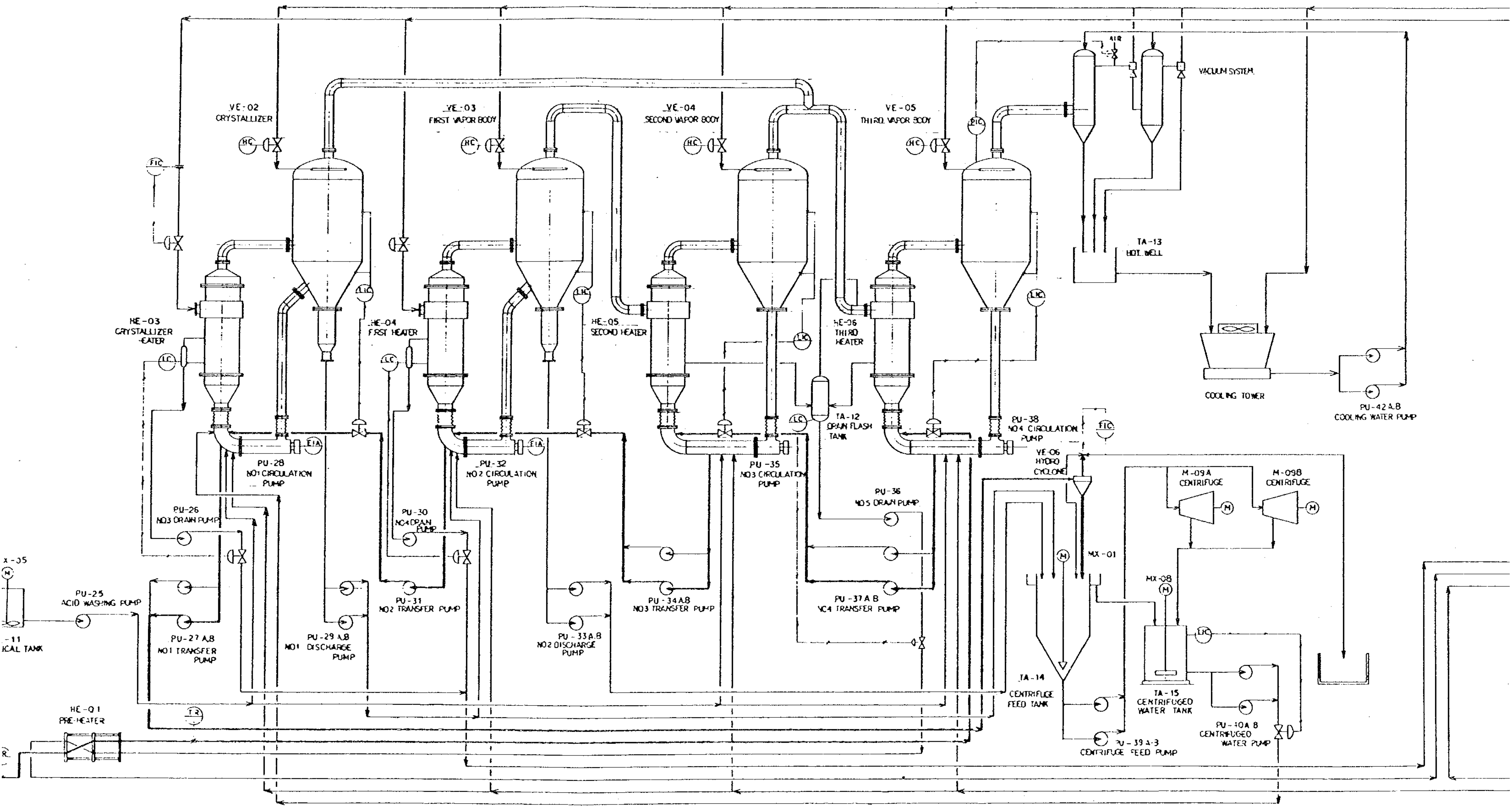
Approximate 120 $m^3$ of high purity water must be transfered from other boiler plants near the Integrated Plant site as the initial charge for the boiler plant.



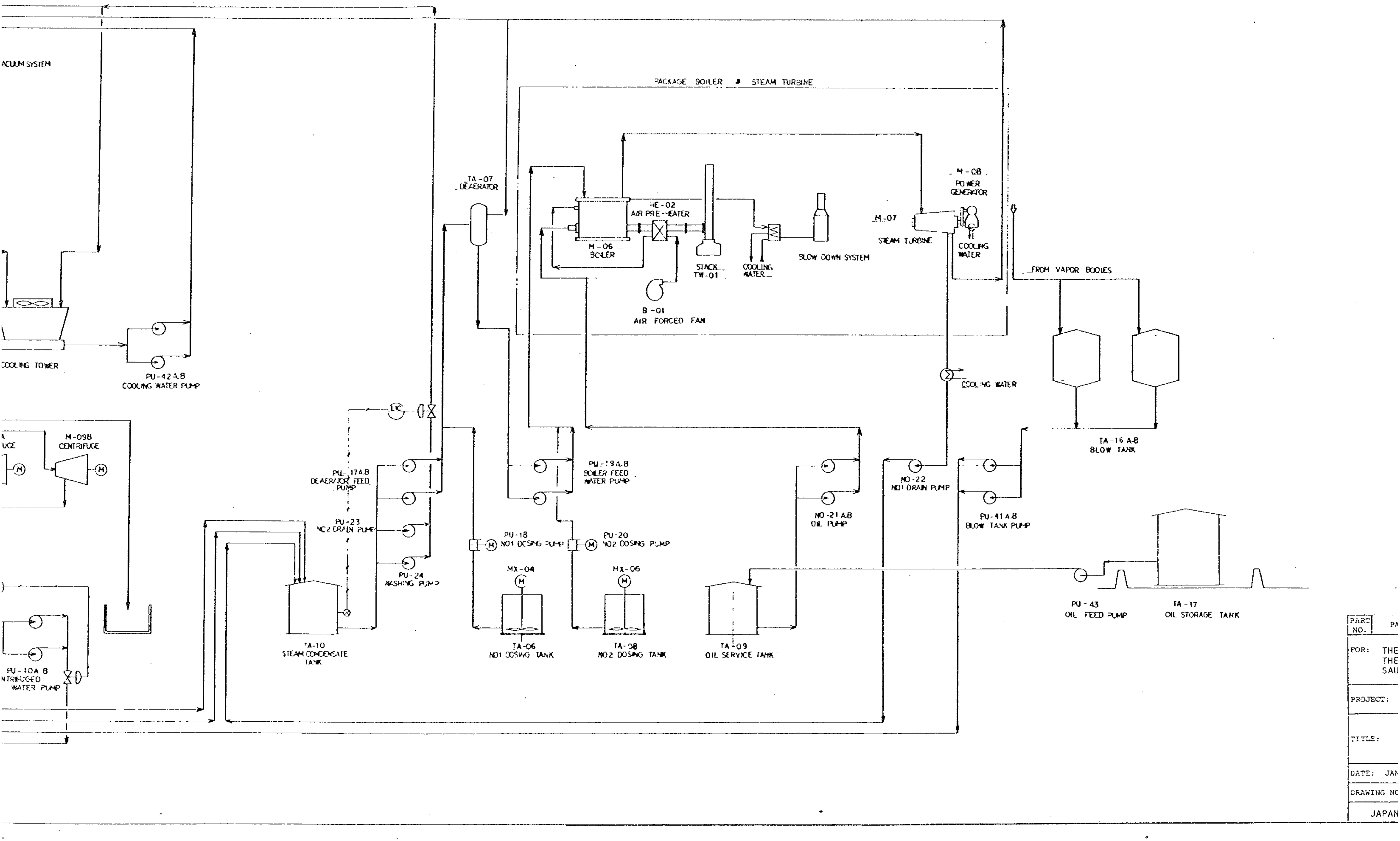
M-01
LIME FEED SYSTEM
(CHEMICAL SILO)
M
LIC
PU-01A,B
RAW WATER FEED
PUMP
PT-01
RAW WATER PIT

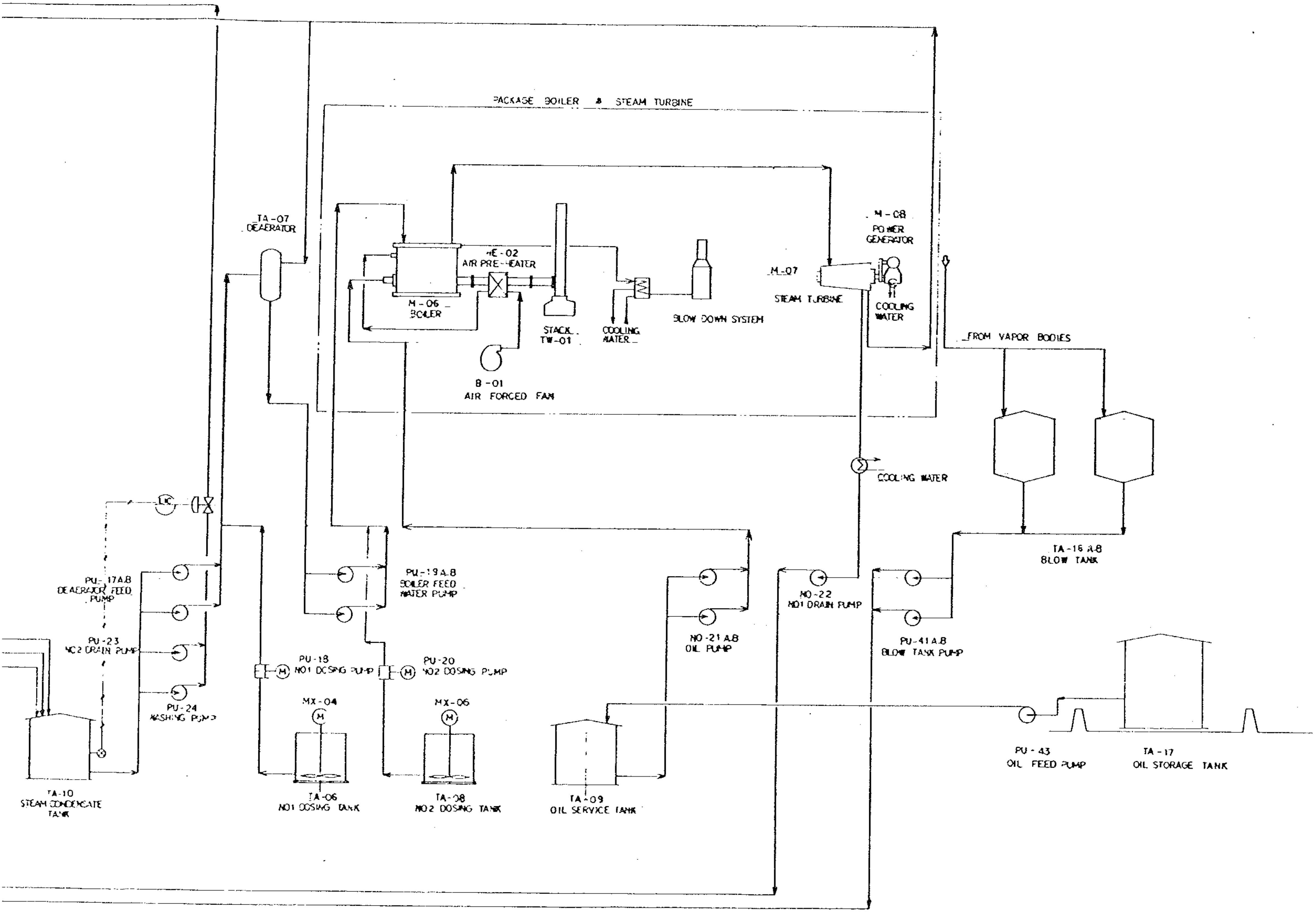

-01
EED SYSTEM
AL SILO )
M-02AB
SODA SASH FEED SYSTEM
(CHEMICAL SILO)
M-03A
COLD LIME-SODA SOFTENER
V-01A
SAND FILTER
V-01B
SAND FILTER
V-01C
SAND FILTER
V-01D
SAND FILTER
SQV
PU-05A.B
SLUDGE PUMP
M-03B
COLD LIME-SODA SOFTENER
PU-05C.D
SLUDGE PUMP
J-01A.B
WATER FEED
PUMP
M-04A.B
FILTER PRESS
PT-05
SLUDGE YARD
PU-04A.B
SLUDGE PUMP
PU-03
BACK
WASHING
PUMP
PU-2A.B
E/O FEED PUMP
LIC
PT-04
BACKWASH
WASTE PIT
PT-03
FILTERED
WATER PIT
B-02
BLOWER
PU-15
NaOH FEED
PUMP
TA-05
NaOH TANK
PU-16A.B
WASTE WATER PUMP
PU-
RECOVERE
PU
MX-03
MIXER
MX-02
NaOH MIXER
PU-14
NaOH PUMP
TA-04
NaOH MIXING TANK
AICA
pH
PT-09
CONCENTRATE PIT


M-05A
NO1 ELECTRODIALYSIS UNIT
M-05B
NO2 ELECTRODIALYSIS UNIT
M-05C
NO3 ELECTRODIALYSIS UNIT
M-05D
NO4 ELECTRODIALYSIS UNIT
VE-02
CRYSTALLIZER
FIC
HC
HE-03
CRYSTALLIZER HEATER
LC
FICA
AICA
PICA
PU-16 A.B
STE WATER PUMP
PU-09 A.B
RECOVERED WATER PUMP
MX-03
MIXER
PU-07 A.B
DILUTE PUMP
PU-06 A.B
CONCENTRATE PUMP
PU-08 A.B
ELECTRODE RINSE PUMP
PU-10
REDUCING AGENT FEED PUMP
ACID PUMP FOR CATHODE PU-13
PU-11
REDUCING AGENT MAKE-UP PUMP
PU-12
ACID PUMP FOR CONCENTRATE
MX-01
AGENT MIXER
MX-05
PU-25
ACID WASHING PUMP
PU-26
NO3 DRAIN PUMP
PU-27 A.B
NO1 TRANSFER PUMP
PT-09
CONCENTRATE PIT
PT-10
RECOVERED WATER PIT
PT-07
DILUTE PIT
PT-06
CONCENTRATE PIT
PT-08
ELECTRODE RINSE PIT
TA-02
REDUCING AGENT STORAGE TANK
TA-01
REDUCING AGENT PREPARATION TANK
TA-03
ACID STORAGE TANK
TA-11
CHEMICAL TANK
HE-01
PRE-HEATER
TR
TREATMENT WATER



VE-02
CRYSTALLIZER
VE-03
FIRST VAPOR BODY
VE-04
SECOND VAPOR BODY
VE-05
THIRD VAPOR BODY
VACUUM SYSTEM
AIR
TA-13
HOT WELL
COOLING TOWER
PU-42 A,B
COOLING WATER PUMP
HE-03
CRYSTALLIZER HEATER
HE-04
FIRST HEATER
HE-05
SECOND HEATER
HE-06
THIRD HEATER
TA-12
DRAIN FLASH TANK
PU-28
NO1 CIRCULATION PUMP
PU-32
NO2 CIRCULATION PUMP
PU-35
NO3 CIRCULATION PUMP
PU-38
NO4 CIRCULATION PUMP
VE-06
HYDRO CYCLONE
M-09A
CENTRIFUGE
M-09B
CENTRIFUGE
PU-26
NO3 DRAIN PUMP
PU-30
NO4 DRAIN PUMP
PU-36
NO5 DRAIN PUMP
MX-01
MX-08
PU-25
ACID WASHING PUMP
PU-27 A,B
NO1 TRANSFER PUMP
PU-29 A,B
NO1 DISCHARGE PUMP
PU-31
NO2 TRANSFER PUMP
PU-33 A,B
NO2 DISCHARGE PUMP
PU-34 A,B
NO3 TRANSFER PUMP
PU-37 A,B
NO4 TRANSFER PUMP
TA-14
CENTRIFUGE FEED TANK
TA-15
CENTRIFUGED WATER TANK
PU-39 A,B
CENTRIFUGE FEED PUMP
PU-40A,B
CENTRIFUGED WATER PUMP
HE-01
PRE-HEATER


ACUUM SYSTEM
PACKAGE BOILER & STEAM TURBINE
TA-07
DEAERATOR
HE-02
AIR PRE-HEATER
M-06
BOILER
STACK
TW-01
COOLING
WATER
BLOW DOWN SYSTEM
M-08
POWER
GENERATOR
M-07
STEAM TURBINE
COOLING
WATER
FROM VAPOR BODIES
B-01
AIR FORCED FAN
COOLING TOWER
PU-42 A.B
COOLING WATER PUMP
COOLING WATER
M-09B
CENTRIFUGE
PU-17A.B
DEAERATOR FEED PUMP
PU-19 A.B
BOILER FEED
WATER PUMP
NO-21 A.B
OIL PUMP
NO-22
NO1 DRAIN PUMP
PU-41 A.B
BLOW TANK PUMP
TA-16 A.B
BLOW TANK
PU-23
NO2 DRAIN PUMP
PU-18
NO1 DOSING PUMP
PU-20
NO2 DOSING PUMP
PU-24
WASHING PUMP
MX-04
MX-06
PU-43
OIL FEED PUMP
TA-17
OIL STORAGE TANK
TA-10
STEAM CONDENSATE
TANK
TA-06
NO1 DOSING TANK
TA-08
NO2 DOSING TANK
TA-09
OIL SERVICE TANK
PU-40A B
NTRIFUGED
WATER PUMP
PART
NO.
PA
FOR:
THE
THE
SAU
PROJECT:
TITLE:
DATE: JA
DRAWING NO
JAPAN




| PART NO. | PART NAME | MAT'L | WORK QUANT/SET | SPARE | REMARK |
|---|---|---|---|---|---|

FOR: THE MINISTRY OF AGRICULTURE AND WATER THE GOVERNMENT OF THE KINGDOM OF SAUDI ARABIA

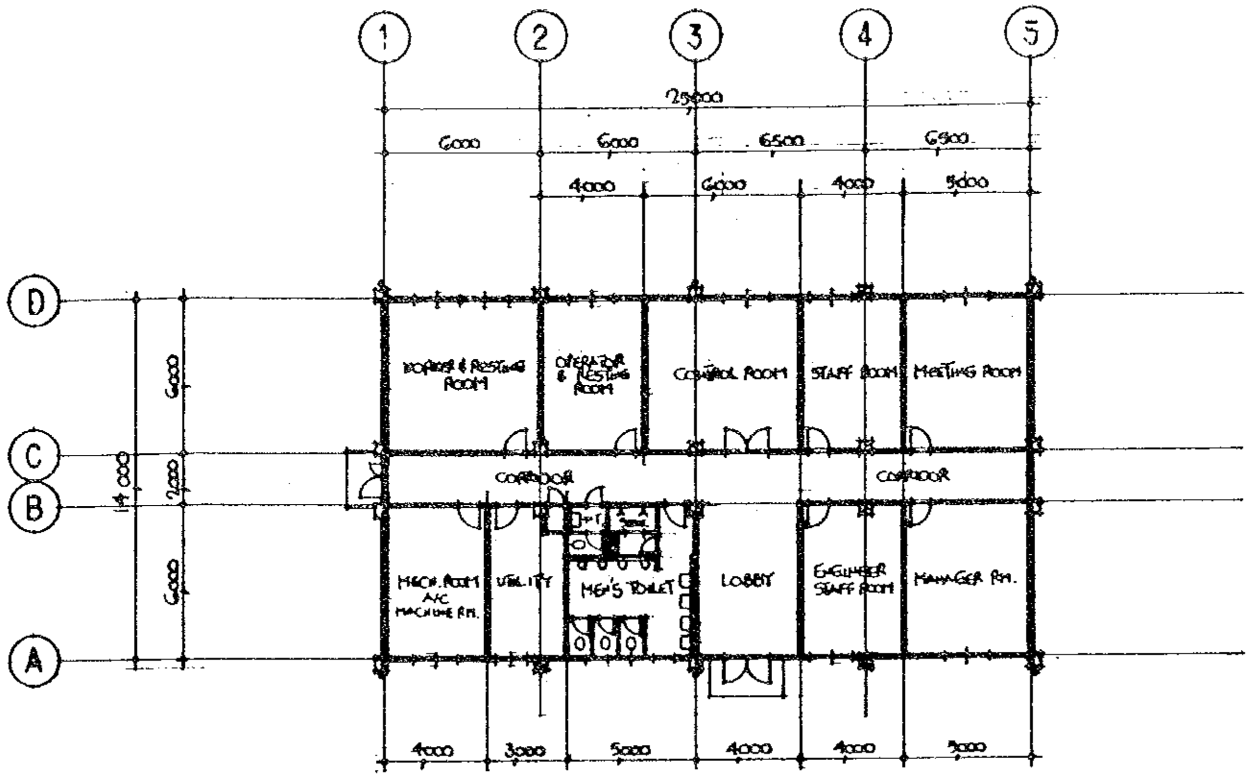
PROJECT: RO BRINE REJECT TREATMENT

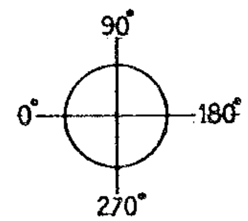
TITLE: PROCESS FLOW SHEME

DATE: JANUARY 15, 1981 | SCALE: NONE

DRAWING NO.: SAJ/RO-101

JAPAN INTERNATIONAL COOPERATION AGENCY




FLOOR PLAN

FLOOR AREA: 350 $m^2$

INTERIOR FINISH SCHEDULE

| ROOM NAME | FLOOR | BASE H=100 | WAINSCOT | WALL | CEILING | REMARKS |
|---|---|---|---|---|---|---|
| LOBBY AND CORRIDOR | VINYL ASBESTOS TILE | VINYL ASBESTOS TILE BASE | — | CEMENT PLASTER W/VINYL PAINT | ACOUSTICAL FIBER BOARD H=2,400 | |
| ENGINEER STAFF ROOM | " | " | — | " | ACOUSTICAL FIBER BOARD H=2,800 | A/C |
| MANAGER ROOM | " | " | — | " | " | " |
| MEETING ROOM | " | " | — | " | " | " |
| STAFF ROOM | " | " | — | " | " | " |
| CONTROL ROOM | " | " | — | " | " | " |
| OPERATOR AND RESTING ROOM | " | " | — | " | " | " |
| WORKING AND RESTING ROOM | " | " | — | " | " | " |
| UTILITY ROOM | PORCELAIN UNGLAZED MOSAIC TILE | — | — | SEMI-PORCELAIN GLAZED TILE | ASBESTOS CEMENT BOARD W/VINYL PAINT H=2,600 | |
| MEN'S WOMEN'S TOILET AND SHOWER & JANITORS CLOSET | " | — | — | " | " | |
| MECHANICAL ROOM (A/C MACHINE RM) | CONCRETE STEEL TROWEL | — | — | CEMENT PLASTER W/VINYL PAINT | EXPOSED CEILING W/VINYL PAINT | |

EXTERIOR FINISH SCHEDULE

| SURFACE | MATERIAL AND FINISH | REMARKS |
|---|---|---|
| STRUCTURAL FRAME | REINFORCED CONCRETE | |
| FOUNDATION | " | |
| ROOF | REINFORCED CONCRETE W/VINYL WATER PROOFING SLOPE: 1/100 | |
| COLUMN AND GIRDER | REINFORCED CONCRETE EXPOSED W/VINYL PAINT | |
| WALL | CONCRETE BLOCK W/CEMENT MORTAR STUCCO SPRAY FINISH | |
| BASE | REINFORCED CONCRETE EXPOSED W/VINYL PAINT H=300 | |
| STOOP | REINFORCED CONCRETE STEEL TROWEL FINISH | |
| DOOR AND FRAME | STEEL W/OIL PAINT | |
| WINDOW AND FRAME | ALUMINUM | |
| DOWNSPOUT | POLY VINYL CHLORIDE 100ø W/METAL ROOF DRAIN OIL PAINT FINISH | |

LEGEND

: REINFORCED CONCRETE

: CONCRETE BLOCK, EXT 200 & INT 150, 100

| PART NO. | PART NAME | MAT'L | WORK QUANY/SET | SPARE | REMARK |
|---|---|---|---|---|---|

FOR: THE MINISTRY OF AGRICULTURE AND WATER THE GOVERNMENT OF THE KINGDOM OF SAUDI ARABIA

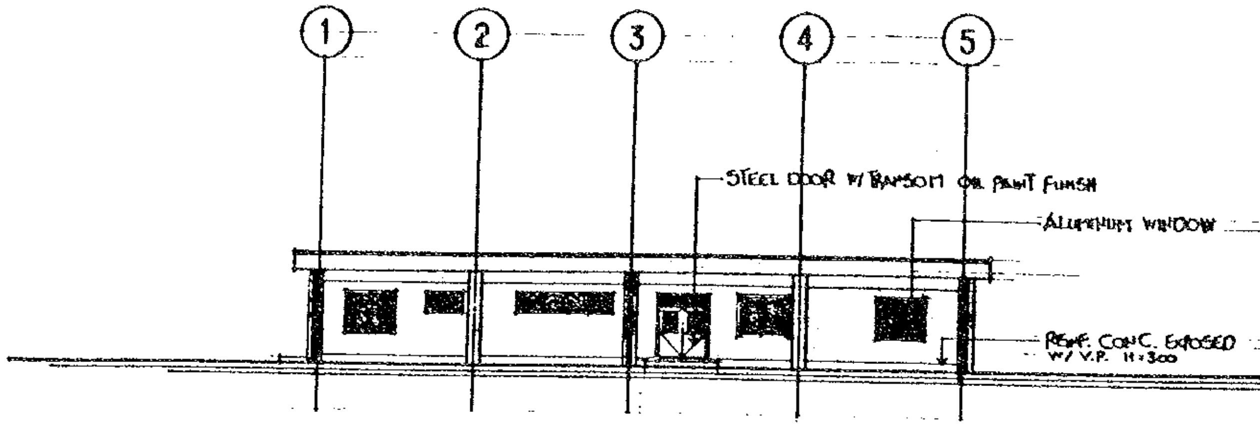
PROJECT: RO BRINE REJECT TREATMENT

TITLE: CONTROL BUILDING PLAN & FINISH SCHEDULE

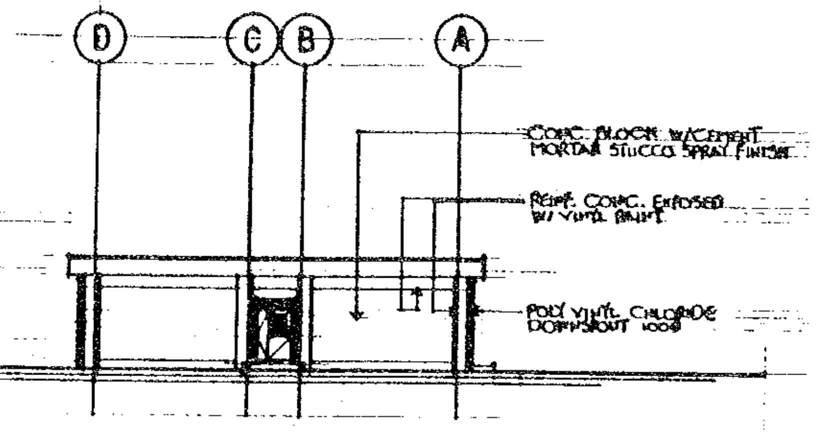
DATE: JANUARY 15, 1981 | SCALE: NONE

DRAWING NO.: SAJ/RO-102

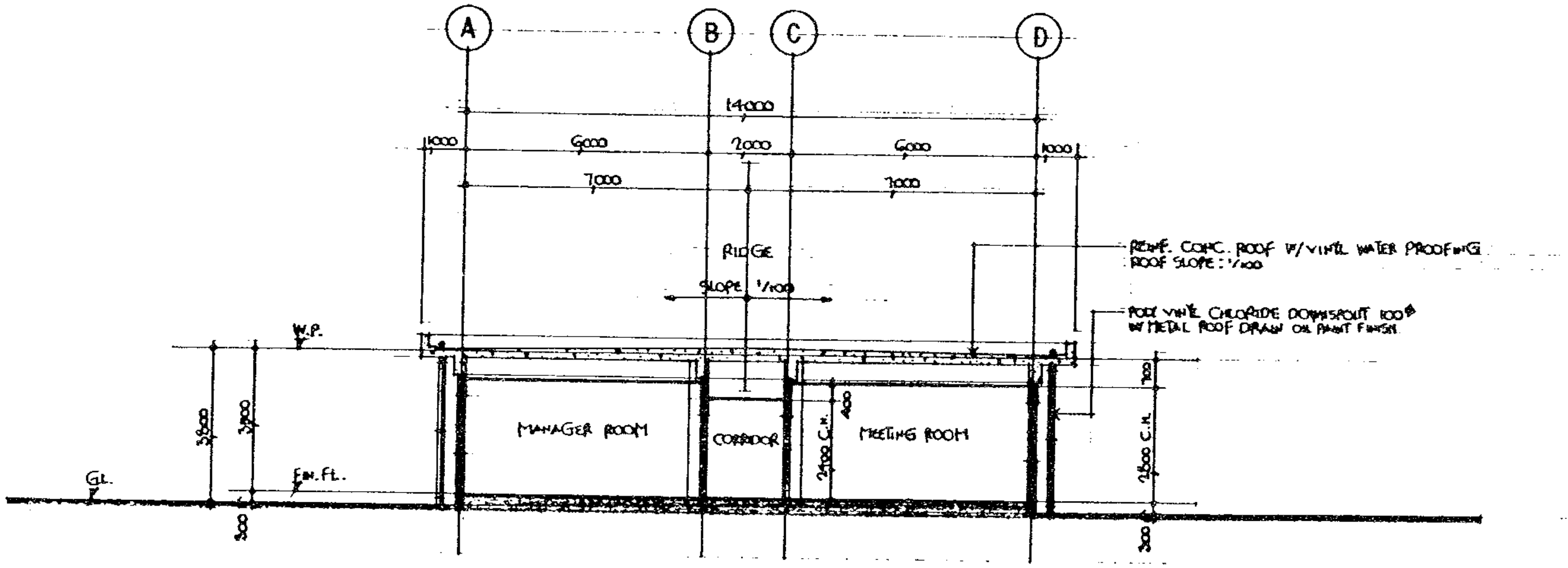
JAPAN INTERNATIONAL COOPERATION AGENCY




270° SIDE ELEVATION




0° SIDE ELEVATION




CROSS SECTION

| PART NO. | PART NAME | MAT'L | WORK QUANT/SET | SPARE | REMARK |
|---|---|---|---|---|---|

FOR: THE MINISTRY OF AGRICULTURE AND WATER THE GOVERNMENT OF THE KINGDOM OF SAUDI ARABIA

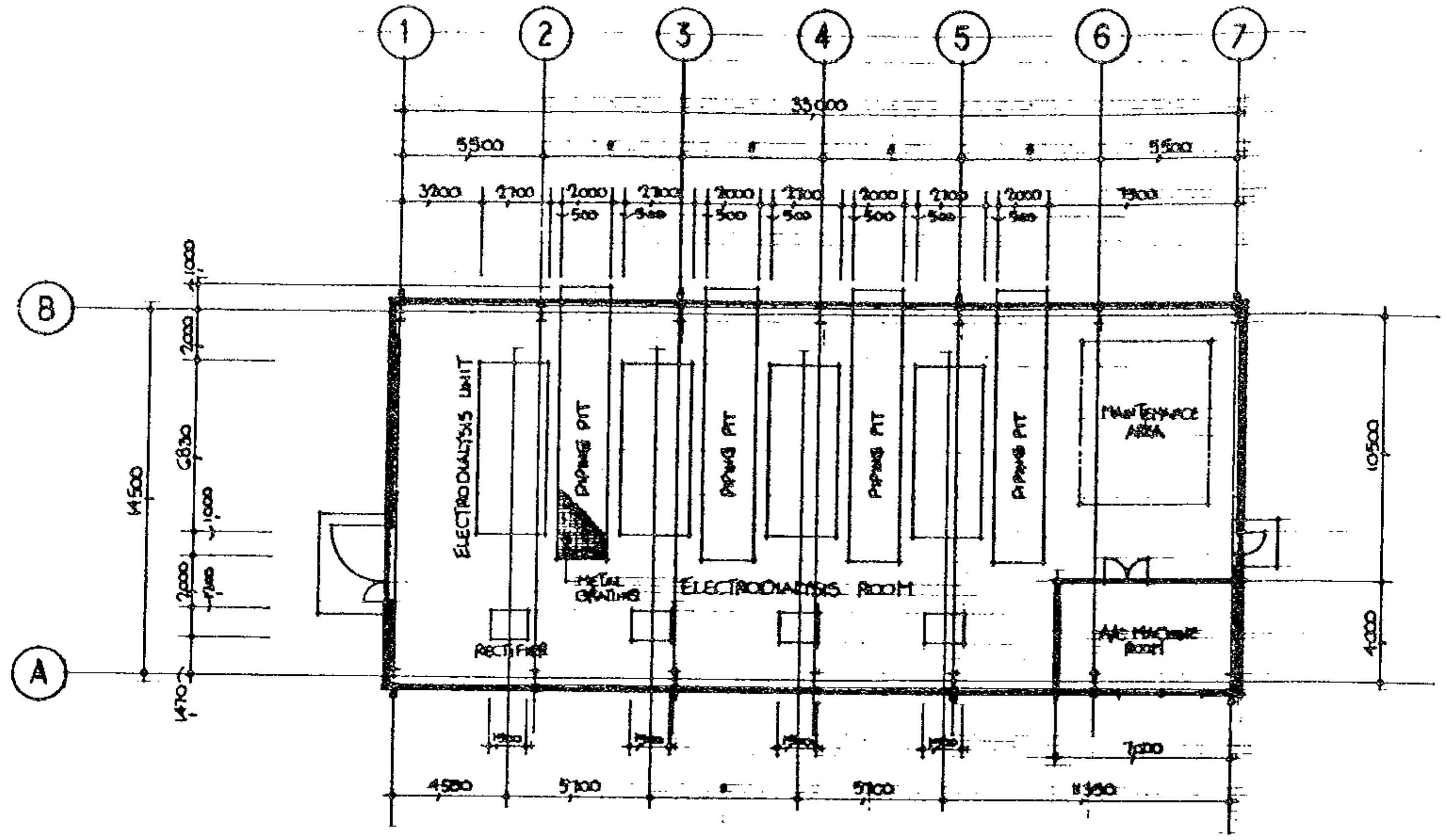
PROJECT: RO BRINE REJECT TREATMENT

TITLE: CONTROL BUILDING
ELEVATIONS & SECTION

DATE: JANUARY 15, 1981 SCALE: NONE

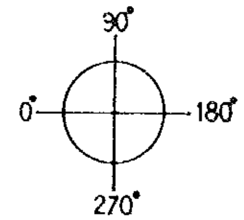
DRAWING NO.: SAJ/RO-103

JAPAN INTERNATIONAL COOPERATION AGENCY




FLOOR PLAN

FLOOR AREA: 478.5 $m^2$




## INTERIOR FINISH SCHEDULE

| ROOM NAME | FLOOR | BASE H=100 | WAINSCOT | WALL | CEILING | REMARKS |
|---|---|---|---|---|---|---|
| ELECTRODIALYSIS ROOM | CONCRETE SHEEL TROWEL | — | CEMENT MORTAR STEEL TROWEL H=1,000 | CORRUGATED ASB. CEMENT SHEET EXPOSED | EXPOSED ROOF | A/C |
| MAINTENANCE ROOM | 〃 | — | 〃 | 〃 | 〃 | 〃 |
| A/C MACHINE ROOM | 〃 | — | 〃 | 〃 | STEEL DECK PLATE EXPOSED W/O.P. | |
| PIPING PIT | CEMENT MORTAR STEEL TROWEL FL=2,000 | — | | CEMENT MORTAR STEEL TROWEL | GRATING EXPOSED | |

LEGEND

CONCRETE BLOCK 150THK & 100THK

REINFORCED CONCRETE

## EXTERIOR FINISH SCHEDULE

| SURFACE | MATERIAL AND FINISH | REMARKS |
|---|---|---|
| STRUCTURAL FRAME | STEEL W/OIL PAINT | |
| FOUNDATION | REINFORCED CONCRETE | |
| ROOF | CORRUGATED ASBESTOS CEMENT SHEET SLOPE: 3/10 | |
| WALL | CORRUGATED ASBESTOS CEMENT SHEET W/TRANSLUCENT F.R.P. SHEET | |
| WAINSCOT | CONCRETE BLOCK W/CEMENT MORTAR STUCCO SPRAY FINISH | |
| BASE | REINFORCED CONCRETE EXPOSED W/VINYL PAINT H=200 | |
| STOOP | REINFORCED CONCRETE STEEL TROWEL FINISH | |
| DOOR AND FRAME | STEEL W/OIL PAINT | |
| WINDOW AND FRAME | ALUMINUM | |
| DOWNSPOUT | POLY VINYL CHLORIDE 100Ø W/GUTTER | |

| PART NO. | PART NAME | MAT'L | WORK / SPARE QUANT/SET | REMARK |
|---|---|---|---|---|

FOR: THE MINISTRY OF AGRICULTURE AND WATER THE GOVERNMENT OF THE KINGDOM OF SAUDI ARABIA

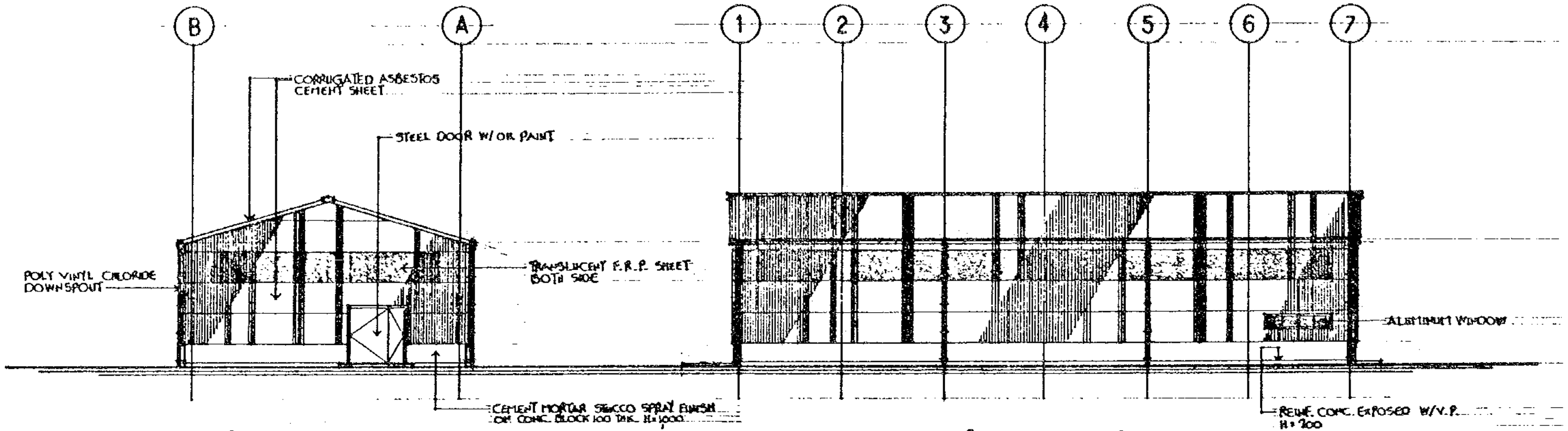
PROJECT: RO BRINE REJECT TREATMENT

TITLE: ELECTRODIALYSIS BUILDING PLAN & FINISH SCHEDULE

DATE: JANUARY 15, 1981 | SCALE: NONE

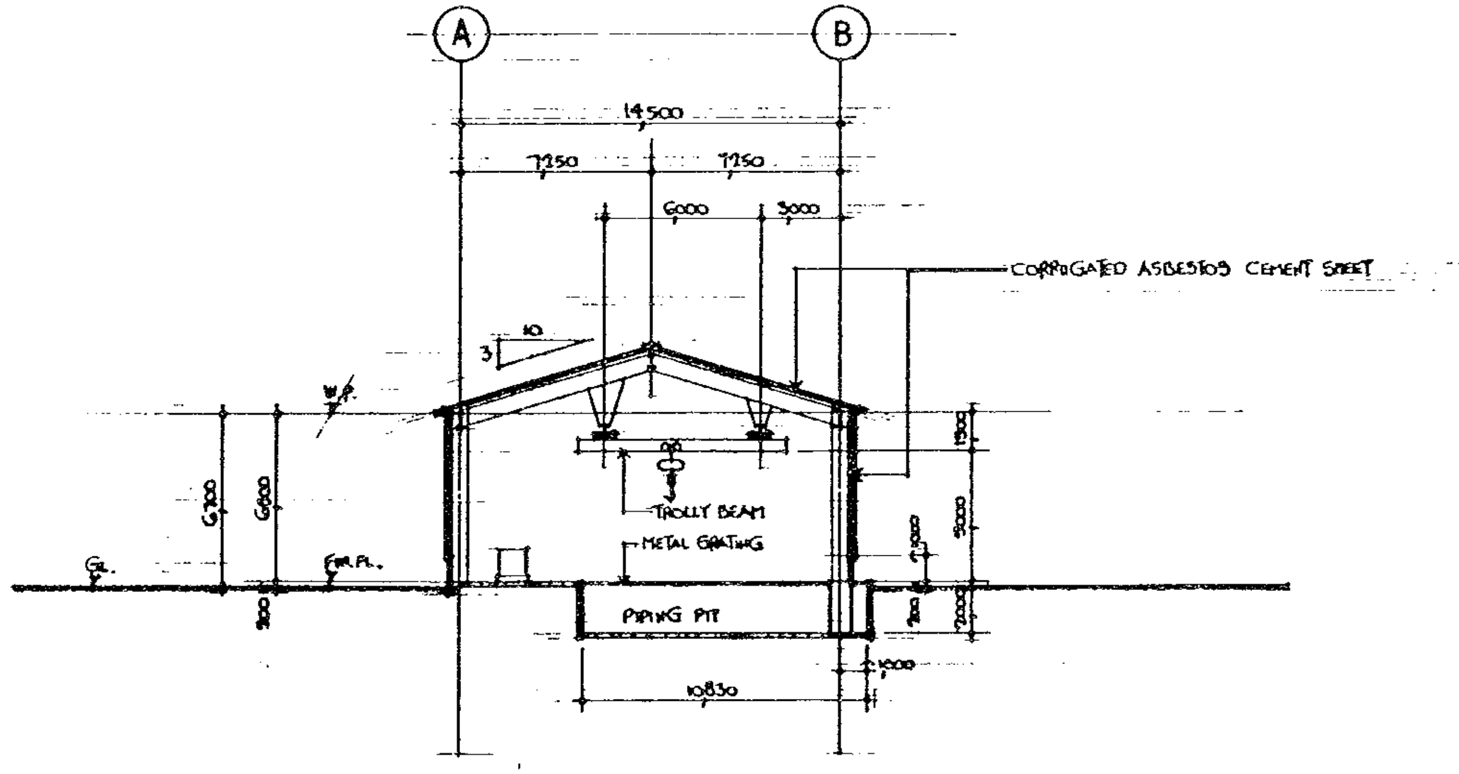
DRAWING NO.: SAJ/RO-104

JAPAN INTERNATIONAL COOPERATION AGENCY




0° SIDE ELEVATION

270° SIDE ELEVATION




CROSS SECTION

| PART NO. | PART NAME | MAT'L | WORK QUANT/SET | SPARE | REMARK |
|---|---|---|---|---|---|

FOR: THE MINISTRY OF AGRICULTURE AND WATER
THE GOVERNMENT OF THE KINGDOM OF
SAUDI ARABIA

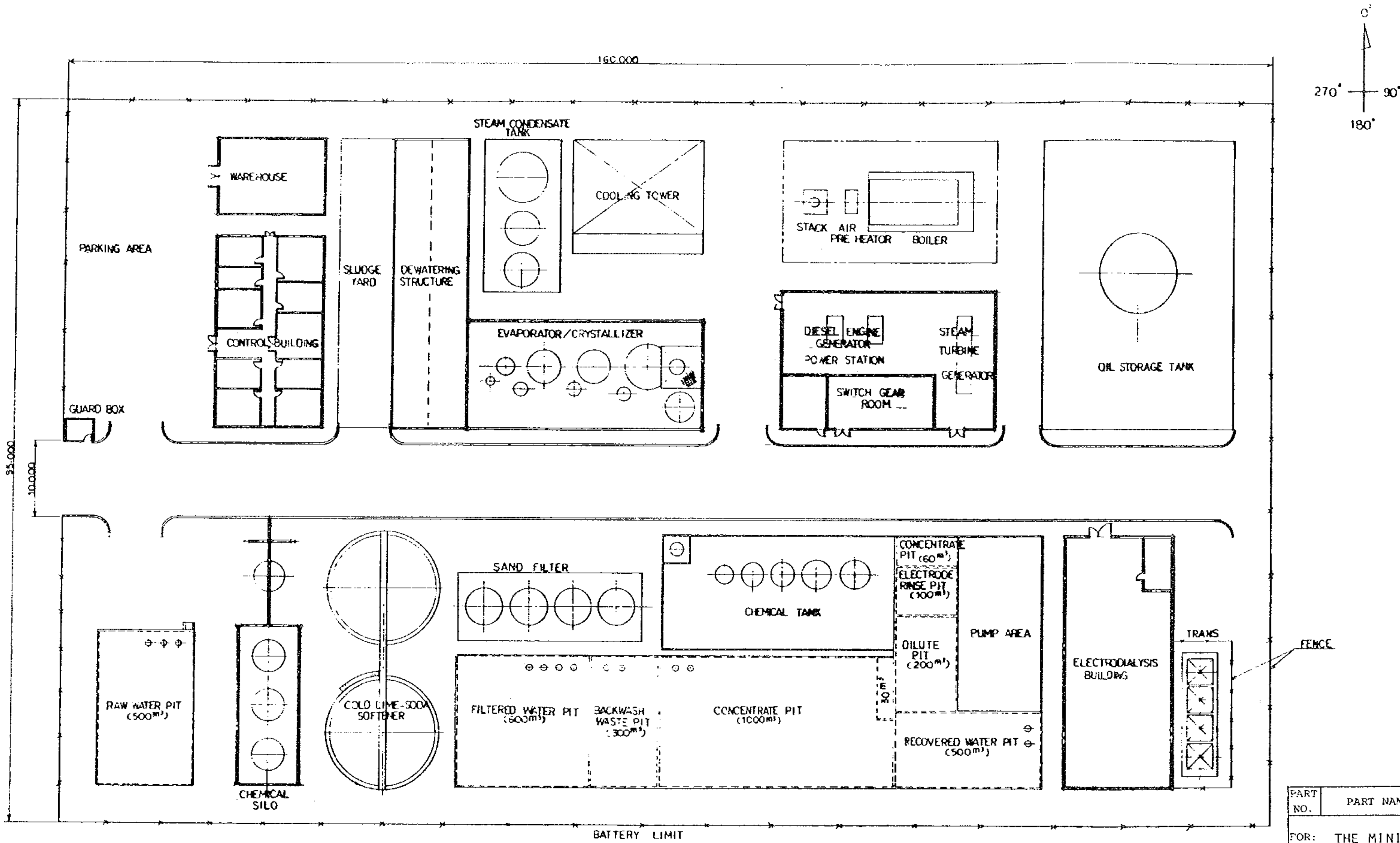
PROJECT: RO BRINE REJECT TREATMENT

TITLE: ELECTRODIALYSIS BUILDING
ELEVATIONS & SECTION

DATE: JANUARY 15, 1981 | SCALE: NONE

DRAWING NO.: SAJ/RO-105

JAPAN INTERNATIONAL COOPERATION AGENCY




PLOT PLAN FOR R.O BRINE REJECT TREATMENT PLANT

| PART NO. | PART NAME | MAT'L | WORK QUANT/SET | SPARE QUANT/SET | REMARK |
|---|---|---|---|---|---|

FOR: THE MINISTRY OF AGRICULTURE AND WATER THE GOVERNMENT OF THE KINGDOM OF SAUDI ARABIA

PROJECT: RO BRINE REJECT TREATMENT

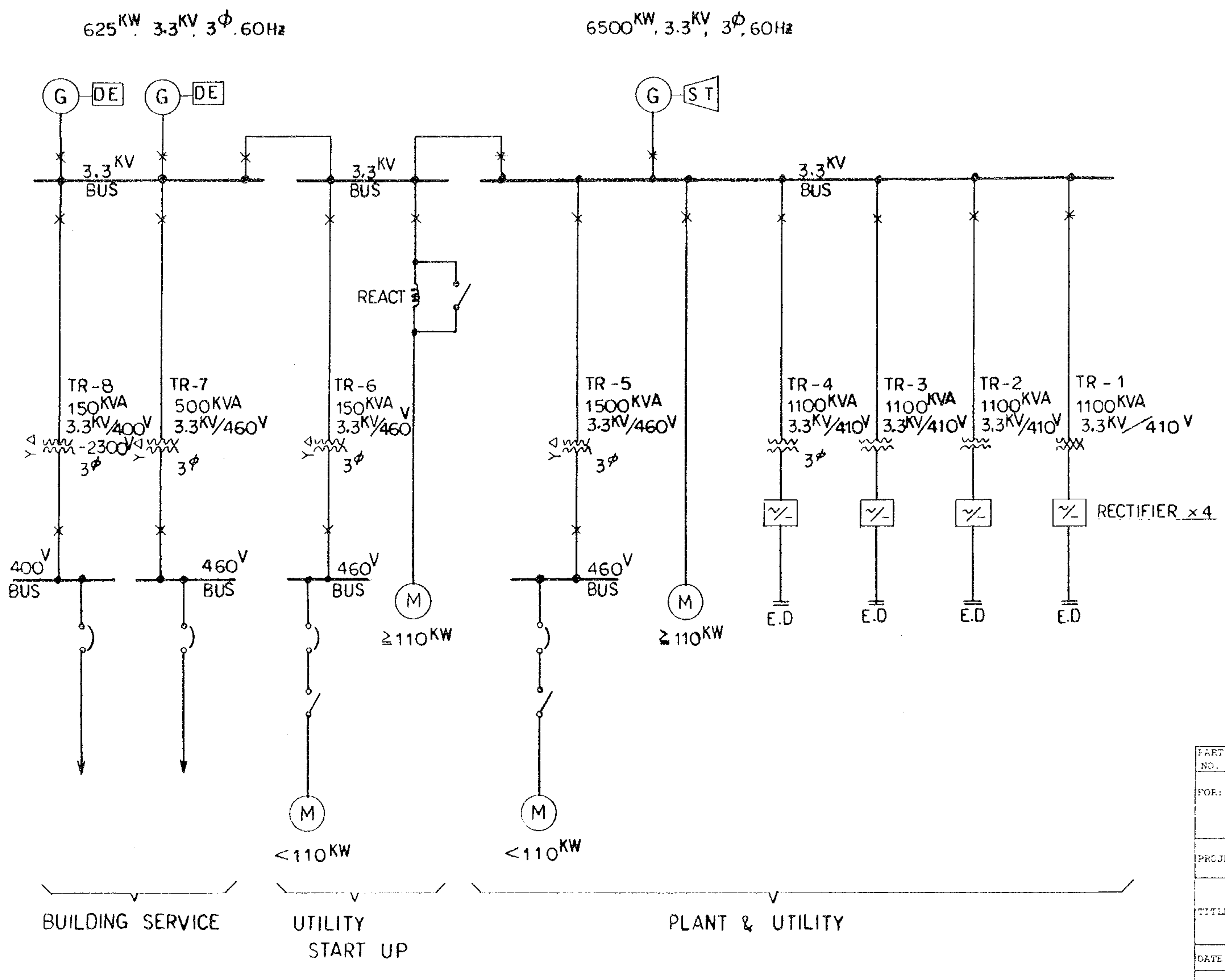
TITLE: PLOT PLAN

DATE: JANUARY 15, 1981 SCALE: NONE

DRAWING NO.: SAJ/RO-106

JAPAN INTERNATIONAL COOPERATION AGENCY

# SINGLE LINE DIAGRAM (R.O BRINE REJECT TREATMENT)




| PART NO. | PART NAME | MAT'L | WORK / SPARE QUANT/SET | REMARK |
|---|---|---|---|---|

FOR: THE MINISTRY OF AGRICULTURE AND WATER THE GOVERNMENT OF THE KINGDOM OF SAUDI ARABIA

PROJECT: RO BRINE REJECT TREATMENT

TITLE: SINGLE LINE DIAGRAM

DATE: JANUARY 15, 1981 SCALE:

DRAWING NO.: SAJ/RO-107

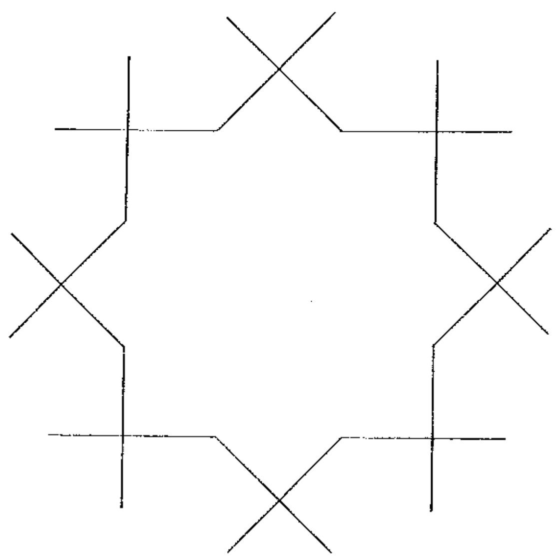
JAPAN INTERNATIONAL COOPERATION AGENCY

## 13. Attachment

Through the study, three minutes of meetings between MOAW and study team have been made by both parties. The minutes are attached concerning matters which offer important information to this study report.

It is supposed useful to record those data in this report for the future development of this project.

Those matters show questionnaires, perspective of the study, the attendants of the meetings and actual schedule of the site survey, etc.



13.1 (1) Annex to the Minutes dated September 28, 1980.

At the site survey, following matters are proposed and agreed by the both parties:

1. List of Attendants
2. Schedule
3. Scope of Feasibility Study
4. Step of Works
5. Method of RO Brine Reject Treatment
6. Tentative Report (see next chapter)
7. Questionnaires

Annex 1: List of Attendants

1. JAPANESE DELEGATION

| | |
|---|---|
| Masaru Ikai | Delegation Leader, Water Re-Use Promotion Center |
| Masahiro Miyazaki | Industrial Water Division Ministry of International Trade and Industry |
| Keiichi Kato | Japan International Cooperation Agency (JICA) |
| Koh Tsuda | Water Re-Use Promotion Center |
| Shigeru Itoi | Water Re-Use Promotion Center |
| Yo Takahashi | Water Re-Use Promotion Center |
| Junzo Hori | Water Re-Use Promotion Center |
| Gennosuke Inoue | Water Re-Use Promotion Center |
| Hisao Ogasawara | Water Re-Use Promotion Center |

2. Japanese Observers

| | |
|---|---|
| Naotoshi Osada | Deputy Japanese Representative for the Secretariat to the Saudi-Japanese Joint Committee |
| Takashi Komori | Resident Representative Riyadh Office JICA |

3. MOAW

| | |
|---|---|
| H.E. Abdulla Al Gholaikha | Deputy Minister for Water Affairs MOAW |
| Mohamed Aquil Khan | Deputy Director General Projects Execution Department MOAW |
| Amer Hossein | Assistant Director General Water Resources Development Department MOAW |
| Omar Al-Sheikh | Civil Engineer Projects Execution Department MOAW |

Annex 2: Schedule

| Date | Schedule | Person to Meet |
|---|---|---|
| Sept 26, Fri | Leave Japan | |
| " 27, Sat | Arrive in Riyadh | |
| " 28, Sun | Visit to Min. of Agr. & Water<br>Explanation of scope of work, step of works, site survey and tentative report | H.E. Al Gholaikha |
| " 29, Mon | Visit to Water & Sewage Authority (WSA)<br>Same explanation as above | |
| " 30, Tue | Visit to Manfouha Sewage Treatment Plant<br>Visit to Manfouha Water Treatment Plant | Mr. M. El-Baker |
| Oct 1, Wed | Visit to Water Division, WSA<br>Visit to Malez Water Treatment Plant | |
| " 2, Thu | | |
| " 3, Fri | | |
| " 4, Sat | Visit to Haiyr Pretreatment Plant | |
| " 5, Sun | Visit to Salbukh Water Treatment Plant | |
| " 6, Mon | Visit to Sewage Division, WSA<br>Visit to Shemessy Water Treatment Plant | |
| " 7, Tue | Pigeonholing of obtained data & preparation of interim report | |
| " 8, Wed | Explanation of interim report | H.E. Al Gholaikha |
| " 9, Thu | | |
| " 10, Fri | | |
| " 11, Sat | (Reserved for the above explanation) | |
| " 12, Sun | Leave Riyadh | |
| " 13, Mon | Return to Japan | |

Annex 3: Scope of Feasibility Study

1. Asseeement and investigation of RO brine reject disposal
   (1) Disposal into the municipal sewage pipeline
   (2) Disposal into the sewage treatment plant
   (3) Water re-use program
   (4) Proposition and evaluation of effective concentration method of RO brine reject
2. Selection of disposal method
3. Planning
   (1) Conceptual design of selected method
   (2) Cost estimation
   (3) Economical analysis
4. Conclusion
   (1) Conclusion
   (2) Proposal and comment
5. Explanation of the result to the Ministry of Agriculture and Water, the Government of the Kingdom of Saudi Arabia

Annex 4: Step of Works

1. On the spot survey in Riyadh

    (1) Meetings

    (2) Visits to plants

    (3) Interim reporting

    (4) Confirmation of figures (data)

2. Works in Japan

    (1) Analysis

    (2) Planning

    (3) Evaluation

    (4) Drafting of final report

3. Explanation of draft of final report to the Ministry of Agriculture and Water, the Government of the Kingdom of Saudi Arabia

Annex 5: Method of RO Brine Reject Treatment

1. Evaporation pond in the suburbs
2. Deep well injection
3. Concentration by electrodialysis (ED) process
    3.1 ED process followed by evaporation pond in the suburbs
    3.2 ED process followed by evaporation pond in the RO plant site
    3.3 ED process followed by Evaporator/Crystallizer
    3.4 ED process followed by deep well injection
4. Concentration by reverse osmosis (RO) process
5. Disposal into municipal sewage pipeline
6. Recovery of valuables

Annex 6: Tentative Report

# TENTATIVE REPORT ON
# FEASIBILITY STUDY OF
# RO BRINE REJECT TREATMENT IN
# THE KINGDOM OF SAUDI ARABIA

(DOCUMENT NO. SAJ/RO-101)

SEPTEMBER 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO, JAPAN

Annex 7: Questionnaires

## Questionnaire (1) -- Water Treatment Plant in Riyadh

1. Capacity and expansion program

| Name of Plant | Design Capacity ($m^3$/day) | Operational Record ($m^3$/day) | | | Expansion Program ($m^3$/day by year) |
|---|---|---|---|---|---|
| | | Maximum | Minimum | Average | |
| Malez | | | | | |
| Manfouha | | | | | |
| Shemessy | | | | | |
| Haiyr | | | | | |
| | | | | | |

2. Quality of treated water

| Items \ Plant | Malez | Manfouha | Shemessy |
|---|---|---|---|
| Total dissolved solids (TDS), mg/l | 1,100 | 900 | 800 |
| Chloride, $Cl^-$, mg/l | 270 | 180 | 170 |
| Sulphate, $SO_4^{2-}$, mg/l | 450 | 370 | 300 |
| Calcium, $Ca^{2+}$, mg/l | 40 | 40 | 40 |
| meqv./l | 2 | 2 | 2 |
| Magnesium, $Mg^{2+}$, mg/l | 36 | 36 | 36 |
| meqv./l | 3 | 3 | 3 |
| Total hardness, meqv./l | 5 | 5 | 5 |

Source: Proceedings of Nice Int'l Congress in 1979

3. Layout drawings, both present & expansion program

Questionnaire (2) -- Sewage Treatment Plant

1. Manfouha Sewage Treatment Plant

   Design capacity: __________ $m^3$/day

   Operational record: Maximum __________ $m^3$/day

   Minimum __________ $m^3$/day

   Average __________ $m^3$/day

   Expansion program: __________ $m^3$ by ________ (Year)

   __________ $m^3$ by ________

2. Planned plant

   Location: ______________________________

   Design capacity: __________ $m^3$/day

   Year of completion: ________

3. Quality of influent, both design & operational record

   a) Temperature: _____/_____
   b) pH: _____/_____
   c) BOD: _____/_____
   d) SS: _____/_____
   e) n-Hesan Extract Substances: _____/_____
   f) Iodine consumed: _____/_____
   g) Phenols: _____/_____
   h) Cyanide: _____/_____
   i) Alkyl Hg: _____/_____
   j) Organic P: _____/_____
   k) Cd: _____/_____
   l) Pb: _____/_____
   m) Cr (6 valence: _____/_____
   n) As: _____/_____
   O) Total Hg: _____/_____
   p) Cr: _____/_____
   q) Cu: _____/_____
   r) Zn: _____/_____
   s) Fe (soluble): _____/_____
   t) Mn (soluble): _____/_____
   u) F: _____/_____

4. Layout drawings, both present & expansion program

## Questionnaire (3) -- Sewage Re-Use Program

1. Capacity and expansion program

| Name of Plant | Design Capacity ($m^3$/day) | Operational Record ($m^3$/day) | | | Expansion Program ($m^3$/day by year) |
|---|---|---|---|---|---|
| | | Maximum | Minimum | Average | |
| | | | | | |
| | | | | | |
| | | | | | |

2. Quality of reclaimed water, both design & operation record

a) Temperature: ______/______

b) pH: ______/______

c) BOD: ______/______

d) SS: ______/______

e) n-Hexan Extract Substance: ______/______

f) Iodine consumed: ______/______

g) Phenols: ______/______

h) Cyanide: ______/______

i) Alkyl Hg: ______/______

j) Organic P: ______/______

k) Cd: ______/______

l) Pb: ______/______

m) Cr (6 valence): ______/______

n) As: ______/______

O) Total Hg: ______/______

P) Cr: ______/______

q) Cu: ______/______

r) Zn: ______/______

s) Fe (soluble): ______/______

t) Mn (soluble): ______/______

u) F: ______/______

3. Layout drawings, both present & expansion program

Questionnaire (4) -- Governmental Office in Charge of Water Administration

1. Basic Plan of Water Resources Development:

2. Potable Water:

3. Industrial Water:

4. Agricultural Water:

5. Sewage:

6. Organization Chart of the above

7. Law and Regulation related to Water Administration:

8. Budgetary System:

\#  \#  \#

## Questionnaire

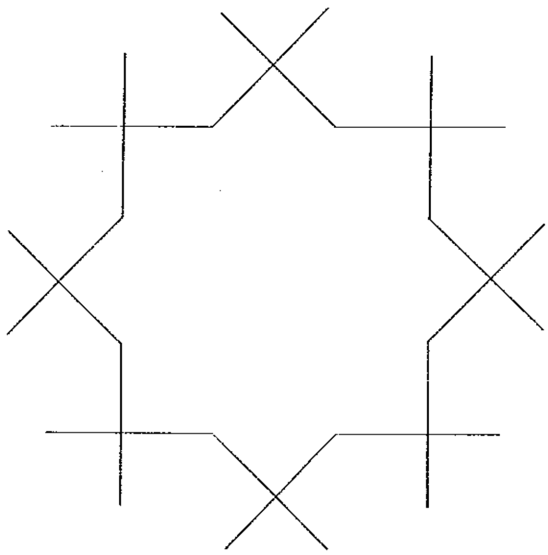
1. Bearing capacity in the Riyadh area
2. Boring log of deep well more than 1,000 m in the Riyadh area
3. Permeability coefficient of aquifer
4. Atomospheric pressure in the Riyadh area
5. Wind velocity and direction in the Riyadh area
6. Evaporation rate in the Riyadh area
7. Topographical map of the Riyadh area
8. Available utilities and their unit prices
   1) Electric power
   2) Fuel
   3) Steam: Pressure ($kg/cm^2G$), Temperature (°C), Quantity (kg/h)
   4) Water (for cooling):
      Quantity ($m^3/h$), Temperature (°C), Quality
   5) Chemicals
      (1) Hydrazin
      (2) Coagulation aid
      (3) Biocide
      (4) $Na_2CO_3$
      (5) NaOH
      (6) NaCl
      (7) $H_2SO_4$
      (8) $Na_2SO_4$
9. Labor
   1) Cost per hour
   2) Cost per year
   3) Working day per year
10. Depreciation

    Formula used by MAW and WSA

13.1 (2) Annex to the Minutes dated October 8, 1980.

After the site survey following matters are confirmed:

1. Actual Schedule of the Japanese Delegation
2. List of Attendants
3. References obtained by the Japanese Delegation
4. General Conditions
5. Summary of Interim Report



Annex 1: Actual Schedule of the JAPANESE DELEGATION

| Date | Actural Schedule |
|---|---|
| Fri., Sept. 26 | Leave Japan |
| Sat., " 27 | Arrive in Riyadh |
| Sun., " 28 | Visit to Ministry of Agriculture and Water (MOAW) to explain scope of work, step of works, site survey and tentative report |
| Mon., " 29 | Visit to Water and Sewage Authority (WSA) to explain the same items as above |
| Tue., " 30 | Visit to Manfouha Sewage Treatment Plant<br>Visit to Manfouha Water Treatment Plant |
| Wed., Oct. 1 | Visit to Water Division, WSA<br>Visit to Malez Water Treatment Plant |
| Thu., " 2 | |
| Fri., " 3 | |
| Sat., " 4 | Visit to Haiyr Pretreatment Plant<br>Visit to Shemessy Water Treatment Plant<br>Visit to Water Division, WSA, to receive data |
| Sun., " 5 | Visit to Salbukh Water Treatment Plant |
| Mon., " 6 | Visit to MOAW to receive data and to discuss general conditions<br>Visit to Sewage Division, WSA, to receive data |
| Tue., " 7 | Visit to MOAW to receive additional data<br>Preparation of interim report |

Annex 2: List of Attendants

1. JAPANESE DELEGATION

| | |
|---|---|
| Masaru Ikai | Delegation Leader,<br>Water Re-Use Promotion Center |
| Masahiro Miyazaki | Industrial Water Division<br>Ministry of International Trade and Industry |
| Koh Tsuda | Water Re-Use Promotion Center |
| Gennosuke Inoue | Water Re-Use Promotion Center |

2. Japanese Observers

| | |
|---|---|
| Naotoshi Osada | Deputy Japanese Representative for the Secretariat to the Saudi-Japanese Joint Committee |
| Takashi Komori | Resident Representative<br>Riyadh Office<br>Japan International Cooperation Agency |

3. MOAW

| | |
|---|---|
| H.E. Abdulla Al Gholaikha | Deputy Minister for Water Affairs<br>MOAW |
| Mohamed Aquil Khan | Deputy Director General<br>Projects Execution Department<br>MOAW |
| Amer Hossein | Assistant Director General<br>Water Resources Development Department<br>MOAW |
| Omar Al-Sheikh | Civil Engineer<br>Projects Execution Department<br>MOAW |

Annex 3: References obtained by the JAPANESE DELEGATION

1. Water treatment facilities

1.1 Water treatment plants

(1) Quality of treated water

Month: August 1979

Plants: Malez, Shemessy and Manfouha

Items: pH, total hardness, total alkalinity

Range: Minimum, average and maximum

(2) Results of water analysis (average)

Month: August 1979

Plants: Malez, Shemessy and Manfouha

Items: Temperature
pH
Hardness (TTL Ca, Mg)
Alkalinity (TTL Phenolphtalein)
Chloride
Conductivity
$KMnO_6$ demand
Manganese
Aluminium
Free Chlorine
Dissolved oxygen

Checking point: Parsh Flume

Before filters*

After pumps

Note: * Items from Chloride to dissolved oxygen are not incicated.

(3) Capacity and expansion program (design capacity) in $m^3/h$

Malez: 1,200

Manfouha: No.1 -- 1,800 (plus 600 from Hayir)

No.2 -- 2,400

Shemessy: 3,600

Haiyr: 900

(4) Available utilities and their unit prices

Electric power: SR 0.07/KHW

Fuel (diesel oil): SR 0.055/liter

(5) Prices of chemicals

| | |
|---|---|
| Coagulant aid (polyelectrolite): | SR 21,000/ton |
| $Na_2CO_3$: | SR 1,030/ton |
| $H_2SO_4$: | SR 1,050/ton |

(6) Operator

Cost per year: SR 100,000 (approximate)

Working days per year: 365

(7) Depreciation

Depreciation or amortization is not applied

(8) Drawings

1) General layout of Malez Plant

2) General layout of Shemessy Plant

3) General layout of Manfouha Plant

1.2 Salbukh RO Plant (verbal information)

(1) Capacity ($m^3/d$)

Design: 60,000

Maximum: 65,000

Minimum 55,000

Average: 60,000

(2) Quality of permeate water

| Items | | Raw | Softened | Permeate | Brine Reject |
|---|---|---|---|---|---|
| TTL dissolved solids | mg/l | 1,300 | 1,300 | 75 | 10,000 - 12,000 |
| Chloride, $Cl^-$ | mg/l | 300 | 200 - 300 | 14-15 | 3,000 |
| Sulphate, $SO_4^{2-}$ | mg/l | 375 | 475 | 20 | 500 |
| Calcium $Ca^{2+}$ | mg/l | 450 | 70 | 40 | 600 |
| | meqv/l | 2.5 | | | |
| Magnesium, $Mg^{2+}$ | mg/l | 225 | 140 | 14 | 900 |
| | meqv/l | | | | |
| Silica | mg/l | 22-28 | 8 | trace | 80 |
| TTL hardness | mg/l | 14 | | | |
| | meqv/l | | 6.8 | (6.6)* | 5.5 |

*: read from meter

(3) TTL operating volume ($m^3/h$)

After cooling: 2,824

RO feed: 2,112

RO permeate 1,950

Brine reject: 195

## 2. Sewage Treatment

### 2.1 Manfouha Sewage Treatment Plant

(1) Capacity ($m^3/d$)

Design: 40,000

Maximum: 57,000

Minimum: 42,000

Average: 45,000

(2) Check items of effluent quality

BOD and SS

(3) Reduction ratio of BOD

80% (designed and operational record)

(4) Expansion program

80,000 $m^3/d$ in 1981

200,000 $m^3/d$ in 1983

(5) Quantity of influent

1) Monthly maximum, minimum and average

2) Daily maximum, minimum and average

3) Hourly change

(6) Quality of effluent

1) Effluent standard

None

2) TDS variation of effluent

2,000 to 3,000 mg/l

### 2.2 Sewage pipeline

(1) Drawings

(2) Profiles

1) Trunk line

2) Branch line connecting water treatment plant and trunk line

# Annex 4: General Conditions

## 1. Sewage

(1) TTL volume: 80,000 $m^3/d$ in 1981

200,000 $m^3/d$ in 1983

(2) Quality of influent and effluent

| Items | Influent | Effluent |
|---|---|---|
| TDS | 910 - 3,130 | 1,800 - 2,340 |
| BOD | 207 - 269 | 77 - 95 |
| SS | 333 - 460 | 82 - 117 |
| pH | 7.2 - 7.8 | 7.2 - 8.0 |

## 2. Re-Use

(1) Standard of effluent from sewage treatment plant:

None

(2) Object for re-use

1) Agriculture

2) Ground water increase by injection

3) Industry

## 3. Design basis of RO brine reject treatment method

(1) Quantity of RO brine reject ($m^3/d$)

1) Malez: 2,230

2) Manfouha: 6,800

3) Shemessy: 3,310

(2) Recovery ratio: 90%

(3) Salt rejection: 97%

4. Weather conditions

| Items | Data in Tentative Report | Present Data |
|---|---|---|
| Temperature | | |
| Minimum | $-4^{\circ}C$ | $-5.6^{\circ}C$ |
| Maximum | $52^{\circ}C$ | $47.7^{\circ}C$ |
| Relative Humidity | | |
| Winter | 100-16% | 100-6% |
| Summer | 51-5% | 68-2% |
| Highest Total Daily Rainfall | | |
| Maximum | 57 mm/d | 51.5 mm/d |
| Annual Reainfall | | |
| Minimum | 15 mm | 12.6 mm |
| Maximum | 230 mm | 176.6 mm |
| Wind Velocity | | |
| Maximum | 128 km/h | 32 km/h |
| Wettest Month | March - April | November - February |
| Driest Month | June - October | June - September |
| Evaporation rate | 3,000 mm/y | 2,890 mm/y |

Annex 5: Summary of Interim Report

1. Disposal method of RO brine reject

(1) Manfouha

1) Concentration by electrodialysis (ED) followed by evaporator/crystallizer

* Construction cost: 17 million US$
* Required area: 2,450 $m^2$

2) Concentration by ED followed by evaporation pond

* Construction cost: 10 million US$
* Required area: 188,000 $m^2$

(2) Shemessy

1) Concentration by ED followed by evaporator/crystallizer

* Construction cost: 11 million US$
* Required area: 1,200 $m^2$

2) Evaporation pond in the suburbs

* Construction cost: 8 million US$
* Required area: 150 $m^2$ (in plant site)
420,000 $m^2$ (present lagoon)

(3) Malez

Disposal into sewage pipeline

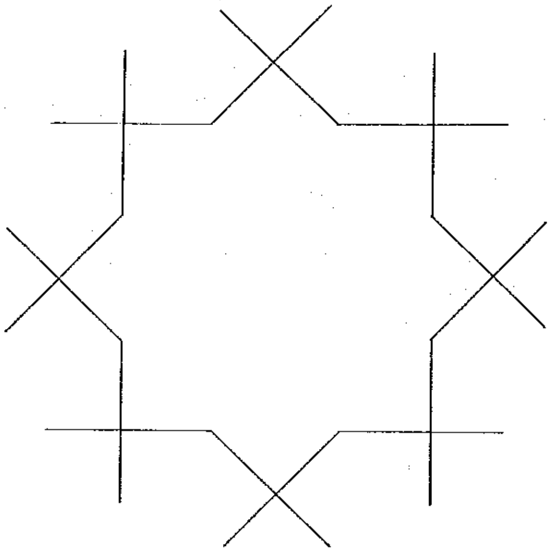
2. Schedule

| Method \ Year | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| ED plant in Manfouha | | (P) | | (C) | (O) | |
| ED plant in Shemessy | | (P) | | (C) | (O) | |
| Brine disposal from Malez | | | | | | |
| (Reference) Expansion of Sewage treatment plant | | | 80,000 | $m^3$/d | 200,000 | $m^3$/d |

(P)=Preparation; (C)=Construction; (O)=Operation

13.1 (3) Annex to the Minutes dated February 7, 1981.

1. Attendants to the Meetings



## ANNEX I

## Attendants to the Meetings

MOAW Side:

| | |
|---|---|
| H.E. Dr. Abdullah Al-Ghulaikah | Deputy Minister for Water Affairs MOAW (partly attended) |
| Mr. Mustafa Noori | Director General, Water Resources Development Dept. |
| Mr. Amer Husein | Assistant Director General, Water R. D. Dept. |
| Mr. M. Aquil Khan | Assistant Director General, Projects Execution Dept. |
| Mr. Mosa Robaian | Assistant Director General, Water Resources D. Dept. |
| Mr. Musfir Al Kalthan | W.R.D. Dept. |
| Mr. Ibrahim Saqabi | " " |
| Mr. Fahad Marshond | " " |
| Mr. Omar Al-Sheikh | Project Execution Dept. |
| Mr. Abdullah Sadhan | W.R.D. Dept. |

JICA Side:

| | |
|---|---|
| Mr. Masaru Ikai | Team Leader JICA Study Team |
| Mr. Hiroyuki Maki | Deputy Director Industrial Water Division Ministry of International Trade and Industry |
| Mr. Akira Nishimura | JICA Study Team |

(With attendance of - )

| | |
|---|---|
| Mr. Susumu Akiyama | Representative for the Secretariat to the Saudi-Japanese Joint Committee |
| Mr. Michio Hirano | 1st Secretary, Embassy of Japan/Jeddah |
| Mr. Naotoshi Osada | Deputy Representative for the secretariat to the Saudi-Japanese Joint Committee |
| Mr. Takeshi Komori | Resident Representative Japan International Cooperation Agency |