Chapter 17 Maintenance

Chapter 17 Maintenance

17-1 Objectives of the Study

This chapter discusses maintenance activities as measures for water pollution control. Specifically, the maintenance organizations and their roles, management, and specifications applied to maintenance activities are discussed, covering all maintenance organizations within the concerned oil sectors. The discussions are limited to facilities that can cause serious oil pollutions, specifically:

1. Oil well related facilities installed above ground, Christmas trees for example,
2. Pipelines (trunk lines and flow lines),
3. Crude oil tanks, wash tanks and fiscalization tanks,
4. Loading and unloading facilities,
5. Sea bed pipelines,
6. Waste water treating facilities,
7. Others.

The oil industry of Trinidad and Tobago has been in existence since the beginning of this century. Production of crude oil on a commercial scale started in 1907. Point Fortin Refinery was constructed in 1912 and Pointe-A-Pierre Refinery in 1916. TEXACO operated Pointe-A-Pierre Refinery from 1956 to 1985. Petrotrin learned much from TEXACO. Petrotrin's technical level in maintenance is high, with a long history. However, those facilities which have direct bearing on prevention and control of oil pollution, the API separators for example, have not been well maintained, cleaned of mud or foreign materials, as far as the study team was able to observe. This means that modifications and renewal of certain facilities are needed. In addition, education of the employees in preventing oil pollution is also essential. Petrotrin is attempting to perform better maintenance work at a level considered adequate in the present situation. Breakdown maintenance (BM) is mainly applied to the facilities discussed in this chapter. Scheduled replacement of facilities will, however, become necessary soon.

17-2 Outline of the Facilities

17-2-1 Production Fields, Tank Farm and Crude Oil Transportation

The oil fields in the study area are situated in and around the four river basins. There are about

1,200 production wells including those practicing Enhanced Oil Recovery (EOR). Seven tank farms are located in the study area, all treating non-thermal and/or thermal crude oils. None of the crude oils contains hydrogen sulfide at high contents except that of Brighton. These crude oils are about neutral in pH but viscous, and essentially not corrosive. Secondary recovery of crude oil, or EOR by steam injection, is extensively applied in this area. Injection of carbon dioxide is also applied in some areas. Sea water injection is not done.

The sizes of pipelines connecting the sites are given below. The major pipelines are underlined. The pipelines laid between wells and tank farms via gathering stations are called flow lines, and the pipelines connecting tank farms and Pointe-A-Pierre Refinery are called trunk lines.

- Production well - gathering station	2	3		
- Gathering Station - Tank farm	4	6	8	
- Tank Farm - P.A.P Refinery	8	10	12	16

The flow lines are laid on frames about 20 to 30 centimeters above ground and installed along roads. Some portions of these pipelines are bent to the ground by gravity. The pipes are buried at the road crossings. The pipes are painted for protection against corrosion by two layers of an anticorrosive paint and two layers of a cover paint (silver color or enamel). The thickness of painting is from six to eight mils, or from 150 to 200 microns. No other anti-corrosive measures but painting are applied. The pipe connections and fittings for pipes smaller than three inches -- couplings, bends, etc. -- are of screw type. The flow lines seem to have been very deteriorated over many years since installation, and because of the painting being not well maintained. In September 1993 during the first field survey, the study team noticed small ponds of oil at several locations along the road generated by leaks from flow lines, and many pipes smeared with pitch, the remnants of past leaks. The oil pollution report of Petrotrin also mentions frequent oil leaks from the flow lines. The flow lines are taken care of by breakdown maintenance. The operators periodically patrol along the lines to check leaks so that maintenance can be done promptly.

Several leaks from the stuffing boxes of well equipment are also reported. Rotating equipment is checked once a day by a patrol squad.

The crude oil tanks, wash tanks and fiscalization tanks in the tank farms are, like crude oil tanks in the refinery, objects of the preventive maintenance; the following periodic maintenance is performed. There are no serious problems with the tanks installed at the tank farms from the viewpoint of maintenance.

- The wash tanks are opened once a year for cleaning and inspection.
- The fiscalization tanks are opened for cleaning and inspection when three feet of sludge accumulates on the bottom.

Both API separators and open pits are used for treating waste water at tank farms. In the very small tank farms, only open pits are used. These facilities can recover surface oil only, and cannot recover oil contained in water in the form of tough emulsions, with the diameter of oil particles ranging from less than one micron to 10 microns. Although their effects are limited to removing the visible surface oil, they should be cleaned more often to remove accumulated oily sludges and sticky materials. When it rains, rain water enters the waste water treating facilities and overloads them. As a result, the separators are inundated and the accumulated surface oil overflows and pollutes the environment.

About 90 percent of the trunk lines are laid underground. The outer surfaces of the underground portion are protected by asphalt coating and electrical corrosion prevention. The trunk lines are checked for leakage once a week by a team of two persons patrolling along the lines. They also look for oil oozing from the ground. Accurate flow measurement is important for detecting leaks. The volume of fluid transported is measured by gauging the concerned tanks in tank farms with a measuring tape and by flow meters at the refinery. GIS (Geographical Information System) is applied to monitoring leakages from the trunk lines. The maximum operation pressure of the trunk lines is 390 psig, at which pressure relief valves are set. The materials of trunk lines and flow lines are either API 5L-A or B. The selection between A and B is based on the pressure and corrosion rate. About 90 percent of corrosion on the trunk lines and flow lines occurs on the outer surfaces, or on the soil side, of the pipes. The type of corrosion is mainly pittings, which occur at places where there are cracks in the anti-corrosion coating or where stray current flows. API standard-type semi-sleeve or full-sleeve plates are welded to repair the leaks. Hot tapping, a technique applicable to pipes in use, is also practiced.

17-2-2 Pointe-a-Pierre Refinery

For the maintenance of processing units in the refinery, standard maintenance practice, traditional and widely adopted by major European and American oil companies, is applied. The maintenance history data are accumulated. The following are their practices.

Epoxy-coating is applied to the crude oil and slop oil tanks on the bottom plates and on the lower parts of side walls up to eight feet high. Cathodic protection is also applied to the outside of the bottom plates. Safety inspection is done according to the in-house standard (IRP-T-01), which specifies different inspection intervals depending upon the types and uses of tanks. Table 17-1 shows the intervals of inspection of the tanks.

Thickness is measured at intervals of five years on the side walls and bottom plates, when the tank is opened for full inspection. Magnetic particle inspection is also performed on the occasion of periodical overhaul inspections.

Table 17-1 Intervals of Inspections of Tanks at Pointe-a-Pierre Refinery

Tank Type-Product		Visual	Ultrasonic Internal	Full (Level Survey)	Foundation
Fixed Roof or Open Top tanks					
(1)	Lube oil, Fuel oil, Gas oil, Diesel, Air foam, Soda	1 year	8 years	15 years	-
(2)	Slops (internally coated)	1 year	2 years	5 years	-
(3)	Slops (not internally coated)	1 year	1 year	2 years	-
(4)	Crude, light prod., fresh wat.	1 year	5 year	10 years	-
Floating Roof Tanks					
(5)	All products	1 year	3 years	10 years (including measurement of pontoon bottom)	5 years

The pipelines for imported crude oil are laid on the sea bed. There are new as well as old lines. Cathodic protection is applied to the new lines. Recently, the refinery started to apply cathodic protection to the old lines installed when TEXACO was operating the refinery. Leaks are frequently reported, and repaired by underwater welding. Inspection using an intelligent pig is performed for important pipes. Since old pipings use bends of short radii, it is difficult to pass pigs through them. New lines are designed to fit for inspections by intelligent pigs. Measurement of thickness is practiced once every three years for the above-ground lines in the refinery. The thickness of the lines having high corrosion rates is measured by X-rays before turnaround shutdown. The Process Section is in charge of corrosion inhibitor management, including selection of the inhibitors to be used and the points of injection. However, the refinery understands that the basis of corrosion management is the selection of materials used.

There is no authorized general procedure for preventive maintenance in the refinery. Preventive maintenance is done on the following units and facilities.

- Main equipment of processing units such as heaters, towers and vessels, heat exchangers, pumps, compressors, turbines, etc.,
- Electrical equipment such as control centers, power switches, main cables, etc.,
- Steam turbines, power plants,
- Tanks,
- Vibration analysis of main rotating machines.

The waste water treating system of the refinery is categorized as follows:

1. API separator → Guard basin → Rivers → Oil catches → Oil booms → Sea (for processing areas and part of tank areas),
2. Oil sump → Oil catches → Sea (for tank areas).

The refinery has four API separators. The maximum water content of crude oil received by the refinery is two percent. The water containing the tough emulsion is drained, mostly at the upstream tank farms. The water bled from the crude oil tanks is not so much the problem as is the case with the tank farms. Storm water flows into the API separators due to the structure of the separators. If it rains very hard, the separators could be inundated and the surface oil could be washed out of the refinery. Oily sludges are dumped to open pits in the refinery premises. This practice also causes oil pollution after heavy rainfall. The waste water ditches are polluted with oil. The guard basins, oil catches and oil booms are unable to prevent such oil from being washed out. These are typical of oil pollution in the refinery.

17-3 Current Maintenance System

17-3-1 Organization and Roles

The main responsibility for maintenance within Petrotrin is the Engineering Department and

Maintenance Department; they have their independent functions and roles. The maintenance organization chart is shown in Figure 17-1.

(1) Engineering Department

1) Inspection Section

This section belongs to the Technical Service Department, which is in charge of both new projects and existing facilities, and is independent of the Maintenance Department. They are responsible for:

- Static equipment such as tanks, pipelines, towers, vessels, heat exchangers, heaters,
- Management of standards, accumulation of inspection data and historical analysis,
- Recommendations for the maintenance of static equipment,
- Promoting preventive maintenance activities.

2) Reliability Engineering Section

This section belongs to the Maintenance Department, and is responsible for inspection, maintenance and repair work on rotating equipment, including such large machines as LNG-driven engine compressors, electrical equipment, measuring and controlling instruments. This section is also responsible for lubrication management. They analyze causes of failures and prepare recommendations on maintenance and repair work on rotating equipment and electric motors. For electrical equipment and instrumentation, they analyze the causes of malfunctions, accumulate performance records, analyze the historical data and prepare recommendations for proper maintenance. For lubrication management, they analyze lubricating oils, determine replacement intervals, select the right lubricants and prepare recommendations on the right use of lubricants. They also train the personnel of the Maintenance Section and the Operation Section. They manage the standards for the equipment they are in charge of, and promote preventive maintenance activities.

3) Design Engineering Section

This section is in charge of maintenance and construction of new facilities. It has area engineers, mechanical engineers and craftsmen.

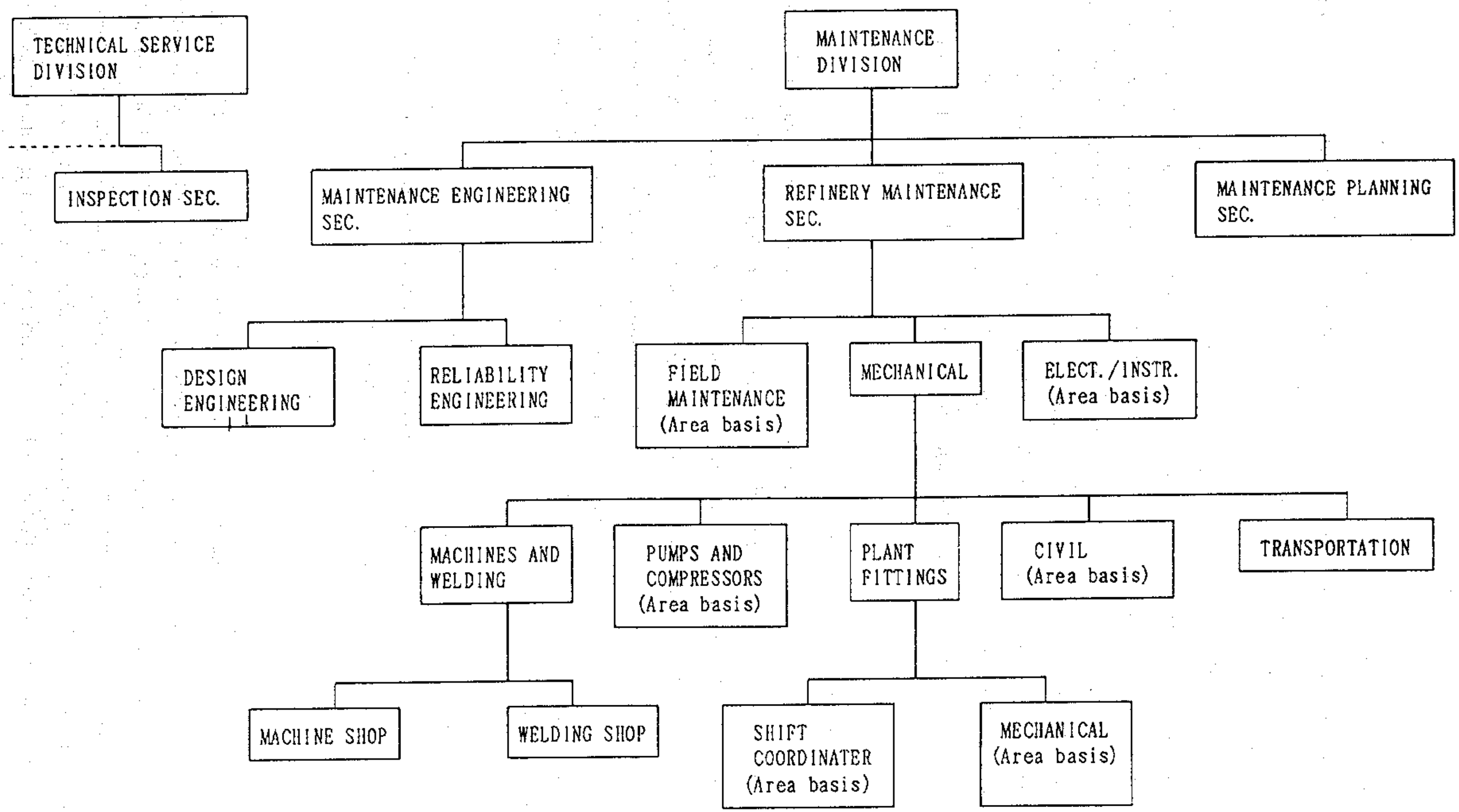

Figure 17-1 Organization concerning Maintenance of Petrotrin

(2) Maintenance Department

This department consists of three sections, the Field Maintenance Section, the Refinery Maintenance Section and the Maintenance Planning Section.

1) Field Maintenance Section

This section is responsible for maintenance of the field equipment at wells, tank farms and transportation facilities. Maintenance engineers are stationed at key locations in the fields, and monitor the condition of equipment, and take necessary measures in cooperation with the refinery engineers of the Machinery, Electrical and Instrumentation Sections. They prepare an annual maintenance schedule, and decide on methods for solving problems. This section conducts tests and inspections, but it does not have enough manpower for actual repair work. Other sections such as Machinery, Electrical and Instrumentation Sections conduct repair work, assisting this section.

2) Refinery Maintenance Section

This section has two sub-sections; one is responsible for maintenance on machinery, and the other for electric equipment and instrumentation. The machinery functions are classified into five technical groups; i.e., machinery and welding, pumps and compressors, plant fittings, civil works, and transportation. The machinery and welding group has factories for machinery and welding work in the refinery. The members of the pumps/compressors and plant fitting groups are stationed at key locations in the refinery. A portion of the refinery maintenance operation is carried out in a shift rotation. Each shift consists of four members: shift coordinator, machinery, electrical and inspection specialists.

3) Maintenance Planning Section

This section is responsible for developing annual maintenance schedules and contract work as well as budget and cost controls for the maintenance activities.

17-3-2 Standards, Codes and Laws

Petrotrin conducts its maintenance work in conformity with the API codes, GEMS (in-house standards), TECS (Trintoc Engineering and Construction Specification) and IRP (Inspection Recommended Practice). There are local regulations on boilers, vessels and instrumentation based on the Labor Laws, while there are no official regulations concerning tanks and pipeline. TECS is usually applied to the standards related to constructions. GEMS, TEXACO's standard, is applied to the piping designs. IRP is used as the guideline for the inspection of tanks and pipings.

17-3-3 Preventive Maintenance

The Inspection Section is responsible for the preventive maintenance of static equipment, while the Reliability Section is in charge of rotating equipment, electrical equipment and meters and instruments. Preventive maintenance is performed on the following equipment:

- Static equipment in process units such as heaters, towers and vessels, heat exchangers, etc.,
- Rotating equipments such as pumps, compressors and turbines,
- Electrical and instrumentation equipment,
- Tanks,
- Major trunk lines and offshore crude oil lines.

Only breakdown maintenance is applied to other equipment. Most pipelines and valves, which can cause oil pollution when they break down, fall into this category. However, preventive maintenance is performed on tanks, major trunk lines and offshore crude oil lines as listed above. Inspection data and maintenance history are recorded, and preventive maintenance is done based on these data.

17-3-4 Corrosion Management

The Inspection Section combats corrosion problems. It has two groups, one for the refinery and the other for the fields. Crude oil is not corrosive, as is indicated by the low hydrogen sulfide and sulfur contents and neutral pH values. The operating conditions of the facilities in the scope of this study are relatively mild since the subject facilities are used in the ambient temperatures and at low pressures (max. 390 psig). However, crude oil produced by CO_2 injection shows some corrosiveness. There is no significant difference in corrosion of the flow lines between primary crude and thermal crude. Therefore, prevention of corrosion on the outer surfaces -- soil side, sea water side or atmospheric air side -- is more important. Corrosion is mostly pittings. The tendency of corrosion is checked by corrosion coupons.

17-3-5 Oil Leakage Monitoring System

Operators conduct periodic visual checks on the lines and equipment in the fields and refinery for possible leaks by patrolling along the lines. When a leak is found, it is reported to the Maintenance Section, then remedial repairing work starts. An automatic monitoring system has not been introduced. Leakage from the underground portion of trunk lines is detected by checking oil oozing from the ground. GIS is also applied to discovering leakage from the transport lines. According to the oil leakage report issued by Petrotrin, periodic patrols are carried out very frequently.

17-4 Plan for Improvement

17-4-1 Maintenance of Waste Water Treatment Facilities

The basic conditions for maintaining waste water treating facilities are not always fulfilled. The following are the basic requirements for keeping them in good condition.

- Periodic cleaning of the facilities to prevent accumulation of and clogging by sludge thorough checks on operating conditions. Scales deposited on the baffle plates and weirs should be removed in scheduled maintenance work.
- Prevention of overloading of the facilities. Operating conditions should be checked and the facilities should be operated to maintain normal conditions according to the operation manuals.
- Continuously removing surface oil and floating debris from the treating facilities.
- Daily maintenance such as cleaning, checks and minor repairs.
- Correct operation and prevention of human errors.
- Finding malfunctions and preventing their recurrence.

Above are the basic requirements for proper operation. Training and education of operators are also very important. The most important of all is complete separation of process water from rain water. The waste water treating system will not work properly and the problems cannot be solved without this. A large quantity of rain water generated in a short time in a heavy rain is the biggest problem in preventing oil pollution. A plan to improve operation is such conditions is needed. It is considered adequate to apply breakdown maintenance to the waste water treating facilities. However, a back-up system such as cushion tanks will be required to prevent emergency plant shut-down. Since corroded and weakened metal parts are observed, expanded-metal of the walkways for example, corrosion prevention painting must be applied as a daily maintenance activity.

17-4-2 Prevention of Pipeline Corrosion

The corrosion on the flow lines and trunk lines and the methods for preventing it are discussed here.

Flow lines and trunk lines are used for crude oil transportation. The crude oil is not corrosive, because it contains virtually no hydrogen sulfide. However, attention should be paid to the water contained in the crude oil.

Although there is no significant problem in the straight portions of the lines since the water moves downstream with oil and does not stagnate, corrosion could occur in drain nozzles installed at the lower side of the pipes or in straight parts where water can accumulate for structural reasons.

As for the outside of the lines, corrosion by soil can occur at places where pipes are in contact with the soil or buried. The type of corrosion caused by soil varies with soil conditions such as resistivity, pH, air permeability, existence of interfaces among several different types of soil, conditions of sleeve insulation at the point where the pipe traverses a concrete wall, etc.; the commonest type is pitting. The rate of general corrosion of the buried portion is low while the rate of partial pitting corrosion is high. Table 17-2 shows cases of bare steel corrosion that have occurred underground.

The life of a pipe ends when a pitting hole penetrates the pipe wall. This table shows that the maximum pitting rate B ranges from several times to tens of times the rate of general corrosion A; therefore, it is obvious that the problem of corrosion prevention of flow lines and trunk lines is a problem of countermeasures against pitting. In addition, one must recognize that local corrosion occurs in places where air permeability and water drainage are not adequate, where soils of different character contact, where pipes penetrate concrete walls and where stray current exists. Petrotrin applies asphalt coating together with electrical protection to prevent outside corrosion of underground pipes. Painting is applied to prevent corrosion of above-ground pipes.

The flow lines and trunk lines of Petrotrin are old. Adequate measures to extend the lives of pipes and scheduled replacement of the old pipes are required. Periodic thickness measurements must be done on important pipes (trunk lines and some flow lines). Old lines, of which the normal life time has passed, must be replaced according to a replacement plan. However, considering the cost of replacement, measures to extend pipe life should be applied to most flow lines. Inside lining is recommended for these pipes.

Table 17-2 Corrosion Rate of Bare Steel. Materials in Soil in USA

Sort of Soil	Resistivity [ohm · cm]	Ventilation	pH	General corrosion rate A [mm/Y]	Max pitting rate B [mm/Y]	B/A
Cecil loamy clay	17,800	good	4.8	0.016	0.62	39
Hangerstown loam	5,210	good	5.8	0.019	0.26	13.7
Susquehana clay	6,920	fair	4.5	0.028	0.16	5.7
Chino silty loam	148	good	8.0	0.029	0.20	6.9
Mohave loam	232	fair	8.0	0.085	1.75	21.0
Acadia clay	190	not good	6.2	0.031	0.13	4.2
Docus clay	62	fair	7.5	0.070	0.24	3.4
Lake Charles clay	406	not good	7.1	0.114	0.75	6.6
Merced silty clay	278	fair	9.4	0.163	0.66	4.1
Carlisle black peat	1,660	bad	5.6	0.045	0.18	4.0
Rifle peat	218	not good	2.6	0.072	0.25	3.5
Tidal marsh	84	bad	6.9	0.086	0.23	2.7
Black peat	712	not good	4.8	0.057	0.25	4.4
Shekey clay	943	not good	6.8	0.100	0.36	3.6
Cinders	455	bad	7.6	0.37	1.75	4.7

This can be applied in the field. Inside lining is recommended against outside corrosion, because this method is easy to apply on site to existing underground pipes.

Since pitting corrosion does not affect pipe strength, the steel pipe itself is regarded as the supporting member and the lining as the sealing member. The pipe becomes a composite pipe and the life is extended. The operation pressures of the pipes are low, an advantage in the present case. Two lining materials, resin and cement, are applicable. The thickness of lining layer is more than one millimeter in the case of FRP resin lining, and more than five millimeters in the case of cement lining.

(1) Resin Lining

Epoxy resin is well known as material for resin lining, but polyester resin is also used. This study recommends vinyl-ester resin which has superior thermal resistance, acid resistance, caustic resistance and abrasion resistance; therefore, it is better as an all-purpose resin than epoxy resin for this use. Table 17-3 compares several lining materials.

Glass flakes blended in the resin reportedly reinforce the merits of the resin. Glass flakes two to three microns thick and about 150 microns wide make the resin layer far more impermeable to corrosive materials, when the flakes are 25 to 35 percent on the mixture, and if about 100 flakes are arranged in parallel in a layer of resin one millimeter thick. In addition to the above barrier effect, reduction of expansion coefficient and hardening shrinkage coefficient would improve adherence ability and reduce crackability, thereby preventing peeling of the resin. For complete prevention of pinholes, the layer needs to be sufficiently thick and the lining must be done repeatedly.

On the basis of comparison of depths of pin-holes with several different thicknesses of linings, it is reported that the average thickness should be more than 450 microns, and preferably more than one millimeter. The welded parts and flange portions of the existing lines can be lined simultaneously with the pipe itself; it is therefore economical and efficient to apply.

Table 17-3 General Properties of Typical Resins Used as Lining Material

Properties	Kind of resin	Ortho-phthalic type	Iso phthalic type	Bisphenolic type	Vinyl ester type	Epoxy-type amine cured	Neoprene rubber	Teflon	Stainless steel
Physical properties	Elongation (%) (Flexibility)	2.0	2.0	2.0	3~5.0	10.0 or below	300 or below	100	—
	Heat distortion temperature (°C) (heat resistance)	95	115	125	110	100	40 or less	300	200 or more
Chemical resistance	Resistance to inorganic acid	△	○	○	◎	△	△	◎	◎
	Caustic resistance	××	×~△	○	◎	◎	△~○	◎	◎
	Resistance to organic acid	××	△~×	○	◎	×	×~△	◎	○
	Resistance to solvents	×	△~×	△	○	○	×	◎	◎
	Linear expansion coefficient 10^{-5}/°C				2.2*	4.0			1.6
	Rate of shrinkage from mould dimensions %				0.1~0.2*	1.4			

* When filler such as glass flakes, etc. is added.
(Note) ◎ : Good; ○ : Fair; △ : Acceptable; × : Unacceptable; ×× : Prohibited

(2) Cement Mortar Lining

Corrosion prevention by cement mortar lining consists in keeping the pH on the steel surface at 12 to 13 and keeping the steel in a passive state. The inside surface of the steel pipe is kept in an alkaline environment created by an alkaline component leached from the cement. Based on this mechanism, corrosion prevention ability is not weakened even if there are pinholes in the lining layer. However, there is an allowable limit in the gap between the inside surface of pipe and lining layer, reportedly up to 1.6 to 2.5 millimeters. Corrosion will occur when the gap exceeds these values. In general, the lining layer thickness is over five millimeters. The adherence ability of the lining depends mainly on the arch action of the cement layer caused by the cubic expansion of cement when it solidifies. Therefore, the lining layer does not easily tear off even if haircracks are generated. To improve the quality of mortar, several kinds of polymers are sometimes mixed. A method for full lining of a pipe including bends at one time has been developed and applied. The method is the same as that used for resin lining; a pig lining method using special pigs -- bullet type, cup type, ball type or their combination -- is practiced for this purpose.

(3) Pig Lining Method

The inside pipe surface must be cleaned to be ready for lining by acid cleaning, cleaning pigs, sand blasting, or chemical cleaning. Then resin or cement is applied by a pig of suitable size and shape.

Generally, lining is done by forcing two pigs through the pipe by air pressure. Between these two pigs, resin or cement is filled. There are advantages to this method in that a long line with vertical and bending parts can be lined at one time, and in that the unit cost of this method is low when applied to a large diameter pipe, from 20 to 30 inches, and over a long distance, more than several hundred meters. The drawback is that the pipeline must be divided according to size and branches, and different sections lined separately. A remarkable feature of this lining method is that a thick layer of resin or cement, ranging from one to four millimeters, can be applied. A lining of such a thickness can act as a plate rather than a film.

There are advantages to this method compared with film lining. The surface need not be prepared very smooth. The thickness of painted film is about several hundred microns at most; the film sometimes comes off or swells if the surface has not been prepared smooth before application, which is very difficult in the case of existing long pipelines.

Pig lining is very quick since a thick layer is formed by one lining operation. Three lining operations can form a layer of enough thickness either with resin or cement.

Since the completed lining is like a plate, it does not come off or flow out like a film. Even if the lining layer detaches from the pipe wall, it can still hold the shape of the pipe, thereby protecting the pipe.

1. Specifications of lining (resin, cement mortar)

   (1) Materials

   Primers:

   Epoxy urethane, cement mortar or polymer mortar

   Main materials:

   Vinyl ester resin with glass flakes, cement mortar or polymer mortar

   (2) Lining thickness

   Primer: 25 microns to one millimeter

   Main material: one to four millimeters

   Lining layers: one of primer and two of the main material

2. Cleaning method

   Forcing cleaning pigs through the pipe by water and/or air

3. Procedure: Refer to Figure 17-2.

4. Modification of branch pipes or nozzles: Refer to Figures 17-3 (1) to (3).

5. Work model: Refer to Figures 17-4 (1) to (7)

6. Applicability: from two to 30 inches

   Pipe size: from two to 30 inches

   Length: The longer the pipe, the more economical this method is. Usually it is applied to pipes longer than 500 meters long.

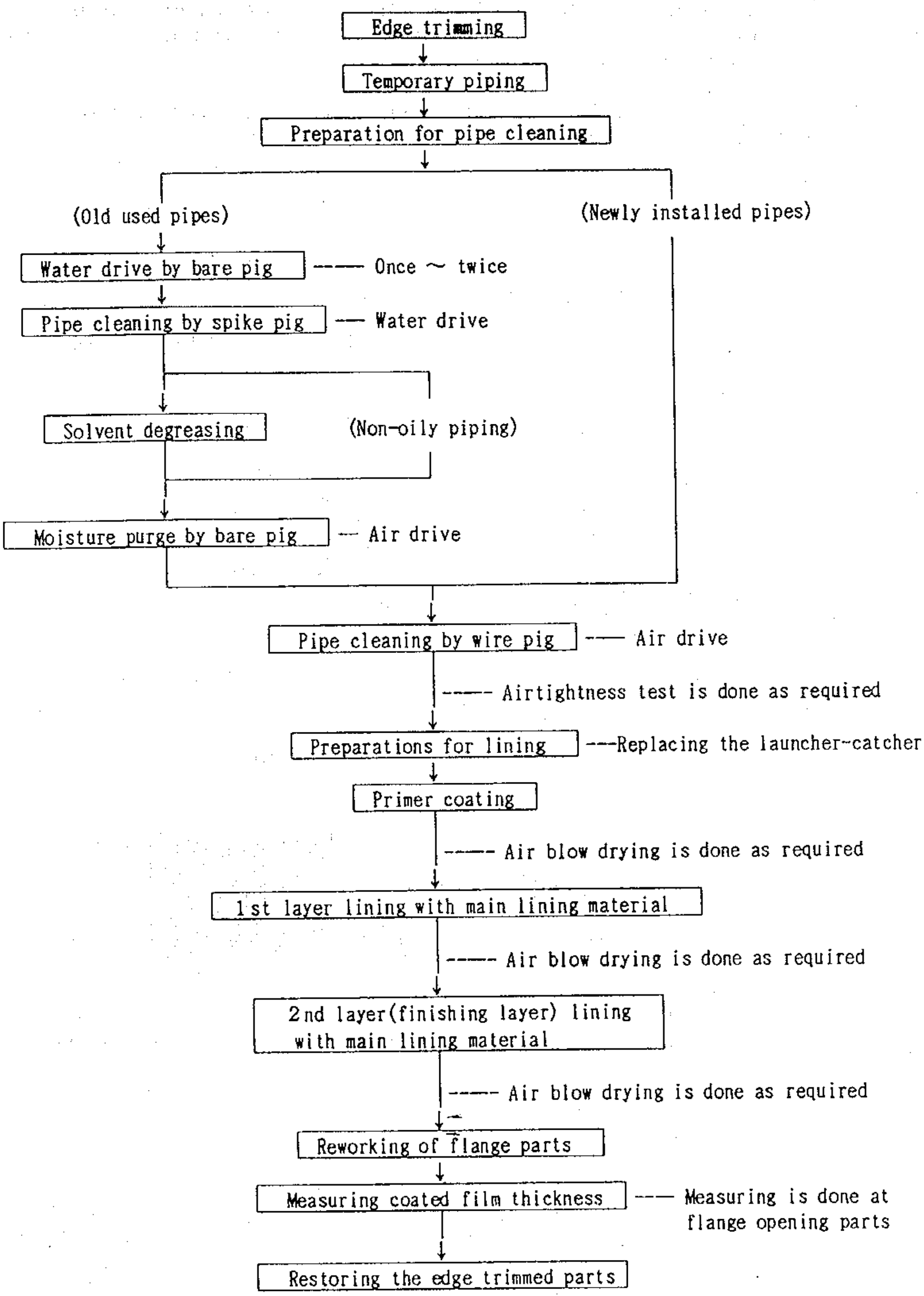

Figure 17-2 Lining Procedure

Modification of branch pipe:

(1) Edge trimming is done at both ends of the pipes to be lined, and a launcher and a catcher part are attached. (Temporary piping should be provided when needed)

(2) A flange is attached to the branching portion, then removed and special core is inserted therein.

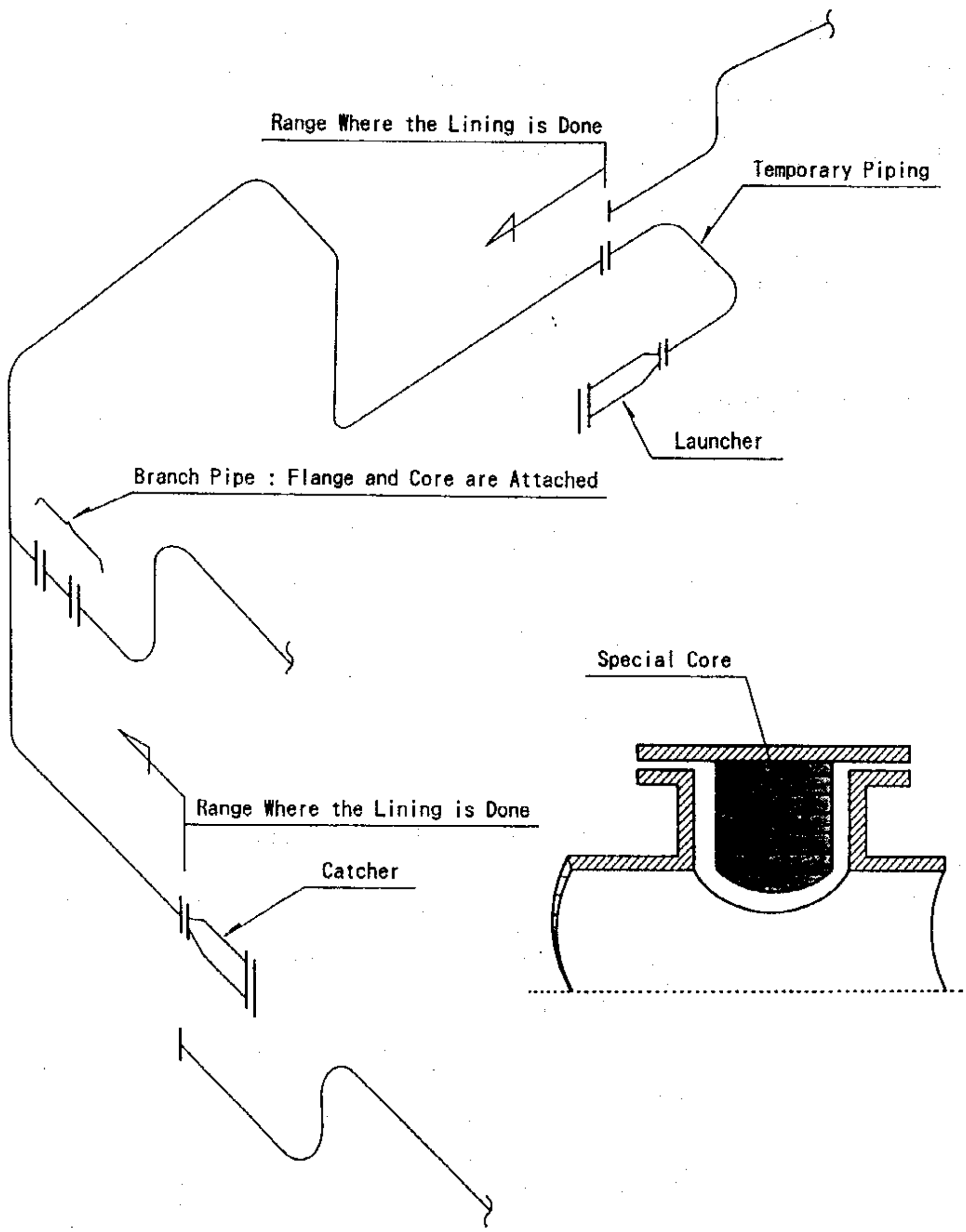

Figure 17-3 (1) Modification for Branch Pipe

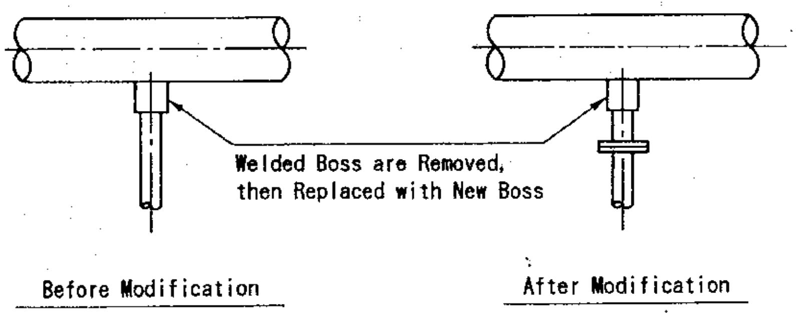

Figure 17-3 (2) Modification of Small Diameter Nozzles

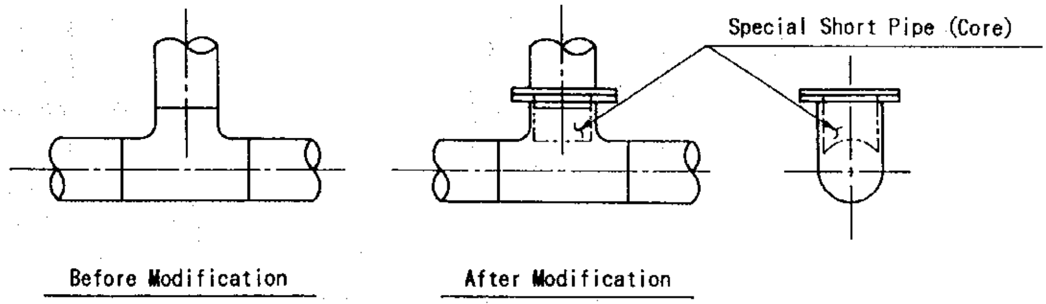

Figure 17-3 (3) Protective Measure for Branch Pipe

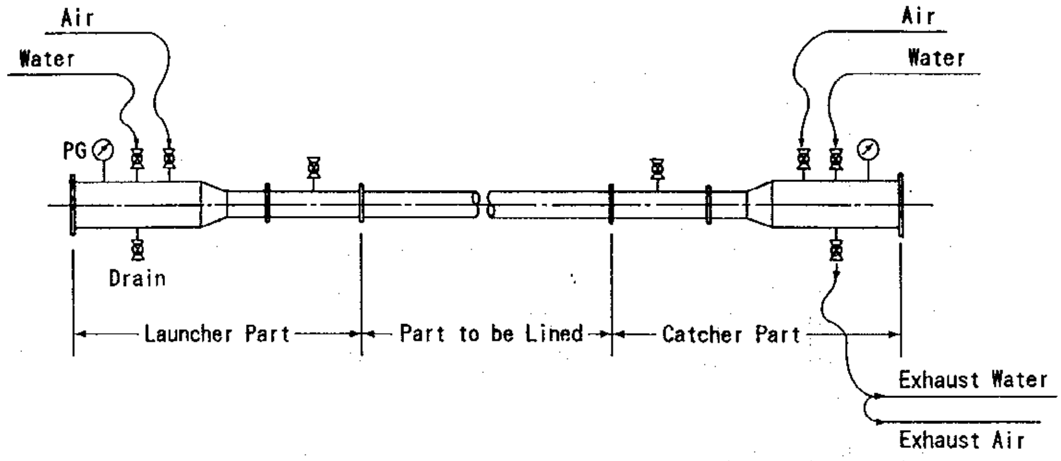

Figure 17-4 (1) Basic Scheme for Cleaning

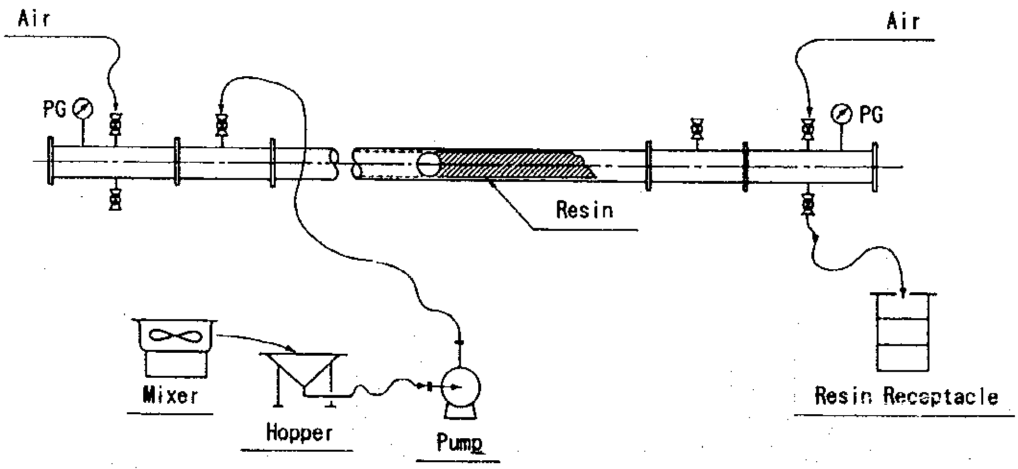

Figure 17-4 (2) Basic Scheme for Lining

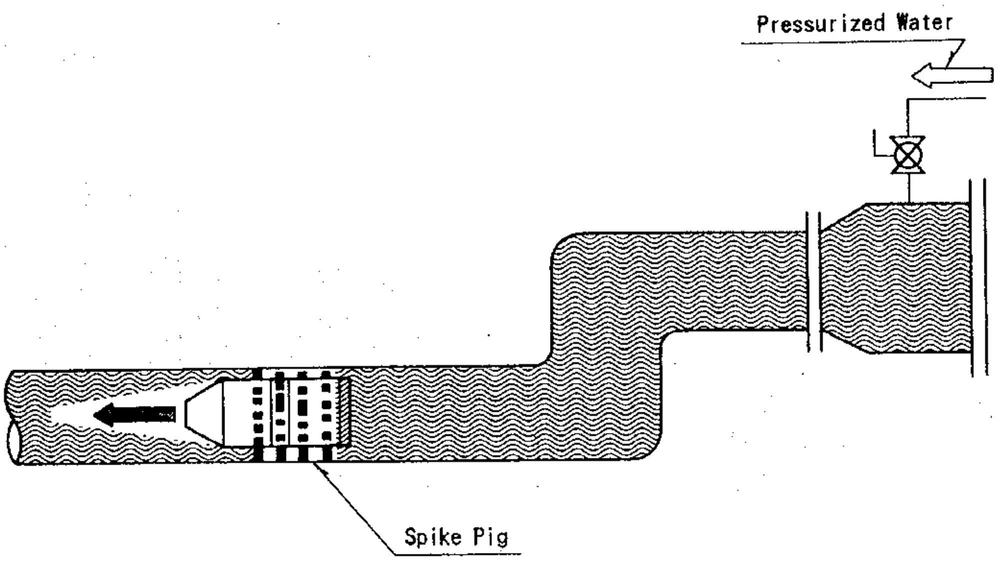

Figure 17-4 (3) Washing with Spike Pig and Water

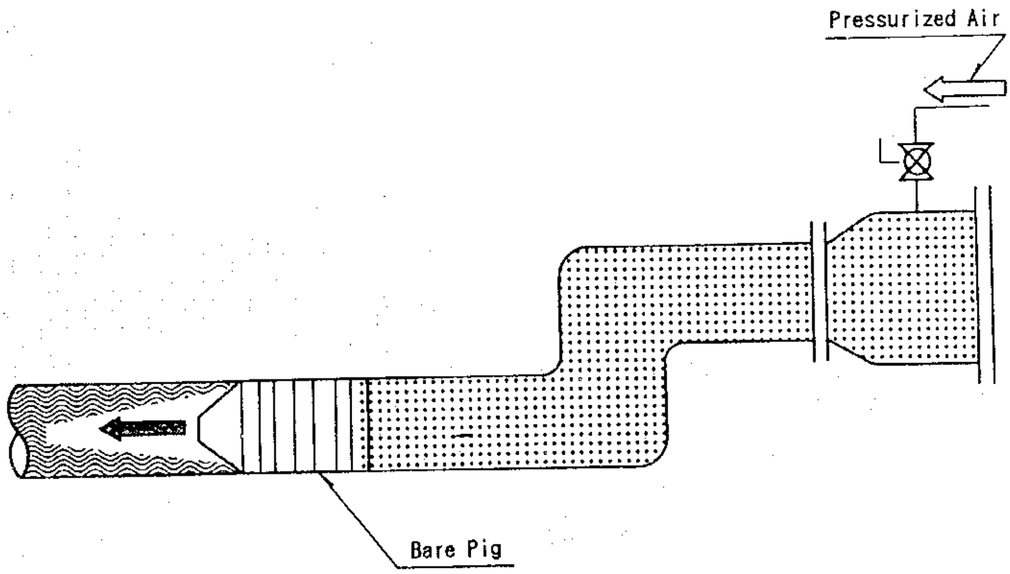

Figure 17-4 (4) Internal Drying of Pipe

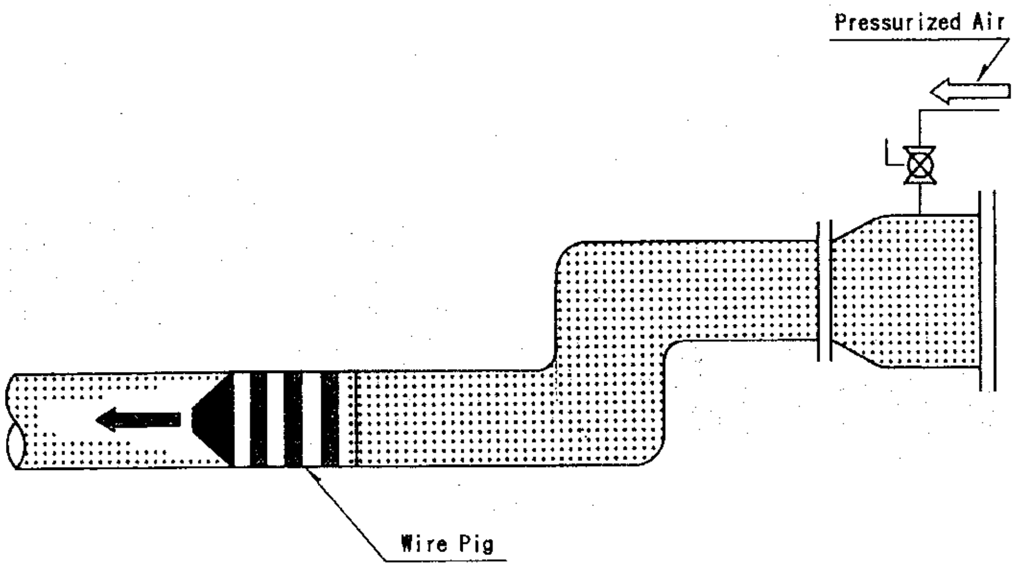

Figure 17-4 (5) Surface Preparation by Wire Pig

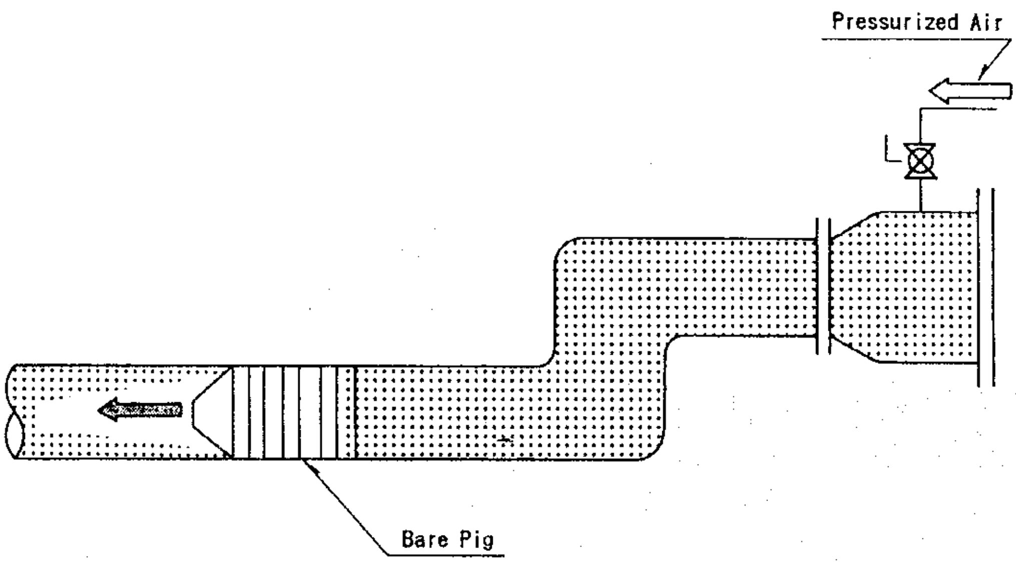

Figure 17-4 (6) Cleaning by Bare Pig

Lining procedure:

(1) Remove pig launcher and catcher
(2) Pig coating with primer
(3) Pig coating with resin

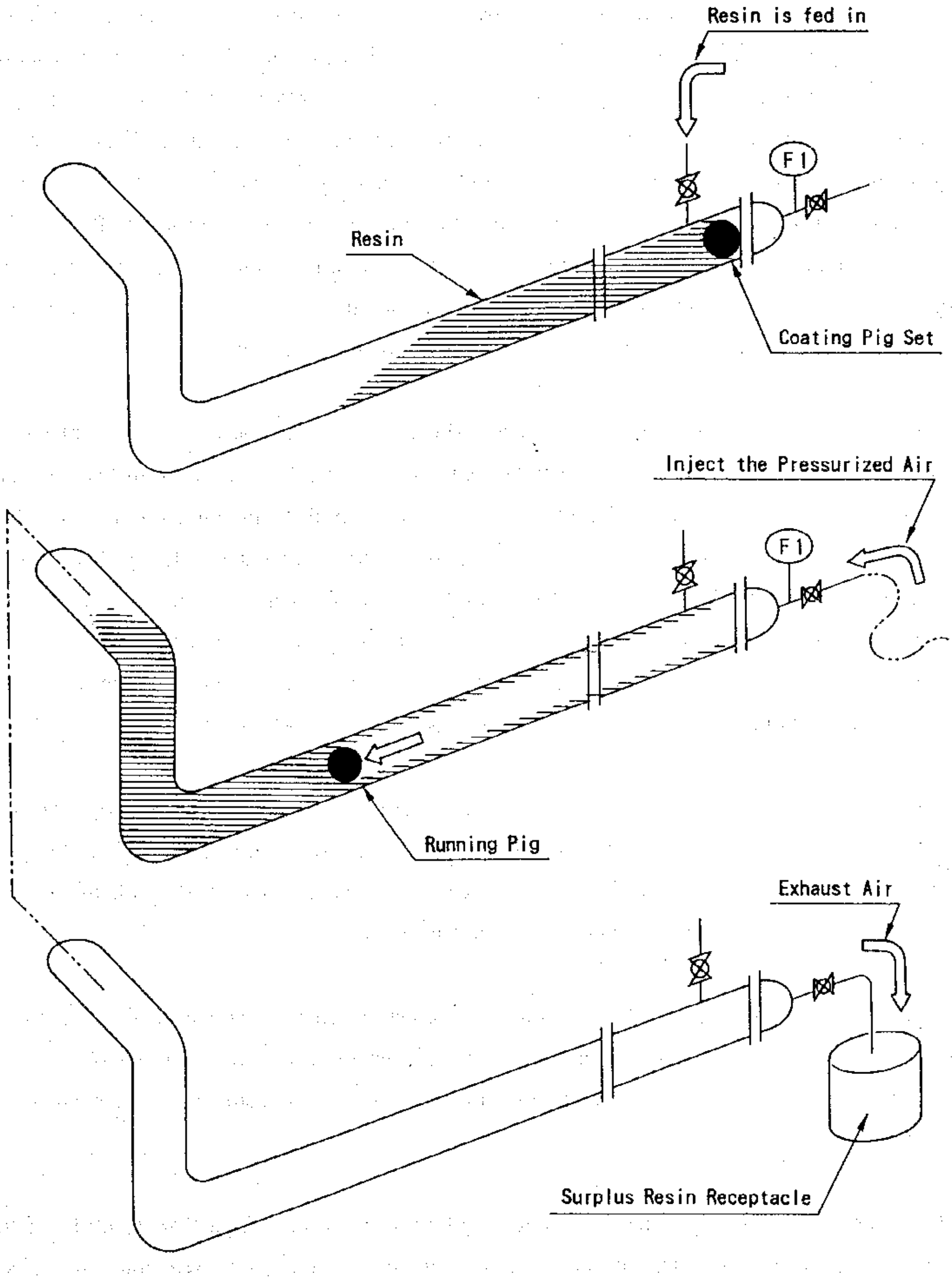

Figure 17-4 (7) Lining with Coating Pig

17-4-3 Maintenance of Storage Tanks

A large quantity of oil is stored in the tanks in the study area. If an adequate measure is not taken in the case of accidental leakage, there is a possibility of serious oil pollution. In general, tanks are guarded by oil retaining dikes. However, a number of cases of accidental oil pollution have been reported throughout the world, where leaking oil flowed into the sea and caused serious oil pollution. In Japan, a major accidental oil pollution occurred in 1974. It was caused by leakage of a large quantity of fuel oil from a tank in a refinery located at the Seto Inland Sea Industrial Complex. This is an example of serious accidental oil pollution. After this accident, the government of Japan and private enterprises made a joint effort to develop and accumulate new technologies for the prevention of accidental oil pollution and to establish necessary organizations as well as laws and regulations relating to such accidents. As a result of these efforts, maintenance and inspection technology have improved remarkably.

The majority of tank damage and leakage occurs along welding lines between annular plates and bottom plates, and on floating roofs. The bottom plates are most important from the viewpoint of maintenance. Troubles on the bottom plates are caused by deformation and distortion which in turn are caused by uneven settlement of tank bases, or by residual welding stress, and/or corrosion. Uneven settlement of tank bases results mainly from poor initial foundation work. Secular distortion also causes uneven settlement. Correction work is required when the degree of uneven settlement becomes intolerable. There are two types of corrosion which may occur on the bottom plates: outside corrosion (soil side) and inside corrosion (liquid side).

Outside corrosion is caused mainly by corrosive materials contained in the underground soil. For the prevention of inside corrosion, BS&W and salt content of the oil should be kept low. In recent years, paints prepared specifically for preventing corrosion on the inside walls of tanks are generally applied, and their effectiveness has been confirmed.

The main causes of trouble on floating roofs are excessive stresses exerted on them when the roofs move, caused by the change of circularity, or deformation of the tank shells by uneven base settlement, frequent and unnecessary landings of the roofs, and inadequate arrangement of the deck supports.

In Japan, periodic tank inspections are mandatory by law. For tanks larger than 1,000 kiloliters, periodic safety inspections after full cleaning are obligatory at five to 10 year intervals. As a result, historical inspection data are being accumulated. Most Japanese tanks are 20 to 30 years old. According to a statistical analysis, the main troubles are corrosion damage on the welding lines connecting the annular plates with the bottom plates and defects in welding work. Damage has been found on 80 percent of the tanks inspected. Based on the knowledge obtained from experience in Japan, the following measures are recommended in order to prevent tank leakage trouble.

1. Measures to prevent rain water permeation into the ring edge of annular plates or bottom plates,

2. Periodic full inspections by opening the tanks, to inspect faults on the welding lines connecting the annular plates and the bottom plates caused by corrosion, and to inspect cracks and faults in welding lines,

3. Modification of drain nozzles to siphon type and burying of drain pits,

4. Detailed inspection of corrosion faults in bottom plates of tanks equipped with heating coils,

5. Periodic measurement of uneven base settlement.

(1) Measures for the Prevention of Rain Water Permeation

Corrosion can occur on the back side of the welding line between annular plates and bottom plates of tanks by permeation of rain water. Especially, that portion of the plates which is welded to the tank shell is vulnerable and therefore is an important subject of tank safety management, since a very high bending stress is exerted on them. Such elastic materials as asphalt, gums, resins, etc. that have good flexibility are recommended for sealing the rings around the connections between the annular plates and the bottom plates, to prevent incursion by rain water. The ring is subjected to repeated expansion and shrinkage caused by the change in liquid pressure and temperature. It is also reported that the ring shrinks when the tank is opened. The shrinkage sometimes becomes as large as 10 millimeters in case of a large tank. When selecting materials and inspection methods, it is important to select materials that have enough flexibility and can absorb expansion and shrinkage of the rings, and that are not liable to crack by deterioration and hardening. Figure 17-5 illustrates application of waterproofing.

(2) Periodic Overhaul Inspection, Inspection Area and Items

In Japan, intervals of periodic overhaul inspections are stipulated by the Fire Prevention Law.

- Opening interval:	Tanks of 1,000 kl to 10,000 kl	10 years
	Over 10,000 kl	5 years
	(Safety inspections:	every 10 years)
- Inspection items:	Thickness of bottom plate, conditions of welding lines, etc.	

There has been a remarkable improvement in the quality of bottom plate maintenance and correction of uneven settlement by the mandatory overhaul inspections. Meanwhile, according to the in-house standard of Petrotrin (#IRP-T-01), overhaul inspections of tanks are stipulated as shown in Table 17-1. Overhaul intervals in Japan are classified based on the capacity of tanks while Petrotrin's is based on the usage and types of tanks. It is difficult to say which is better; however, the overhaul intervals should be less than 10 years for tanks of more than 1,000 kiloliters. Although decisions must be made referring to past inspection records, the priority inspection areas are as follows:

- Defects and cracks of welded parts at T-welding joints of the annular plate fillets,
- Defects and cracks of welded parts at the triple layer and triple welding joints of annular plate/bottom plates,
- Defects at back side edges of annular plate/bottom plate rings caused by corrosion,
- Cracks on welding lines at places where uneven base settlement occurs,
- Places where tank nozzles are attached.

There have been cases in overhaul inspections in which a tank plate was pierced through when the triple welded area was ground to remove welding defects. In some cases, whole annular plates were replaced on account of corrosion occurring in the back side of the annular plate at the fillet welding area. These were caused by permeation of rain water or by subsidence of the ground at the bottom of the tank shell.

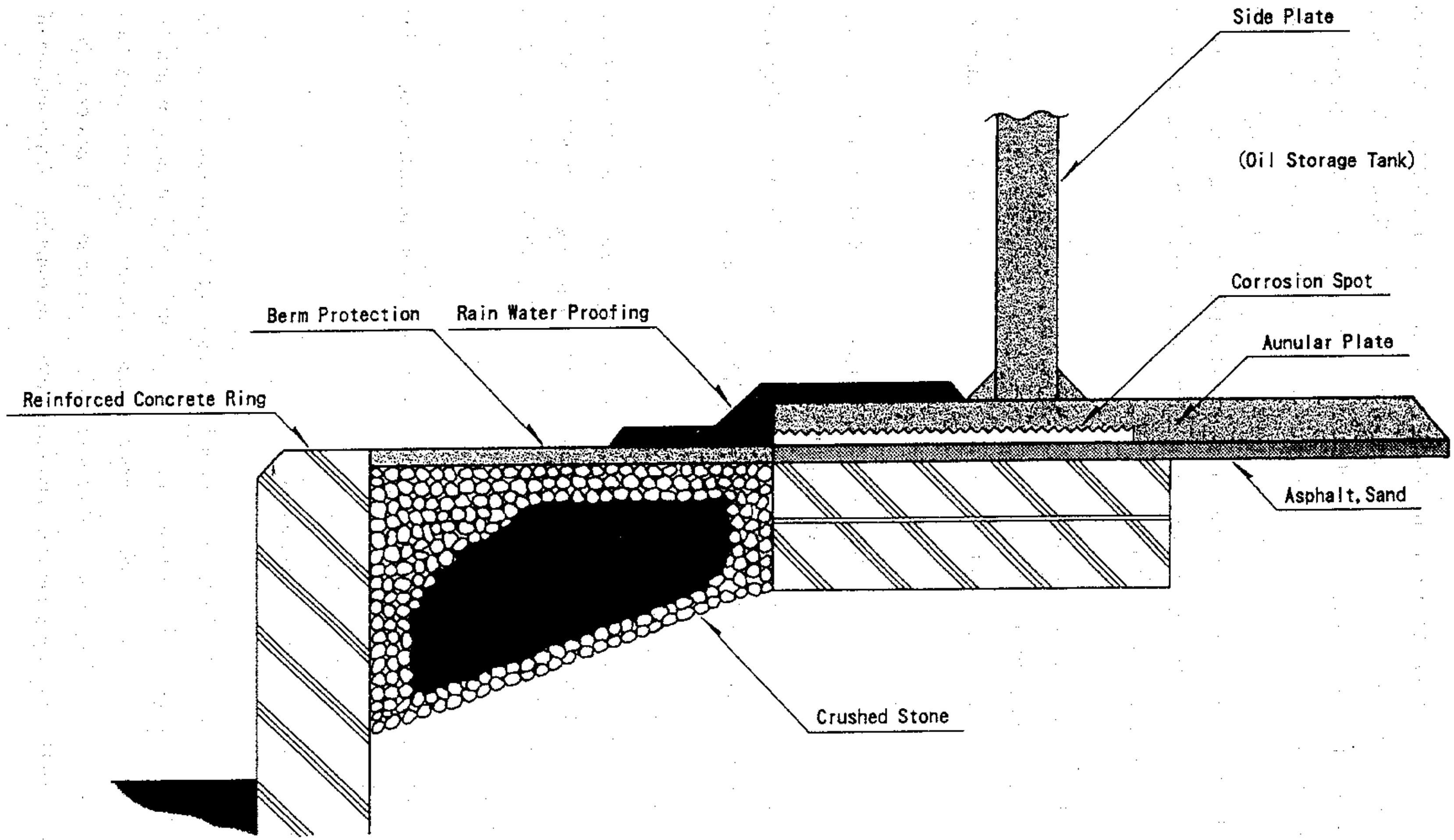

Figure 17-5 Water Proofing at the Annular Portion of Tank Bottom

(3) Modification of Drain Nozzles and Backfilling of Drain Pits

Drain nozzles are installed to drain the bottom sludge and water accumulated at the tank bottom. There are two types of drain nozzles, siphon type and elbow type. The elbow type drain nozzles are efficient in draining water since they are attached to the tank bottom plate; however, there is a possibility of weakening the strength of the bottom plate for structural reason. Therefore the siphon type is mainly used now. Petrotrin's tanks were mostly constructed many years ago. The tanks with elbow-type drain nozzles and with drain pits installed under bottom plate should have them replaced by siphon-type nozzles. Drain pits which may be a cause of uneven settlement of a bottom plate should be buried.

(4) Detailed Inspection of Tanks Equipped with Heating Coils

If a tank is equipped with heating coils, the back side of the bottom plate should be inspected by cutting part of the plate, even if the inside is in good conditions. The reason for recommending this is as follows:

- It is often reported that the thickness of the bottom plate is drastically reduced or the plate is penetrated by pitting corrosion.
- Corrosion on the back side of the bottom plate is accelerated when the underground environment is in cyclic repetition of wet and dry conditions.

(5) Periodic Measurement of Uneven Base Settlement

The foundations of Petrotrin's tanks are built mostly by banking of soil. Uneven settlement sometimes occurs in a banking basement depending on soil compacting condition. Data on uneven settlement should be accumulated. The following are possible effects of uneven settlement of tanks.

- Adverse affects on movement of floating roofs and/or causing defects in sealing equipment,
- Increase of internal stress in tank structure,
- Aggravation of the corrosion environment.

Of the above items, the increase of internal stress and aggravation of the corrosion environment can cause serious accidental oil pollution. Especially, the fillet welding area of annular plate/bottom plate is a critical point. When uneven subsidence arises in this area, cracks and deformation occur at the welding joints as a result of stress concentration. In addition, stress concentration can cause stress corrosion cracking in a corrosive environment. Accumulation of secular distortion data on ground subsidence is necessary to investigate the characteristics and causes of uneven settlement, and to predict failures and develop countermeasures. In general, vertical displacements at eight to 24 points, allocated at equal distance on the circular shell, are measured. It is necessary to measure the vertical displacements at the annular plate/bottom plate area in the overhaul inspections.

(6) Days Required for Tank Overhaul Inspection

According to Japanese experience, a long period of 190 days on average is necessary for overhaul inspection of a crude oil tank if the capacity exceeds 50,000 kiloliters. Of all work, inspection and repair take the longest. It is hard to control the work period, because the amount of work varies depending on the degree of corrosion. However, the period can be shortened by applying parallel inspections at each phase of the work, early order placement and introduction of new technology. The Crude Oil Washing (COW) method is effectively applied to cleaning tanks as a pretreatment for overhaul. The cleaning period can be cut almost by half by using this method. It can be shortened to 160 days (cleaning: 45 days, inspection: 20 days, official application: 10 days, repair work: 55 days, painting and small repairs: 30 days). The time can be further shortened at each stage by making further effort.

(7) COW Method

A crude oil tank is a source of a large quantity of oily sludge and slop oil. The slop oil contains tough emulsions; therefore, their treatment is important in terms of oil recovery, waste water treatment and waste disposal control. The COW method uses crude oil as a washing liquid. The crude oil is jetted at the pile of oily sludge by jet machines to break the pile. Oil in the sludge is dissolved in the crude oil and recovered, and the cleaning period is considerably shortened by reducing the quantity of sludge. Since this washing is practiced in the atmospheric environment, nitrogen is introduced to the crude oil tank to keep oxygen concentration in the tank lower than five percent, to prevent explosions that may be triggered by generation of static electricity. Oxygen concentration in the tank is continuously monitored using an automatic oxygen analyzer, usually at six points, until the completion of washing. Regarding the effectiveness of this method, it has been reported that, in one case, 3,500 kl of oily sludge was reduced to 51.1 tons. The target oil content in the final sludge is less than 30 percent. This washing method is used very extensively in Japan. Washing time itself is 120 hours, or five days, at most, only a fraction of the total overhaul period. The procedure in this method is given below.

1. Bringing equipment and materials into the tank yard
2. Sludge measurement
3. Installation of temporary piping
4. Leakage test of piping
5. Transferring the oil remaining in the tank
6. Nitrogen introduction and supply
7. COW washing
8. Manhole opening and gas freeing
9. Scraping inside of roof and shell wall
10. Transferring wax dissolving oil
11. Bagging final sludge and scales
12. Brushing bottom plate and shell wall
13. Steaming
14. Water jet washing for finishing
15. Cleaning pontoon and removing tube seals
16. Cleaning oil pits
17. Collection of equipment and materials
18. Completion

Total cleaning period is 45 days from equipment carry-in to the completion of cleaning. Bagging, Item 11 above, is usually done manually. This period can be shortened by introducing proper machinery.

(8) Thickness Measurement from Coating Surface

Coating is generally applied to bottom plates of tanks to prevent corrosion. It is therefore necessary to measure the plate thickness from the coating surface. In Japan, the measured data are accepted as official if the instrument used has been approved beforehand by the government, backed by an adequate performance test.

17-5 Conclusion

Inspection and maintenance of facilities that can cause serious accidental oil pollution are matters of paramount importance. On Petrotrin's premises, the pipelines and tanks can be regarded as such facilities.

As pipelines age, leakage trouble is reported more often. Leaks can get out of control as long as the breakdown maintenance is continued as it is done now. Petrotrin needs to invest in measures for extending the lives of pipelines and their replacement from a long-term perspective.

Tanks should be periodically overhauled at appropriate time intervals. Attention should be paid to corrosion defects on the welding lines of the annular plates and the bottom plates, cracks and defects in all welding areas. In addition, data on secular distortion of uneven base settlement should be accumulated. This should be regarded as an important data base, since most serious oil leaks are associated with such distortion.

Simultaneously, education and training of the personnel in charge of operation, inspection and maintenance should be planned and carried out.

Chapter 18 Key Issues in Pollution and Pollution Prevention

Chapter 18 Key Issues in Pollution and Pollution Prevention

The preceding chapters presented current status, problems, and issues in their respective areas. Throughout the entire study there are issues of critical importance on which decisions must be made among possible alternatives. The purpose of this chapter is to review and summarize these important issues presented in different chapters, to discuss, and to indicate the decisions the study team has made with rationale for supporting them.

The counterparts discussed these key issues with the study team during the third field survey and both parties shared the same understanding about these issues and also on how to cope with them. Such understanding constitutes the basis for the definitive project scheme on which conceptual designs and estimation of the costs were done.

These key issues may be allocated to six categories: (1) General, (2) Oil wells, main storage and tank farms, (3) Dams and catches, (4) Pointe-a-Pierre Refinery, (5) Wastes, contaminated soils, earthen pits, and (6) Others.

(1) General

1. Definition of the oil content target
2. Effect of the target level on the environment

(2) Oil wells, main storage, tank farms

1. Treatment of water produced with crude oil
2. Dissolved air flotation with coagulation
3. Treatment of water after dissolved air flotation
4. Oil leaks from the facilities
5. Disposal of water upstream of the main storage
6. Separation of storm water from oily water
7. Review of oil production under enhanced oil recovery

(3) Dams and catches

1. Results of the climatic and hydrometric study
2. Roles of dams and catches in pollution prevention
3. Problems with oil and debris floating against the dams and catches

(4) Pointe-a-Pierre Refinery

1. Capacities and performances of the existing separators
2. Proposed concept of water treating system
3. Ongoing upgrading project

(5) Wastes, contaminated soils, earthen pits

1. Rehabilitation of soils
2. Amounts and varieties of oil-containing wastes
3. Concept of waste treatment center
4. Measures to reduce wastes
5. Treatment of slop, a thick water-in-oil emulsion
6. Incineration

(6) Others

1. Accidental pollution
2. Maintenance
3. Legal and administrative measures
4. Human resource development
5. Monitoring
6. Evaluation of the benefits and costs of the project

18-1 General

18-1-1 Definition of the Oil Content Target

As Chapter 3 explains, quoting from the Minutes of Meeting signed by the representatives of the Ministry of Energy and Energy Industries and the Preparatory Study Team of JICA, the Ministry of Energy and Energy Industries' draft instructions to the oil companies will be employed as the basis of the study. To be specific, oil and grease discharges from refineries and land based petroleum facilities shall not normally exceed 50 ppm on monthly average or 75 ppm on a daily maximum. The study team has thus set the target level at 50 milligrams of oil per liter of water based on the ASTM Testing Method D-4281, Freon Extraction Method. Methods for testing normal hexane solubles and carbon tetrachloride solubles were frequently used during the course of this study in preference to the ASTM testing method for convenience. The results of these tests were evaluated in reference to the equivalent in freon solubles.

The effluent water streams leaving petroleum facilities and before entering the environment -- rivers, sea, or any public facilities -- must meet this target level. Any attempt to meet this target by diluting the waste water by sea or river water is out of the question.

18-1-2 Effect of the Target Level on the Environment

An oil content of 50 ppm is still very high when its effects on the ecological environment are considered. Notwithstanding, its effects on the environment are beyond the scope of this study.

18-2 Oil Wells, Main Storage, Tank Farms

18-2-1 Treatment of Water Produced with Crude Oil

The water produced with crude oil is in the form of very stable oil-in-water emulsions. The study team did not receive correct information about the nature of such water during the first field survey. The effluent water from the main storages and tank farms appears just like normal muddy river water, and the study team was informed that the water contained mud and was therefore brown. During the first home-office work, samples of such effluent water were examined under a microscope, and they were found to be such emulsions.

The treatment of such emulsions then became the central issue in this area of the study. The particle sizes of oil droplets dispersed in water range from less than one micron to a maximum of nine to 10 microns. The system of water and oil in which such small sizes of oil particles are well dispersed in the continuous phase of water forms a very stable and tenacious emulsion. First of all, it is important to understand and accept that such emulsions are being discharged to the environment from the main storages and tank farms and that such emulsions are not separable into oil and water by gravity no matter how long they are allowed to stand still. In addition, the water phase contains in solution organic acids combined with alkaline metallic irons that can perhaps help stabilize the emulsions.

18-2-2 Dissolved Air Flotation with Coagulation

After having confirmed that such emulsions are not amenable to gravity-induced separators and that demulsifiers are either only partially effective or ineffective, the study team has decided that dissolved air flotation with the use of (a) coagulant(s) is the only method that can effectively collect emulsified oil particles and separate them from water. The study team confirmed the effects of dissolved air flotation using genuine samples taken from Bernstein Main Storage and Pointe-a-Pierre Refinery during the first home-office work period, the second field survey, the second home-office work period.

One may wish to adhere to use of demulsifiers to solve this problem, because a joint public and private sector study aiming to solve this problem by demulsifier is underway in Trinidad and Tobago. Some may argue that very effective chemicals may be found tomorrow. The experiments by the study team indicate that chemicals are either not effective or only partially effective. In addition, all the opinions of the experts in this field support the use of dissolved air flotation with the help of coagulants. The study team can recommend nothing but the surest way to achieve the target.

Besides, the study team is very conservative about the use of chemicals because of their yet-to-be-proven effects upon the environment, upon the ecological environment in particular. What is labeled safe today may be found dangerous tomorrow, as has actually been the case with many chemicals.

18-2-3 Treatment of Water after Dissolved Air Flotation

It has also been found that water after treatment by dissolved air flotation can contain what is identified as oil at higher than 50 ppm. The results of mass-spectrometry tests indicate that the substances dissolved in the treated water are most likely naturally-occurring organic acids combined with alkaline metallic ions. An organic acid combined with alkaline metallic ions is a kind of soap, a substance that increases the solubility of oil in water. Therefore, the existence of such organic acids increases the measured oil content, first by being identified as oil by the standard test method, and second by increasing the solubility of oil in water.

The study team tested two alternative routes for treating such waters; namely, biological degradation and activated carbon adsorption. By experiments on water samples taken at Bernstein Main Storage the possibility of bio-treatment has been ruled out. On the other hand, activated carbon proved to be very effective in treating this waste water. On the ground of the results of such experiments, the study team recommends a combination of dissolved air flotation with coagulation and adsorption by activated carbon as the only practical means of treating water produced with crude oil. By this the target of oil content in water less than 50 ppm cab be achieved.

The study team and the counterpart agreed on the basic concept of treating waste water and the locations of the water treating systems, layout of the facilities, and basic design conditions.

18-2-4 Oil Leaks from Facilities

As the study team sees the situation, the problem of oil leaking from the facilities is not a problem of Petrotrin's maintenance technology level. Petrotrin and those engaged in production are by no means low in the level of maintenance technology. They have capable maintenance teams and they know how to maintain the facilities in best condition.

The study team does not necessarily believe that all these facilities should be maintained in the best condition regardless of cost. It is nevertheless important that all the facilities be properly maintained so that major accidents may be prevented and that any leak that does happen will not be a major one but be a manageable one. It is also very important that the leaking oil be not allowed to escape the spot where the leak takes place but be contained and the oil collected. Under present conditions, in which leaks are sporadically found, one or two vacuum cars should go around and collect oil before it pollutes the environment.

18-2-5 Disposal of Water Upstream of the Main Storage

Water produced with oil is camouflaged as muddy water. The water may not have any floating oil on its surface but it contains considerable oil in the form of a very stable emulsion. Such water should not be allowed to be discharged to the environment. All water should be sent to Bernstein Main Storage and treated with dissolved air flotation with coagulation and activated carbon adsorption before being discharged to the environment.

18-2-6 Separation of Storm Water from Oily Water

Storm water should be prevented from entering the oily water treating system so that the load on the water treating system is minimized.

18-2-7 Review of Oil Production under Enhanced Oil Recovery

Trinidad and Tobago produces oil in certain cases under heavy steam injection. As injected steam increases, the water produced in association of oil increases. Given that the water produced with crude oil is a tenacious emulsion and that treatment of such water is not a matter of inexpensive skimming, crude production with intensive steam injection should be reviewed in the light of economy of water treatment. Now, barrels of water produced per barrel of oil takes on new economic importance. Reduction of oil production by 10 percent by closing the least productive wells could reduce production of water by 40 to 50 percent. The policy of further promoting oil production by intensive steam injection should also be re-evaluated in light of the economic burden of treating water. This study reviewed oil production by steam injection in terms of water treatment cost. The result is given in Chapter 23, Evaluation.

18-3 Dams and Catches

18-3-1 Results of the Climatic and Hydrometric Study

The climatic and hydrometric study done as part of this study indicates that all the dams and catches in the scope of the study cannot accommodate flow rates under flooding conditions.

18-3-2 Roles of Dams and Catches in Pollution Prevention

In Trinidad and Tobago, where it pours very heavily and intermittently during the rainy season, the flow rates to the waste water treating facilities could rise very high if storm water is allowed to enter them. The whole system of prevention and control of petroleum pollution becomes very large and consequently expensive if the system attempts to accommodate the storm water.

Under such conditions, the study team believes that the whole system should be designed not to be affected by the weather conditions rather than to handle them. This philosophy of the study team is adhered to throughout this study. The conceptual designs and recommendations by the study team incorporate, in line with this principle, provisions to prevent the non-oily storm water from entering the oily effluent streams that go to the treating facilities, whereby the amounts of water to be treated are held to a minimum.

Another rationale for not supporting expansion of dams and catches is that the most serious cause of petroleum pollution is not visible oil that floats on the water surface but oil-in-water emulsions produced with crude oil. Such emulsions mingle completely with water; therefore, any device -- dams or weirs -- that stop matter that floats on water is utterly ineffective to matter that mingles with water. Expansion of dams and catches is therefore meaningless.

18-3-3 Problems with Oil and Debris Floating against the Dams and Catches

Presently, oil and debris floating against the weirs of the dams and catches are not regarded as a serious threat to the environment. Notwithstanding the fact that the floating oil is less of a problem than the emulsions that flow freely with the body of water under the weirs down to the sea, such visible pollution sources as floating oil and debris should not be tolerated. The moment they are found, the emergency squad should be mobilized to collect them; the party responsible for leaking oil or dumping debris should be identified and warned against their defective operations. The habit of regarding oil or debris floating on public water as an extremely abnormal and intolerable condition should be established.

18-4 Pointe-a-Pierre Refinery

18-4-1 Capacities and Performances of the Existing Separators

The throughputs of water to the existing four API separators and guard basins far exceed their design capacities due to inflows of large volumes of non-oily water; namely storm water and once-through cooling water. Effluent water from all four API separators contains oil far exceeding 50 ppm, more than 1,000 ppm in many cases. Again the study team does not recommend expansion of these separators to large enough capacities to easily accommodate the present flow rates. As is explained below the study team believes that the storm water and oily water should be separated and treated separately.

18-4-2 Concept of Proposed Water Treating System

(1) Separation of Storm Water from Oily Water

This is a very big theme in the design of the recommended facility for waste water treatment. Instead of the existing separators being expanded to better meet the present flow rates, storm water should be kept separate from the oily water system.

(2) Water Treatment

The study team recommends that a new independent system for oily water treating system be installed. The existing water treating system will be converted into a non-only water treating system. The proposed oily water treating system will collect all oily water from the plant areas and tank sites and deliver the oily water by above-ground pipes to an appropriate place where the water treating system will be installed. The water treating system will consist of separators, dissolved air flotation plus coagulation and associated facilities. It must be accepted that no combination of gravity-induced separators alone will be capable of bringing the oil content down to the 50 ppm target level and the proposed system is the only conceivable and also the least expensive way to achieve the target.

Similar to the case of Bernstein Main Storage, the study team and the counterpart agreed on the routing of the oily water pipes, the location of the water treating system, layout of the facilities, basic design conditions.

18-4-3 Ongoing Upgrading Project

As part of the upgrading project financed by IADB, a project to separate non-oily water from oily water is underway. This is part of Petrotrin's plan to reduce the oil content in the effluent water to 150 ppm. One might think that when the proposed system is complete, the present modification will become useless and the money spent for this will not be well spent, because the proposed system will convert the present oily system into a non-oily system.

It will take a long time to realize all the proposed modifications including appropriation of the necessary funds. It would however be a matter of serious concern not only to Trinidad and Tobago but to adjacent countries if Trinidad and Tobago continues to discharge waste water containing more than 1,000 ppm oil to the sea. Under such a circumstance, the present upgrading project, though incomplete as it is only capable of achieving about 150 ppm oil in water, is meaningful and worth implementing as an intermediate measure.

At the final stage, when the recommendations of this study have been implemented, all elements of the present upgrading project will be used for the treatment of storm water. Even the clean water effluent needs a system for treatment as a guard against unexpected situations. In this sense, the systems provided by the present upgrading project will be effectively utilized in the future.

18-5 Waste, Contaminated Soil, Earthen Pit

18-5-1 Rehabilitation of Soil

The study team believes that the present practice of dumping oil-containing wastes in earthen pits should be abandoned. Whether soils that have already been stained with oil -- banks of rivers to which oil is discharged, soils of earthen pits, soils contaminated with oil leaking from pipes and other facilities -- should be rehabilitated or not is a question to which the answers will be different for different cases. The method and cost of treatment, danger of secondary pollution, and possibility of natural bio-degradation should be considered in each case. The study team conducted experiments on typical chemical and biological treatments and found them effective, though depending significantly upon the soil conditions. Chapter 14 provides information on soil rehabilitation tests and the treatment concept the study team proposes.

18-5-2 Amounts and Varieties of Oil-containing Wastes

During the third field survey, the study team and the counterpart studied this issue and agreed on the quantities of scums from the dissolved air flotation and middle-layer emulsion that have to be incinerated. These figures have direct bearings on the designs of the waste treatment centers proposed in Pointe-a-Pierre Refinery and Bernstein Main Storage. It was confirmed between both parties that Petrotrin does not produce such oil-containing wastes as spent clay, sulfuric acid sludge, heavy extract, catalysts.

18-5-3 Concept of Waste Treatment Center

The study team proposes a concept of waste treatment centers, one to be located in the premises of Pointe-a-Pierre Refinery and the other in Bernstein Main Storage. The study team and the counterpart agreed on the proposed concept.

18-5-4 Measures to Reduce Wastes

If the amount of oil-containing wastes is reduced, the capacities of the waste treatment centers could also be reduced. As is mentioned in 18-2-7, Review of Oil Production under Enhanced Oil Recovery, if the amount of waste water to be treated is substantially reduced by closing some of the least efficient oil wells, this possibility should be studied to reduce the sizes of the waste water treating facilities and also the waste treatment center. The study team and the counterpart discussed this issue and agreed that a sensitivity case study will be done on the benefits and costs of closing the least effective wells.

Another possibility could be the use of oil-containing scum as feed and the middle-layer emulsion as fuel to a cement plant. Trinidad and Tobago has a first-class cement manufacturer called Trinidad Cement Limited (TCL) with a capacity of two thousand tons per day. During the third field survey, the study team and TCL had meetings on this issue and TCL agreed to study the possibility of feeding the scum and burning the middle-layer emulsion. If TCL finds both scum and middle-layer emulsion acceptable, the amount of oil-containing waste that has to be disposed of by the waste treatment centers will be greatly reduced. With the result of the study not expected by the time this report is submitted, the conceptual design will have full capacities to burn the entire amount of the scum and middle-layer emulsion.

18-5-5 Treatment of Slop, a Thick Water-in-oil Emulsion

The emulsions produced with crude oil have been well explained. Another type of emulsion plagues oil wells, main storages, tank farms and also Pointe-a-Pierre Refinery. These are water-in-oil emulsions consisting of water and oil in the range of about 30 to 70 percent. They have a sticky, mud-like appearance. They are called slop, intermediate emulsion, middle-layer emulsion, or rag. These emulsions are formed on the surfaces of API and other types of separators and guard basins, on the surfaces of dams and catches, on the surfaces of water in earthen pits, at the interfaces between the water and oil phases in tanks. These emulsions are also seen on the sea adjacent to the water outlets from the Main Storage at Point Ligoure and Pointe-a-Pierre Refinery. These emulsions are very stable and can be broken into oil and water only partially by heat, demulsifiers, or any other method.

At Pointe-a-Pierre Refinery these emulsions are heated in the tank and the separated oil-rich portion is distilled to remove water; however, the thick emulsions still remain unseparated in the tank.

The study team thinks that there is no alternative but to incinerate such emulsions, although effort should be made to the extent reasonably and economically possible to squeeze the emulsions by heat or by chemicals to recover oil and to remove water to reduce the emulsion volume. Therefore, incinerators will be provided in the proposed waste treatment centers.

18-5-6 Incineration

Oil-containing wastes should not be buried. This is the basic principle behind proposing incineration. The study team believes that this principle is right and should therefore be observed for the prevention and control of petroleum pollution.

Chapter 19 Experiments on Waste Water Treatment

Chapter 19 Experiments on Waste Water Treatment

19-1 Characteristics of the Effluent Water from Petroleum Installations

A prime objective of this study is to develop a scheme whereby the oil content of effluent streams from petroleum installations in the study area can be reduced to the target level of 50 ppm.

It was found through the first field survey that the effluent waters from the API separators of several tank farms were turbid, mud-colored, and emit strong oil odor. Also, during the first home-office work period the suspended materials in the effluent waters were identified as emulsified oil particles. The oil contents of the effluent water streams from the petroleum facilities ranged from 100 to 10,000 ppm according to periodic measurements carried out by the concerned organizations of Trinidad and Tobago.

The number of on-shore oil wells in the study area exceeds 2,000, and the crude oil production is about 30,000 bpd. One third of this crude oil is produced by an Enhanced Oil Recovery method using steam injection, and therefore is called thermal crude. As a result of steam injection, a large quantity of water is produced with crude oil. This water contains crude oil particles in the form of a very stable oil-in-water emulsion.

Water is separated, mainly in the tanks in the tank farms, bled from the bottoms of the tanks, and discharged to public rivers through gravity-induced oil water separators. However, the emulsion cannot be separated by gravity-induced separators such as API separators or guard basins, because the specific gravity of this emulsion is almost unity and oil particles are suspended in the water very uniformly. Such a tough oil-in-water emulsion has seldom been experienced in Japan, and it was understood during the first home-office work period that the 50 ppm oil and grease concentration in the effluent water is not an easy target to achieve.

19-2 Necessity of Experiments

The Japanese Water Pollution Control Law stipulates that the concentration of oil in effluent water should be less than 5 ppm; however, this law also provides that the concerned local government can apply stricter regulations to large-scale installations in consideration of situations unique to local areas. Major oil refineries in Japan are located in coastal industrial zones, and regulation of one or two ppm of normal-hexane solubles is applied to refinery effluents by local governments.

Accordingly, most petroleum refineries in Japan control the oil contents of their effluent waters in the range between 0.4 and 0.7 ppm, generally using a series of waste water treating facilities consisting of API separators, CPI (or PPI) separators, and facilities for coagulation sedimentation or air flotation, followed by facilities for biological treatment, scum concentration, guard basins and incinerators.

As was mentioned before, the target of this study is to achieve 50 ppm of oil in the effluent water. No target is given for COD or BOD. The study team envisaged during the first home-office work period that the core unit of the waste water treating system to be recommended to Trinidad and Tobago would be an air flotation unit and gravity-induced separation facilities.

To confirm the effectiveness of the air flotation and relevant technology to the above-mentioned waste water from the petroleum installations, the study team conducted a series of experiments at the laboratory of the Chiba Refinery of COSMO OIL CO., LTD. The experiments used very limited water sample bled from Bernstein Main Storage collected during the first field survey and brought back to Japan.

The study team became convinced that a series of experiments should be performed at Trinidad and Tobago during the second field survey period generously using genuine water samples, in order to obtain data deemed necessary for developing and preparing the basic project scheme and conceptual design of the waste water treatment system. In order to prepare for the experiments in Trinidad and Tobago, a series of experiments of a preparatory nature were done in Japan during the first home-office work period.

19-3 Experiments Performed in Japan

19-3-1 Purpose and Items of Experiments

The main purpose and items of these preparatory experiments were as follows.

(1) Development of Correlation Curve

The study team expected that a large number of samples would have to be analyzed very quickly for oil content during the field survey to enable jar-tests and flotation tests to be done in rapid succession. This is possible only with the infra-red rays test method. The data obtained must be readily convertible into values supposed to be obtained by the official method; therefore, correlation curve between the data by these two methods is necessary. Although the ASTM D-4281 freon extraction method is the official one in Trinidad and Tobago, tests by the freon method are not readily done in Japan. Therefore, a correlation was developed between the infra-red rays method and the normal-hexane method, the latter being the method officially adopted in Japan. The necessary correlation between the infra-red rays method and freon extraction method was developed afterward during the field survey.

(2) Jar Tests

To obtain information necessary for selecting suitable coagulants, jar tests and flotation tests were performed on samples of bleed water taken from the selected wash tank at Bernstein Main Storage and brought to Japan. PAC (Poly-Aluminum Chloride), an inorganic coagulant, and several kinds of organic coagulants (polymers) were tested. The function of organic coagulants is to coagulate small dispersed flocs that have been produced by an inorganic coagulant into larger ones. Larger flocs are easier to float to the surface when small air bubbles adhere on them. The air bubbles are generated when water forced to contain air under pressure is relieved of the pressure.

(3) Air Flotation Tests

A series of tests were conducted using an air flotation tester to evaluate the effects of the selected coagulants on the Bernstein water samples and to measure the decrease of oil content by air-flotation.

(4) Tests on the Desalter Interfacial Emulsion

Tests were done to find whether such materials as HCl, NaCl, heavy naphtha, kerosene are effective in breaking by physical means the heavy interfacial emulsions produced at the Chiba Refinery of COSMO OIL CO., LTD.

(5) Waste Water Emulsion Pretreatment Test

This test was done to determine whether such materials as HCl, NaCl, or heavy naphtha, or heat, are effective as pretreatment to the air flotation to reduce the load on the latter.

19-3-2 Test Results

The results of the above tests are summarized as follows:

(1) Correlation Curve

1) Test result

The Bernstein wash tank bleed water containing oil at 17,000 mg/l by n-hexane solubles was diluted in varying ratios by pure water to prepare a number of samples ranging in oil content from 10 to 17,000 mg/liter. The samples were divided into two parts, one to be tested by the infrared rays adsorption method for CTC solubles and the other to be tested by the n-hexane method. As a result, the correlation curves shown in Figures 19-1 and 19-2 were developed.

2) Evaluation

- Repeatability of the infrared rays oil content meter was found good.

- The data obtained by both methods cross at oil content of about 1,500 ppm, above which the infrared rays method gave higher values and below which it gave lower values.

- This phenomenon may be attributable to yellow coloring of oil-containing carbon tetrachloride.

- The reason why the infrared rays method gives lower values in the range below 1,500 ppm is not clear. Perhaps this phenomenon is caused by the inappropriateness of this analyzer for measurements at such high oil concentrations. Although such a range is normal in Trinidad and Tobago, this Japanese analyzer is designed for measurement in the lower than 100 ppm range.

- It was planned that the correlation curve between the infrared rays method and the official measurement method of Trinidad and Tobago would be used when the experiments are actually performed during the field survey. Therefore, development of a correlation curve between the infrared rays method and the ASTM D-4281 freon method should be given first priority and precede all other work of the field survey.

- As mentioned, this analyzer is designed for measurement of lower than 100 ppm oil concentrations. When a sample of high oil content is tested by the infrared rays method, the sample is diluted before the measurement, and the dilution method affects the accuracy of measurement. The study team discussed with the meter manufacturer the dilution method that should be applied to the Trinidad and Tobago samples. The results of the discussions were reflected in the procedures of the experiments done during the second field survey period.

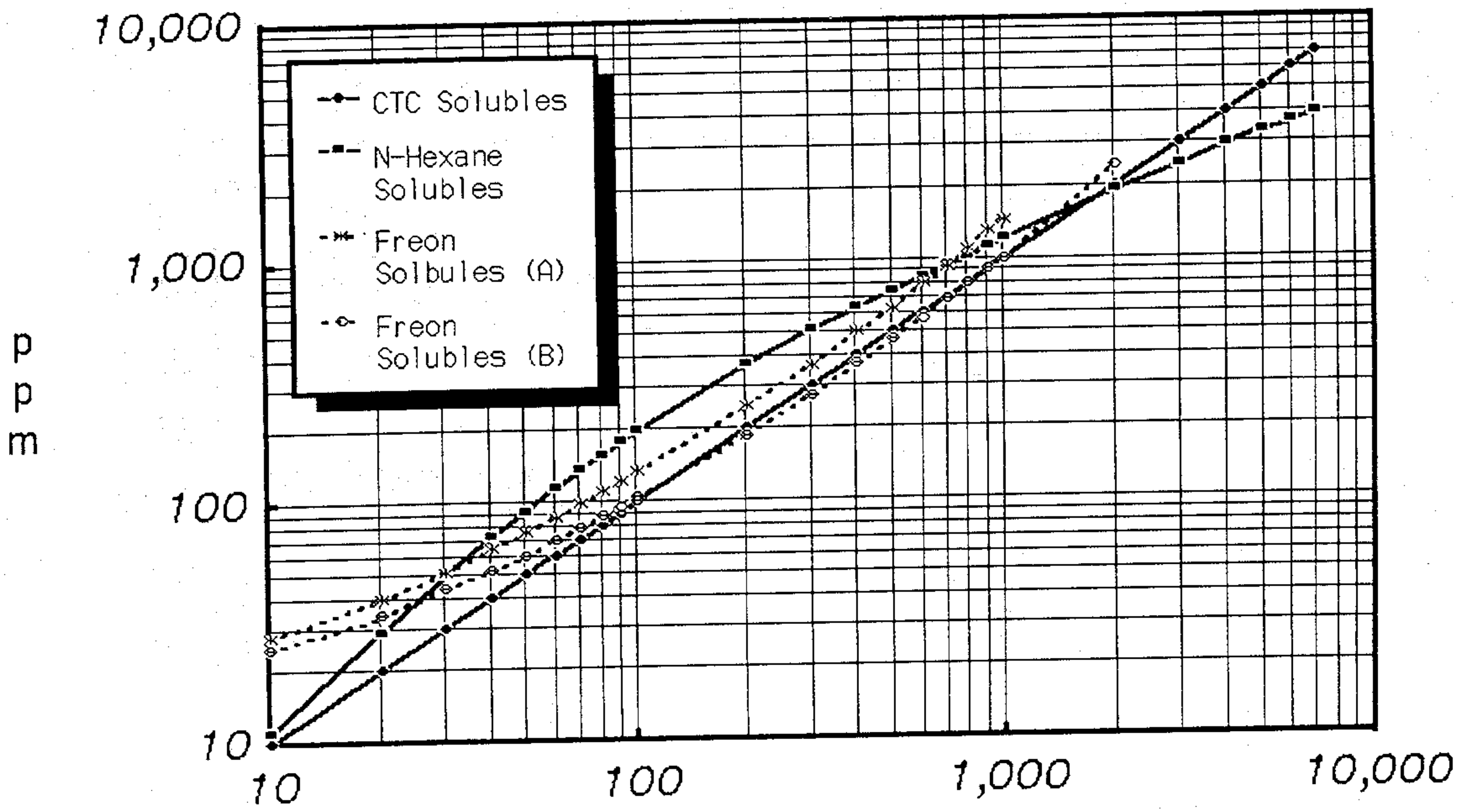

Figure 19–1 Oil Content, CTC Solubles

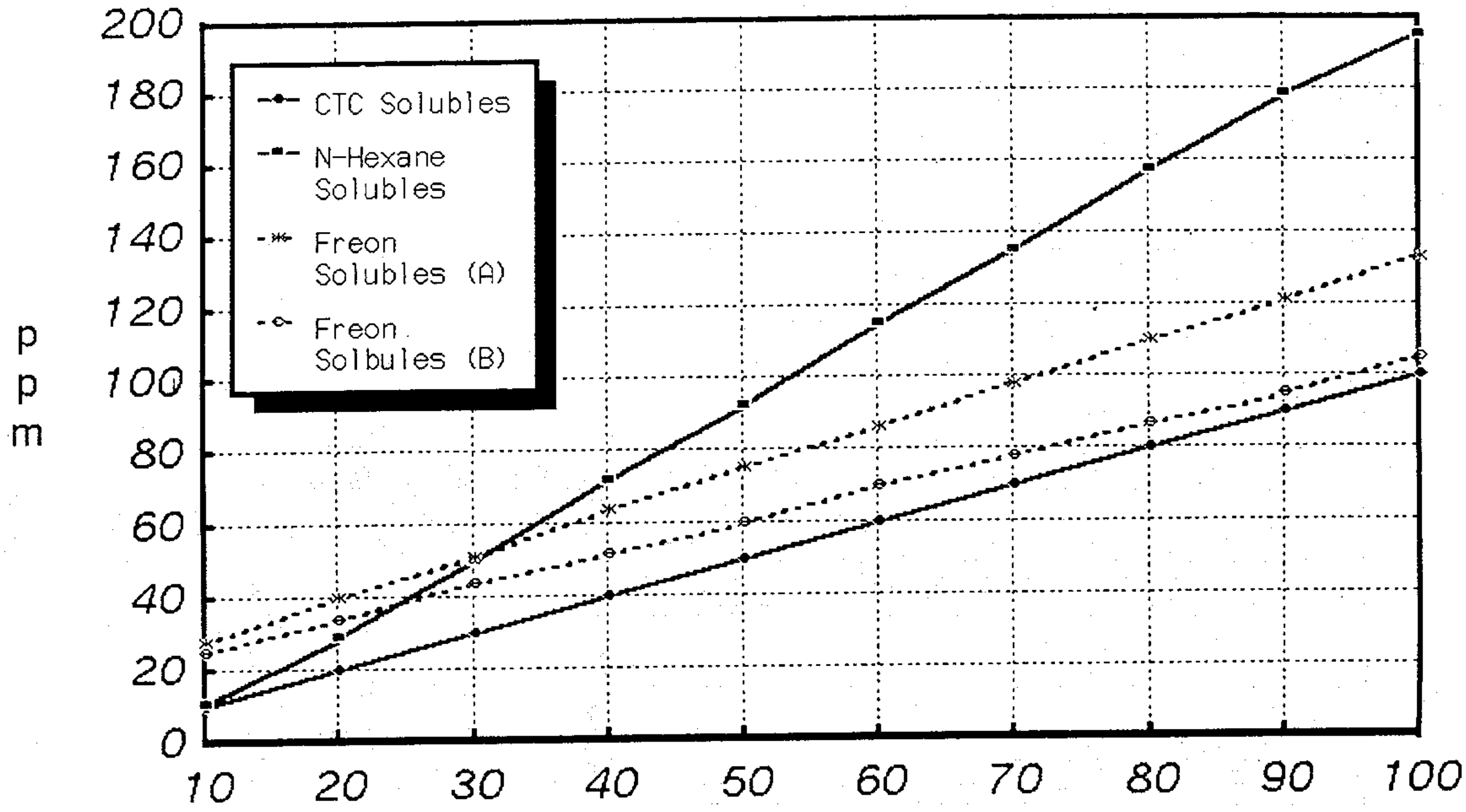

Figure 19–2 Oil Content, CTC Solubles

- Both official analytical methods, the normal-hexane extraction in Japan and the freon extraction in Trinidad and Tobago, take a rather long time. By contrast, the infrared rays method proved very efficient, capable of being done in a very short time, and easy to use. A large number of measurements were done during the second field survey period because of the inherent trial-and-error nature of the air flotation experiments. Use of the infrared rays method was considered essential to the success of the experiments in Trinidad and Tobago.

(2) Jar Test

Using the samples of diluted Bernstein wash tank bleed water, a series of jar tests were conducted. The test results were as follows:

- PAC acts very effectively on this water and makes good flocs.
- Anion System Polymer (PA-378 KURITA make) was found best for this sample water.

(3) Air Flotation Tests

Using the diluted sample of the bleed water from the Bernstein wash tank, a series of air flotation tests were conducted. The results are summarized in Table 19-1. By the air flotation test, oil content less than 50 ppm was achieved on the samples containing oil at less than 1,000 ppm, but not on the samples containing more than 1,000. The study team considered it necessary to explore methods that are effective in further decreasing the oil content of the treated water, because feed water could contain more than 1,000 ppm oil. Filtration by filter paper was found effective for reducing the oil content of the treated water. The study team considered that appropriate filtering equipment would be effective. Therefore, the study team decided to bring to Trinidad and Tobago a filter containing columns of anthracite and sand to test its effectiveness with the water treated by air flotation.

Table 19-1 Results of Air-Flotation

Sample oil content (mg/l)	PAC (mg/l)	Polymer (mg/l)	Pressurized Water (%)	Oil in treated water (mg/l)
273	40	1	15	28
273	40	1	30	14
935	120	1	30	33
1670	140	1	30	102
1670	140	1	30	57 *

Note: * After filtration

(4) Desalter Emulsion Test

An interfacial emulsion was taken from a desalter of the Chiba Refinery to identify substances that could effectively break such emulsions by physical means. Test results are summarized below:

1) Addition of HCl

By controlling the pH value of emulsion at low levels, some portion of the emulsion seemed broken. However, the effect was not clear.

2) Addition of NaCl

The effect was not clear.

3) Heating

The emulsion was heated to 50, 70, 83 degree C. However, the effect was not clear.

4) Extraction by Heavy Naphtha or Kerosene

Oil was extracted uniformly from the emulsion by heavy naphtha and kerosene, indicating the possibility of recovering oil from the heavy emulsions contained in the recovered oil from the API separators.

(5) Pre-treatment Tests on Emulsions in the Waste Water

For the purpose of finding an adequate pretreatment method of air flotation, several substances were tested to reduce the concentration of emulsion. This test was also done on a diluted desalter interfacial emulsion. The test results are briefly summarized below.

1) Addition of HCl

By controlling pH values of the waste water at low levels, some portion of the emulsion seemed to be broken. However the effect was not adequate. Controlling the pH values of waste water is not easy under practical conditions and may not be applicable to the existing waste water treatment system.

2) Addition of NaCl

The effect was not clear.

3) Heating

The sample was heated to 88 degrees C. The effect was not clear.

4) Extraction by Heavy Naphtha and Kerosene

Oil was extracted uniformly from the emulsion by heavy naphtha and kerosene. However, applying this to waste water under practical conditions would be difficult.

It was considered necessary to try these physical methods during the field survey on genuine samples to confirm their effectiveness.

19-4 Experiments Conducted during the Second Field Survey

On the basis of the knowledge obtained through the experiments done in Japan, a series of experiments were done on air flotation and relevant technologies during the second field survey period. The objective is to establish a proper method to treat the waste water that can achieve the target oil and grease content of 50 ppm, and to obtain basic data necessary for the conceptual design of the waste water treating system.

19-4-1 Test Items

The following tests and measurements were done:

- Measurement of oil contents necessary for the development of a correlation curve between the data obtained by the infrared rays method and those by the ASTM D-4281 freon extraction gravimetric method,
- Jar tests,
- Air flotation tests,
- Filtration tests on flotation-treated water by anthracite plus sand filter,
- Activated carbon absorption tests on flotation-treated water.

19-4-2 Test Schedule and Subjects of Tests

(1) Sample Collection: February 23 and 24

Necessary samples were collected on February 23 and 24. The samples collected for waste water treating tests were:

- Bernstein Main Storage
  . Bleed water from the thermal wash tank
  . Bleed water from the non-thermal wash tank
  . API separator outlet water

- Los Bajos Tank Farm
  . Bleed water from the thermal wash tank
  . API separator outlet water

- Point Fortin Tank Farm
  . Bleed water from the non-thermal wash tank
  . API separator outlet water

- Point-a-Pierre Refinery
  . Outlet water of Nos. 1, 2, 3 and 4 API separators

Concurrent with sample collection, the testing equipment brought from Japan was installed in the laboratory of Point-a-Pierre Refinery in preparation for the planned experiments.

(2) Correlation Analysis: February 28 to March 3

1) Analysis

Using eleven-stage double diluted samples of Bernstein thermal wash tank bleed water, a necessary number of samples were prepared. Their oil contents should range from 10 to 10,000 mg/l. All these samples were divided into two parts: one was measured by the study team by means of the infrared rays method; the other by CARIRI by the ASTM D-4281 freon method.

2) Results

The required results were obtained and a correlation curve was developed. The correlation curves are shown on Figures 19-1 and 19-2. The accuracy of these curves were considered to be good enough for the planned field experiments.

(3) Jar Tests: March 1 to March 4

Prior to the air flotation tests, a series of jar tests were done to find the most suitable coagulant. The study team brought two series of coagulants from Japan. One series was PAC and six kinds of polymers of Kurita; the other was three kinds of coagulants of Kanebo. The best coagulant for each sample water was selected from the Kurita series of six polymers. In the following air flotation tests, the selected Kurita coagulant and Kanebo coagulant were used.

(4) Air Flotation Tests and Filtering Tests: March 5 to March 10

Air flotation tests were done using an air flotation tester brought from Japan. Figure 19-3 shows a cutaway view of the air flotation tester. This tester consists mainly of a pressure water tube, sample tube, and pipes and a pressure gauge. The sample tube holds the sample water to which has been added coagulants. The sample water contains the scum generated by addition of the coagulants. In the pressure water tube water absorbs air under air pressure. When the pressurized water is introduced into the sample tube, dissolved air is released under atmospheric pressure and generates a very large number of minute bubbles. The bubbles attach to the flocs of scum and let them float to the surface. The water remaining in the lower part of the tube is the treated water.

A filter containing anthracite bed and sand bed as filtering elements was assembled in the laboratory. All the flotation-treated water was filtered by this filter and its effects in decreasing the oil content were measured. Figure 19-4 shows the filter structure.

The filter has the following specifications:

-	Tube inside diameter, millimeters	25
-	Tube total length, millimeters	2,000
-	Anthracite bed length, millimeters	750
-	Sand bed length, millimeters	250
-	Shingle bed length, millimeters	100

(5) Activated Carbon Test: March 11

An activated carbon obtained in Trinidad and Tobago was used to test its effects in reducing oil content of the samples of water that have been treated by air flotation but still contain more oil than the target 50 ppm. One volume of the activated carbon was put into two volumes of the flotation-treated water and stirred. After stirring, the water was filtered through filter paper and measured for oil and grease concentration.

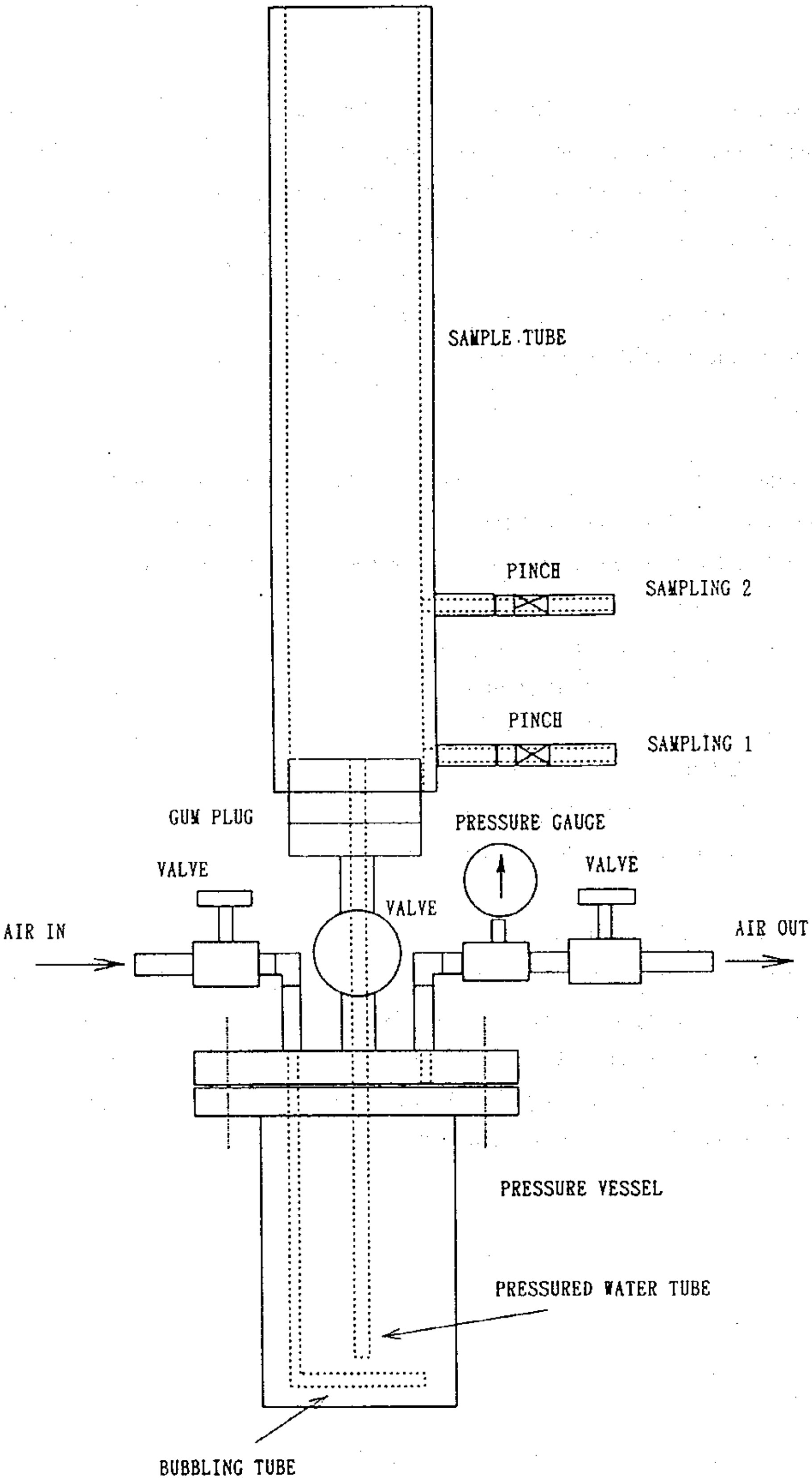

Figure 19-3 Flotation Tester

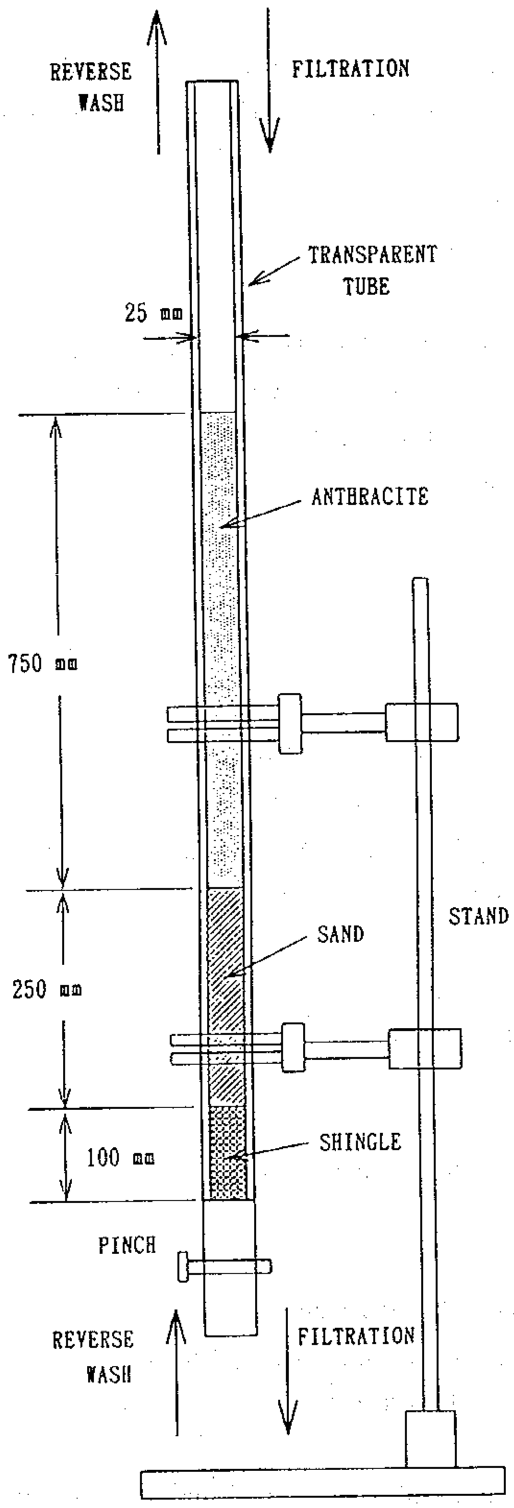

Figure 19-4 Filter

19-4-3 Results of Air Flotation test

Many trials were done to achieve the 50 ppm oil and grease target. Table 19-2 gives all the data. The following are the best results obtained on each sample from the series of air flotation tests.

(1) Bernstein API Outlet Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 10,000 ppm

. Organic coagulant: PN-161 (nonion system) 25 ppm

Scum height produced: 95 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 400 ppm

. After air flotation: 95 ppm

. After filtration: 94 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 500 ppm

. Organic coagulant: Kanebinol-TO 260 ppm

. High molecule coagulant: Kanebinol-L 10 ppm

Scum height produced: 95 mm in 1 liter sample

Oil and grease concentration:

. Original sample: 450 ppm

. After air flotation: 110 ppm

. After filtration: 105 ppm

(2) Bernstein Thermal Wash Tank Bleed Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 10,000 ppm

. Organic coagulant: PA-378 (anion system) 25 ppm

Scum height produced: 80 mm for 1 liter sample

Oil and grease concentration:

. Original sample: over 2,500 ppm (Correlation curve was not prepared for over 2,900 mg/liter since, in the CARIRI's analysis, a thick gelatinous emulsion was formed upon addition of freon, and this emulsion could not be separated.)

. After air flotation: 41 ppm

. After filtration: 36 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 1,000 ppm

. Organic coagulant: Kanebinol-TO 520 ppm

. High molecule coagulant: Kanebinol-L 20 ppm

Scum height produced: 57 mm in 1 liter sample

Oil and grease concentration:

. Original sample: over 2,500 ppm

. After air flotation: 66 ppm

. After filtration: 95 ppm

(3) Bernstein Non-thermal Wash Tank Bleed Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 7,000 ppm

. Organic coagulant: PN-161 (nonion system) 22 ppm

Scum height produced: 50 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 440 ppm

. After air flotation: 280 ppm

. After filtration: 275 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: kanebinol-CL 250 ppm

. Organic coagulant: Kanebinol-TO 130 ppm

. High molecule coagulant: kanebinol-L 5 ppm

Scum height produced: 15 mm in 1 liter sample

Oil and grease concentration:

. Original sample: 730 ppm

. After air flotation: 295 ppm

. After filtration: 290 ppm

Table 19-2 Data of Flotation, Filtration and Activated Carbon Treatment

ORG : Original Sample
TRD : Treated Sample (by Coagulation/Flotation)
FTD : Filtered (after Coagulation/Filtration)
AC-TRD : Activated-Carbon-Treated

Sample No.	Sample Name	Dosing Rate (ppm) Coag't -1	Coag't-2	Polymer	(1) Chemical (Yen/m³)	(2) Oil Concentration (ppm) ORG	TRD	FTD	AC-TRD
BS-1	BS API OL	PAC/ 1000		PA378/ 3	23	1300	170	130	-
		PAC/ 6000		PA378/ 6	126	2500 ↑	125	115	-
		PAC/ 10000		PA378/ 25	225	480	91	-	-
		PAC/ 10000		PN161/ 25	225	400	95	94	-
		PAC/ 10000		PA378/ 25	225	505	87	-	25
		CL/ 500	TO/ 260	L/ 10	270	1500	180	115	-
		CL/ 1000	TO/ 520	L/ 20	540	-	-	-	-
		CL/ 500	TO/ 260	L/ 10	270	450	110	105	-
BS-2	BS THERM WT	PAC/ 10000		PA378/ 25	225	2500 ↑	41	36	-
		CL/ 1000	TO/ 520	L/ 20	540	2500 ↑	66	95	-
BS-3	BS N-THE WT	PAC/ 300		PN161/ 3	9	200	-	-	-
		PAC/ 5000		PA378/ 20	120	350	115	-	-
		PAC/ 7000		PN161/ 22	162	440	280	275	-
		CL/ 250	TO/ 130	L/ 5	135	730	295	290	-
LB-1	LB API OL	PAC/ 150		PA378/ 2	5	360	170	-	-
		PAC/ 6000		PA378/ 20	140	230	118	121	-
		PAC/ 6000		PA378/ 20	140	-	100	-	44
		CL/ 500	TO/ 260	L/ 10	270	260	90	82	-
LB-2	LB THERM WT	PAC/ 6000		PA378/ 20	140	280	103	100	-
		CL/ 1000	TO/ 520	L/ 20	540	260	93	88	-
PF-1	PF API OL	PAC/ 100		PN161/ 1	3	1200	-	-	-
		PAC/ 800		PN161/ 8	24	-	-	-	-
		PAC/ 7000		PA378/ 25	165	600	320	330	-
		PAC/ 7000		PN161/ 20	160	630	370	275	-
		PAC/ 7000		PN161/ 20	160	-	300	-	13
		CL/ 250	TO/ 130	L/ 5	135	2500 ↑	530	490	-
PF-2	PF N-THE WT	PAC/ 5000		PA378/ 20	120	770	360	360	-
		PAC/ 7000		PN161/ 20	160	520	290	290	-
		CL/ 250	TO/ 130	L/ 5	135	510	610	460	-

Sample No.	Sample Name	Dosing Rate (ppm)			(1) Chemical (Yen/m³)	(2) Oil Concentration (ppm)			
		Coag't-1	Coag't-2	Polymer		ORG	TRD	FTD	AC-TRD
RF-1	RF #1 API OL	PAC/ 100		PA378/ 1	3	500	190	175	-
		PAC/ 400		PA378/ 3	11	320	220	215	-
		PAC/ 3000		PN161/ 25	85	290	26	17	-
		CL/ 500	TO/ 260	L/ 10	270	360	53	50	-
RF-2	RF #2 API OL	PAC/ 90		PA378/ 1	3	130	46	81	-
		PAC/ 400		PA378/ 3	11	130	52	50	-
		CL/ 1000	TO/ 520	L/ 20	540	140	28	33	-
RF-3	RF #3 API OL	PAC/ 200		PA378/ 2	6	45	36	36	-
		CL/ 250	TO/ 130	L/ 5	135	44	26	26	-
RF-4	RF #4 API OL	PAC/ 200		PA378/ 2	6	26↓	26↓	26↓	-
		CL/ 500	TO/ 260	L/ 10	270	90	26↓	26↓	-

(1) Chemicals Cost Calculation

PAC System

PAC dosing rate ppm (g/m³)／1000(g) × 20(Yen/kg) = PAC Cost (Yen/m³)
\+ Polymer Dosing Rate ppm (g/m³)／1000(g) × 1000(Yen/kg) = Polymer Cost (Yen/m³)

Total = Chemicals Cost (Yen/m³)

CL-TO System

CL Dosing Rate ppm (g/m³)／1000(g) × 297(Yen/kg) = CL Cost (Yen/m³)
TO Dosing rate ppm (g/m³)／1000(g) × 408(Yen/kg) = TO Cost (Yen/kg)
\+ L Dosing rate ppm (g/m³)／1000(g) × 1538(Yen/kg) = L Cost (Yen/m³)

Total = Chemicals Cost (Yen/m³)

(2) By ASTM D-4281 Freon Method

(4) Los Bajos API Outlet Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 6,000 ppm

. Organic coagulant: PA-378 (anion system) 20 ppm

Scum height produced: 45 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 230 ppm

. After air flotation: 118 ppm

. After filtration: 121 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 500 ppm

. Organic coagulant: Kanebinol-TO 260 ppm

. High molecule coagulant: Kanebinol-L 10 ppm

Scum height produced: 15 mm in 1 liter sample

Oil and grease concentration:

. Original sample: 260 ppm

. After air flotation: 90 ppm

. After filtration: 82 ppm

(5) Los Bajos Thermal Wash Tank Bleed Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 6,000 ppm

. Organic coagulant: PA-378 (anion system) 20 ppm

Scum height produced: 52 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 280 ppm

. After air flotation: 103 ppm

. After filtration: 100 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 1,000 ppm

. Organic coagulant: Kanebinol-TO 520 ppm

. High molecule coagulant: Kanebinol-L 20 ppm

Scum height produced: 60 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 260 ppm

. After air flotation: 93 ppm

. After filtration: 88 ppm

(6) Point Fortin API Outlet Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 7,000 ppm

. Organic coagulant: PN-161 (nonion system) 20 ppm

Scum height produced: 30 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 630 ppm

. After air flotation: 370 ppm

. After filtration: 275 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 250 ppm

. Organic coagulant: Kanebinol-TO 130 ppm

. High molecule coagulant: Kanebinol-L 5 ppm

Scum height produced: 45 mm in 1 liter sample

Oil and grease concentration:

. Original sample: over 2,500 ppm

. After air flotation: 530 ppm

. After filtration: 490 ppm

(7) Point Fortin Non-thermal Wash Tank Bleed Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 7,000 ppm

. Organic coagulant: PN-161 (nonion system) 20 ppm

Scum height produced: 45 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 520 ppm

. After air flotation: 290 ppm

. After filtration: 290 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 250 ppm

. Organic coagulant: Kanebinol-TO 130 ppm

. High molecule coagulant: Kanebinol-L 5 ppm

Scum height produced: 60 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 610 ppm

. After air flotation: 510 ppm

. After filtration: 460 ppm

(8) Pointe-a-Pierre Refinery No. 1 API Outlet Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 3,000 ppm

. Organic coagulant: PN-161 (nonion system) 25 ppm

Scum height produced: 15 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 290 ppm

. After air flotation: 26 ppm

. After filtration: 17 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 500 ppm

. Organic coagulant: Kanebinol-TO 260 ppm

. High molecule coagulant: Kanebinol-L 10 ppm

Scum height produced: 16 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 360 ppm

. After air flotation: 53 ppm

. After filtration: 50 ppm

(9) Pointe-a-Pierre Refinery No. 2 API Outlet Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 400 ppm

. Organic coagulant: PA-378 (anion system) 3 ppm

Scum height produced: 8 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 130 ppm

. After air flotation: 52 ppm

. After filtration: 50 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 1,000 ppm

. Organic coagulant: Kanebinol-TO 520 ppm

. High molecule coagulant: Kanebinol-L 20 ppm

Scum height produced: 40 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 140 ppm

. After air flotation: 28 ppm

. After filtration: 33 ppm

(10) Pointe-a-Pierre Refinery No. 3 API Outlet Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 200 ppm

. Organic coagulant: PA-378 3 ppm

Scum height produced: 4 mm for 2 liter sample

Oil and grease concentration:

. Original sample: 45 ppm

. After air flotation: 36 ppm

. After filtration: 36 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 500 ppm

. Organic coagulant: Kanebinol-TO 260 ppm

. High molecule coagulant: Kanebinol-L 10 ppm

Scum height produced: 13 mm for 1 liter sample

Oil and grease concentration:

. Original sample: 44 ppm

. After air flotation: below 26 ppm

. After filtration: below 26 ppm

(11) Pointe-a-Pierre Refinery No. 4 API Outlet Water

(Kurita)

Dosing rate:

. Inorganic coagulant: PAC 200 ppm

. Organic coagulant: PA-378 2 ppm

Scum height produced: 4 mm for 1 liter sample

Oil and grease concentration:

. Original sample: below 26 ppm

. After air flotation: below 26 ppm

. After filtration: below 26 ppm

(Kanebo)

Dosing rate:

. Inorganic coagulant: Kanebinol-CL 500 ppm

. Organic coagulant: Kanebinol-TO 260 ppm

. High molecule coagulant: Kanebinol-L 10 ppm

Scum height produced: 15 mm in 1 liter sample

Oil and grease concentration:

. Original sample: 44 ppm

. After air flotation: below 26 ppm

. After filtration: below 26 ppm

19-4-4 Evaluation of Air Flotation Test

The following conclusions could be drawn from the results of the above air flotation tests.

- Both coagulants, Kurita and Kanebo, are almost equivalent in effectiveness for the waste waters tested. Selection may depend on cost.

- All treated waters were very clear, almost colorless and transparent. Air flotation was found very effective in removing oil particles from the emulsions in the waste water tested. However, in certain waste waters, oil concentration of the treated water did not meet the oil and grease target of 50 ppm. This should be considered to be the limit of air flotation.

- The volume of scum collected is large. The flotation scum must be treated as oily sludge; therefore, it is expected that the capacity of treatment facilities will be large.

- Compared with the thermal bleed water, the non-thermal bleed water was found more difficult to treat. The reason for this is not identified.

- The anthracite-plus-sand filter was not effective for the waste waters tested. The reason may be that, in the flotation-treated water, there remains almost no oil particle large enough to be removable by such a filter.

- Regarding the outlet waters of the API separators at Bernstein, Los Bajos and Point Fortin tank farms, air flotation tests could not achieve the target level of 50 ppm oil and grease. The objective of the study is to reduce oil content of the effluent streams to below 50 ppm. Since these waters are discharged to public rivers, the target of 50 ppm must be achieved. To confirm that there is a sure measure to achieve the 50 ppm target, the following activated carbon adsorption test was done.

19-4-5 Activated Carbon Test

One volume of the activated carbon was put into two volumes of air-flotation-treated water sample in a beaker and stirred. After this, the water sample was separated from the activated carbon by filtration through filter paper and its oil content was measured. The results are as follows:

Bernstein

. Air flotation treated water: 87 mg/liter oil and grease

. After activated carbon treatment: 25 mg/liter

Los Bajos

. Air flotation treated water: 100 ppm oil and grease

. After activated carbon treatment: 44 ppm

Point Fortin

. Air flotation treated water: 300 ppm oil and grease

. After activated carbon treatment: 13 ppm.

The above results show that the 50 ppm target is achievable for all the waste waters tested. Normally, installation of air flotation is enough to reduce the oil content to less than 50 ppm in the case of usual refinery waste water; however, the waste waters in the study area are special in their characteristics.

To establish an economic means of achieving the 50 ppm target using activated carbon or other methods such as biological treatment, and to obtain data necessary for the conceptual design, further experiments were considered necessary. Therefore, the study team brought 40 liters of the Bernstein API separator outlet water back to Japan. The water was considered representative in difficulty of treating. Using this water, further tests were done during the second home-office work period.

19-5 Tests Performed during the Second Home-Office Work Period

A series of tests on the outlet water of Bernstein API separator were performed at the Research and Development Center of Kurita Water Industries Co. LTD.

19-5-1 Purpose of the Tests

The purposes of the tests were as follows.

(1) Reconfirmation of the Results of Jar Tests and Air Flotation Tests

One purpose was to reconfirm whether the oil and grease target of 50 ppm in the treated water is achievable by air flotation if the right coagulant and operating conditions are selected. A series of jar tests and air flotation tests were carried out for this purpose.

(2) Study of Post-treatment

The other purpose is to study the possibility of further treating the water if air flotation alone proved unable to achieve the 50 ppm target. The candidates were adsorption by activated carbon, biological treatment, and any other process that Kurita could recommend. For the purpose of this study, the capacity was assumed to be 200 cubic meters per hour, corresponding to 30,000 bpd of crude oil at Bernstein Main Storage.

1) Activated Carbon Treatment

In this case the purpose is to confirm the feasibility of this technology and develop the most economical treating conditions, to develop a configuration of the facility, construction and operating costs.

2) **Biological Treatment**

In this case the purpose was to study the feasibility of achieving the 50 ppm target by biological treatment, and if it proved feasible, to select the right facilities, estimate construction and operating costs, and develop key operating factors.

19-5-2 Test Results

(1) Reconfirmation of the Results of Jar Tests and Air Flotation Tests

1) **Reconfirmation of the Air-flotation Tests**

Table 19-3 shows the results of the test. The most effective inorganic coagulant and polymers were selected first; then, air flotation tests were done using the selected coagulant. The coagulants selected were PAC (Poly Aluminum Chloride) and liquid alum (Aluminum Sulfate) as inorganic coagulant, and a combination of Kurita-made polymer coagulant PA322 (anion system) and CP948 (cation system). Oil concentration was measured by two methods, carbon tetrachloride extraction followed by infrared rays absorption and the normal-hexane extraction gravimetric methods. Test results are summarized below.

1. As was the case with the experiments done in Trinidad and Tobago by the study team during the second field survey, air flotation alone failed to achieve the 50 ppm target.
2. A difference between PAC and alum was not noticed as far as coagulation effectiveness was concerned.
3. Regarding selection of polymer, a combination of anion system and cation system proved to be best in the effect on coagulation.
4. Calcium chloride was dosed to test applicability to pre-treatment of flotation. Its effectiveness was not clear.

2) **Activated Carbon Test**

Powdered activated carbon was added to pure water at a rate of 10 percent and thoroughly dispersed. This suspension was added to the air-flotation-treated water and vigorously stirred for 10 minutes at 150 rpm; then the treated water was measured for oil content.

It was confirmed that treatment by activated carbon can attain the 50 ppm target, as was the case with the tests done in Trinidad and Tobago.

3) BOD Measurement

The water treated by air flotation, but not by activated carbon, showed BOD values from 63 to 78 ppm.

(2) Study on the Post-treatment Facility

It became evident on the basis of the results of the tests explained above that the dissolved air flotation with coagulation alone cannot achieve the 50 ppm target. A series of tests were done by the Research and Development Center of Kurita Water Industries Co. to identify a proper post-treatment method that can reduce oil content of the flotation-treated water to less then 50 ppm. The following tests were done for this purpose:

1. Detailed analysis of the sample water,
2. Batch tests on biological treatment,
3. Tests on activated carbon Treatment.

Table 19-3 Experiments done in the Second Home-office Period

(Sample: Bernstein API separator outlet water)

Dosing rate Inorg'c. Coal't (ppm)	Dosing rate Polymer (ppm)	Activ'd carbon (ppm)	State of floc Float'g speed (m/hr)	State of floc Vol. (%)	pH	Treated water Oil CCl_4 (ppm)	Treated water Oil n-Hex (ppm)	Treated water BOD (ppm)
Liq. Alum/3,500 Liq. Alum/3,500	PA322/05 CP948/20	500	30	4.0	7.4	75	127	60
Liq. Alum/3,500 Liq. Alum/3,500	PA322/05 CP948/20	2,000	25	6.0	7.4	36		41
Liq. Alum/3,000 Liq. Alum/3,000	PA322/05 CP948/20		30	4.0	7.6	139	70	78
Liq. Alum/2,000 Liq. Alum/2,000	PA322/05 CP948/20		25	6.0	5.9	60		63
PAC/10,000	PA211/10 CP948/40		20	15.0	6.8	95	37	

$CaCl_2 2H_2O$/5,000	PA322/10
Liq. Alum/3,000	CP948/40

Note: 1. Activated carbon test: Dosing 10 percent suspension of activated carbon dispersed in water, and stirring for 10 minutes at 150 rpm.

1) Detailed Analysis of the Sample Water

Table 19-4 shows the results of detailed analysis of the Bernstein API separator outlet water.

It is concluded from the above data that coagulation treatment is effective in removing organic substances as exemplified in the form of SS (Suspended Solid) as well as in reducing the contents of CCl_4 solubles and N-Hexane solubles.

Table 19-4 Analysis Data of Sample Water

(Unit: mg/liter)

Analysis Item	Original sample	Coagulation treated water
pH	8.5	7.8
CODmn	700	275
CODcr	2,770	1,020
BOD5	89.0	31.0
TOC	551	264
SS	480	-
K-N	30.8	25.8
NH4-N	26.6	25.6
T-P	0.4	less than 0.1
PO4-P	3.0	1.4
N-hex solubles	745	99.0
CCl_4 solubles	985	187

Note: Coagulation treatment: Alum 3,500ppm, PA331 2ppm, pH neutral

The coagulation-treated water was almost transparent though slightly colored yellow or brown. The BOD value of this treated water was 31 mg/liter and the ratio of BOD_5 to CODcr was 0.03. Consequently, this sample water was evaluated as difficult to be treated by biological means.

2) Batch Test of Biological Treatment

Tests on biological treatment were done using a sludge that had been acclimated for five days.

The results of the tests are shown in Figure 19-5. The tests measured chronic changes of TOC being decomposed by the action of bacteria. The concentration of TOC remained virtually unchanged even after 48 hours. This indicates that the water is difficult to treat by biological methods. The low ratio of BOD_5 to CODcr mentioned indicates that the substances contained in this water, which have been extracted from crude oil, are not susceptible to biological decomposition. The concentration of N-Hexane solubles measured 24 hours after the start of test was 112 mg/liter, virtually unchanged within the accuracy of the test method. On the ground of the these results, biological means may be judged unable to achieve the 50 ppm target with this air flotation-treated water. The substances dissolved in this water and recognized as N-Hexane solubles were not identified by this analysis, but they could be naphthenic or aromatic high-molecular compounds.

3) Activated Carbon Treatment

Figure 19-6 shows the results of the tests on activated carbon adsorption. The test results show that the adsorptivity of the activated carbon with respect to TOC is high enough to reduce it to about 40 mg/liter. Also, N-Hexane solubles can be reduced to less than 10 mg/liter by the very high adsorptivity of activated carbon. It is concluded, therefore, that treatment by activated carbon is a very effective measure for removing N-Hexane solubles, and that efficiency in the utilization of activated carbon for achieving the 50 ppm oil concentration is very high.

Figure 19-7 shows the relationship between TOC removal and the concentration of N-Hexane solubles. This figure indicates the existence of a good proportional relationship between these two in the range below 10 mg/liter. Consequently, it may be seen from this figure that the reduction of TOC by activated carbon treatment to less than 166 mg/liter is a good measure for controlling the concentration of N-Hexane solubles to less than 50 ppm.

Using these results, a simulation was done to specify the necessary design conditions of the activated carbon treatment process. The result of the simulation is shown in Figure 19-8.

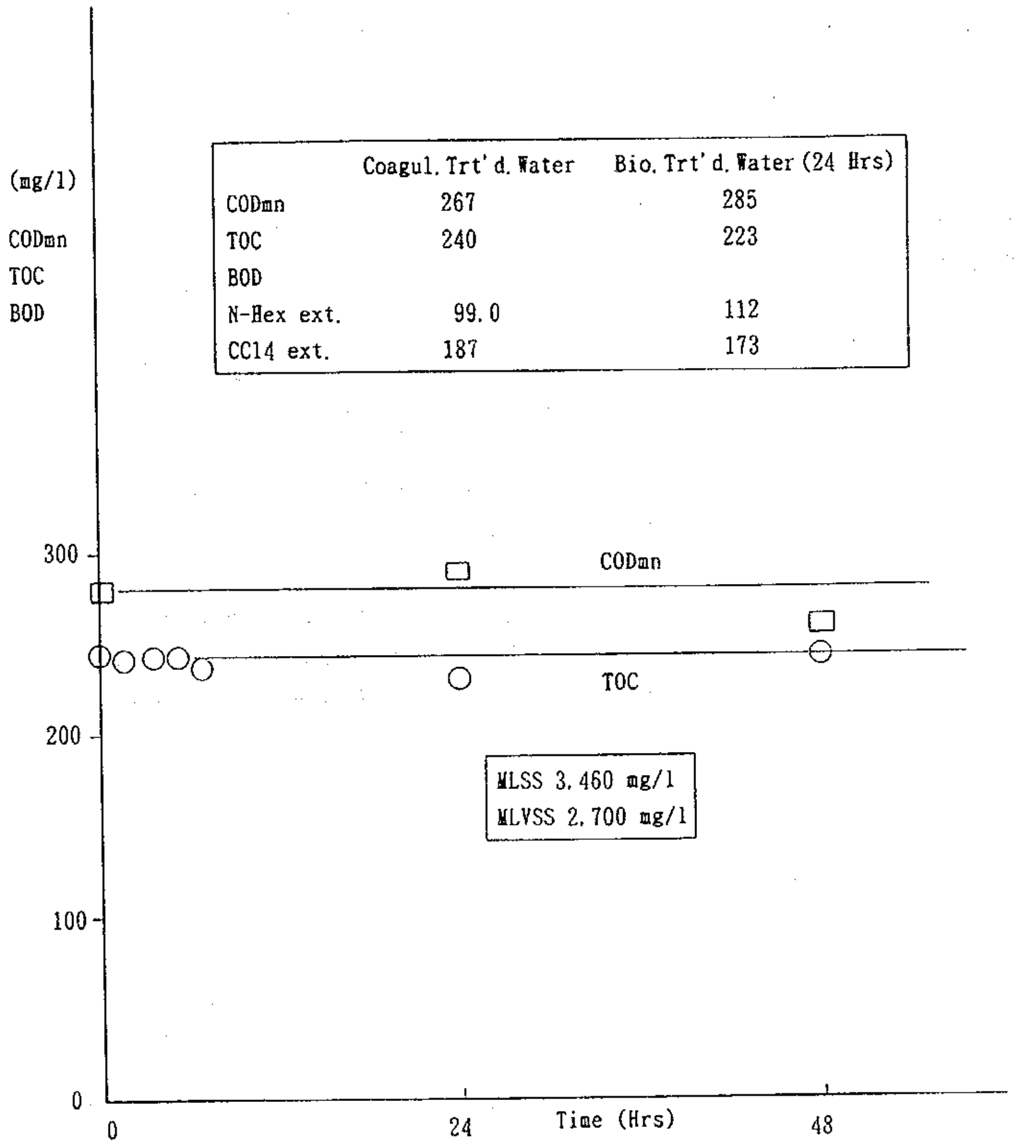

Figure 19-5 Batch Test of Biological Treatment

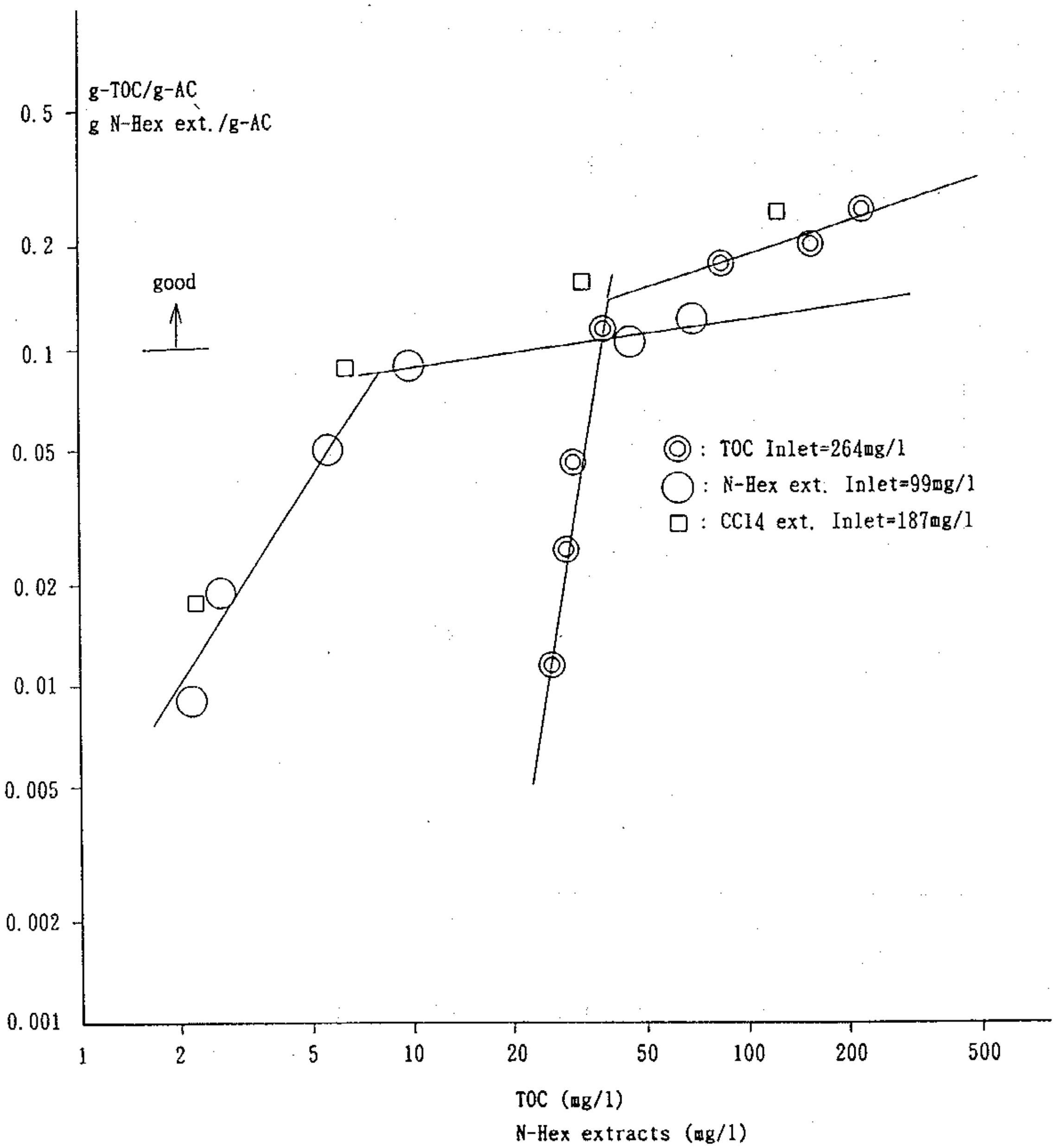

Figure 19-6 Activated Carbon Equilibrium Adsorption Isotherm

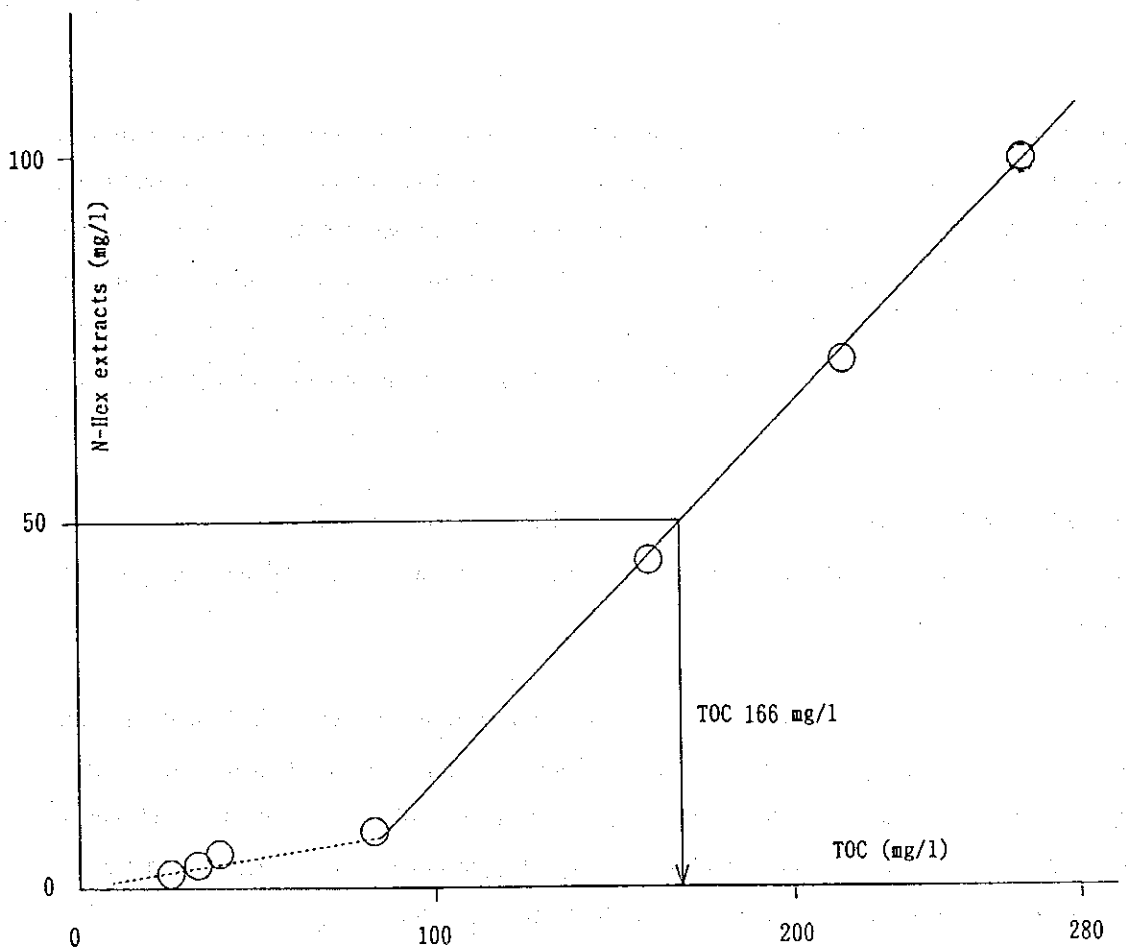

Figure 19-7 Relationship between TOC and n-Hex Extracts

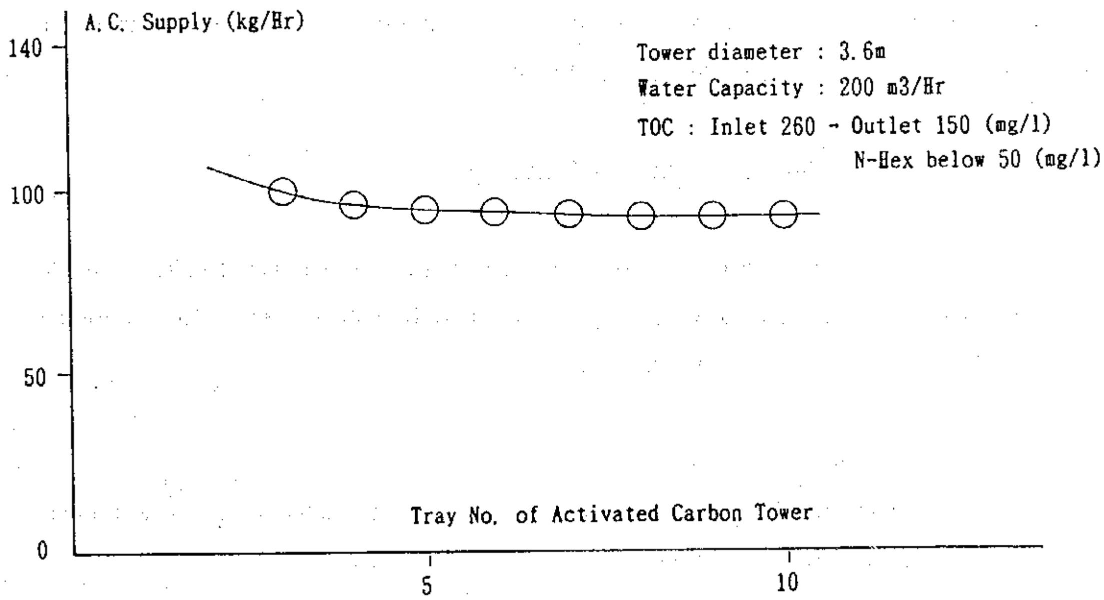

Figure 19-8 Relationship between Activated Carbon Supply and Tray No.

It has been found as a result of the simulation that the number of trays does not make a significant difference in the consumption of activated carbon, if there are five or more trays. Therefore, the number of trays should be five in practice. The quantity of activated carbon to be fed is 93 kg/hr (2,232 kg/day) for treating 200 m^3/hr of water. The efficiency of activated carbon utilization is higher than 95 percent and the adsorption rate is very high, 0.237 kg-TOC/kg-AC. From this simulation, it is concluded that activated carbon treatment can be applied to this water very effectively.

(3) The Results of Tests performed in the Second Home-Office Period

The results of a series of tests done during the second home-office work period are summarized as follows.

Dissolved air flotation with coagulation was a very effective in removing oil from the sample water; that is, the oil existing as oil-in-water emulsion. Therefore, oil contained in the water at high concentrations can be almost thoroughly removed by applying this method. However, application of this method alone cannot achieve the 50 ppm target, since about 100 ppm of N-Hexane solubles still remain dissolved in the flotation-treated water.

Therefore, proper post-treatment is necessary downstream of dissolved air flotation with coagulation. Biological treatment which generally works well for such a purpose, has been found not effective for this water. Instead, the activated carbon process has been found to be very effective for this water. By adopting the activated carbon process, the 50 ppm target of the treated waste will be achieved very effectively and easily.

19-6 Experiments Done during the Third Field Survey

The air flotation unit to be constructed in Trinidad and Tobago will use locally available coagulants. The study team conducted an experiment to confirm their effects using the outlet water of the API separator of Bernstein Main Storage.

1. Coagulant

   Alum actually being used by a household waste water treating plant near Pointe-a-Pierre Refinery was used.

Supplier: Caribbean Export LTD. (Kingston. Jamaica)

Package: Powdered alum packed in 25 kilogram bags.

2. Polymer

The study team was unable to obtain one locally; therefore, Kurita's PA331, an anionic polymer coagulant, was used.

The locally procured alum was found equally effective to the Japanese alum and could be used for the air flotation.

The dehydrated scum produced with the locally procured alum was handed over to Trinidad Cement Limited to be used in their study on the possibility of feeding the scum to the cement kiln.

19-7 Conclusion

Information and data required for the conceptual design of the waste water treatment process were obtained through a series of experiments and tests. The conceptual design aims to reduce the oil content of the waste water streams effluent from oil-related installations in Trinidad and Tobago to less than 50 ppm. Experiments and tests carried out were: preliminary experiments done in Japan on samples of genuine Trinidad and Tobago water, experiments conducted during the second field survey period in Trinidad and Tobago mainly on air flotation and relevant technologies, and tests performed during the second home-office work period on the sample of genuine water brought back to Japan. The results are summarized below.

19-7-1 Characteristics of Trinidad and Tobago Waste Water

The waste water treating facilities currently operated by the oil installations in the study area are only gravity-induced separators such as API separators and guard basins. Oil concentration in the effluent water discharged from these installations ranges from several hundred to several thousand ppm, which largely exceeds the 50 ppm target of this study. Such high concentrations of oil are attributable mainly to the oil-in-water emulsions generated by the EOR using steam injection. These emulsions cannot be separated into oil and water by the function of gravity-induced separators. Waste water containing such a highly concentrated emulsion has seldom been experienced in Japan.

19-7-2 Effectiveness of Dissolved Air Flotation with Coagulation

Dissolved air flotation with coagulation is very effective in treating waste water containing such emulsions. It effectively removes such emulsions almost entirely. PAC and alum were tested as being representatives of inorganic coagulants, both exhibiting nearly equal effectiveness in coagulation. Alum is preferred for practical application in Trinidad and Tobago, because of its ready availability and better cost performance ratio. Adequate dosage will be about 3,500 ppm. As for polymer coagulants, an anion type at 5 ppm plus a cation type at 20 ppm were steadily effective.

19-7-3 Necessity of Post-treatment

All the samples treated by dissolved air flotation with coagulation became almost transparent at high dosages of the coagulant. This is indicative of the effectiveness of this process when applied to the waste waters of Trinidad and Tobago.

It has been confirmed that the effluent streams of water from all the API separators of Pointe-a-Pierre Refinery can meet the 50 ppm target by dissolved air flotation with coagulation. However, those from the API separators at the Bernstein, Los Bajos and Point Fortin tank farms still contain about 100 ppm of oil after treatment by dissolved air flotation with coagulation, though the water becomes transparent. This fact suggests that some of the N-Hexane solubles, which are also soluble in water, cannot be removed by the dissolved air flotation with coagulation alone and remain dissolved in the treated water. Therefore, it is necessary to install a proper post-treatment facility downstream of the air flotation process to decrease the dissolved substances to less than the 50 ppm target.

19-7-4 Activated Carbon Process as Post-treatment

In light of the results of tests done on the effluent water from the Bernstein API separators brought back to Japan, the activated carbon process has proved to be the proper choice as post-treatment. Biological processes, generally preferred for such purpose because of lower operation costs, have been found almost ineffective for this water. Instead, the activated carbon treatment proved fit to this water and can effectively achieve the target. The activated carbon process is the right post-treatment placed downstream of the dissolved air flotation with coagulation process, to be installed at the tank farm. In the light of the results of experiments and tests performed so far, there is no possible alternative to activated carbon adsorption.

19-7-5 Importance of Waste treatment

A large quantity of combustible waste will be generated with the operation of dissolved air flotation with coagulation units. These wastes should be burned properly after applying adequate pretreatment, of which details are mentioned in Chapter 13.

Chapter 20 Project Scheme for the Master Plan

Chapter 20 Project Scheme for the Master Plan

This chapter presents the project scheme. The project scheme is defined as a proposed program for installation of new facilities and modifications of the existing ones necessary to achieve the 50 ppm oil target in the most economical and efficient way, based on the outcomes of all the preceding work as explained in the previous chapters. Discussions on the key issues elaborated in Chapter 18 and the results of the experiments given in Chapter 19, in particular, are instrumental to the development of the proposed project scheme. The project scheme has been developed within the framework of the Scope of Study agreed upon between the Ministry of Energy and Energy Industries and the Preparatory Study Team of JICA.

Establishment of the project scheme was the most important objective of the third field survey conducted from July to August 1994. The study team presented the Interim Report before arrival of the team in Port of Spain. The counterpart and the study team fully discussed the Interim Report, Chapter 18 in particular, "Key Issues in Pollution and Pollution Prevention." During the third field survey, the counterpart and the study team frequently discussed various key issues and the whole program, or the project scheme. At the closing stage of the third field survey, the study team presented a progress report which explained, among other things, the project scheme on which the counterpart and the study team agreed.

The project scheme has remained basically unchanged except that the amount of oily waste water in Pointe-a-Pierre Refinery has changed from the agreed 200 to 250 cubic meters per hour on the basis of more detailed estimates.

20-1 Definition of the 50 ppm Target

The 50 ppm target is not the concentration of pure hydrocarbons dissolved in the water effluent from the petroleum facilities but 50 milligrams per liter of oil and grease as measured by the ASTM Testing Method D-4281, Freon Extraction Method. The oil and grease content indicated by the ASTM method could include substances other than pure hydrocarbons soluble in freon. This definition is very significant in the development of the project scheme, because the effluent stream of the dissolved air flotation facility proposed at Bernstein would not have to be treated by activated carbon if the target level were defined as pure hydrocarbons contained in water having less than 50 ppm.

20-2 Waste Water Treatment in Pointe-a-Pierre Refinery

The main features of the proposed program for Pointe-a-Pierre Refinery are as follows:

1. Oily water flows and non-only water flows should be separated in principle. However, upon thorough inspection of the sites, it has been found difficult in certain areas to prevent storm water from flowing into the oily water streams with the existing facilities duly taken into consideration. Therefore, the waste water treating system must accept a marginal amount of storm water and hence needs a slight marginal capacity in excess of the estimated oily water flow rate.

2. The amount of oily water after the planned upgrading project is estimated at 250 tons per hour. This figure does not include water from the barometric condensers at the vacuum distillation units for the lubricating oil complex. The amount of this water alone is estimated at more than 200 tons per hour, which would put a heavy load on the planned water treating system. The project scheme specified replacement of these barometric condensers by surface condensers.

3. Oily water is collected from a large number of places of origin by two above-ground piping systems, one for plain oily water and the other for chemical oily water, which converge to the central water treating system. Pits and pumps are installed as required to collect, store and inject oily water into the piping systems. Oily water includes: water bled from tanks, desalter effluent, overhead condensed water from distillation columns, water carrying oil leaking from stuffing boxes of pumps, water leg occasionally drained from processing facilities, water collected within areas enclosed by spill walls, etc. Non-oily water includes: storm water, cooling water for tubular coolers and condensers, discharge from the cooling towers, etc.

4. The central waste water treating system will have four buffer tanks, one CPI, one dissolved air flotation unit, and will be designed to meet the target 50 ppm on a monthly average and 75 ppm on a daily maximum. Provisions will be made to tide over troubles with pumps and other key machines with the necessary inventory of spares. However, a standby train to cope with total failure of the system will not be provided in view of the very remote possibility of such a case.

5. The existing water treating systems -- oil sumps, API separators and guard basins -- are used for treatment of non-oily water streams. The non-oily streams will carry down the oil trapped in the sewage system for a while after non-oily flows have been completely separated from the oily water streams. Eventually, non-oily streams will become free from oil.

6. The basic design conditions of the central waste water treating system are:

(1)	Flow rate, cubic meters per hour:	250
(2)	Oil content of water at CPI inlet, mg/liter:	500
(3)	Oil content of water at DAF intlet, mg/liter:	400
(4)	Oil content of water at DAF outlet, mg/liter:	<50

Note: DAF stands for dissolved air flotation unit.

The proposed configuration and location of the waste water treating system are shown on Figures 20-1 and 20-2, respectively.

20-3 Waste Water Treatment at Bernstein Main Storage

Bernstein Main Storage is selected as the representative production facility mentioned in the scope of work as having all features of the production facilities in the study area. The proposed program for Bernstein Main Storage is as follows:

1. A waste water treatment system consisting of one train of dissolved air flotation with coagulation unit and activated carbon adsorption unit will be installed. In view of the very remote possibility of total failure of the system, a standby train will not be provided.

2. The capacity of the waste water treating system is 400 cubic meters per hour.

3. The waste water from Los Bajos Main Storage is sent to Bernstein Main Storage over a distance of 12 kilometers, by a water pipeline of 8 inches diameter.

4. The basic design conditions of the waste water treatment system in Bernstein Main Storage are as follows:

(1)	Flow rate, cubic meters per hour:	400
(2)	Oil content of water at inlet to the system, mg/liter:	1,675

(3) Oil content of water at DAF inlet, mg/liter: 1,000

(4) Oil content of water at ACA outlet, mg/liter: <50

Note: ACA stands for activated carbon adsorption unit.

The proposed configuration and location of the waste water treating system are shown on Figures 4-3 and 4-4, respectively.

20-4 Dams and Catches

The dams and catches will not be expanded to accommodate storm conditions for the reasons explained in Chapter 18-3, "Dams and Catches."

20-5 Waste Treatment Centers

Two waste treatment centers are proposed, one in Pointe-a-Pierre Refinery and the other in Bernstein Main Storage. The waste treatment centers will vary both in scale and configuration depending upon whether Trinidad Cement Limited accepts either of the middle-layer emulsion or scums, or both or none. Whatever decision TCL may make, this study needs to develop its own program for disposing of all oil-containing wastes.

The basic design conditions of the waste treatment centers are as follows:

Pointe-a-Pierre Refinery:

(1)	Scum (moisture 91 wt.%), tons per hour	2.0
(2)	Middle-layer emulsions, barrels per day	33
(3)	Water/oil ratio of the middle-layer emulsions	35/65.

Bernstein Main Storage:

(1)	Scum (moisture 97.9 wt%), tons per hour	32.2
(2)	Middle-layer emulsions, barrels per day	75
(3)	Water/oil ratio of the middle-layer emulsions	35/65.

It is a pre-requisite of the designs that the sludges from cleaning of tanks and separators will not be dumped in earthen pits but will be treated in Petrotrin's expanded bio-remediation project.

Disposal of spent lubricating oils to be collected from service stations and maintenance shops will be best done by expanding Petrotrin's ongoing plan to reuse the spent lubricating oil.

20-6 Schedule of Implementation

The schedule of implementation may be considered as follows assuming that each step proceeds efficiently. Considering the present condition of petroleum pollution, each step must be expedited.

		Months
First year		
1.	Study of this report	2
2.	Approval by the government	3
3.	Negotiation with financiers	6
4.	Application for finances	1
Second year		
5.	Selection of consultants	2
6.	Basic engineering	4
7.	Preparation of BID documents	2
8.	Invitation for BID	1
9.	Evaluation of tenders	1
10.	Contract with the contractor	2
Third year		
11.	Engineering, design, construction	12
Fourth year and on		
12.	Operation	

Much of the technical work can be done by Petrotrin. Petrotrin's active participation can expedite each step.

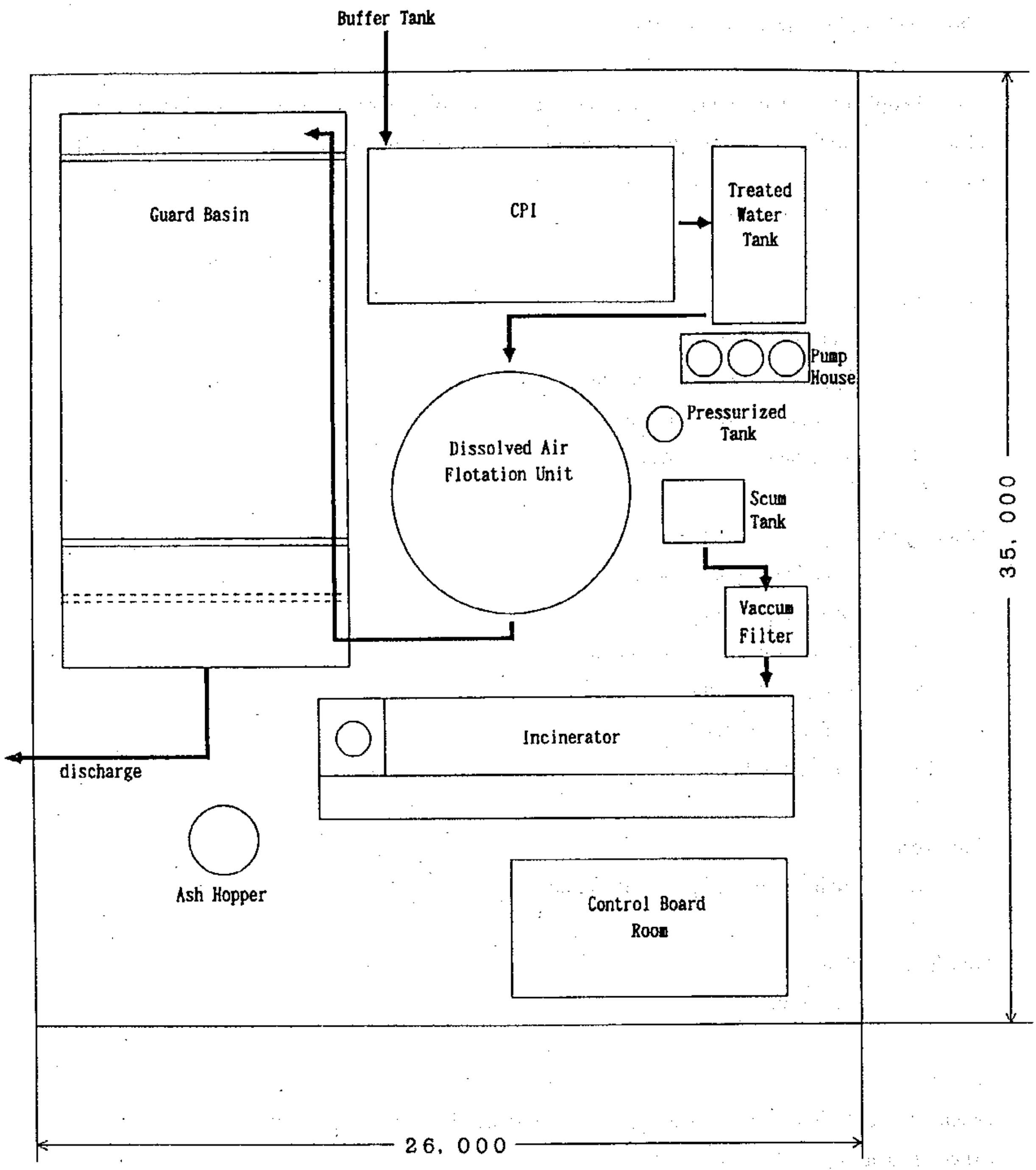

Figure 20-1 Configuration of Waste Water Treating System in Pointe-a-Pierre Refinery

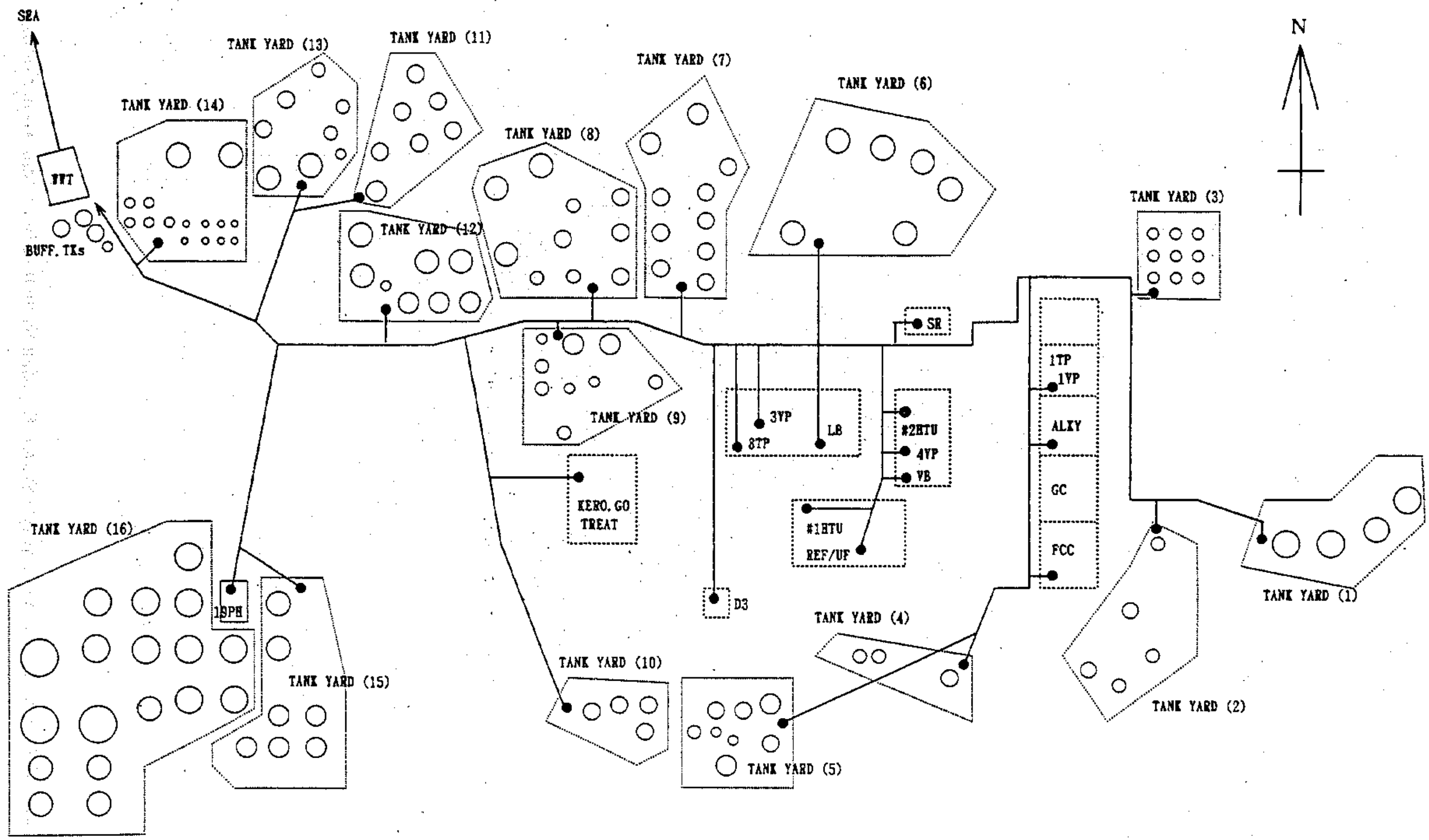

Figure 20-2 Location of Waste Water Treating System and Waste Treatment Center in Pointe-a-Pierre Refinery

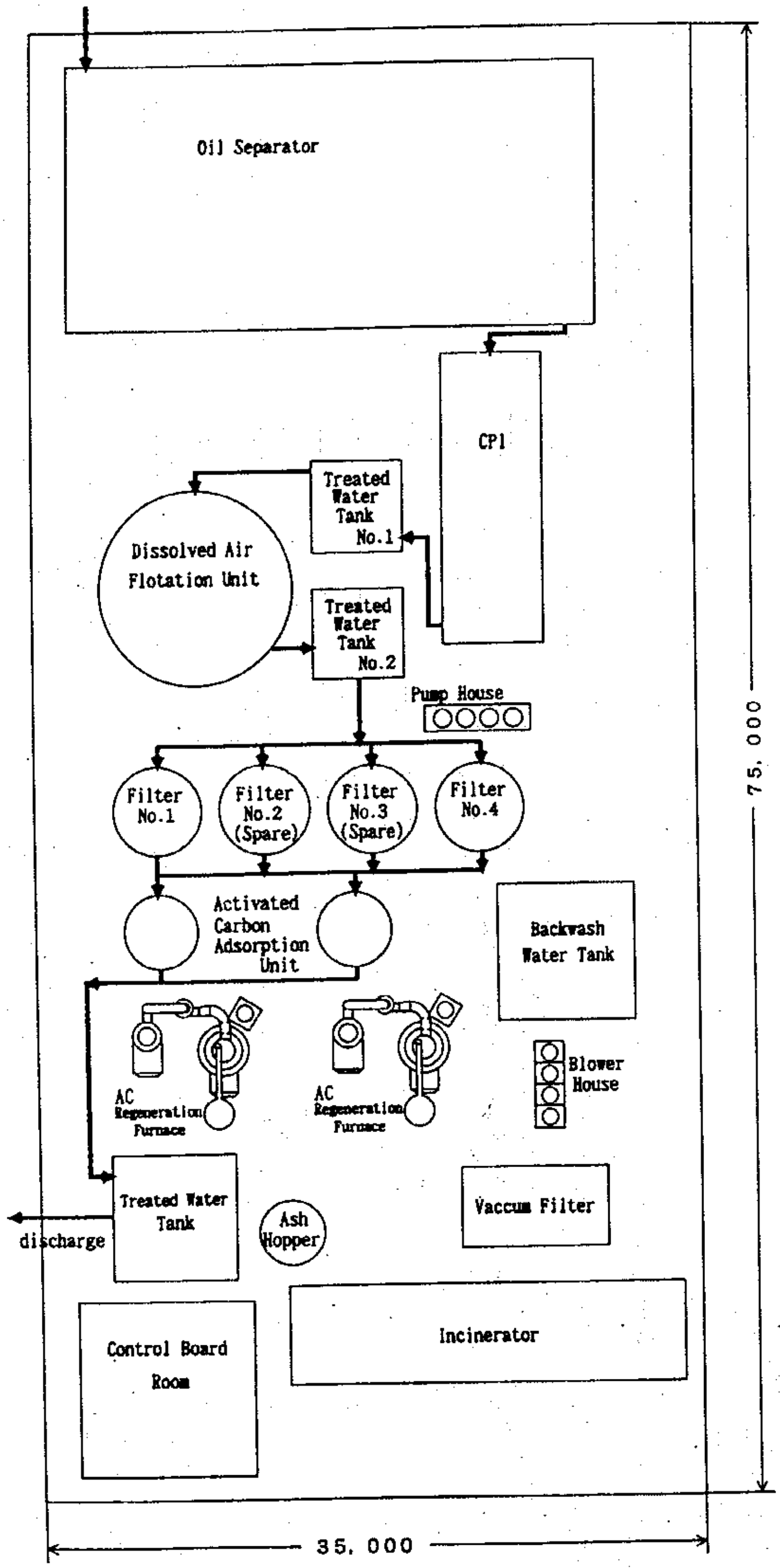

Figure 20-3 Configuration of Waste Water Treating System in Bernstein Main Storage

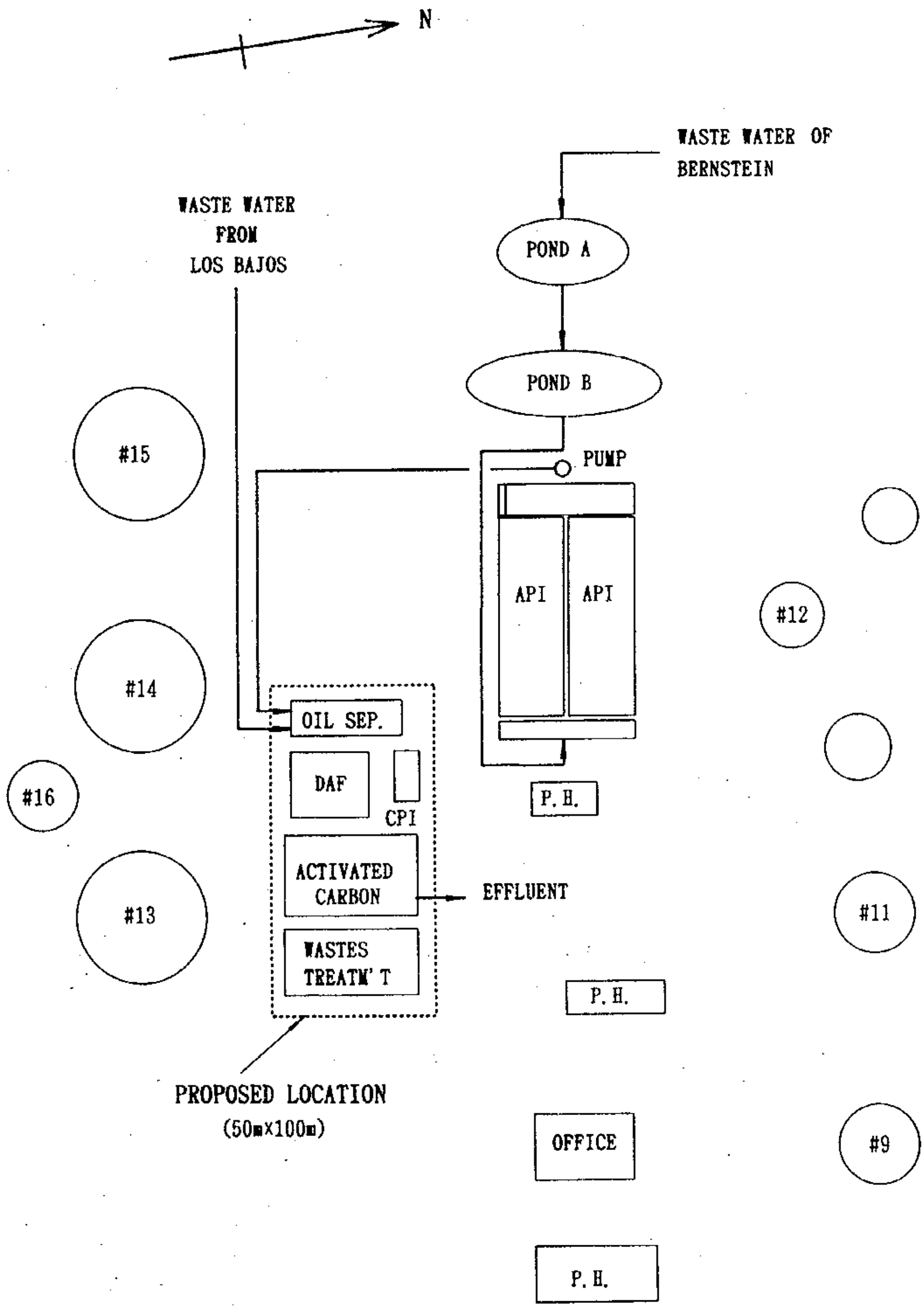

Figure 20-4 Location of Waste Water Treating System and Waste Treatment Center in Bernstein Main Storage