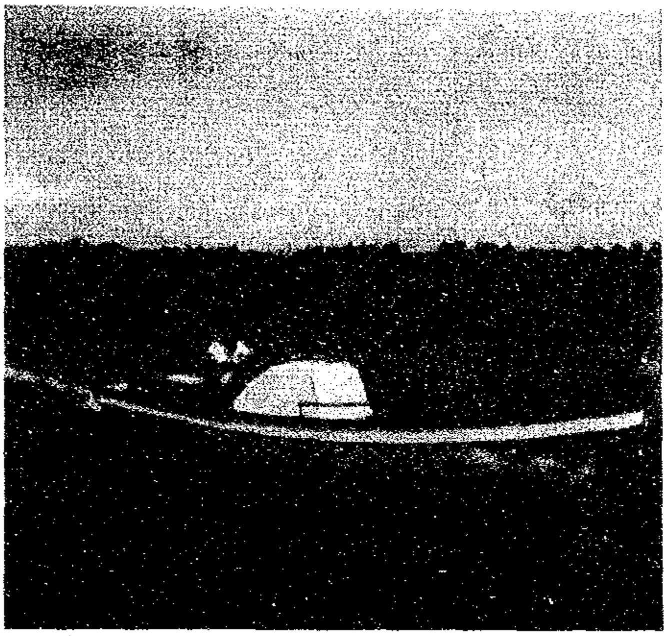


Fig. 5.3.5: Oil Fence Extension Ship

For these facilities, about 3 to 4 hours is necessary to extend the oil fence of 1,300 m length. Therefore, the oil monitoring system must be located in a position whereby it can give alarm 5 hours in advance of the spill.

5.3.5 Improvement of Existing Sea Water Intake Facility of Umm Al Nar Plant

As mentioned above, the surface sea water is introduced into the station by the existing No.1 to 3 sea water intake systems under some tidal conditions. Therefore, it is almost impossible to prevent oil invasion if an unexpected oil spill accident were to occur.

Therefore, the improvement of the existing sea water intake system so as to be able to avoid invasion of surface oil into the station, would be an effective measure to prevent oil contamination. Using the sea water intake system as shown in Fig. 5.3.6, inflow of not only surface water but also contaminated sediment from the sea bottom could be avoided. The abrasion of the system caused by sand intake would be reduced by this improvement.

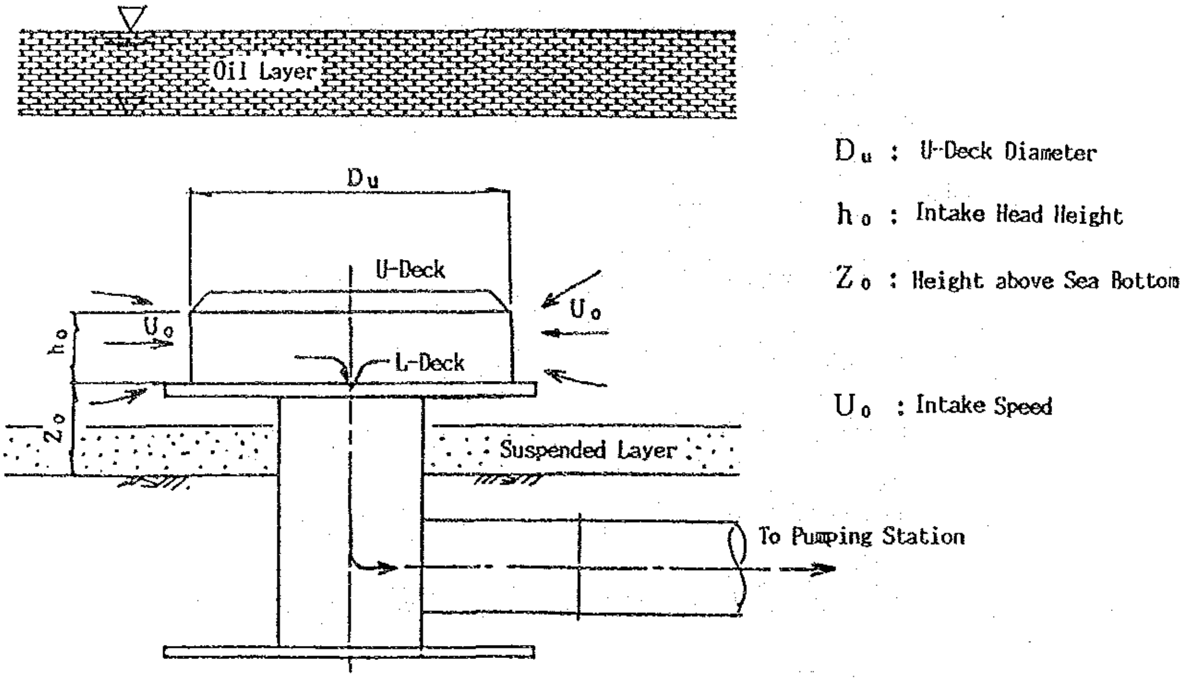


Fig. 5.3.6: Facility for Intake of Water from Middle Layer

The above mentioned measures to prevent the oil contamination including intake head as shown in Fig. 5.3.6, are only effective against surface oil invasion, but not entirely effective against floating oil such as emulsion oil.

Therefore, improved intake includes aeration on system which is one of the effective countermeasure to prevent oil contamination by floating oil.

(1) Study on Shape of the Intake Head

1) Condition of Study

* Water Depth

The sea water intake head will be located at the middle point between the embankment of Umm Al Nar Station and the offshore sea route. According to the results of site investigation, the depth in this area is assumed to be about ACD -6.00m and the water depth "h" at the lowest tide is 6.3m.

* Thickness of Oil Film

Generally, oil film thickness floating on the sea surface is about several micron meters to several centimeters. As the aeration system will be installed around the intake head, the influence of aeration must be considered. The intake head is designed so as to avoid flow of sea water from the thickness of horizontal surface flow which is caused by aeration, which is called "friction depth", is assumed to be same with oil film thickness.

According to the past report, friction depth also depends on the air quantity.

The following formula is applied, for small air quantity.

$h_d = 0.3\ h$

where,

h_d: friction depth
h: water depth

Friction depth is assumed to be the same as the oil film thickness.

$h_d = 0.3 \times 6.3 = 1.89 \fallingdotseq 2.0\ m$

2) Study on Critical Intake Height

According to a report by WRPC (1985), in compliance with the request by Ministry of International Trade of Industry, Japan, intake conditions necessary to avoid contamination by surface oil film, are given by the following formula.

$$\frac{\Delta h}{h_0} = 0.279\ F_i^{1.47}$$

where,

Δh: Critical intake height (Refer to Fig. 5.3.6)
h_0: Height of intake mouth
F_i: Internal Froude number

3) Specification of Intake Head

According to the above mentioned formula, each of the dimensions of the intake heads necessary so that contamination will not occur due to surface oil, is given in Table 5.3.1.

Table 5.3.1: Specification of Intake Head

Sea Water Intake / Items		No. 1	No. 2	No. 3
Total Sea Water Intake Quantity		61.0 m^3/s	50.0 m^3/s	15.3 m^3/s
No. of Intake Heads		2 sets	2 sets	1 set
Intake Quantity per Head		30.5 m^3/s	25.0 m^3/s	15.3 m^3/s
Height above Seabed	Zo	1.5 m	1.5 m	1.5 m
Height of Inlet	ho	2.0 m	2.0 m	2.0 m
U-deck Diameter	Du	15.0 m	12.0 m	8.0 m
Intake Velocity	Uo	0.36 m^3/s	0.37 m^3/s	0.34 m^3/s
Critical Intake Height	h	0.20 m	0.20 m	0.17 m

(2) Diameter of Sea Water Intake Pipe

Sea water is introduced from the newly installed intake head to the presently used intake gate through pipes. The most suitable pipe diameter is decided considering various costs such as construction cost, running cost and depreciation cost. The procedure to decide the most suitable pipe diameter is carried out by calculations for several different pipe diameters. The most suitable pipe diameter is as shown in Table 5.3.2.

Table 5.3.2: Most Suitable Pipe Diameter

Sea Water Intake / Items	No. 1	No. 2	No. 3
No. of pipe	2 sets	2 sets	1 set
Most Suitable Diameter	34,800 mm	34,400 mm	33,400 mm
Loss Head	38 cm	41 cm	41 cm

(3) Study on the Aeration system

1) Location of the aeration system

If the aeration system is installed too close to the intake head bubbling air is introduced into the intake head. Also, if the intake area is influenced by upwardly rising oil with unstable conditions, the above mentioned assumption of critical intake height will not be invalid.

Therefore, a distance, by which the surface stream generated by the aeration system will be sufficiently low, is adopted.

According to the past study, the distance by which the velocity of the rising air bubbles and accompanying surface stream decrease by up to 1/50 to 1/100 of their initial velocity, is said to be about 3.5 to 5.5 times the depth of the water.

Therefore, the aeration system is installed a distance of 4.5 times the water depth away from the installed head (at radius). The water depth at the site is 7.2 m from M.W.L. (ACD + 1.29m). Then, the aeration system is installed 33 m (≒ 7.3 x 4.5) at the radius away from the intake head.

2) Air quantity

The purpose of the aeration system installation is not to eliminate oil by adsorption into the air bubbles, but to repress the invasion of the oil into the intake head by the rising stream of water containing oil emulsion generated by the aeration system.

Therefore, air quantity to obtain the sufficient up-lift for the stream is necessary. According to the past study regarding prevention of effluent oil dispersion, air quantity of 0.01 m^3/s.m with a stream velocity of about 0.3 m/s in the area is effective for the prevention of dispersion. Therefore in this system the total air quantity for the intake head is 2.07 m^3/s (Q = 0.01 x 2 x p x 33 = 2.07) each, assuming a unit air quantity of 0.01 m^3/s.m.

The general arrangement is shown in Figs. 5.3.7 and 5.3.8.

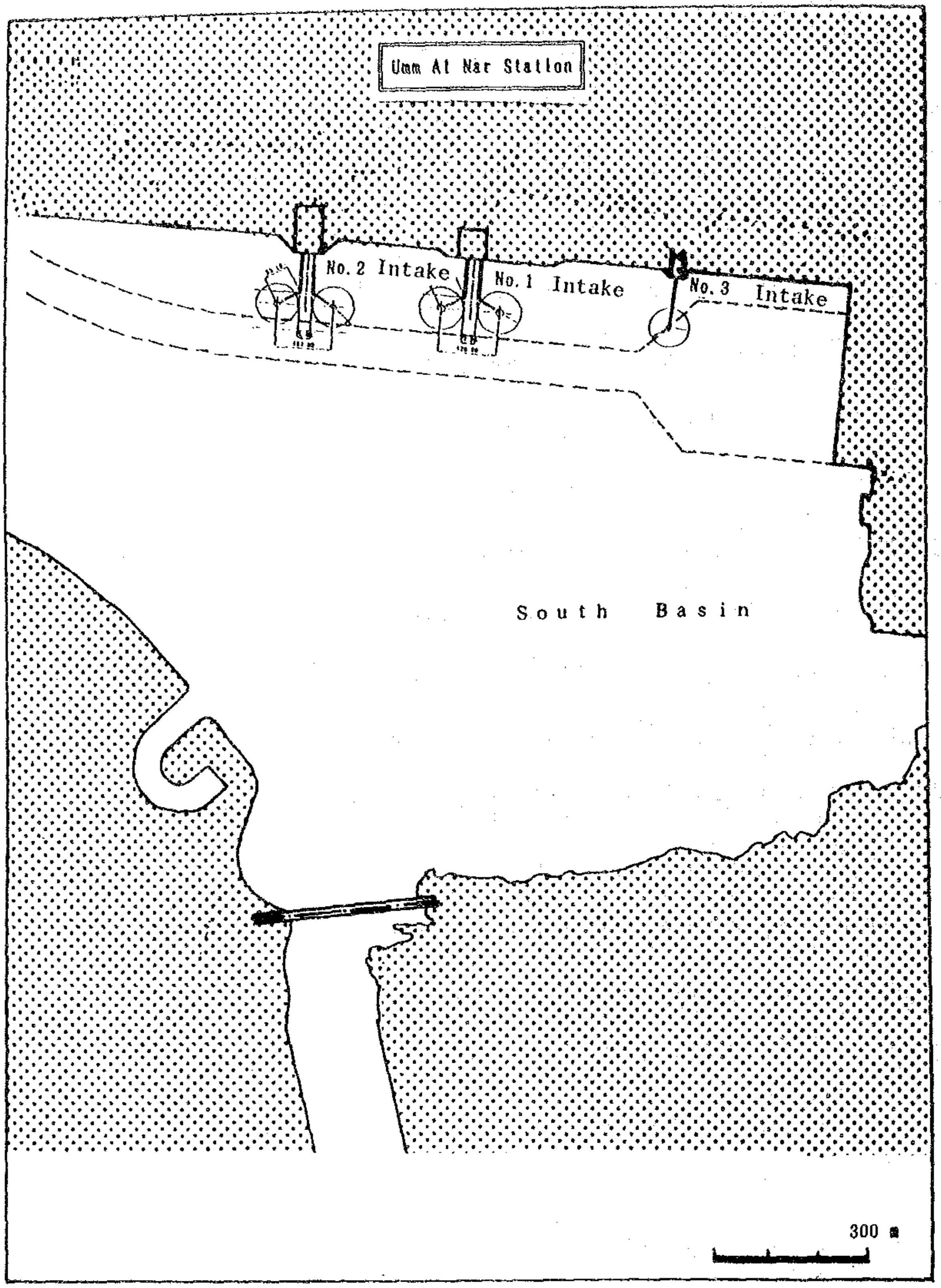
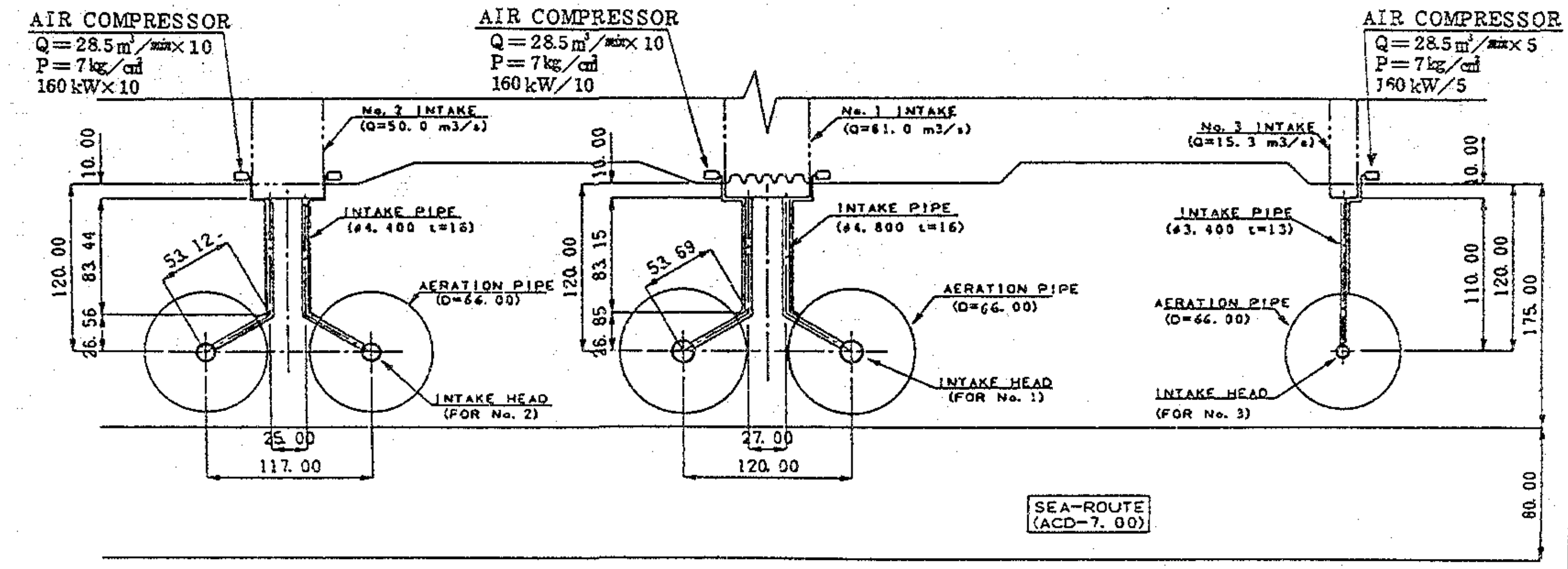
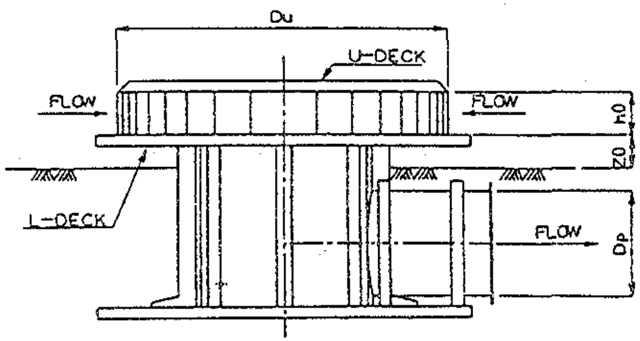


Fig. 5. 3. 7: Layout of Sea Water Intake Head

GENERAL PLAN



OUTLINESHAPE OF INTAKE HEAD



	No. 1 INTAKE	No. 2 INTAKE	No. 3 INTAKE
Du (mm)	φ15.000	φ12.000	φ8.000
h0 (mm)	2.000	2.000	2.000
Z0 (mm)	1.500	1.500	1.500
Dp (mm)	φ4.800	φ4.400	φ3.400

GENERAL PLAN AND OUTLINE SHAPE OF INTAKE HEAD

Fig. 5.3.8: General Plan and Outline Shape of Intake Head

5.3.6 Rough Estimation of Construction Costs

Rough construction costs, based on the current commodity price level, of the oil prevention systems which are described in 5.3.1 are as follows:

(1) Preventive measures against oil pollution in Arabian Gulf	500 milion yen
(2) Preventive measures against oil pollution at entrance part of Umm Al Nar South Basin	180 milion yen
(3) Preventive measures against oil pollution by rectification of existing system	4,830 milion yen

The rough estimation was made according to the Japan domestic material as of March 1989.

5.3.7 Construction Time Schedule

Construction time schedules of the three method mentioned in previous paragraphs are shown as follows:

1) Preventive measures of oil pollution in Arabian Gulf

   13 months

2) Preventive measures of oil pollution at the entrance part of South Basin of Umm Al Nar

   12 months

3) Preventive measures of oil pollution by rectification of the existing intake system

   19 months

5.4 Emergency Shut-Down of Plant and Measures to Secure Living Water

5.4.1 Emergency Shut-Down of Plant

In cases of oil spills in the adjacent locations of sea water intake, oil flooding and stormy weather, there are occasions when prevention of inflow of oil into the plant is unattainable with the prevailing preventive systems.

It is imperative to continue operation of the plants to the utmost extent since no water resources can be found other than sea water desalination in this area. However, if concentration of oil component in feed sea water increases beyond the allowable limit, there should be no other way than to stop the plants operation.

It can be considered from a view of safe preservation of the plant to shut-down its operation on emergency when oil concentration in sea water exceeds 1,000 mg/l, but the final decision must be made after making a comprehensive study of conditions surrounding this area, i.e., availability of adaptable emergency water resources and consequence due to stop of water supply.

As for the power plants, stop of their operation can not happen unless sea water enters into the heat cycle, which is to be caused by accidents such as corrosion occasioned by sulfur content contained in the oil.

In case of emergency shut-down of the plants, the following measures should be taken:

(1) To adjust the number of operating units or operation load to avoid concentration of load on specific intake facilities.

(2) To keep the product water storage tank always filled. (180,000 m3)

(3) In order to restart the operation immediately after the oil contamination of sea water is passed over, operation of the required 2 to 3 number of sea water distilling units necessary to secure minimum quantity of living water (100ℓ/person) should be stopped while pollution of the plants by oil is not getting worse and keep them for later use.

(4) To change the plant operation to the method which can prevent intermix of oil into product water, as described in Chapter 6.

(5) To prevent intermix of oil to the utmost extent by reducing the operation load and lowering the intake volume of sea water.

(6) To prepare chemicals such as neutral detergent, alkaline detergent, solvent detergent, etc. and jet cleaning apparatus which will be necessary for cleaning of oil-polluted plants.

After the plant operation is stopped, drain should be extracted, and the plant should be cleaned with fresh water and naturally dried to prevent corrosion. Rotating machinery should be greased-up at oiling parts and all gaps of rotating parts should be sealed up by grease and otherwise. Sterilizer should be injected into the intake and the water storage pond, as occasion demands.

5.4.2 Measures to Secure Living Water during Plant Shut-Down

In order to be prepared for emergency shut-down of the plants, it is important to take necessary measures beforehand to secure the minimum required quantity of living water. The following is conceivable as such measures.

(1) Storage of Product Water

Storage capacity should be strengthened by installing additional water storage tanks or constructing large-scale reservoirs in Umm Al Nar Station.

(2) Measures for Water Saving

The water supply system should be divided into supply systems for living water and for other uses, and an arrangement should be made so that in case of emergency, water supply for other uses can be restricted.

Also, in order to make a fair supply during the restricted time, pumps, valves, regulators, etc., should be properly maintained beforehand. Water wagons should also be arranged.

(3) Coordination with Desalination Plants in Other Areas

Connection should be made to plants in other areas within Abu Dhabi Emirate and in other emirates through pipelines for mutual adaptation of product water.

(4) Conversion of Raw Water

The Umm Al Nar Plants should be operated with other stock water instead of the oil polluted sea water. For other stock water, underground brackish water sent from Al Ain, lake water from nearby saline water lakes, brackish water from brackish water wells, and sea water from beach wells

can be conceived, and these water can be supplied to the plants in Umm Al Nar.

(5) Emergency Transport of Water from Other Areas

Product water from desalination plants or underground water in other areas should be transported by a water tanker. Joint ownership of this water tanker with neighboring countries to establish a mutual water adaptation system will be effective to secure safety and guarantee of water supply in this area.

The above 5 measures for living water during plant shut-down, the study and planning of concrete enforcement plan in the existing facilities are required without delay especially for the saving water measure in (2).

Also, it is necessary to study the way to get into communication with the water consumers exactly about decrease of water supply, suspension of water supply, etc. to prevent occurrence of confusion.

As for the connection with sea water desalination plants in other area shown in (3), the desalination plant which has capacity of 100,000 m^3/d is to be completed in 1989 in Taweelha 70 km away from the Abu Dhabi Island and synthetic operation with Umm Al Nar Plant may become possible.

As for other measures, considerable investment in plant and equipment such as installation of more water storage tanks, securing of water supply tankers, installation of brackish water wells and beach wells, becomes necessary. Therefore, comprehensive investigation should be performed prior to the enforcement of the plan.

Chapter 6 Countermeasures against Oil Contamination

6.1 Methods of Treating Oil-Contaminated Product Water

6.1.1 Methods of Removing Oil Content from Product Water

The following methods can be employed for removal of oil content from product water; each method has its own merit and demerit as to the processing capacity and distinctive feature.

(1) Gravity Separation Method

A method of flowing oil-containing water in the shallow water tank having rectangular shape at slow speed and separating water and oil by difference of specific gravity

(2) Air Flotation Method

A method of blowing air bubbles into oil-containing water and having oil drops float up together with air bubbles

(3) Coagulation/Sedimentation Method

A method of adding flocculant and flocculating the emulsion state oil and precipitate it

(4) Filtration and Coalescence Method

A method of amalgamating particular oil drops using filtration media and separating the formed large-size oil drops

(5) Membrane Method

A method of permeating oil-polluted water through ultrafiltrating on membrane

(6) Biological Treatment Method

A method of treating oil-containing water which was rid of floating oil beforehand, using activated sludge

(7) Activated Carbon Absorbing Method

A method of absorbing oil by passing through activated carbon layer after removing free oil

(8) High-Temperature Water Discharging Method

A method of discharging exhaust gas condensate from the deaerator in MSF plant and the product water from high-temperature stages and recovering the product water from medium and low temperature stages

(9) Exhaust Gas Increasing Method

A method of removing volatile oil components by increasing the exhaust gas from the deaerator and the venting gas from the evaporation chamber in MSF plant

(10) Re-Distillation Method

A method of re-distillating oil-contaminated product water in MSF plant

6.1.2 Comparison and Evaluation of Each Method for Removing Oil Content

The following shows comparison and evaluation of each method for removing oil content, which was made in light of conditions required in this subject.

(1) Treated water should have adequate quality for drinking.
(Oil concentration should be set 50 μg/l.)

Stable emulsion such as dispersed fine particles smaller than 10 μm, mixed with surfactant and soluble oil cannot be removed by gravity separation method. Therefore, its effluent concentration of oil is minimum 30 mg/l.

The effluent concentration of oil would be around 10 mg/l by air floatation and coagulation/sedimentation processes.

By the high-temperature water discharging method and the exhaust gas increasing method, product water with concentration of a few mg/l can be obtained if the concentration of oil content in feed sea water is about 100 mg/l.

By the re-distillation method, the concentration can be easily reduced to 1 mg/l or less. Both the activated carbon absorption method and the biological treatment method are effective for low-level dissolved oil and can remove to 50 ppb and less order. However, since the methods cannot be used under the presence of floating oil, preliminary removal of floating oil is necessary.

(2) Installation cost should be low.

Each of the exhaust gas increasing method, the high-temperature water discharging method and the re-distillation method requires some modification of the existing MSF plant such as modification of piping, addition of accessory facilities, etc., but their installation cost will be much smaller than that for other methods.

(3) Operation and maintenance should be easy.

Since the biological treatment method requiring constant upkeep and control of activated sludge, it is not desirable as the emergency measures. As both the membrane method and the coagulation/sedimentation methods requires long time to start, they are somewhat short of adequacy for immediate start in emergency.

The exhaust gas increasing method, the high-temperature water discharging method and the re-distillation method require change of plant operation, but it can be handled by application of the present operating technique.

(4) Derivative problems should be less.

Since the air floatation method using flocculant, the coagulation/sedimentation methods and the biological method by activated sludge produces much sludge, its disposal will be serious problem.

With the re-distillation method, operating rate of the plant is dropped because the operation of MSF plant must be shared to re-distribution.

6.1.3 Planning of Suitable Treating Method for Plant

After comparison and evaluation described in the preceding paragraphs, the following plan is proposed as the treating method suitable to the subject plant.

(1) Case 1

In case of the concentration of oil contents in feed sea water is about 100 mg/l or less, combination of the high-temperature water discharging method and the activated carbon adsorption method should be employed.

As an example, the material balance of the case where the concentration of oil content in feed water is 100 mg/l, is indicated in Fig. 6.1.1.

By this method, oil concentration in product water at MSF outlet becomes 3.94 mg/ℓ, and by treating this with activated carbon, 39 μg/l treated water can be obtained.

Also, when exhaust gas rate is raised from present 0.2% to 0.3%, oil concentration in product water at MSF outlet is reduced to a half or 2 mg/l according to 6.1.1 (9).

Quantity of treated water is reduced to 569 t/h or 75% of 750 t/h which is the quantity of product water under normal conditions.

In case oil concentration in raw water is low, needless to say, it is possible to omit activated carbon treatment or discharging of product water from high temperature stages, as the occasion demands. (discharging of deaerator condensate should be continued.)

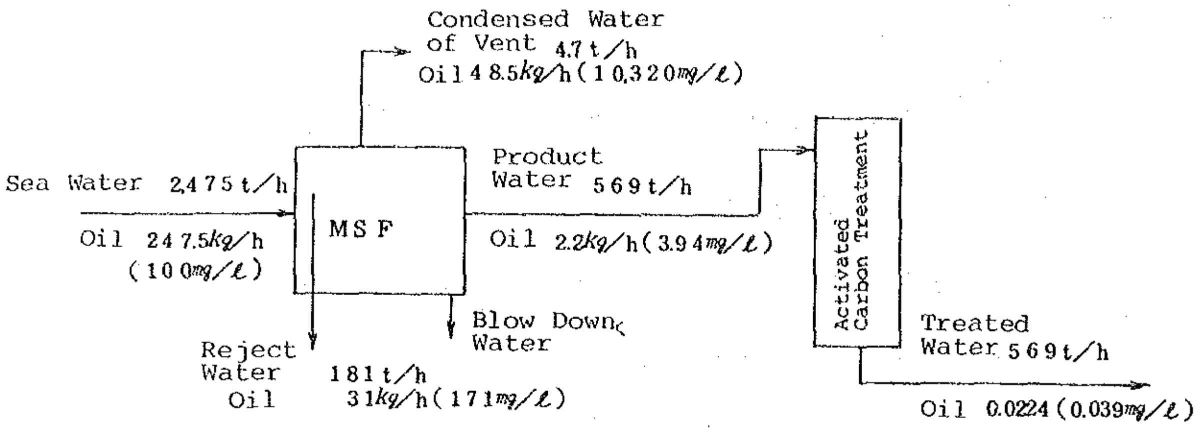


Fig. 6.1.1: Material Balance of Case 1

(2) Case 2

When the concentration of oil content in feed sea water further increases and the quality standard of treated water cannot be maintained, the re-distillation method should be combined with the method described in Case 1.

The material balance in this case is indicated in Fig. 6.1.2.

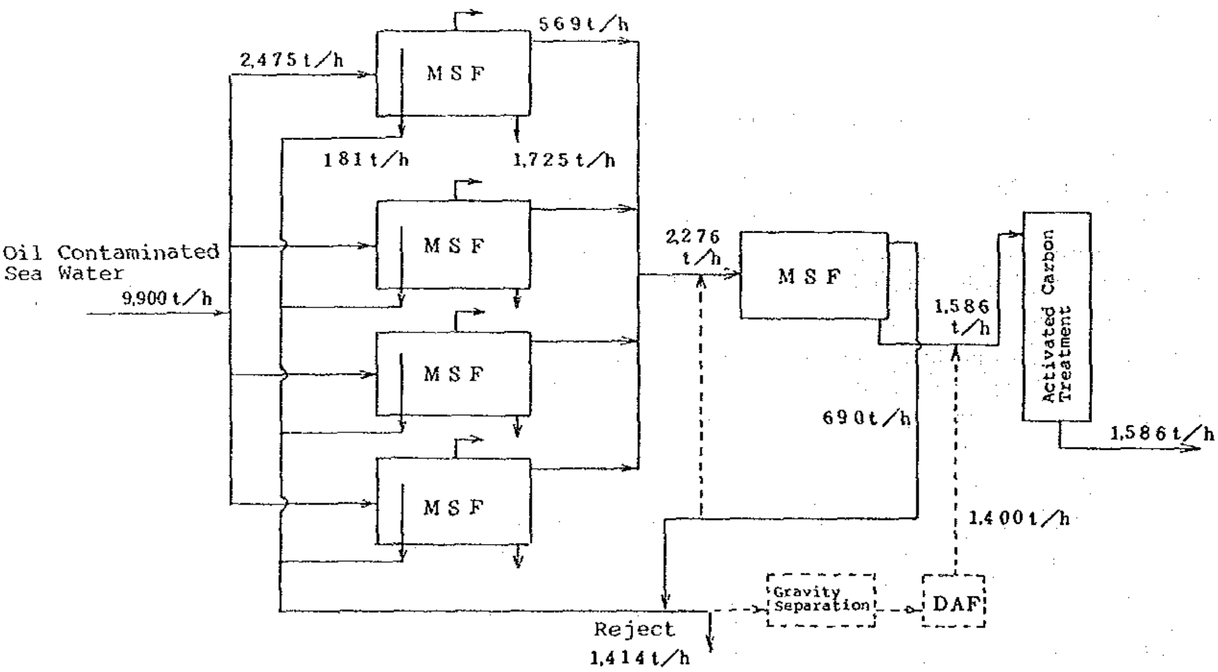


Fig. 6.1.2: Material Balance of Case 2

The product water obtained by 5 units of MSF plants is reduced to 1,586 t/h or 42% of the product water under normal operation.
If a part of the distilled water (containing an oil component) from the distillation is recirculated to the inlet of the re-distillation plant, quantity of feed water supplied to the re-distillation plant can be reduced, resulting in improvement of the operating ratio of the total plant as well as the yield of fresh water.

If the distilled water containing oil components of high concentration from 0 to 4 stages and the distilled water from the re-distillation plant (containing oil) are treated by gravity separation and air flotation, and performing activated carbon treatment, there becomes no discharging water and so the yield of water is improved.

For executing the above methods, it is necessary to conduct experiments under the condition close to actual application and confirm their effectiveness by collecting experimental data.

6.2 Method for Removing THM

As a method for removing THM from product water, the aeration method cannot be regarded as an effective method because it requires a large volume of dispersing air comparing to quantity of water (air-liquid ratio), though the method is usable in case of a small scale operation.

Its effectiveness for removal of bromoform is worse (Fig. 6.2.1). Therefore, so the employment of the aeration system is not recomended, especially when bromoform occupies most part of THM as it does in the subject case.

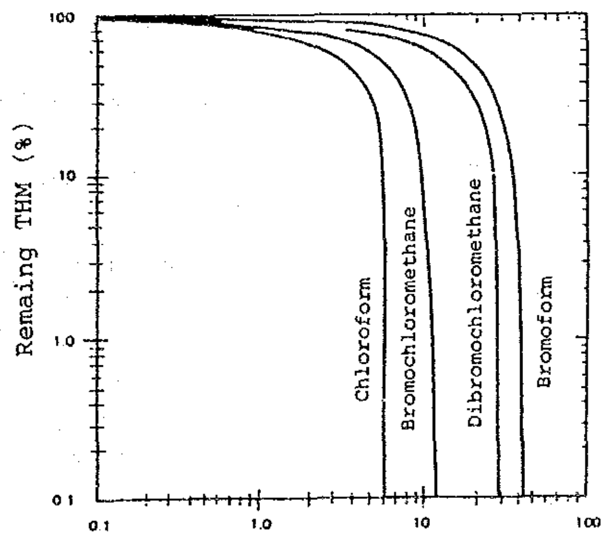
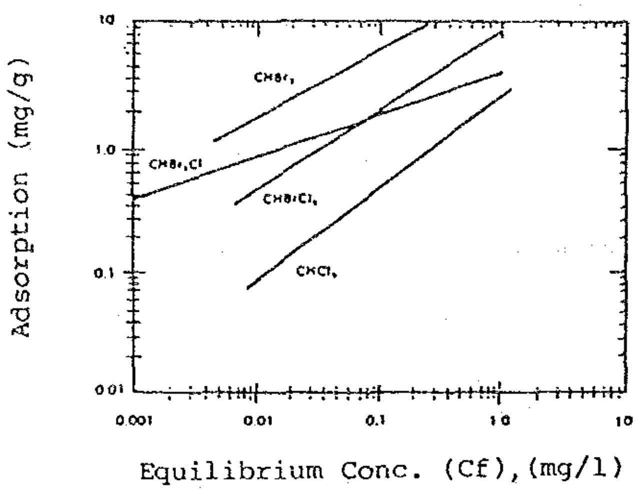


Fig. 6.2.1: THM Removal by Ideal Contact Tower

As for the powder activated carbon, since far more injection is required than for removal of usual smell of mold, it is not considered as effective measures. However, it may be usable on temporary base for a short period in emergency.

Effective life of the granular activated carbon filter is only about two months according to an experiment of removing THM from city water, and therefore, it requires frequent regeneration.

However, since the capacity of activated carbon to adsorb bromoform is greater than other adsorptives for other THM (Fig. 6.2.2), it is effective when the ratio of pressure of bromoform is high as in this case. The granular activated carbon method has a processing capacity to satisfy the allowable water quality and can be used in actual applications.



$$\text{* Adsorption} = \frac{\text{Adsorbate (mg)}}{\text{Activated Carbon (g)}}$$

Fig. 6.2.2: Isotherm Curve of THM

Further, the performance of the activated carbon method varies depending on the kind of carbon and also depending on the presence of other oil components. Therefore, its employment should be decided after confirming its performance by pilot test or other means.

The boiling method is effective for the removal of THM performed by consumers themselves and it can remove THM almost completely by 50 to 60 minute boiling (Fig. 6.2.3).

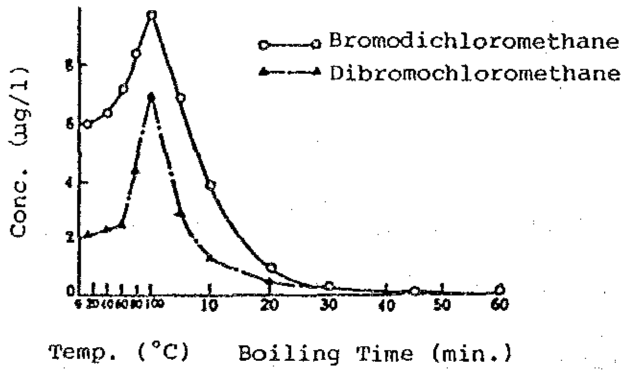


Fig. 6.2.3: Concentration of Bromodichloromethane and Dibromochloromethane (According to Report by Osaka City in 1979)

6.3 Improvement of Sterilizing Method

In order to prevent formation of THM during the desalination process it is necessary to restudy the present method of chlorination.

6.3.1 Modification of Chlorination of Feed Sea Water

Effect of controlling the quantity of chlorine injection on the prevention of THM formation cannot be expected much, because from the reaction equation of THM formation, the effect of concentration of chlorine on the THM formation is not great.

Intermittent chlorine injection method of slightly higher concentration is not more effective than continuous injection of chlorine of normal concentration, because there is not much difference in the total quantity of THM formed in 24 hours between these two methods.

6.3.2 Substitute Method for Chlorination of Feed Sea Water

Several methods for preventing fouling by marine organisms other than chlorination are now under study, but there are only a few examples of research and almost no example of practical applications.

As methods considered to be applicable in the objective plants, combined use of hydrogen peroxide and ferrous sulfate, ozone, chloroamine, chlorine dioxide, surface treating, physical treatment and other methods can be considered, and the most effective one, from a view point of sterilizing feed sea water to prevent THM formation, is the combined use of hydrogen peroxide and ferrous sulfate.

However, this method costs a little higher than chlorination, and in Japan, it has a few practical applications but not in large-capacity plants.

6.3.3 Substitute Method for Chlorination of Product Water

Of sterilizer used for city water, the ones which have no fear of forming THM are ozone, chlorine dioxide and chloroamine. Of these three kinds of sterilizer, ozone is the most effective sterilizer because it can remove source substances of THM, and its removability of ill smell and taste is good and also effectiveness as disinfectant is highest.

However, its residual effect cannot be expected and the cost of treatment is high and several times as much as the cost of other methods.

Chlorine dioxide is effective for removal of source substances of THM, does not leave ill smell or taste in water, and can maintain the sterilizing effect for a long time, while it has difficulty in transportation and storage because it is chemically unstable.

Chloroamine has relatively weak sterilizing capability but has advantages in other points such as durability, handling of chemicals, etc. and its cost is the lowest.

Therefore, if the product water has the possibility to be contaminated by oil, sterilization by chloroamine is most desirable.

6.4 Method of Restarting Oil-Contaminated Plant

If a plant is by any chance contaminated by effluent crude oil, means of rehabilitation such as washing should be carried out. Washing must be carried out by selecting the most suitable method out of the mechanical washing, chemical washing and combination of mechanical and chemical washing methods, which conforms to the actual condition of each equipment and unit, using non-polluted sea water or fresh water.

In case the extent of pollution is slight or if each equipment has been washed to some extent, alkali washing of evaporators all together will be an efficient way. For washing of water chamber and inside of heat transfer tubes in the heat rejection section of evaporator, temporary piping should be installed because it is difficult only to wash through the existing pipes, and warm alkaline water should be filled in sea water pipes and water chambers in the heat rejection section, and circulated by the circulation pump.

There is the possibility that gaseous-state oil is present inside the oil-contaminated evaporation chamber. Therefore, full attention should be paid to danger of fire, explosion and lack of oxygen while working.

Detergent to be used must be selected upon due study of safety against human body, taking into consideration that the detergent will remain in the evaporator even after washing.

Since a great amount of waste water is produced by washing, and oil and detergent are mixed in the waste water, it must be discharged after treating by the waste water treatment facilities, in view of preservation of marine environment and quality of raw sea water.

Even after the plant is restarted, it takes a long time for the sea area surrounding the plants to be thoroughly cleaned, and there is the possibility that oil lumps at the bottom of the sea area float up an come near the sea water intake of the plants.

Therefore, it is necessary to continue installation of oil preventive systems, and measurement by monitoring system and observation by eye and smell.

When a damage like oil contamination of sea water occurs, it seems that the "Integration System for Optimum Control by Computer" will be effective for optimum control of operation of the power and desalination plants in conformity with the degree of damage. Therefore, it is desirable to study introduction of this system.

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