5.2 Test with the Heat Transfer Test Equipment

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1. Introduction

Scaling is one of the major factors exerting negative influences on the operation of Multi Stage Flashing (MSF) process seawater desalination plants.

Scaling is a phenomenon in which the soluble constituents of seawater are deposited on and adhere to the internal surface of heat transfer tubes, and then this adhered scale causes a decrease in heat transfer efficiency. There is, however, a chemical dosing method which is used to prevent scale from deposition and adhesion.

This method in which chemicals are added to the MSF brine at rates of few ppm is currently widely used in Middle Eastern desalination plants. These chemicals are called scale inhibitors, and have two principal effects, as explained earlier, the threshold effect and the crystal distortion effect.

There are several types of scale inhibitors in the market. The testing of their characteristics and the selection of those most suitable is being carried out now under actual plant conditions.

Based on the background mentioned above, a selection method has been developed for scale inhibitors under laboratory conditions. This method is composed of two steps. In the first step, each scale inhibitor is tested for the threshold effect and as a result of this first test, some are selected out. In the second step, those scale inhibitors which are selected during the first step, are required to be tested for the crystal distortion effect. Thus, the most optimum one can be selected.

The test of the threshold effect is carried out by measuring the residual M–alkalinity of brine.

On the confirmation of the threshold effect, the first paper (the SWCC/JICA final report of fiscal year 1991), the second paper (the progress report in March of latter half of the fiscal year 1992) and the third paper (the progress report in November of the first half of the fiscal year 1993) have already been reported. As a result of this series of studies, it has been demonstrated that a scale inhibitor has the ability to prevent the deposition of scale when it contacts brine in a supersaturated condition, but its ability decreases with the increase of retention time, and a polyphosphonate scale inhibitor (PPN) has the highest threshold effect among the three tested scale inhibitors; polymaleic acid (PMA) and polycarboxylic acid

(PCA) at conditions of 95 ℃ at a dose rate of 2 ppm and a retention time of around 20 minutes. Furthermore, the scale inhibitor polyphosphonate modified PPN(M) has been selected out for the tests with the heat transfer test unit from six scale inhibitors; PCE, PCS, PMA, PPN, PPN(M) and PPN(A).

In this study, for the purpose of establishing the method of experimentation and of evaluation of the crystal distortion effect with the heat transfer test unit, experiments were carried out under two conditions of top brine temperature; 90 ℃ and 102 ℃. Experiments were carried out at these two temperatures one with PPN(M) and the other without any scale inhibitor (Blank test).

This report describes the results of the selection tests obtained with the heat transfer test unit.

2. Crystal distortion effect on the scale inhibitor and adhesion

It is well known that scale inhibitors have an effect which prevents adhesion between the individual precipitated particles or between the particles and solid (metal) surfaces with which they are in contact. This occurs because the scale inhibitor completely distorts the soft scale composed of normal regular crystals.

It is generally pointed out that the scale distorted by a scale inhibitor is easier to disperse, and that the normal flow of water in the distillation plant is sufficient to keep the small particles on the move until they are removed from the plant during normal blow-down as an effluent brine. For this reason scaling does not easily occur.

Observing normal regular crystals and crystals distorted by a scale inhibitor through a scanning electron microscope, it can be seen that the former are flat-shaped spreading into branches, while the latter are spheroid. Naturally a spheroid shaped scale has less contact surface between each particle and the metal surface than a flat shaped one. Also, a spheroid shaped particle tends to rotate around its own axis while moving with the liquid stream along pipe axis. This combined motion results in a radial force that causes the particle to migrate towards the pipe center leaving a particle-free layer near the pipe walls.

Crystal distortion effect of a scale inhibitor, can be confirmed at an actual plant by means of measuring the decrease in heat transfer efficiency, that is, the increase of the fouling factor of the heat transfer tubes in this study.

3. Purpose

This study, which is meant to be the second step of the selection test using the heat transfer test unit has been carried out in order to confirm the crystal distortion effect of PPN(M) by determining the fouling factors at 90℃ and 102℃.

The heat transfer test unit, which is constructed as a recirculation system so as to operate continuously, has a capacity of heat load of 4~8kW/m^2 at a velocity of brine in the heat transfer tube of 1.8~2m/s. The brine to be used has almost the same water quality as the actual plant.

Through the above process, experimental and evaluation method will be established.

4. Experimental method

4.1 Materials

(1) Brine

In order to simulate the recirculating brine concentration of Al-Jubail Plant it was necessary to use the brine which was 1.4 times the concentration of normal seawater in the Arabian Gulf. Such concentrated seawater was collected from the reject brine of the RO test plant, under possession of SWCC, RDC, without any acid dosing in the RO feed and after adjusting the recovery ratio to achieve the required concentration in the reject.

The water quality of RO reject brine is shown in Table 1.

(2) Scale inhibitor

Name, physical properties, composition and results of the experiment on threshold effect, which were to be used for this test, are shown in Table 2.

(3) Operating conditions

Operating conditions were monitored by measuring the following parameters:

a. Temperature : T_1 (tube inlet Temp.)
T_2 (tube outlet Temp.)
t_1 (shell side inlet Temp.)

		t_2 (shell side outlet Temp.)
b. Flow rate	:	F_1 (flow rate of recirculating brine)
		F_2 (make up feed flow rate)
		F_3 (blow down flow rate)
		F_4 (heating water flow rate)
c. Water quality		
– pH	:	pH meter (Fisher 825MP)
– M–alkalinity	:	Automatic titrater (Fisher Model 465)
– Calcium ion	:	EDTA titration method
– Magnesium ion	:	EDTA titration method
– Conductivity	:	Electric conductivity meter
d. System pressure	:	P_1 (Recirculation tank pressure)
		P_2 (Recirculation pump discharge pressure)

4.2 Experimental Equipment

A flow sheet for the heat transfer test unit is shown in Fig. 1, and its specifications are shown in Table 3.

This test unit is composed of a heat exchanger section which is a simulated brine heater of an MSF plant, a pressurized recirculation section, a chemical dosing section, a brine make–up supply section and hot water supplying section for the purpose of brine heating.

Heat exchanger section consists of a 1–5 exchanger. Shell side has single pass while Cu–Ni tube side has five passes with four U bends. The brine, which is stored in the circulating tank, is supplied by the recirculation pump to the heat exchanger where the brine is heated by the hot water circulation shell, and returned to the circulation tank again. The recirculation tank is pressurized from its top side above the liquid surface by air from an air compressor in order to provide sufficient positive suction head to recirculation pump. The hot water supply section consists of a 3 kW heater, a recirculation pump and a flow meter.

Some of the hot brine in the system is constantly discharged out of the recirculation line as a blow down and, at the same time, the same amount of fresh brine is injected after preheating

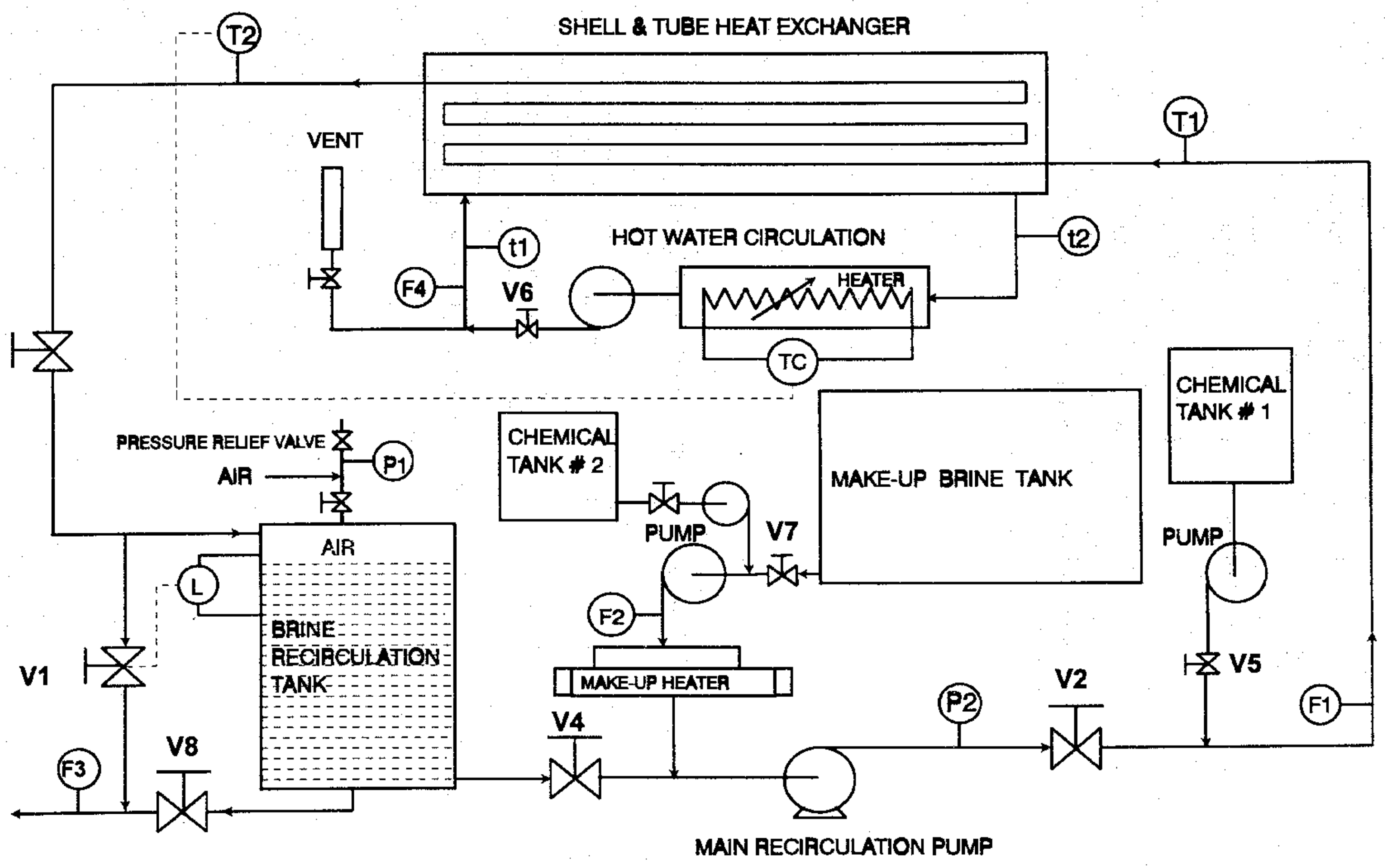


Fig. 1 Flow Sheet for the Heat Transfer Test Unit

Table 1 Water Quality of RO Reject Brine

Items	Values
pH	8.0
M-alkalinity (mg/L)	180
Ca^{2+} (mg/L)	678.0
Mg^{2+} (mg/L)	2,350
Conductivity (μS/cm)	85,000

Table 2 Properties of Scale Inhibitors

Name	Specific Gravity	pH	Major Constituent	Result of Test on Threshold Effect
PPN(M)	1.37	11.0	Polyphosphonate	Best Quality at 95 ℃ & 110 ℃

Table 3 Specification of the Heat Transfer Test Unit

No	NAME	Q	MATERIAL	CAPACITY
1	Heat Exchanger (H.E.)	1	Cu-Ni(70/30) SUS 316	Tube ; 22 mm φ x 1 mm t x 5,700 mm l Shell; 200 mm φ x 3 mm t x 1,120 mm l Temp. Control Range ; ~ 102℃
2	Hot Water Circulation Vessel (HW)	1		3 kW, interlocking by T_2
R_1	Circulation Tank Level Controller (LC)	1 1	SUS 316	Tank ; 500 mm φ × 1,000 mmH, Interlocking to V_1
R_2	Make Up Feed Tank	1	PVC	1 m^3
R_3	Chemical Tank	1	PVC	460 mm □ x 660 mmH,
P_1	Brine Re-Circulation Pump	1	SUS 316	2.5 m^3/h x 40 mWH, 0.75 kW
P_2	Hot Water Circulation Pump	1	SUS 316	110 l/min x 16 mWH, 0.5 hp
P_3	Make-Up Feed Pump	1	Teflon	1.25 l/min x kgf/cm^2, kW
P_4	Chemical Feed Pump	1	Teflon	1.25 l/min x kgf/cm^2, kW
T_1	HE Inlet Temp. Indicator	1	SUS 316	~ 150 ℃
T_2	HE Outlet Temp. Indicator	1	SUS 316	~ 150 ℃
t_1	HW Inlet Temp. Indicator	1	SUS 316	~ 150 ℃
t_2	HW Outlet Temp. Indicator & Controller	1	SUS 316	~ 150 ℃, Interlocking to EH
F_1	Recycle Brine Flow Rate Indicator	1	SUS 316	~ 50 l/min
F_2	Make-Up Feed Flow Rate Indicator	1	SUS 316	0.1 ~ 1.0 l/min
F_3	Blow Down Flow Rate Indicator	1	SUS 316	0.1 ~ 1.0 l/min
F_4	Heating Water Flow Rate Indicator	1	Bronze	0 ~ 10 GPM
PG	Pressure Indicator at Brine Recir Tank	1	Carbon Steel	0 ~ 4.0 kgf/cm^2
V_1	Blow Down Solenoid Valve	1	Teflon	10 mm φ, Interlocking by LC
V_2	P_1 Delivery Side Valve	1	Bronze	20 mm φ
V_3	HE Outlet Valve	1	Bronze	20 mm φ
V_4	Circulation Tank Outlet Valve	1	Bronze	20 mm φ
V_5	P_4 Delivery Side Valve	1	Bronze	20 mm φ
V_6	P_2 Suction Side Valve	1	Bronze	20 mm φ
V_7	Make-up Pump Suction Side Valve	1	Bronze	20 mm φ
V_8	Circulation Tank Drain Valve	1	Bronze	20 mm φ
EC	Expansion Chamber	1	Carbon Steel	50 mm φ x200 mmH
CP	Control Panel	1	Carbon Steel	500 mmL x 400 mmW x 225 mmH

into the suction side of the recirculation pump from the make-up feed tank using the make-up feed pump.

Also, a scale inhibitor, which is dissolved to a constant concentration in distilled water is stored in the chemical tank, and is continuously dosed into the delivery side of the recirculation pump by the chemical pump. This system keeps the concentration of effective scale inhibitor in the brine as well as the brine chemical composition constant throughout the experiment. For all tests including blank tests, chemical is dosed at very low concentration, only about 1 ppm, in the make-up feed line before preheater in order to avoid scaling in the make-up heater.

4.3 Experimental Conditions

The experimental conditions are shown in Table 4.

(1) Brine temperature

a. Experiment at normal temperature
Since the outlet temperature of the brine heater during normal operation is 90.56℃ in Al-Jubail Phase-II Plant, it was decided that the experiment should be conducted at 90℃.

b. Experiment at high temperature
The temperature condition, which was above 90℃, was set at 102℃.

(2) Brine concentration
According to the operating conditions in Al-Jubail Phase-II Plant, it was decided that the brine concentration should be 1.4 times that of seawater in the Gulf and RO reject brine was to be used. The values of M-alkalinity of the brine from RO should be controlled so as to keep at 180+/-10mg/L. Therefore, it was decided that the RO brine should be diluted with ordinary potable water, when concentration is higher than 180mg/L, on the other hand, sodium bicarbonate should be added into the RO brine, when the concentration is less than 180mg/L.

(3) Dose rate of scale inhibitor
It was confirmed in the previous study of threshold effect that the optimum dose rate of scale inhibitors is 2mg/L, and also that the retention time at which threshold effect was lost is about 20 minutes.

Table 4 Conditions of Experiments

Items \ Test No.		Test-1	Test-2	Test-3	Test-4
Brine Temperature	(℃)	90	102	90	102
Name of Scale Inhibitor		Blank	Blank	PPN(M)	PPN(M)
Heat Exchange Inlet Temp.	(℃)	90.13	101.29	89.40	101.28
Heat Exchange Outlet Temp.	(℃)	90.78	101.92	90.11	102.01
Shell Side Inlet Temp.	(℃)	93.36	105.07	92.82	105.15
Shell Side Outlet Temp.	(℃)	93.22	104.04	92.48	104.35
Recirculating Brine Flow Rate(F_1)	(L/min)	36	36	36	36
Make-Up Feed Flow Rate(F_2)	(L/min)	0.6	0.6	0.7	0.7
Chemical Feed Flow Rate	(L/min)	0.0	0.0	0.03	0.03
Blow Down Flow Rate(F_3)	(L/min)	0.6	0.6	0.73	0.73

As the retention time of scale inhibitor in this test unit was much more than 20minutes, the chemical degradation due to high retention time was considered in the chemical dosing calculation. The calculation of the chemical dosing rate is given below. A chemical dosing rate of 12mg/L in the make-up feed was calculated for balancing the chemical degradation in the system beyond 20 minutes retention time and to maintain a concentration of about 0.8-1.0mg/L of effective scale inhibitor in the recycling brine similar to that of Al-Jubail Phase-II MSF Plant.
An additional 1.0mg/L was injected for all tests into the feed line before make-up heater. This was required to prevent scaling in the make-up heater. It was found that 1.0mg/L of chemical was enough to prevent scale formation in the heater which was set to heat make-up brine up to a maximum temperature of 60℃. In blank tests, 1.0mg/L of chemical through make-up feed had negligible effects as the concentration of effective scale inhibitor in the recirculating brine was only 0.02mg/L.

[Scale Inhibitor Dosing Rate Calculation for Heat Transfer Experiment]

<u>Constant Parameters</u>

The chemical retention time	(TR)	=	20min.
The quantity of brine in the system	(Ms)	=	150L
The make-up feed and blow down flow rates (M_M& M_B)		=	0.7L/min.(each)
Chemical Concentration in the recirculating brine (Cs)		=	1.0ppm

<u>Chemical Balance</u>

The rate of change of chemical in the system
= [Rate of chemical in through make-up feed] - [Rate of chemical out through blow down] - [Rate of chemical degeneration in the system]

$$Ms \cdot \Delta Cs/\Delta t = M_M \cdot C_M - M_B \cdot C_B - Ms \cdot Cs/T_R$$

At steady state, $\Delta Cs/\Delta t \rightarrow 0$

$$M_M \cdot C_M = 0.7\text{L/min.} \times 1.0\text{mg/L} + (150\text{L} \times 1.0\text{mg/L}) / 20 \text{ min.}$$
$$C_M = 8.2/0.7\text{mg/L} = 12\text{mg/L}$$

So the chemical dosing should be 12mg/L of make-up feed in order to maintain 1mg/L of scale inhibitor in the recirculating brine.

4.4 Experimental Method

Each experiment of the crystal distortion effect with the heat transfer test unit, was carried out in accordance with the experimental method mentioned below.

Each test was carried out over a period of 10days, that is, the 1st day was applied to preparation and calibration, 8days from the 2nd day to the 9th day were for testing and the last day was for cleaning up the unit with acid.

(1) Preparation of brine

Whenever RO reject brine was resupplied to the make-up feed tank, its M-alkalinity was measured and adjusted to 180 +/- 10mg/L by diluting with ordinary potable water or by adding sodium bicarbonate.

(2) Preparation of scale inhibitor

Whenever a scale inhibitor was added to the chemical tank, it was dissolved in distilled water in order to keep its concentration such that at certain chemical pump stroke length & speed, the chemical dosing rate should be 11ppm of make-up feed flow rate. An additional 1ppm of chemical was added to the make-up line to avoid scaling in the make-up heater.

(3) Time of the beginning of test

Values of the temperature gauge attached to the outlet of the heat exchanger tube are regarded as the brine temperature(T_2).

After turning on the switch for hot water circulation, it was decided that the time, when system attained steady state and T_2 had reached a constant value, was the time of the beginning of the test.

During normalization of the process, the system was pressurized by air up to 10psi in order to prevent any vapor formation and to maintain the required brine recirculation flow rate of 36L/min. For this, air was pressurized at the top of recirculation tank and the above pressure was maintained constant throughout the experiment.

The make-up brine was preheated up to 60℃ by a separate heater before injection into suction line of recirculation pump.

(4) **Sampling of specimens and measurements**
During each test, the values of each gauge were recorded and samples of blow down brine were collected for chemical analysis.

5. Evaluation Method

Out of the data obtained by testing, a fouling factor can be calculated in accordance with the following formula, and thus crystal distortion effect on each scale inhibitor can be evaluated.

The more the scale adheres to the internal surfaces of heat transfer tubes, the higher is the fouling factor. Therefore, the scale inhibitor, which has low fouling factor, has a high crystal distortion effect.

$$\Delta T = T_2 - T_1 \quad (1)$$
$$\Delta t_1 = t_1 - T_1 \quad (2)$$
$$\Delta t_2 = t_2 - T_2 \quad (3)$$
$$\Delta tm = (\Delta t_2 - \Delta t_1)/\ln(\Delta t_2/\Delta t_1) \quad (4)$$
$$Q = F_1 \; Cp \; \Delta T \quad (5)$$
$$U = Q/(S \; \Delta Tm) \quad (6)$$
$$Fo = (1/U) - (1/Uc) \quad (7)$$

where,

ΔT	:	rising Temp.	(℃)
T_1	:	heat exchanger tube inlet temp.	(℃)
T_2	:	heat exchanger tube outlet temp.	(℃)
t_1	:	shell hot water inlet temp.	(℃)
t_2	:	shell hot water outlet temp.	(℃)
Δtm	:	logarithmic mean Temp. difference $(\Delta t_2 - \Delta t_1)/\ln(\Delta t_2/\Delta t_1)$	(℃)
Q	:	heat transfer rate	(kJ/s)
F_1	:	recycle brine flow rate	(kg/s)
Cp	:	specific heat	(kJ/(kg K))
U	:	overall heat transfer coefficient	$(kW/(m^2 K))$
S	:	heat transfer area	(m^2)
Fo	:	fouling factor	$((m^2 K)/kW)$
Uc	:	clean U value	$(kW/(m^2 K))$

6. Results

(1) The performance test of the heat transfer test unit

Table 5 shows the results of the performance tests.

(2) Tests with the heat transfer test unit

Results of Test−1, 2, 3 & 4 are as follows.

(a) Results of blank tests run No.1 & 2 and tests with scale inhibitor run No.3 & 4 at the conditions of a dosing rate 1ppm and brine temperature of 90℃ and 102℃, and the values obtained by calculation such as logarithmic mean temperature difference (Δtm), heat flux (Hf), overall heat transfer coefficients (U) and clean U value are all shown in Table 6(1) to 6(4).

(b) The changes in heat transfer coefficients with the time are shown in Fig.2(1) to 2(4).

(c) The changes in fouling factors with the time are shown in Fig.3(1) to 3(4).

(d) The changes in fouling factors with the time are shown in Fig.4(1) to 4(3).

Table 5 Results of the Performance Test

Tube Side	Inlet Temp. (℃)	99.5
	Outlet Temp. (℃)	101
Shell Side	Inlet Temp. (℃)	104.41
	Outlet Temp. (℃)	103.40
Brine Flow Rate(F_1) (ℓ/h)		2,160
Blow Down Flow Rate(F_4) (ℓ/h)		43.8
Holding Water in Test Unit (m³)		0.18
Heat Transfer Area (m²)		0.4 (20 ^{ID} × 5,700 ^{L})
Brine Tube Velocity (m/sec)		1.85
Heat Flux (kW/m²)		5～8
Dosing Rate of Scale Inhibitor in Recycle Brine (ppm)		0.8 - 1.0 as PPN(M)
Conc. of Scale Inhibitor (ppm)		240
Dilution Ratio of RO Brine (times)		0.0

NOTE) Performance and Calibration Tests are carried out using ordinary potable water.

Table 6(1) Results of Test–1 (1/2)

Time (hrs)	T1 (C)	T2 (C)	t1 (C)	t2 (C)	FR(l/min)	HF(kW/m2)	LMTD	U(kW/m2/K)	Fo(m2.K/kW)
0	90.13	90.78	93.36	93.22	36	4.121	2.320	1.463	0.0505
2	90.07	90.57	92.69	92.33	36	3.170	2.162	1.467	0.0489
4	89.96	90.6	93.2	92.94	36	4.058	2.766	1.467	0.0487
6	89.8	90.43	93.07	92.67	36	3.994	2.723	1.467	0.0487
8	90.03	90.64	93.03	92.94	36	3.868	2.635	1.468	0.0483
10	89.13	89.86	92.87	92.56	36	4.628	3.192	1.450	0.0567
12	89.35	90.01	92.62	92.49	36	4.185	2.857	1.465	0.0498
14	89.71	90.35	93.05	92.61	36	4.058	2.765	1.468	0.0485
16	89.81	90.45	93.11	92.92	36	4.058	2.865	1.416	0.0731
18	89.3	89.95	92.65	92.36	36	4.121	2.854	1.444	0.0597
20	89.48	90.14	92.85	92.53	36	4.185	2.852	1.467	0.0486
22	89.49	90.12	92.76	92.42	36	3.994	2.757	1.449	0.0572
24	89.69	90.31	92.85	92.55	36	3.931	2.674	1.470	0.0472
26	89.88	90.51	93.09	92.87	36	3.994	2.763	1.446	0.0589
28	89.35	89.75	91.41	91.29	36	2.536	1.787	1.419	0.0719
30	89.61	90.27	93.01	92.74	36	4.185	2.910	1.438	0.0626
32	89.58	90.25	93.05	92.74	36	4.248	2.953	1.439	0.0622
34	89.51	90.19	92.98	92.74	36	4.311	2.986	1.444	0.0598
36	89.56	90.22	93.01	92.77	36	4.185	2.977	1.405	0.0786
38	89.72	90.35	92.99	92.65	36	3.994	2.757	1.449	0.0572
40	89.56	90.22	92.97	92.74	36	4.185	2.943	1.422	0.0703
42	89.39	90.03	92.68	92.47	36	4.058	2.844	1.427	0.0679
44	90.03	90.62	93.14	92.87	36	3.741	2.657	1.408	0.0773
46	89.68	90.31	92.98	92.67	36	3.994	2.804	1.425	0.0690
48	89.28	89.94	92.62	92.46	36	4.185	2.911	1.438	0.0627
50	89.5	90.15	92.87	92.6	36	4.121	2.886	1.428	0.0673
52	89.55	90.25	93.99	92.56	36	4.438	3.260	1.361	0.1016
54	89.87	90.45	92.91	92.67	36	3.677	2.609	1.410	0.0764
56	89.79	90.35	92.92	92.69	36	3.551	2.716	1.307	0.1320
58	90.09	90.65	93.12	92.87	36	3.551	2.604	1.363	0.1005
60	89.87	90.45	92.92	92.67	36	3.677	2.613	1.407	0.0777
62	89.54	90.17	92.97	92.65	36	3.994	2.929	1.364	0.1005
64	89.69	90.29	92.94	92.61	36	3.804	2.759	1.379	0.0923
66	89.57	90.19	92.95	92.67	36	3.931	2.907	1.352	0.1066
68	90.1	90.62	93.03	92.8	36	3.297	2.537	1.300	0.1364
70	90.27	90.52	91.35	91.1	36	1.585	0.804	1.971	-0.1255
72	90.02	90.59	93.07	92.89	36	3.614	2.657	1.360	0.1024
74	90.07	90.61	92.98	92.85	36	3.424	2.560	1.337	0.1149
76	90.13	90.69	93.03	92.92	36	3.551	2.550	1.392	0.0854
78	90.3	90.8	93	92.87	36	3.170	2.371	1.337	0.1150
80	90.26	90.8	93.14	93.09	36	3.424	2.574	1.330	0.1188
82	90.33	90.85	92.96	93.09	36	3.297	2.430	1.357	0.1041
84	89.79	90.37	92.79	92.87	36	3.677	2.742	1.341	0.1128
86	89.22	89.95	93.18	93.12	36	4.628	3.550	1.304	0.1342
88	89.86	90.42	92.84	92.75	36	3.551	2.642	1.344	0.1111
90	89.86	90.41	92.86	92.75	36	3.487	2.656	1.313	0.1288
92	89.89	90.42	92.87	92.77	36	3.360	2.653	1.267	0.1565
94	90.03	90.52	92.82	92.73	36	3.107	2.489	1.248	0.1682
96	90.02	90.52	92.85	92.75	36	3.170	2.098	1.259	0.1614

* Cp AND DENSITY AS PER TABLE OF SEA WATER PROPERTIES
* HEAT TRANSFER SURFACE AREA = 0.37605 M^2

Table 6(1) Results of Test-1 (2/2)

98	90.08	90.62	93	92.92	36	3.424	2.598	1.318	0.1258
100	89.95	90.45	92.74	92.68	36	3.170	2.500	1.268	0.1556
102	89.92	90.42	92.78	92.76	36	3.170	2.591	1.223	0.1845
104	89.9	90.41	92.79	92.74	36	3.234	2.600	1.244	0.1711
106	89.54	90.07	92.64	92.51	36	3.360	2.757	1.219	0.1875
108	89.48	90.07	92.56	92.45	36	3.741	2.715	1.378	0.0929
110	89.6	90.15	92.92	92.63	36	3.487	2.880	1.211	0.1929
112	89.71	90.21	92.86	92.44	36	3.170	2.664	1.190	0.2073
114	89.18	89.79	93.27	92.49	36	3.868	3.347	1.156	0.2325
116	89.23	89.85	93.33	92.62	36	3.931	3.392	1.159	0.2299
118	89.3	89.9	92.7	92.62	36	3.804	3.047	1.248	0.1681
120	89.24	89.89	93.38	92.71	36	4.121	3.438	1.199	0.2013
122	89.1	89.72	93.2	92.47	36	3.931	3.380	1.163	0.2270
124	89.21	89.85	93.33	92.55	36	4.058	3.360	1.208	0.1952
126	89.19	89.82	93.31	92.56	36	3.994	3.383	1.181	0.2141
128	88.97	89.64	92.38	93.22	36	4.248	3.494	1.216	0.1897
130	88.95	89.59	93.26	92.56	36	4.058	3.599	1.128	0.2539
132	89.05	89.7	93.38	92.59	36	4.121	3.562	1.157	0.2313
134	89.03	89.69	93.34	92.54	36	4.185	3.530	1.186	0.2106
136	89.04	89.71	93.31	92.56	36	4.248	3.512	1.209	0.1939
138	89.58	90.18	93.97	92.59	36	3.804	3.302	1.152	0.2350
140	89.2	89.82	93.53	92.73	36	3.931	3.573	1.100	0.2760
142	89.29	89.9	93.49	92.73	36	3.868	3.470	1.115	0.2643
144	89.26	89.88	93.42	92.64	36	3.931	3.412	1.152	0.2351
146	89.26	89.93	93.53	92.71	36	4.248	3.472	1.224	0.1844
148	89.34	89.95	93.14	92.82	36	3.868	3.313	1.167	0.2238
150	89.32	89.93	93.47	92.65	36	3.868	3.385	1.143	0.2423
152	89.24	89.89	93.49	92.73	36	4.121	3.498	1.178	0.2158
154	89.51	90.25	93.81	93.25	36	4.692	3.611	1.299	0.1367
156	89.4	89.98	93.42	92.64	36	3.677	3.293	1.117	0.2627
158	89.37	89.95	93.47	92.67	36	3.677	3.363	1.094	0.2816
160	89.42	89.97	93.46	92.65	36	3.487	3.314	1.052	0.3173
162	89.39	89.94	93.45	92.63	36	3.487	3.328	1.048	0.3215
164	89.46	90.01	93.42	92.64	36	3.487	3.250	1.073	0.2990
166	89.51	90.05	93.44	92.58	36	3.424	3.179	1.077	0.2955
168	89.74	90.33	93.62	92.92	36	3.741	3.192	1.172	0.2203
170	89.87	90.36	93.58	92.78	36	3.107	3.019	1.029	0.3389
172	89.75	90.29	93.5	92.48	36	3.424	2.900	1.180	0.2142
174	89.85	90.38	93.53	92.78	36	3.360	2.995	1.122	0.2582
176	89.15	89.77	93.36	92.59	36	3.931	3.469	1.133	0.2495

- Cp AND DENSITY AS PER TABLE OF SEA WATER PROPERTIES
- HEAT TRANSFER SURFACE AREA = 0.37605 M^2

Table 6(2) Results of Test-2 (1/2)

Time (hrs)	T1 (C)	T2 (C)	t1 (C)	t2 (C)	FR(l/min)	HF(kW/m2)	LMTD	U(kW/m2/K)	Fo(m2.K/kW)
0	101.2	101.95	105.28	104.27	34	4.474	3.118	1.435	0.0639
2	101.35	102.01	104.95	103.93	33.5	3.880	2.673	1.452	0.0560
4	101.1	101.81	105.03	104.24	35.5	4.423	3.120	1.417	0.0726
6	101.32	102.05	105.22	104.43	33.5	4.291	3.078	1.394	0.0843
8	100.04	100.88	104.43	103.61	33.5	4.938	3.495	1.413	0.0748
10	100.88	101.72	105.25	104.5	33.5	4.938	3.515	1.405	0.0790
12	100.75	101.65	105.08	104.27	32	5.053	3.404	1.485	0.0406
14	100.67	101.45	104.79	103.81	33	4.517	3.159	1.430	0.0665
16	100.81	101.61	105.09	104.13	33	4.632	3.323	1.394	0.0844
18	100.98	101.76	105.13	104.14	33	4.517	3.183	1.419	0.0719
20	100.94	101.73	105.12	104.18	33.5	4.644	3.238	1.434	0.0644
22	101.47	102.41	105.91	105.05	31.5	5.196	3.462	1.501	0.0335
24	100.89	101.69	105.14	104.3	33	4.632	3.364	1.377	0.0932
26	101.45	102.17	105.53	104.14	33	4.169	2.898	1.439	0.0622
28	101.42	102.17	105.54	104.43	33	4.343	3.097	1.402	0.0803
30	101.54	102.07	104.74	103.42	33	3.069	2.144	1.432	0.0656
32	101.35	102.05	105.21	104.24	33	4.053	2.947	1.376	0.0940
34	101.21	101.72	104.16	103.14	33	2.953	2.093	1.411	0.0757
36	101.24	101.89	104.87	103.82	33	3.764	2.691	1.399	0.0821
38	101.23	101.88	104.88	103.74	33	3.764	2.655	1.418	0.0725
40	101.09	101.83	105.08	104.08	33	4.285	3.037	1.411	0.0759
42	101.71	102.31	104.56	104.42	33	3.474	2.461	1.411	0.0756
44	101.27	102.01	105.18	104.22	33	4.285	2.980	1.438	0.0625
46	101.19	101.82	104.81	103.64	33	3.648	2.618	1.394	0.0847
48	101.65	102.36	105.5	104.41	33	4.111	2.856	1.439	0.0618
50	101.34	102.03	105.12	104.27	33	3.995	2.943	1.358	0.1037
52	101.2	101.93	105.03	104.16	33	4.227	2.958	1.429	0.0669
54	101.49	102.13	105.21	104.49	33	3.706	2.989	1.240	0.1735
56	101.38	102.09	105.19	104.45	33	4.111	3.027	1.358	0.1035
58	101.39	102.08	105.2	104.51	33	3.995	3.068	1.302	0.1351
60	101.39	102.1	105.23	104.45	33	4.111	3.034	1.355	0.1051
62	101.33	102.04	105.21	104.49	33	4.111	3.110	1.322	0.1237
64	101.08	101.86	105.12	104.41	33	4.517	3.238	1.395	0.0840
66	101.33	101.99	105.12	104.36	33	3.822	3.025	1.264	0.1585
68	101.06	101.8	105.12	104.35	33	4.285	3.247	1.320	0.1248
70	101.28	102.04	105.29	104.49	32	4.267	3.166	1.348	0.1090
72	101.11	101.83	105.01	104.16	32	4.043	3.048	1.326	0.1210
74	101.09	101.81	105.2	104.35	33	4.169	3.262	1.278	0.1496
76	101.23	101.97	105.37	104.5	33	4.285	3.269	1.311	0.1300
78	101.15	101.9	105.3	104.45	32	4.211	3.285	1.282	0.1472
80	101.47	102.08	104.9	104.2	33	3.532	2.723	1.297	0.1379
82	101.57	102.2	105.6	104.14	33	3.648	2.859	1.276	0.1508
84	101.49	102.08	105	104.19	33	3.416	2.751	1.242	0.1723
86	101.39	102.08	105.39	104.62	33	3.995	3.215	1.243	0.1717
88	100.99	101.73	105.25	104.45	33	4.285	3.433	1.248	0.1682
90	101.17	101.9	105.3	104.52	33	4.227	3.318	1.274	0.1520
92	100.93	101.65	105.18	104.38	33	4.169	3.434	1.214	0.1908
94	100.95	101.66	105.1	104.29	33	4.111	3.332	1.234	0.1777
96	100.68	101.39	104.79	103.84	32	3.987	3.209	1.242	0.1720

* Cp AND DENSITY AS PER TABLE OF SEA WATER PROPERTIES
* HEAT TRANSFER SURFACE AREA = 0.37605 M^2

Table 6(2) Results of Test-2 (2/2)

98	100.83	101.56	105.06	104.23	33	4.227	3.390	1.247	0.1692
100	100.62	101.29	104.4	103.57	32	3.762	2.967	1.268	0.1558
102	101.19	101.87	105.24	104.36	33	3.937	3.207	1.228	0.1816
104	101.17	101.82	105.17	104.21	33	3.764	3.126	1.204	0.1977
106	101.47	102.1	105.33	104.45	33	3.648	3.043	1.199	0.2012
108	101.62	102.09	104.56	103.85	33	2.722	2.300	1.183	0.2121
110	101.36	102.03	105.33	104.57	33	3.880	3.202	1.212	0.1924
112	101.35	102.03	105.42	104.57	33	3.937	3.245	1.213	0.1912
114	101.42	102.04	105.1	104.31	33	3.590	2.918	1.230	0.1800
116	100.9	101.5	104.53	103.69	33	3.474	2.850	1.219	0.1873
118	101.54	102.25	105.71	104.88	33	4.111	3.341	1.231	0.1798
120	101.18	101.9	105.4	104.59	33	4.169	3.398	1.227	0.1821
122	101.19	101.82	105.13	104.23	33.5	3.703	3.113	1.190	0.2076
124	101.23	101.86	105.05	104.15	33	3.648	2.990	1.220	0.1867
126	101.12	101.66	104.46	103.58	33	3.127	2.565	1.219	0.1873
128	101.71	102.09	103.96	103.61	33	2.200	1.861	1.182	0.2129
130	101.46	102.05	105.24	104.16	33	3.416	2.864	1.193	0.2055
132	101.51	102.04	105.15	103.89	33	3.069	2.645	1.160	0.2289
134	101.54	102.03	104.87	103.67	33	2.837	2.386	1.189	0.2081
136	101.48	101.95	104.81	103.45	33	2.722	2.295	1.186	0.2102
138	101.59	102.08	104.98	103.72	33	2.837	2.410	1.177	0.2165
140	101.58	102.1	105.3	104.24	33	3.011	2.858	1.054	0.3161
142	101.29	101.87	105.01	104.11	33	3.358	2.918	1.151	0.2359
144	101.47	101.9	105.32	102.95	33	2.490	2.155	1.155	0.2326
146	101.35	101.85	105.13	103.42	33	2.895	2.515	1.151	0.2358
148	101.48	101.9	105.03	103.07	33	2.432	2.144	1.134	0.2488
150	101.64	102.07	105.39	103.2	33	2.490	2.184	1.140	0.2443
152	101.56	101.98	105.14	103.14	33	2.432	2.147	1.133	0.2501
154	101.73	102.15	105.06	103.37	33	2.432	2.101	1.157	0.2311
156	101.46	101.91	105.33	103.15	33	2.606	2.311	1.128	0.2539
158	101.58	102.01	104.98	103.42	33	2.490	2.261	1.101	0.2751
160	101.58	101.99	104.73	103.33	33	2.374	2.118	1.121	0.2591
162	101.84	102.24	104.62	103.8	33	2.316	2.112	1.097	0.2788
164	101.58	101.98	104.6	103.33	33	2.316	2.074	1.117	0.2626
166	101.45	101.87	105.03	103.12	33	2.432	2.214	1.098	0.2776
168	101.71	102.09	104.79	103.31	33	2.200	2.008	1.096	0.2799
170	101.76	102.15	104.75	103.52	33	2.258	2.076	1.088	0.2862

- Cp AND DENSITY AS PER TABLE OF SEA WATER PROPERTIES
- HEAT TRANSFER SURFACE AREA = 0.37605 M^2

Table 6(3) Results of Test-3 (1/2)

Time (hrs)	T1 (C)	T2 (C)	t1 (C)	t2 (C)	FR(l/min)	HF(kW/m2)	LMTD	U(kW/m2/K)	Fo(m2.K/kW)
0	89.90	90.64	93.71	92.94	36	4.710	2.991	1.575	0.0021
2	90.03	90.78	93.79	93.14	36	4.732	3.006	1.574	0.0024
4	90.02	90.66	93.27	92.74	36	4.091	2.624	1.559	0.0085
6	89.27	90.05	93.29	92.46	36	4.915	3.142	1.564	0.0065
8	89.69	90.43	93.44	92.82	36	4.674	3.015	1.550	0.0122
10	89.72	90.48	93.51	92.89	36	4.785	3.046	1.571	0.0037
12	89.66	90.39	93.40	92.74	36	4.668	2.990	1.561	0.0076
14	89.80	90.54	93.47	92.96	36	4.693	2.998	1.565	0.0060
16	89.92	90.53	93.16	92.46	36	3.865	2.529	1.529	0.0213
18	89.93	90.61	93.47	92.69	36	4.291	2.743	1.564	0.0065
20	89.90	90.54	93.31	92.53	36	4.074	2.630	1.549	0.0127
22	88.74	89.48	92.67	91.84	36	4.719	3.078	1.533	0.0194
24	89.39	90.16	93.42	92.71	36	4.935	3.230	1.528	0.0216
26	89.51	90.28	93.49	92.67	36	4.853	3.118	1.557	0.0095
28	89.48	90.16	93.03	92.37	36	4.326	2.824	1.532	0.0199
30	90.18	90.95	94.07	93.38	36	4.864	3.105	1.567	0.0054
32	88.97	89.72	92.78	92.07	36	4.759	3.016	1.578	0.0007
34	89.32	90.02	92.96	92.24	36	4.404	2.875	1.532	0.0198
36	90.33	90.96	93.75	93.00	36	4.030	2.667	1.511	0.0289
38	90.53	90.86	92.21	92.01	36	2.125	1.399	1.518	0.0257
40	90.80	91.29	93.53	92.69	36	3.119	1.994	1.564	0.0064
42	88.43	89.23	92.67	91.98	36	5.068	3.444	1.472	0.0466
44	89.10	89.77	92.58	91.93	36	4.266	2.765	1.543	0.0153
46	88.46	89.15	92.05	91.39	36	4.369	2.864	1.526	0.0226
48	89.13	89.87	93.01	92.30	36	4.683	3.098	1.512	0.0286
52	89.56	90.30	93.33	92.60	36	4.652	2.974	1.564	0.0063
54	89.34	90.03	93.20	92.46	36	4.407	3.086	1.428	0.0673
56	88.96	89.61	92.33	91.67	36	4.142	2.660	1.557	0.0093
58	89.07	89.79	92.40	92.31	36	4.570	2.912	1.569	0.0042
60	89.32	89.97	92.33	92.39	36	4.093	2.703	1.514	0.0274
62	89.19	89.79	92.31	91.77	36	3.766	2.507	1.502	0.0329
64	89.27	89.93	92.83	92.08	36	4.190	2.795	1.499	0.0343
66	89.23	89.89	92.62	92.03	36	4.182	2.721	1.537	0.0177
68	89.61	90.15	92.47	91.80	36	3.405	2.206	1.544	0.0148
70	89.68	90.39	93.40	92.71	36	4.566	2.962	1.541	0.0158
74	89.37	90.10	93.22	92.46	36	4.620	3.041	1.519	0.0254
76	89.15	89.95	93.42	92.71	36	5.099	3.458	1.475	0.0452
78	89.61	90.39	93.79	93.07	36	4.975	3.370	1.476	0.0445
80	89.42	90.18	93.47	92.76	36	4.836	3.262	1.482	0.0416
82	89.32	90.03	93.22	92.49	36	4.508	3.121	1.444	0.0595
84	88.72	89.50	92.89	92.17	36	4.919	3.365	1.462	0.0511
86	89.34	90.08	93.36	92.64	36	4.718	3.233	1.459	0.0523
88	89.77	90.26	92.40	91.72	36	3.111	1.985	1.567	0.0052
90	89.72	90.41	93.40	92.69	36	4.363	2.921	1.494	0.0365
92	89.45	90.23	93.58	92.83	36	4.946	3.310	1.494	0.0362
94	89.61	90.35	93.58	92.92	36	4.660	3.226	1.445	0.0592
96	89.56	90.35	93.69	93.00	36	4.967	3.337	1.488	0.0390
98	89.29	90.05	93.34	92.64	36	4.814	3.265	1.474	0.0453
100	89.12	89.89	93.22	92.53	36	4.887	3.317	1.473	0.0459

* Cp AND DENSITY AS PER TABLE OF SEA WATER PROPERTIES
* HEAT TRANSFER SURFACE AREA = 0.37605 M^2

Table 6(3) Results of Test-3 (2/2)

102	89.66	90.38	93.55	92.83	36	4.563	3.116	1.464	0.0500
104	89.19	89.90	93.07	92.37	36	4.487	3.117	1.440	0.0617
106	88.72	89.45	92.74	92.01	36	4.614	3.238	1.425	0.0688
108	88.69	89.43	92.80	91.94	36	4.711	3.243	1.453	0.0555
110	88.75	89.50	92.87	92.14	36	4.721	3.323	1.421	0.0709
112	88.68	89.42	92.64	91.91	36	4.708	3.169	1.486	0.0402
114	88.74	89.48	92.82	92.10	36	4.719	3.295	1.432	0.0654
116	88.79	89.58	93.07	92.37	36	5.033	3.483	1.445	0.0592
118	88.63	89.23	91.70	91.15	36	3.790	2.453	1.545	0.0142
120	89.39	90.15	93.49	92.78	36	4.831	3.314	1.458	0.0531
122	89.13	89.92	93.34	92.64	36	4.993	3.410	1.464	0.0500
124	89.21	89.87	92.89	92.17	36	4.180	2.936	1.424	0.0696
126	89.26	90.03	93.47	92.73	36	4.912	3.397	1.446	0.0585
128	89.07	89.85	93.27	92.55	36	4.981	3.391	1.469	0.0478
130	89.21	89.97	93.36	92.58	36	4.800	3.324	1.444	0.0595
132	89.15	89.93	93.38	92.67	36	4.996	3.430	1.456	0.0537
134	89.24	89.97	93.23	92.51	36	4.599	3.212	1.431	0.0657
136	89.37	90.15	93.53	92.80	36	4.932	3.347	1.473	0.0458
138	89.53	90.26	93.56	92.85	36	4.647	3.258	1.426	0.0683
140	89.35	90.10	93.47	92.56	36	4.721	3.221	1.466	0.0494
142	89.56	90.30	93.60	92.83	36	4.652	3.231	1.440	0.0615
144	89.55	89.95	91.82	91.22	36	2.568	1.723	1.491	0.0379
146	89.43	90.10	93.01	92.30	36	4.214	2.833	1.487	0.0395
148	89.43	89.95	92.31	91.65	36	3.280	2.237	1.467	0.0490
150	89.50	90.23	93.34	92.58	36	4.641	3.038	1.528	0.0216
152	89.39	90.15	93.53	92.83	36	4.831	3.361	1.437	0.0629
154	89.43	89.97	92.44	91.80	36	3.384	2.373	1.426	0.0684
156	89.61	90.21	92.96	92.28	36	3.823	2.656	1.439	0.0619
158	89.50	90.21	93.47	92.73	36	4.537	3.187	1.423	0.0696
160	89.34	90.05	93.27	92.53	36	4.511	3.150	1.432	0.0654
162	89.32	90.10	93.55	92.80	36	4.924	3.405	1.446	0.0586
164	89.31	90.02	93.18	92.42	36	4.505	3.080	1.463	0.0508
166	89.02	89.79	93.14	92.58	36	4.870	3.414	1.426	0.0681
168	89.35	90.07	93.33	92.55	36	4.513	3.167	1.425	0.0689
170	89.29	90.05	93.40	92.67	36	4.814	3.310	1.454	0.0546
172	88.55	89.34	92.82	92.07	36	4.990	3.439	1.451	0.0563
174	88.32	89.08	92.49	91.75	36	4.848	3.364	1.441	0.0611
176	90.07	90.80	94.15	93.42	36	4.631	3.297	1.404	0.0791
178	91.80	92.53	95.84	95.09	36	4.589	3.242	1.416	0.0735
180	90.08	90.74	93.60	93.22	36	4.207	2.964	1.419	0.0717

* Cp AND DENSITY AS PER TABLE OF SEA WATER PROPERTIES
* HEAT TRANSFER SURFACE AREA = 0.37605 M^2

Table 6(4) Results of Test-4 (1/2)

Time (hrs)	T1 (C)	T2 (C)	t1 (C)	t2 (C)	FR(l/min)	HF(kW/m2)	LMTD	U(kW/m2/K)	Fo(m2.K/kW)
0	99.811	100.58	103.74	102.96	36	4.857	3.093	1.571	0.0038
2	100.28	100.98	103.87	103.22	36	4.481	2.863	1.565	0.0061
4	100.04	100.87	104.01	103.22	33	4.764	3.090	1.542	0.0157
6	100.04	100.82	104.01	102.96	34	4.624	2.962	1.561	0.0078
8	100.75	101.52	104.54	103.74	34	4.592	2.940	1.562	0.0075
10	101.22	102.01	105.08	104.24	34	4.668	2.975	1.569	0.0045
14	100.98	101.74	105.36	103.79	36	4.747	3.073	1.545	0.0144
16	101.27	101.96	104.81	104.11	36	4.324	2.789	1.551	0.0120
18	101.71	102.46	105.53	104.54	34.5	4.511	2.863	1.576	0.0017
20	101.49	102.26	105.06	104.59	34	4.561	2.909	1.568	0.0048
22	101.25	102.03	104.95	104.41	34	4.672	2.987	1.564	0.0065
24	100.96	101.74	104.7	104.08	34	4.626	2.991	1.546	0.0138
26	100.51	101.27	104.32	103.43	34	4.555	2.906	1.567	0.0052
28	101.03	101.81	104.87	104.14	34.5	4.705	3.018	1.559	0.0086
30	101.56	102.33	105.42	104.59	34.5	4.640	2.987	1.553	0.0108
34	103.12	103.87	106.75	106.2	34.5	4.572	2.933	1.559	0.0086
36	102.94	103.77	106.72	106.03	31.5	4.585	2.959	1.549	0.0125
38	102.11	102.89	105.78	104.92	31	4.247	2.772	1.532	0.0198
40	101.61	102.36	105.42	104.68	36	4.691	3.000	1.564	0.0065
42	102.11	102.84	106	105.03	36	4.610	2.964	1.555	0.0101
44	102.76	103.48	106.63	105.64	36	4.549	2.933	1.551	0.0119
48	100.46	101.18	104.24	103.38	36	4.510	2.920	1.545	0.0144
50	100.72	101.44	104.46	103.58	35	4.424	2.866	1.544	0.0148
52	101.44	102.18	105.36	104.41	36	4.664	2.991	1.559	0.0084
54	100.98	101.64	104.41	103.61	36	4.127	2.631	1.569	0.0045
56	101.13	101.91	104.87	104.14	33	4.515	2.919	1.547	0.0135
58	100.42	101.18	104.11	103.48	34	4.540	2.945	1.542	0.0158
60	101.59	102.36	105.3	104.73	34	4.577	2.994	1.528	0.0214
62	102.16	102.89	106	105.19	36	4.618	3.012	1.533	0.0194
64	101.76	102.48	105.53	104.76	36	4.556	2.958	1.540	0.0164
66	101.35	102.03	104.76	104.32	36	4.335	2.815	1.540	0.0164
68	102.23	102.94	106.06	105.17	36	4.468	2.957	1.511	0.0290
70	101.91	102.58	105.47	104.78	36	4.260	2.828	1.506	0.0309
72	101.56	102.26	105.25	104.51	36	4.368	2.913	1.499	0.0340
74	101.44	102.03	104.59	103.87	36	3.722	2.438	1.527	0.0221
76	101.49	102.23	105.33	104.62	36	4.672	3.058	1.528	0.0217
78	101.37	101.81	103.82	103.09	36	2.778	1.804	1.540	0.0165
80	101.39	102.13	105.3	104.51	36	4.656	3.083	1.510	0.0292
82	101.37	102.08	105.39	104.59	36	4.496	3.206	1.402	0.0803
84	101.54	102.31	105.58	104.84	36	4.838	3.229	1.498	0.0345
86	101.06	101.81	105.11	104.38	36	4.758	3.256	1.462	0.0513
88	101.18	101.93	105.22	104.49	36	4.778	3.242	1.474	0.0457
90	101.54	102.11	104.78	103.87	36	3.577	2.431	1.472	0.0466
92	101.76	102.51	105.86	105.14	36	4.715	3.313	1.423	0.0698
94	101.66	102.43	105.78	104.97	36	4.858	3.267	1.487	0.0396
96	101.81	102.48	105.47	104.57	36	4.245	2.800	1.516	0.0266
98	101.22	102.01	105.44	104.7	36	4.942	3.400	1.454	0.0551
100	101.32	102.08	105.36	104.59	36	4.802	3.215	1.493	0.0367
102	101.08	101.86	105.3	104.54	36	4.918	3.394	1.449	0.0573

* CP AND DENSITY AS PER TABLE OF SEA WATER PROPERTIES
* HEAT TRANSFER SURFACE AREA = 0.37605 M^2

Table 6(4) Results of Test–4 (2/2)

104	100.87	101.66	105.19	104.46	36	5.036	3.507	1.436	0.0635
106	101.44	102.08	104.92	104.16	36	4.035	2.721	1.483	0.0413
108	101.47	102.26	105.75	104.95	36	4.983	3.426	1.455	0.0546
110	102.06	102.84	106.29	105.53	36	4.924	3.403	1.447	0.0583
114	101.03	101.76	105.06	104.22	36	4.599	3.177	1.448	0.0578
118	101.49	102.21	105.36	104.54	36	4.514	3.037	1.486	0.0398
120	101.49	102.23	105.5	104.7	36	4.672	3.178	1.470	0.0473
122	101.35	102.03	105.14	104.3	36	4.335	2.965	1.462	0.0509
124	101.32	102.03	105.3	104.51	36	4.488	3.173	1.414	0.0741
126	101.06	101.81	105.22	104.38	36	4.758	3.303	1.441	0.0613
128	100.96	101.54	104.24	103.48	36	3.661	2.553	1.434	0.0645
130	101.01	101.78	105.22	104.35	36	4.906	3.322	1.477	0.0443
132	100.82	101.59	105	104.14	36	4.874	3.300	1.477	0.0441
134	100.84	101.59	104.95	104.11	36	4.723	3.250	1.453	0.0552
136	101.03	101.69	104.7	103.79	36	4.134	2.817	1.468	0.0484
138	101.06	101.71	104.78	103.82	36	4.137	2.842	1.456	0.0539
140	100.84	101.61	105.14	104.3	36	4.878	3.428	1.423	0.0699
142	101.03	101.76	105.03	104.24	36	4.599	3.181	1.446	0.0587
144	101.37	102.11	105.42	104.62	36	4.653	3.220	1.445	0.0591
146	101.37	102.03	105.11	104.3	36	4.182	2.943	1.421	0.0707
148	101.39	102.16	105.61	104.76	36	4.814	3.343	1.440	0.0617
150	100.98	101.71	104.89	104.35	36	4.592	3.233	1.420	0.0712
152	100.77	101.52	104.89	104.16	36	4.712	3.332	1.414	0.0742
154	100.84	101.59	104.97	104.24	36	4.723	3.340	1.414	0.0743
158	101.03	101.69	104.76	103.93	36	4.134	2.919	1.416	0.0731
160	101.32	102.03	105.36	104.57	36	4.488	3.229	1.390	0.0865
162	101.35	102.08	105.44	104.62	36	4.649	3.257	1.427	0.0676
164	101.37	102.03	105.3	104.46	36	4.182	3.120	1.340	0.1133
166	101.3	102.01	105.36	104.51	36	4.484	3.222	1.392	0.0855
168	101.35	102.06	105.42	104.59	36	4.492	3.243	1.385	0.0891
170	100.96	101.66	105.03	104.19	36	4.433	3.238	1.369	0.0975
172	101.01	101.74	105.11	104.41	36	4.595	3.335	1.378	0.0929
174	101.3	101.91	104.84	104.06	36	3.859	2.788	1.384	0.0894
176	101.27	101.96	105.3	104.32	36	4.324	3.126	1.383	0.0899

* Cp AND DENSITY AS PER TABLE OF SEA WATER PROPERTIES
* HEAT TRANSFER SURFACE AREA = 0.37605 M^2

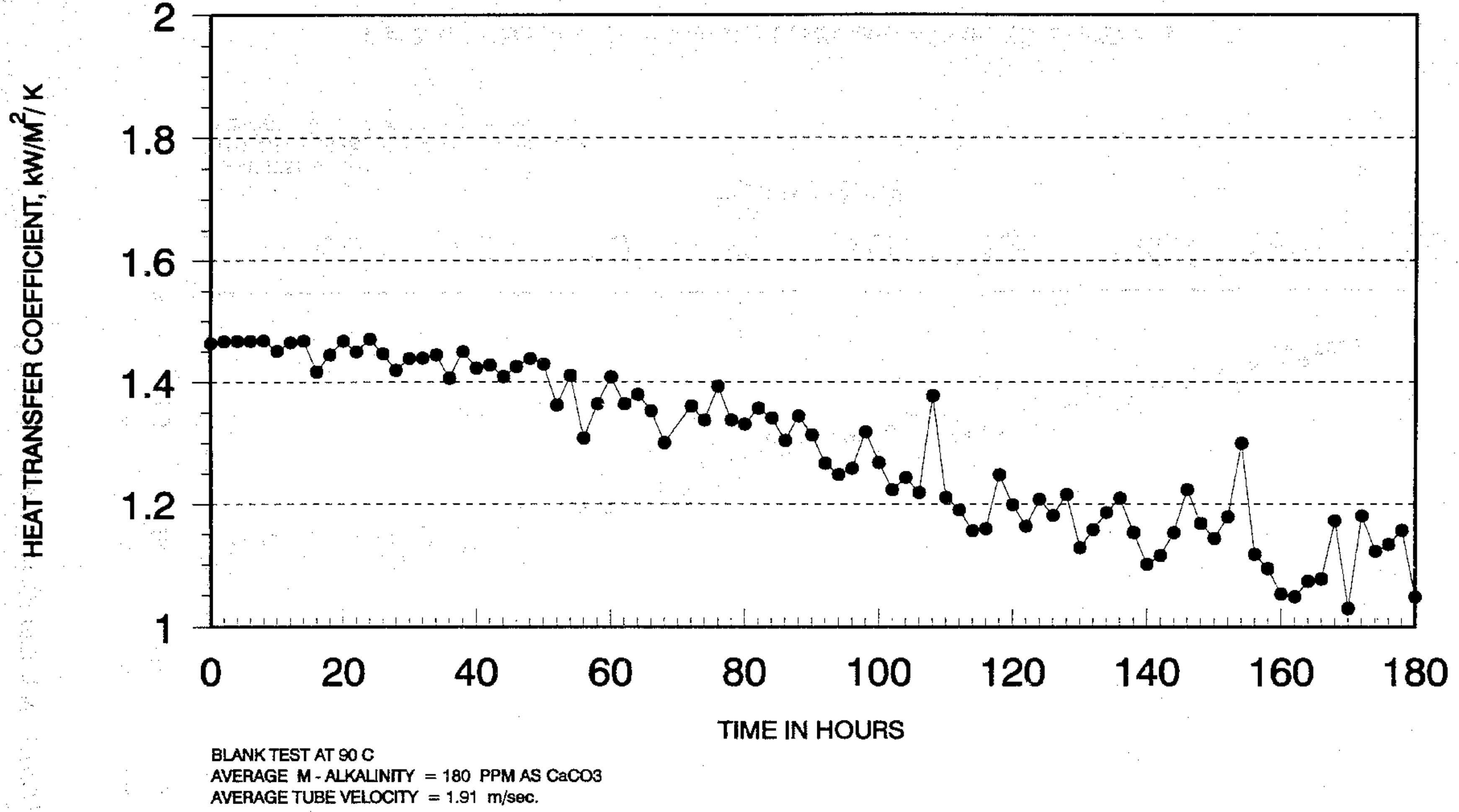


Fig. 2(1) Changes in Heat Transfer Coefficients with the Time on Test–1

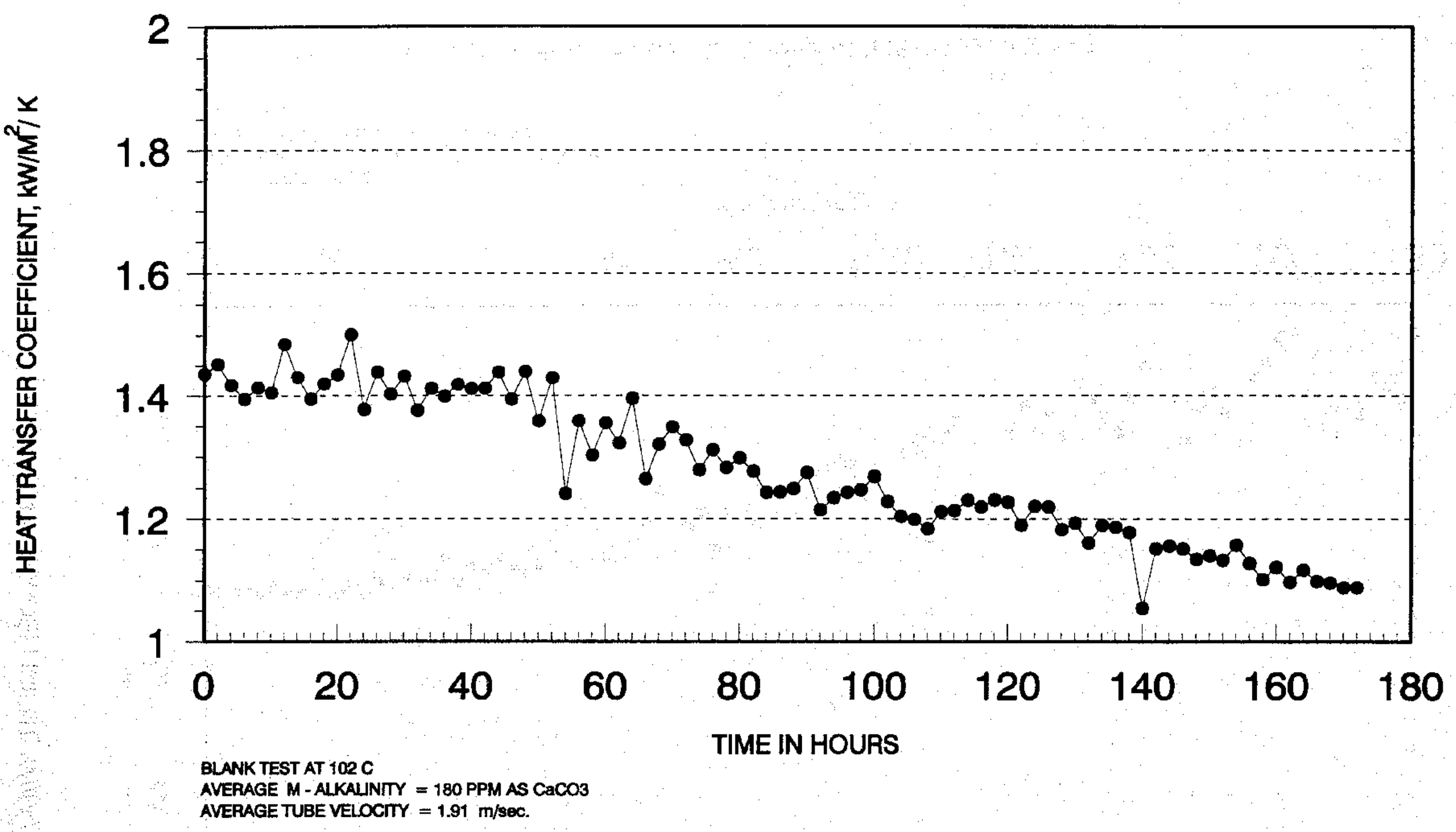
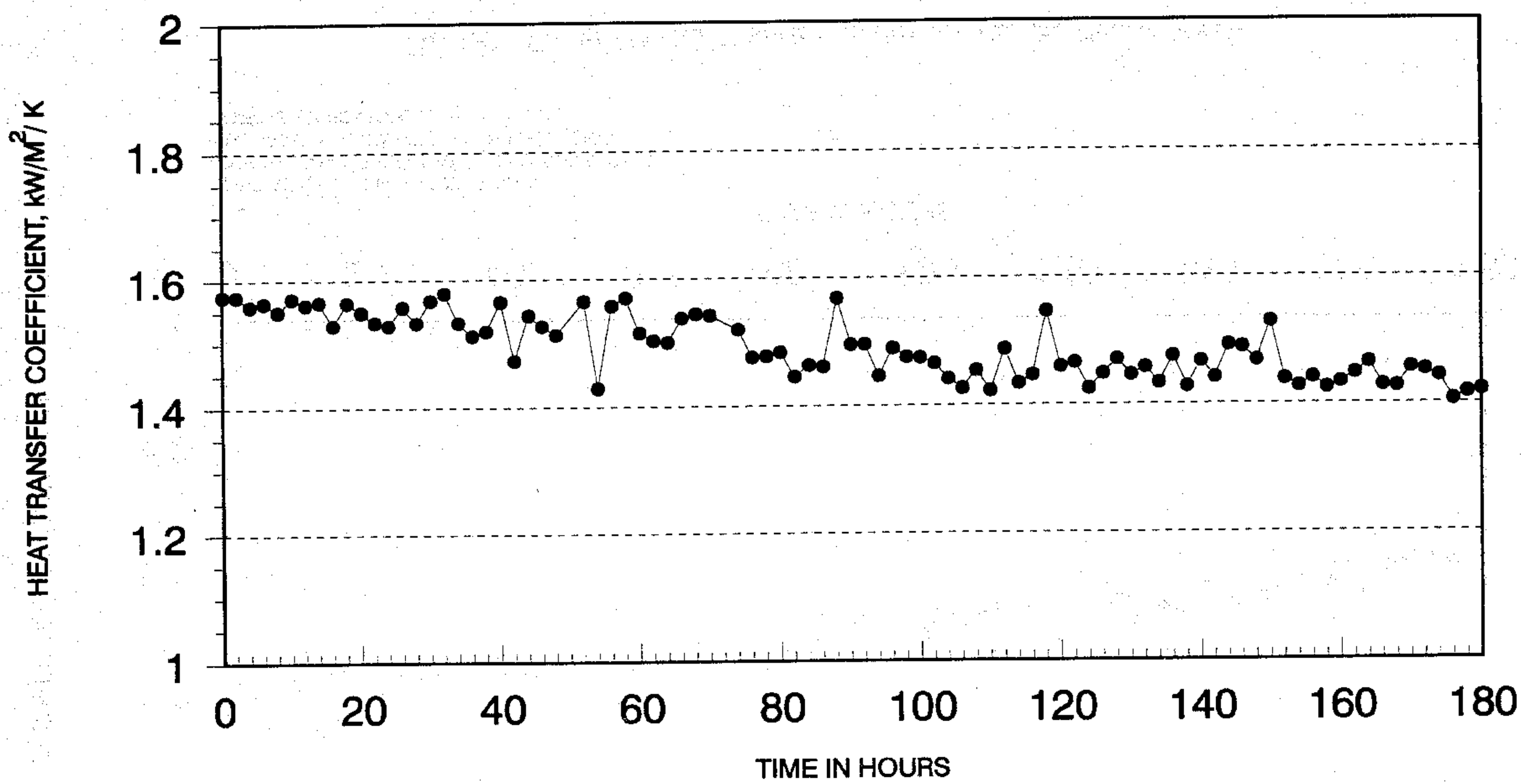
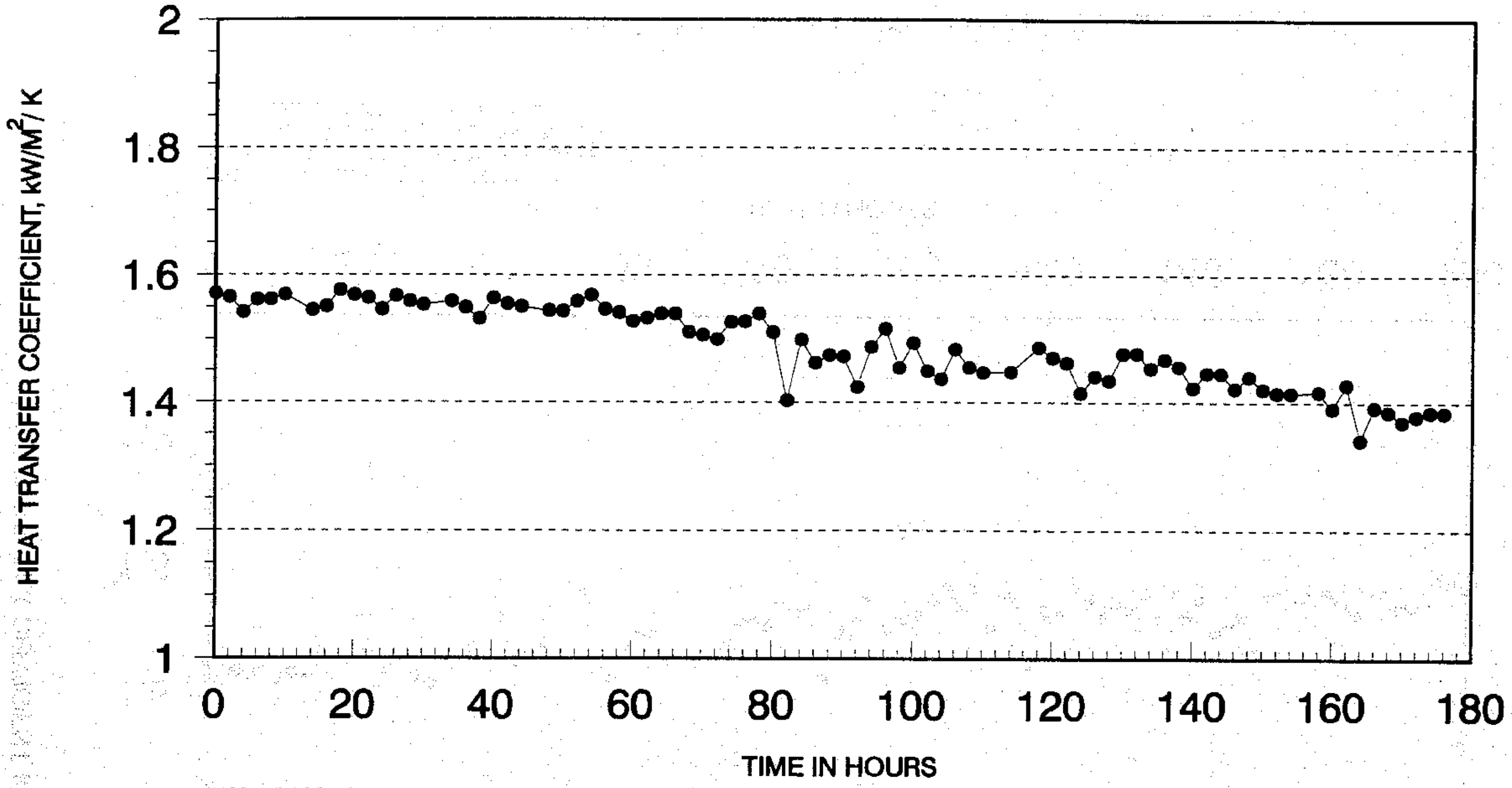


Fig. 2(2) Changes in Heat Transfer Coefficients with the Time on Test–2



TEST WITH SCALE INHIBITOR AT 90 C
DSB(M) DOSING RATE - 1 PPM IN RECYCLING BRINE
AVERAGE M - ALKALINITY = 180 PPM AS CaCO3
AVERAGE TUBE VELOCITY =1.91 m/sec.

Fig. 2(3) Changes in Heat Transfer Coefficient with the Time on Test–3



TEST WITH SCALE INHIBITOR AT 102 C
DSB(M) DOSING RATE - 1 PPM IN RECYCLING BRINE
AVERAGE M - ALKALINITY = 180 PPM AS $CaCO_3$
AVERAGE TUBE VELOCITY =1.91 m/sec.

Fig. 2(4) Changes in Heat Transfer Coefficients with the Time on Test–4

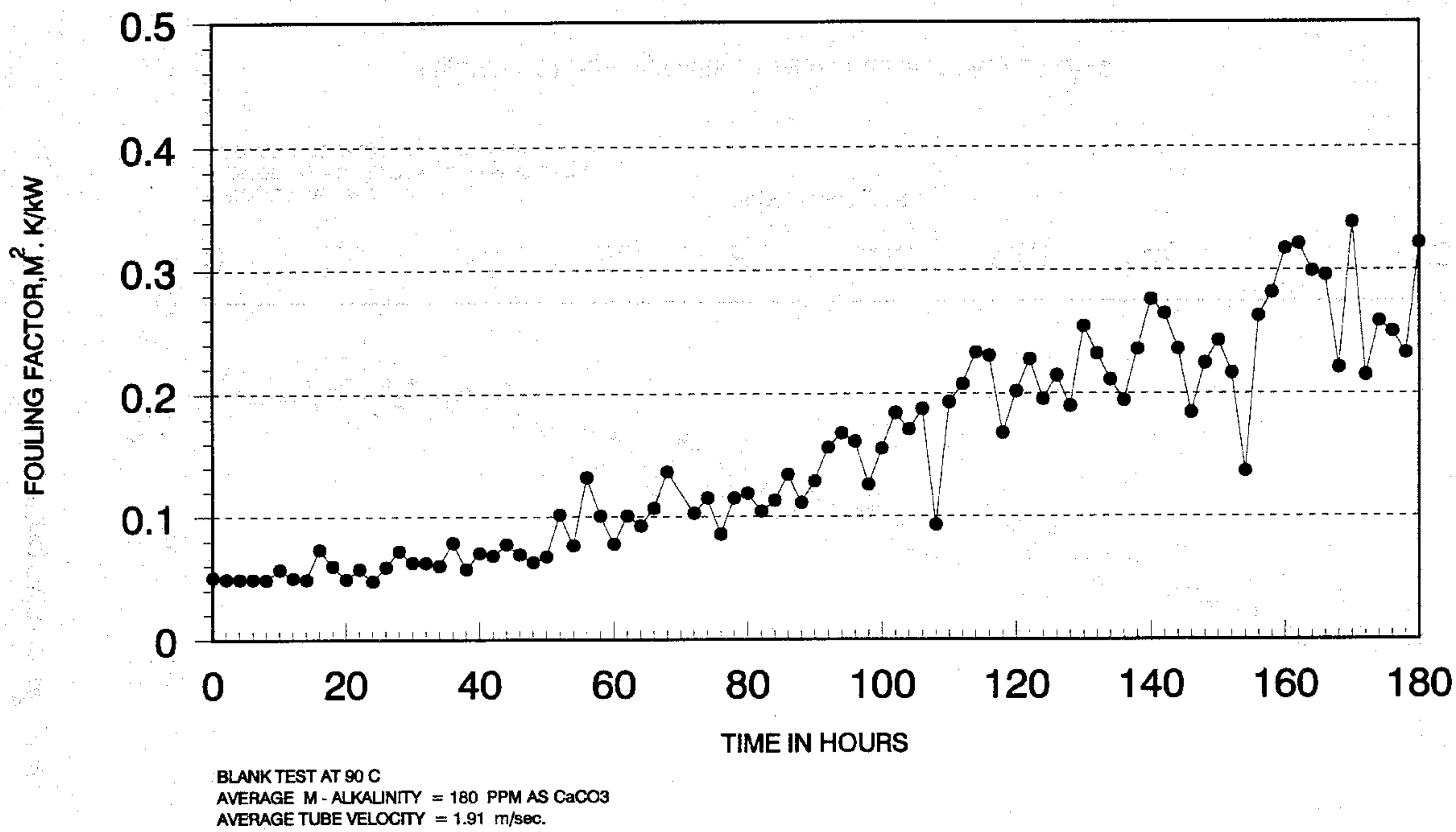


Fig. 3(1) Changes in Fouling Factors with the Time on Test–1

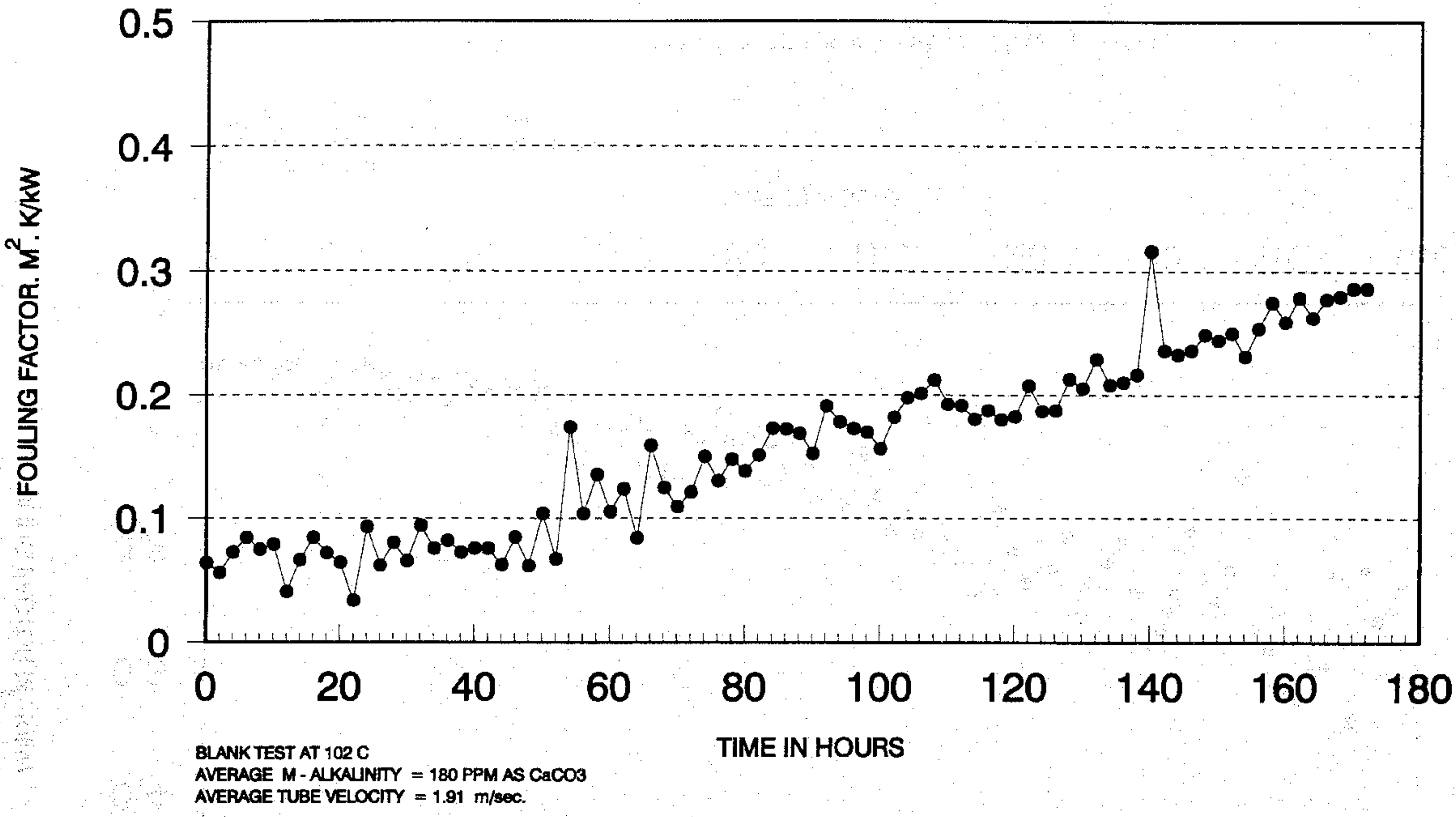


Fig. 3(2) Changes in Fouling Factors with the Time on Test–2

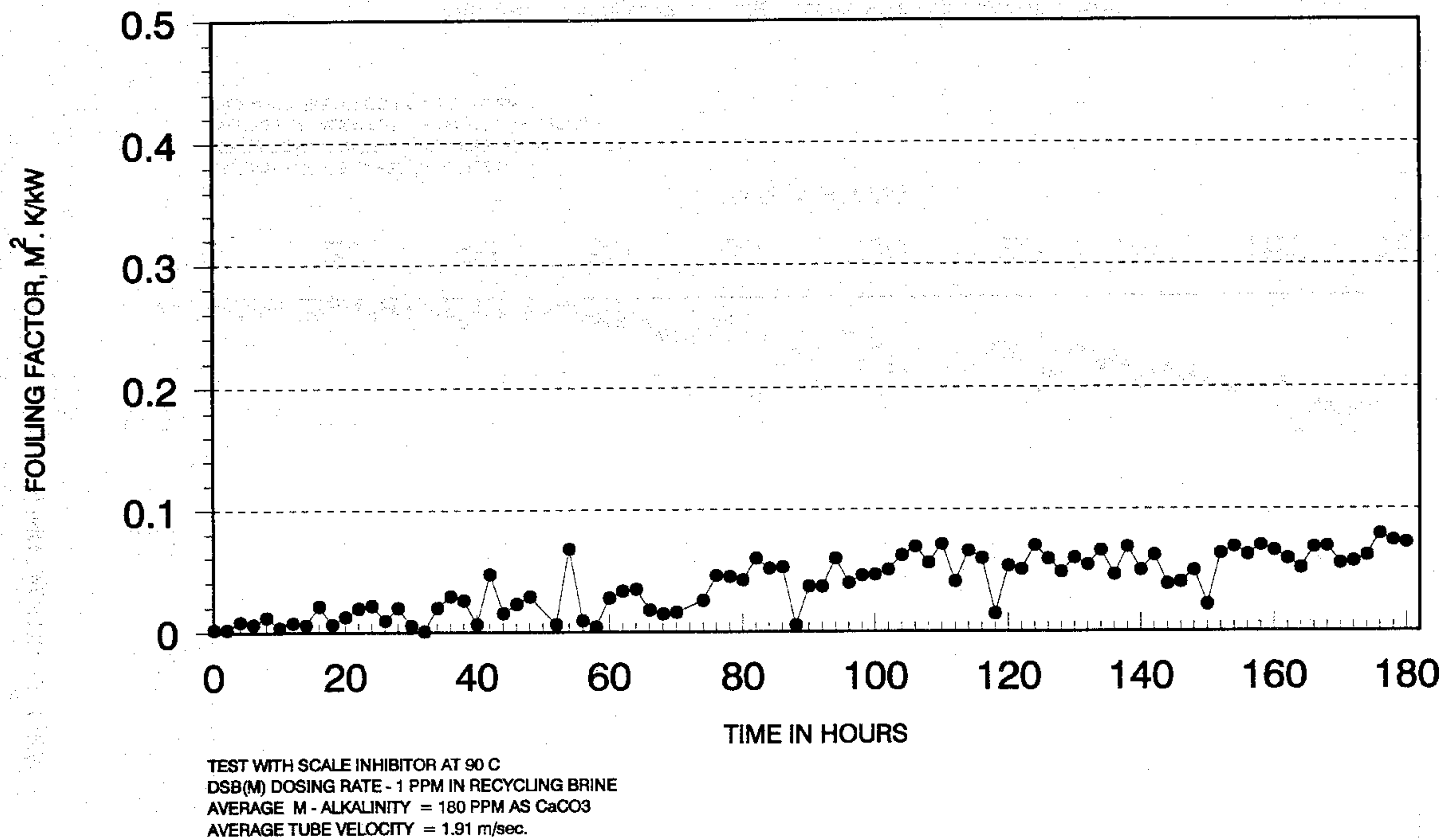
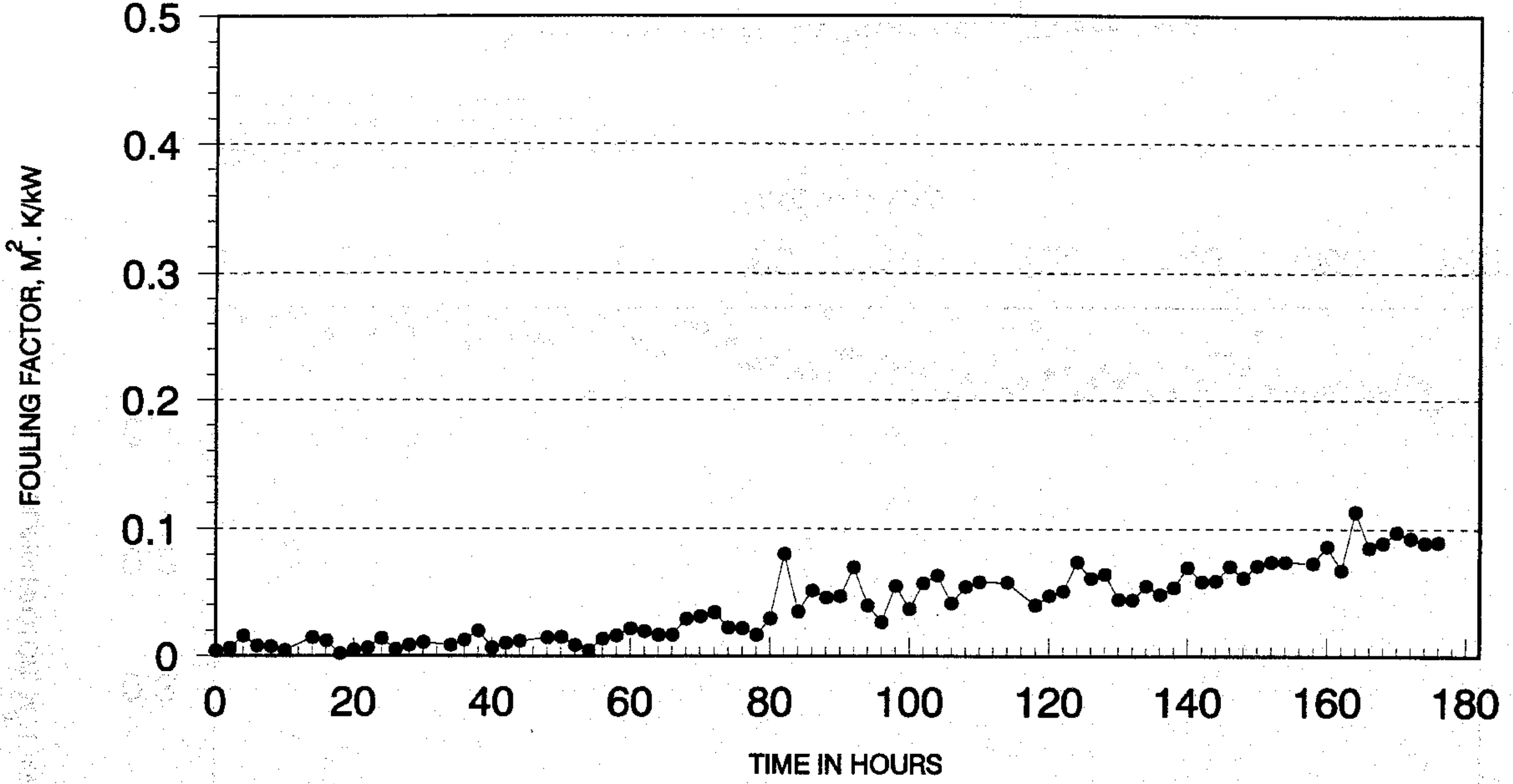


Fig. 3(3) Changes in Fouling Factors with the Time on Test–3



TEST WITH SCALE INHIBITOR AT 102 C
DSB(M) DOSING RATE - 1 PPM IN RECYCLING BRINE
AVERAGE M - ALKALINITY = 180 PPM AS $CaCO_3$
AVERAGE TUBE VELOCITY =1.91 m/sec.

Fig. 3(4) Changes in Fouling Factors with the Time on Test–4

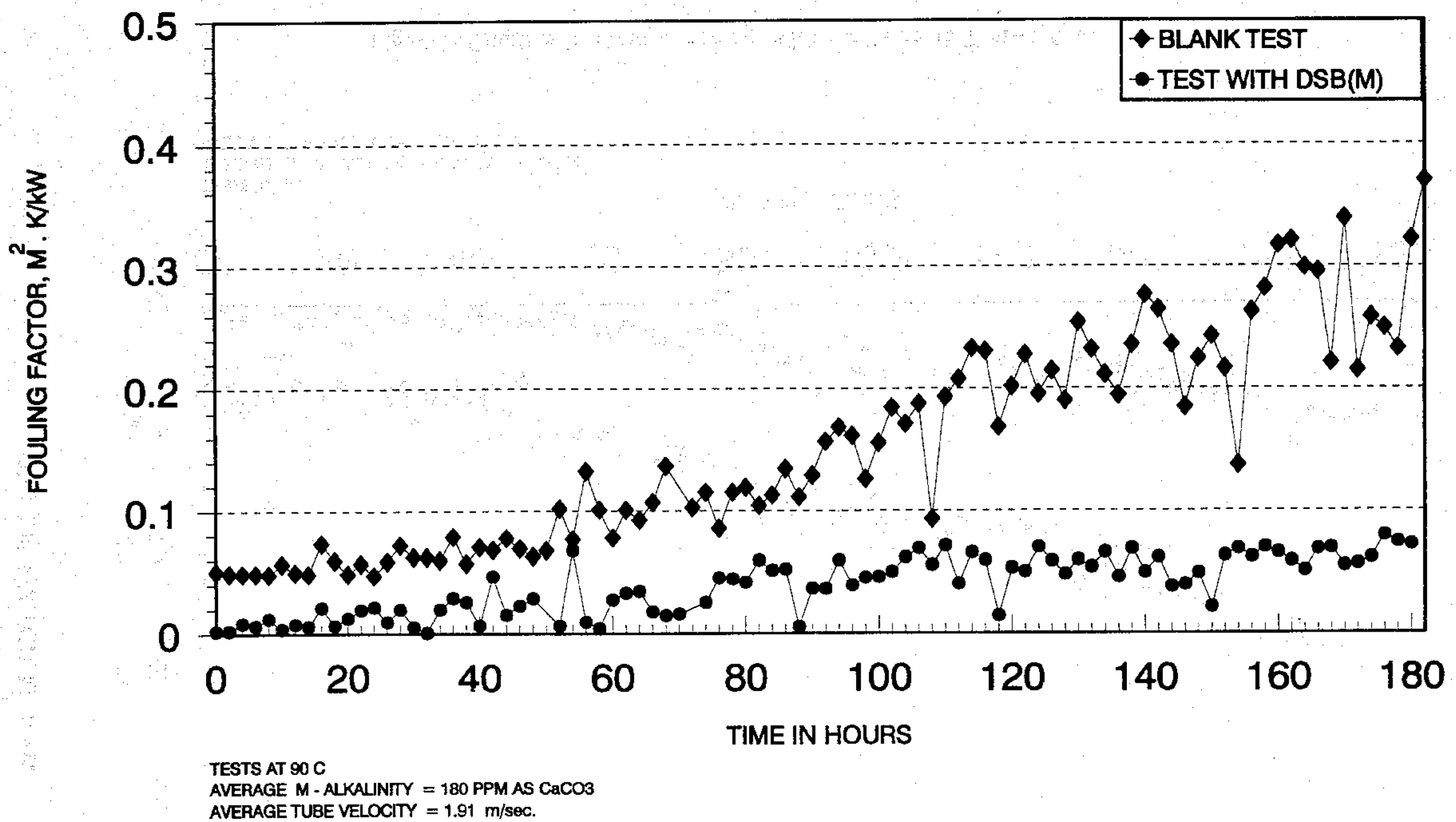


Fig. 4(1) Changes in Fouling Factors with the Time on Test–1 & 3

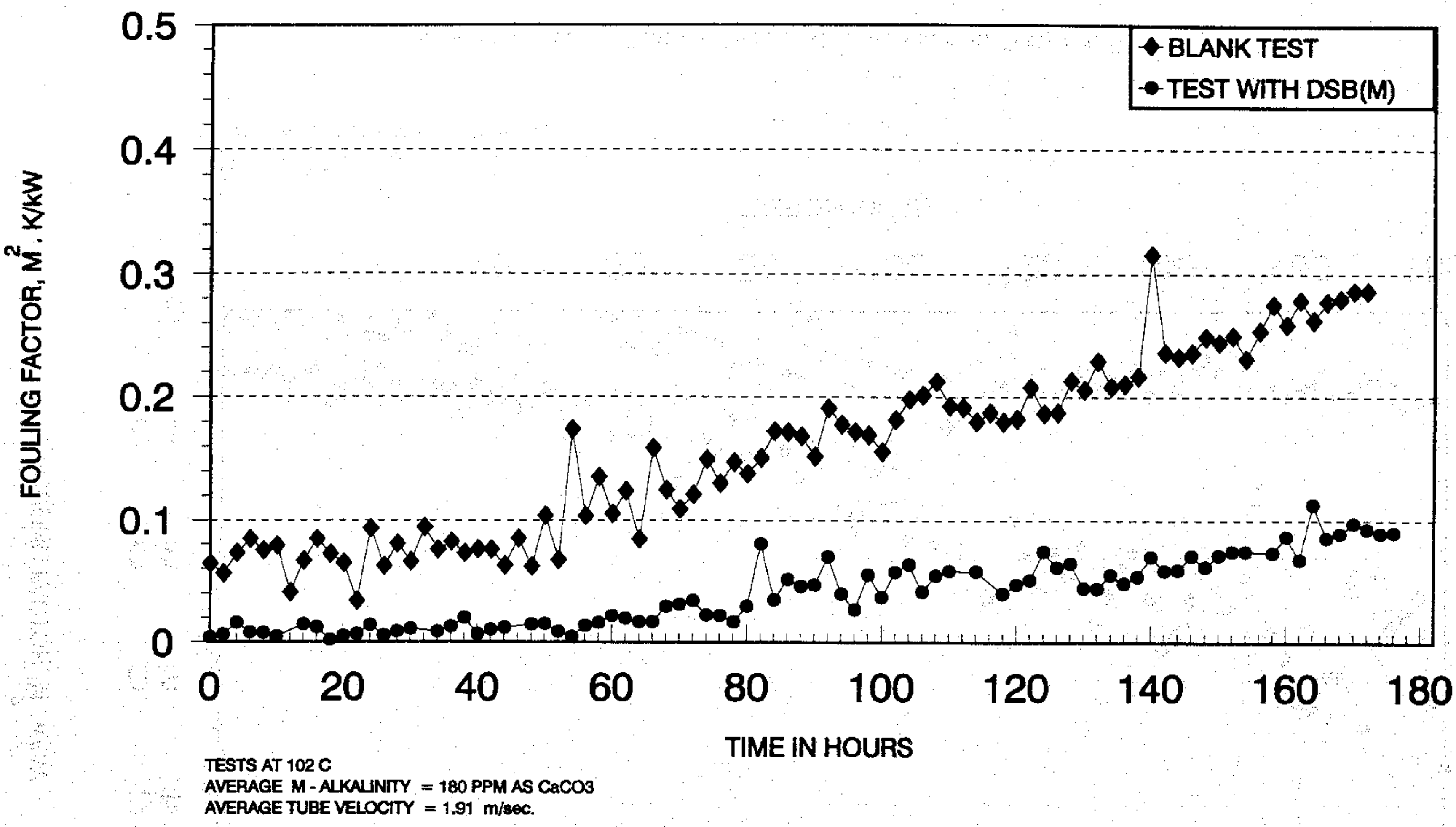
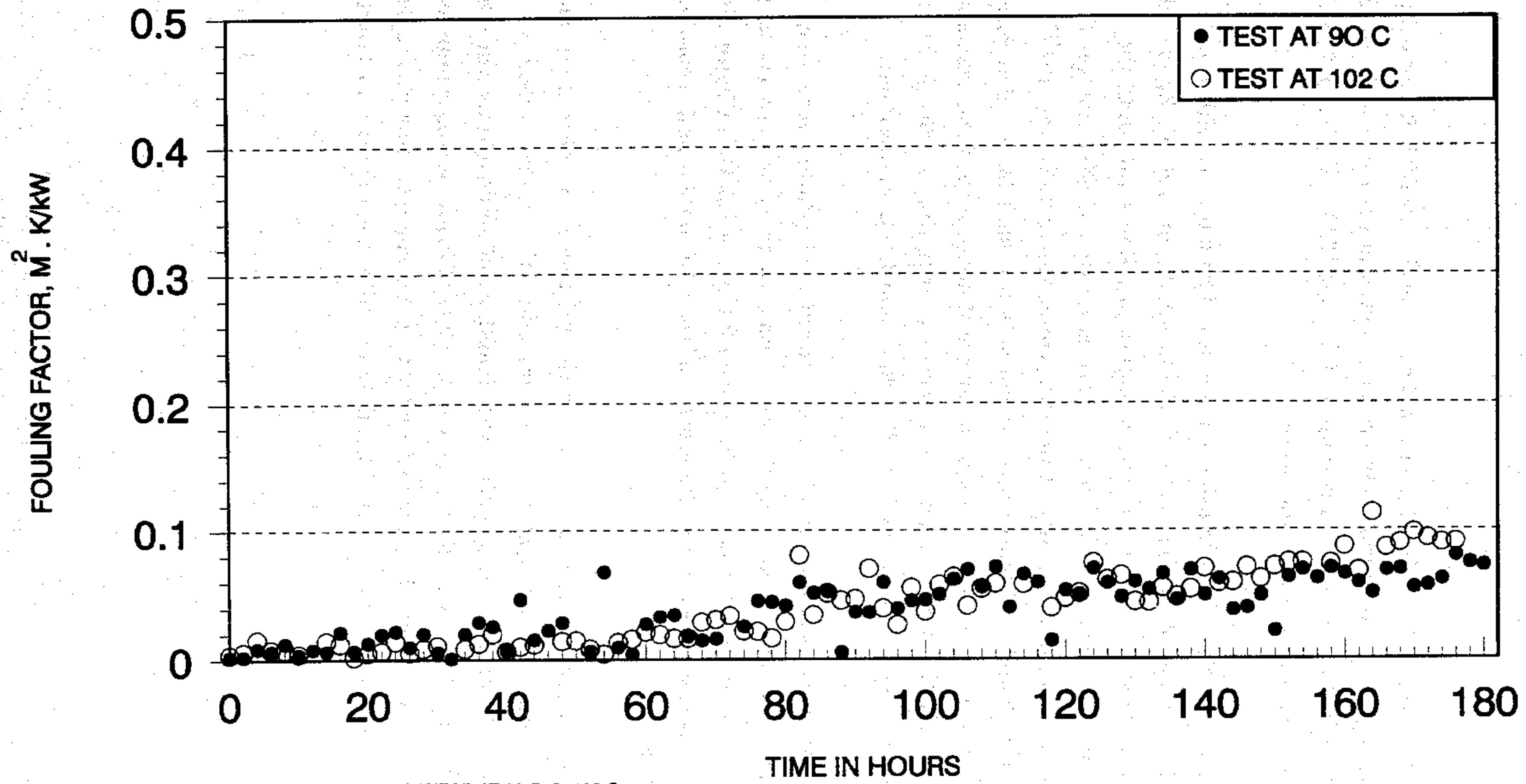


Fig. 4(2) Changes in Fouling Factors with the Time on Test–2 & 4



TEST WITH SCALE INHIBITOR AT 90 C & 102 C
DSB(M) DOSING RATE - 1 PPM IN RECYCLING BRINE
AVERAGE M - ALKALINITY = 180 PPM AS $CaCO_3$
AVERAGE TUBE VELOCITY = 1.91 m/sec.

Fig. 4(3) Changes in Fouling Factors with the Time on Test–3 & 4

7. Discussion

Figures 2(1)–(4) and 3(1)–(4) show the changes in heat transfer coefficients and fouling factors with time respectively. The numbers in brackets represent the run number where 1 and 2 are for blank (reference) tests at temperatures 90℃ and 102℃ respectively, while 3 and 4 are for additive tests at the same temperatures.

Fast deterioration in the quality of heat transfer in the case of blank tests is evident in figures 2(1)–(2) and 3(1)–(2). Values of fouling factor at the beginning of each of the two blank tests are of the order of $0.05 m^2 K/kW$; then increase almost at a linear rate until they reach about $0.3 m^2 K/kW$ over a period of 180 hours. There is no quantitative nor qualitative differences in the behavior of heat transfer at the two temperatures 90℃ and 102℃. On the other hand, tests with additives, Figures 2(3)–(4) and 3(3)–(4), show far less deterioration in the quality of heat transfer. Values of fouling factor are at about zero at the beginning of both runs at 90℃ and 102℃. Fouling factor then increases with time at slow linear rates where its values reach about 0.07 and $0.08 m^2 K/kW$ at 90℃ and 102℃ respectively.

Comparisons of heat transfer behaviors in blank tests to those of additive tests show that effectiveness of the scale inhibitor is quite significant. Also a comparison between the heat transfer behavior in the additive tests show that the rate of fouling at 102℃ is slightly higher than that at 90℃. This is expected since the process of scale formation and deposition is temperature dependent.

The clean value of heat transfer coefficient taken as the reference for calculating fouling factors was fixed for all runs at $1.58 kW/m^2 K$. One may notice that values of heat transfer coefficient at the start of blank tests are slightly lower than those of additive tests which have resulted in slightly higher values for fouling factors at the start of blank tests as compared to additive tests. This can be explained by the fact that the heat exchanger tube was replaced when leakage was observed after completion of blank tests and a new tube was installed for the additive tests.

8. Conclusion

1. **Experiments were carried out using a laboratory scale heat exchange test unit which facilitates heat transfer measurements under conditions that resemble those in the brine heater of MSF plants.**
2. **Results obtained from the experiments, though they are very limited, show that this technique where heat transfer measurements are used in determining the effectiveness of a given scale inhibitor can be successfully used.**
3. **Further tests where scale inhibitors can be tested for longer durations (1000–2000 hours) are requested. Such tests will make available a body of data and results which can be reliably used in validating the present technique and in determining its effectiveness.**

9. Reference

1) SWCC (Saline Water Conversion Corporation) / JICA (Japan International Agency) ; Research cooperation for the project of the sea water desalination technology, Final report (1992)
2) SWCC (Saline Water Conversion Corporation) / JICA (Japan International Agency) ; Research cooperation for the project of the sea water desalination technology, Progress Report (1993)
3) SWCC (Saline Water Conversion Corporation)/ JICA (Japan International Agency) ; Research corporation for the project of the sea water desalination technology, Progress report in second half fiscal year (1993)

5.3 Tests with the MSF Test Plant

5.3.1 Installation of the MSF Test Plant

CONTENTS

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List of Figures

1. Introduction

The installation work for the MSF Test Plant has progressed as scheduled. The boiler fuel oil for trial runs and performance tests, was prepared by mixing heavy oil (Bunker C) and light diesel oil at a predetermined ratio.

Commissioning record of each pump are illustrated in Fig. 7.

Dates of installation and calibration of the instruments for the MSF Test Plant are shown in Table 1.

P&I Diagram of 20ton/d MSF Test Plant is illustrated in Fig. 8.

2. Installation and Commissioning

Progress of installation for the MSF Test Plant until beginning of trial run is as follows:

•First/Second weeks (July 31, 1993 – Aug. 11, 1993)

(1) Mechanical
1) Alignment of the coupling for the brine recirculation, distillate, and make up pumps.
2) Change the oil level gauge, and tie–up the coupling bolts for the brine recirculation, Distillate, and make-up pumps.
3) Check the inside of fuel oil tank and 6th stage of the flash chamber.
4) Fix and adjust the level gauge for fuel oil tank.
5) Hydraulic test and flushing of the boiler.

(2) Piping
1) Check prefabricated piping.
Raw seawater, make–up, brine recirculation, distillate, and chemical lines.
2) Install the distillate water line from MSF product water line to boiler feed water tank.
3) Instrumentation
1) Fix the thermo–wells, pressure gauges, transmitters, flow switches and level controllers etc..
4) Insulation
1) Explain about insulation method.

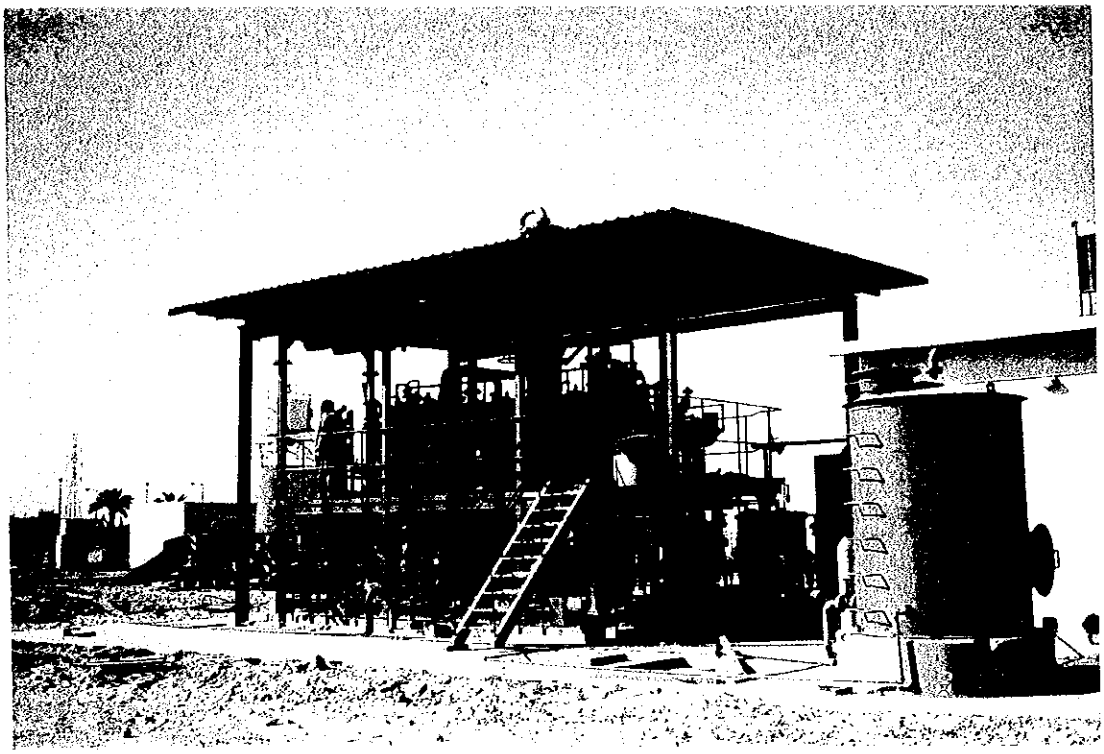


Fig. 1 The State of Installation at the Second Week.

•Third week (Aug. 12, 1993 – Aug. 18, 1993)

(1) Mechanical

1) Air–leak test of the evaporator, brine heater, ejector condenser, deaerator, and steam line.

2) Open the water box cover of brine heater for checking the tubes, tied by ferrule type.

(2) Instrumentation

1) Install the transmitters and pneumatic copper tubes for control valves.

(3) Electrical

1) Lay and terminate the power cables for chemical injection pumps, blower and agitator.

(4) Painting

1) Discuss about painting procedure.

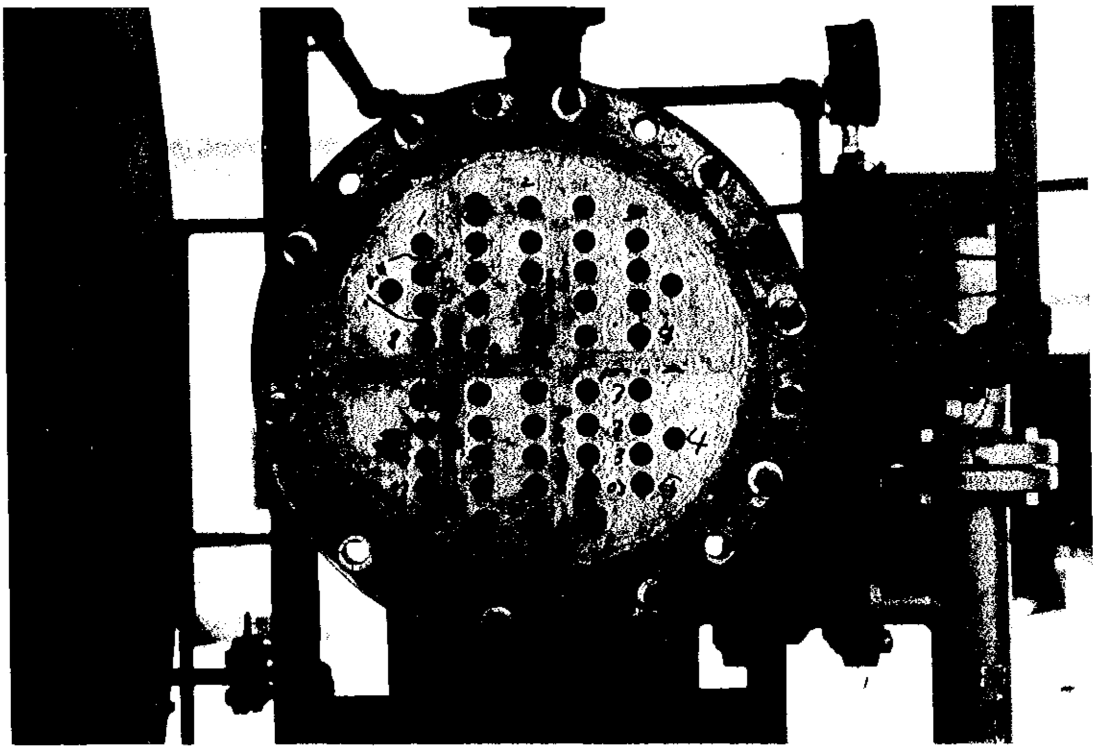


Fig. 2 Air–leak Testing of the Brine Heater.

•4th week (Aug. 19, 1993 – Aug. 25, 1993)

(1) Mechanical

1) Dismantle each motor attached to brine recirculation pump, distillate pump and make–up pump for overhauling.

(2) Electrical

1) Lay and terminate the power cables between the control panel and the field.

(3) Instrumentation

1) Install cable trays
2) Install the transmitters and pneumatic copper tube for control valves.
3) Lay and terminate the signal cables between control panel and the field.
4) Check and calibrate the actuator of the control valves.
5) Calibrate the pressure indicators.

(4) Painting

1) Paint the fuel oil tank, water tank and structure of the evaporator.

•5th week (Aug. 26, 1993 - Sep. 1, 1993)

(1) Mechanical

1) Dismantle each motor attached to following pumps for overhaul.
  - •Anti-foam injection pump
  - •Acid injection pump
  - •Anti-scale injection pump
  - •Sodium sulfite injection pump
  - •Acid cleaning pump

2) Dismantle each motor attached to the agitator and the blower.

(2) Piping

1) Install the fuel oil line and seawater supply line.

(3) Electrical

1) Install the light fixtures in the field.

2) Overhaul each motor attached to following pumps:
  - •Brine recirculation pump
  - •Distillate pump
  - •Make-up pump
  - •Anti-scale injection pump
  - •Acid injection pump
  - •Sodium sulfite injection pump
  - •Anti-foam injection pump
  - •Acid cleaning pump

(4) Instrumentation

1) Calibrate the pressure controller for the boiler.

(5.3.1)

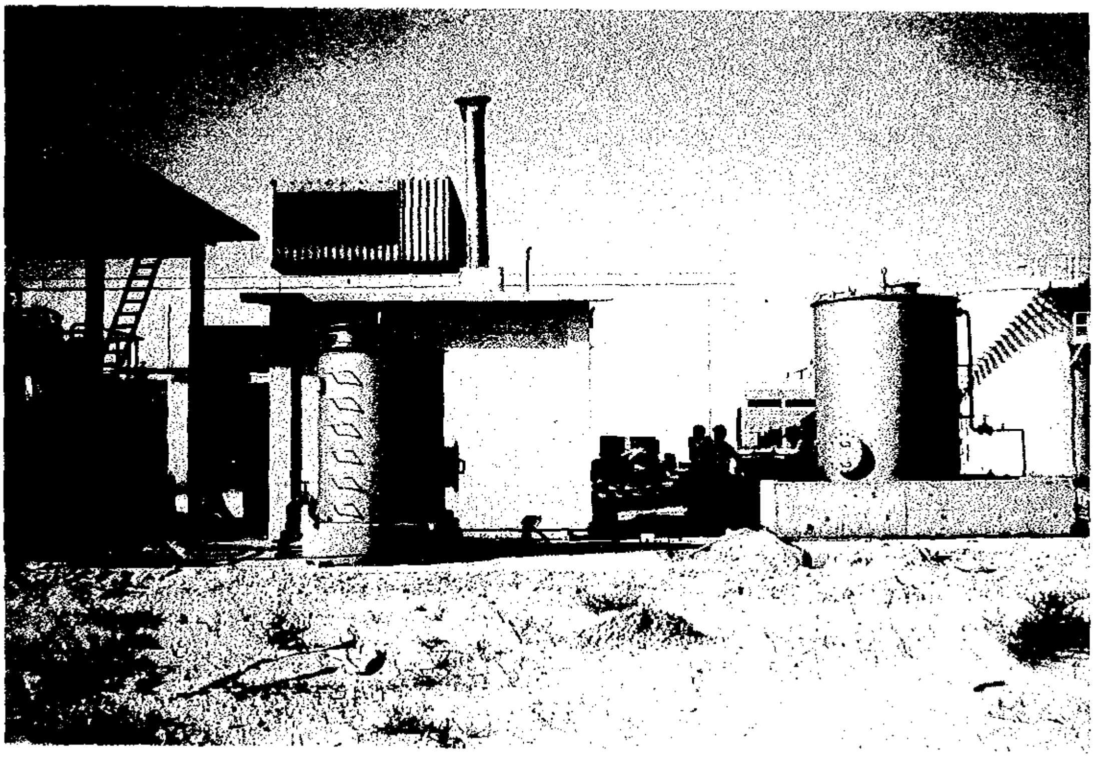


Fig. 3 Feed Water Tank and Fuel Oil Tank.

•6th week (Sep. 2, 1993 – Sep. 8, 1993)

(1) Mechanical

1) Remount each motor attached to following pumps.
   - •Brine recirculation pump
   - •Distillate pump
   - •Make–up pump
   - •Anti–scale injection pump
   - •Acid injection pump
   - •Sodium sulfite injection pump
   - •Anti–foam injection pump
   - •Acid cleaning pump

2) Remount each motor attached to the agitator and the blower.

3) Perform alignment for all centrifugal pumps.

(2) Electrical

1) Connect cables for the motors and check direction of rotation.

2) Install the light fixtures in the field.

3) Lay and terminate the cables for the boiler panel and the oil heater.

(3) Instrumentation

1) Calibrate the pH meter, controllers and recorders on the control panel.

2) Connect the signal cables for the thermometers.

3) Install the cover for cable trough.

(4) Insulation

1) Insulate the evaporator, brine heater, ejector condenser, and steam line.

(5) Painting

1) Paint the components of MSF Test Plant.

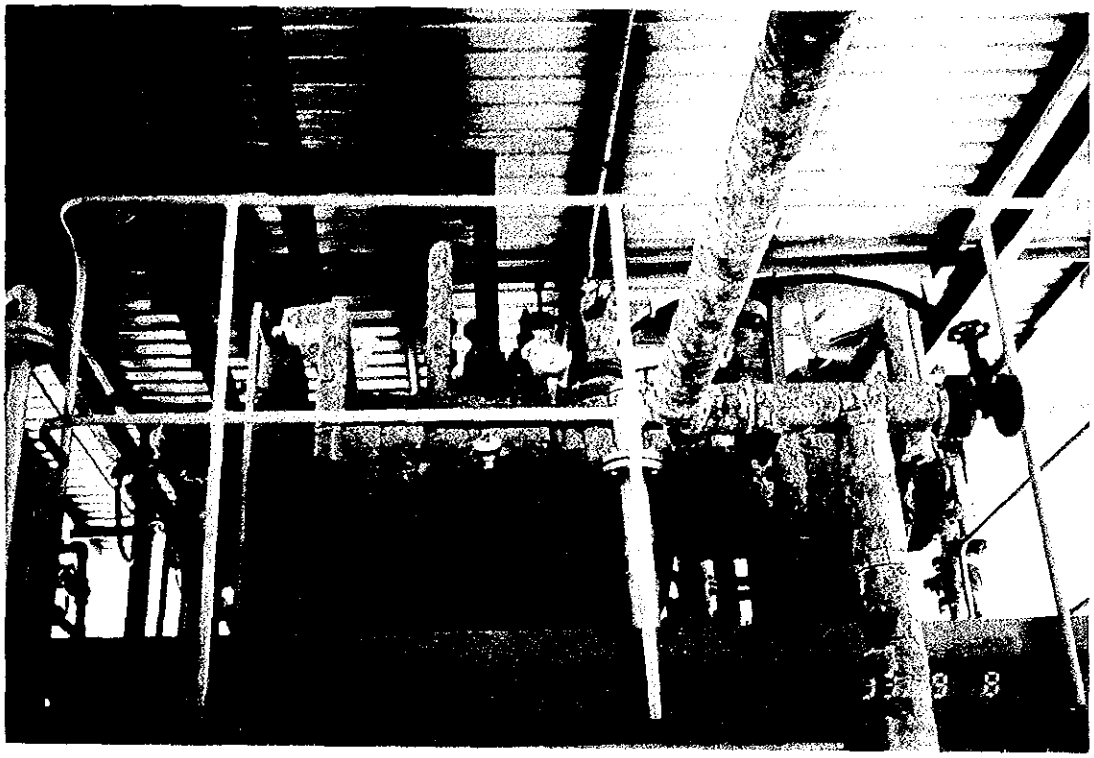


Fig. 4 Thermal Insulation of the Brine Heater

•7th week (Sep. 9, 1993 – Sep. 15, 1993)

(1) Mechanical
1) Check the orifice in the 1st–5th flash chambers.
2) Check the spray nozzle in the deaerator.
3) Change the gland packings of brine recirculation, distillate, and make–up pumps.
4) Perform alignment for the fuel oil booster pump.

(2) Piping
1) Install the instrument air line and the service water line.

(3) Electrical
1) Check sequence of the boiler panel.

(4) Instrumentation
1) Calibrate the DO meter, controllers, and recorders on the control panel.
2) Check function of the control valves, flow meters, pH meters, thermometers and level controllers.

(5) Insulation
1) Insulate the evaporator, brine heater, ejector condenser, steam line and fuel oil line.

(6) Painting
1) Paint the components of MSF Test Plant.

(7) Civil
1) Grout the evaporator skid, boiler fuel oil tank, and boiler feed water tank.

(8) Commissioning
1) Test run of the air compressor.
2) Test run of the following chemical injection pumps.
•Sodium sulfite
•Anti–foam
•Anti–scale
•Acid

•8th week (Sep. 16, 1993 – Sep. 22, 1993)

(1) Mechanical

1) Check the boiler burner, softener and fuel oil tank.

(2) Electrical

1) Check rotation of pumps and blower for the boiler.

2) Terminate the HV electric cable at main transformer.

(3) Instrumentation

1) Flush the instrument air lines by air from the air compressor.

2) Find trouble in the brine level controller of the last stage flash chamber.

(4) Insulation

1) Insulate the evaporator, brine heater, ejector condenser, steam line and fuel oil line.

(5) Commissioning

1) Check flow rate of the chemical injection pumps.

2) Test run of the following pumps.

•Acid cleaning

•Distillate water

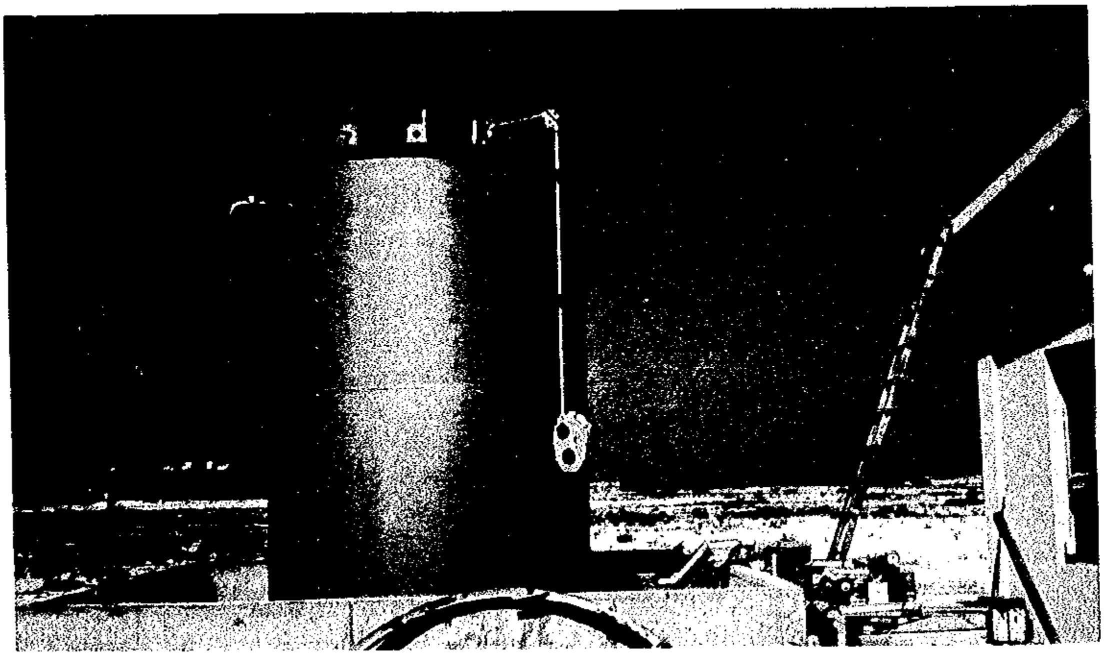


Fig. 5 The Fuel Oil Tank

•9th week (Sep. 23, 1993 – Sep. 29, 1993)

(1) Mechanical
1) Store service water in the flash chambers for test run of the brine recirculation pump.
2) Install the fuel oil transfer pump.

(2) Piping
1) Install the fuel oil transfer line.

(3) Electrical
1) Channel permanent power supply on 28 Sep..
2) Lay and terminate power cables for the fuel transfer pump.

(4) Instrumentation
1) Check the last stage brine level controller at Al-Jubail Phase II maintenance workshop.

(5) Insulation
1) Insulate the evaporator, brine heater, ejector condenser and steam line.

(6) Commissioning
1) Test water flow rate for the brine recirculation pump.

•10th week (Sep. 30, 1993 – Oct. 6, 1993)

(1) Piping
1) Install the recirculation line for mixing light diesel oil and heavy oil in the fuel tank.

(2) Instrumentation
1) Repair of the last stage level controller at the Al-Jubail Phase II maintenance workshop was not possible. Operation could not be carried out automatically but manually. The level controller was reinstalled in the control panel with auto mode off.

(3) Insulation
1) Insulate the evaporator, brine heater and ejector condenser and pipes.

(4) Preparation for trial run
1) Clean out the boiler feed water tank.
2) Fill up water in the boiler feed water tank.
3) Take out the temporary suction strainer attached to the make-up pump.

(5) Commissioning
1) Test operation of the brine recirculation, distillate and make-up pump.

•11th week (Oct. 7, 1993 – Oct. 13, 1993)

(1) Instrumentation

1) Install the temperature gauges for each flash chamber.

(2) Insulation

1) Insulate the evaporator, brine heater and ejector condenser.

(3) Preparation for trial run

1) Rinse the rejection section, deaerator, and make–up line pipes by service water.

2) Transfer 5,000 liter of fuel oil mixture into the fuel tank.

•12th week (Oct. 14, 1993 – Oct. 20, 1993)

(1) Insulation
1) Insulate the evaporator and brine heater.

(2) Preparation for trial run
1) Explain operation procedure to operators.

(3) Boiler
1) Confirm the following items:
•The feed water and fuel oil lines
•The fuel oil and feed water booster pumps
2) Check the burner spray condition after analyzing the control sequence.
3) Change the set point of oil preheating temperature.
4) Discuss about the specification of a new boiler after receiving it from a boiler maker. However, other source of steam is also being considered, that is to receive steam from Al-Jubail Phase I plant.

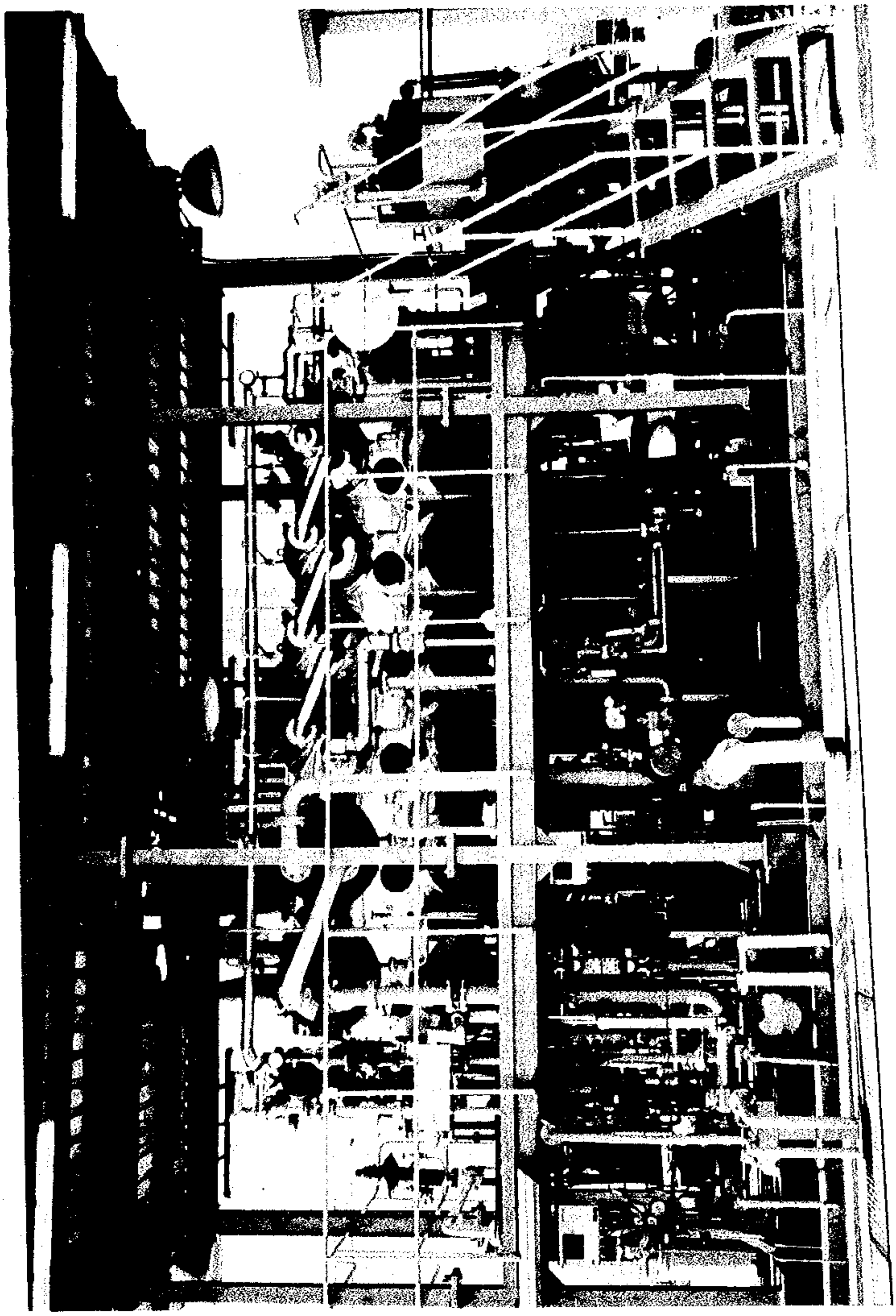


Fig. 6 Completed MSF Test Plant

•13th week (Oct.21, 1993 – Oct.27, 1993)

(1) Preparation for trial run
1) Confirm running condition of the boiler
2) Remove the temporary strainers of the brine recirculation and distillate water pumps.
3) Prepare the following chemicals.
•Scale inhibitor : 5% ALBRIVAP DSB
•Anti–foam reagent
4) Carry out vacuum test.

(2) Trial run
1) Carry out trial run.

•14th week (Oct.28, 1993 – Nov. 1, 1993)

(1) Trial run
(2) Performance test
(3) Training of SWCC's operators
(4) Rinsing of the heat transfer tubes and the flash chambers
(5) Completion ceremony

Table 1

CALIBRATED/INSTALLED DATE OF INSTRUMENTATION FOR THE MSF TEST PLANT

L-1

TAG NO.	NAME OF INSTRUMENTS	CALIBRATED DATE	INSTALLED DATE	NOTE
	CONTROL VALVE			
XV-101	Seawater discharge temp. cont. V/V	Aug. 24. '93	Have been fitted up on the skid	
-201	Make-up flow cont. V/V	DITTO		
-202	Decarbonator level cont. V/V	DITTO	Jun. 20. '93	
-203	Deaerator level cont. V/V	Aug. 25. '93	Have been fitted up on the skid.	
-301	Recirc. brine flow cont. V/V	DITTO		
-302	Last stage brine level cont. V/V	Aug. 23. '93		
-401	Flash tank level cont. V/V	Aug. 25 '93		
-402	Distillate water three way V/V	Aug. 26 '93		
-601	Heating steam press. cont. V/V	Aug. 25 '93		
-602	B/heater outlet brine temp. cont. V/V	Aug. 22 '93		
-604	B/heater condensate level cont. V/V	DITTO		
-605	Ejector steam	DITTO		
	LEVEL CONTROLLER			
LIC-201	Decarbonator level cont.	Aug. 28 '93	Aug. 9 '93	
-401	Flash tank level cont.	Aug. 26 '93	Aug. 10 '93	
-601	B/heater condensate level cont.	DITTO	DITTO	
	LEVEL TRANSMITTER			
LT-202	Deaerator level transmitter	Aug. 27 '93	Aug. 11 '93	
-507	Last stage level transmitter	DITTO	DITTO	
	FLOW TRANSMITTER			
FT-101	Seawater to rejection flow	Aug. 26 '93	Aug. 14 '93	
-201	Make-up flow	DITTO	DITTO	
-301	Recirc. brine flow	DITTO	Aug. 15 '93	
-401	Distillate water flow	Aug. 27	Aug. 16 '93	
-601	Steam condensate flow	DITTO	DITTO	

Table 1

CALIBRATED/INSTALLED DATE OF INSTRUMENTATION FOR THE MSF TEST PLANT

L-2

TAG NO.	NAME OF INSTRUMENTS	CALIBRATED DATE	INSTALLED DATE	NOTE
	FLOW SWITCH			
FIS-102	E/condenser cooling seawater flow	Sep. 12 '93	Aug. 9 '93	
-801	Anti-scale injection flow	Sep. 13 '93	Aug. 10 '93	
-802	Acid injection flow	DITTO	DITTO	
	PH TRANSMITTER			
PHT-201	Decarbonator outlet PH	Sep. 13 '93	Aug. 21 '93	
-301	Recirc. brine PH	DITTO	DITTO	
	DO TRANSMITTER			
DOT-201	Make-up seawater DO	Sep. 13 '93	Aug. 19 '93	
-301	Brine recirc. pump discharge DO	DITTO	DITTO	
	CONDUCTIVITY TRANSMITTER			
CT-401	Distillate water conductivity	Sep. 14 '93	Aug. 8 '93	
-601	Steam condensate conductivity	DITTO	DITTO	
	LEVEL INDICATOR			
LI-901	Fuel oil tank level	Aug. 28 '93	Aug. 10 '93	
	THERMO METER			
TI-103	E/condenser outlet seawater temp.	Aug. 30 '93	Oct. 10 '93	
-104	Supply seawater temp.	DITTO	DITTO	
-105	Seawater temp stage 6th to 5th	DITTO	DITTO	
-106	Seawater temp stage 5th outlet	DITTO	DITTO	
-304	Recirc. brine temp stage 4th inlet	DITTO	DITTO	
-305	Recirc. brine temp stage 4th to 3rd	DITTO	DITTO	
-306	Recirc. brine temp. stage 3rd to 2nd	DITTO	DITTO	
-307	Recirc. brine temp. stage 2nd to 1st	DITTO	DITTO	
-308	Brine heater inlet brine temp.	DITTO	DITTO	

Table 1

CALIBRATED/INSTALLED DATE OF INSTRUMENTATION FOR THE MSF TEST PLANT

L-3

TAG NO.	NAME OF INSTRUMENTS	CALIBRATED DATE	INSTALLED DATE	NOTE
	THERMO METER			
TI-309	Brine heater outlet brine Temp.	Aug. 30 '93	Oct. 10 '93	
-501	1st stage vapour temp.	DITTO	DITTO	
-502	2nd stage vapour Temp.	DITTO	DITTO	
-503	3rd stage vapour temp.	DITTO	DITTO	
-504	4th stage vapour Temp.	DITTO	DITTO	
-505	5th stage vapour temp.	DITTO	DITTO	
-506	Last stage vapour Temp.	DITTO	DITTO	
-601	Heating steam temp.	DITTO	DITTO	
	RESISTANS BULB			
TR-101	H/rejection inlet seawater Temp.	Aug. 30 '93	Aug. 7 '93	
-102	H/rejection outlet seawater Temp.	DITTO	DITTO	
-201	Make-up seawater Temp.	DITTO	DITTO	
-301	Brine recirc. pump outlet brine Temp.	DITTO	Aug. 8 '93	
-302	Brine heater inlet brine temp.	DITTO	DITTO	
-303	Brine heater outlet brine Temp.	DITTO	DITTO	
-602	Brine heater shell temp.	DITTO	DITTO	
	PRESSURE INDICATOR			
PI-001	Compress. Air tank press.	Aug. 25 '93	Aug. 25 '93	
-101	Supply seawater press.	DITTO	DITTO	
-102	E/condenser inlet seawater press.	DITTO	DITTO	
-201	Mak-up pump discharge press.	DITTO	DITTO	
-301	Brine recirc. pump discharge press.	DITTO	DITTO	
-302	Brine heater inlet brine press.	DITTO	DITTO	
-303	Brine heater outlet brine press.	DITTO	DITTO	
-401	Flash tank press.	DITTO	DITTO	
-402	Distillate pump discharge press.	DITTO	DITTO	
-501	1st stage press.	DITTO	DITTO	
-603	Brine heater shell press.	DITTO	Aug. 26 '93	
-604	Ejector steam press.	DITTO	DITTO	
-801	Anti-scale pump discharge press.	DITTO	DITTO	

Table 1

CALIBRATED/INSTALLED DATE OF INSTRUMENTATION FOR THE MSF TEST PLANT

L-4

TAG NO.	NAME OF INSTRUMENTS	CALIBRATED DATE	INSTALLED DATE	NOTE
	PRESSURE INDICATOR			
PI-802	Acid pump discharge press.	Aug. 25 '93	Aug. 26 '93	
803	Sodium sulphite pump discharge press.	DITTO	DITTO	
804	Anti-foam pump discharge press.	DITTO	DITTO	
805	Acid cleaning pump discharge press.	DITTO	DITTO	
	PRESSURE TRANSMITTER			
PT-506	Last stage press.	Aug. 28. '93	Aug. 17 '93	
605	Supply steam press.	DITTO	Aug. 18 '93	
606	Brine heater inlet steam press.	DITTO	DITTO	
	LEVEL INDICATOR			
LI-801	Anti-scale tank level	—	Aug. 24 '93	
802	Acid tank level	—	DITTO	
803	Sodium sulphite tank level	—	DITTO	
804	Anti-foam tank level.	—	DITTO	
805	Acid cleaning tank level.	—	DITTO	

Table 1

CALIBRATED/INSTALLED DATE OF INSTRUMENTATION FOR THE MSF TEST PLANT

P-1

TAG NO.	NAME OF INSTRUMENTS	CALIBRATED DATE	INSTALLED DATE	NOTE
	RECORDER			
TR-101	Supply seawater Temp.	Sep. 1 '93	Have been fitted up on the control panel	
-201	Make-up water temp.			
-301	Recirc. brine temp.			
-302	Brine heater inlet brine temp.			
-602	Brine heater shell Temp.			
FR-101	Seawater to rejection flow	Aug. 31 '93		
-201	Make-up water flow			
-301	Recirc. brine flow			
FR-401	Distillate water flow	Aug. 31 '93		
-601	Steam condensate flow			
PHR-201	Decorbonator outlet PH	Aug. 31 '93		
-301	Recirc. brine PH			
DOR-201	Make-up water DO	Aug. 31 '93		
-301	Recirc. brine DO			
CR-401	Distillate conductivily	Aug. 31 '93		
-601	Steam condensate conductivity			
TR-102	H/rejection outlet seawater temp.	Aug. 31 '93		
-303	Brine heater outlet brine Temp.			
PR-506	Last stage press.			
	CONTROLLER			
TIC-102	H/rejection outlet seawater temp.	Sep. 7 '93	Have been fitted up on the control panel	
-303	Brine heater outlet brine Temp.	DITTO		
FIC-201	Make-up water flow	DITTO		
-301	Recirc. brine flow	DITTO		
PIC-606	Heating steam press.	Sep. 8 '93		
LIC-202	Deaerator level	DITTO		
-507	Last stage brine level	DITTO		
	CONVERTER			
TT-102	H/rejection outlet seawater Temp.	Sep. 1 '93	Have been fitted up on the control panel	
-303	Brine heater outlet brine Temp.	DITTO		

Table 1

CALIBRATED/INSTALLED DATE OF INSTRUMENTATION FOR THE MSF TEST PLANT

P-2

TAG NO.	NAME OF INSTRUMENTS	CALIBRATED DATE	INSTALLED DATE	NOTE
	ALARM UNIT			
PHS-201	Decorbnator outlet pH	Sep. 14 '93		
-301	Recirc. brine pH	DITTO		
DOS-201	Make-up water DO	DITTO	Have been fitted up	
-301	Recirc. brine pH	DITTO	on the control panel	
CS-401	Distillate water conductivity	DITTO		
-601	Steam condensate conductivity	DITTO		
TS-303	Brine heater outlet brine temp.	Sep. 9 '93		
	RATIO SETTER			
FR-201	Acid injection flow	Sep. 6 '93	Have been fitted up	
-202	Anti-scale injection flow	DITTO	on the control panel	
	ISOLATOR			
FR-201A	Acid injection flow	Sep. 1 '93	Have been fitted up	
-202A	Anti-scale injection flow	DITTO	on the control panel	
	DISTRIBUTOR			
PD-506	Last stage press.	Sep. 4 '93		
-606	Heating steam press.	DITTO		
PHD-201	Decorbnator outlet pH	DITTO		
-301	Recirc. brine pH	DITTO		
DOD-201	Make-up water DO	DITTO	Have been fitted up	
-301	Recir. brine DO	Sep. 5 '93	on the control panel	
CD-401	Distillate water conductivity	DITTO		
-601	Steam condensate conductivity	DITTO		
LD-202	Deaerator level	DITTO		
507	Last stage level	DITTO		

Table 1

CALIBRATED/INSTALLED DATE OF INSTRUMENTATION FOR THE MSF TEST PLANT

P-3

TAG NO.	NAME OF INSTRUMENTS	CALIBRATED DATE	INSTALLED DATE	NOTE
	ROOT EXTRACTOR			
FEX-101	Seawater to rejection flow	Sep. 1 '93		
-201	Make-up seawater flow	DITTO		
-301	Recirc. brine flow	DITTO	Have been fitted up on the control panel	
-401	Distillate water flow	DITTO		
-601	Steam condensate flow	DITTO		

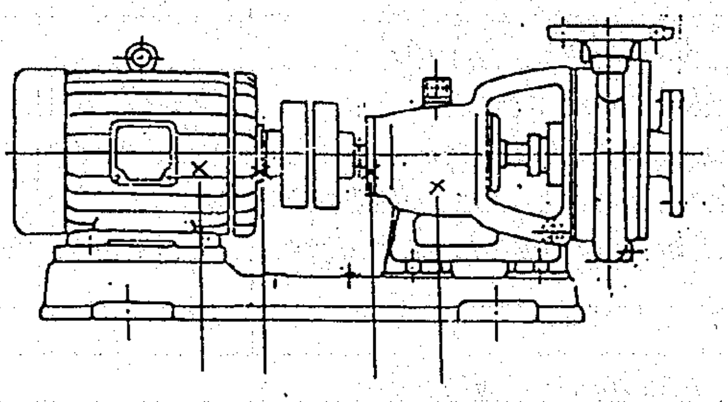
Table 1

CALIBRATED/INSTALLED DATE OF INSTRUMENTATION FOR THE MSF TEST PLANT

B-1

TAG NO.	NAME OF INSTRUMENTS	CALIBRATED DATE	INSTALLED DATE	NOTE
	PRESSURE GAUGE			
1-17	Boiler steam press.	Aug. 27. '93	Have been fitted up on the boiler	
-26	Oil pump discharge	Aug. 30. '93		
2-2	Water booster pump discharge	Aug. 12. '93		
6-1	Oil booster pump discharge	DITTO	Aug. 25 '93	
	PESSURE SWITCH			
1-15	High steam press.	Aug. 30 '93	Have been fitted up on the boiler	
-16	Low steam press.	DITTO		
2-17	Water booster pump discharge	DITTO		
OV1	Low burning solenoid valve	Aug. 25 '93	Have been fitted up on The boiler	
OV2	High borning solenoid valve	DITTO		
SV	solenoid valve	DITTO		
TS	Thermostat	DITTO		
AF	Air flow switch	DITTO		
TH	THERMO STAT	DITTO		
	Water level SWITCH	DITTO		

Fig. 7-1 Test operation record for Brine Recycle Pump P-001

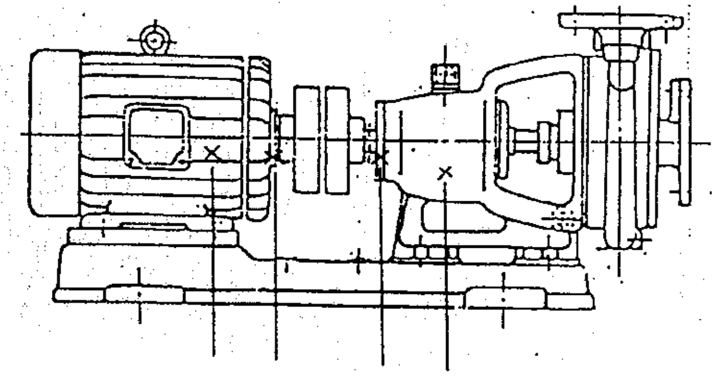


UNIT. °C

TIME	Atmos Temp.	(1)	(2)	(3)	(4)
9:15	35.0°C	35.8	34.5	34.5	34.3
10:15	38.5	38.5	41.0	40.0	38.2
10:25	38.0	38.9	41.6	41.2	38.4
10:45	37.8	38.2	41.8	39.9	38.4
11.05	37.8	37.3	41.3	39.8	37.8

Monarin 4/10/93 J. Sugimoto

Fig. 7-2 Test operation record for Distillate pump (P-002)



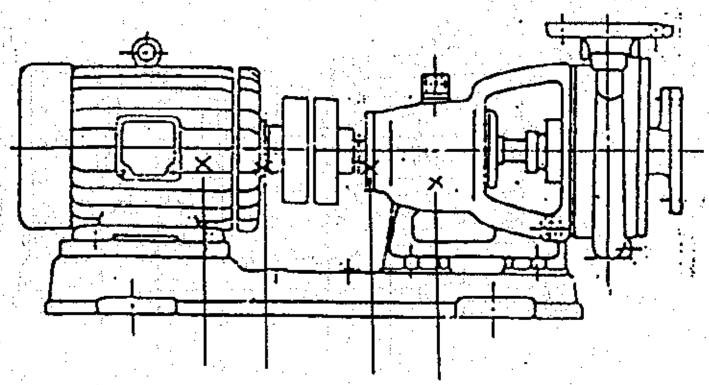
UNIT. °C

TIME	Atmos Temp.	(1)	(2)	(3)	(4)	
13:20	34 °c	39.2	39.4	39.3	39.0	← Befor operation.
13:40	34	40.8	41.4	41.9	39.5	
14:00	34	41.7	41.4	44.5	38.6	
14:20	34	41.7	42.1	43.6	39.0	
14:40	34	41.6	41.3	43.6	38.1	

Monazir Omar 2/10/93.

Y. Miyamoto 2/oct./93

Fig. 7–3 Test operation record for Make up Pump P-003.

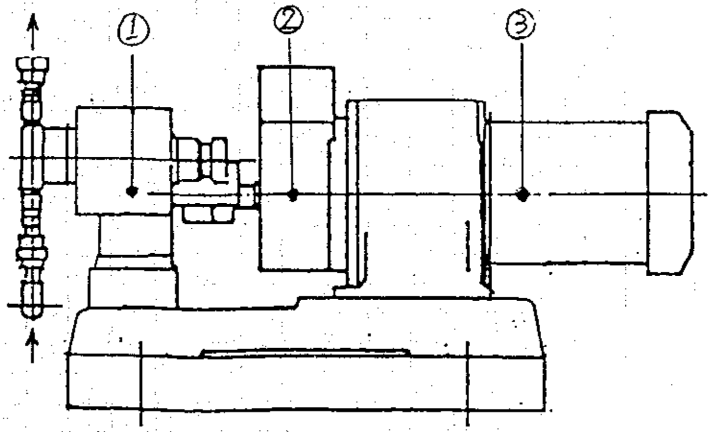


UNIT. °C

TIME	Atmos Temp.	(1)	(2)	(3)	(4)
11:10	36°C	34.7	35.0	36.3	36.1
11:35	38.0	38.6	41.2	39.6	38.3
11.45	38.0	39.2	41.7	40.5	39.9
12.05	38.0	39.5	42.4	41.9	40.2
12.25	38.0	40.2	43.5	41.7	40.3
12.45	38.0	39.9	43.6	41.3	40.2

Monazir [signature] 3/10/93 [signature] 4 Oct. '93

Fig. 7–4 Test operation of chemical injection pumps



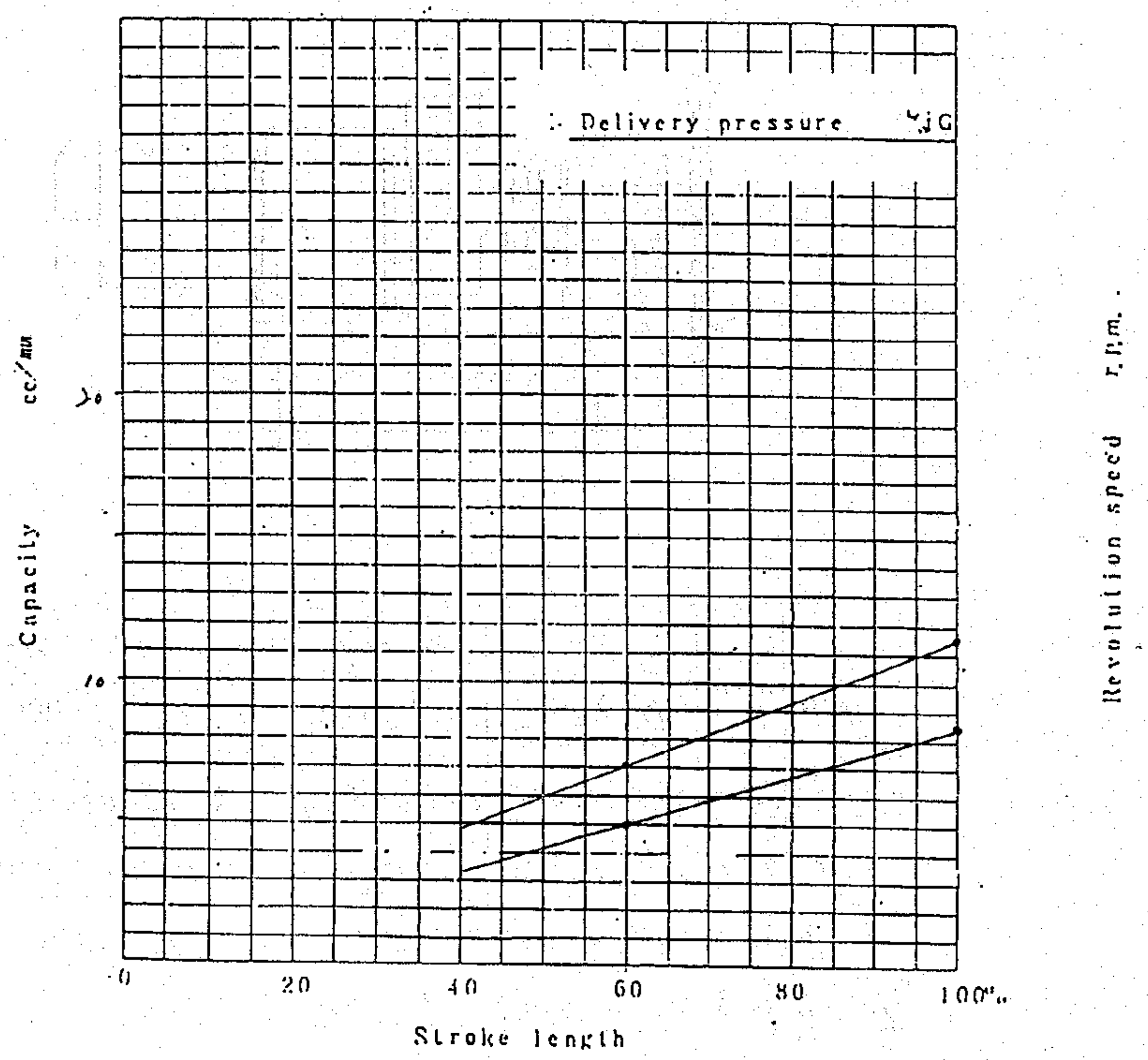
TIME	Atmos. temp (°C)	P-005			P-007			P-009			Agitator		
		①	②	③	①	②	③	①	②	③	Motor Casing	Motor Bearing	Gear
9:00	32.0	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
9:10	34.0	31.9	31.7	32.5	32.2	32.2	32.9	31.6	31.6	32.4	33.9	34.0	32.5
9:30	36.0	33.5	33.5	35.0	33.7	33.7	35.7	33.0	33.0	34.8	38.2	36.6	35.4
10:00	36.5	35.1	35.0	37.7	35.6	35.4	37.5	34.1	34.2	31.6	38.7	37.2	35.9
10:30	38.0	35.5	35.5	38.7	36.5	36.2	37.8	35.7	35.7	38.0	41.1	39.5	37.5

[illegible] 29/9/93.

Y. Miyamoto 29. Sep. '93

(5.3.1)

Fig. 7-5 ANTI-SCALE Injection pump P-005



Discharge Pressure	r.p.m	Stroke 100 %	60 %	
3.4 kg/cm²G	1200	11.25	7.0	
	900	8.5	5.0	

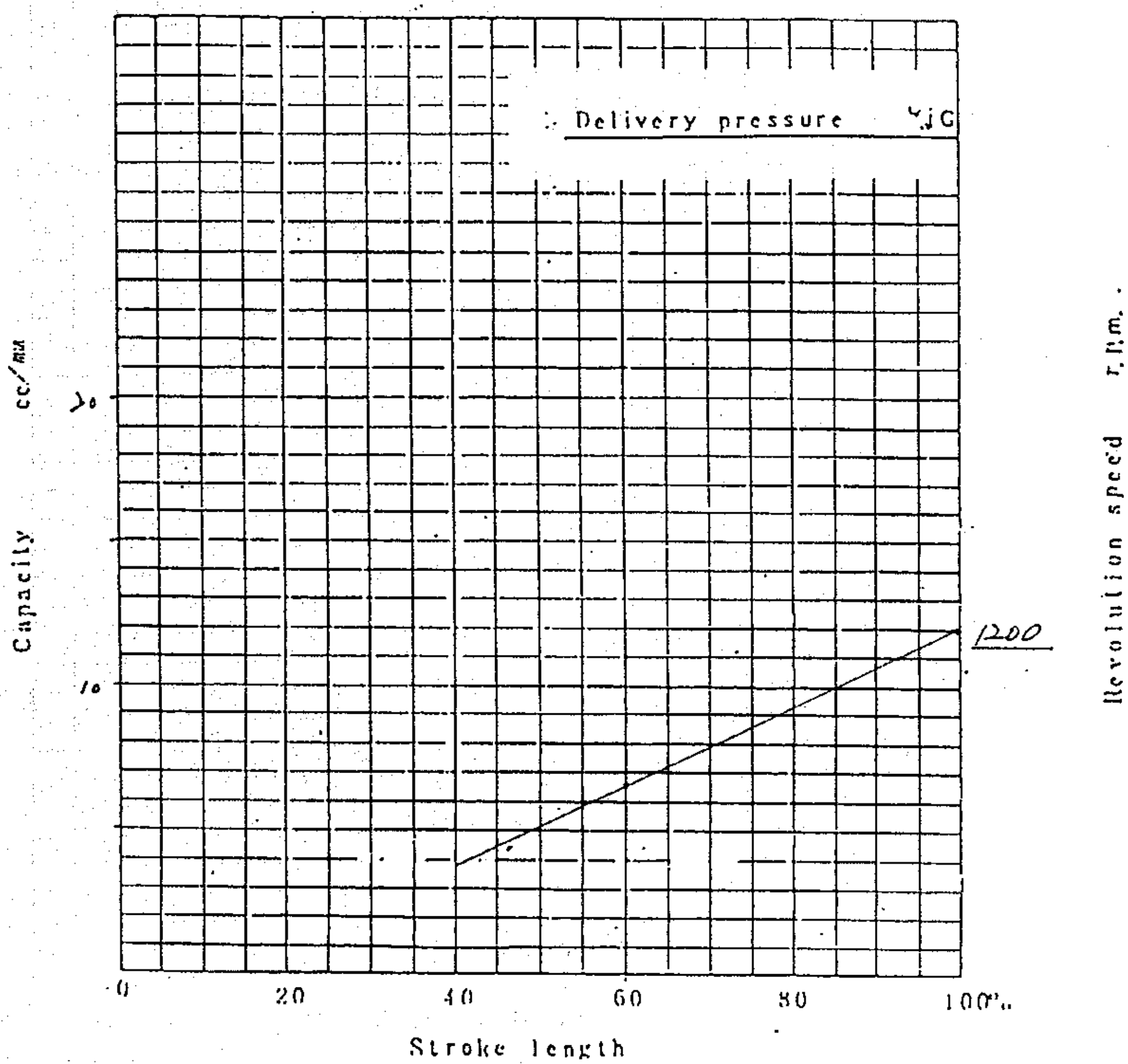
Serial No.	Pump	1042
	Motor	G11085

29. Sep. 1993

Monsuddin 29/9/93 Y. Miyamoto

(5.3.1)

Fig. 7–6 ACID Injection Pump
P-006



Discharge Pressure	r.p.m	Stroke 100%	60%	
3.3 kg/cm²G	1200	12.0	6.6	
	900			

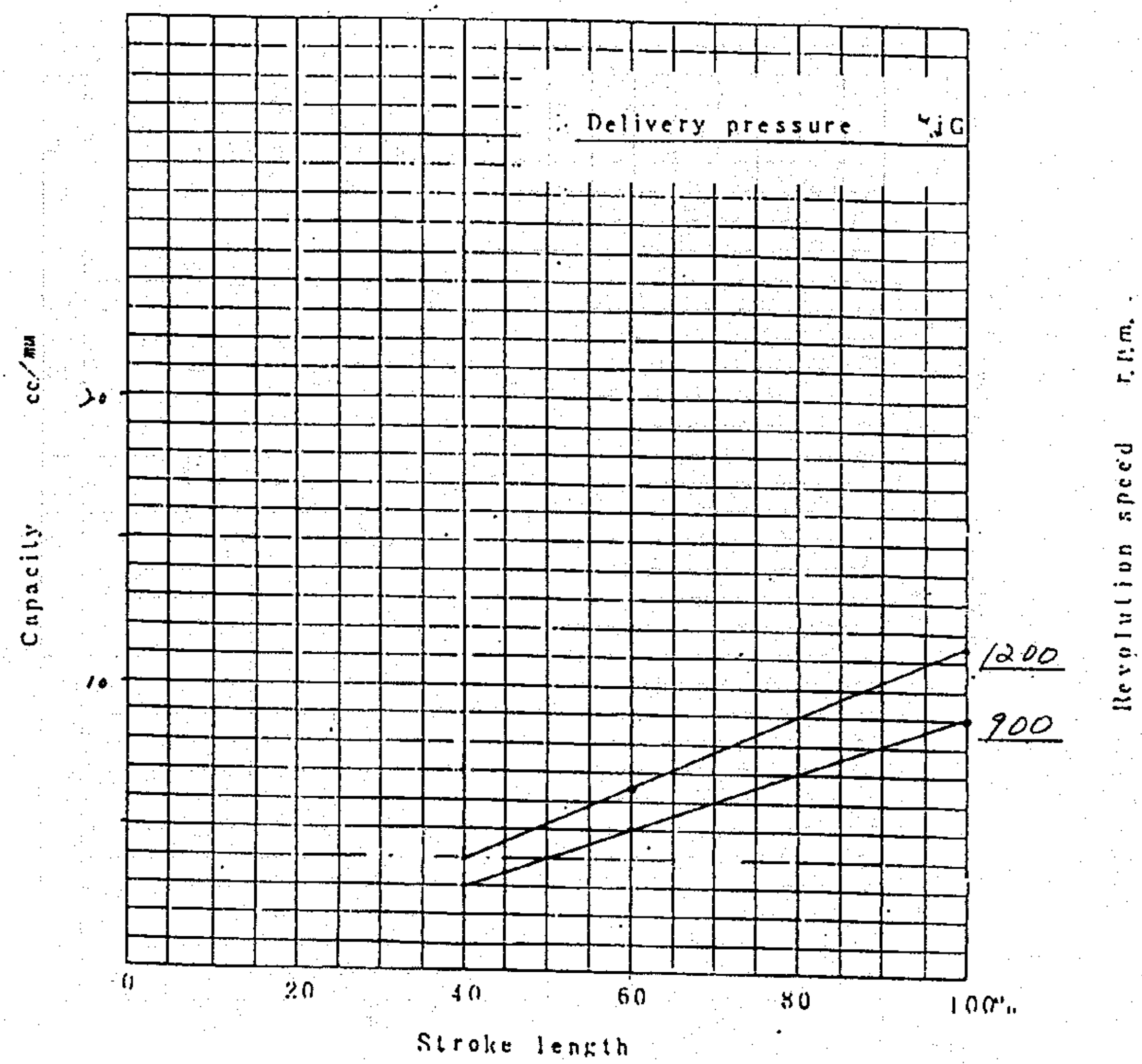
Serial No.	Pump	1043
	Motor	G11085

15 Sep 1993

Monaziwaran
15/9/93

Y. Miyamoto

Fig. 7–7 SODIUM SULPHITE Injection pump
P-007



Discharge Pressure	r.p.m	Stroke 100 %	60 %	
3.3 kg/cm²G	1200	11.5	6.5	
	900	9.0	5.0	

Serial No.	Pump	1040
	Motor	G1108E

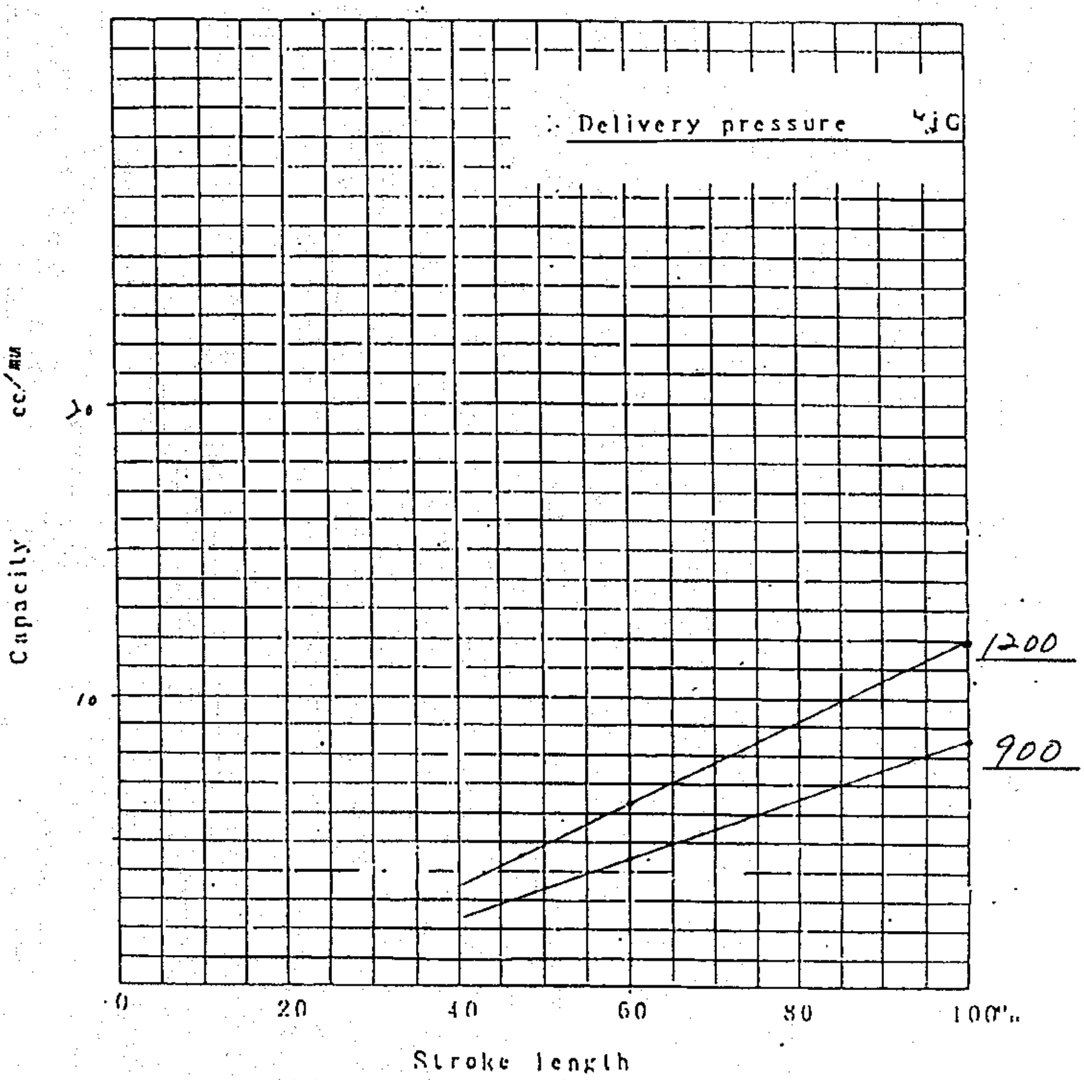
28 Sep. 93

Monecir Quam
28/9/93

Y. Miyamoto

(5.3.1)

Fig. 7-8 ANTI-FOAM Injection pump
P-009



Discharge Pressure	r.p.m	Stroke 100%	60%	
3.3 kg/cm²G	1200	12.0	6.25	
	900	8.5	4.5	

Serial No.	Pump	1041
	Motor	G11085

28 Sep. 1993

28/9/93

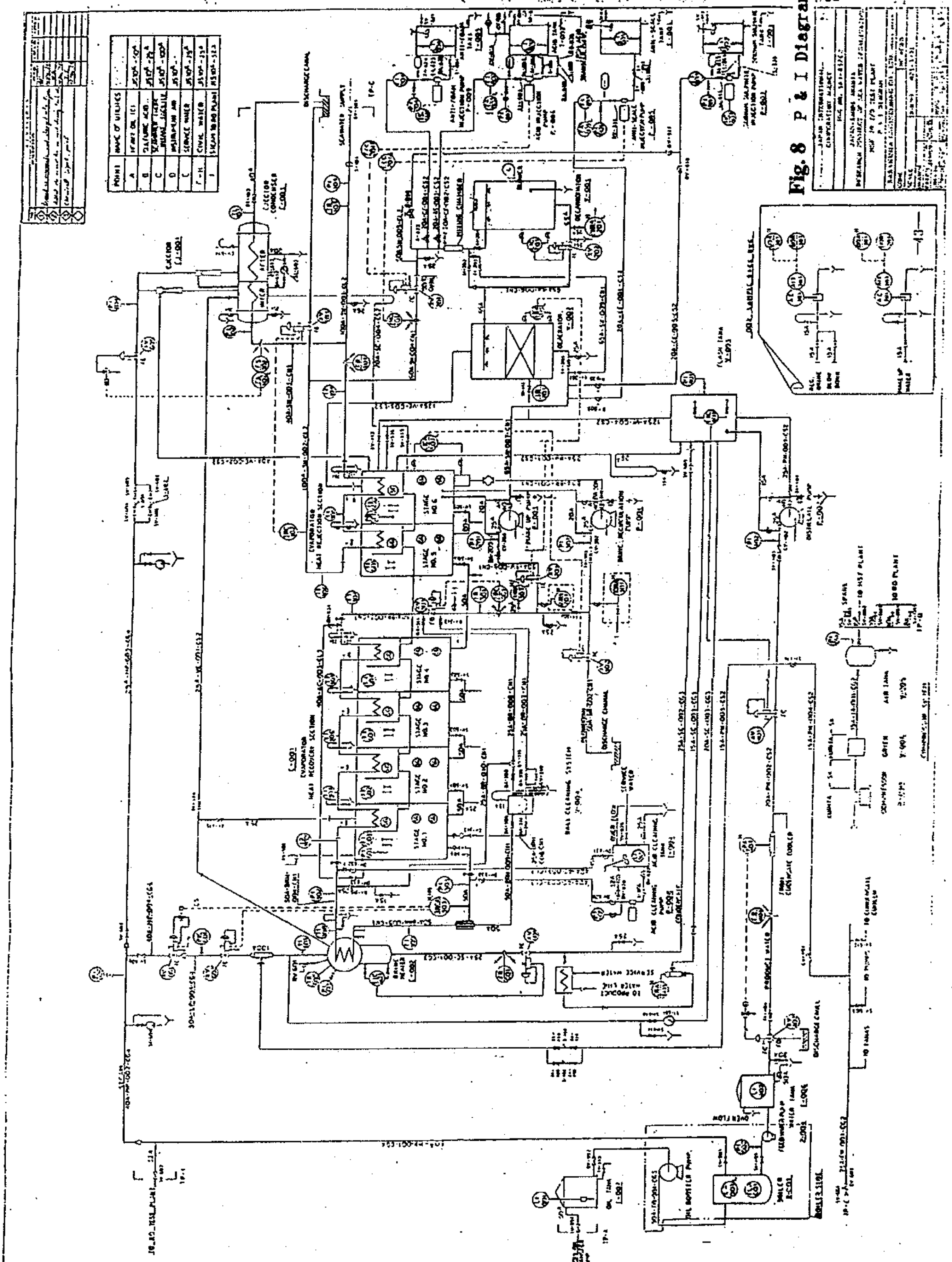


Fig. 8 P & I Diagram