6.4 Test with the MSF Test Plant

6.4.1 Modification of the MSF Test Plant

CONTENTS

1. Introduction 1

2. Installation 1

3. Confirmation of Actuation 2

4. Others 3

List of Tables

Table	Description	Page
Table 1	Time Table for Modification of MSF Test Plant	4
Table 2	Results of the Performance Test of the Oil Injection Pump	8

List of Figures

Figure	Description	Page
Fig. 1	Piping of Brine Sampling	5
Fig. 2	Piping of Distillate Water Sampling	6
Fig. 3	The Relation between Recorder Number and Sensor	7
Fig. 4	Results of the Performance Test of the Oil Injection Pump	8
Fig. 5	Suction Piping & Installation of Brine Sampling Pump	9
Fig. 6	Installation of Resistance Thermometer Bulb (Vapor Stage Side)	9
Fig. 7	Installation of Resistance Thermometer Bulb (Brine Inlet Side)	10
Fig. 8	Control Panel & Recorder	10

1. Introduction

The test with the modified MSF test plant should be carried out in order to evaluate the phenomena of contaminants which were assumed by the computer programming. Consequently, the modification of the MSF test plant has been conducted so as to add the sampling instrumentation to the MSF test plant.

This work has been done from Aug. 13 to Sep. 14, 1994 according to the schedule shown in Table 1. The contents of the work are as follows.

2. Installation

The installation works were as follows.

(1) Installation of the pump for the sampling of brine
To sample brine at each stage from No. one to six, five pumps were installed at the loop seal pipe. The piping work was carried out. The piping drawing is shown in Fig. 1.

(2) Installation of the pumps for the sampling of product water
For the purpose of sampling product water at each stage from No. one to six, five pumps were installed at the loop seal pipe, and one pump was installed at the drain pipe of product water and then the piping work was carried out. The piping drawing is shown in Fig. 2.

(3) Installation of the pump for oil injection
To inject oil into the brine, the pump for oil injection was installed at the pipe after the brine heater and then piping work was carried out.

(4) Installation of the oil separator and the pump for oily seawater transfer
Because it was decided that the separated oil from the oily seawater should be stored in the oil tank, a FRP tank was installed.

(5) Installation of electrical and instrument
To measure temperature of vapor at each stage from No. one to six and of brine at each inlet of stage from No. one to five, RTDs were installed at each optimum point.

And each sensor were connected with recorder in the center control panel.
The start and stop control of the sampling pump for the brine and the product water and, of the transfer pump for the oily seawater are manipulated at the center control panel. The start and stop control of the transfer pump for the oil seawater manipulated at the satellite control panel.

3. Confirmation of Actuation

Confirmation of each actuation were as follows.

(1) Brine sampling pump
After flushing the pipe, the direction of rotation of the pump was confirmed.

(2) Product water sampling pump
After flushing the pipe, the direction of rotation of the pump was confirmed.

(3) Oil injection pump
After confirmation of the direction of rotation, the discharge was measured. The results of measure were shown in Table 2 and Fig. 3.

(4) Oil separator

1) The direction of rotation of the transfer pump for the oily seawater was confirmed.
2) The interlock between the oily seawater transfer pump and the level meter was confirmed.
3) The interlock between the valve for oil discharge at the oil separator and the level meter was confirmed.

(5) Fixation of numbers between the recorder and sensors
The range of temperature at the recorder was fixed from 0 to 150 $^{\circ}$C. The record numbers of each sensor which is consisted of a resistance thermometer bulb are as follows.

vapor temperature	:	CH-1, CH-2, CH-3, CH-4, CH-5, CH-6
brine temperature	:	CH-11, CH-12, CH-13, CH-14, CH-15

The relation between the sensor and the record number is shown in Fig.4.

(6) Air test

The air test was carried out and the air tightness was confirmed at a pressure of 0.75 $kg/cm^2 \cdot G$.

4. Others

Matters to be attended under operation are as follows.

(1) Brine sampling pump

Because discharge operation is not for the pump, one person should wait at that place to open the outlet valve as soon as the pump starts.

(2) Oil separator

When the blow down water is poured into the oil separator under the carryover testing, close the manual valve slowly.

Above mentioned modification works are shown in photos from Fig. 5 to Fig. 8.

Table 1 TIME TABLE FOR MODIFICATION OF MSF TEST PLANT

ITEM	MONTH: AUGUST / SEPTEMBER — DAY: 11, 13, 18, 25, 26, 01, 08, 12, 15, 16, 22	NOTE
1. Meeting with JICA/SWCC at MERIDIEN about the schedule & contents.	◎ ← Mr. Miyamoto arrives at SWCC Jubail. (11 Aug) ← Mr. Hamada leaves SWCC Jubail. (13 Aug) ← Mr. Hamada arrives at SWCC Jubail. (12 Sep)	
2. Making of the structure for equipmemt 2-1 O.W. separator, Pump unit for O.W.S 2-2 Distilate water and brine sampling pump	Mr. Tanaka leaves SWCC Jubail → (26 Aug) Mr. Miyamoto leaves SWCC Jubail. → (16 Sep)	· At center work shop
3. Set-up the structures 3-1 for recirculation brine 3-2 for product water		· Plumber : 2 persons · Welder : 1 person
4. Installation of the equipment		
5. Piping for equipments 5-1 Distilate water sampling 5-2 Brine sampling 5-3 O.W. Separator and pump 5-4 Oil injection line		· Plumber : 2 persons
6. Electrical & Instrument 6-1 Piping of the conduct pipe 6-2 Connection between test plant and panel/electric supply etc.,		· Civil work : 2 persons · Electrician : 2 persons (include Instrument work)
7. Inspection 7-1 Piping and equipment 7-2 Electric and Instrument		
8. Test run 8-1 Vacuum test and test run 8-2 Performance Test		· Operator
9. Preparation for starting up Run 2.		
ITEM	DAY 11, 13, 18, 25, 01, 08, 15, 22	

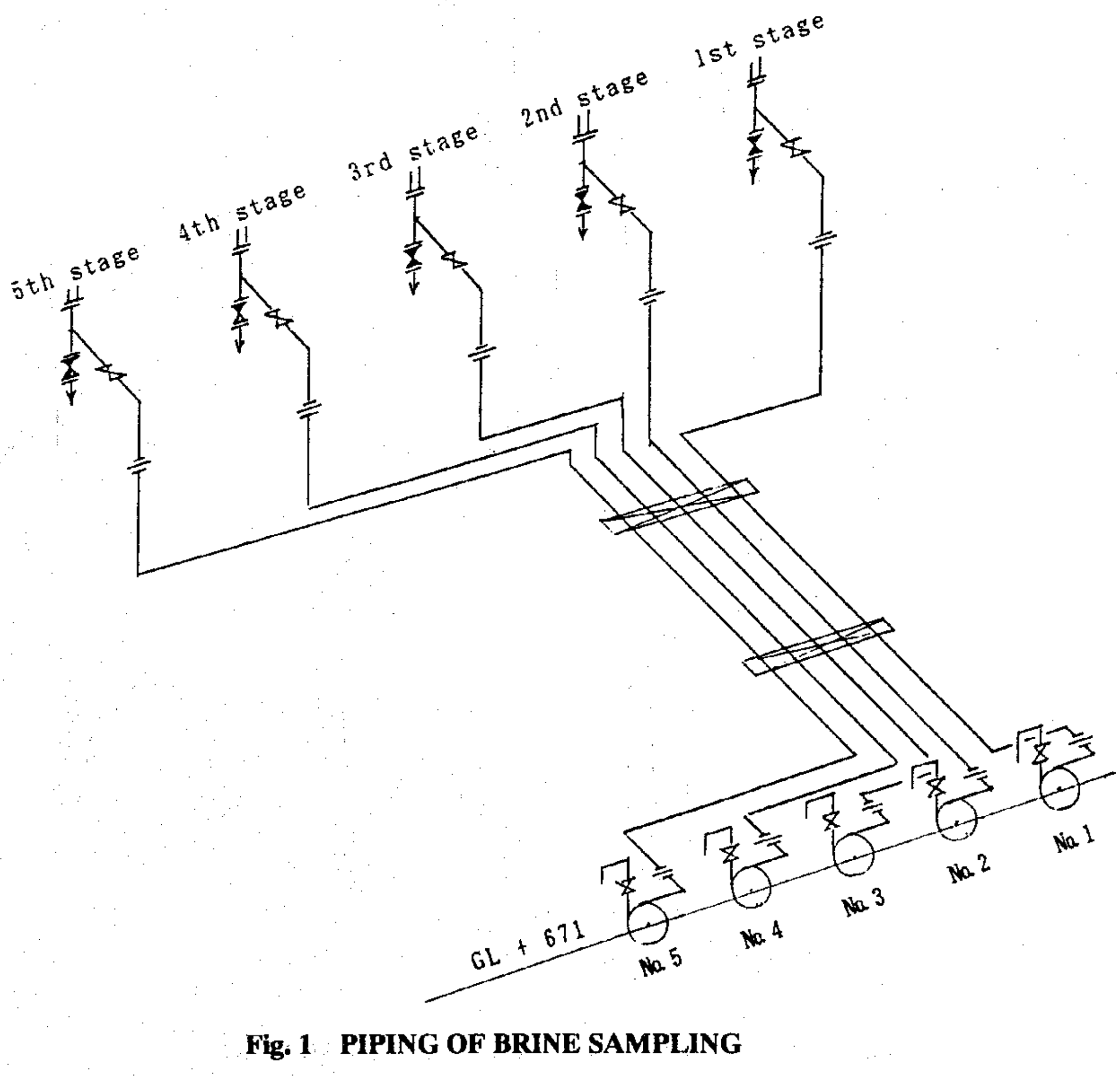

Fig. 1 PIPING OF BRINE SAMPLING

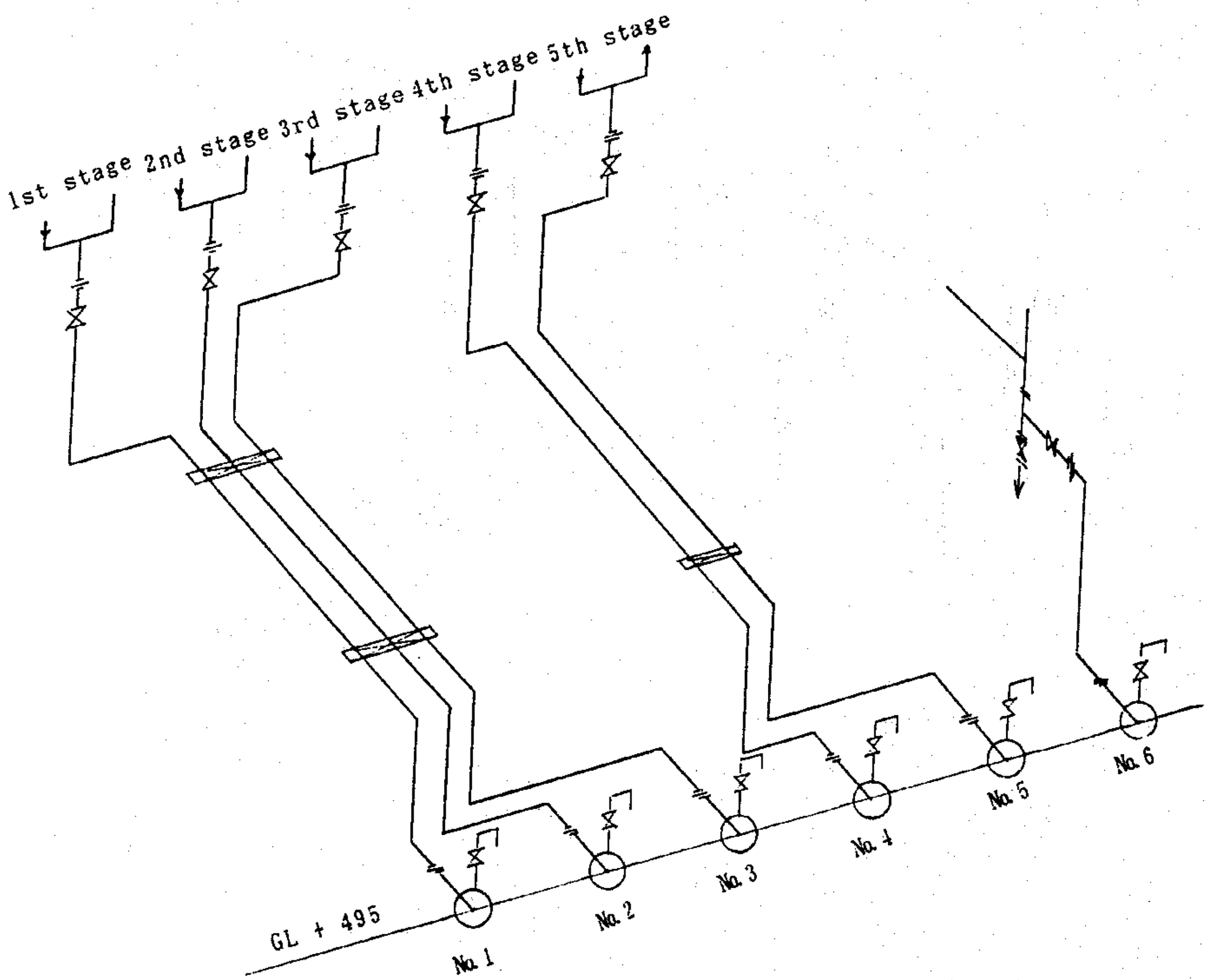

Fig. 2 PIPING OF DISTILATE WATER SAMPLING

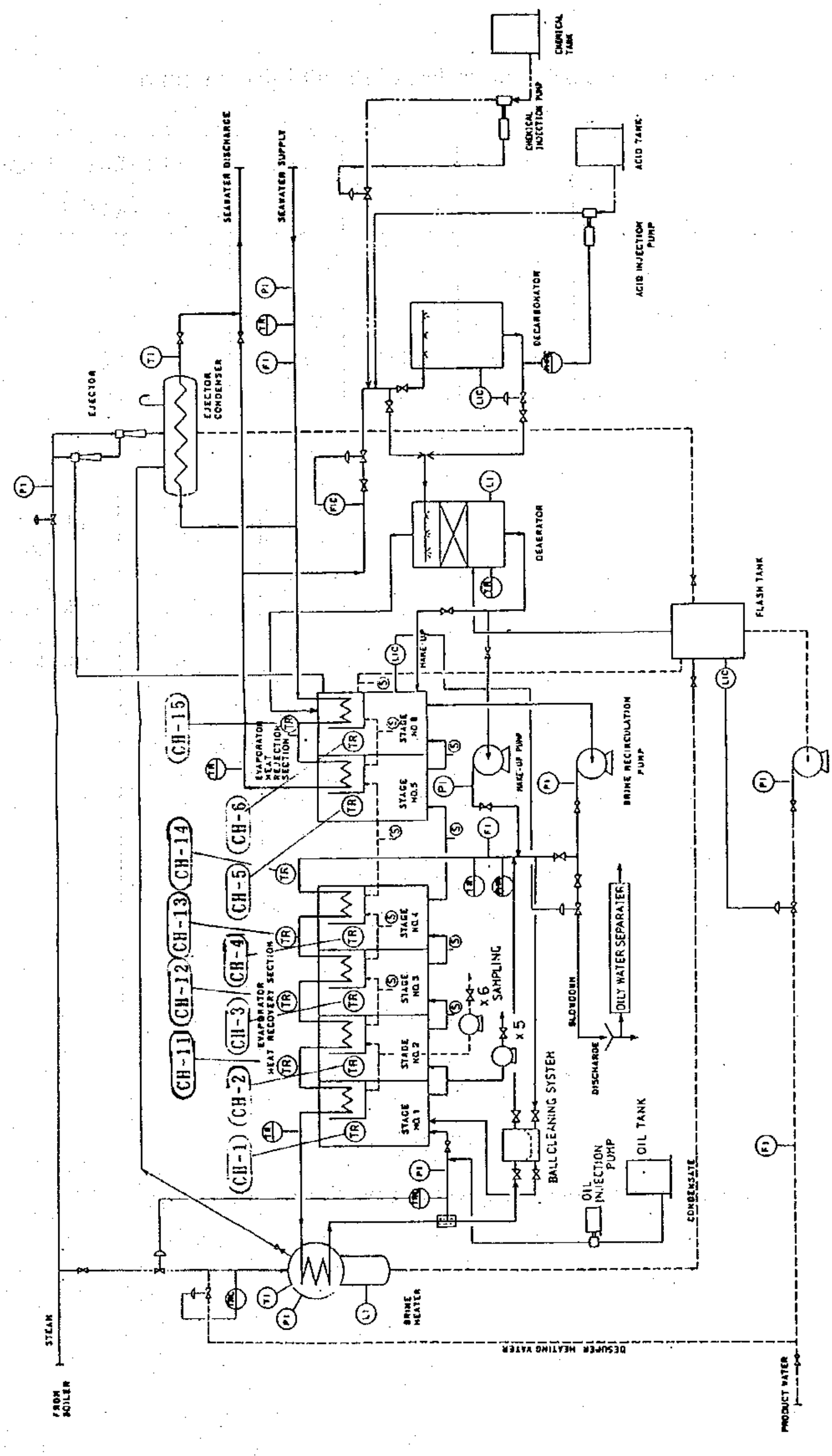

Fig. 3 THE RELATION BETWEEN RECORDER NUMBER AND SENSOR

Table 2 Results of the performance test of the oil injection pump

STROKE (%)		25	50	75	100	DELIVERY PRESSURE (kg/cm²)
DISCHARGE (mL/min)	SITE	20.5	44	68	86	0
	MAKER	11.2	36.2	53.0	76.2	10

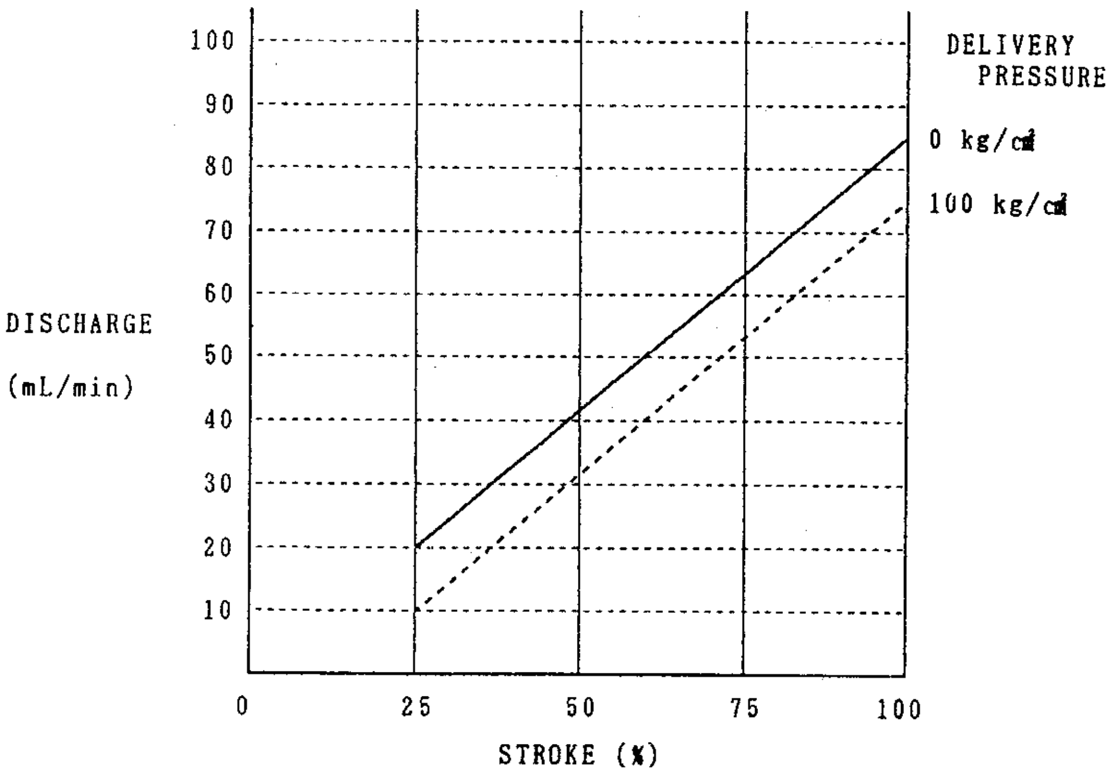

Fig. 4 Results of the performance test of the oil injection pump

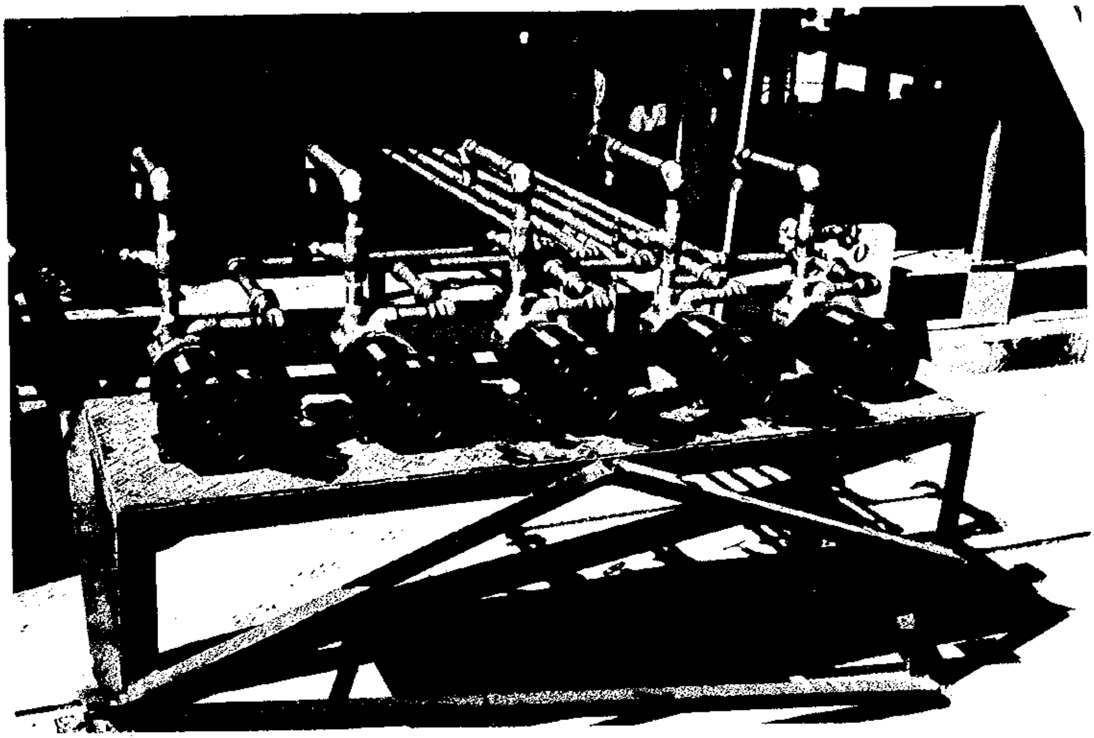

Fig. 5 SUCTION PIPING & INSTALLATION OF BRINE SAMPLING PUMPS

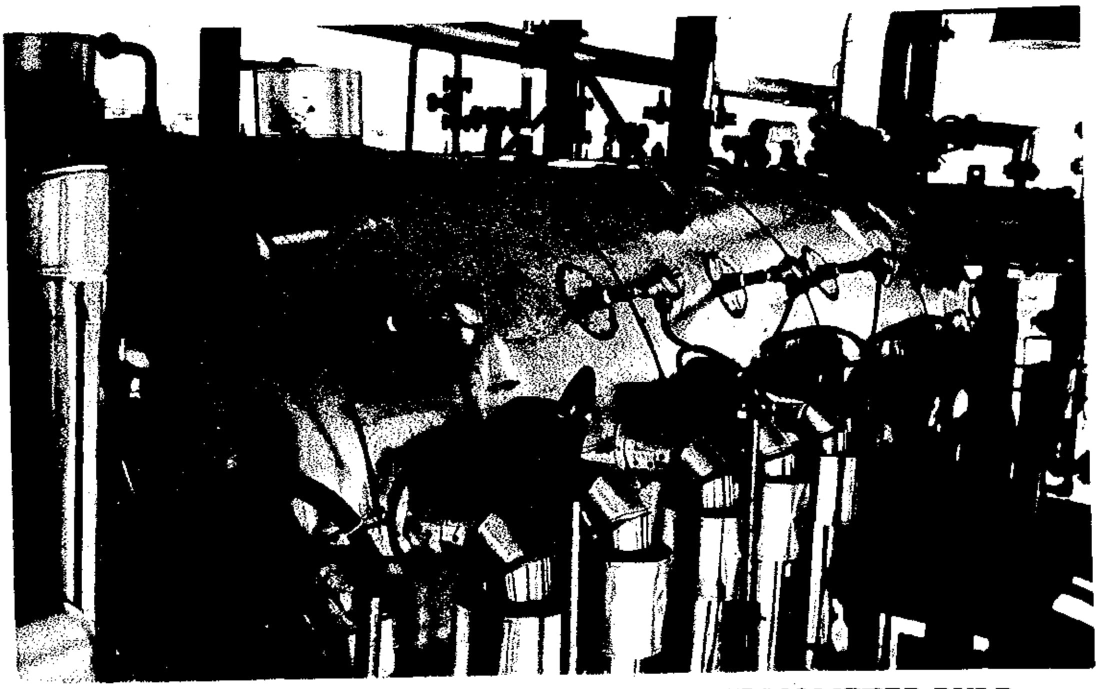

Fig. 6 INSTALLATION OF RESISTANCE THERMOMETER BULB (VAPOR STAGE SIDE)

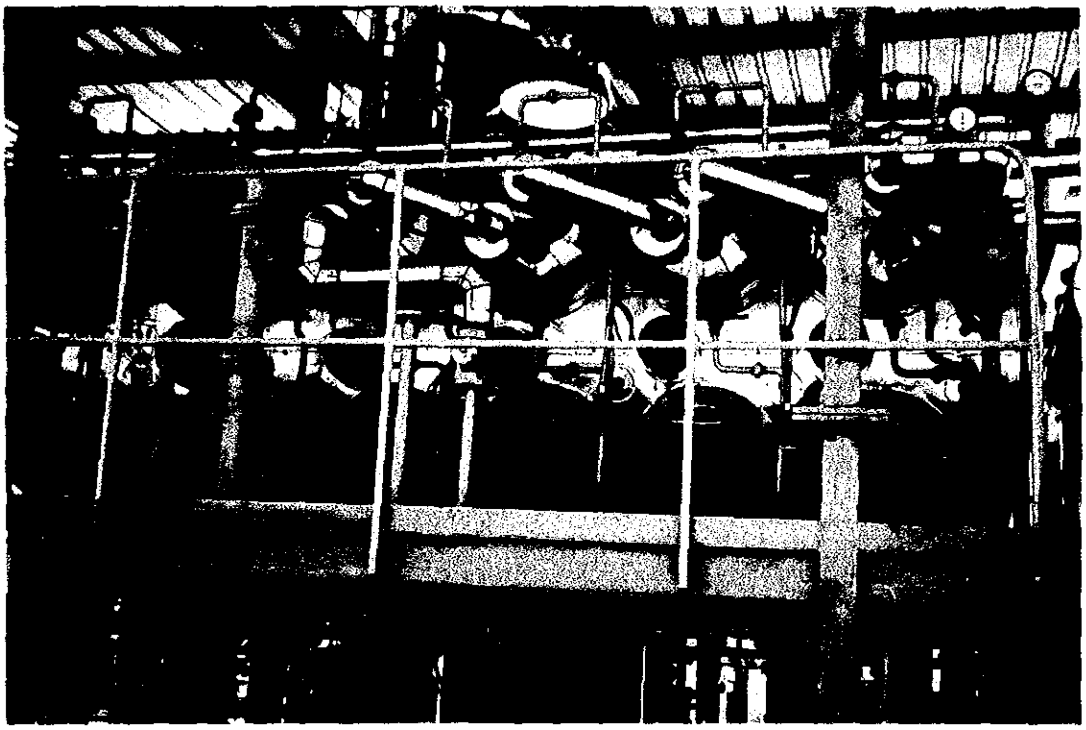

Fig. 7 INSTALLATION OF RESISTANCE THERMOMETER BULB (BRINE INLET SIDE)

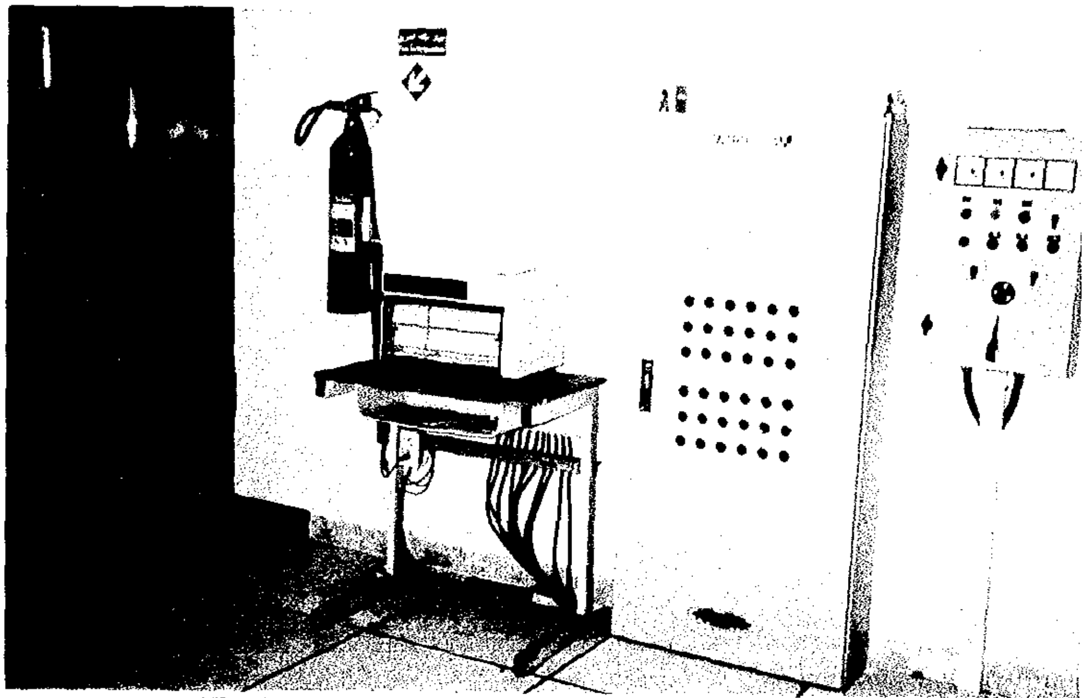

Fig. 8 CONTROL PANEL & RECORDER

6.4.2 Mixture of Bromoform and Product Water

CONTENTS

1. Introduction 1

2. Test Plan 1
2.1 Test Condition 1
2.2 Test Procedure 2
2.2.1 Preparation of Bromoform Solution 2
2.2.2 Measured Items 2
2.2.3 Sampling Position for Bromoform Analysis 2
2.2.4 Instrument Used for Bromoform Analysis 3

3. Test Results 5
3.1 RUN 6–1 5
3.2 RUN 6–2 5

4. Discussion 10
4.1 Mass Balance of Bromoform 10
4.2 Material Balance from Computer Calculation 11
4.3 Dispersion of Bromoform by Deaerator 26

5. Conclusion 27

List of Tables

Table	Description	Page
Table 1	Test Conditions	4
Table 2	Results of Bromoform Carryover Test at RUN 6–1	6
Table 3	Results of Bromoform Carryover Test at RUN 6–2	8
Table 4	Summary of Computer Output	24

List of Figures

Figure	Description	Page
Fig. 1	Calculation Results of Bromoform Carryover by Computer (RUN 6–1)	13
Fig. 2	Calculation Results of Bromoform Carryover by Computer (RUN 6–2)	19

1. Introduction

In the previous section, the computer program for predicting the behavior of organic contaminants in MSF plant based on the volatility mechanisms discussed in 6.1 and 6.2 has been introduced. The flow chart, used formula and the structure of the program has been shown in 6.3.

In this section, the behavior of bromoform has been investigated by charging it to the MSF test plant. The experimental results has been compared with the computer prediction.

2. Test Plan

The carryover experiment of bromoform has been conducted as RUN 6 in the series of MSF test plant experiments which are listed in 5.3.3.

The loss of bromoform from the ejector has been observed during the test. Thus two different location for charging bromoform has been tested. One experiment is at the outlet of the brine heater, and the other experiment at the inlet of the deaerator. The former is named RUN 6–1 and the latter is named RUN 6–2.

The operation conditions of RUN 6–1 is kept identical to that of RUN 5–2.

2.1 Test Condition

The carryover test conditions of bromoform are shown in Table 1 together with that of oil carryover test.

The concentration of charged bromoform of RUN 6–1 was 0.5mg/L, and that of RUN 6–2 was 2.75mg/L. The latter is five times more than the former since large amount of loss has been expected at deaerator for RUN 6–2.

2.2 Test Procedure

2.2.1 Preparation of Bromoform Solution

The feed rate of make up water was 2.45m^3/h. Thus, bromoform feed of 1.2g/h was required for 0.5mg/L concentration. However, the minimum charging rate of the pump was 600mL/h. So, the concentration of charging solution was set to 2000mg/L. It was confirmed by preliminary test that the solubility of bromoform in pure water is more than 2000mg/L.

2.2.2 Measured Items

The measured items during the experiments are shown below.

1) Feed Rate : make up seawater, recirculating brine
2) Seawater/brine Temperature : inlet and outlet of deaerator(RUN5-2), outlet of brine heater
3) Vapor Temperature : every stage
4) TDS Concentration : make up water
5) Electric Conductivity : recirculating brine at every stage

The sampling of water was started after bromoform has been detected in blow down brine which means the whole system has been filled with bromoform contaminated brine.

2.2.3 Sampling position for bromoform analysis

Seawater/Brine	Product Water
Deaerator outlet(RUN 5-2 only)	
No.1 Stage outlet	No.1 Stage
No.2 Stage outlet	No.2 Stage
No.3 Stage outlet	No.3 Stage
No.4 Stage outlet	No.4 Stage
No.5 Stage outlet	No.5 Stage
No.6 Stage outlet(Blow Brine)	No.6 Stage

2.2.4 Instrument used for bromoform analysis

Type	:	**GC-ECD by purge & trap method**
Detect limit	:	**0.1×10^{-3}mg/L**

Table 1 TEST CONDITIONS

RUN NO.		6-1	6-2	7	9
1. Operation Mode		Recir.	Recir.	Once	Once
2. Scale Control Method		Hybrid	Chemi.	Chemi.	Chemi.
3. Top Brine Temperature	℃	112	112	112	112
4. Flow Rate					
-Make up Seawater	m^3/h	2.45	2.30	6.40	6.40
-Recirculation Brine	m^3/h	6.50	6.50	6.40	6.40
-Product Water	m^3/h	0.81	0.86	0.90	0.90
5. Chemical Constituents of Brine					
-pH at 25C		8.04	8.52	8.24	8.24
-M-alkalinity as CaCO3	mg/L	55-60	180	128	128
-Chloride ion	mg/L	32,730	33,320	23,360	23,360
-Concentration Factor	mg/L	1.39	1.40	1.01	1.01
6. Dosing Rate of Chemicals					
-Scale Inhibitor(PPN(M))	mg/L	1	2	2	2
-Acid(98% H2SO4)	mg/L	72	None	None	None
-Trihalomethene(CHBr3)	mg/L	0.5	2.75	None	None
-Oil(Light Diesel Oil #2)	mg/L	None	None	10	2.5
7. Injection Point of Contaminants		After B.H	Before Dea.	After B.H	After B.H

3. Test Results

3.1 RUN 6–1

Five samplings have been conducted from 1 to 5 of November. The results are shown in Table 2.

The concentration of bromoform in brine at No.1 stage outlet reduced to 2ppb from initial concentration of 500ppb. The concentration of bromoform in product water is little. Thus, most of bromoform should have been dispersed from the ejector as vapor. The behavior will be discussed later.

3.2 RUN 6–2

Four samplings have been done from 8 to 11 of November. Those results are shown in Table 3.

High amount of bromoform, 2,750ppb, was charged at the inlet of deaerator. However, more than 95% of them had been dispersed out through deaerator as expected. The concentration of bromoform in brine charged to No.1 stage was very little. This phenomena will be discussed later.

Table 2 Results of Bromoform Carryover Test at RUN NO. : 6–1

1. Operation Type :Recirculation

2. Date of taking samples :Oct. 30th - 5th, 1994

3. Brine Exit Data
   - -Temperature : 112 C (TBLO)
   - -Flow Rate : 6,500 kg/h (FBLO)
   - -Electric Conductivity :79,700 μS/cm (SBLO)

4. Make up Data
   - -Temperature : 34 C (TBLM)
   - -Flow Rate :2,450 kg/h (FBLM)
   - -TDS Concentration : 39.9E-3 kg/kg (CBSM)
   - -Bromoform Conc. after Deaerator : 0.5E-6 kg/kg (COMM)

5. Steam Temperature(C) and Electric Conductivity(μS/cm) in Each Stage

Stage	Dea.	1	2	3	4	5	6
Steam Temp.	—	94.1	83.4	71.4	57.7	41.7	36.8
Electric C.	—	81.2E3	82.8E3	84.1E3	85.6E3	87.6E3	89.4E3

(NOTE) Ex:10*

6. Bromoform Concentration in Each Stage of the Evaporator

Sampling date : Nov, 1st, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	44.51	34.02	17.35	19.28	7.74	7.35
Brine	—	1.76	0.34	0.1	< 0.1	< 0.1	0.67

Sampling date : Nov, 2nd, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	37.67	24.45	16.45	16.82	11.85	7.07
Brine	—	1.35	0.29	< 0.1	< 0.1	< 0.1	0.64

Sampling date : Nov, 3rd, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	39.85	25.30	17.80	19.98	10.63	8.12
Brine	—	1.41	0.33	< 0.1	< 0.1	< 0.1	0.05

Sampling date : Nov, 4th, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	41.60	44.39	28.95	28.49	12.85	16.12
Brine	—	2.02	0.41	0.11	< 0.1	< 0.1	< 0.1

Sampling date : Nov, 5th, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	46.37	50.63	32.75	30.77	15.94	23.32
Brine	—	2.05	0.51	0.15	< 0.1	< 0.1	< 0.1

Table 3 Results of Bromoform Carryover Test at RUN NO. : 6-2

1. Operation Type :Recirculation

2. Date of taking samples :Nov. 7th,- 11th, 1994

3. Brine Exit Data
   - -Temperature : 112 C (TBLO)
   - -Flow Rate : 6,500 kg/h (FBLO)
   - -Electric Conductivity :79,700 μS/cm (SBLO)

4. Make up Data
   - -Temperature in Deaerator Inlet : 37.3 C (TBLD)
   - -Temperature in Deaerator Outlet : 34.0 C (TBLG)
   - -Flow Rate :2,450 kg/h (FBLM)
   - -TDS Concentration : 39.9 E-3 kg/kg (CBSM)
   - -Bromoform Conc. before Deaerator : 2.75E-6 kg/kg (COMD)

5. Steam Temperature(C) and Electric Conductivity(μS/cm) in Each Stage

Stage	Dea.	1	2	3	4	5	6
Steam Temp.	34.0	94.1	83.4	71.4	57.7	41.7	36.8
Electric C.	—	81.2E3	82.8E3	84.1E3	85.6E3	87.6E3	89.4E3

(NOTE) Ex:10^x

6. Bromoform Concentration in Each Stage of the Evaporator

Sampling date : Nov. 8th, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	138.28	147.69	139.06	64.59	24.46	78.24
Brine	97.48	5.48	0.95	0.30	< 0.1	< 0.1	< 0.1

Sampling date : Nov. 10th, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	257.9	238.2	72.5	83.8	163.1	166.28
Brine	97.2	17.34	1.36	0.42	0.13	< 0.1	< 0.1

Sampling date : Nov. 10th, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	252.3	237.5	65.0	159.9	48.6	102.1
Brine	99.8	13.81	1.70	0.42	0.12	< 0.1	< 0.1

Sampling date : Nov. 11th, 1994 (Unit:ppb)

Stage	Dea.	1	2	3	4	5	6
Product W.	—	393.2	266.5	129.6	168.0	92.9	193.0
Brine	123.48	10.11	1.22	0.25	< 0.1	< 0.1	< 0.1

4. Discussion

4.1 Mass balance of bromoform

Mass balance of bromoform of RUN 6–1 and 6–2 has been investigated. The flow rate of make up water, product water and blow brine are as follows.

- Make up seawater : 2,450 kg/h
- Product water : 780 kg/h
- Blow Brine : 2,450 – 780 = 1,670 kg/h

The amount of bromoform dosed in RUN 6–1 and 6–2 are 0.5mg/L and 2.75mg/L, respectively.

The concentration of product water and blow brine used for the mass balance calculation are as follows. They are average value of the sample analysis excluding the initial sample.

RUN No.	Feed	Product Water	Blow down brine
6–1	0.5 mg/L	0.0137mg/L	0.0001mg/L
6–2	2.75 mg/L	0.1538mg/L	0.0001mg/L

RUN 6–1

- Feed rate : 2450kg/h x 0.5mg/L x 0.97L/kg = 1188.25 mg/h
- Outlet by blow brine : 1670kg/h x 0.0001mg/L x 0.97L/kg = 0.161 mg/h
- Outlet by product water : 780kg/h x 0.0137mg/L x 0.97L/kg = 10.36 mg/h
- Outlet from ejector : 188.25 – (0.161 + 10.36) = 1177.72 mg/h
- Percent ejection : (1177.72/1188.25) x 100 = 99.1%

RUN 6–2

- Feed rate : 2450kg/h x 2.75mg/L x 0.97L/kg = 6535.38 mg/h
- Outlet by blow brine : 1670kg/h x 0.0001mg/L x 0.97L/kg = 0.161 mg/h
- Outlet by product water : 780kg/h x 0.1538mg/L x 0.97L/kg = 116.4 mg/h
- Outlet from ejector : 6535.38 – (0.161 + 116.4) = 6418.81 mg/h
- Percent ejection : (6418.81/6535.38) x 100 = 98.2%

From this analysis, it came clear that most of bromoform has been dispersed out of the system from ejector.

4.2 Material balance from computer calculation

The calculated results based on the condition in 4.1 are shown in Fig. 1 and Fig.2. The results can be summarized as Table 4.

The mass balance of bromoform of RUN 6-1 by computer calculation will be as follows.

- Feed rate : 2450kg/h x 0.5mg/L x 0.97L/kg = 1188.25 mg/L
- Outlet as blow brine : 1670kg/h x 0.0895mg/L x 0.97L/kg = 144.98 mg/h
- Outlet as product water : 780kg/h x 1.321mg/L x 0.97L/kg = 999.46 mg/h
- Calculation error : 1188.25 – (144.98 + 999.46) = 43.81 mg/h

The comparison of calculated and experimental results are shown below.

Comparison of calculated and experimental results

Method	Bromoform concentration: Product water	Bromoform concentration: Blow brine	Production rate of water
Experiment(RUN 6-1)	0.0137 mg/L	$< 10^{-4}$ mg/L	810 kg/h
Calculation	1.321 mg/L	0.0895 mg/L	779 kg/h

The production rate of product water is in good agreement between two figures. Thus, it can be concluded that the behavior of water in MSF plant can be predicted by this computer program.

However, the concentration of bromoform was completely different between experiment and calculation.

In order to adjust the concentration of blow brine, the Henry's constant (mol./L•atm) should be reduced to 1/3.4 of the measured value. The calculated results by reducing Henry's constant to 1/3.4 of the measured value are as follows.

(6.4.2)

Method	Bromoform concentration		Production rate of water
	Product water	Blow Brine	
Calculation (Henry's C. : 1/3.4)	1.526mg/L	0.74×10^{-4}mg/L	779.5kg/h

By the above calculation, the concentration of blow brine has been adjusted, however, that of product water remain unadjusted. This indicates that the difference is not due to the volatility behavior of bromoform.

In the computer calculation, it was assumed that all the evaporated bromoform will condensate with water. This assumption should be the main reason for the discrepancy.

The possible explanation for the discrepancy is the difference in condensation rate between bromoform and water. The condensation rate of bromoform should be far less than that of water.

In order to accomplish the computer program, the condensation behavior of bromoform and the factors affecting the behavior should be investigated. By clarifying those subjects, the countermeasures for preventing transference of bromoform in product water would be resolved. One of the possible countermeasures we can assume from the above discussion is the change of vent system to enhance the dispersion of bromoform through ejector.

INPUT DATA

COMPUTER PROGRAMMING FOR CARRYOVER 1994 VERSION

RUN NO: 6-1 HFACTOR: 1

DATE: 1-5/11/94

OPERATOR: AHMAD

MAX BRINE TEMP: 112

CONTAMINANT TYPE: 2

CALCULATION TYPE: 2

DEAERATOR: 1

HEAT & MASS BALANCE INPUT DATA

FBL(0): 6500	TWE(1): 94.1	TWE(4): 57.7
TBL(0): 112	TWE(2): 83.4	TWE(5): 41.7
SBL(0): 79700D-6	TWE(3): 71.0	TWE(6): 36.8

SBL(1): 81200D-6	SBL(4): 85600D-6
SBL(2): 82800D-6	SBL(5): 87600D-6
SBL(3): 84100D-6	SBL(6): 89400D-6

HOMOGENEOUS/RECIRCULATION INPUT DATA

BROME: 5.0D-7 FBLM: 2450 TBLM: 34 CBSM: 39901.5D-6

Fig. 1 Cauculation Results of Bromoform Carryover by Computer (RUN 6-1)

OUTPUT-1

RUN NO: 6-1 DATE: 1-5/11/94 OPERATOR: AHMAD MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	9.4100E+01	8.3400E+01	7.1000E+01	5.7700E+01	4.1700E+01	3.6800E+01
SBL	8.1200E-02	8.2800E-02	8.4100E-02	8.5600E-02	8.7600E-02	8.9400E-02

7.7959E+02
FWLT

RESULTS

	1	2	3	4	5	6
FWL	1.8886E+02	1.2711E+02	1.0047E+02	1.1123E+02	1.4189E+02	1.1003E+02
PWE	8.1744E+04	5.4258E+04	3.2549E+04	1.7904E+04	8.0408E+03	6.1939E+03
TWE	9.4100E+01	8.3400E+01	7.1000E+01	5.7700E+01	4.1700E+01	3.6800E+01
TBL	9.5400E+01	8.3700E+01	7.4100E+01	6.3100E+01	4.8500E+01	3.6800E+01
CBS	5.4989E-02	5.6600E-02	5.7897E-02	5.9373E-02	6.1306E-02	6.2976E-02
FBL	6.3111E+03	6.1840E+03	6.0836E+03	5.9723E+03	5.8304E+03	5.7204E+03

FBLO → FBLM 2.4500E+03

TBL 1.1200E+02

CBS 5.3232E-02(SBL=7.9700E-02)

FBL 6.5000E+03

(6.4.2)

OUTPUT-2

CARRYOVER CALCULATION RESULTS(RECIRCULATION)

	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)	FOMT
BROME	2.2742D-06	1.9082D-06	1.7311D-06	1.5876D-06	1.4481D-06	1.3215D-06	1.0386D-03

	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
BROME	1.7246D-07	1.4889D-07	1.3273D-07	1.1649D-07	9.7732D-08	8.9956D-08

↑

COMM
5.0000E-7

(6.4.2)

INPUT DATA

COMPUTER PROGRAMMING FOR CARRYOVER 1994 VERSION

RUN NO: 6-1 HFACTOR: 3.4 (Henry's Const. : 1/3.4)

DATE: 1-5/11/94

OPERATOR: AHMAD

MAX BRINE TEMP: 112

CONTAMINANT TYPE: 2

CALCULATION TYPE: 2

DEAERATOR: 1

HEAT & MASS BALANCE INPUT DATA

FBL(0): 6500	TWE(1): 94.1	TWE(4): 57.7
TBL(0): 112	TWE(2): 83.4	TWE(5): 41.7
SBL(0): 79700D-6	TWE(3): 71.0	TWE(6): 36.8

SBL(1): 81200D-6	SBL(4): 85600D-6
SBL(2): 82800D-6	SBL(5): 87600D-6
SBL(3): 84100D-6	SBL(6): 89400D-6

HOMOGENEOUS/RECIRCULATION INPUT DATA

BROME: 5.0D-7 FBLM: 2450 TBLM: 34 CBSM: 39901.5D-6

OUTPUT-1

RUN NO: 6-1 DATE: 1-5/11/94 OPERATOR: AHMAD MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	9.4100E+01	8.3400E+01	7.1000E+01	5.7700E+01	4.1700E+01	3.6800E+01
SBL	8.1200E-02	8.2800E-02	8.4100E-02	8.5600E-02	8.7600E-02	8.9400E-02

7.7959E+02

FWLT

RESULTS

	1	2	3	4	5	6
FWL	1.8886E+02	1.2711E+02	1.0047E+02	1.1123E+02	1.4189E+02	1.1003E+02
PWE	8.1744E+04	5.4258E+04	3.2549E+04	1.7904E+04	8.0408E+03	6.1939E+03
TWE	9.4100E+01	8.3400E+01	7.1000E+01	5.7700E+01	4.1700E+01	3.6800E+01
TBL	9.5400E+01	8.3700E+01	7.4100E+01	6.3100E+01	4.8500E+01	3.6800E+01
CBS	5.4989E-02	5.6600E-02	5.7897E-02	5.9373E-02	6.1306E-02	6.2976E-02
FBL	6.3111E+03	6.1840E+03	6.0836E+03	5.9723E+03	5.8304E+03	5.7204E+03

FBLO

FBLM 2.4500E+03

TBL 1.1200E+02

CBS 5.3232E-02(SBL=7.9700E-02)

FBL 6.5000E+03

OUTPUT-2

CARRYOVER CALCULATION RESULTS(RECIRCULATION)

	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)	FOMT
BROME	6.0418D-06	3.6617D-06	2.8005D-06	2.2265D-06	1.7685D-06	1.5264D-06	1.1996D-03

	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
BROME	2.1099D-09	9.8145D-10	5.6508D-10	2.9544D-10	1.1069D-10	7.4102D-11

↑

COMM
5.0000E-7

INPUT DATA

COMPUTER PROGRAMMING FOR CARRYOVER 1994 VERSION

RUN NO: 6-2 HFACTOR: 1

DATE: 7-11/11/94

OPERATOR: AHMAD

MAX BRINE TEMP: 112

CONTAMINANT TYPE: 2

CALCULATION TYPE: 2

DEAERATOR: 2

HEAT & MASS BALANCE INPUT DATA

FBL(0): 6500	TWE(1): 94.1	TWE(4): 57.7
TBL(0): 112	TWE(2): 83.4	TWE(5): 41.7
SBL(0): 79700D-6	TWE(3): 71.0	TWE(6): 36.8

SBL(1): 81200D-6	SBL(4): 85600D-6
SBL(2): 82800D-6	SBL(5): 87600D-6
SBL(3): 84100D-6	SBL(6): 89400D-6

DEAERATOR INPUT DATA

TBLD: 37.3

HOMOGENEOUS/RECIRCULATION INPUT DATA

BROME: 2.75D-6 FBLM: 2450 TBLM: 34 CBSM: 39901.5D-6

Fig. 2 Calculation Results of Bromoform Carryover by Computer (RUN 6–2)

OUTPUT-1

RUN NO: 6-2 DATE: 7-11/11/94 OPERATOR: AHMAD MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	9.4100E+01	8.3400E+01	7.1000E+01	5.7700E+01	4.1700E+01	3.6800E+01
SBL	8.1200E-02	8.2800E-02	8.4100E-02	8.5600E-02	8.7600E-02	8.9400E-02

TBLD 3.7300E+01
FBLM 2.4500E+03

7.7959E+02
FWLT

RESULTS

	DEAERATOR	1	2	3	4	5	6
FWL	1.3309E+01	1.8886E+02	1.2711E+02	1.0047E+02	1.1123E+02	1.4189E+02	1.1003E+02
PWE	5.2260E+03	8.1744E+04	5.4258E+04	3.2549E+04	1.7904E+04	8.0408E+03	6.1939E+03
TWE	3.3612E+01	9.4100E+01	8.3400E+01	7.1000E+01	5.7700E+01	4.1700E+01	3.6800E+01
TBL	3.4000E+01	9.5400E+01	8.3700E+01	7.4100E+01	6.3100E+01	4.8500E+01	3.6800E+01
CBS	3.9902E-02	5.4989E-02	5.6600E-02	5.7897E-02	5.9373E-02	6.1306E-02	6.2976E-02
FBL	2.4367E+03	6.3111E+03	6.1840E+03	6.0836E+03	5.9723E+03	5.8304E+03	5.7204E+03

FBLO
TBL 1.1200E+02
CBS 5.3232E-02(SBL=7.9700E-02)
FBL 6.5000E+03

OUTPUT-2

CARRYOVER CALCULATION RESULTS(RECIRCULATION)

	COEG	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)
BROME	1.4565D-05	1.2081D-05	1.0137D-05	9.1960D-06	8.4338D-06	7.6928D-06	7.0202D-06

	COMG	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
BROME	2.6682D-06	9.1614D-07	7.9092D-07	7.0508D-07	6.1880D-07	5.1917D-07	4.7786D-07

COMM
2.7500E-06

(6.4.2)

OUTPUT-1 (Henry's Const. : 1/3.4)

RUN NO: 6-2 DATE: 7-11/11/94 OPERATOR: AHMAD MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	9.4100E+01	8.3400E+01	7.1000E+01	5.7700E+01	4.1700E+01	3.6800E+01
SBL	8.1200E-02	8.2800E-02	8.4100E-02	8.5600E-02	8.7600E-02	8.9400E-02

TBLD 3.7300E+01
FBLM 2.4500E+03

7.7959E+02
FWLT

RESULTS

	DEAERATOR	1	2	3	4	5	6
FWL	1.3309E+01	1.8886E+02	1.2711E+02	1.0047E+02	1.1123E+02	1.4189E+02	1.1003E+02
PWE	5 2260E+03	8.1744E+04	5.4258E+04	3.2549E+04	1.7904E+04	8.0408E+03	6.1939E+03
TWE	3.3612E+01	9.4100E+01	8.3400E+01	7.1000E+01	5.7700E+01	4.1700E+01	3.6800E+01
TBL	3.4000E+01	9.5400E+01	8.3700E+01	7.4100E+01	6.3100E+01	4.8500E+01	3.6800E+01
CBS	3.9902E-02	5.4989E-02	5.6600E-02	5.7897E-02	5.9373E-02	6.1306E-02	6.2976E-02
FBL	2.4367E+03	6.3111E+03	6.1840E+03	6.0836E+03	5.9723E+03	5.8304E+03	5.7204E+03

FBLO
TBL 1.1200E+02
CBS 5.3232E-02(SBL=7.9700E-02)
FBL 6.5000E+03

OUTPUT-2

CARRYOVER CALCULATION RESULTS(RECIRCULATION)

	COEG	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)
BROME	4.9522D-05	2.9707D-05	1.8004D-05	1.3770D-05	1.0948D-05	8.6956D-06	7.5052D-06

	COMG	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
BROME	2.4719D-06	1.0374D-08	4.8257D-09	2.7785D-09	1.4527D-09	5.4426D-10	3.6435D-10

↑

COMM
2.7500E-06

Table 4 Summary of Computer Output

RUN 6-1 COMM = 0.5 mg/L, Henry's Constant:Log H = 0.24-0.024T

Stage	Dea.	1	2	3	4	5	6
Product W.		2.2742	1.9082	1.7311	1.5867	1.4481	1.3215
Brine		0.1724	0.1488	0.1327	1.1649	0.0977	0.0089

RUN 6-1 COMM = 0.5 mg/L, Henry's Constant: H' = H/3.4

Stage	Dea.	1	2	3	4	5	6
Product W.		6.0418	3.6617	2.8005	2.2265	1.7685	1.5264
Brine		0.0021	0.0009	0.0005	0.0002	0.0001	0.00007

RUN 6-2 COMM = 2.75 mg/L, Henry's Constant:Log H = 0.24-0.024T

Stage	Dea.	1	2	3	4	5	6
Product W.	14.565	12.081	10.137	9.1960	8.4338	7.6928	7.0202
Brine	2.6682	0.9161	0.7909	0.7050	0.6188	0.5191	0.4778

(6.4.2)

RUN 6-2 COMM = 2.75 mg/L, Henry's Constant: H' = H/3.4

Stage	Dea.	1	2	3	4	5	6
Product W.	49.522	29.707	18.004	13.770	10.948	8.6956	7.5052
Brine	2.4719	0.0103	0.0048	0.0027	0.0014	0.0005	0.0003

4.3 Dispersion of bromoform by deaerator

The bromoform removal effect by deaerator has been tested in RUN 6-2. The test results are shown in Table 3 and the computer calculation results are as Fig. 2. Those results are summarized in following table. The states of #1 stage are listed in the table for reference.

Item	Unit	Deaerator			#1 Stage (Cal.)
		Cal.	Given Cond.	Measured	Measured
Make up water	kg/h		2,450.0		6,500
Amount evaporated	kg/h	13.3			(188.8)
Evaporation ratio	-	5.42×10^{-3}			(29×10^{-3})
Inlet Temp.	℃		37.3		112
Outlet Temp.	℃		34.3		(95.4)
Temp. Difference	℃		3.3		(16.6)
Inlet Conc.	mg/L		2.75		99.9 ~123.4
Outlet Conc.	mg/L	2.6682		0.097 ~0.123	10.1 ~13.8
Removal Ratio	%	2.9		96.3	(90)

Evaporation Ratio = (Amount Evaporated)/(Make up water)

The test result of the removal ratio is 96.3%, however, the calculated result is 2.9%, when assuming that the bromoform removal ratio is proportional to evaporation ratio. There in no doubt that the removal ratio will increase as the evaporation ratio increases, according to the study of #1 stage.

Consequently, those factors other than the evaporation ratio should be taken into account for the prediction of the bromoform removal ratio.

One of those factors which should be taken into consideration should be the condensation rate. Since the condensation rate of bromoform seems to be very stagnant, according to the

previous discussion, large portion of the bromoform should have been dispersed out through the ejector. The non–equilibrium flow of bromoform might be existing in the system, which would enhance the evaporation of bromoform from brine.

The quantitative investigation of the condensation kinetics and the dispersion rate out of the system should be necessary for the further analysis.

5. Conclusion

The behavior of bromoform, a kind of trihalomethane, in MSF plant has been calculated by the computer program and the results have been compared with the experiments. The conclusions obtained are as follows:

(1) The prediction of quantity of the product water by the computer program is in good accordance with the test results.

(2) In order to predict the behavior of bromoform in MSF plant, not only the vapor liquid equilibrium but also the kinetics of condensation should be taken into consideration.

(3) One of the possible countermeasure for the prevention of bromoform transferring to the product water would be the increase of the capability of the vent system, including the deaerator, by dispersing out bromoform as vapor.

6.4.3 Mixture of Crude Oil Components into Product Water

(6.4.3)

CONTENTS

1. Introduction 1

2. Test Plan 1
2.1 Test Condition 1
2.2 Test Procedure 1
2.2.1 Measurement 1
2.2.2 Sampling position for oil analysis 5
2.2.3 Instrument used for the oil analysis 5

3. Test Results 5
3.1 RUN 7 5
3.2 RUN 9 9

4. Discussion 13
4.1 Mass balance of oil 13
4.2 Mass balance of oil by computer calculation 14
4.2.1 RUN 7 (oil concentration 10mg/L) 14
4.2.2 RUN 9 (oil concentration 2.5mg/L) 29

5. Conclusion 36

List of Figures

Figures	Description	Page
Fig.1	Calculation Results by Computer(Run7)	16
Fig.2	Calculation Results for RUN 9 by Computer(RUN 7, POE:1.0)	17
Fig.3	Calculation Results for RUN 9 by Computer(RUN 7, POE:1/3)	20
Fig.4	Calculation Results for RUN 9 by Computer(RUN 7, POE:1/6)	23
Fig.5	Calculation Results for RUN 9 by Computer(RUN 7, POE:1/8)	26
Fig.6	Calculation Results for RUN 9 by Computer(RUN 9)	30

List of Tables

Table	Description	Page
Table 1	Test Conditions	3
Table 2	Components of Injecting Light Diesel Oil #2	4
Table 3	Results of Oil Carryover Test at RUN No.7	6
Table 4	Results of Oil Carryover Test at RUN No.9	10
Table 5	Summary of both Experimental & Calculated Results (COMM=10mg/L)	33
Table 6	Summary of both Experimental & Calculated Results (COMM=2.5mg/L)	33

1. Introduction

In the previous section, details of the computer program with flow chart and used formula have been introduced based on the evaporation mechanisms of the bromoform in brine discussed in 6.1 and 6.2, in order to analyze the behavior of the homogeneous organic contaminants in brine.

In this section, oil[1)] was added to the MSF test plant to analyze the behavior of oil, heterogeneous organic contaminants, in the plant. The computer analysis was compared with the experimental results.

2. Test Plan

The oil carryover tests with different oil concentration were conducted as RUN 7 and RUN 9 in the series of MSF Test Plant experiments shown in Table 1 of 5.3.3. In order to prevent the oil contamination of deaerator and heat transfer tubes, the operation mode has been changed from recirculation mode to once through mode and oil was charged at the outlet of brine heater.

2.1 Test Condition

The oil carryover tests conditions are shown in Table 1 together with that of bromoform carryover test. The amount of oil used is 10mg/L for RUN 7 and 2.5mg/L for RUN 9.

2.2 Test Procedure

2.2.1 Measurement

Those items measured in each RUN are as follows.

1) Flow rate : feed seawater(brine)
2) Seawater/Brine Temperature : brine heater outlet
3) Steam Temperature : each stage
4) TDS concentration : feed seawater(brine)

---

1) Light Diesel Oil #2, instead of crude oil, was used for the consistency to RO experiments.

5) **Electric Conductivity** : **each stage**
6) **Composition of Oil** : **(shown in Table 2)**

The sampling of brine for oil concentration analysis was started when the oil has been detected at blow brine since the oil distribution in the system should be taken into account.

Table 1 TEST CONDITIONS

RUN NO.		6-1	6-2	7	9
1. Operation Mode		Recir.	Recir.	Once	Once
2. Scale Control Method		Hybrid	Chemi.	Chemi.	Chemi.
3. Top Brine Temperature	℃	112	112	112	112
4. Flow Rate					
-Make up Seawater	m^3/h	2.45	2.30	6.40	6.40
-Recirculation Brine	m^3/h	6.50	6.50	6.40	6.40
-Product Water	m^3/h	0.81	0.86	0.90	0.90
5. Chemical Constituents of Brine					
-pH at 25C		8.04	8.52	8.24	8.24
-M-alkalinity as CaCO3	mg/L	55-60	180	128	128
-Chloride ion	mg/L	32,730	33,320	23,360	23,360
-Concentration Factor	mg/L	1.39	1.40	1.01	1.01
6. Dosing Rate of Chemicals					
-Scale Inhibitor(PPN(M))	mg/L	1	2	2	2
-Acid(98% H2SO4)	mg/L	72	None	None	None
-Trihalomethene(CHBr3)	mg/L	0.5	2.75	None	None
-Oil(Light Diesel Oil #2)	mg/L	None	None	10	2.5
7. Injection Point of Contaminants		After B.H	Before Dea.	After B.H	After B.H

Table 2 Components of Injecting Light Diesel Oil #2

Conponents (C No. s)	Ratio in Oil (%)	Concent. in Oil (kg/L)*	Concent. in 1L of Make up (kg/L)
C10	2.46	0.0199	0.246E-6
C11	4.18	0.0338	0.418E-6
C12	5.13	0.0415	0.513E-6
C13	6.46	0.0523	0.646E-6
C14	7.67	0.0621	0.767E-6
C15	9.2	0.0745	0.92 E-6
C16	9.76	0.0790	0.976E-6
C17	11.01	0.0892	1.101E-6
C18	11.18	0.0905	1.118E-6
C19	10.9	0.0883	1.09 E-6
C20	8.9	0.0721	0.89 E-6
C21	6.84	0.0554	0.684E-6
C22	4.42	0.0358	0.442E-6
C23	1.9	0.0153	0.19 E-6
C24	-		
C25	-		
C26	-		
C27	-		
C28	-		
C29	-		
C30	-		

* : Specific Gravity of injecting oil : 0.81 kg/L

2.2.2 Sampling position for oil analysis

Brine	Product Water
No.1 stage outlet	No.1 stage
No.2 stage outlet	No.2 stage
No.3 stage outlet	No.3 stage
No.4 stage outlet	No.4 stage
No.5 stage outlet	No.5 stage
No.6 stage outlet(Blow brine)	No.6 stage

2.2.3 Instrument used for the oil analysis

Type : GC-MS
Detecting limit : 1×10^{-3}mg/L

3. Test Results

3.1 RUN 7

The measurement of RUN 7, oil concentration of 10mg/L, has been conducted from 14 to 15 of November. The test conditions and the results are shown in Table 3.

The oil concentration in brine decreased to 1/2~1/3 of the initial value at stage #1, then gradually decreased at the following stages and end up with 1/10 at the final stage #6.

The decrease rate of oil is far less than that of bromoform which showed decrease to 1/250 at stage #1.

Table 3 Results of Oil Carryover Test at RUN No.7

1. Operation Type :Once through

2. Date of taking samples :Nov. 14th & 15th & 15th, 1994

3. Brine Exit Data
   - -Temperature : 112 C (TBLO)
   - -Flow Rate : 6,400 kg/h (FBLO)
   - -Electric Conductivity :60,200 μS/cm (SBLO)

4. Make up Data
   - -Temperature in Deaerator Inlet : ----- C (TBLD)
   - -Temperature in Deaerator Outlet : ----- C (TBLG)
   - -Flow Rate : 6,400 kg/h (FBLM)
   - -TDS Concentration : ----- kg/kg (CBSM)
   - -Oil Concentration after Brine H. : 10.00E-6 kg/kg (COMG)
   - -Kind of Injecting Oil :Light Diesel Oil #2

5. Steam Temperature(C) and Electric Conductivity(μS/cm)in Each Stage

Stage	Dea.	1	2	3	4	5	6
Steam Temp.	—	94.8	83.9	71.5	57.4	40.1	34.0
Electric C.	—	61,500	62,900	64,000	65,200	67,000	67,800

(NOTE) Ex:10^{x}

6. Oil Concentration in Each Stage of the Evaporator(Cont.)

Sampling date : 7am, Nov,15th, 1994

(23hrs after start of oil injection) (Unit:ppm)

Stage	C No.s	1	2	3	4	5	6
Product W.	C10	0.054	ND	ND	ND	ND	ND
	C11	0.051	0.052	0.03	ND	0.05	0.05
	C12	0.232	0.15	0.14	0.097	0.17	0.25
	C13	0.647	0.59	0.59	0.43	1.21	0.81
	C14	1.68	1.54	1.29	1.07	2.97	1.71
	C15	2.36	2.75	1.91	2.02	7.22	2.76
	C16	3.17	3.89	2.93	3.14	6.71	3.15
	C17	3.20	3.90	2.77	2.66	7.04	2.31
	C18	3.35	3.40	2.70	2.80	7.02	2.16
	C19	2.40	3.25	2.72	3.00	7.20	2.00
	C20	1.82	2.07	1.85	2.00	4.6	1.32
	C21	0.64	1.51	1.51	1.80	2.21	1.09
	C22	0.35	0.55	0.80	0.90	0.92	0.55
	C23	0.18	0.41	0.69	0.40	0.60	0.79
	C24	ND	0.72	0.32	0.13	0.60	0.096
	C25						
	C26						
	C27						
	C28						
	C29						
	C30						
Sum of Oil Concent.		20.0	24.7	20.3	20.4	43.4	18.4
Brine	C10	0.047	0.029	ND	0.013	0.006	0.009
	C11	0.086	0.064	ND	0.02	0.023	0.012
	C12	0.14	0.096	0.006	0.027	0.024	0.016
	C13	0.19	0.14	0.007	0.04	0.04	0.03
	C14	0.22	0.184	0.012	0.061	0.06	0.039
	C15	0.28	0.24	0.02	0.073	0.071	0.060
	C16	0.31	0.33	0.02	0.108	0.010	0.063
	C17	0.36	0.35	0.03	0.095	0.09	0.09
	C18	0.36	0.35	0.03	0.108	0.093	0.101
	C19	0.42	0.38	0.057	0.13	0.111	0.12
	C20	0.30	0.36	0.031	0.102	0.103	0.11
	C21	0.21	0.25	0.034	0.10	0.092	0.11
	C22	0.22	0.16	0.028	0.083	0.07	0.09
	C23	0.22	0.05	0.009	0.042	0.03	0.045
	C24	ND	0.02	ND	0.026	0.02	0.038
	C25						
	C26						
	C27						
	C28						
	C29						
	C30						
Sum of Oil Concent.		3.13	3.02	0.27	1.15	0.93	0.93

6. Oil Concentration in Each Stage of the Evaporator

Sampling date : 1pm, Nov,14th, 1994

(5hrs after start of oil injection) (Unit:ppm)

Stage	C No.s	1	2	3	4	5	6
Product W.	C10	ND	ND	ND	ND	ND	ND
	C11	0.07	0.05	ND	ND	ND	ND
	C12	0.101	0.09	0.073	0.08	0.033	0.39
	C13	0.21	0.32	0.27	0.20	0.17	0.54
	C14	0.48	0.75	0.58	0.66	0.4	0.65
	C15	0.68	1.30	0.78	0.95	0.66	0.72
	C16	1.0	1.93	0.81	1.0	0/72	0.73
	C17	1.35	2.60	1.05	1.1	0.97	0.88
	C18	1.47	2.62	1.03	1.01	0.98	0.79
	C19	1.36	1.93	1.16	1.2	1.0	0.74
	C20	1.22	1.87	0.80	0.85	0.74	0.52
	C21	0.84	1.57	0.72	0.55	0.70	0.37
	C22	0.35	0.62	0.32	0.41	0.36	0.14
	C23	0.12	0.30	0.18	0.2	0.21	0.09
	C24	0.07	0.14	0.11	0.12	ND	0.054
	C25						
	C26						
	C27						
	C28						
	C29						
	C30						
Sum of Oil Concent.		9.32	17.1	7.9	8.33	6.95	6.62
Brine	C10	0.16	ND	ND	ND	ND	ND
	C11	0.22	0.10	0.012	0.01	0.01	0.006
	C12	0.18	0.05	0.031	0.009	0.009	0.006
	C13	0.23	0.09	0.012	0.013	0.015	0.009
	C14	0.27	0.10	0.021	0.16	0.023	0.011
	C15	0.32	0.11	0.019	0.02	0.03	0.011
	C16	0.30	0.10	0.019	0.02	0.034	0.013
	C17	0.41	0.16	0.25	0.027	0.049	0.017
	C18	0.45	0.15	0.27	0.015	0.053	0.014
	C19	0.54	0.17	0.08	0.04	0.06	0.02
	C20	0.37	0.13	0.043	0.025	0.025	0.015
	C21	0.40	0.11	0.042	0.026	0.028	0.01
	C22	0.23	0.05	0.12	0.004	0.024	0.007
	C23	0.16	0.03	0.18	0.014	0.021	0.009
	C24	0.11	ND	0.04	ND	ND	ND
	C25						
	C26						
	C27						
	C28						
	C29						
	C30						
Sum of Oil Concent.		4.35	1.35	1.49	0.24	0.38	0.15

3.2 RUN 9

The measurement of RUN 9, oil concentration of 2.5mg/L, has been conducted from 6 to 7 of December. The test conditions and the results are shown in Table 4.

No oil was detected in brine for both sample but only in product water.

Table 4 Results of Oil Carryover Test at RUN No.9

1. Operation Type :Once through

2. Date of taking samples :Dec. 4th & 5th, 1994

3. Brine Exit Data

-Temperature	: 112	C	(TBLO)
-Flow Rate	: 6,400	kg/h	(FBLO)
-Electric Conductivity	:60,200	μ S/cm	(SBLO)

4. Make up Data

-Temperature in Deaerator Inlet	: -----	C	(TBLD)
-Temperature in Deaerator Outlet	: -----	C	(TBLG)
-Flow Rate	: 6,400	kg/h	(FBLM)
-TDS Concentration	: -----	kg/kg	(CBSM)
-Oil Concentration after Brine H.	: 10.00E-6	kg/kg	(COMG)
-Kind of Injecting Oil	:Light Diesel Oil #2		

5. Steam Temperature(C) and Electric Conductivity(μ S/cm)in Each Stage

Stage	Dea.	1	2	3	4	5	6
Steam Temp.	—	94.8	83.9	71.5	57.4	40.1	34.0
Electric C.	—	61,500	62,900	64,000	65,200	67,000	67,800

(NOTE) Ex:10^x

(6.4.3)

6. Oil Concentration in Each Stage of the Evaporator

Sampling date : 8:00 Dec. 7th, 1994 (Unit:ppm)

Stage	C No.s	1	2	3	4	5	6
Product W.	C10	ND	ND	ND	ND	ND	ND
	C11	ND	ND	ND	ND	0.003	ND
	C12	ND	ND	0.009	0.006	0.007	ND
	C13	ND	ND	0.004	0.041	0.021	ND
	C14	ND	ND	0.181	0.17	0.053	ND
	C15	ND	ND	0.34	0.64	0.023	0.002
	C16	ND	0.004	0.59	0.53	0.122	0.005
	C17	0.003	0.006	0.49	0.32	0.05	0.005
	C18	0.003	0.007	0.21	0.23	0.07	0.008
	C19	0.005	0.006	0.10	0.101	0.05	0.09
	C20	0.006	0.009	0.08	0.074	0.017	0.007
	C21	0.003	0.003	0.04	0.054	0.007	ND
	C22	ND	ND	0.04	0.04	0.003	ND
	C23	ND	ND	0.09	0.007	ND	ND
	C24						
	C25						
	C26						
	C27						
	C28						
	C29						
	C30						
Sum of Oil Concent.		0.021	0.035	2.17	2.21	0.42	0.036
Brine	C10	ND	ND	ND	ND	ND	ND
	C11	ND	ND	ND	ND	ND	ND
	C12	ND	ND	ND	ND	ND	ND
	C13	ND	ND	ND	ND	ND	ND
	C14	ND	ND	ND	ND	ND	ND
	C15	ND	ND	ND	ND	ND	ND
	C16	ND	ND	ND	ND	ND	ND
	C17	ND	ND	ND	ND	ND	ND
	C18	ND	ND	ND	ND	ND	ND
	C19	ND	ND	ND	ND	ND	ND
	C20	ND	ND	ND	ND	ND	ND
	C21	ND	ND	ND	ND	ND	ND
	C22	ND	ND	ND	ND	ND	ND
	C23	ND	ND	ND	ND	ND	ND
	C24	ND	ND	ND	ND	ND	ND
	C25						
	C26						
	C27						
	C28						
	C29						
	C30						
Sum of Oil Concent.		ND	ND	ND	ND	ND	ND

6. Oil Concentration in Each Stage of the Evaporator (Cont.)

Sampling date : 13:00, Dec, 7th, 1994 (Unit:ppm)

Stage	C No.s	1	2	3	4	5	6
Product W.	C10	ND	ND	ND	ND	ND	ND
	C11	ND	ND	ND	ND	ND	ND
	C12	ND	ND	ND	ND	ND	ND
	C13	0.009	ND	0.007	0.021	0.007	0.003
	C14	0.008	ND	0.015	0.08	0.013	0.005
	C15	0.012	ND	0.028	0.24	0.018	0.006
	C16	0.018	ND	0.04	0.24	0.013	0.008
	C17	0.023	0.01	0.04	0.22	0.021	0.008
	C18	0.029	0.013	0.041	0.17	0.019	0.007
	C19	0.029	0.011	0.030	0.055	0.012	0.004
	C20	0.022	0.012	0.033	0.019	0.009	0.002
	C21	0.016	0.006	0.007	0.023	ND	ND
	C22	0.012	0.004	0.010	0.017	ND	ND
	C23	ND	ND	ND	0.015	ND	ND
	C24	ND	ND	ND	ND	ND	ND
	C25						
	C26						
	C27						
	C28						
	C29						
	C30						
Sum of Oil Concent.		0.17	0/064	0.26	1.11	0.122	0.043
Brine	C10	ND	ND	ND	ND	ND	ND
	C11	ND	ND	ND	ND	ND	ND
	C12	ND	ND	ND	ND	ND	ND
	C13	ND	ND	ND	ND	ND	ND
	C14	ND	ND	ND	ND	ND	ND
	C15	ND	ND	ND	ND	ND	ND
	C16	ND	ND	ND	ND	ND	ND
	C17	ND	ND	ND	ND	ND	ND
	C18	ND	ND	ND	ND	ND	ND
	C19	ND	ND	ND	ND	ND	ND
	C20	ND	ND	ND	ND	ND	ND
	C21	ND	ND	ND	ND	ND	ND
	C22	ND	ND	ND	ND	ND	ND
	C23	ND	ND	ND	ND	ND	ND
	C24	ND	ND	ND	ND	ND	ND
	C25						
	C26						
	C27						
	C28						
	C29						
	C30						
Sum of Oil Concent.		ND	ND	ND	ND	ND	ND

4. Discussion

4.1 Mass balance of oil

The mass balance of RUN 7 and RUN 9 has been analyzed from those carryover test results. The flow rates of feed seawater, product water and brine are as follows.

- Feed seawater(brine) : 6,400kg/h
- Product water : 900kg/h
- Blow brine : 6,400 – 900 = 5,500kg/h

The initial oil concentration of RUN 7 and RUN 9 are 10mg/L and 2.5mg/L, respectively. The amount of oil discharged out from the system has been calculated from the second sampling results. They are as follows.

RUN No.	Dosing Conc.	Product Water	#1 Stage	Blow Down Brine
7	10 mg/L	18.4 mg/L	3.13mg/L	0.93mg/L
9	2.5mg/L	0.043mg/L	Not Detected	Not Detected

RUN 7

• Oil feed rate	: 6400kg/h x 10mg/L x 0.97L/kg	= 62080 mg/h
• Outlet as blow brine	: 5500kg/h x 0.93mg/L x 0.97L/kg	= 4961 mg/h
• Outlet as product water	: 900kh/h x 18.4mg/L x 0.97L/kg	= 16063 mg/h
• Ejection out of system	: 62080 – (4961 + 16063)	= 41056 mg/h
• Ejection ratio	: (41056/62080) x 100	= 66.13 %

RUN 9

• Oil feed rate	: 6400kg/h x 2.5mg/L x 0.97L/kg	= 15520 mg/h
• Outlet as blow brine	: Not Detected	
• Outlet as product water	: 900kg/h x 0.043mg/L x 0.97L/kg	= 37 mg/h
• Ejection out of system	: 15520 – (37 + 0)	= 15483 mg/h
• Ejection rate	: (15483/15520) x 100	= 99.7 %

In case of RUN 7 with 10mg/L oil concentration, about 66% of total oil has discharged from

the system through ejector.
On the other hand, in RUN 9 with oil concentration of 2.5mg/L, about 99% of total oil has discharged from the system through ejector.

4.2 Mass balance of oil by computer calculation

The results of computer calculation based on the test condition described in 4.1 are shown in Fig.1 and Fig.2. The summary of the results are listed in Table 5 and 6 with comparison to the test results.

4.2.1 RUN 7 (oil concentration 10mg/L)

The mass balance of RUN 7 according to Fig.1 is as follows.

• Total oil addition	: 6400kg/h x 10mg/L x 0.97L/kg	= 62080 mg/h
• Outlet as blow brine	: 5500kg/h x 0.0mg/L x 0.97L/kg	= 0.0 mg/h
• Outlet as product water	: 806kg/h x 80.64mg/L x 1.00	= 64995 mg/h
• Calculation error	: 62080 – (64995 + 0.0)	= –2915 mg/h

As is seen in Table 5, there are significant difference between calculated value and test results. The discrepancy in product water is due to the difference in condensation rate of oil and water as discussed in 6.4.2.

As for brine, the calculated value of oil concentration at stage #1 is 0.8042mg/L while that of measured value is 3.13mg/L. In other words, oil evaporates less than calculation. Thus, the partial pressure of oil has been lowered to 1/3, 1/6 and 1/8 of the value calculated by Antoine's formula and calculated again to compare with the test results.

The calculated results are shown in the following Table. The calculated value will be in good agreement with the test results of stage #1 when the partial pressure of oil has been decreased to 1/8. On the other hand, oil concentration of blow brine will be in good agreement when the partial pressure is lowered to 1/3.

The calculated value can be adjusted to the test results by changing the partial pressure of the hydrocarbons. Thus, the improvement of Antoine's formula should be considered.

(6.4.3)

Item	Total Oil Concentration			Dose Conc.
	Product Water	#1 Stage	Blow Down Brine	
Cal.(POE:1/3)	76.86 mg/L	1.76 mg/L	0.56 mg/L	10 mg/L
Cal.(POE:1/6)	70.56 mg/L	2.6 mg/L	1.4 mg/L	10 mg/L
Cal.(POE:1/8)	67.47 mg/L	3.06 mg/L	1.86 mg/L	10 mg/L

INPUT DATA

COMPUTER PROGRAMMING FOR CARRYOVER 1994 VERSION

RUN NO: 7 HFACTOR: 1

DATE: 14/11/94

OPERATOR: AHMAD

MAX BRINE TEMP: 112

CONTAMINANT TYPE: 1

CALCULATION TYPE: 1

DEAERATOR: 1

HEAT & MASS BALANCE INPUT DATA

FBL(0): 6400	TWE(1): 94.1	TWE(4): 57.4
TBL(0): 112	TWE(2): 83.9	TWE(5): 40.1
SBL(0): 60200D-6	TWE(3): 71.5	TWE(6): 34.0

SBL(1): 61500D-6	SBL(4): 65200D-6
SBL(2): 62900D-6	SBL(5): 67000D-6
SBL(3): 64000D-6	SBL(6): 67800D-6

HOMOGENEOUS/RECIRCULATION INPUT DATA

COMM: 10.0D-6

COMP(1): 0	COMP(11): 4.18D-2	COMP(21): 6.84D-2
COMP(2): 0	COMP(12): 5.13D-2	COMP(22): 4.42D-2
COMP(3): 0	COMP(13): 6.46D-2	COMP(23): 1.90D-2
COMP(4): 0	COMP(14): 7.67D-2	COMP(24): 0
COMP(5): 0	COMP(15): 9.20D-2	COMP(25): 0
COMP(6): 0	COMP(16): 9.76D-2	COMP(26): 0
COMP(7): 0	COMP(17): 11.01D-2	COMP(27): 0
COMP(8): 0	COMP(18): 11.18D-2	COMP(28): 0
COMP(9): 0	COMP(19): 10.9D-2	COMP(29): 0
COMP(10): 2.46D-2	COMP(20): 8.90D-2	COMP(30): 0

COM(0,1): 0	COM(0,11): 0	COM(0,21): 0
COM(0,2): 0	COM(0,12): 0	COM(0,22): 0
COM(0,3): 0	COM(0,13): 0	COM(0,23): 0
COM(0,4): 0	COM(0,14): 0	COM(0,24): 0
COM(0,5): 0	COM(0,15): 0	COM(0,25): 0
COM(0,6): 0	COM(0,16): 0	COM(0,26): 0
COM(0,7): 0	COM(0,17): 0	COM(0,27): 0
COM(0,8): 0	COM(0,18): 0	COM(0,28): 0
COM(0,9): 0	COM(0,19): 0	COM(0,29): 0
COM(0,10): 0	COM(0,20): 0	COM(0,30): 0

Fig. 1 Calculation Results by Computer(RUN 7)

OUTPUT-1

RUN NO: 7 DATE: 14/11/94 OPERATOR: AHMAD MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	9.4800E+01	8.3900E+01	7.1500E+01	5.7400E+01	4.0100E+01	3.4000E+01
SBL	6.1500E-02	6.2900E-02	6.4000E-02	6.5200E-02	6.7000E-02	6.7800E-02

8.0667E+02
FWLT

RESULTS

	1	2	3	4	5	6
FWL	1.9548E+02	1.1815E+02	1.2958E+02	1.3452E+02	1.6603E+02	6.2908E+01
PWE	8.3886E+04	5.5341E+04	3.3253E+04	1.7653E+04	7.3873E+03	5.3347E+03
TWE	9.4800E+01	8.3900E+01	7.1500E+01	5.7400E+01	4.0100E+01	3.4000E+01
TBL	9.4800E+01	8.3900E+01	7.1500E+01	5.8100E+01	4.0800E+01	3.4000E+01
CBS	4.0530E-02	4.1941E-02	4.3057E-02	4.4248E-02	4.5932E-02	4.6651E-02
FBL	6.2045E+03	6.0864E+03	5.9568E+03	5.8223E+03	5.6562E+03	5.5933E+03

FBL0
TBL 1.1200E+02
CBS 3.9193E-02(SBL=6.0200E-02)
FBL 6.4000E+03

Fig. 2 Calculation Results for RUN 9 by Computer(RUN 7, POE:1.0)

(6.4.3)

OUTPUT-2

CARRYOVER CALCULATION RESULTS(ONCE THROUGH)

C#	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)	FOMT
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	7.9301E-06	4.9783E-06	3.5488E-06	2.7417E-06	2.1459E-06	1.9836E-06	1.6114E-03
11	1.3475E-05	8.4590E-06	6.0301E-06	4.6586E-06	3.6463E-06	3.3706E-06	2.7381E-03
12	1.6537E-05	1.0382E-05	7.4006E-06	5.7173E-06	4.4750E-06	4.1366E-06	3.3604E-03
13	2.0825E-05	1.3073E-05	9.3192E-06	7.1996E-06	5.6352E-06	5.2090E-06	4.2316E-03
14	2.4725E-05	1.5522E-05	1.1065E-05	8.5482E-06	6.6907E-06	6.1847E-06	5.0242E-03
15	2.9657E-05	1.8618E-05	1.3272E-05	1.0253E-05	8.0253E-06	7.4184E-06	6.0264E-03
16	3.1462E-05	1.9751E-05	1.4080E-05	1.0877E-05	8.5138E-06	7.8700E-06	6.3933E-03
17	3.5492E-05	2.2281E-05	1.5883E-05	1.2271E-05	9.6042E-06	8.8779E-06	7.2121E-03
18	3.6040E-05	2.2625E-05	1.6128E-05	1.2460E-05	9.7525E-06	9.0150E-06	7.3234E-03
19	3.5137E-05	2.2058E-05	1.5724E-05	1.2148E-05	9.5083E-06	8.7892E-06	7.1400E-03
20	2.8690E-05	1.8011E-05	1.2839E-05	9.9190E-06	7.7636E-06	7.1765E-06	5.8299E-03
21	1.2871E-05	1.3842E-05	9.8674E-06	7.6231E-06	5.9667E-06	5.5154E-06	4.4805E-03
22	3.8850E-06	8.9447E-06	6.3763E-06	4.9261E-06	3.8557E-06	3.5641E-06	2.8953E-03
23	8.5319E-07	2.7666E-06	2.7410E-06	2.1175E-06	1.6574E-06	1.5321E-06	1.2446E-03
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

(6.4.3)

OUTPUT-3

C#	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
12	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
13	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
16	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
18	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
19	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
20	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
21	2.9762E-07	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
22	3.3604E-07	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
23	1.7094E-07	5.7228E-08	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

OUTPUT-1

RUN NO: 7 DATE: 14/11/94 OPERATOR: AHMAD MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	9.4800E+01	8.3900E+01	7.1500E+01	5.7400E+01	4.0100E+01	3.4000E+01
SBL	6.1500E-02	6.2900E-02	6.4000E-02	6.5200E-02	6.7000E-02	6.7800E-02

8.0667E+02

FWLT

RESULTS

	1	2	3	4	5	6
FWL	1.9548E+02	1.1815E+02	1.2958E+02	1.3452E+02	1.6603E+02	6.2908E+01
PWE	8.3886E+04	5.5341E+04	3.3253E+04	1.7653E+04	7.3873E+03	5.3347E+03
TWE	9.4800E+01	8.3900E+01	7.1500E+01	5.7400E+01	4.0100E+01	3.4000E+01
TBL	9.4800E+01	8.3900E+01	7.1500E+01	5.8100E+01	4.0800E+01	3.4000E+01
CBS	4.0630E-02	4.1941E-02	4.3057E-02	4.4248E-02	4.5932E-02	4.6651E-02
FBL	6.2045E+03	6.0864E+03	5.9568E+03	5.8223E+03	5.6562E+03	5.5933E+03

FBLO

TBL 1.1200E+02

CBS 3.9193E-02(SBL=6.0200E-02)

FBL 6.4000E+03

Fig. 3 Calculation Results for RUN 9 by Computer (RUN 7, POE:1/3)

(6.4.3)

OUTPUT-2

CARRYOVER CALCULATION RESULTS(ONCE THROUGH)

C#	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)	FOMT
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	7.9301E-06	4.9783E-06	3.5488E-06	2.7417E-06	2.1459E-06	1.9836E-06	1.6114E-03
11	1.3475E-05	8.4590E-06	6.0301E-06	4.6586E-06	3.6463E-06	3.3706E-06	2.7381E-03
12	1.6537E-05	1.0382E-05	7.4006E-06	5.7173E-06	4.4750E-06	4.1366E-06	3.3604E-03
13	2.0825E-05	1.3073E-05	9.3192E-06	7.1996E-06	5.6352E-06	5.2090E-06	4.2316E-03
14	2.4725E-05	1.5522E-05	1.1065E-05	8.5482E-06	6.6907E-06	6.1847E-06	5.0242E-03
15	2.9657E-05	1.8618E-05	1.3272E-05	1.0253E-05	8.0253E-06	7.4184E-06	6.0264E-03
16	3.1462E-05	1.9751E-05	1.4080E-05	1.0877E-05	8.5138E-06	7.8700E-06	6.3933E-03
17	3.5492E-05	2.2281E-05	1.5883E-05	1.2271E-05	9.6042E-06	8.8779E-06	7.2121E-03
18	3.6040E-05	2.2625E-05	1.6128E-05	1.2460E-05	9.7525E-06	9.0150E-06	7.3234E-03
19	3.4258E-05	2.2058E-05	1.5724E-05	1.2148E-05	9.5083E-06	8.7892E-06	7.1400E-03
20	1.1995E-05	1.8011E-05	1.2839E-05	9.9190E-06	7.7636E-06	7.1765E-06	5.8299E-03
21	4.2903E-06	7.9719E-06	7.7604E-06	6.4115E-06	5.0811E-06	4.7061E-06	3.8230E-03
22	1.2950E-06	2.4935E-06	2.6881E-06	2.3351E-06	1.8670E-06	1.7313E-06	1.4065E-03
23	2.8440E-07	5.4332E-07	5.9463E-07	5.1973E-07	4.1500E-07	3.8469E-07	3.1251E-04
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

(6.4.3)

OUTPUT-3

C#	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
12	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
13	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
16	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
18	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
19	2.8515E-08	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
20	5.4134E-07	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
21	5.7585E-07	3.1152E-07	1.6153E-07	1.2395E-07	1.2016E-07	1.2050E-07
22	4.2002E-07	3.4236E-07	2.8275E-07	2.6505E-07	2.6984E-07	2.7286E-07
23	1.8938E-07	1.7522E-07	1.6455E-07	1.6346E-07	1.6858E-07	1.7082E-07
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

(6.4.3)

OUTPUT-1

RUN NO: 7 DATE: 14/11/94 OPERATOR: AHMAD MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	9.4800E+01	8.3900E+01	7.1500E+01	5.7400E+01	4.0100E+01	3.4000E+01
SBL	6.1500E-02	6.2900E-02	6.4000E-02	6.5200E-02	6.7000E-02	6.7800E-02

8.0667E+02
FWLT

RESULTS

	1	2	3	4	5	6
FWL	1.9548E+02	1.1815E+02	1.2958E+02	1.3452E+02	1.6603E+02	6.2908E+01
PWE	8.3886E+04	5.5341E+04	3.3253E+04	1.7653E+04	7.3873E+03	5.3347E+03
TWE	9.4800E+01	8.3900E+01	7.1500E+01	5.7400E+01	4.0100E+01	3.4000E+01
TBL	9.4800E+01	8.3900E+01	7.1500E+01	5.8100E+01	4.0800E+01	3.4000E+01
CBS	4.0630E-02	4.1941E-02	4.3057E-02	4.4248E-02	4.5932E-02	4.6651E-02
FBL	6.2045E+03	6.0864E+03	5.9568E+03	5.8223E+03	5.6562E+03	5.5933E+03

FBLO
TBL 1.1200E+02
CBS 3.9193E-02(SBL=6.0200E-02)
FBL 6.4000E+03

Fig. 4 Calculation Results for RUN 9 by Computer (RUN7, POE:1/6)

(6.4.3)

OUTPUT-2

CARRYOVER CALCULATION RESULTS(ONCE THROUGH)

C#	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)	FOMT
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	7.9301E-06	4.9783E-06	3.5488E-06	2.7417E-06	2.1459E-06	1.9836E-06	1.6114E-03
11	1.3475E-05	8.4590E-06	6.0301E-06	4.6586E-06	3.6463E-06	3.3706E-06	2.7381E-03
12	1.6537E-05	1.0382E-05	7.4006E-06	5.7173E-06	4.4750E-06	4.1366E-06	3.3604E-03
13	2.0825E-05	1.3073E-05	9.3192E-06	7.1996E-06	5.6352E-06	5.2090E-06	4.2316E-03
14	2.4725E-05	1.5522E-05	1.1065E-05	8.5482E-06	6.6907E-06	6.1847E-06	5.0242E-03
15	2.9657E-05	1.8618E-05	1.3272E-05	1.0253E-05	8.0253E-06	7.4184E-06	6.0264E-03
16	3.1462E-05	1.9751E-05	1.4080E-05	1.0877E-05	8.5138E-06	7.8700E-06	6.3933E-03
17	3.5492E-05	2.2281E-05	1.5883E-05	1.2271E-05	9.6042E-06	8.8779E-06	7.2121E-03
18	3.6040E-05	2.2625E-05	1.6128E-05	1.2460E-05	9.7525E-06	9.0150E-06	7.3234E-03
19	1.7129E-05	2.0848E-05	1.5543E-05	1.2069E-05	9.4559E-06	8.7423E-06	7.1019E-03
20	5.9977E-06	8.8448E-06	8.1815E-06	6.8255E-06	5.4407E-06	5.0452E-06	4.0985E-03
21	2.1452E-06	3.2916E-06	3.2128E-06	2.7415E-06	2.1925E-06	2.0339E-06	1.6522E-03
22	6.4750E-07	9.8656E-07	9.6391E-07	8.1951E-07	6.5295E-07	6.0519E-07	4.9163E-04
23	1.4220E-07	2.1211E-07	2.0413E-07	1.7178E-07	1.3630E-07	1.2623E-07	1.0255E-04
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

(6.4.3)

OUTPUT-3

C=	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
12	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
13	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
16	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
18	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
19	5.8393E-07	6.4231E-08	1.3887E-08	8.0809E-09	7.1028E-09	6.9832E-09
20	7.3582E-07	4.8643E-07	3.5708E-07	3.1647E-07	3.1520E-07	3.1732E-07
21	6.4541E-07	5.5990E-07	5.1018E-07	4.9940E-07	5.1211E-07	5.1834E-07
22	4.4102E-07	4.2233E-07	4.1494E-07	4.2010E-07	4.3457E-07	4.4052E-07
23	1.9399E-07	1.9279E-07	1.9448E-07	1.9905E-07	2.0640E-07	2.0930E-07
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

OUTPUT-1

RUN NO: 7   DATE: 14/11/94   OPERATOR: AHMAD   MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	9.4800E+01	8.3900E+01	7.1500E+01	5.7400E+01	4.0100E+01	3.4000E+01
SBL	6.1500E-02	6.2900E-02	6.4000E-02	6.5200E-02	6.7000E-02	6.7800E-02

8.0667E+02

FWLT

RESULTS

	1	2	3	4	5	6
FWL	1.9548E+02	1.1815E+02	1.2958E+02	1.3452E+02	1.6603E+02	6.2908E+01
PWE	8.3886E+04	5.5341E+04	3.3253E+04	1.7653E+04	7.3873E+03	5.3347E+03
TWE	9.4800E+01	8.3900E+01	7.1500E+01	5.7400E+01	4.0100E+01	3.4000E+01
TBL	9.4800E+01	8.3900E+01	7.1500E+01	5.8100E+01	4.0800E+01	3.4000E+01
CBS	4.0630E-02	4.1941E-02	4.3057E-02	4.4248E-02	4.5932E-02	4.6651E-02
FBL	6.2045E+03	6.0864E+03	5.9568E+03	5.8223E+03	5.6562E+03	5.5933E+03

FBL0

TBL 1.1200E+02

CBS 3.9193E-02(SBL=6.0200E-02)

FBL 6.4000E+03

Fig. 5 Calculation Results for RUN 9 by Computer (RUN 7, POE:1/8)

(6.4.3)

OUTPUT-2

CARRYOVER CALCULATION RESULTS(ONCE THROUGH)

C#	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)	FOMT
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	7.9301E-06	4.9783E-06	3.5488E-06	2.7417E-06	2.1459E-06	1.9836E-06	1.6114E-03
11	1.3475E-05	8.4590E-06	6.0301E-06	4.6586E-06	3.6463E-06	3.3706E-06	2.7381E-03
12	1.6537E-05	1.0382E-05	7.4006E-06	5.7173E-06	4.4750E-06	4.1366E-06	3.3604E-03
13	2.0825E-05	1.3073E-05	9.3192E-06	7.1996E-06	5.6352E-06	5.2090E-06	4.2316E-03
14	2.4725E-05	1.5522E-05	1.1065E-05	8.5482E-06	6.6907E-06	6.1847E-06	5.0242E-03
15	2.9657E-05	1.8618E-05	1.3272E-05	1.0253E-05	8.0253E-06	7.4184E-06	6.0264E-03
16	3.1462E-05	1.9751E-05	1.4080E-05	1.0877E-05	8.5138E-06	7.8700E-06	6.3933E-03
17	3.5492E-05	2.2281E-05	1.5883E-05	1.2271E-05	9.6042E-06	8.8779E-06	7.2121E-03
18	2.8486E-05	2.2625E-05	1.6128E-05	1.2460E-05	9.7525E-06	9.0150E-06	7.3234E-03
19	1.2847E-05	1.5921E-05	1.3351E-05	1.0765E-05	8.5194E-06	7.8909E-06	6.4102E-03
20	4.4982E-06	6.2286E-06	5.8368E-06	4.9378E-06	3.9539E-06	3.6696E-06	2.9810E-03
21	1.6089E-06	2.2658E-06	2.1656E-06	1.8426E-06	1.4734E-06	1.3667E-06	1.1103E-03
22	4.8563E-07	6.7391E-07	6.3725E-07	5.3713E-07	4.2733E-07	3.9599E-07	3.2169E-04
23	1.0665E-07	1.4464E-07	1.3433E-07	1.1194E-07	8.8690E-03	8.2122E-08	6.6713E-05
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

(6.4.3)

OUTPUT-3

C#	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
12	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
13	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
16	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
18	2.4493E-07	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
19	7.2279E-07	3.2570E-07	1.8197E-07	1.4145E-07	1.3418E-07	1.3375E-07
20	7.8444E-07	6.2527E-07	5.3684E-07	5.0957E-07	5.1693E-07	5.2212E-07
21	6.6280E-07	6.1433E-07	5.9046E-07	5.9135E-07	6.0969E-07	6.1767E-07
22	4.4627E-07	4.3892E-07	4.3998E-07	4.4899E-07	4.6518E-07	4.7167E-07
23	1.9514E-07	1.9637E-07	1.9984E-07	2.0517E-07	2.1286E-07	2.1587E-07
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

4.2.2 RUN 9 (oil concentration 2.5mg/L)

RUN 9 was planned to survey the effect of initial oil concentration by comparing the results to that of RUN 7. Under the condition of RUN 9, which oil concentration is 1/4 of RUN 7, most of the oil in brine will carryover and propelled out of the system through ejector and only little goes to product water.(4.1) Calculated results are shown in Fig. 2, and the comparison to the test results are shown in Table 6.

In case of heterogeneous state like oil, the amount of carryover do not depend on the concentration but depends on the total amount of water evaporated, according to the water distillation theory.

Consequently, in case of 2.5mg/L oil concentration, it is no wonder that all the oil will evaporate at stage #1 and no oil in brine will be detected in the following stages. However, if we assume that the partial pressure of hydrocarbon is 1/8 of Antoine's formula, according to 4.2.1, oil should remain in brine.

Anyhow, the elaborated experiments for accurate measurement and enough data for analysis as well as the improvement of Antoine's formula is required for further investigation.

(6.4.3)

OUTPUT-1

RUN NO: 9 DATE: 12/4/94 OPERATOR: AHMAD MAX BRINE TEMP: 112

HEAT/MASS BALANCE

GIVEN CONDITIONS

	1	2	3	4	5	6
TWE	8.8400E+01	7.7500E+01	6.3100E+01	4.8100E+01	3.1000E+01	2.6200E+01
SBL	6.2700E-02	6.3700E-02	6.5300E-02	6.6800E-02	6.8800E-02	6.9100E-02

8.2475E+02

FWLT

RESULTS

	1	2	3	4	5	6
FWL	2.3057E+02	1.0201E+02	1.5403E+02	1.3844E+02	1.7474E+02	2.4956E+01
PWE	6.5934E+04	4.2764E+04	2.2978E+04	1.1200E+04	4.5602E+03	3.6181E+03
TWE	8.8400E+01	7.7500E+01	6.3100E+01	4.8100E+01	3.1000E+01	2.6200E+01
TBL	9.1200E+01	8.1500E+01	6.6300E+01	5.2000E+01	3.3100E+01	3.0300E+01
CBS	4.1599E-02	4.2587E-02	4.4138E-02	4.5565E-02	4.7418E-02	4.7690E-02
FBL	6.0694E+03	5.9674E+03	5.8134E+03	5.6750E+03	5.5002E+03	5.4753E+03

FBLO

TBL 1.1200E+02

CBS 3.9835E-02(SBL=6.1100E-02)

FBL 6.3000E+03

Fig. 6 Calculation Results for RUN 9 by Computer (RUN 9)

OUTPUT-2

CARRYOVER CALCULATION RESULTS(ONCE THROUGH)

C#	COE(1)	COE(2)	COE(3)	COE(4)	COE(5)	COE(6)	FOMT
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	1.6578E-06	1.1565E-06	7.9735E-07	6.2514E-07	4.9229E-07	4.7786E-07	3.9585E-04
11	2.8169E-06	1.9651E-06	1.3548E-06	1.0622E-06	8.3650E-07	8.1197E-07	6.7262E-04
12	3.4571E-06	2.4117E-06	1.6628E-06	1.3036E-06	1.0266E-06	9.9651E-07	8.2549E-04
13	4.3534E-06	3.0370E-06	2.0939E-06	1.6416E-06	1.2928E-06	1.2549E-06	1.0395E-03
14	5.1688E-06	3.6059E-06	2.4861E-06	1.9491E-06	1.5349E-06	1.4899E-06	1.2342E-03
15	6.1999E-06	4.3251E-06	2.9820E-06	2.3379E-06	1.8411E-06	1.7871E-06	1.4804E-03
16	6.5773E-06	4.5884E-06	3.1635E-06	2.4802E-06	1.9532E-06	1.8959E-06	1.5705E-03
17	7.4197E-06	5.1761E-06	3.5686E-06	2.7979E-06	2.2033E-06	2.1387E-06	1.7717E-03
18	7.5342E-06	5.2560E-06	3.6237E-06	2.8411E-06	2.2373E-06	2.1717E-06	1.7990E-03
19	7.3456E-06	5.1244E-06	3.5330E-06	2.7699E-06	2.1813E-06	2.1174E-06	1.7540E-03
20	4.1532E-06	4.1841E-06	2.8847E-06	2.2617E-06	1.7811E-06	1.7288E-06	1.4321E-03
21	1.4558E-06	2.8231E-06	2.2170E-06	1.7382E-06	1.3688E-06	1.3287E-06	1.1006E-03
22	4.3013E-07	9.2733E-07	9.8761E-07	8.4340E-07	6.7018E-07	6.5113E-07	5.3938E-04
23	9.2714E-08	2.0342E-07	2.2970E-07	2.0288E-07	1.6162E-07	1.5706E-07	1.3011E-04
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

(6.4.3)

OUTPUT-3

C#	COM(1)	COM(2)	COM(3)	COM(4)	COM(5)	COM(6)
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
12	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
13	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
16	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
18	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
19	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
20	7.2160E-08	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
21	1.2338E-07	2.2538E-08	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
22	9.9702E-08	6.6068E-08	3.8407E-08	3.1798E-08	3.2192E-08	3.2283E-08
23	4.6465E-08	3.9609E-08	3.3325E-08	3.1814E-08	3.2832E-08	3.2991E-08
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

Table 5 Summary of Experimental & Calculated Results(COMM=10mg/L)

Eva. Position	Dea.	1	2	3	4	5	6
Product W.	—	20.0	24.7	20.3	20.4	43.4	18.4
Brine	—	3.13	3.02	0.27	1.15	0.83	0.93

＜Calculated Results＞ (mg/L)

Eva. Position	Dea.	1	2	3	4	5	6
Product W.	—	302.54	187.80	144.27	123.37	87.24	75.64
Brine	—	0.8042	0.0572	0.0	0.0	0.0	0.0

Table 6 Summary of Experimental & calculated Results (COMM=2.5mg/L)

＜Experimental Results＞ (mg/L)

Eva. Position	Dea.	1	2	3	4	5	6
Product W.	—	0.17	0.054	0.26	1.111	0.122	0.043
Brine	—	ND	ND	ND	ND	ND	ND

＜Calculated Results＞ (mg/L)

Eva. Positio	Dea.	1	2	3	4	5	6
Product W.	—	65.93	40.98	32.48	25.34	19.95	19.37
Brine	—	0.0	0.0	0.0	0.0	0.0	0.0

5. Conclusion

One of the serious seawater contaminants which can happen in Arabian Gulf is oil. For the purpose of understanding the behavior of oil when oil contaminated seawater has been fed into MSF plant, computer prediction and the experiments by MSF test plant has been conducted. Those results are as follows.

(1) The behavior of water in MSF plant can be well predicted by computer program, however, the behavior of oil as well as bromoform cannot be predicted without knowing the condensation rate which is slower than water.
(2) The vapor pressure of each hydrocarbon in oil needs to be evaluated.
(3) The sampling of low oil concentration brine needs special care.
(4) The countermeasure for oil contamination cannot be made without solving the above mentioned problems, and it will differ according to the composition and the total concentration of oil.
(5) The computer simulation will be powerful tool to predict the behavior of various composition and various concentration of oil. The method constructed in this study should be able to apply to other contaminants.

6.5 Transfer of Technology

CONTENTS

1. Objective 1

2. Procedure of Technology Transfer 1

3. Results 1

List of Tables

Table	Description	Page
Table 1	Transfer of Technology for MSF-2	3

1. Objective

The technology transfer is aimed especially for the young researchers in SWCC for their improved understandings on the carryover behavior of oil contaminants in seawater fed into MSF plant by conducting cooperative research work between JICA and SWCC.

2. Procedure of technology transfer

The oil contamination of seawater is becoming crucial problem for the Gulf countries. The quantitative analysis of carryover behavior of oil contaminants to product water when contaminated seawater had been fed into MSF plant was conducted. The basic experiments of laboratory scale and bench scale test by MSF test plant had been conducted as cooperative research work. The results would be prepared to a full paper by applying the chemical engineering technology approach for the potential upgrading of the research capability of young researchers.

Subjects for the cooperative research work.

1) Evaluation technology of MSF plant oil contamination
   (Preparative work)
2) Evaluation technology by Vapor/Liquid equilibrium apparatus
   (Simulation)
3) Evaluation technology by simulation and prediction
   (Computer simulation)
4) Evaluation technology of contaminants carryover by MSF test plant
   (Confirmation)

3. Results

1) Evaluation technology of MSF plant oil contamination (Preparative work)
   The sophisticated data analysis procedure and water analysis method had been established for the evaluation of the oil contaminants in MSF plant.
   The results was prepared to a full paper for publication.
2) Evaluation technology by Vapor/Liquid equilibrium apparatus
   The vapor/liquid equilibrium apparatus had been instrumented and basic research was conducted. The better understanding of mass balance of the phenomena was achieved and the operation manual of the apparatus has been accomplished.

3) **Evaluation technology by simulation and prediction**
   The computer program for the simulation and prediction of the behavior of oil contaminants in MSF plant had been established by applying those related formula.
4) **Evaluation technology of contaminants carryover by MSF test plant**
   The test with oil contaminants had been conducted by MSF test plant. The obtained test data had been analyzed and compared with computer calculation. The effect of various parameters had been studied. The understanding of the seawater contamination has been deepened through the evaluation.

The target, procedure and results of the transfer of technologies are listed in Table 1 according to the subjects.

Table 1. Transfer of Technology for MSF-2

SUBJECT	TARGET	PROCEDURE	RESULTS
Evaluation technology contaminants in plants [Preparative experiment]	To master the evaluation technology on behavior of oil contaminants in MSF plants	1)To apply analytical techniques	The trainees applied water analytical techniques and have obtained sophisticated analytical method which was published in the Journal of Desalination
Evaluation technology of vapor/liquid equilibrium measurement [Vapor/liquid equilibrium]	To master the evaluation technology on the equilibrium between (1) seawater and Hydrocarabon or bromoform (2) seawater and Hydrocarbon + bromoform	1)Assemble equipment 2)Conduct experiments 3)Develop formulas	The trainees have gained knowledge about mass balance in vapor/liquid equilibrium. They have prepared section 6.2 in this report as well as an operational procedures guide to the vapor/liquid apparatus
Evaluation technology of Simulation and prediction [Simulation]	To master the evaluation technology on the development of relational expressions that simulate a behavior of oil contaminants in an MSF plants	1)Identify all expressions and variables 2)Develop the logic flow diagram 3)Develop the computer source codes	The trainees became able to understand the logic of the computer program and propose further improvements
Evaluation technology carry over of contaminants in MSF Test Plant [Confirmation]	To master the evaluation technology on the confirmation method for carry over of contaminants in MSF plants	1)Set up experimental conditions and carry out experiments 2)Collect samples and make chemical analysis 3)Compare results to computer results	The trainee became able to understand the crucial points for the dosing of constaminants in the MSF test plant during the experiments and its impact on the results. Also, they were able to discuss and relate different parameters affecting the comparison between experimental and predicted results

7. Study on Selection of RO Membrane for Hybrid System (RO–1)

7.1 Investigation and Preparative Experiment