Annual Report (FY 1969) Freeport Test Facility and Vertical-Tube-Evaporator Test-Bed Plant, Freeport, Texas

United States Department of the Interior

Office of Saline Water • Research and Development Progress Report No. 559

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Annual Report (FY 1969) Freeport Test Facility and Vertical-Tube-Evaporator Test-Bed Plant, Freeport, Texas

By Keith S. Campbell, Project Engineer, and Donald L. Williams, Development Engineer, Stearns-Roger, Denver, Colorado, for Office of Saline Water: Chung-ming Wong, Director; John W. Heintz, Assistant Director, Project Management & Plant Engineering; Walter L. Barnes, Jr., Chief, Plant Engineering Division; John R. Newton, Facility Manager.

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FOREWORD

This is one of a continuing series of reports designed to present accounts of progress in saline water conversion and the economics of its application. Such data are expected to contribute to the long-range development of economical processes applicable to low-cost demineralization of sea and other saline water.

Except for minor editing, the data herein are as contained in a report submitted by the contractor. The data and conclusions given in the report are essentially those of the contractor and are not necessarily endorsed by the Department of the Interior.

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INTRODUCTION

A. AUTHORIZATION

On September 2, 1958, Public Law 85-833 authorizing the Demonstration Plant Program was enacted. The law provided for construction of not less than five desalination plants, each to demonstrate a different water conversion process in actual production tests. Upon completion of site selection and other related studies, a plant designed for a 12-effect, Long-Tube Vertical (LTV) evaporator method was selected to be constructed at Freeport, Texas. The Plant was designated as Demonstration Plant No. 1 by the Office of Saline Water. A five effect module was added to the original 12 effect plant by Stearns-Roger in 1967.

Management and Operations Contract No. 14-01-0001-1804 governed the operation of the Freeport Plant.

B. HISTORY

The Facility site, and type of desalination process to be demonstrated were selected March 2, 1959.

Actual Plant startup was accomplished in April, 1961. Stearns-Roger has operated the Plant since that date, first demonstrating the LTV process as being both economically feasible and possessing a high degree of reliability; and then developing and instituting many improvements in both hardware and process.

The production of the first billion gallons of product was realized at the Freeport Demonstration Plant May 21, 1965. The Development Runs have demonstrated the continued improved production, efficiency, and reliability, resulting from the process and hardware modifications which have been made. Design innovations which will result in reduced desalination plant capital investment and operating cost requirements have been tested.

The highly promising results of past developments and demonstrations resulted in a major hardware modification at the Freeport Plant. In Fiscal Year 1967 Stearns-Roger was given the responsibility of procuring and installing a 5-effect modular evaporator at the Freeport Plant, thus extending the multiple-effect train to 17 effects.

In May 1969, The Freeport Test Facility was shut down for inspection and non-destructive materials testing. Effective September 30, 1969, all activities at the Freeport Test Facility LTV plant were terminated pending a major plant modification late in fiscal 1970.

C. ABSTRACT

This Eighth Annual Report presents a wide variety of information, findings, and recommendations concerning the LTV multiple-effect evaporation method of desalination. Most of the data included are derived from the development studies conducted for the U. S. Department of the Interior, Office of Saline Water, at the Freeport Test Facility located in Freeport, Texas. Not only are the technical, logistical, and economical evaluations for Fiscal Year 1969 operations presented herein, but also the process and mechanical development program results as related to the LTV process in particular, and desalination in general.

Actual capital and operating costs are presented and compared to theoretical "normalized" capital and operating costs. Production and maintenance cost averages are presented; relevant operating and maintenance experiences are discussed. A thorough technical evaluation of the performance of the existing process (including the 5-effect module), the mechanical equipment, and the construction materials is included in this Report. The process evaluation is elaborated to include presently defined limitations of the temperatures and concentration ratios for scale-free operation of LTV evaporators without presoftening the feed water. An evaluation of certain process equipment has been made and is included. The operations of the single effect test evaporator (Auxiliary Test Unit) are analyzed and discussed. The results of tests with newly installed equipment of advanced design are presented.

SECTION I

SUMMARY

The Freeport Test Facility has completed its eighth full year of demonstration and developmental operation as the prime Office of Saline Water Test Bed for Vertical Tube, Falling Film Evaporation of Seawater. During this fiscal year, 203 million gallons of water were produced during 12 months of developmental operations.

1. TECHNICAL STATUS

The Freeport VTE Plant has developed into a reliable, efficient water producer utilizing conventional heat transfer surfaces and vessels.

Two development runs (No. 15 and 16) were worked on during the year. Efforts were directed at producing reliable heat transfer data for the 17 Effect plant. Double fluted tubes have been found to perform excellently in a commercial plant sized bundle; however, the performance has declined with time. A titanium tube bundle and a horizontal, enhanced surface preheater have both performed well.

The Auxiliary Test Unit (ATU) was run extensively in series with Effect 1 to study high-temperature operations with various tube materials without risking the deposition of anhydrite scale in the main plant. The incipient scale point for this unit operating on normal seawater is a little above 270°F.

The deaerator-decarbonator was found to have good capability when operated at conditions of slight flash-down and minimum stripping steam. Decarbonation appeared satisfactory at an effluent brine pH between 5.5 and 6.0; caustic neutralization was unnecessary.

A great many miscellaneous items were studied and are reported in Sections II and IV of this report.

2. ECONOMICS

Using a theoretical normalized capital cost of $1,668,930 for a VTE facility, a normalized water cost of $1.37 per 1000 gallons was developed. An actual water cost for the month of February, 1969, is reported at $1.31 per 1000 gallons.

3. RECOMMENDATIONS

It is recommended that the Development Program be extended and include not only continuous evaluation of the new hardware recently installed but also the initiation of planning and engineering to develop and study

SECTION I

SUMMARY

3. RECOMMENDATIONS (CONTD)

a. A high-temperature modular evaporator system utilizing enhanced surface bundles operating at high temperatures.

b. Corrosion inhibition by oxygen scavenging agents.

c. Novel enhanced surface tubes in evaporators and heat exchangers.

d. Improved and less expensive methods of inter-sump brine transfer.

e. Improved, less expensive, and more reliable materials of construction for hot brine transfer piping.

f. Automated plant operation.

g. Non-condensable venting restrictions.

Complete conclusions and recommendations are contained in Section V.

4. MAJOR MODIFICATIONS

Modifications to the 17 Effect plant and the ATU have been continued because of their influence on the Development Program. Because of an inability to transfer condensate from flash tanks in the module without high steam chest levels, the condensate lines were modified to a larger size.

An experimental horizontal vapor shear preheater was put in to replace HX-306(b). Data-taking systems were modified and simplified. A novel brine flash-down device was installed between Effects 13 and 14. Effect 15 was equipped for special steam distribution and venting studies. Numerous equipment repairs and replacements were made. Additional details are in Section IV.

SECTION II

TECHNICAL EVALUATION

A. GENERAL.

The first three years of operations at the Office of Saline Water Freeport Plant were demonstrations of the successful commercial operation of a multiple-effect, vertical tube, falling film seawater evaporator. From that time forward the plant has become a Vertical Tube Evaporator (VTE) Test Facility, incorporating many process and hardware developments, and carrying out a technically oriented program to improve the VTE multiple-effect process and evaporative desalination in general.

B. THE DEVELOPMENT PROGRAM.

The development program was originated and is constantly up-dated to accomplish the broad development objectives of:

1. Identification and definition of process and equipment limitations.

2. On-line testing of process and materials innovations.

3. Demonstration through actual commercial size operations of the degree to which promising theoretical and research results can be approached when incorporated into commercial facilities.

The program consists of alternate "development runs" and "modification, maintenance, and inspection periods".

Development Runs 15 and 16 were completed in this reporting period.

Development Run 15 was started on April 17, 1968 and terminated on September 20, 1968 after 3100 hours of operation at the approximate conditions shown in table II-1. Development Run 16 was started on December 18, 1968 and terminated by O.S.W. on May 9, 1969 after 3100 hours of operation at the approximate conditions shown in table II-1. The objectives for these two Development runs were:

1. Obtain complete heat and material balance data for evaluation of overall 17 effect performance with time.

2. Evaluate the heat transfer performance of the double fluted tube bundle, the titanium tube and stainless steel tube bundles and the vapor shear preheater.

3. Evaluate sump to sump brine transfer. Evaluate the effectiveness of enlargements in the module condensate transfer system. Study brine distribution patterns with alternate types of distribution weirs.

TABLE II-1
TARGET OPERATING CONDITIONS

	Units	Development Run 15	Development Run 16
A. SEA WATER FEED CIRCUIT			
1. Brine Feed Conditions			
a. Blended Brine Concentration Factor	Concentration Factor	0.97 to 1.01	No Blending
b. Blended Brine Feed Rate	lbs./hr.	Maximum Attainable	Maximum Attainable
2. Feed Brine Treatment			
a. Acid Injection Control Point	---	Deaerator-Decarbonator Outlet	Deaerator-Decarbonator Outlet
b. pH of Deaerator-Decarbonator Outlet (Before Caustic Neutralization)	pH	Variable With Testing	Variable With Testing
B. FIRST EFFECT OPERATIONS			
1. Sump Brine Temperature	°F	268 Max.	266 Max.
2. Chest Pressure	PSIG	31 ± 0.5 Max.	31 ± 0.5 Max.
3. Desuperheater			
a. Outlet Temperature	°F	Between Saturated & 325°F	Between Saturated & 325°F
C. LAST (17) EFFECT OPERATIONS			
1. Final Effect Brine Blowdown (P-27 Discharge) Concentration Factor	Concentration Factor	3.0 Max.	3.0 Max.
2. Gypsum ($CaSO_4.2H_2O$) Scale Inhibitor			
a. Type	---	None	None
D. CONDENSATE TRANSFER SYSTEM	---	As Needed to Keep Flash Tank Levels Down.	As Needed to Keep Flash Tank Levels Down.
E. VENTS			
1. From Effect 4 to Atmosphere	lbs./hr.	400 - 600	400 - 600
2. From Effect 12 to Barometric	lbs./hr.	400 - 600	400 - 600
3. Cascade Vents	lbs./hr.	As Needed	As Needed

Page 1 of 2

TABLE II-1
TARGET OPERATING CONDITIONS

	Units	Development Run	
		15	16
F. INTER-EFFECT BRINE FLOW	---	Forward Feed & Sump-to-Sump; Varies With Testing	Forward Feed & Sump-to-Sump; Varies With Testing
G. PRODUCT CORROSION INHIBITOR			
1. Injection Point	---	Freeport Product Line	Freeport Product Line
2. Type Inhibitor	---	Sodium Silicate	Sodium Silicate
3. Freeport Product pH Control Range	pH	8.5 - 10.5	8.5 - 10.5
H. ACTIVE OUTSIDE HEAT TRANSFER AREA (A_0)			
1. Evaporators	$Ft.^2$	64760	64690
2. Preheaters	$Ft.^2$	35890	33800
3. Product Coolers	$Ft.^2$	3990	3990
4. Heat Rejection Condenser	$Ft.^2$	2220	2220

B. THE DEVELOPMENT PROGRAM. (CONTD)

4. Evaluate the routine performance of the deaerator-deacarbonator.

   Study the effectiveness of catalyzed sodium sulfite in scavenging residual oxygen from the deaerator brine effluent.

   Determine the feasability and practicability of running the deaerator at an unadjusted pH out of as high as 6.5 and eliminating caustic addition.

5. Evaluate the relative performance of modular effects with and without mist eliminators.

6. Determine the effect of changes in vent configuration and/or venting rate.

7. Monitor brine corrosion potential with instantaneous and continuous corrater readings.

8. Determine optimum shock chlorination frequency, level, and duration.

9. Operate the auxiliary test unit (ATU) with enhanced surface tubes at various evaporating brine temperatures for investigation of enhanced surface heat transfer performance and determination of calcium sulfate anhydrite scaling limits with enhanced surface.

10. Perform special chemical analyses related to scaling and corrosion.

11. Evaluate the performance of competetive materials of construction.

12. Investigate any unusual process problems that interfere with or influence the development program.

A discussion of the development work on an objective by objective basis follows:

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 1 - OVERALL PLANT PERFORMANCE

a. Evaporative Heat Transfer Coefficients

Evaporator overall evaporative heat transfer coefficients determined on a salt balance basis have been calculated for selected heat and material balance tests. The results are shown on Table II-1-a. For comparison purposes, the individual coefficients calculated for each heat and material balance are averaged on a development run basis.

The evaporative heat transfer coefficients are for the most part calculated from raw, unadjusted data. In some cases it was necessary to adjust the brine sump temperature because of serious irregularities in the observed boiling point rise. It also appeared necessary in several cases to adjust the evaporator ΔT in the low temperature effects (16 and 17) to compensate for a lower temperature driving force at the top of the tubes due to the pressure drop across the brine side of the tube bundle. Note also that the ΔT for the 1st Effect was based on totally evaporating 1st Effect service. It was not felt that enough of the tube surface was used for preheating service to warrant the downward adjustment of the 1st Effect ΔT.

It is estimated that these coefficients are good at the 90% confidence level to about $\pm$ 5%. Increased precision would require more accurate data gathering equipment than was available during the runs.

The average heat transfer coefficients shown on Table II-1-a have been averaged and plotted against brine sump temperatures on Figure II-1-a. This represents operations at the Freeport Test Facility from September 1967 through May 1968. Note that the heat transfer coefficients for the No. 13 Effect double fluted tube bundle are not shown on this graph.

On Figure II-1-a, the average data points for the even numbered evaporators have been identified. Note that Development Runs 14 and 16 represent, in general, cold weather operations; Development Run 15 represents mostly summer operations. Regarding the individual plots:

1) As expected the overall heat transfer coefficient trends up with temperature. The extreme variability of the heat transfer coefficients for the first four effects in Development Run 14 is probably due to sampling and analytical problems rather than erratic evaporator performance.

2) In the first four, highest temperature, evaporators the heat transfer versus brine boiling point trend seems to fall off. This could be in part due to the more open tube configuration in these bundles since some tubes were removed when the module was installed. This open tube configuration would have the most influence in the first few effects where the steam specific volumes and the steam velocities are the lowest.

TABLE II-1-a

DEVELOPMENT RUN 15 & 16

OVERALL EVAPORATIVE HEAT TRANSFER COEFFICIENTS

Btu/hr., ^{o}F, $ft.^{2}$

DETERMINED ON A SALT BALANCE BASIS

Heat & Material Balance No.	Average Development Run 14	15-5	15-6	15-7	15-8	Average Development Run 15	16-1	16-2	16-3	Average Development Run 16
Heat & Material Balance Date		7/1/68	7/22/68	8/7/68	9/12/68		1/8/69	3/7/69	5/2/69	
Evaporator										
1	730	-	-	650	590	670	540	680	630	620
2	600	500	600	540	750	610	640	560	670	620
3 Positive	530	610	600	670	680	610	640	-	680	660
4 Pressure	750	730	650	660	700	650	670	600	560	610
5 ↑	500	690	550	620	680	620	470	650	580	570
6	660	640	610	690	690	650	490	600	580	560
7	600	660	600	540	650	610	500	480	540	510
8	700	540	500	540	510	520	580	520	520	540
9 ↓	430	640	660	550	660	610	610	590	550	580
10	360	460	320	380	420	400	480	340	360	390
11 Vacuum	390	350	300	390	340	360	360	-	400	380
12	350	270	260	460	290	320	530	-	520	530
13	530	1380	1080	1010	1140	1180	1050	1060	1020	1040
14	340	450	410	400	430	410	260	320	310	300
15	330	340	320	350	380	360	200	310	290	270
16	430	310	320	340	420	360	230	350	310	300
17	350	310	310	290	330	330	230	290	280	270

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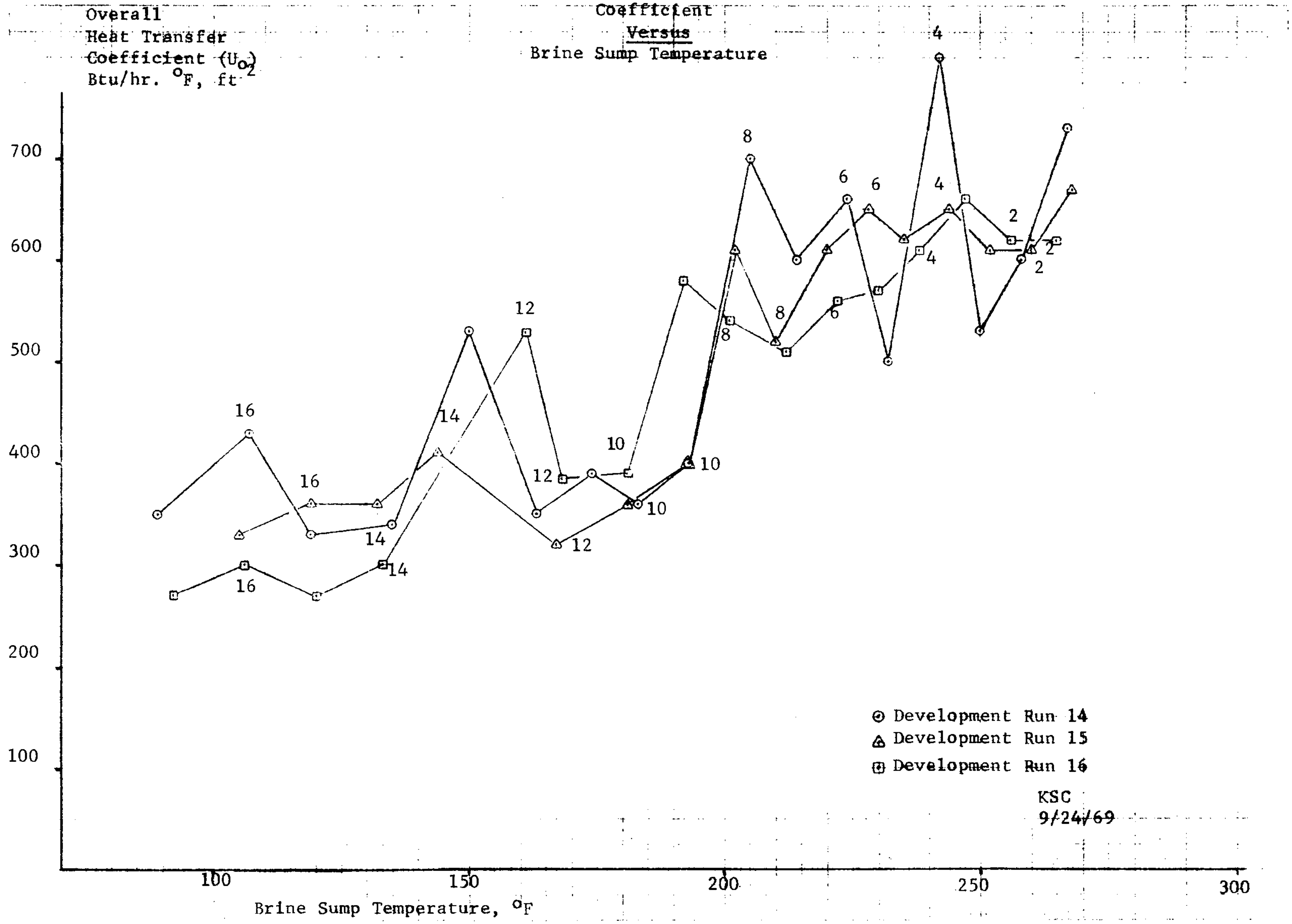
FIGURE II-1-a
Evaporator Average Overall Heat Transfer Coefficient *Versus* Brine Sump Temperature



3) It can be seen that the average coefficients for Effects 10 through 12 are considerably out of line on the low side relative to the coefficients for the other effects. This is most probably due to the fact that the efficiency of these effects was significantly lowered by air inleakage. The heat transfer coefficients for these three effects were low in both the feed forward and the sump-to-sump modes of operation. The apparent performance of the No. 12 Effect bundle improved significantly during Development Run 16; at the same time the apparent performance of the adjacent No. 13 effect double fluted tube bundle declined.

4) The performance of the modular low temperature effects declined significantly during Development Run 16. These reasons for the decline in performance is not known. There was no obvious sign of tube fouling on either the steam or brine side. Preliminary experiments did, however, show that the module performance could be seriously impared by fairly low noncondensable inleakage. It is probable that the poor performance was caused by a combination of high noncondensable loading and inadequate venting.

b. Detailed Heat & Material Balances

The performance of the process during Development Run 16 is most clearly indicated by reference to the complete, detailed heat and material balance calculations summarize for run 16-3 in Part 3 of the Appendix.

These heat material balance flow sheets were generated from the raw data taken during the heat and material balance run. The plant was balanced on an effect by effect basis starting at the hot end and working backward to the product end. Heat losses were estimated as a function of evaporator operating temperature and insulation competency. Heat losses were recalculated and the balance calculations repeated until a compatibility of $\pm$ 1% on total water production was obtained.

These calculations were made using standard steam and brine enthalpy values. Actual observed temperatures were used. For balancing purposes, the brine enthalpy values were carred out to the nearest 0.1 Btu/lb; this is one digit beyond the actual accuracy of the enthalpy data.

On occasion, attempts have been made to determine the evaporator heat loss by difference between the heat in and the heat out. It is impossible accurately to determine the heat loss by difference; the heat loss is simply too small relative to the total quantities of heat going into and out of the system.

The calculation technique was changed slightly for this heat and material balance. During the actual data gathering, it was noted

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 1 - OVERALL PLANT PERFORMANCE

that as much as 15,000 lbs/hr of purge and seal water was used but could not be accounted for. Experiments showed that most of this was going into faulty mechanical seals on the brine sump pumps. The heat and material balance calculations were adjusted to show the influence of additional water being added through the pump seals and the level control purge systems.

c. Preheater Performance

The attached Table II-1-b show heat transfer coefficients that have been calculated for the preheat exchangers using data taken at various times during Development Runs 15 and 16. For comparison purposes, average overall heat transfer coefficients from Development Run 14 and the average brine velocities are also shown on the table:

(1) The average overall heat transfer coefficient for HX-313 remains high. Because of its position in the path of the steam coming to the module from Effect 12, this exchanger is exposed to a lot more turbulence on the steam side than the other exchangers.

(2) The heat exchanger vents on the module were opened wide for Heat & Material Balance No. 15-5; there was no significant or apparent increase in heat transfer coefficient that could be attributed to the opening of these external vents.

The vents on exchangers HX-306b through HX-311 were gradually opened more and more during the run. There is no indication that the change in the vent setting caused any improvement in the operation of any of the heat exchangers.

(3) Heat exchangers HX-310 and HX-311 performed quite poorly during most of Development Run 15. This is most probably due to the fact that there were serious vacuum leaks in this area all during the run and the non-condensables that were introduced through these leaks served to vapor bind the heat exchangers and consequently lower their performance.

(4) HX-307 has CDA-194 tubes. The heat transfer performance of this bundle does not differ from adjacent exchangers. There is no reason to expect the CDA-194 tubes to perform significantly better from a heat transfer stand point.

(5) The brine velocities in the heat exchangers in the old plant are, for the most part, quite low. Higher brine velocities would undoubtedly result in better exchanger performance and in more efficient plant operation.

(6) The performance of the heat exchangers in the module seems to be deteriorating with time. This is most probably due to tube

TABLE II-1-b

Preheat Exchanger - Heat Transfer Coefficients (U_o)

Btu/hr. ^oF, ft^2

HEAT EXCHANGER NO.	Development Run 15				Development Run 16			TUBE BRINE VELOCITY ft/sec	AVE. RUN 14	AVE. RUN 15	AVE. RUN 16
	H&MB 5 7/1/68	H&MB 6 7/22/68	H&MB 7 8/7/68	H&MB 8 9/12/68	H&MB 1 1/8/69	H&MB 2 3/7/69	H&MB 3 5/2/69				
HX-302a	310	310	340	480	-	360	420	2.7	400	290	390
HX-302b	460	410	420	590	560	430	420	3.1	530	480	470
HX-303a	730	360	470	720	900	490	310	3.6	860	540	570
HX-303b	660	680	590	620	510	350	480	3.4	490	630	450
HX-304	390	390	300	260	370	150	130	2.1	310	370	220
HX-305	-	410	290	270	290	250	260	1.6	250	340	270
HX-306a	-	-	-	-	480	460	430	2.9	475	370	460
HX-306b	360	330	280	360	940 (1)	780 (1)	930 (1)	4.3 (1)	400	330	880(1)
HX-307	360	390	350	410	330	320	270	2.7	420	400	310
HX-308	400	390	380	440	320	270	300	2.7	390	410	300
HX- 09	410	430	370	400	360	330	280	2.7	355	410	320
HX-310	270	270	250	300	360	270	300	2.8	330	280	310
HX-311	270	300	270	290	80	790	260	2.8	380	290	380
HX-312	500	530	520	540	520	540	540	6.5	430	410	540
HX-313	430	450	360	460	380	380	360	9.9	725	460	380
HX-314	400	380	280	290	390	310	280	9.9	445	380	330
HX-315	360	350	260	420	420	390	350	8.3	440	350	390
HX-316	330	320	260	340	440	240	230	4.8	350	330	300
HX-317	200	330	350	400	320	320	320	4.8	435	340	320

(1) Changed to vapor shear preheater.

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fouling. These tubes should be chemically cleaned to determine if performance improves up to the original level.

d. Performance of Heat Rejection Condenser (HX-318)

During this time period, the overall heat transfer coefficient for HX-318 ranged from a low of 160 to a high of 450 Btu/hr., °F, ft.^{2}. The extimated accuracy of these heat transfer coefficients is $\pm$ 5%. All observed coefficients were below the design coefficient.

The performance of the condenser fell off significantly during cold weather operations; this severely limited the ability of the plant to produce more water when the seawater temperature dropped down in the winter. The vacuum producing equipment was not the cause, it pulled down to an extremely low backpressure (0.7 m.Hg) during these low temperature operations.

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 2 - SPECIAL HEAT TRANSFER SURFACE PERFORMANCE

a. Effect 13, Double Fluted Tube Bundle

The first enhanced surface tubes to be used at the Freeport Test Facility were installed, as a complete bundle, in the 13th Effect during the shutdown between Development Runs 14 and 15. The tubes used had a General Electric Company double-fluted surface configuration. For installation details see Seventh Annual Report.(1)

The performance factors that were calculated for the double-fluted tube bundle are shown graphically on Figure II-2-a and in tabular form on Table II-2-a.

The heat transfer coefficient during Run 15 was fairly steady with no decreasing trend with time. During Run 16 the tube performance was lower by about 15%; a slight but gradual decrease with time was also evident. To date, the bundle has had more than 6200 operating hours in evaporating service. The initial performance of the double-fluted tube bundle was reported (2) at the recent OSW enhanced surface symposium.

For most of July 1968, the tube feed rate was cut down to about 900 lb/hr per tube; there was no significant change in the average heat transfer coefficient.

During Run 16, operations were generally constant, with tube feed provided at 1,100 lbs/hr on recycle, evaporator feed sump-to-sump from the 12th Effect while venting full from the chest at about 500 lbs/hr with the dome vent open.

The double-fluted tube bundle was probably the single most important piece of equipment tested during this reporting period. Regarding future runs, it is suggested that:

1) The tubes be inspected carefully for any sign of fouling on either the evaporating or condensing side.

2) Specimen tubes be pulled and tested in laboratory evaporators for a direct comparison with the performance of clean or reference tubes.

3) The #13 double-fluted tube bundle be run with open top S.V.L. weirs at different tube feed rates to determine the relative performance between nozzle type distributors and the S.V.L. Distributors.

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(1) "Seventh Annual Report"; Freeport Test Facility; Fiscal Period July 1, 1967 to June 30, 1968; Stearns-Roger Corporation.

(2) "Large Plant Performance Testing of a Commercial Sized Double- Fluted Tube Bundle"; Keith S. Campbell and J. P. Lennox; March, 1969.

TABLE II-2-a

NO. 13 EFFECT DOUBLE FLUTED TUBE PERFORMANCE

Date	Plant Feed M lb/hr	No. 13 Chest °F	Qt 10^6 Btu/hr	ΔT °F	Uo Btu/hr-ft^2-°F
Run 14 Average Smooth Tube:	485	158.5	16.2	7.8	500
Run 15:					
5-2-68	478	159.1	15.7	6.2	1,470
5-8-68	468	166.6	15.7	6.9	1,320
5-17-68	455	161.8	16.9	7.3	1,350
5-22-68	467	162.1	16.1	7.9	1,190
5-28-68	472	162.5	16.2	7.1	1,330
6-11-68	484	165.4	17.2	7.2	1,390
6-25-68	460	164.2	17.8	6.9	1,500
6-28-68	470	166.2	15.6	6.3	1,440
7-1-68	450	164.8	17.8	6.5	1,590
7-5-68	472	166.3	15.3	6.9	1,290
7-10-68	457	166.8	17.0	7.2	1,370
7-22-68	480	164.1	16.6	7.2	1,340
7-30-68	481	165.4	16.2	6.8	1,380
8-3-68	480	166.1	17.1	6.7	1,480
8-7-68	480	167.6	17.8	6.7	1,540
8-12-68	481	166.3	17.4	6.7	1,510
8-15-68	479	168.4	16.8	6.5	1,500
8-27-68	482	169.0	13.5	6.4	1,220
9-12-68	496	163.2	15.9	7.4	1,250
9-20-68	409	164.4	15.0	6.5	1,340
Run 15 Average:	470	165.0	16.4	6.9	1,380

TABLE II-2-a (CONTD)

No. 13 EFFECT DOUBLE FLUTED TUBE PERFORMANCE

Date	Plant Feed 10^3 lb/hr	No. 13 Chest °F	Qt 10^6 Btu/hr	ΔT °F	Uo Btu/hr-ft^2-°F
Run 16:					
1-8-69	441	158.3	16.9	8.4	1,170
2-18-69	492	155.2	17.4	8.4	1,200
2-24-69	492	156.3	17.6	8.0	1,280
2-27-69	492	155.6	18.5	8.1	1,330
3-7-69	489	156.6	17.6	8.5	1,200
3-18-69	489	154.9	14.4	8.6	970
3-27-69	491	155.8	14.5	8.2	1,030
4-17-69	480	160.5	15.5	7.8	1,150
5-2-69	473	161.1	13.5	7.8	1,010
Run 16 Average:	482	157.1	16.2	8.2	1,150

FIGURE II-2-a

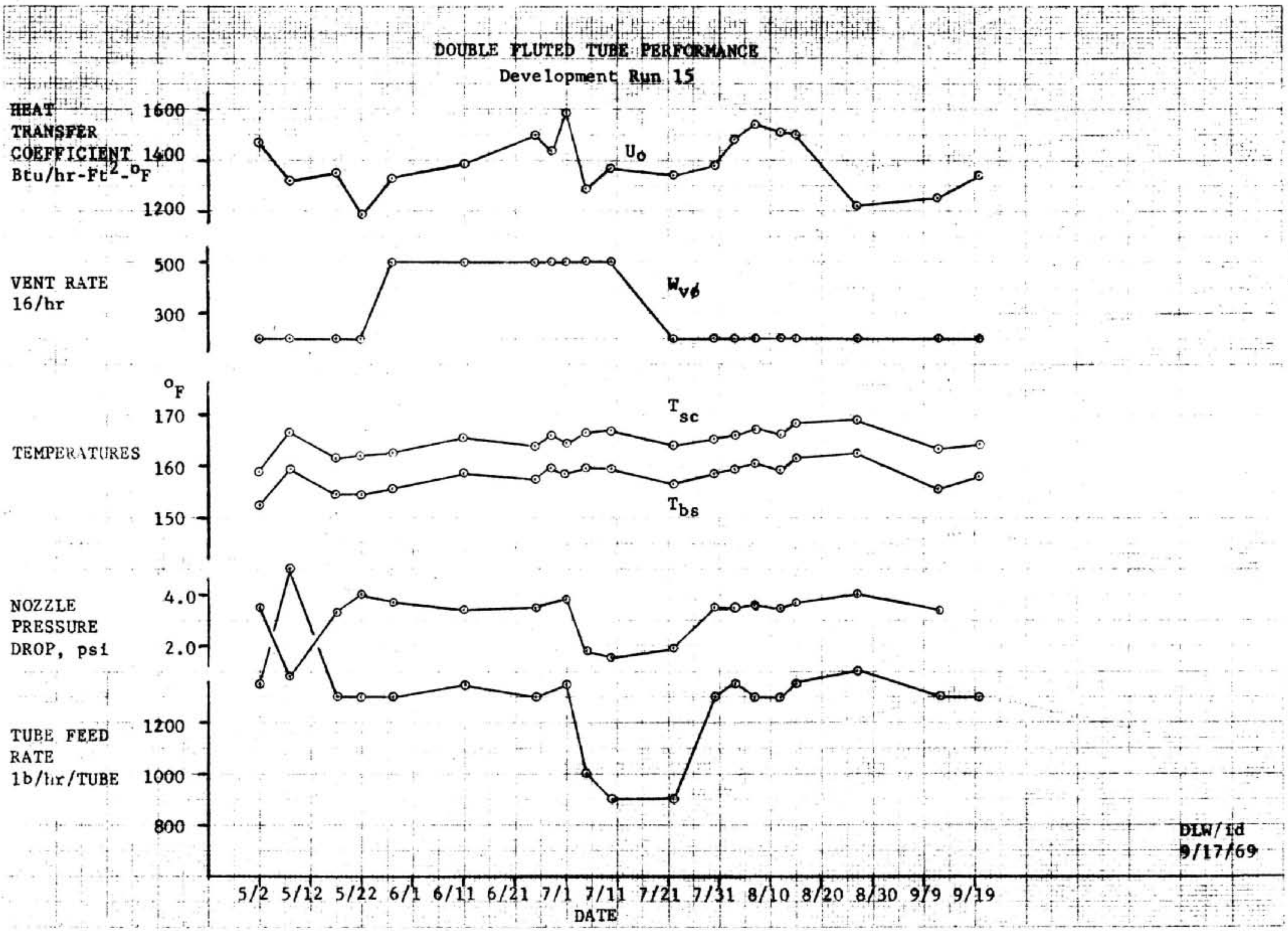
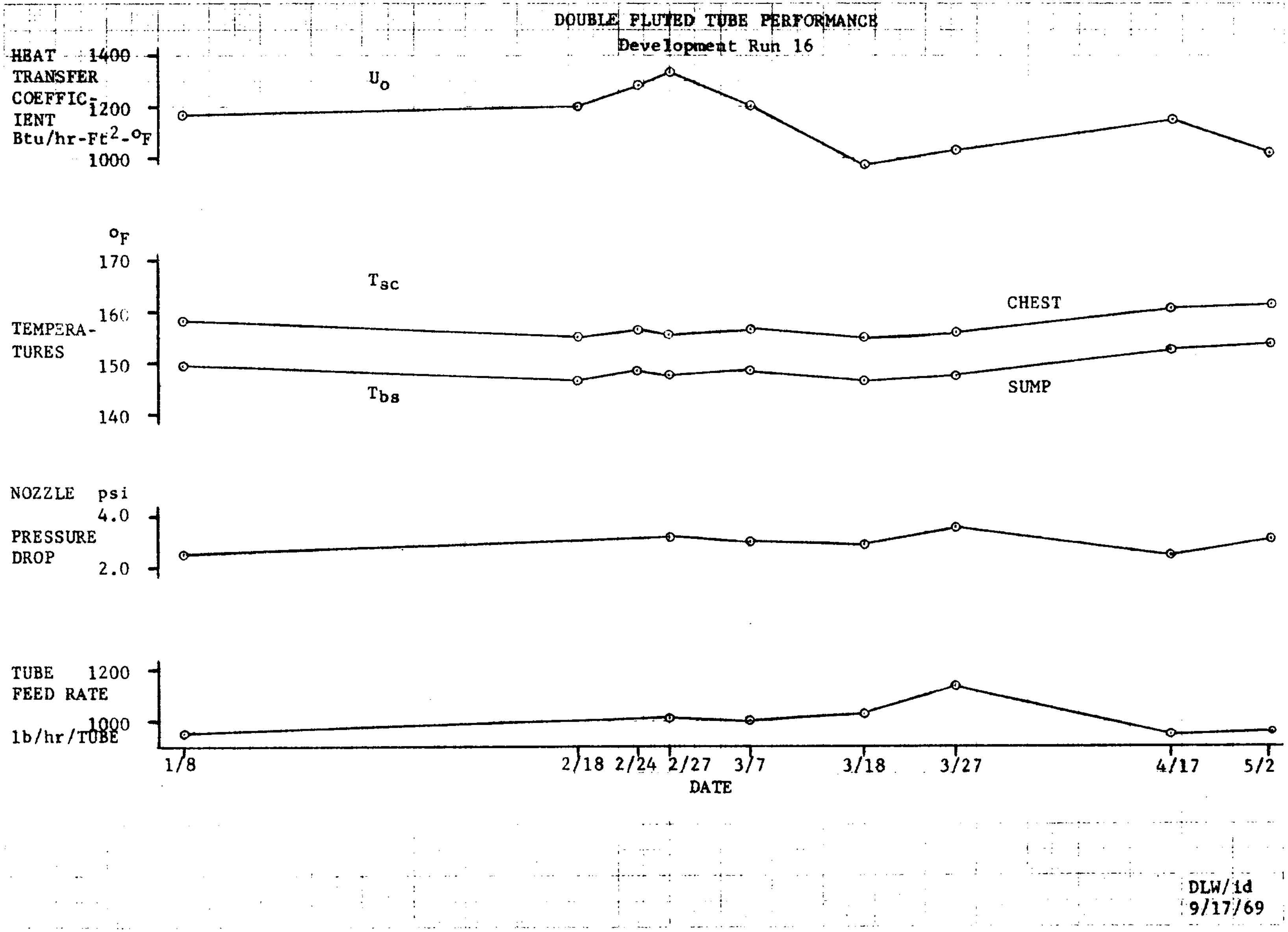

DOUBLE FLUTED TUBE PERFORMANCE
Development Run 15
HEAT
TRANSFER
COEFFICIENT
Btu/hr-Ft2-oF
1600
1400
1200
Uo
VENT RATE
16/hr
500
300
Wvφ
oF
170
160
150
TEMPERATURES
Tsc
Tbs
NOZZLE
PRESSURE
DROP, psi
4.0
2.0
TUBE FEED
RATE
1b/hr/TUBE
1200
1000
800
5/2 5/12 5/22 6/1 6/11 6/21 7/1 7/11 7/21 7/31 8/10 8/20 8/30 9/9 9/19
DATE
DLW/ld
9/17/69

FIGURE II-2-a (cont'd)



SECTION II

TECHNICAL EVALUATION

OBJECTIVE - 2 SPECIAL HEAT TRANSFER SURFACE PERFORMANCE

4) The bundle be chemically or mechanically cleaned to see if it can be restored to its original performance level.

5) That the existing #13 Effect temperature measurement equipment either be recalibrated or replaced with resistance thermometers to achieve an accuracy of $\pm$ 0.1°F compared to the present estimated accuracy of $\pm$ 0.5°F.

b. Effect 9, Titanium Tube Bundle

During the modification period between Development Runs 14 and 15, the water box and tube bundle in Effect No. 9 was replaced with a new modified assembly. For installation details see Seventh Annual Report.(1)

After 6,200 operation hours, the tubes were inspected, with special care taken to look for any sign of stress corrosion cracking at the tube roller expanded. No corrosion of any type was evident and the brine side of the tubes appeared in an "as new" condition.

Data taken around #9 Effect during Development Runs 15 and 16 are shown along with some calculated values on Table II-2-b. The overall evaporative heat transfer coefficients (U_o) were calculated on a salt balance basis.

The new titanium bundle has performed significantly better than the old admiralty bundle; the overall heat transfer coefficient appears to be slowly decreasing with time.

c. Effect 14, 316 Stainless Steel Tube Bundle

The number 14 Effect in the five effect module was equipped with thin wall 316 stainless steel tubes as an original modular component. The purpose of this installation was to expose 316 Stainless Steel to actual saline water evaporator environment, and evaluate this material as a heat transfer medium.

The average overall heat transfer coefficient (U_o) for this bundle dropped from 410 to 300 Btu/hr., °F,ft^2, between Development Runs 15 and 16. Follow Run 16, six percent of the tubes in No. 14 were found scaled with calcium sulfate (gypsum); also, a large air lead was discovered in flash tank 14. The poor performance during Run 16 is attributed to a combination of these two items and the fact that at each inspection, a continuous reddish-brown deposit has been noted in these tubes.

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(1) "Seventh Annual Report"; Freeport Test Facility; Fiscal Period July 1, 1967 to June 30, 1968; Stearns-Roger Corporation.

TABLE II-2-b

DATA AND CALCULATED VALUES FOR #9 EFFECT (TITANIUM TUBES)

Date	Plant Feed MPPH	No. 9 Feed MPPH	No. 9 Product MPPH	No. 9 Chest °F	Qt 10^6 Btu/hr	ΔT °F	Uo Btu/hr-ft^2-°F
Development Run 14 (Admiralty Tubes)							
Average	---	---	---	---	---	---	470
Development Run 15 (Titanium Tubes)							
5/2/68	479	322	18.8	203.2	15.9	7.7	570
5/28/68	471	308	17.7	208.7	15.1	7.1	580
6/11/68	483	319	18.4	208.2	15.7	7.1	600
7/1/68	449	306	18.5	210.1	15.9	6.8	640
7/22/68	479	317	17.7	209.4	15.1	6.3	660
8/7/68	479	323	16.5	210.0	13.9	6.9	550
9/12/68	495	327	19.7	210.6	16.9	7.0	660
Development Run 16 (Titanium Tubes)							
1/8/69	470	293	19.4	200.3	16.8	7.2	640
2/12/69	492	329	26.7	201.8	23.6	8.4	770
3/7/69	489	314	20.2	200.9	17.3	8.6	550
3/14/69	490	315	19.8	198.8	16.9	8.0	580
3/28/69	490	327	18.6	201.1	15.7	8.3	520
4/16/69	480	312	18.5	205.0	15.7	8.1	530
5/2/69	472	300	18.9	203.9	16.1	8.2	540

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SECTION II

TECHNICAL EVALUATION

OBJECTIVE 2 - SPECIAL HEAT TRANSFER SURFACE PERFORMANCE

The cause of the gypsum scale that deposited during Development Run 16 has not been exactly determined. It could be due to insufficient top water box feed in this sump-to-sump effect; the evaporator bottoms pump P-24 is set up to provide feed forward brine to Effect 15 and total recycle to Effect 14.

d. Preheater HX-306(x), Experimental Horizontal Enhanced Surface Vapor Shear Tube Bundle

During the shutdown between Development Runs 15 and 16, a new experimental preheat exchanger was installed in the plant. It was designed and furnished to the plant by ORNL, and replaced an original conventional vertical tube preheater in the main plant preheating circuit. A comparison of the two preheaters is shown in Table II-2-c.

Table II-2-c

Comparison of Preheater Data

	Conventional	Experimental
Vessel Number	HX-306(b)	HX-306(x)
Surface Area, ft^2	1,791	220
Tube Surface	Smooth	Spiral Grooved (Rope)
Number of Tubes	342	104
Tube O.D., in.	1	1
Tube Wall, in.	0.049	0.035
Tube Length, ft.	20'	8'
Tube Material	Al-Brass	Cu-Ni, 90-10
Vessel Orientation	Vertical	Horizontal
Passes Brine Side	2	1
Passes Steam Side	1	3

The vessel installation was designed to allow two modes of operation - full condensing and flow thru - both being conditions of the steam side.

From the data presented in Table II-2-d, it can be seen that the heat transfer coefficient has average 970 Btu/hr-ft.^{2}--^{o}F for 3,100 hours of operation, and has not decreased with time. It has not performed as well as the design, but considerably above the 370 Btu/hr-ft.^{2}-^{o}F coefficient of the conventional preheater which it replaced. This is due to some combination of the following:

1) The enchanced surface tubes.

2) The horizontal tube configuration.

3) The steam side baffling.

TABLE II-2-d

HX 306(X) PERFORMANCE

Date	SWF MPPH	SWF In °F	SWF Out °F	Stm. Chest °F	LMTD °F	Qt MMBtu/hr	Uo Btu/hr-ft^2-°F
Design (2)	500	218	224	230	8.7	3.0	1,100
1-1-69 (1)	450	216.5	221.5	229.0	9.8	2.18	1,010
1-7-69 (1)	440	217.3	222.5	230.3	10.2	2.23	990
1-8-69 (1)(3)	441	216.2	221.4	230.3	11.2	2.23	910
2-12-69 (2)	492	214.9	218.8	226.9	8.3	1.87	1,000
3-7-69 (1)(3)	489	216.0	219.9	228.8	10.7	1.87	790
3-12-69 (1)	489	213.1	217.8	227.0	11.2	2.25	910
3-25-69 (1)	491	214.8	219.8	227.4	9.9	2.39	1,100
4-16-69 (1)	480	219.2	223.7	230.5	8.9	2.12	1,080
5-2-69 (1)(3)	472	217.8	222.4	230.5	10.2	2.12	950

Notes: (1) Full Condensing Mode
(2) Flow Thru Mode
(3) Temperatures Taken with Laboratory Grade Thermometers

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SECTION II

TECHNICAL EVALUATION

OBJECTIVE 3 - REVISED METHODS OF FLUID TRANSFER

a. Sump-to-Sump Brine Transfer

The two most generally favored methods of transferring brine from evaporator to evaporator in a VTE Plant are:

(1) Feed Forward. In this mode of operation, brine is pumped from the sump of the evaporator to the top water box of the next evaporator.
In the top water box, the brine flashes down to the lower temperature and pressure. A level controller is required to regulate the brine level in the previous sump.

(2) Sump-to-Sump. In this mode of operation, the effect pressure differential is used to force brine from the sump of one effect into the sump of the next effect. The brine being transferred flashes down to the pressure and temperature existing in the next sump. To regulate the level and protect the pump, a standpipe is usually put inside the sump of the evaporator from which the brine is being transferred. To avoid turbulence and direct the flashing brine, a flash cap is usually placed on the outlet of the sump-to-sump transfer line inside of the lower temperature effect. Equilibrium brine is pumped from the sump up to the upper water box of the same effect. No flashing occurs in the upper water box. No level control is needed on the brine pump discharge.

Elimination of flashing in the top water box serves to improve brine distribution to the tubes and lessen the pressure drop across the tube bundle. A control system is eliminated. The system is self-regulating. In modular effects, additional savings can be realized if it becomes possible to transfer the brine internally through the intereffect bulkhead.

The sump-to-sump transfer piping operated satisfactorily. Data taken during Development Run 15 indicated that there was no flashing in the sump-to-sump line between Effects 10 and 11; and between Effects 11 and 12. Aside from line loss and elevation loss, all the inter-effect pressure drop was taken across the inlet nozzle to the low pressure effect.

The top water boxes of the effects operating in the sump-to-sump mode were observed several times during operations. Under sump-to-sump operations with no flashing taking place in the top water box, very little turbulence was noted. Brine distribution seemed uniform. Considerable turbulence due to flashing was observed in other top water boxes that were operating in the feed forward mode.

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 3 - REVISED METHODS OF FLUID TRANSFER (CONTD)

b. Condensate Transfer

During Development Run 14 it became apparent that some of the modular evaporators were operating with condensate levels in their respective steam chests. This resulted in poor heat transfer performance and less than 100% plant rate operation. The major cause of this problem was attributed to undersized condensate transfer piping. During the Development Run 14/15 shutdown, several equipment changes were made in the condensate transfer system.

During Run 15, the condensate transfer system in the modular evaporators performed significantly better; the condensate levels were lower, flash tank 12 included; total plant production was increased. It was still, however, necessary to divert water from #15 flash tank to the suction of product pump P-41 in order to get maximum plant output.

c. Brine Distribution

The 11th Effect at Freeport is equipped with a device to measure the liquid rate out of a number of tubes. Tests were conducted using two types of brine distributors; polypropylene swirl promoting weirs (SVL), and porcelain spray nozzles. Also, each distributor was tested with flashing feed, and recycle feed.

Several sets of data were taken at each of the four combinations of feed mode - distributor type. Typical distribution patterns are summarized on Table II-3-a; some results of the tests are shown on Table II-3-b. The spray nozzle distribution is much more even. It is not known whether this is due to the SVL weirs or the action of the distribution plate.

Looking at the data in Table II-3-b it can be seen that the average of the measured tube feed rates is about 65% of the average tube feed that was calculated by dividing the unit top water box feed by the number of tubes. It could be that some of the tubes--not in the measurement system--are heavily loaded; there might be some brine coming out of the tubes that is not collected. It should be pointed out, that there is excellent repeatability between data taken under the same conditions but at different times with the flow measurement device. When the brine falls out of the end of the tube, it bells out because of edge effects. This coupled with the cross-flowing steam probably diverts some of the brine out of the collection device.

There is a considerable variation in tube feed rate; those tubes receiving less than 40% of the average tube feed could, on occasion, dry up and encounter scale problems.

<u>TABLE II-3-a</u>

<u>#11 EFFECT DISTRIBUTION PATTERN</u>

<u>SUMMARY</u>

Type Nozzles	SVL	Porcelain Spray
Date	1/10/68	1/31/69
Calculated Average Tube Feed Rate, #/Hr./Tube	850	920
Mode of Brine Transfer	Feed Forward	Sump-to-Sump
Tube Rate, Volume Fraction of Average Tube Rate	% of Tubes in Each Class	
Less than 0.2	5	2
0.3-0.4	17	0
0.5-0.6	30	4
0.7-0.8	17	24
0.9-1.0	19	67
1.1-1.2	4	3
More than 1.3	8	0
	100	100

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9/22/69

TABLE II-3-b

BRINE DISTRIBUTION IN EFFECT NO. 11

DEVELOPMENT RUN 16

Date	Water Box Feed Rate, lbs/hr	Water Box Feed Mode	Tube Feed Measured lb/hr (Average)	Tube Feed Calculated, lb/hr
1-3-69	324,000	Recycle	640	950
1-10-69	328,000	Recycle	620	980
2-12-69	349,000	Recycle	700	1,040
2-14-69	264,000	Forward (Flashing)	480	770
3-7-69	276,000	Forward (Flashing)	450	810

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SECTION II

TECHNICAL EVALUATION

OBJECTIVE 4 - DEAERATOR-DECARBONATOR

a. Acid Mix Chamber

At the shutdown between Development Run Nos. 14 and 15, an acid mix chamber, constructed entirely of glass-fiber reinforced polyester and filled with the same packing as the deaerator, was inserted between the acid injection point and the deaerator-decarbonator. The presence of this mixing chamber did not improve the erratic trace of the continuous pH meter monitoring the pH of acidified brine into the deaerator-decarbonator. Neither was any improvement in acid mixing noted. The packing was removed from this device to reduce system pressure drop to compensate for the reduced output from brine feed pump P-3. The chamber remained in the line through Development Run 16; the polyester material was unaffected by the acidified sea water.

b. Deaerator Effluent pH Control

In Development Run 15, the control sample point for acid addition was switched to the deaerator-decarbonator outlet brine before the caustic injection point. The acid addition was regulated to control the pH between 5.0 to 5.5.

On the basis of work done during Development Run 14, it was decided to determine if the acid addition requirements could be minimized and the caustic neutralization step could be eliminated. If the deaerator effluent pH is kept at 5.6 - 6.0, the pH of the brine is raised to the neutral range in the preheat train eliminating the necessity of caustic neutralization. This saves equipment, chemicals, and operator attention.

During Run 16, this carefully monitored increase of pH operating level was carried out. The deaerated-decarbonated brine pH control ranges specified were:

Stage 1	5.6 to 6.0 pH
Stage 2	5.8 to 6.2 pH
Stage 3	6.0 to 6.4 pH

At the middle pH range, caustic addition for excess acid neutralization was stopped. Since the total alkalinity of the bine into the first effect remained below 25 ppm as Ca CO_3 and no venting problems arose, the run was completed at the last set of conditions. No alkaline scale was observed in the preheat exchangers when they were inspected at the end of the run; no serious corrosion problems were observed when the high temperature condensate system was inspected.

c. Carbon Dioxide and Total Alkalinity of Decarbonated Brine

Carbon dioxide analyses were performed on a routine basis on deaerator effluent and blended sea water samples. The carbon dioxide content of the dearator effluent brine ranged from 0.3 ppm up to as high as 9.9 ppm.

d. Dissolved Oxygen

1) The dissolved oxygen content of the deaerator unadjusted outlet brine was above 50 ppb for the first part of Run 15. After several leaks in the deaerator were repaired, the dissolved oxygen of the deaerated brine dropped to between 30 and 50 ppb for the remainder of the run.

During Development Run 16, most dissolved oxygen determinations were run as part of the sub-objective of sulfite addition; the results of which are discussed in the next section.

e. Sulfite Addition

1) Background

The economics of chemical scavenging of the residual dissolved oxygen was studied. Assuming the addition of 10 parts of sodium sulfite per part of oxygen at a cost of 20¢ per pound for the sodium sulfite, the cost of sulfite addition in VTE plants with high extraction ratios would not be much more than 0.2¢ per 1000 gallons of product water, based on deaerator effluent dissolved oxygen scavenging only. Scavenging of subsequent inleakage might raise the cost significantly.

2) Analytical Problems

During Run 16, sodium sulfite was injected into deaerator effluent in an attempt to study the effects of sulfite as an oxygen scavenger in a seawater environment. A sulfite residual of 0.1 to 0.2 ppm was chosen as a control point. A suitable analytical method was required which would be usable to detect these low sulfite residuals. Since most of the published sulfite methods are for higher levels of sulfite, it was necessary to modify these methods to suit the test requirements.

A method was developed that is considered good to $\pm$ 0.2 ppm as Na_2SO_3. Note that since it takes at least an hour to take the sample and run the analysis, the observed sulfite residual may be low due to reaction during sampling and analytical time.

3) Injection Point Plugging

During the first part of the run, the sodium sulfite solutions were made up at the strength recommended by the manufacturer. However, plugging of the injection point occurred necessitating cleaning at least once per shift. It was assumed that the plugging was due to the precipitation of calcium sulfite, which is extremely insoluble, at the injection point. Experiments with different injection point locations and configurations did not solve the problem. The plugging problem was reduced, but not totally solved by going to a much reduced sodium sulfite concentration.

4) Results

During Development Run 16, dissolved oxygen analyses were performed on a routine and/or as needed basis on deaerator effluent both before and after sodium sulfite injection. The sulfite was generally effective in reducing the dissolved oxygen to nil.

The results indicate that the addition of sodium sulfite apparently reduces the dissolved oxygen content of the deaerated brine below the threshold of measurement. The rate at which this occurs in the actual preheat train environment is, unfortunately, not known. Since it takes about fifteen minutes to collect and "fix" a sample for the Winkler determination, it is possible that residual sodium sulfite reacts with oxygen during analysis giving a low apparent dissolved oxygen. The actual instantaneous dissolved oxygen level in the preheat brine after sulfite addition can only be determined by use of an on-line continuous dissolved oxygen meter. It is recommended that one of these be obtained for future runs.

f. Deaeration Control

The proper operation of the deaerator - decarbonator during Runs 15 and 16 followed those conditions found during Run 14 that resulted in the lowest dissolved oxygen levels in the deaerator effluent brine. They are as follows:

Stripping Steam Rate	500-1,000 lb/hr.
Vent Steam Rate	Enough to allow for flashing feed
Degree of Feed Flash Down	0.5 - 1.0°F

These conditions were monitored by the plant operators and controlled manually. The degree of flash down was determined by reading a matched pair of calibrated thermometers.

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 5 - MIST ELIMINATORS

During the shutdown between Runs 15 and 16, special piping was installed in the 14th and 15th effects to allow samples of condensate to be withdrawn from the steam chests of these effects for product purity analysis. At the same time, the mist eliminators were removed from the No. 14 effect steam product passage. Two sets of data were taken with this configuration. During a plant shutdown, the mist eliminators were reinstalled and an additional data set was taken. The condensate from the 14th effect was always sampled when sampling the 15th effect's condensate. The test data was always taken during high plant rates. Also, sampling was continuously composited and the conductivity was read hourly for a 24-hour period.

From the data shown on Table II-5-a it can be seen that the presence of a mist eliminator does improve the product water purity. However, considering the high plant rates, the increase in the impurity level due to the absence of the mist eliminator was very small and this effect did not need such a unit if it was only required to produce potable water.

TABLE II-5-a

PRODUCT PURITY WITH AND WITHOUT MIST ELIMINATORS

Date	Condensate Sample Source Steam Chest of Effect	Mist Eliminators	Plant Rate, %	Product Purity ppm NaCl
2/5/69	14	Yes	100	2
2/5/69	15	No	100	26
3/12/69	14	Yes	105	2
3/13/69	15	No	111	26
3/24/69	14	Yes	100	1
3/25/69	15	Yes	101	9

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 6 - VENTING STUDIES

A preliminary test of the effectiveness of the module venting system to remove non-condensable gas was performed during Run 16. Air was allowed to enter the No. 13 steam chest through a critical flow orifice which limited the flow to 30-40 lbs/hr, or about 0.2 wt % of the steam to this effect. The following observations were made:

a. Plant production rate declined from 100 to 80%.

b. Stripping steam to the deaerator increased from 700 to 1,000 lbs/hr.

c. Final brine discharge rate increased 45% from 155,000 to 225,000 lbs/hr.

d. Final concentration factor decreased from 2.0 to 1.4.

e. Final condensing temperature increased 2°F.

f. Steam rate to the first effect decreased 2% from 26,500 to 26,000 lbs/hr.

After approximately three hours, to allow the plant to approach steady conditions, the external vent of Effect 13 was closed. No noticeable change in plant operations resulted from this. After four and one-half hours all control room data indicated the plant was steady. The results indicate a severe limitation somewhere in the module venting system.

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 7 - CORRATER

At the beginning of Development Run 15, Corrater probes were located in No. 1 Evaporator sump and the No. 13 to 14 sump-to-sump transfer line. Reading frequency was twice a week during Development Run 15. The results are plotted on Figure II-7-a.

The calculated corrosion rates were plotted against dissolved oxygen, the major corrosion rate determining process variable. With regards to the actual plots:

a. The corrosion rates at both points were very close for much of the run.

b. The corrosion rates at both points increased and decreased together for much of the run.

c. The pitting index at both points followed each other very closely during the majority of the run. A change in pitting index number has significance; the number itself does not.

d. The large decrease in DO which occurred on Day 70, which was due to repair of a vacuum leak in the deaerator, did not show up as a corrosion rate decrease in No. 1 sump.

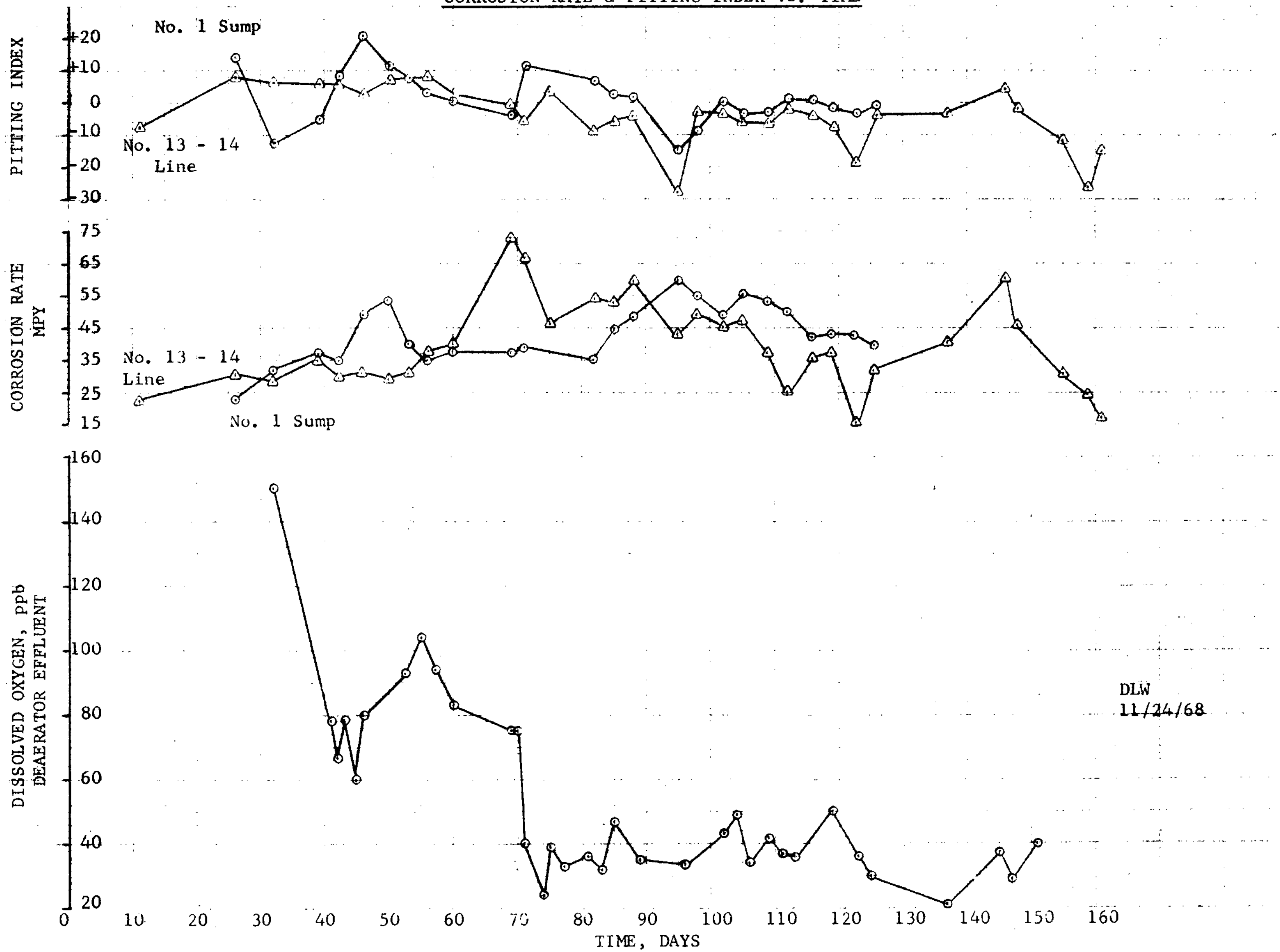
During Development Run 16, a Magna Corporation Model 1180, 6-Point corrater, together with a Model 1190 programmer, was added to the plant control room instrumentation. The purpose of this installation was to determine the reliability of the instrumentation package as an operating tool. Trial evaluation of the unit was still underway at the end of the run.

The six probe locations were:

	Location	Environment	Temperature °F (Approx.)
1.	Heat Rejection Condenser Inlet Cooling Water	Raw Sea Water	Ambient
2.	Deaerator Brine Effluent	Deaerated Brine	100
3.	No. 1 Effect Blowdown	Deaerated Brine	266
4.	No. 8 Effect Blowdown	Deaerated Brine	200
5.	No. 13 Dome	Deaerated Brine	160
6.	No. 17 Sump	Deaerated Brine	100

FIGURE II-7-a

CORROSION RATE & PITTING INDEX vs. TIME



SECTION II

TECHNICAL EVALUATION

OBJECTIVE 8 - EFFECTIVENESS OF SHOCK CHLORINATION

This objective was to evaluate the effectiveness of shock chlorination in preventing the growth of marine organisms in processing equipment. The minimum injection dosages that provided effective treatment was determined from an inspection of the water boxes of the protected exchangers. For previous discussion, see Seventh Annual Report (1).

Following each development run, the top water boxes of HX-213, 212 and 317 and the inlet, outlet, and return water boxes of Exchanger HX-318 were opened for inspection. At these times no attached-type marine organisms were found.

During Run 16, the procedure was made an operations task, including the time to initiate the injection, operation of the equipment, record keeping, and residual analyses. The major change for this run was a reduction of injection time to one hour each circuit.

It is not felt that there is significant economic incentive to investigate chlorination periods of less than an hour or chlorination frequencies of less than once per week.

(1) "Seventh Annual Report", O.S.W. Freeport Test Facility, fiscal period July 1, 1967, to June 30, 1968, Stearns-Roger Corporation.

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 9 - ATU (AUXILIARY TEST UNIT) OPERATIONS

a. Introduction

The ATU (Auxiliary Test Unit) is a self-contained, totally instrumented, seven-tube evaporator that is used to test such things as scaling threshold, tube performance, venting effectiveness, etc. The ATU is set up to run in parallel with the first effect; it receives the same brine feed as the first effect.

During Development Run 15, there were three major ATU runs, all directed at determining first effect scaling threshold.

During Development Run 16, the ATU was shortened to accommodate seven enhanced surface tubes. Test operations were directed at developing base line heat transfer coefficient data for the new tubes and determining the performance of these tubes under different operating conditions and equipment configurations, such as: flashing feed versus subcooled feed; SVL weirs versus spray nozzles; maximum venting versus no venting; etc.

b. Discussion of Runs - Development Run 15

Run 15-1 (268°F Sump): At the end of July, after being run for about 500 hours at operating conditions close to those experienced by the first effect, the ATU was shut down and inspected. The tubes were scrubbed down with a plastic brush and washed down with fresh water. There was no sign of any scale in the tubes. The 1.84" diameter gage ball easily passed down all of the 1.87" I.D. aluminum brass tubes. There was no scale formed in the ATU tubes during the 268°F, 500-hour run.

For the most part, the ATU ran quite smoothly during this 268°F, 500-hour run. The ATU was accomplishing approximately the same degree of concentration as the first effect during the run.

Run 15-2 (273°F Sump with Aluminum Brass Tubes): This run was started at 1800 on 7/26/68 and terminated at 1400 on 8/16/68 after 476 hours of unusually smooth operation. When the unit was shutdown and opened up for inspection, the tubes were found to be heavily fouled with calcium sulfate scale.

Run 15-3 (273°F Sump with Stainless Steel Tubes): For Run 15-3, the ATU was retubed with seven 2" x 20 BWG x 22' long, welded 316 L stainless steel tubes all from Red Heat No. 41923. These tubes have a nominal I.D. of 1.93".

This run was started at 2200 on 8/31/68 and terminated at 1230 on 9/20/68 after a run of 458 hours, which was interrupted by one shutdown during which the tubes were inspected. Additionally, there were two serious upsets during the run.

On 9/13/68 the ATU was shut down for an interim inspection. The 1.84" gage ball passed easily down all of the tubes. In an unwashed state, the tubes appeared shiny with a light speckle of adherent materia on the surface. The scale was hard and not easily removed from the tube surface. There was not enough of it significantly to affect the heat transfer rate.

At the end of the run, the ATU tubes were again inspected. The 1.84" gage ball passed easily down all of the 1.93" I.D. tubes before they were washed. The 1.90" gauge ball would pass no further than two feet down any of the tubes even after they had been washed down with a nylon brush and fresh water. The tubes had the same shiny, speckled appearance that they showed when inspected at the interim shutdown. There were some bigger patches of continuous scale; however, there was still not enough scale to affect heat transfer rates. It is estimated that about 5% of the surface area was spotted with scale.

c. Discussions of Runs - Development Run 16

At the beginning of Development Run 16, the ATU was modified and fitted with 14' long, spirally enhanced 2" O.D. Phelps Dodge tubes. These 90/10 copper/nickel tubes had a 0.049" wall thickness. The following tests were undertaken with the ATU during Development Run 16:

- Run 16-1 Shake-down to evaluate ATU performance with shorter tubes.
- Run 16-2 Constant operation tube performance test at No. 1 effect conditions.
- Run 16-3 Venting studies.
- Run 16-4 Effect of flashing feed.
- Run 16-5 SVL weir test.

d. Heat and Material Balance Data

Development Run 15: The special ATU heat and material balance data that were taken during Development Run 15 are presented in Table II-9-a. These data were taken when the unit was well lined out and operating smoothly. The critical flow meters were zeroed and spanned just prior to the data-taking period. Seawater feed and brine sump samples were composited over the entire data-gathering period.

A material balance for each set of data is also shown in the table. The metered flow for four of the six streams is shown. The condensate indicating flow meter is too erratic to be used; therefore, the condensate rate was calculated. The brine out of the ATU was calculated by difference to force the material balance. There is reasonable agreement between the calculated and the metered brine out-flow rate. An extra, non-significant digit is carried along in the brine out of sump numbers in order to close the balance.

Overall heat transfer coefficients have been calculated and are presented in the table for each set of heat and material balance data taken around the ATU during Development Run 15. These coefficients are good to $\pm5\%$. The accuracy is limited by the temperature and steam production measurements.

Development Run 16: The ATU heat material balance data that were taken and reduced for Development Run 16 are shown on Table II-9-b. During this entire run, the ATU contained seven Phelps Dodge spirally enhanced tubes.

For most of Development Run 16, the ATU was run on unblended seawater. This was done to avoid any chance of scaling the experimental tubes. During most of the shutdowns, the ATU tubes were carefully inspected for any signs of scale. No scale was formed in the ATU tubes during Development Run 16.

e. Conclusions and Recommendations

In Run 15-1 no scale was formed after about 500 hours of operation at nominal No. 1 effect conditions. In Run 15-2 the ATU aluminum brass tubes were heavily scaled with positively identified calcium sulfate anhydrite after having been run smoothly and continuously at a 273°F sump temperature for 476 hours. In Run 15-3 the 316 stainless steel tubes were only slightly scaled after having been run irregularly at the sump temperature of 273°F for 458 hours. It can be said that at these conditions of temperature, pressure, and concentration factor the incipient scaling point is in the neighborhood of 273°F. Certainly no scale was observed during the earlier 268°F sump temperature run, and at least some scale was observed to form during both of the 273°F runs. It must be remembered that the calcium sulfate anhydrite scaling

TABLE II-9-a

Development Run 15

Summary of ATU Heat & Material Balance Data

I. BACKGROUND INFORMATION												
A. ATU Run Number →	15-1			15-2						15-3		
B. Inclusive Dates →	6/26/68 to 7/17/68			7/26/68 to 8/16/68						8/31/68 to 9/20/68		
C. Intent of Run →	No.1 Eff.Conditions			272°F Sump Temperature						Repeat of Run 15-2		
D. Type of Tubes →	7 x 2"OD x 22' Long x 16 BWG Arsenical Aluminum Brass			Same as Run 15-1						7 x 2"OD x 22'Long x 20 BWG 316L Stainless Steel		
II. BASIC DATA												
A. Temperatures, °F												
1. Steam Chest Temperature (1)	273.7	275.6	275.4	278.9	279.2	280.8	280.7	281.0	280.2	283.4	281.8	284.3
2. Sea Water Feed In (2)	264.3	265.4	265.0	272.0	270.8	271.3	270.2	270.2	270.9	270.6	270.0	270.5
3. Brine Sump (2)	267.2	268.2	268.0	272.9	272.9	273.0	272.9	272.8	272.8	272.9	273.0	272.8
B. Chlorinity, Wt.% Halide												
1. Sea Water Feed	1.883	1.833	2.013	1.765	1.965	1.965	1.920	1.956	1.954	1.929	1.937	2.027
2. Sump Brine	1.945	1.932	2.136	1.844	2.054	2.054	2.019	2.101	2.031	2.009	2.003	2.101
C. Steam Production Rates, lbs/hr												
1. By Salt Balance	360	570	610	480	480	480	530	760	420	450	360	390
2. By Flow Meter	290	400	390	330	350	470	480	440	470	470	360	420
III. MATERIAL BALANCE, LBS./HR.												
IN												
Sea Water Feed (Metered)	11400	11000	10600	11100	11000	11000	10900	11000	10900	11100	10900	10900
Steam to Chest (Metered)	440	520	520	480	500	630	650	570	550	550	560	550

NOTES: (1) Calculated
(2) Calibrated Glass, Mercury Filled Thermometer

TABLE II-9-a

(Contd)

III. Cont'd.												
OUT												
Brine Out Sump (By Difference)	11110	10600	10210	10770	10650	10530	10420	10560	10430	10630	10540	1048(
Condensate (Steam to Chest Minus Vent Out)	400	480	480	440	460	590	610	530	510	500	510	500
Vent Out (Metered)	40	40	40	40	40	40	40	40	40	50	50	50'
Steam Produced	290	400	390	330	350	470	480	440	470	470	360	420
IV. HEAT TRANSFER												
A. Outside Heat Transfer Area (A_o), ft.^{2}	←					80.6						→
B. Steam Chest Temperature - Brine Sump Temperature (L.M.T.D.), ^oF	6.5	7.4	7.4	6.0	6.3	7.8	7.8	8.2	7.4	10.5	8.8	11.5
C. Heat Transferred Through Tubes To Brine (Q_T), MM Btu/hr.	0.27	0.37	0.36	0.31	0.33	0.44	0.45	0.41	0.44	0.44	0.33	0.39
D. Overall Evaporative Heat Transfer Coefficient, Btu/hr, ^oF, ft.^{2}	520	630	610	640	640	700	710	620	730	520	470	420

TABLE II-9-b

Performance of Spiral Enhanced Tubes

ATU - Development Run 16

(RUN DATA)

1969 Operations	Date Start	Date Finish	Duration Hours	To Test	Type Weirs	Feed Condition	Tube Condition at End of Run
Run 16-1	--	--	--	Shake-down	--	--	No Scale
Run 16-2	2/5	3/2	600	Tube Performance	Spray Nozzles	Non-Flashing	No Scale
2/7				Tube Performance	Spray Nozzles	Non-Flashing	
2/10				Tube Performance	Spray Nozzles	Non-Flashing	
2/18				Tube Performance	Spray Nozzles	Non-Flashing	
2/24				Tube Performance	Spray Nozzles	Non-Flashing	
2/26				Tube Performance	Spray Nozzles	Non-Flashing	
Run 16-3	3/6	4/2	400	Venting	Spray Nozzles	Non-Flashing	No Scale
3/7	3/6	3/8	50	Venting	Spray Nozzles	Non-Flashing	
3/13	3/12	3/18	140	Venting	Spray Nozzles	Non-Flashing	
3/13				Venting	Spray Nozzles	Non-Flashing	
3/26	3/24	4/2	210	Venting	Spray Nozzles	Non-Flashing	
Run 16-4	4/14	4/22	190	Flashing Feed	Spray Nozzles	Flashing	No Scale
4/16				Flashing Feed	Spray Nozzles	Flashing	
4/17				Flashing Feed	Spray Nozzles	Flashing	
Run 16-5	4/27	4/29	50	SVL Weirs	SVL Weirs	Non-Flashing	No Scale
4/28				SVL Weirs	SVL Weirs	Non-Flashing	
4/29				SVL Weirs	SVL Weirs	Non-Flashing	
Run 16-6	4/29	5/3	120	Scaling	SVL Weirs	Non-Flashing	No Scale
5/9				Scaling	SVL Weirs	Non-Flashing	

(1) $A_o = 51.3 \text{ Ft.}^2$
(2) Calibrated Thermocouples

TABLE II-9-b

Performance of Spiral Enhanced Tubes

ATU - Development Run 16

(OPERATING DATA)

1969 Operations	Sump Temp. °F (2)	Feed Temp. °F (2)	Vent Rate #/Hr.	Vent Rate % Steam In	Feed Concentration Wt. % Total Dissolved Solids	Feed Rate #/Hr/Tube	Overall (1) Heat Transfer Coefficient Btu/Hr.,°F,Ft.^{2}
Run 16-2							
2/7	266.7	263.1	20	5	3.02	1600	880
2/10	266.9	262.5	20	5	3.07	1600	820
2/18	265.7	264.3	40	8	2.56	1600	880
2/24	263.3	261.1	40	8	2.77	1600	780
2/26	265.9	263.3	40	8	2.65	1600	870
Run 16-3							
3/7	265.0	261.1	40	8	2.37	1600	770
3/13	265.7	262.1	0	0	2.40	1600	800
3/13	265.3	261.5	110	19	2.61	1600	800
3/26	266.0	263.2	290	39	3.11	1600	860
Run 16-4							
4/16	265.8	267.0	50	12	2.22	1600	830
4/17	264.9	265.7	50	11	1.95	1600	780
Run 16-5							
4/28	265.9	264.6	40	9	2.09	1600	820
4/29	266.6	264.8	50	11	2.23	1600	840
Run 16-6	267.0	263.6	50	7	3.64	1600	860

OBJECTIVE 9 - ATU (AUXILIARY TEST UNIT) OPERATIONS (CONTD)

point is not a uniquely determinable independently derived temperature, but rather it is a function of such things as concentration factor, brine temperature, residence time, nature of tube material, nature of any suspended phase in the brine, pH, temperature driving force, turbulence in the tube, etc.

In Development Run 15, coefficients all ran lower than the 700-800 Btu/hr, ^oF, ft^2 coefficients that are normally observed in the highest temperature (268^oF) effect. The coefficients for Run 15-2 are significantly higher than the coefficients for ATU Run 15-1. This is partly due to the higher average operating temperatures during the later run. Although heavy scaling of the ATU tubes occurred during the later part of Run 15-2, there is no indication in these data of the decline in overall heat transfer coefficient that usually accompanies heavy scaling. The heat transfer coefficients for ATU Run 15-3 are significantly lower than those observed in the previous runs. This is probably due to the fact that stainless steel tubes were used in the ATU during this run.

In Development Run 16, the Phelps Dodge spirally enhanced tubes had heat transfer coefficients ranging from 770 to 880 Btu/hr, ^oF, ft^2 operating on raw, unblended seawater at a nominal sump temperature of 265^oF. The heat transfer coefficients for these enhanced tubes were higher than the heat transfer coefficients for the smooth tubes in the ATU in Development Run 15. The values are, however, about what would be predicted from past data for a seawater evaporator operation at 265^oF.

It is not known whether the higher heat transfer coefficients were due to the tube enhancement or due to the fact that the ATU was operating with 14' long tubes in a smaller steam chest. Test runs with 14' smooth 90/10 copper/nickel tubes were planned but not carried out because of the abrupt termination of Development Run 16. This test work will have to be repeated along with the projected base line run before any conclusions regarding relative performance of the spirally enhanced tubes can be made.

Runs were made to investigate the effect of variations in vent rate on the overall heat transfer coefficient in the ATU. The bottom chest vent on the ATU was regulated from totally closed to wide open with data being taken at the terminal and some intermediate points. According to theory, high steam velocity parallel to the tubes should increase the steam side film coefficient by keeping the tube surface clear of non-condensables. The results on Table II-9-b show almost no change in overall heat transfer coefficient when varying the bottom chest vent rate from zero up to 39% of the steam into the steam chest.

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 9 - ATU (AUXILIARY TEST UNIT) OPERATIONS (CONTD)

During the first part of the Development Run 16, the ATU tubes were equipped with procelain spray nozzles; SVL weirs were substituted during the last part of the run. There is no significant increase in the heat transfer performance that could be attributed to the SVL weirs. According to these data, both distributing devices work equally as well with the spirally enhanced tubes. The spray nozzles do use up some pressure drop. The spray nozzles were used with both a non-flashing and a flashing feed. Changing the condition of the feed did not significantly change the heat transfer performance of the spirally enhanced tubes.

It is recommended that future work with the ATU be at Freeport discontinued. The original intention was to be able to run a small "package" evaporator in parallel with various effects in the Freeport Plant. Experience has shown that a little evaporator such as this requires operating attention all out of proportion to its size. Additionally, any such unit needs an extremely high level of instrumentation in order to produce significant and relevant data. It is our recommendation that small units can be more appropriately and effectively operated at small unit test stations, such as Wrightsville Beach.

It is also recommended that the promising spirally enhanced tubes be further tested in small evaporators to determine their actual performance relative to smooth tubes of the same length, thickness, and composition.

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 10 - CHEMICAL ANALYSES

a. Calcium, Magnesium and Sulfate

The results of the calcium and sulfate determinations on raw and blended seawater samples collected at various times are shown on Table II-10-a. Also shown on these tables are the concentration factors of these samples and some calculated values.

Of particular interest are the calcium and sulfate values of raw and blended seawaters adjusted to a 1.0 concentration factor. On the basis of the adjusted raw seawater data, it appears that the local seawater contains about as much sulfate and a little less calcium than normal sea water. The calcium and sulfate values both fluctuate; the ratio between sulfate concentration and calcium concentration that has been calculated for these raw seawater samples also fluctuates from a low of 5.9 to a high of 7.9. It appears that there is significant random, independent, variation in both the calcium and the sulfate concentration in the local Gulf of Mexico brine.

The blended seawater--adjusted to a 1.0 concentration factor--tends to run a little more highly concentrated in both calcium and sulfate than does normal seawater.

As with raw seawater, there is considerable variability in the blended seawater concentration of both calcium and sulfate. The ratio between sulfate and calcium also varies considerably. However, there does seem to be a day-by-day agreement in the sulfate to calcium ratio between the raw and blended seawater samples.

The molar concentration product [1] has been calculated for the blended seawater samples, unadjusted for concentration factor. It is known that in brines approaching the concentration of raw seawater, the activity coefficient does not vary a great deal with small changes in ionic strength. Thus, all other things being equal, the activity coefficient for 0.96 concentration factor blended seawater would be about the same as the activity coefficient for 1.0 concentration factor blended seawater. Under these circumstances, the molar concentration product can be used qualitatively to predict relative scaling tendency.

Looking at the data on Table II-10-a, it can be seen that the molar concentration product for the blended seawater was generally about 10% higher than the molar concentration product for normal seawater. This implies that--all other things being equal--the scaling potential of the Freeport blended seawater is greater than the scaling potential

(1) Molar Concentration Product - Molar Calcium Concentration (Moles/Liter) X Molar Sulfate Concentration (Moles/Liter)

TABLE II-10-a

Results of Calcium & Sulfate Analyses - Development Run 15

Date 1968	Raw Sea Water		Blended Sea Water		ppm Sulfate / ppm Calcium		Raw Sea Water			Blended Sea Water			Concentration Product Blended Sea Water $(\frac{Moles}{Liter})^2$ X 10^4	ATU Run No.
	Calcium ppm	Sulfate ppm	Calcium ppm	Sulfate ppm	Raw Sea Water	Blended Sea Water	C. F.	Concentration Adjusted to 1.00 C. F. Calcium ppm	Concentration Adjusted to 1.00 C. F. Sulfate ppm	C. F.	Concentration Adjusted to 1.0 C. F. Calcium ppm	Concentration Adjusted to 1.0 C. F. Sulfate ppm		
5/7	---	---	415	3000	---	7.2	---	---	---	0.920	450	3300	3.2	---
5/9	---	---	450	3300	---	7.3	---	---	---	0.966	465	3400	3.8	---
5/20	---	---	435	3000	---	6.8	---	---	---	0.874	495	3400	3.4	---
5/23	---	---	425	3000	---	7.0	---	---	---	0.920	460	3300	3.3	---
5/27	---	---	415	2900	---	7.0	---	---	---	0.966	430	3000	3.1	---
5/31	---	---	415	2900	---	7.0	---	---	---	0.920	450	3100	3.1	---
6/3	---	---	430	3200	---	7.4	---	---	---	0.966	445	3300	3.6	---
6/6	---	---	415	2800	---	6.7	---	---	---	0.920	450	3000	3.0	---
6/10	---	---	435	2800	---	6.4	---	---	---	0.920	475	3000	3.2	---
6/21	---	---	385	3000	---	7.7	---	---	---	0.990	390	3000	3.0	---
6/25	---	---	350	2900	---	8.3	---	---	---	0.830	420	3500	2.6	---
6/28	225	1500	425	2600	5.9	6.1	0.603	425	2500	0.964	440	2700	2.9	15-1
7/1	320	2000	390	2600	6.3	6.7	0.799	400	2500	0.960	405	2700	2.7	15-1
7/5	220	1300	390	2300	5.9	5.9	0.534	415	2400	0.913	425	2500	2.3	15-1
7/8	240	1400	415	2500	5.8	6.0	0.584	410	2400	0.982	420	2500	2.7	15-1
7/15	250	1900	390	3100	7.6	7.9	0.620	405	3000	0.992	395	3100	3.1	15-1
7/17	290	2300	385	3000	7.9	7.7	0.787	370	2900	1.060	365	2800	3.0	---
7/29	295	2300	400	3200	7.7	8.0	0.771	385	3000	1.033	385	3100	3.3	15-2
8/1	345	2500	400	2800	7.2	7.0	0.896	385	2800	1.040	385	2700	2.9	15-2
8/7	320	2300	430	2900	7.2	6.7	0.843	380	2700	1.049	410	2800	3.2	15-2
8/9	305	2200	430	2800	7.2	6.5	0.804	380	2700	0.997	430	2800	3.1	15-2
8/12	345	2400	400	3100	6.9	7.8	0.871	395	2800	1.070	375	2900	3.2	15-2
8/27	310	2300	400	3000	7.4	7.5	0.766	405	3000	0.987	405	3000	3.1	---
9/3	---	---	410	3100	---	7.7	---	---	---	0.97	420	3200	3.3	15-3
9/6	---	---	400	3100	---	7.8	---	---	---	0.97	410	3200	3.2	15-3
9/9	---	---	405	3100	---	7.7	---	---	---	0.97	415	3200	3.3	15-3
9/12	---	---	410	3100	---	7.7	---	---	---	0.97	420	3200	3.3	15-3
9/19	---	---	420	3000	---	7.1	---	---	---	0.97	435	3100	3.3	15-3
9/20	---	---	415	3200	---	7.7	---	---	---	0.99	420	3200	3.5	15-3
"Normal SW"	---	---	---	---	6.62	6.6	1.00	410	2700	1.00	410	2700	2.9	

of normal seawater. Thus, from the standpoint of calcium and sulfate concentration alone, the Freeport First Effect high temperature scaling data can be considered conservative. Note that for ATU Test Run 15-1, during which no scale was formed, the molar concentration product of the blended seawater (and ATU feed) was lower than the molar concentration product of normal seawater. The reverse was true for ATU Runs 15-2 and 15-3; that is, the molar concentration product of the feed was high--relative to normal seawater--and scale was formed.

Toward the end of Development Run 16, a technique for determining magnesium content on the atomic absorption unit was developed. Weekly composite samples were analyzed for magnesium content; the results are shown on Table II-10-b. Also shown are the magnesium contents of the samples adjusted to a concentration factor of 1.0; these are almost 20 percent higher than the normal seawater value.

b. Copper and Iron

1) Background - Work was continued during the reporting period on monitoring the iron and copper content of the liquid streams leaving the plant.

Knowing the physical dimensions and composition of the evaporator and preheater tubes, it is possible to calculate the equivalent copper surface in the plant that is exposed to brine. Assuming uniform corrosion, a copper alloy corrosion rate in mils per year can be calculated as a function of the copper content of the effluent brine; this has been done and plotted in Figure II-10-a. Note that this graph is good only for uniform copper dissolution and does not take into account corrosion products remaining in solid form in the evaporators; this approach will not pick up pitting attack.

2) Routine Samples - Composite samples of brines and condensates were collected on a weekly basis throughout Development Run 15 and 16 for copper and iron analysis.

Inspection of the data showed that there are unexplained random changes in the iron and copper content of the brines. The concentration of both these cations in the condensate was usually less than 0.1 ppM.

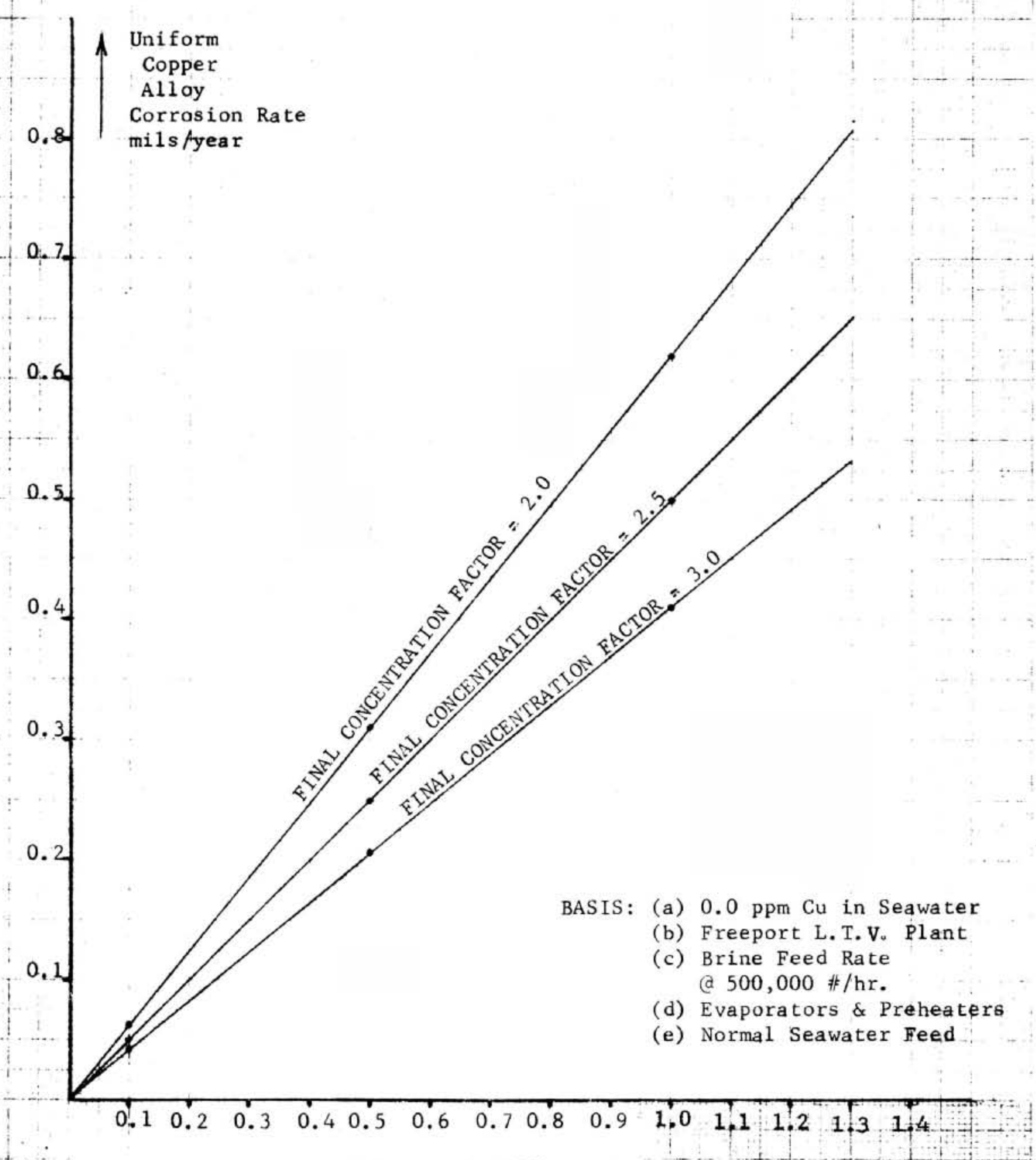
3) Special Studies - On February 25, hour long composite samples were taken every hour for a 23-hour period. When the sampling was started, sodium sulfite was being injected into the deaerator effluent. Dissolved oxygen analyses showed no oxygen at this time. After collection of the samples at 2400, the sulfite injection was again started. The dissolved oxygen again fell to zero. Atomic absorption analyses of these samples gave the results shown in Table II-10-c.

FIGURE II-10-a

UNIFORM COPPER ALLOY CORROSION RATE

versus

COPPER CONTENT OF EFFLUENT BRINE



KSC:alb
9/20/69

TABLE II-10-b

RESULTS OF MAGNESIUM ANALYSES

Date	C. F.	Plant Feed Magnesium ppm	Adjusted to 1.0 Concentration Factor Magnesium ppm
1-20-69	0.74	1,130	1,530
2-4-69	0.74	1,100	1,490
2-18-69	0.78	1,170	1,500
3-4-69	0.71	1,070	1,510
3-14-69	0.64	960	1,500
3-19-69	0.85	1,260	1,480
3-28-69	0.92	1,350	1,470
4-14-69	0.64	1,000	1,560
"Normal" Sea Water	1.0	---	1,270

TABLE II-10-c

IRON AND COPPER ANALYSES

1 HOUR COMPOSITE SAMPLES

2-25/26-69

	ppm Fe		ppm Cu		
Time	Feed	No. 17	Feed	No. 17	
1600	1.5	5.0	0.08	0.41	
1700	1.2	5.3	0.04	0.32	
1800	1.1	5.3	0.04	0.55	
1900	1.1	4.7	0.05	0.45	
2000	1.1	5.0	0.04	0.43	
2100	1.0	4.4	0.04	0.29	
2200	0.9	4.4	0.04	0.36	
2300	0.9	4.5	0.04	0.58	
2400	0.9	4.5	0.04	0.39	
					Sulfite Addition Off
0100	1.1	4.2	0.04	0.36	
0200	1.0	4.3	0.05	0.41	
0300	0.9	4.1	0.05	0.37	
0400	0.9	4.2	0.04	0.39	
0500	1.0	4.5	0.04	0.44	
0600	1.1	4.6	0.04	0.42	
0700	1.2	5.0	0.04	0.36	
0800	1.3	5.4	0.05	0.34	
0900	1.0	5.5	0.04	0.37	
1000	1.1	5.5	0.04	0.36	
					Sulfite Addition Back On
1100	1.0	6.0	0.04	0.38	
1200	1.1	5.7	0.04	0.36	
1300	1.0	5.4	0.04	0.35	
1400	0.9	5.3	0.05	0.33	

PW:alb
7/69

The iron and the copper content of the Number 17 Effect brine blowdown was quite constant for this 24-hour period. The extreme fluctuation in iron and copper that is seen in the weekly composite samples does not appear in these results. The copper content of the Number 17 Effect brine blowdown is quite low; using Figure II-10-a, the apparent uniform copper alloy corrosion rate would be about 0.1 mils per year. There was no significant change in either iron or copper concentration of Number 17 Effect blowdown caused by the 10-hour termination of sulfite addition.

On March 4,through March 13, a special sampling program was carried out which consisted of collecting 8-hour composite samples of plant feed and Effect 17 blowdown. The sampling was started right after a plant start-up. At this time sodium sulfite was being injected into the deaerator effluent. On March 7, 1969, at 1600, the sulfite injection was stopped; sampling was continued.

The results of copper and iron analyses that were run on these samples by atomic absorption are shown in Table II-10-d. The results in this table show a random variation in copper and iron from one sampling period to the next. There is, however, a definite trend shown--the copper and iron content of the plant blowdown starts out relatively high, drops rapidly after start-up, and shows a slow rise when the sulfite injection is shut off.

On the basis of these studies, the following conclusions can be drawn.

a) The concentration of iron and copper in the effluent brine is high at start up and then drops sharply to a much lower equilibrium value.

b) The average copper concentration in the effluent brine is equivalent to a copper alloy uniform corrosion rate of 0.1 to 0.2 mils per year.

c) Sulfite addition does not seem to greatly change the concentration of copper or iron in the effluent brine.

d) The copper and iron pickup on the condensate side is extremely low.

c. Deposit Analyses

The approximate analysis of several samples that were taken during the shutdown after Run 15 are shown on Table II-10-e. It should be noted that these are only approximate analyses which serve to characterize the sample.

TABLE II-10-d

IRON AND COPPER

8 HOUR COMPOSITES

Date	Time	ppm Cu Feed	ppm Cu No. 17	ppm Fe Feed	ppm Fe No. 17	
3-4-69	0800	0.14	1.5	1.2	7.2	
	1600	0.07	1.4	1.3	7.4	
	2400	0.07	0.5	1.0	5.2	
3-5-69	0800	0.09	0.4	1.0	4.6	
	1600	0.07	0.4	1.3	6.7	
	2400	0.09	0.4	1.1	5.0	
3-6-69	0800	0.07	0.4	0.9	4.6	
	1600	0.09	0.6	1.3	5.9	
	2400	0.06	0.4	1.0	5.3	
3-7-69	0800	0.06	0.4	0.9	4.9	
						Stop Sulfite Addition
	1600	0.05	0.4	0.9	4.8	
	2400	0.06	0.5	0.9	4.7	
3-8-69	0800	0.15	0.5	1.0	4.9	
	1600	0.06	0.5	1.0	5.7	
	2400	0.13	0.5	1.4	5.3	
3-9-69	0800	0.05	0.5	1.4	5.3	
	1600	0.17	0.6	1.3	5.6	
	2400	0.08	0.5	0.9	4.6	
3-10-69	0800	0.05	0.6	1.2	4.8	
	1600	0.07	0.8	1.6	6.3	
	2400	0.07	0.6	1.2	6.1	
3-11-69	0800	0.05	0.6	1.2	5.3	
	1600	0.05	1.5	1.4	7.1	
	2400	0.04	0.7	1.4	6.7	
3-12-69	0800	0.04	0.6	1.0	5.0	
	1600	0.04	0.6	1.1	5.3	
	2400	0.04	0.6	1.1	5.9	
3-13-69	0800	0.04	0.6	0.9	4.7	
	1600	0.04	0.6	1.4	6.6	
	2400	0.04	0.5	0.8	4.9	

BPW:alb
7/69

TABLE II-10-e

DEPOSIT ANALYSIS RESULTS

DEVELOPMENT RUN 15

Sample Point[1] and Description	Approximate Analysis, %				
	Gain/Loss on Ignition	Silica as SiO_2	Iron as Fe_2O_3	Copper[2] as CuO	Calcium as $CaSO_4$
Effect No. 5: Hard deposit from top water box adhering to alloy liner close to carbon steel tube sheet.	-1	4	20	75	4
Evaporator No. 9: Deposit adhering above "water line" to upper water box outlet alloy riser.	5	6	None	87	None
HX-302a: White/blue/gray deposit w/brown underneath; adhering to alloy inlet pass baffle.	12	3	None	99	None
HX-303b: White/blue/gray deposit adhering to alloy inlet pass baffle.	13	4	None	100	None
HX-308: Brown deposit from north side of alloy water box.	10	9	None	96	None
HX-308: Surface of alloy inlet baffle & south side of water box.	11	6	None	100	None

(1) All samples taken on 10/1/68 by B. P. Webb and K. S. Campbell.
(2) Metallic copper found to be present in all cases.

OBJECTIVE 10 - CHEMICAL ANALYSES (CONTD)

Most of these samples were scraped from alloy surfaces which are exposed to hot brine. The samples are predominately copper oxide. The presence of significant metallic copper in these samples is evidence of electrochemical reaction.

The fact that these samples gain weight on ignition is probably caused by the presence of significant amounts of metallic copper. Oxidation of metallic copper during ignition would cause the sample to gain weight.

d. Atomic Absorption Standardization

Analytical procedures for use on the atomic absorption unit were set up and checked out for copper, iron, calcium and magnesium. Results are repeatable. Noise problems were nil. Cation analysis time with the atomic absorption unit is extremly short (30 sec/sample.)

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 11 - MATERIALS PERFORMANCE REPORT SYSTEM

Late in 1968 the Materials Performance Report System (MPRS) replaced the MERS System and absorbed all the information already submitted. At the completion of the 17 Effect Plant Operation, about 200 MPRS Forms were completed and transmitted to the Materials Information Center (MIC) at Oak Ridge National Laboratory.

Some of the more interesting material failures and inspections are compiled below:

a. Failure of the carbon steel pipe spools at reducers and elbows in the high-temperature brine suction and discharge lines continued to be an operating and maintenance problem.

b. During the Development Run 14-15 shutdown, several spools of glass reinforced epoxy pipe were put in hot brine transfer service. Early in Development Run 15, there were some failures of the glass reinforced epoxy components primarily due to expansion problems or inadequate shop fabrication of joints.

c. The condensate drain line from Heat Exchangers HX-302a and 302b that was replaced was hammer tested and found to be in fairly good shape, except where the leak had developed at one of the elbows. Similar leaks were also found in the 45° elbows in the condensate drains of HX-305, 306, 307, 309, 310 and 311.

d. A number of holes were found and repaired in the steam chest of No. 2 and No. 3 Effects just above where the monel expansion joint is welded to the carbon steel evaporator steam chest.

e. The plastic SVL distribution weirs in a higher temperature effect (Effect 9) showed signs of shrinking and general deterioration. In some of the other effects, the unrestrained weirs had a tendency to pop out of the tubes.

f. After more than 8,500 operating hours, the cement-mortar lined brine sumps of Effects 8 and 9 appear to be in good condition.

g. Superficial scraping with a pick of the 70-30; Cu-Ni liners in the top water box of HX-304 and 305 revealed a soft layer of coppery material on the surface. Hard scraping revealed the sub-surface of whitish 70-30; Cu-Ni. It was thought that the outer layer of copper was due to "parting" corrosion which leads to denickelification.

It is also possible that this external layer of copper could be due to plating out of copper ions from the brine solution; if this were the case, the external layer of copper would have been a great deal softer.

SECTION II

TECHNICAL EVALUATION

OBJECTIVE 12 - MISCELLANEOUS STUDIES

a. Steam Jet Ejectors

The steam jet ejectors that were installed at the Freeport Test Facility in the late spring of 1966 have been a continuing operating problem. During the first part of Development Run 15, the steam jets performed satisfactorily. In the middle of the Run, there were repeated random failures. Spraying water on the throat chamber and second stage diffuser and allowing the excess to drain off through a cooling water jacket improved the reliability of the steam jet ejectors for the balance of Development Run 15.

During the shutdown between Run 15 and 16, a by-pass was put in so that if the second stage failed, the first stage jet and the vacuum pump could be operated in series. This provided two alternate/separable vacuum systems.

At the start of Run 16, the second stage jet still would not pump; the new first stage jet-vacuum pump combination was tried out. Operations in this mode were extremely smooth. Absolute pressures as low as 0.7 inches of mercury were observed at the barometric precondenser.

The combination vacuum pump and first stage jet operation has afforded the plant stable operations and excellent non-condensible pumping capacity. This system remained in operation for over 3,100 operating hours, all Run 16, and experienced no failures.

The cause of the jet trouble is probably the second stage diffuser. It is obviously badly corroded and eroded. It has been thermally shocked and wire brushed several times. It has been recommended that this carbon steel diffuser be replaced with a new stainless steel diffuser of the same size. This would give the plant two competent vacuum producing systems.

b. Tube Gaging - High Temperature Effects

Table II-13-a shows the results of gaging randomly selected tubes in the first four effects at the Freeport Test Facility after Development Run 15.

OBJECTIVE 12 - MISCELLANEOUS STUDIES (CONTD)

Table II-12-a

Evaporator Tube Gaging - December 1968

Evaporator No.	Nominal Tube I.D. Inches	No. of Tubes Tested	Number of Tubes that Gage Ball Passed Completely Thru — Gage Ball Size 1.84"	1.80"	1.75"
1	1.87	55	11	26	15
2	1.87	40	36	4	--
3	1.87	41	38	3	--
4	1.87	40	37	3	--
5	1.87	0	--	--	--

Effects 2 through 4 are considered to be clean and without scale. The 1st Effect is showing signs of some deposit buildup. During Development Run 15 this effect was run at a 268°F brine sump temperature receiving a feed with an average concentration factor of 1.0. No deterioration of the heat transfer coefficients that could be caused by scaling was observed during Development Run 15. However, the 268°F brine sump temperature is quite close to the incipient scaling point that was observed during two of the ATU runs (about 273°F).

At the end of Development Run 16, every other tube in every other row in the first effect was gaged with a 1.800 inch diameter gage ball. The gage ball would not pass down about five of the 90 odd tubes gaged. This is a very significant improvement over the gaging results observed for the first effect at the end of the Development Run 15. It appears that running the first effect of a temperature of 265° and with unblended Gulf of Mexico sea water served to dissolve some of the scale that had accumulated on the tubes. This is in direct contradiction to normal experience.

c. Gypsum Scale in Effect 14

At the post Development Run 15 shutdown, two tubes in Effect No. 14 were found to be almost plugged with gypsum scale. Forty or fifty other tubes in this bundle were inspected and found to be clean and totally free of any evidence of gypsum scale.

At the end of Development Run 16, 22 tubes in effect 14 were found to contain gypsum scale. After the effect was water washed for 3-4 days, two tubes still contained gypsum scale.

SECTION III

ECONOMIC EVALUATION

1. GENERAL

The main function of the Freeport Test Facility Desalination Plant is to test full size components of LTV multiple effect plants in order to advance the state of the desalting art. Considerable money, therefore, must be spent on testing equipment and manpower.

In the proper economic evaluation, theanalyst must be careful to exclude these research and development costs when attempting to define the "normal" unit cost of water. The "Normalizing" procedure is a standard OSW method[1] which offsets the effects of local variations in cost and the low on-stream factor resulting from the R&D efforts of this type of plant.

2. THEORETICAL CAPITAL COSTS

The theoretical capital costs of a 17-effect plant were developed in the Fifth Annual Report[2] and are detailed in Table III-1. The total cost of $1,668,930 represents a cost per daily gallon capacity of $1.55 based on a daily capacity of 1,080,000 gallons per day.

3. ACTUAL PLANT OPERATING COSTS

Table III-2 presents the monthly production summary for fiscal year 1969. The production and cost report for February, 1969 is presented in Table III-3. The actual cost of producing water during February, 1969 is detailed in Table III-4. During this month, the plant on-stream factor was 100%. This should represent the lowest unit cost of the 12-month period. From the table, the water cost of 131 cents per 1000 U. S. gallons represents actual production costs at the Freeport VTE plant.

(1) OSW Saline Water R&D Progress Report No. 72: "A Study of Large Size Saline Water Conversion Plants"· Washington, D.C., 1963.

(2) Stearns-Roger Corporation; "Fifth Annual Report"; Sea Water Desalting Plant, 1966.

17-EFFECT FREEPORT TEST BED PLANT

FISCAL YEAR 1969

	DOLLARS	% OF PIE
I. PRINCIPAL ITEMS OF EQUIPMENT (PIE)		
1. Special Equipment (Shop and Field Assembled)		
a. Evaporator Effects	600,000	60.18
b. Deaerator Equipment	16,600	1.67
c. Vacuum Equipment	19,000	1.91
d. Heat Exchangers	125,000	12.54
e. Pumps and Drivers	65,000	6.52
f. Desuperheater Pump Seals System	25,000	2.51
g. Water Cooling Equipment	7,500	0.75
h. Air Compressor Equipment	7,000	0.70
i. Acid and Caustic System	5,630	0.56
j. Concrete Work	35,000	3.51
k. Miscellaneous	50,000	5.03
SUB TOTAL	955,730	95.87
2. Standard Engineering Equipment		
a. Spare Parts	21,200	2.13
b. Overhead Cranes	20,000	2.00
SUB TOTAL	41,200	
TOTAL PIE	996,930	100.00
II. PROCESS FACILITIES		
1. Raw Feed and Cooling Water Intake Facilities (includes Pumps and Pipelines only)	120,000	
2. Site Development	36,800	
3. Insulation	50,000	
4. Painting	25,000	
5. Electrical	80,000	
6. Piping	Included Elsewhere	
7. Instruments	56,000	
8. Buildings	42,800	
9. Boiler Plant Facilities	60,000	
TOTAL PROCESS FACILITIES	470,600	
III. OTHER PLANT COSTS		
1. Engineering	120,000	
2. Interest on Investment	31,400	
3. Startup Expense	30,000	
4. Cost of Site	20,000	
	201,400	
TOTAL PLANT COST	1,668,930	
Capital Cost Per Gallon of Daily Capacity (Based on 1,080,000 Gal/Day)	1.55	

THEORETICAL CAPITAL COST
17-EFFECT PLANT

TABLE III-1

FREEPORT TEST FACILITY

FISCAL YEAR 1969

MONTH	PRODUCTION M GAL.	GROSS STEAM ECONOMY LB WATER/LB STEAM	POWER M KWH	SULFURIC ACID, 93% LB.	CAUSTIC SODA, 50% LB.	OPERATING TIME HOURS	% ON-STREAM
July	26,700	12.3	364	33,400	930	665	89.3
August	21,000	12.3	306	27,000	1,430	522	70.2
Sept.	18,900	12.5	296	-	-	472	65.6
Oct.	0	-	48	0	0	0	0
Nov.	0	-	20	0	0	0	0
Dec.	12,800	12.1	187	19,600	490	305	40.9
Jan.	26,900	12.8	323	35,200	500	650	87.4
Feb.	29,900	13.1	361	38,700	630	672	100
March	32,100	12.7	390	34,200	516	705	94.8
April	25,700	12.8	325	38,800	0	567	78.7
May	9,000	13.1	139	-	0	207	27.8
June	0	-	42	0	0	0	0
TOTALS	203,000	12.6	2,801	226,900	4,496	4,765	54.4

TABLE III-2

MONTHLY PRODUCTION SUMMARY

FREEPORT TEST FACILITY

FEBRUARY 1969

PRODUCTION: 29,900,000 GALLONS

	DESCRIPTION	MONTH COST	¢/K GAL.
	<u>Direct Costs</u>		
501	Production	$ 5,290	17.7
520	Utilities	13,370	44.7
530	Laboratory	410	1.4
601	General Maintenance	3,680	12.3
606	Buildings	500	1.7
607	Site Improvements	0	0
608	Evaporators	0	0
609	Tubes	0	0
610	Heat Exchangers	0	0
615	Tank and Vessels	110	0.4
616	Gas Removal Equipment	30	0.1
617	Piping	1,150	3.9
618	Process Pumps	40	0.1
619	Instruments and Controls	810	2.7
620	Electrical Equipment	240	0.8
622	I&D Facilities	0	0
623	I&D Structures	0	0
625	I&D Pumps	0	0
626	I&D Equipment	0	0
628	I&D Tanks and Vessels	0	0
680	Distribution Plant	0	0
691	Office Equipment	0	0
694	Tools and Shop Equipment	220	0.7
695	Laboratory Equipment	0	0
699	Test Facility	0	0
SUB-TOTAL, DIRECT COSTS		$25,850	86.5

TABLE III-3

PRODUCTION AND COST REPORT FOR TYPICAL MONTH

(Sheet 1 of 2)

FREEPORT TEST FACILITY

FEBRUARY, 1969

PRODUCTION: 29,900,000 GALLONS

	DESCRIPTION	MONTH COST	¢/K GAL.
	<u>Indirect Costs</u>		
701	General and Administrative	$ 5,220	17.5
702	M&O Contractor Expense	5,370	18.0
710	Depreciation	4,370	14.6
SUB-TOTAL, INDIRECT COSTS		$14,960	50.1
	<u>Other Costs</u>		
720	R&D	$ 2,740	9.2
730	Extraordinary	0	0
740	Gain/Loss on Disposal of Plant	0	0
SUB-TOTAL, OTHER COSTS		$ 2,740	9.2
TOTAL ACTUAL COSTS		$43,550	145.8

TABLE III-3

PRODUCTION AND COST REPORT FOR TYPICAL MONTH

(Sheet 2 of 2)

FREEPORT TEST FACILITY

BASIS: ONE STREAM DAY & PLANT FACTORY
28.0 STREAM DAYS IN FEBRUARY, 1969; PRODUCTION 29,900,000 GAL.

I. DIRECT OPERATING COSTS	$ UNIT PRICE	UNIT	$ MONTHLY COST	$ PER STREAM DAY	¢ PER 1000 GAL
1. Energy					
a. Electric Power	0.008	KW HR	2,890	103.2	9.7
b. Steam	0.55	M lbs.	10,480	374.4	35.1
2. Chemicals					
a. Sulfuric Acid	0.1445	lb	680	24.2	2.3
b. Caustic Soda	0.0345	lb	20	0.8	0.1
c. Polyphosphate	0.235	lb	0	0	0
3. Operating Labor			2,810	100.3	9.4
4. Maintenance Labor			5,630	201.0	18.8
5. Supervision of O&M			5,170	184.8	17.3
6. Supplies			1,540	55.1	5.2
TOTAL DIRECT OPERATING COSTS			29,220	1,043.8	97.9
II. INDIRECT OPERATING COSTS					
7. Payroll Extras (included in Labor)			-	-	-
8. G&A Expense			5,220	186.6	17.5
9. Depreciation & Interest			4,360	155.7	14.5
10. Taxes & Insurance (in Labor)			-	-	-
11. Interest on Working Capital			280	10.1	1.0
TOTAL INDIRECT OPERATING COSTS			9,860	352.4	33.0
TOTAL WATER COSTS			$39,090	1,396.2	130.9

TABLE III-4

ACTUAL AVERAGE DAILY OPERATING AND PRODUCTION COSTS

SECTION III

ECONOMIC EVALUATION

4. NORMALIZED WATER COST

Normalized water costs are derived on the method prescribed in OSW R&D Report No. 72, and are presented in Table III-5; the theoretical capital cost was presented in Table III-1. The other normalizing ground rules are as follows:

a.	Electric Power Cost (Input Basis in Op. Demand of 520 KW)	\$ 0.008 per KWHR
b.	Fuel Cost (Input Basis is Boiler Efficiency of 85% to produce 150 psig Steam Superheated to 500°F, Net Gain Ratio 13.8)	\$ 0.374 per 10^6 Btu
c.	Sulfuric Acid (Input Basis 0.12 lbs. per 1000 lbs. of sea water feed)	\$ 0.0125 per lb.
d.	Caustic Soda (Input Basis 0.0091 lbs. per 1000 lbs. of sea water feed)	\$ 0.035 per lb.
e.	Polyphosphate (Input Basis 0.004 lbs. per 1000 lbs. of sea water feed)	\$ 0.200 per lb.

f. Operating Labor on the basis of Freeport experience - One man per 8-hour shift, with a premium rate of 3% for afternoon and 5% for graveyard shifts. (Resulting Rate: \$3.99 per man hour.)

g. Maintenance labor basis is five (5) maintenance men working a full week with 5% overtime for emergencies and operator relief. (The base hourly rate is \$3.99 per hour.)

h. Supervision basis is one-half time supervisor at \$5,200 cost chargeable to the operating plant per year.

i. Maintenance supplies and material are estimated at 0.5% of capital investment, excluding start-up costs and land.

j. Payroll extras are 16.0% of operating and maintenance labor.

k. General and administrative costs are estimated at 25.0% of operating and maintenance labor and payroll extras.

l. Depreciation and interest is based on the method proposed by OSW which uses a different life expectancy for the different classes of equipment.

FREEPORT TEST FACILITY

(BASIS: ONE STREAM DAY AND 330 OPERATING DAYS PER YEAR)
BASIS: 1,080,000 GPD CAPACITY

		$/STREAM-DAY	¢/1000 GAL
I.	DIRECT OPERATING COSTS		
	1. Energy		
	a. Electric Power	112	10.4
	b. Fuel (Gas)	329	30.5
	2. Chemicals		
	a. Sulfuric Acid	18	1.7
	b. Caustic Soda	4	0.4
	c. Polyphosphate	10	0.9
	3. Operating Labor	148	13.7
	4. Maintenance Labor	209	19.4
	5. Supervision of O&M	16	1.5
	6. Supplies	25	2.3
	TOTAL DIRECT COSTS	871	80.8
II.	INDIRECT OPERATING COSTS		
	7. Payroll Extras	57	5.3
	8. G&A Expenses	103	9.5
	9. Depreciation & Interest	341	31.6
	10. Taxes & Insurance	99	9.2
	11. Interest on Working Capital	11	1.0
	TOTAL INDIRECT COSTS	611	56.6
	TOTAL OPERATING COSTS	1,482	137.4

TABLE III-5

NORMALIZED OPERATING COSTS

4. NORMALIZED WATER COST (CONT'D)

m. Taxes and insurance costs are based on 2.0% of the capital cost of the plant less start-up expenses.

n. Interest on working capital is determined by totaling Items 1 through 10 of Table IV-5 and multiplying this total by 60/330 and then computing 4% of the result.

o. The cost per 1000 gallons is based on a production rate of 1,080,000 gallons per day, which is the maintainable production rate with existing arbitrary equipment limitations.

Thus the normalized water cost for the 17-Effect Plant, operating under conditions stated, was 137¢ per 1000 gallons.

SECTION IV

ACTIVITIES

1. GENERAL

This section covers the period July 1, 1968, through June 30, 1969, fiscal year 1969 and July 1, 1969, through September 30, 1969, fiscal year 1970. Subjects discussed, in order of inclusion, are Plant/Project Organization, Major Plant Modifications, Maintenance Activities, Operational Activities and Plant Safety.

2. ORGANIZATION

The Office of Saline Water has authorized 20 full time contractor employees at the plant. These people would hold the following positions:

1	-	Superintendent
1	-	Development Engineer
1	-	Maintenance & Operations Supervisor
1	-	Process Engineer
1	-	Development Chemist
1	-	Field Accountant
1	-	Maintenance Clerk
1	-	Stenographer/Receptionist
4	-	Plant Operators or Development Technicians
8	-	Maintenance Technicians

Figure IV-1 illustrates this organization and the connection with the Denver-based Technical-Management Support Group.

During the year, two papers regarding the VTE Process were prepared and presented by Freeport Test Facility Personnel:

(1) "L.T.V. Process Control";

Keith S. Campbell, Stearns-Roger Corporation; Second Salt Water Conversion Instrumentation Symposium; San Diego, California; February 12 - 14, 1969.

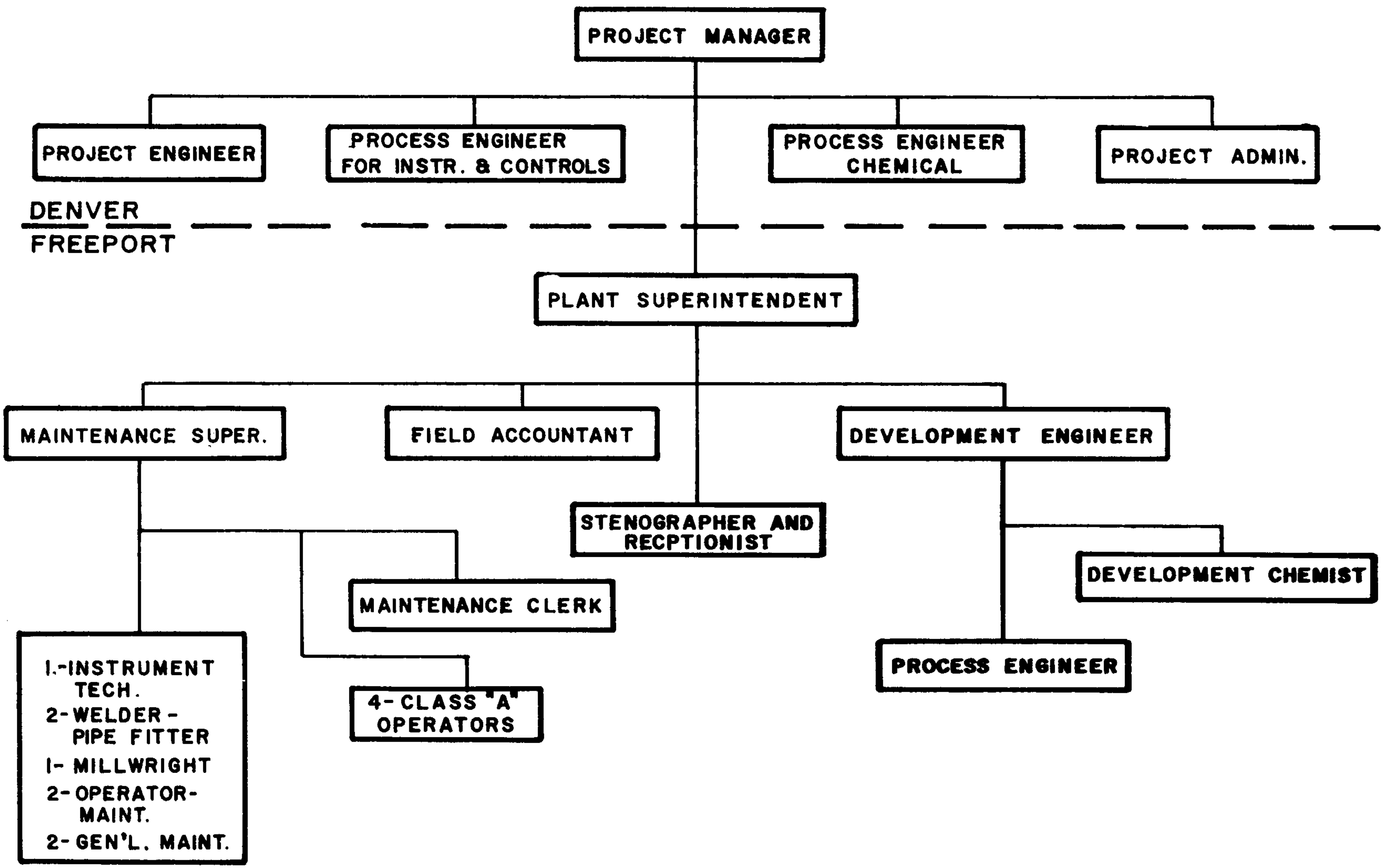
(2) "Large Plant Performance Testing of a Commercial Size Double Fluted Tube Bundle";

Keith S. Campbell and J. P. Lennox, Stearns-Roger Corporation; O.S.W. Symposium on Enhanced Surface; Washington, D.C.; March 11 - 12, 1969.

Additionally, a complete Operating Manual, an Analytical Procedures Manual and a combined report for Development Runs 15 and 16 were all prepared and issued to O.S.W.

FIGURE 4-1

ORGANIZATION CHART



SECTION IV

ACTIVITIES

3. MODIFICATIONS

Major modifications made to the 17 Effect Plant during the reporting period for process and materials testing follow. An updated process and instrumentation diagram is attached in Part 2 of the appendix.

A. Flash Tanks

In order to evaluate modular performance properly, a knowledge of condensate level is necessary. Level sight glasses were installed on flash tanks 14, 15, and 16 in July, 1968. The module came equipped with glasses on flash tanks 13 and 11 only.

During runs 14 and 15, the carbon steel shells of external flash tanks 10, 11 and 12 all perforated at the external support ring; they were replaced. Failure was attributed to external, general surface corrosion. Data on the new tanks are:

Flash Tank No.	Installation Date	Material	Insulation
10	11-68	Glass Reinforced Polyester	None
11	5-69	Epoxy Coated Carbon Steel	1-1/2" Calsite
12	4-69	Epoxy Coated Carbon Steel	1-1/2" Calsite

B. Brine Piping and Valves

Several large test spools were installed in Brine Service. A summary of these installations follow:

Location	Material	Installation Date	Remarks
P-11 Discharge	316 L S.S.	7-68	Still in Service
P-12 Discharge	Bondstrand 2000	7-68	Many Failures
P-18 Discharge	Fibercast OG-2025	8-68	Still in Service

Two Teflon expansion bellows were installed at pump suctions to relieve stress on the pumps. Also, one Dresser coupling was tested. These items are summarized below:

Device	Installation Date	Service Temp.	Remarks
Teflon Bellows	11-68	Ambient	Original Installation
Teflon Bellows	12-68	266°F	Replaced Monel Bellows
Dresser Coupling	12-68	240°F	Replaced Monel Bellows

3. MODIFICATIONS (CONTD)

C. Buildings

A new 3 1/2 ton air conditioner with 70% recirculation was added to the switch house. This effectively eliminated the pump breaker overheating problems and provided a dry, dust-free environment for plant electrical gear.

D. Pumps

During September, 1968, anticipating the installation of porcelain spray nozzles in No. 9 effect, modifications were made to P-18 to increase its discharge head. These included a new 25 HP, 1800 RPM motor, and the trimming of a 316 S.S. impeller from 13" to 9" diameter.

New acid pump suction piping with a large cross-section and dump lines to a special chemical sewer was installed in November, 1968. This was to help eliminate pump plugging by providing a method of removing the acid sludge from the suction lines.

E. Auxiliary Test Unit

As part of testing schedule to determine the calcium sulfate (anhydrite) scaling point, the unit was retubed in August, 1968, with new 316 stainless steel tubes. Following this test, and before run 16 started in December, 1968, a major modification was made. This included the following:

a. Steam chest was shortened from 22' to 14'.
b. Brine discharge, condensate, and bottom vent piping were altered to fit the smaller steam chest.
c. Sump access platform was raised and modified.
d. Seven 14', 2" O.D., spirally grooved, 90-10 Cu-Ni tubes were installed.

F. Heat Exchangers

In October, 1968, HX-200 was completely removed from the plant. At this time the waterboxes were perforated and the admiralty tubes were severely corroded, although no failures had yet occurred. It was planned possibly to use this exchanger as a materials test in the future.

During the same month, HX-306(b) was removed from service to allow a new experimental preheater, HX-306(x), to be installed in its place.

New brass nipples and valves were installed on all heat exchanger vents and drains. This was necessary to stop the high rate of failure at these points due to galvanic corrosion.

3. MODIFICATIONS (CONTD)

G. Sulfite Injection System

The existing Polyphosphate System was modified in August, 1968, for the injection of Catalyzed sodium sulfite solution to the deaerator brine effluent. A higher range pump discharge safety valve, plus a stainless steel discharge line and check valve were required for this installation.

H. Evaporators

In October, 1968, Evaporator No. 9 upper tube sheet and dome flange area were sandblasted to white metal and RTV 112 coating applied to the surface area.

In November, 1968, 2" procelain nozzles were installed for test purposes in Evaporator No. 11 and the corite distributor sheet lowered to hold the nozzles in place.

In the same month, vent tubes in effects 9, 13, 14, 15, 16 and 17 were plugged in the upper tube sheet using tapered brass plugs.

At the end of Development Run 16, the outside semi-circle of tubes in #15 effect were pulled to prepare said effect for venting studies in Development Run 17.

In late summer 1969, an externally adjustable inter-effect Brine flash down device was installed between effects 13 and 14 in the module.

I. Instrumentation

In October 1969, the #13 effect high accuracy cabinet instrumentation was installed and hooked up. During the same month an atomic absorption unit and a muffle furnace were both purchased and installed in the trailer laboratory.

Corrator probe installation was completed and the unit put in operation for preliminary test and range selection in April, 1969. At the same time, the DP transmitter and tubing was installed for the total plant product recorder.

In May, 1969, new 6 point thermocouple connectors were installed in the high accuracy cabinets to aid in thermocouple reading.

An automated acid injection and PH control loop was designed and the instrumentation purchased. Installation was deferred when the plant was shut down.

SECTION IV

ACTIVITIES

3. MODIFICATIONS (CONTD)

J. Steam Jet Ejections

At the end of 1968, by-pass piping and block valve to operate 1st stage steam jet and VP-1 in conjunction was installed.

K. Chemical Tanks

In the fall of 1968, due to failure of the existing tank, a new caustic tank was fabricated and installed.

At the same time, a new acid tank was installed complete with new pump suction, piping, gaging platform, and air breather replacing two failed tanks. The new tank has a storage capacity of 3500 gallons; the storage capacity of the old tanks were 1500 gallons each.

The acid tank vent and drain piping was installed using PVC piping.

A new chemical underground drain line was installed from the chemical storage area to dump in the waste ditch at the west side of the plant area. This drain was installed to eliminate acid spillage into the plant operating area.

4. OPERATIONS

The daily operator data summaries for all of Development Runs 15 and 16 are attached in part 3 of the appendix.

Operations and water production are summarized on a month by month basis on Table III-2. Operations on a month by month basis were:

July 1968

The plant was shut down once for maintenance. The shutdown lasted 3-1/3 days. Main plant and ATU operations were steady during the month with the exception of a 45 minute shutdown of P-24 due to switchgear problems, on July 16. A new air conditioner was installed in the switchhouse on July 23; this eliminated motor control overheating as a cause of plant upsets/shutdowns.

August 1968

The plant was shutdown twice for maintenance. Twenty plant leaks were repaired during the first outage. The second outage was taken to insure the ATU the best chance of completing its last scheduled run during Development Run 15. Testing, at the completion of this shutdown, revealed a severely corroded and perforated steam chest in No. 1 evaporator, a few inches above the monel expansion pipe. Plant time was made available to Mr. Joe Burdett of Texas A&M three times during the month for a continuation of the taking of his special unsteady state data.

4. OPERATIONS (CONTD)

September 1968

This month saw an increase in the plant economy over that of August. The major reason for this was most probably due to the repair to the first effect steam chest, completed at the end of August.

P-24 shutdown on September 5 due to a ground in the control transformer. This was repaired on line.

P-4a was put on-line on September 11 in order to evaluate the new double-volute centrifugal pump as a spare for P-5a. Its operation was satisfactory for flow rates of 400,000 lbs/hr and above. Lower plant feed rates, which are accompanied by lower deaerator liquid levels, caused pump cavitation. The pump adequately handled feed rates of from 400,000 to 500,000 lbs/hr. until September 17 when, during a heavy rain and lightning storm, the motor grounded out and shutdown. P-5a was immediately put on and the plant experienced little upset.

Sodium sulfite addition to the deaerators effluent sea water was started on September 11. The injection point was immediately downstream of the P-4a/P-5a discharge tee. The trial injection rate used was 1 gph of a 3% tank solution. This chemical addition was continued for the remainder of the run.

The ATU was shutdown on September 13 for an inter-run scaling inspection. It was re-started the same day in order to complete its scheduled run.

During the ATU shutdown, plant time was again made available to Mr. Joe Burdett from Texas A&M, to enable him to complete his program of special testing to obtain data for his research project. Plant changes at his request included the following: 1) A typical pump failure, 2) A large sea water feed rate decrease to No. 1 Effect, 3) A large steam rate decrease to No. 1 Effect.

On September 13, the steam jet ejectors failed at the same time the Dow steam temperature increased from 484 to 562°F. After several attempts to restart them, they were shutdown. As the supply steam temperature remained abnormally high during the remainder of the run, the jets were not operated.

The ATU and main plant were shutdown on September 20, following a fresh water wash. This was a scheduled shutdown at the end of Development Run 15 and marked the beginning of the modification period between runs 15 and 16.

October 1968

The plant did not operate during October.

November 1968

The plant did not operate during November.

SECTION IV

ACTIVITIES

December 1968

Fresh water was circulated through the plant on December 11 through 13, in an effort to leak check the sea water system following the 82 day maintenance and modification period between Development Runs 15 and 16. Fresh water was used to avoid extended contact between stagnant sea water and stainless steel used throughout the plant. Extensive continuous testing with cold circulating sea water was started and continued to December 17. On the evening of December 17, the plant was put under full vacuum with all noise stopped in order to facilitate locating vacuum leaks. Sea water circulation was then restarted and continued into December 18 when the plant was started up. A shutdown for repairs to P-11 suction was performed on December 20. The plant was then brought back on line in 4 hours. On December 24, HX-318 cooling water circuits and P-3 discharge circuits were chlorinated for one hour each. On December 31 the plant was placed on full freeze protection for a predicted low of 26-28°F.

The front end conditions (No. 1 Effect) were held to 31.5 PSIG maximum chest pressure and 266°F maximum sump temperature. Rear end conditions (No. 17 Effect) of lowest final condensing temperature possible were achieved by full circulation of sea water through HX-318 and by operating the first stage steam jet in series with the vacuum pump. No. 1 Effect condensate was on direct flash to flash tank No. 2, HX-306x was operated in full condensing mode, and full plant venting was in effect. No brine blending was done at P-3 and the deaerator pressure was controlled to allow 0.8°F flashdown of the 5.2 to 5.6 pH sea water feed to this unit. Stripping steam was taken from No. 17 steam chest at 500 to 1,000 lbs./hr. and caustic and catalyzed sulfite were added to the deaerator sea water effluent to control to 6.5-7.0 pH and 0 ppB oxygen, respectively.

January 1969

On January 2, plant was shutdown for repairs to: (a) H-308 top tube sheet; (b) P-14 discharge elbow; (c) P-15 motor ground; (d) HX-318 hand hole; (e) top water box clean outs of HX-308 through 311. The plant was restarted same day.

On January 21, plant was shutdown for repairs to: (a) P-24 suction cover; (b) P-3 brine blending valve; (c) P-12 coupling; (d) Dow-Smith Chemline pipe test spool; (e) P-15 discharge elbow; (f) No. 4 top vent valve; (g) desuperheater water line; (h) No. 8 LCV; (i) power meter; (j) P-25 seal. The plant was restarted same day.

SECTION IV

ACTIVITIES

February 1969

High tides caused by 50 to 60 mile per hour winds caused in-plant flooding on February 14. An imminent plant shutdown was averted by recycling at the pit and the closing of flood gates by The Dow Chemical Company.

The training of an additional plant operator was initiated on February 18. This training continued until one man was qualified for this position.

High product conductivity necessitated the blocking in of HX-307 condensate drain and vents, an internal leak being indicated in this area.

March 1969

The peak day gross production ocurred on March 13, 1969, and was 1,180,000 gallons. This sets a new record for a 24 hour production period for the 17 effect plant.

There were two (2) shutdowns during the month. These were on the dates and as a result of malfunctions as follows:

March 2:

1. High conductivity of product water from effect 7.
2. A leak in the discharge line of P-20 blowdown pump.

March 20:

1. Continuous increase in the conductivity of the product water from HX-308.

During the two (2) periods of down time miscellaneous repairs were made as required to enhance continuous plant operation.

April 1969

There were five (5) shutdowns during the month.

May 1969

Instructions were received to shut the plant down from Mr. John Newton, Manager, OSW, Freeport Test Facility.

June - September 1969

The plant did not operate in any of the months June through September, 1969.

In late September, 1969, the plant was secured for a long-term shutdown. The procedure consisted mainly of keeping the plant under vacuum and partly filled with deaerated fresh water to which sodium sulfite had been added.

SECTION IV

ACTIVITIES

5. MAINTENANCE ACTIVITIES

Support of the R&D program entailed a great deal of effort on the part of the plant force as did modifications to the plant. The following activities were carried out during the entire year but mostly in preparation for and during shutdown periods. Much of the work is typical of that required to keep equipment working in a damp, saline atmosphere.

A. Evaporators

All the corrosion pits that were found in the sumps of Effects No. 2, 3, and 6 during the plant inspection in June, 1969, were ground down to bright metal, cleaned and repaired by fillwelding, to obtain a deep penetration into the base metal and to avoid porosity, underbead cracks and rough welds.

Twice during the year, sections of the demisters in Effect No. 12 were found to be dislodged. The probable cause was deterioration of the monel tie wire and process upsets. The tie-down wires were found to be loose, broken and corroded on the sections of the demisters still in place. The demisters were reinstalled and all broken, corroded and loose tie-down wires were replaced.

All evaporator cover lifting davits were repaired and lubricated.

Effects No. 1 and 2 steam chest tube bundle skirts were repaired with a 6" x 3/8" ring of mild steel from the top of the monel expansion ring to 6" above. Failures were due to external corrosion.

Pressure tap failures on the evaporator sump chests were caped off using an external weld patch on Effects 9, 10, and 11.

Evaporator No. 8 upper water box carbon steel liner failed and was replaced with new carbon steel 285C liner. It later required additional repair.

Evaporator No. 12 weld failure of the carbon steel flange to the alloy hub liner was repair welded.

Leaking dummy tubes in evaporators 3, 5, 6, and 7 lower tube sheets were replaced with new aluminum-brass dummy tubes; a total of 16 tubes.

Stainless banding failures were replaced on the pump suction screens in the evaporator sumps.

At each main shutdown, evaporators 1 through 17 sump manways and waterbox covers were removed and scale, mud, and silt were removed in preparation for inspection.

5. MAINTENANCE ACTIVITIES (CONTD)

The General Electric RTV-112 silicone rubber coating on No. 9 dome flange had torn in several places. This coating was removed, the area sandblasted and cleaned, and a new coating applied.

B. Heat Exchanges

Several heat exchangers failed due to a leak at the carbon steel drain plug in the upper tube sheet. The drain plug was replaced in kind and back welded.

All heat exchanger cover lifting davits have been repaired and lubricated. Failed heat exchanger cover lifting eyes on HX-302a through HX-311 were replaced in kind.

HX-318 Gaco EHS-55 epoxy coating was repaired in the inlet water box using spot sandblast on failed area and recoating with above material.

There were several heat exchanger external steam chest failures during the year. All were repaired by patch welding.

HX-311 failed; carbon steel liners in upper and lower waterboxes were replaced with carbon steel 285C plate.

Later in the year, repairs to HX-311 carbon steel pass partition baffle at the gasket surface were necessary because of the failure of the carbon steel pass partition gasket retaining strips that allowed the sea water to flow across this area. Also, the carbon steel liner to tube sheet weld failures in both the top and bottom waterboxs had to be weld repaired.

HX-310 was inspected for brine leaks; one tube was found to have failed. The top and bottom ends were plugged off using brass plugs and the unit tested for leaks with none indicated.

The General Electric RTV-112 silicone rubber coating in the inlet waterbox of HX-307 had separated from the tube sheet. This coating was not renewed since the field application was considered to be good -- the rubber's adhesion was not sufficient for the service.

C. Vessels

Brutem coal-tar epoxy coating was repaired in the upper 4' of the deaerator above the maspac. All nozzles not in use in the sump were capped out of service using a weld patch inside the deaerator. Brutem No. 130 epoxy was used for spot repairing.

An external repair patch was been installed on Flash Tank 7 in the area of the tank opposite the tangential condensate inlet. Failure was due to internal washout.

5. MAINTENANCE ACTIVITIES (CONTD)

Flash Tank No. 8 failed in the area opposite the tangential condensate inlet line from internal errosion and external corrosion. A repair patch of A285C plate was installed on the outer shell of the vessel 18" wide and extending approximately 50% around the outer circumference of the flash tank. The support bracket was also repaired.

D. Pumps

Centrifugal brine and condensate pumps required such normal maintenance attention as motor bearing replacement and pump seal adjustment and replacement.

The pumps equipped with mechanical seals required frequent attention. Some failures were due to brine corrosion of seal compression springs. Others were due to overheating because of plugging of the seal water system. At present, mechanical seals are not recommended for desalination plant service.

P-5a failed propeller shaft and upper shaft were repaired with Rokide coating. Failed marine type bearings were replaced in kind; Teflon seal packing was used in the packing gland. Epoxy coating on P-5a lower column was removed; serious pitting had occurred under the epoxy coating.

Corrosion of carbon steel suction covers was a continuing problem. A new suction cover was installed on P-20 pump suction with a test epoxy coating Scotchkote No. 306.

P-3 failed pump shaft was replaced along with new bearings and seals. The bronze impeller wear surface was built up with Bronze spray metal and turned to fit case wear rings. Impeller had vibration and appears to be out of balance or not centerline bored.

Later, P-3 brine pump shaft failed again. Failure due to impeller not fitting shaft with proper clearance causing wearing of the impeller hub. Parts installed were, new shaft, reconditioned and balanced impeller and new shaft bearings.

P-3 pump was inspected for loss of performance. The impeller was found to be undersized and damaged due to foreign material passing through the pump. The impeller was replaced with a 9-7/8" repaired bronze impeller.

P-53 pump impeller "Ni resist" failed and was replaced with used Ni resist impeller from salvage material. A repaired shaft was also installed. P-53 suction foot valve failed and was replaced in kind.

The little positive displacement metering pumps required considerable maintenance on everything from motor bearings to stroke linkage adjustment.

5. MAINTENANCE ACTIVITIES (CONTD)

There were some electrical problems. Several motors and several starter transformers burned out.

P-1 pit pump upper propeller failed. One blade of the propeller type impeller was broken off; this was evidently due to foreign material going through the pump bowl assembly. Parts replaced were propeller shaft, propeller, propeller locking collar, and all marine type bearings.

E. Instrumentation

For data gathering purposes, many of the instruments were frequently cleaned and calibrated. Special data gathering equipment frequently had to be installed and maintained.

Extra instrumentation maintenance was caused by the high oil and water content of the instrument air. The existing instrument air system should be replaced.

The antiquated brine level control systems in the 12 effect plant required considerable maintenance attention.

The main steam control valve and main steam pressure reducing valve were both overhauled as part of a preventative maintenance program.

F. Electrical

In October, 1968, all electrical switchgear starters were removed from service, inspected, and cleaned using high pressure solvent spray and brush wash. All bus bars, structure, and internal wiring was cleaned by removing them from structure then using fine emery cloth or electric wire buffing wheel.

After all cleaning was completed all buses were inspected for foreign material and high pressure washed; then wiped with dry clean rags. After approximately 16 hours time allowed for evaporation of cleaning agent the power was turned on; at this time 440 voltage short circuited on the lower bus insulator of section two in the switchgear. Considerable fire damage to much of the switchgear resulted. The entire plant wiring system was reworked by a subcontractor.

The rest of the year, such things as the plant lighting system, remote start/stop stations, motor starter transformers, the freeze protection system, etc., required routine maintenance.

The office 7-1/2 ton air conditioner compressor failed and was replaced by the service contractor.

5. MAINTENANCE ACTIVITIES (CONTD)

The motor leads from the switchgear to several pump motors failed. New wires had to be pulled into existing underground conduit.

G. Vacuum Equipment

When sandblasting the vacuum pump discharge muffler, it was found that internal corrosion resulted in several small holes on the bottom side of the muffler. Temporary repairs were made by welding a plate on the outer side of the shell of the muffler large enough to cover the corroded area.

Vacuum pump was inspected for low performance and noisy operation. Large quantities of scale and silt accumulation were found in four suction valves. Discharge valves were clogged with oil silt accumulation. Effective repairs were made as follows: suction and discharge valves were lapped and seated new feather springs installed, and the piston and cylinder were cleaned. The vacuum pump was reassembled and put back into operation. Subsequent performance was satisfactory.

An adequate moisture and debris knock-out system just ahead of the vacuum pump suction is needed.

H. Compressed Air

All during the year, regular preventative maintenance was required on all three instrument air compressors and the utility air compressor. The instrument air compressors required considerable attention; the instrument air was oil saturated and wet. The instrument air system should be brought up to date. Instrument air could be brought over from the Materials Test Center.

Number 3 Instrument Air Compressor failed. Failure was due to threads stripping out on the compressor block on the low pressure cylinder letting the cylinder work up and down with the piston which resulted in misalignment. This caused the piston rod to rub against the block and finally resulted in breaking the piston rod, piston, piston rings and bending the crankshaft. Effective repairs were made by having the cylinder honed, installing new piston rings, piston, piston connecting rod and crankshaft.

I. Research and Development Maintenance

Considerable effort was expended in support of the development program on such things as: instrument installation and calibration; sample coil fabrication, sample tube pulling, data taking; sample taking; hydrotesting; laboratory trailer maintenance; preparing equipment for retail inspection; etc.

5. MAINTENANCE ACTIVITIES (CONTD)

J. Piping

Carbon steel hot brine piping continued to fail rapidly at points of turbulence such as elbows, reducers, control valves, etc. Carbon steel straight runs and long sweep elbows - in which the brine velocity was kept below 5-7 ft/sec - did not require much attention.

During this time, much of the 6-8 year old carbon steel brine piping in the hot end of the plant was replaced with glass reinforced plastic pipe. Some of the glass reinforced fittings failed due to supporting and shop fabrication problems.

Control valve problems due to failed rubber seat and disc liners were experienced.

Much of the galvanized instrument and utility air piping had to be replaced because of failure due to external corrosion.

All major pipe support hangers were reworked and repaired.

K. Other Maintenance

Sandblasting and painting of the process area lines and vessels was continued all during the reporting period.

Replacement and renewal of grating, stairway treads, rails, etc. also was carried out during the entire reporting period.

New and replacement piping was insulated after installation. Vessel insulation was renewed and repaired as needed all during the two Development Runs.

In May and June of 1969, the entire plant was hydrotested, and then selected elements were thickness tested. Both efforts have been reported out under separate cover.

In the hydrotest, numerous very minor leaks were disclosed. The conclusion was that the plant was in operable condition and could safely withstand the working pressure. No serious faults were found during the vessel thickness testing.

SECTION IV

ACTIVITIES

6. PLANT SAFETY

The job of safety chairman for each month was rotated among the development engineer, chemist, maintenance and operations supervisors. The primary duties of the monthly safety chairman were:

a. Conduct the safety monthly meeting.

b. Conduct a monthly safety inspection and perform the duties as outlined under the Safety Inspection Program.

The safety meeting was attended by all available employees.

The topics discussed at this meeting were:

a. Items found on the current monthly safety inspection and the progress in completion of the items on the previous month's safety inspection report.

b. Any unsafe practices observed.

c. Any accidents or near accidents which occurred; what caused the accident or near accident; and what steps should be taken to prevent a recurrence.

d. Any special safety topics that would be of general interest.

e. Discussion of the safety precautions to be used on work coming up.

Minutes of the safety meeting were taken, typed and submitted to the plant superintendent within seven days after the meeting. After his approval of the minutes, they were distributed.

Major items of safety accomplishments during the year are listed below:

a. New danger warning signs were installed at the chlorine injection area, caustic barrel filling station, and mercury storage cabinet.

b. Temporary handrails were installed on catwalk to flash tank level gages on Effects 14, 15, and 16.

c. Hand-hold bars were installed in the module man-ways for assistance while entering module sumps.

6. PLANT SAFETY (CONTD)

d. Pocket respirators have been purchased and distributed to the new employees for protection from accidental emissions of acid gas from neighboring plants.

e. Upper deck structural grating repairs were completed.

f. Safety glasses were purchased for all employees.

Special care was taken all during the reporting period to keep the plant in safe operating condition.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

A. General

(1) Development of the vertical tube falling film desalination process has reached the stage of readiness for advanced hardware.

(2) The plant is now and has been kept in a safe operating condition. A thorough metal inspection has shown no unusual or significant flaws in the operating process equipment. Operation of both the module and the old 12 Effect plant can be continued safely for several years as long as the past routine preventitive maintenance procedures are followed.

B. Technical

On the basis of the work done during the reporting period at the Freeport Test Facility, the following conclusions are made:

(1) Overall Plant Performance

a. The overall performance of the 17 Effect plant did not decline noticeably between Development Runs 15 and 16. However, there was what appeared to be a significant decline in performance of some of the individual evaporators, probably due to venting problems and long-term tube fouling.

b. Sump-to-sump brine transfer is a satisfactory mode of operation. Level control in this mode is easy. Under proper design conditions, stratification or over concentration does not occur.

(2) Performance of Experimental Heat Transfer Equipment

a. The double fluted tube bundle performance declined significantly between Development Runs 15 and 16.

b. The titanium tube bundle performance was excellent and showed no decline between development runs. LTV evaporator tubes made of thin walled titanium tubing appear to perform and last well in a hot concentrated brine environment.

(3) Performance of Process Equipment

a. The condensate transfer system in the module is still inadequate. Further enlargement of the condensate transfer piping is indicated.

1. CONCLUSIONS (CONTD)

b. The performance of the module is significantly lowered by small amounts of non-condensable inleakage.

c. The performance of the heat rejection condenser is unsatisfactory; the heat rejection condenser performance declines significantly at low seawater temperatures.

d. The horizontally tubed vapor shear preheater performed well but not up to design during all of Development Run 16.

e. The porcelain spray nozzles do a better job of brine distribution than the SVL weirs. There is no measurable difference in heat transfer performance between tubes equipped with porcelain spray nozzles and tubes equipped with SVL weirs.

f. An acid mix chamber is not required to obtain satisfactory mixing of the acid and the seawater feed to the deaerator.

g. The deaerator effluent is a satisfactory sensing point for pH control. Controlling the deaerator effluent between a pH of 5.6 and 6.0 does not cause any scale or corrosion problems. Caustic neutralization can, under these conditions, be eliminated.

h. Sodium sulfite is successful in scavanging residual oxygen from the deaerator brine. However, removal of the residual oxygen does not significantly affect indirectly measured plant corrosion rates.

i. The deaerator effluent-dissolved oxygen level runs between 50 - 100 ppB. The optimum deaerator operating conditions appear to be one pound of stripping steam per thousand pounds of brine and about 0.5°F flash down at the deaerator top.

j. When making potable water only, the low temperature effects in the module can be operated without mist eliminators.

k. Shock chlorination is effective in preventing marine growth in circulating brine process streams.

(4) Materials Evaluation

a. If properly fabricated, glass reinforced plastic pipe holds up well in hot brine service. There is no significant difference in performance between the products of the two main producers of glass reinforced plastic pipe.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS (CONTD)

b. Cement liners can be used to protect carbon steel evaporator sumps.

c. CDA 194 is a satisfactory material for use in evaporator falling film tubes. The test of CDA 194 in heat exchanger tubes is not deemed significant because of the low brine velocity in the test exchanger.

(5) Scaling

a. With blended seawater, 273°F appears to be the incipient scaling point for LTV evaporator tubes.

b. If operating conditions are controlled properly, calcium sulfate anhydrite scale will gradually wash out of higher temperature effects.

(6) Data Gathering

a. The performance of the data gathering instrumentation has declined with time. Many of the critical instruments require replacement or recalibration if data precision is to be kept up.

b. The atomic absorption spectraphotometer is an exceptionally useful development engineering instrument. It can be used to perform large numbers of cation analyses rapidly and accurately.

c. The concentration of iron and copper in the effluent brine fluctuates in a random fashion during normal operations. The copper and iron concentration in the effluent brine is extremely high just after start-up and quickly drops down to a much lower equilibrium level.

d. The concentration of both calcium and magnesium in blended seawater is higher than the concentration of the cations in "normal" seawater.

2. RECOMMENDATIONS

The following recommendations are made on the basis of the work done during the reporting period at the Freeport Facility:

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

2. RECOMMENDATIONS

A. Overall Plant

(1) Install a high-temperature test module to determine the economics and performance of a multi-stage flash preheater, various enhanced surfaces at high temperatures, and novel bundle arrangements.

(2) Automate the plant so that no operator attention or surveillance is required outside of normal weekday working hours.

(3) The Auxiliary Test Unit objectives have been met with limited success. This unit required considerable operating and engineering attention. It should either be scrapped or shipped to Wrightsville Beach where it would receive the necessary engineering attention.

B. Pursue the Original Development Run 17 Objectives

(1) The brine flash-down device has been installed between Effects 13 and 14. If this device works, considerable savings in external brine piping will be realized in future plants. The device should be thoroughly tested during operations.

(2) The equipment for automatic pH control has been received. Automatic acid addition will save considerable operating attention and allow complete automation of an LTV desalination plant. It should be tested out as soon as possible.

(3) Venting in the low-temperature module is a problem. No. 15 Effect was equipped to carry out venting studies. The mechanical work on No. 15 Effect should be finished and the venting studies be carried out.

(4) There is considerable evidence that brine distribution irregularities exist, especially in the domed effects. The brine catchment and measurement system should be moved to one of the domed effects so that brine distribution patterns under different operating conditions can be observed.

C. Continue the Evaluation of Materials in Actual Operating Process Equipment

(1) Titanium has performed well in an evaporator tube bundle. Install a multi-stage flash preheater bundle with titanium to determine its effectiveness in preheater service.

2. RECOMMENDATIONS (CONTD)

(2) Tube out a preheater bundle with CDA 194 to expose the alloy to tube velocities between 7 and 10 feet per second on the brine side.

(3) Use CDA 194 alloy evaporator tubes in one of the high-temperature effects.

(4) Install stainless steel test spools in hot brine piping exposed to considerable turbulence.

(5) Put cement liners in high-temperature effects.

D. Improved Level of Precision of Data Gathering Equipment

(1) Replace main plant input and output fluid orifice meters with turbine meters.

(2) Discard all existing high-accuracy thermocouples. Carefully and selectively reinstrument the entire plant with precision grade platinum-resistance thermometers. The temperature measuring elements should be positioned in the effect steam chest rather than the steam transfer line. Attempts to measure brine temperature at the top and bottom of tube should be discarded. At least one effect should be instrumented in such a way as to determine the temperature profile in the steam chest.

(3) Obtain the equipment necessary to enable the keeping of the temperature sensing elements in proper calibration.

(4) Discard the absolute pressure manometers. Relocate the differential pressure manometer systems to the top deck so as to minimize problems with liquid in impulse lines.

(5) Defer any further work on the data logger until the new instrumentation is installed, calibrated, and proved out.

E. Staff the Plant to Accomplish the Development Engineering Objectives in the Field

(1) Provide the Development Engineer with field process engineering help.

(2) Provide the Development Engineer with the services of technicians for the purpose of data gathering and routine calculations.

2. RECOMMENDATIONS (CONTD)

F. Undertake Other Studies and Process Changes to Improve the Knowledge of the VTE Process

(1) Study limitations to plant capacity during cold weather. Add a third-stage jet ejector so that the heat rejection condenser can be properly vented during the winter when the water temperature gets down to 50°F.

(2) Determine how much carbon dioxide is absorbed out of the deaerator vent gas in the barometric precondenser and intercondenser.

(3) The double fluted tube bundles performance has significantly declined. Pull out several of the tubes; have some sent to be tested and compared against new tubes in a single or double-tube evaporator. Section and inspect the other tubes.

Run the double fluted tubes bundle in its present condition at the start of Development Run 17; then mechanically or chemically clean the bundle to determine if this brings the performance back to its original level.

Test out SVL weirs in the double fluted tube bundle.

(4) Install and test an internal bundle vent in the module preheater.

(5) By inspection determine the extent of the tube fouling in the various evaporators. Chemically or mechanically clean an entire section of the plant to determine how much performance is improved.

(6) Make probalog and ultrasonic inspection of metal thicknesses throughout the plant. Develop average mil per year corrosion rates for various materials in various environments.

SECTION VI

APPENDIX

PART I

DEVELOPMENT RUN 16
Detailed Heat and Material Balance 16-3
Data taken -- May 2, 1969

1 Foldout Sheet

SECTION VI

APPENDIX

PART II

FREEPORT TEST FACILITY
Mechanical and Instrument Flow Diagram
17 Effect
Revision 6; September 23, 1969

1 Foldout Sheet

SECTION VI

APPENDIX

PART III

DEVELOPMENT RUN 15
OPERATOR DATA SHEETS
From July 7, 1968 through
September 20, 1968

2 Foldout Sheets

DEVELOPMENT RUN 16
OPERATOR DATA SHEETS
From December 18, 1968 through
May 9, 1969

4 Foldout Sheets

U.S. Department of the Interior

OFFICE OF SALINE WATER
FREEPORT DEMONSTRATION PLANT

Operator Data Sheet 3 of 4 — Development Run No. 15

From 4-17-68 To 9-20-68

Prepared By

OPERATING TIME		PRODUCTION (INCLUDING CONDENSATE)					RAW MATERIALS					CHEMICALS		
		M GALLONS				POUNDS	STEAM (DOW)		POWER	SEA WATER FEED		ACID	SC. INH.	CAUSTIC
DATE	HOURS	DOW	FREE-PORT	PLANT	TOTAL	TOTAL M	TOTAL LBS. M	MAXIMUM RATE M LBS./HR.	TOTAL kwhr.	TOTAL LBS. M	MAXIMUM RATE M LBS./HR.	POUNDS	POUNDS	POUNDS
7-6	24	523	413	39	937	7,820	578	25	12,490	11,290	470	984		
7-7	24	521	392	39	913	7,630	557	24	12,490	10,920	455	984		
7-8	24	521	382	39	903	7,630	555	24	12,490	10,920	455	1,032		
7-9	24	513	406	40	959	8,000	570	25	12,220	10,980	465	984		
7-10	16.68	346	275	33	655	5,470	395	24	8,680	7,620	457	600		
7-11														
7-12														
7-13														
7-14	24	433	354	20	809	6,760	435	22	11,520	9,250	400	1,211		36
7-15	24	485	391	33	910	7,600	512	24	12,000	10,450	472	336		29
7-16	24	495	403	26	925	7,730	541	24	12,490	11,300	471	384		22
7-17	24	550	366	36	953	7,960	558	24	12,720	11,280	470	384		36
7-18	24	517	399	35	953	7,960	557	25	12,720	11,280	470	408		29
7-19	24	532	393	42	968	8,080	575	25	12,490	11,300	472	408		29
7-20	24	523	411	48	984	8,210	569	25	12,490	11,300	472	432		36
7-21	24	524	420	34	980	8,180	565	25	12,490	11,450	483	432		29
7-22	24	541	410	29	981	8,190	572	25	12,720	11,500	480	456		29
7-23	24	555	428	30	1,014	8,460	589	25	12,490	11,480	479	720		36
7-24	24	540	441	36	1,019	8,500	591	26	12,490	11,430	478	816		36
7-25	24	579	404	37	1,020	8,550	593	26	12,720	11,430	480	840		44
7-26	24	590	380	38	1,009	8,430	584	26	12,960	11,510	480	864		44
7-27	24	588	358	27	974	8,130	572	25	12,900	11,560	482	744		29
7-28	24	593	345	2	941	7,850	555	24	12,720	11,560	482	554		36
7-29	24	586	347	21	955	7,980	558	25	12,720	11,560	482	408		36
7-30	24	582	374	36	993	8,290	575	25	12,810	11,560	482	384		29
7-31	24	572	381	3	956	7,980	587	25	12,720	11,560	482	576		29
8-1	24	569	378	3	951	7,940	585	25	12,720	11,560	482	576		29
8-2	24	563	373	3	939	7,840	559	25	12,720	11,610	485	600		36
8-3	24	570	385	5	961	8,020	575	25	12,720	11,530	480	552		36
8-4	24	563	382	4	950	7,930	587	25	12,620	11,530	480	552		30
8-5	24	565	383	6	955	7,970	599	26	12,720	11,530	480	552		44
8-6	24	562	390	2	955	7,970	601	26	12,490	11,530	480	528		73
8-7	24	566	391	1	959	8,010	612	25	12,720	11,530	480	504		58
8-8	24	561	392	35	989	8,260	549	25	12,720	11,530	480	480		58
8-9	24	564	404	34	1,003	8,380	592	25	12,850	11,530	480	504		44
8-10	24	569	401	46	1,018	8,500	598	26	12,720	11,530	480	504		29
8-11	24	566	404	31	1,002	8,360	593	25	12,490	11,530	480	516		44
8-12	24	544	394	45	984	8,210	589	25	12,720	11,550	480	504		44
8-13	24	581	398	45	1,025	8,560	598	26	12,720	11,480	488	552		44
8-14	24	561	411	26	999	8,340	601	26	12,720	11,620	490	660		58

PROCESS CONDITIONS

	CONC. FACTOR		TEMPERATURES								PRESSURES				
													318 CONDENSER	VAPOR HEAD psia	
DATE	IN	OUT	SWF TO P-1	SWF TO NO. 1	DISCH. BRINE FROM 17	STEAM TO NO. 1	DOW STEAM	FREEPORT PRODUCT	VAPOR FROM 17	VAPOR FROM 1	TO NO. 1 psig	DOW STEAM psig	psia	NO. 1	NO. 17
7-6	0.92	2.62	85	264	105	274	501	101	109	265	30.2	155	1.0	38.54	1.24
7-7	0.97	2.97	83	264	104	274	503	100	107	265	30.2	156	1.0	38.54	1.17
7-8	0.92	2.67	85	264	106	274	504	101	110	265	30.0	156	1.4	38.54	1.27
7-9	0.94	2.69	84	264	105	274	500	101	109	265	30.1	156	1.3	38.54	1.24
7-10	0.94	2.67	84	264	105	274	501	100	109	265	30.2	155	1.1	38.54	1.24
7-11															
7-12															
7-13															
7-14	0.90	2.74	81	264	120	273	490	100	122	265	28.5	159	1.7	38.54	1.79
7-15	0.94	2.71	83	264	112	281	483	100	120	265	29.0	158	1.4	38.54	1.69
7-16	0.88	2.62	84	264	105	297	497	98	108	265	29.3	158	1.0	38.54	1.20
7-17	0.92	2.53	88	264	109	319	498	99	110	265	29.1	153	1.3	38.54	1.27
7-18	0.92	2.46	85	264	106	275	491	99	109	265	29.3	150	1.0	38.54	1.24
7-19	0.92	2.48	85	264	105	275	514	98	109	265	29.4	150	1.0	38.54	1.24
7-20	0.92	2.46	86	264	106	275	503	98	109	265	29.2	151	1.0	38.54	1.24
7-21	0.92	2.48	85	265	108	276	500	99	109	265	29.3	152	1.1	38.54	1.24
7-22	0.97	2.48	85	264	106	285	498	98	110	265	29.3	150	1.1	38.54	1.27
7-23	0.74	2.19	88	265	106	274	499	96	109	265	29.6	150	1.0	38.54	1.24
7-24	0.76	2.30	84	265	105	274	490	96	108	265	29.7	150	1.0	38.54	1.20
7-25	0.74	2.16	85	264	106	274	490	97	109	265	29.5	149	1.0	38.54	1.24
7-26	0.94	2.12	86	264	107	274	492	97	109	265	29.5	150	1.0	38.54	1.24
7-27	0.97	2.53	86	264	108	274	492	99	111	265	29.4	151	1.1	38.54	1.31
7-28	0.97	2.53	86	265	108	274	494	100	111	265	29.2	154	1.1	38.54	1.31
7-29	0.97	2.55	90	264	108	273	495	100	111	265	29.2	154	1.1	38.54	1.31
7-30	0.97	2.60	88	264	107	274	493	99	110	265	29.3	152	1.1	38.54	1.27
7-31	0.97	2.60	83	265	105	274	487	97	109	265	29.5	152	1.0	38.54	1.24
8-1	0.98	2.60	83	265	106	274	496	97	109	265	29.5	152	1.0	38.54	1.24
8-2	0.97	2.53	84	264	108	274	493	98	110	265	29.5	152	1.1	38.54	1.27
8-3	0.94	2.48	85	264	109	274	494	99	112	265	29.6	153	1.1	38.54	1.35
8-4	0.94	2.47	87	264	110	274	491	100	113	265	29.7	152	1.1	38.54	1.39
8-5	0.94	2.48	89	269	109	274	490	99	112	265	29.7	150	1.1	38.54	1.35
8-6	0.97	2.58	87	264	109	274	493	100	112	265	29.9	150	1.1	38.54	1.35
8-7	0.97	2.58	87	264	109	274	496	100	112	265	29.9	150	1.2	38.54	1.35
8-8	0.97	2.55	88	264	111	274	495	101	114	265	30.0	150	1.2	38.54	1.43
8-9	0.94	2.58	87	265	110	275	497	102	113	266	30.4	151	1.2	39.18	1.39
8-10	0.97	2.65	87	265	109	275	496	100	112	266	30.4	149	1.2	39.18	1.35
8-11	0.97	2.63	86	264	108	275	492	100	112	265	30.4	150	1.2	38.54	1.35
8-12	0.97	2.67	89	264	109	275	495	99	112	264	30.4	151	1.1	37.90	1.35
8-13	0.99	2.71	84	264	108	275	492	99	112	264	30.5	150	1.1	37.90	1.35
8-14	0.97	2.62	84	265	109	275	490	97	112	265	30.8	150	1.1	38.54	1.35

	pH	AMBIENT CONDITIONS							CALCULATED QUANTITIES AND RATIOS					
		DRY BULB TEMP.		WIND		PRECIPITATION								
DATE	FREEPORT PRODUCT	°F MINIMUM	°F AVERAGE	STR.	DIR.	FORM	INT.	DURAT. HOURS	EXTRACTION RATIO	H_2O SEP. M LBS.	CONDENSATE IN PRODUCT M LBS.	H_2O/LB. DOW STEAM FED WITH COND.	M LBS. H_2O PER kwhr	kwhr PER M LBS. SWF
7-6	7.7	72	78	Light	E	None			0.65	7,339	482	13.5	0.626	1.11
7-7	7.7	72	77	Light	SE	None			0.67	7,316	354	13.6	0.610	1.14
7-8	7.7	72	83	Light	SE	None			0.66	7,207	423	13.7	0.610	1.14
7-9	7.7	75	76	Light	NE	None			0.65	7,137	863	14.0	0.655	1.11
7-10	7.9	68	75	Light	E	Rain	Light	4	0.65	4,953	517	13.8	0.630	1.14
7-11														
7-12														
7-13														
7-14	7.9	75	80	Light	S	None			0.67	6,198	563	15.5	0.586	1.25
7-15	8.0	78	81	Light	SE	None			0.65	6,793	808	14.8	0.633	1.14
7-16	7.9	78	81	Light	SE	None			0.67	7,571	159	14.3	0.618	1.11
7-17	8.1	78	81	Light	S	None			0.64	7,219	741	14.2	0.625	1.13
7-18	8.2	78	79	Light	SW	Rain	Light	6	0.63	7,106	854	14.2	0.625	1.13
7-19	8.3	76	76	Light	SW	None			0.63	7,119	961	14.0	0.646	1.11
7-20	8.4	68	74	Light	N	Rain	Light	4	0.63	7,119	1,091	14.4	0.657	1.11
7-21	8.3	75	81	Light	SW	None			0.63	7,214	9,665	14.4	0.654	1.09
7-22	8.4	75	76	Light	SSW	None			0.61	7,015	1,175	14.3	0.643	1.11
7-23	8.4	75	81	Light	S	Rain	Hard	3	0.66	7,577	883	14.3	0.677	1.09
7-24	9.5	78	82	Light	SE	None			0.67	7,658	842	14.3	0.680	1.09
7-25	9.4	78	81	Light	SE	None			0.66	7,543	1,007	14.4	0.672	1.11
7-26	9.2	79	83	Light	SE	Rain	Light	5	0.56	6,446	1,984	14.4	0.650	1.04
7-27	9.4	78	80	Light	SE	None			0.62	7,167	963	14.2	0.630	1.12
7-28	9.4	82	84	Light	SE	None			0.62	7,167	683	14.1	0.617	1.10
7-29	9.2	78	82	Light	SE	None			0.62	7,167	813	14.2	0.627	1.10
7-30	9.3	78	82	Light	SE	None			0.63	7,283	1,007	14.4	0.647	1.11
7-31	9.3	78	82	Light	SE	None			0.63	7,283	697	13.5	0.627	1.10
8-1	9.0	78	81	Light	ESE	None			0.62	7,167	773	13.5	0.624	1.10
8-2	9.2	80	83	Light	SE	None			0.62	7,198	642	14.0	0.616	1.10
8-3	9.0	78	82	Light	E	Rain	Light	4	0.62	7,149	871	13.9	0.630	1.10
8-4	8.8	76	80	Light	E	Rain	Light	3	0.62	7,149	781	13.5	0.628	1.09
8-5	8.9	80	84	Light	SE	Rain	Light	4	0.62	7,149	821	13.3	0.626	1.10
8-6	8.7	79	80	Light	SE	None			0.63	7,264	706	13.3	0.630	1.08
8-7	9.2	76	82	Light	SE	None			0.63	7,264	746	13.1	0.629	1.10
8-8	9.4	78	80	Light	SE	None			0.62	7,149	1,111	15.0	0.649	1.10
8-9	9.3	76	81	Light	SE	None			0.64	7,379	1,001	14.1	0.652	1.11
8-10	9.2	80	82	Light	S	Rain	Light	6	0.73	8,417	83	14.2	0.668	1.10
8-11	9.1	76	81	Light	SW	Rain	Mod	8	0.73	8,417	(57)	14.0	0.669	1.08
8-12	9.2	82	81	Light	SW	None			0.74	8,547	(337)	13.9	0.645	1.10
8-13	9.3	80	83	Light	S	None			0.64	7,347	1,213	14.2	0.672	1.11
8-14	9.4	80	81	Light	SW	None			0.74	8,599	(259)	13.4	0.655	1.09

REMARKS

1. Sc. Inh. used: Polyphosphate

RUN TOTALS (WHERE APPLICABLE)

24 HOUR DAILY AVERAGE (WHERE APPLICABLE)

U.S. Department of the Interior

OFFICE OF SALINE WATER
FREEPORT DEMONSTRATION PLANT

Operator Data Sheet 4 of 4 — Development Run No. 15

From 4-17-68 To 9-20-68

Prepared By

OPERATING TIME / PRODUCTION (INCLUDING CONDENSATE) / RAW MATERIALS / CHEMICALS

DATE	HOURS	Production M Gallons: DOW	FREE-PORT	PLANT	TOTAL	Pounds: TOTAL M	Steam (Dow): TOTAL LBS. M	MAXIMUM RATE M LBS./HR.	Power: TOTAL kwhr.	Sea Water Feed: TOTAL LBS. M	MAXIMUM RATE M LBS./HR.	Acid: POUNDS	Sc. Inh.: POUNDS	Caustic: POUNDS
8-15	24	558	404	45	1,008	8,400	589	25	12,960	11,490	480	648		58
8-16	24	556	387	42	986	8,230	591	25	12,720	11,490	478	720		73
8-17	24	515	347	33	896	7,470	556	25	12,720	11,490	478	648		36
8-18	9.42	204	153	16	374	3,160	226	24	4,900	4,170	443	236	26	15
8-19														
8-20														
8-21														
8-22														
8-23							90					91		36
8-24	20.25	385	296	29	711	5,930	450	24	10,670	8,460	472	600		29
8-25	24	495	410	48	954	7,970	564	25	12,650	10,960	460	696		29
8-26	24	505	400	49	955	7,970	569	25	12,720	11,540	481	744		29
8-27	16.75	350	272	41	664	5,530	424	25	8,980	8,040	480	486		29
8-28														
8-29														
8-30														
8-31	20	391	342	41	775	6,470	470	23	10,810	9,810	490	417		29
9-1	24	511	411	53	976	8,140	532	23	12,960	11,770	490	600		88
9-2	24	519	428	54	1,002	8,370	556	24	12,930	11,750	489	864		117
9-3	24	513	403	55	972	8,100	546	24	12,960	11,700	488	624		77
9-4	24	504	425	45	974	8,130	544	24	12,960	11,390	490			36
9-5	24	536	399	23	958	7,980	533	24	12,960	11,770	490	672		58
9-6	24	564	428	23	1,015	8,460	574	25	13,020	11,730	489	648		44
9-7	24	565	447	12	1,026	8,560	596	25	12,850	11,750	500	648		44
9-8	24	575	435	14	1,025	8,550	586	25	12,960	12,000	500	648		36
9-9	24	557	419	30	1,007	8,390	583	25	13,000	12,000	500	600		44
9-10	24	564	433	10	1,008	8,400	600	26	12,960	12,000	500	600		36
9-11	24	554	445	4	1,004	8,380	572	26	11,800	12,110	541	744		51
9-12	24	525	453	6	985	8,220	598	26	12,820	11,880	500	552		51
9-13	24	516	383	33	933	7,780	528	26	12,960	12,000	500	384		51
9-14	24	570	398	33	1,001	8,350	578	25	13,200	11,420	481	456		58
9-15	24	560	405	32	997	8,310	571	25	13,270	11,190	472	552		58
9-16	24	601	293	41	936	7,810	515	24	13,050	10,240	456	384		49
9-17	24	511	306	45	864	7,200	477	23	12,520	9,600	400	264		49
9-18	24	505	317	45	868	7,240	474	22	12,710	9,840	410	264		17
9-19	24	490	332	45	868	7,240	471	21	14,000	9,840	410	336		
9-20	16.25	257	198	29	485	4,040	261	22	8,570	6,670	410	453		
	3,129													

PROCESS CONDITIONS

DATE	Conc. Factor: IN	OUT	Temperatures: SWF TO P-1	SWF TO NO. 1	DISCH. BRINE FROM 17	STEAM TO NO. 1	DOW STEAM	FREEPORT PRODUCT	VAPOR FROM 17	VAPOR FROM 1	Pressures: TO NO. 1 psig	DOW STEAM psig	318 CONDENSER psia	VAPOR HEAD psia NO. 1	VAPOR HEAD psia NO. 17
8-15	0.97	2.60	83	264	109	275	494	97	113	265	30.8	152	1.2	38.54	1.39
8-16	0.97	2.58	82	264	109	275	488	96	112	265	30.2	154	1.1	38.54	1.35
8-17	0.90	2.43	83	262	109	274	483	96	112	263	29.2	155	1.1	37.27	1.35
8-18	0.87	2.58	84	263	115	274	475	98	118	264	29.2	151	1.3	37.90	1.60
8-19															
8-20															
8-21															
8-22															
8-23															
8-24	0.87	2.45	86	252	105	259	474	95	106	252	27.0	153	1.1	30.88	1.13
8-25	0.87	2.55	86	264	109	273	486	98	112	265	29.7	150	1.2	38.54	1.35
8-26	0.91	2.00	90	264	118	274	568	98	121	266	30.0	145	1.6	39.18	1.74
8-27	0.96	2.30	85	265	116	274	565	100	120	266	29.9	145	1.5	39.18	1.69
8-28															
8-29															
8-30															
8-31	0.91	2.19	84	264	116	293	494	99	118	265	30.9	151	1.5	38.54	1.60
9-1	0.96	2.38	84	266	116	302	501	100	119	265	30.9	151	1.4	38.54	1.65
9-2	0.97	2.40	84	265	116	288	499	100	120	265	30.9	151	1.5	38.54	1.69
9-3	0.97	2.39	87	266	116	280	496	100	119	265	31.0	150	1.4	38.54	1.65
9-4	0.99	2.48	87	266	116	291	498	100	119	266	31.0	148	1.4	39.18	1.65
9-5	0.97	2.53	85	265	116	291	490	100	119	265	30.5	147	1.4	38.54	1.65
9-6	0.97	2.53	83	265	113	276	483	98	118	265	31.0	147	1.3	38.54	1.60
9-7	0.97	2.71	83	265	104	276	483	96	108	265	31.4	146	1.0	38.54	1.20
9-8	0.97	2.67	82	265	105	276	487	96	108	265	31.5	146	1.0	38.54	1.20
9-9	0.97	2.48	83	265	107	276	483	98	110	265	31.4	145	1.0	38.54	1.27
9-10	0.94	2.48	88	265	105	276	489	97	109	265	31.6	146	1.1	38.54	1.24
9-11	0.94	2.58	82	266	106	279	504	95	107	265	31.6	148	1.1	38.54	1.17
9-12	0.97	2.81	80	265	102	277	489	94	107	265	31.3	152	0.9	38.54	1.17
9-13	0.92	2.43	80	265	104	278	505	95	112	265	28.6	153	1.1	38.54	1.35
9-14	0.94	2.39	79	264	114	308	564	97	117	264	31.4	158	1.4	37.90	1.56
9-15	0.94	2.46	84	265	115	315	566	99	118	264	31.8	156	1.4	37.90	1.60
9-16	0.97	2.85	84	264	115	299	556	99	118	263	28.0	157	1.4	37.27	1.60
9-17	0.94	2.85	82	256	114	276	546	99	117	256	24.9	158	1.4	33.09	1.56
9-18	0.94	2.62	81	255	115	277	550	98	118	255	24.0	158	1.4	32.53	1.60
9-19	0.97	2.68	79	256	112	285	544	96	116	255	24.1	156	1.4	32.53	1.51
9-20	0.97	2.58	80	256	115	273	544	99	118	256	24.0	156	1.4	33.09	1.60

pH / AMBIENT CONDITIONS / CALCULATED QUANTITIES AND RATIOS

DATE	pH: FREEPORT PRODUCT	Dry Bulb Temp. °F MINIMUM	°F AVERAGE	Wind: STR.	DIR.	Precipitation: FORM	INT.	DURAT. HOURS	EXTRACTION RATIO	H_2O SEP. M LBS.	CONDENSATE IN PRODUCT M LBS.	H_2O/LB. DOW STEAM FED WITH COND.	M LBS. H_2O PER kwhr	kwhr PER M LBS. SWF
8-15	9.1	80	81	Light	S	None			0.63	7,239	1,161	14.2	0.648	1.13
8-16	9.3	80	87	Light	S	None			0.63	7,239	991	13.9	0.647	1.11
8-17	8.4	80	83	Light	SSW	Rain	Hard	12	0.63	7,239	231	13.4	0.587	1.11
8-18	8.4	79	79	Light	S	None			0.66	692	2,468	13.9	0.645	1.17
8-19														
8-20														
8-21														
8-22														
8-23		84	85	Light	S	None								
8-24	8.1	77	80	Light	S	Rain	Light	20	0.65	5,499	431	13.1	0.555	1.26
8-25	8.3	78	79	Light	S	Rain	Light	16	0.66	7,894	76	14.1	0.630	1.15
8-26	8.3	79	80	Light	S	None			0.55	6,347	1,623	13.9	0.626	1.10
8-27	8.2	74	83	Mod	S	Rain	Hard	2	0.58	4,663	867	13.0	0.615	1.12
8-28														
8-29														
8-30														
8-31	7.6	78	78	Light	S	Rain	Light	6	0.59	5,788	682	13.8	0.598	1.10
9-1	8.0	70	79	Light	SE	None			0.60	7,062	1,078	15.2	0.628	1.10
9-2	8.2	78	78	Light	SE	Rain	Mod	16	0.60	7,050	1,320	15.0	0.647	1.10
9-3	8.1	70	78	Light	S	Rain	Light	12	0.60	7,020	1,080	14.8	0.625	1.12
9-4	8.2	78	81	Light	S	None			0.60	6,834	1,296	14.9	0.627	1.14
9-5	8.6	70	73	Brisk	SE	Rain	Hard	11	0.62	7,297	683	14.9	0.615	1.10
9-6	8.7	70	74	Mod	SE	None			0.62	7,273	1,187	14.7	0.649	1.11
9-7	8.6	72	76	Light	NE	Rain	Hard	8	0.64	7,520	1,040	14.3	0.666	1.09
9-8	8.6	75	73	Light	NE	Rain	Light	5	0.64	7,680	870	14.6	0.659	1.08
9-9	8.5	73	77	Light	E	Rain	Light	8	0.61	7,320	1,070	14.4	0.645	1.08
9-10	8.4	70	75	Light	N	None			0.62	7,440	960	13.9	0.648	1.08
9-11	8.4	68	72	Light	NE	None			0.64	7,750	630	14.6	0.710	0.97
9-12	8.2	72	73	Light	N	None			0.66	7,841	379	13.7	0.641	1.08
9-13	8.1	67	67	Light	N	None			0.62	7,440	340	14.9	0.600	1.08
9-14	8.4	72	75	Light	E	Rain	Light	16	0.61	6,966	1,388	14.4	0.632	1.15
9-15	8.4	74	78	Light	S	None			0.62	6,938	1,372	14.5	0.626	1.19
9-16	8.4	77	81	Light	S	None			0.66	6,758	1,052	15.1	0.598	1.27
9-17	8.5	65	69	Brisk	S	Rain	Hard	8	0.67	6,432	768	15.0	0.575	1.30
9-18	8.5	62	72	Light	SE	None			0.64	6,298	942	15.2	0.569	1.29
9-19	8.5	67	72	Light	S	None			0.64	6,297	943	15.3	0.517	1.42
9-20	8.5	76	77	Light	SE	None			0.63	4,202	(162)	15.4	0.471	1.29

REMARKS

1. Sc. Inh. used: Polyphosphate

RUN TOTALS (WHERE APPLICABLE)

24 HOUR DAILY AVERAGE (WHERE APPLICABLE)

U.S. Department of the Interior

OFFICE OF SALINE WATER
FREEPORT DEMONSTRATION PLANT

Operator Data Sheet — Development Run No. 16

1 of 4

From 12-18-68 To 5-9-69

Prepared By

Operating Time, Production, Raw Materials, Chemicals

Date	Hours	Production (Including Condensate) M Gallons: Dow	Freeport	Plant	Total	Pounds: Total	Raw Materials Steam (Dow): Total Lbs. M	Maximum Rate M Lbs./Hr.	Power: Total kwhr.	Sea Water Feed: Total Lbs. M	Maximum Rate M Lbs./Hr.	Chemicals Acid: Pounds	Sc. Inh.: Pounds	Caustic: Pounds
12-18	1	11	6		18	151	96							
12-19	24	570	421	40	1,038	8,612	625	27	12,480	11,040	460	1,270		85.1
12-20	15.6	329	253	39	622	5,196	478	26	12,480	7,176	460	380		77.1
12-21	24	551	430	41	1,024	8,547	604	26	12,480	11,016	460	1,200		8
12-22	24	540	420	46	1,006	8,402	689	26	12,720	10,776	458	1,128	3.0	8
12-23	24	589	391	41	1,021	8,526	517	27	12,960	10,800	460	1,104	3.2	17.1
12-24	24	628	358	41	1,066	8,898	629	26	12,480	10,992	460	1,128	2.3	9
12-25	24	628	335	40	1,044	8,386	608	26	12,480	10,992	458	1,200	2.4	
12-26	24	633	341	40	1,014	8,470		26	12,480	10,968	458	1,248	2.4	18.3
12-27	24	594	384	41	1,020	8,518		26	12,480	10,848	455	1,248	5.1	37.8
12-28	24	594	381	40	1,016	8,486		27	12,480	10,800	451	1,248	10.5	94.4
12-29	24	579	376	40	997	8,324		26	12,480	10,800	451	1,248	5.5	56.1
12-30	24	576	374	40	991	8,275	605	26	12,480	10,800	450	1,248	13.0	
12-31	24	555	389	30	976	8,146	644	27	12,720	10,848	453	1,248	22.7	36.9
1-1	24	502	416	2	920	7,683	637	27		10,848	453	1,104	20.4	26.3
1-2	16.9	280	194	18	493	4,116	402	27	13,920	7,638	452	777	9.4	25.5
1-3	24	521	430	35	988	8,245	623	27	14,640	10,728	450	1,200	11.2	26.3
1-4	24	508	458	36	1,002	8,368	636	27		10,800	453	1,171	17.9	25.1
1-5	24	486	441	18	946	7,898	615	26		10,800	451	1,104	17.5	26.5
1-6	24	553	414	29	996	8,320	609	26		10,608	448	1,656	20.6	25.0
1-7	24	581	393	38	1,013	8,455	568	26		10,584	441	1,440	18.2	36.5
1-8	24	583	394	39	1,016	8,486	579	25		10,560	441	1,248	15.3	70.5
1-9	24	576	397	39	1,013	8,454	587	26		10,560	441	665	20.9	29.3
1-10	24	571	390	40	1,003	8,370	589	26		10,560	441	624	19.1	13.8
1-11	24	575	320	47	941	7,860	589	25		10,560	441	576	13.2	14.4
1-12	24	571	368	51	990	8,269	482	25		10,560	441	576	14.0	7.3
1-13	24	589	372	50	1,012	8,451	584	25		10,608	441	600	22.7	7.3
1-14	24	613	411	19	1,044	8,716	581	25		10,776	461	672	7.1	15.6
1-15	24	620	418	15	1,054	8,802	578	25		11,040	461	672	7.3	7.3
1-16	24	624	413	14	1,052	8,786	580	25		11,040	460	672	5.7	12.1
1-17	24	623	412	16	1,051	8,778	569	25		10,992	458	624	6.6	4.1
1-18	24	625	412	19	1,057	8,821	575	25		10,992	458	624	6.4	17.2
1-19	24	642	393	18	1,054	8,800	584	25		10,992	458	624	7.2	9.0
1-20	24	662	386	18	1,067	8,911	575	25		10,848	455	624	5.4	8
1-21	10	231	158	13	404	3,372	317	25	12,240	4,400	452	260	1.9	4
1-22	24	597	397	33	1,028	8,582	570	25		10,584	456	504	10.4	4
1-23	24	457	358	37	853	7,121	410	24		9,528	458	504	5.3	4
1-24	24	412	414	40	866	7,231	453	24		8,736	492	384	4.8	4
1-25	24	591	417	39	1,048	8,746	595	25		11,760	490	576	7.5	18
1-26	24	577	442	37	1,057	8,821	577	25		11,688	487	552	8.0	18

Process Conditions

Date	Conc. Factor: In	Out	Temperatures: SWF to P-1	SWF to No. 1	Disch. Brine from 17	Steam to No. 1	Dow Steam	Freeport Product	Vapor from 17	Vapor from 1	Pressures: To No. 1 psig	Dow Steam psig	318 Condenser psia	Vapor Head psia No. 1	No. 17	pH: Freeport Product
12-18																
12-19	0.77	2.51	57	259	89	277	457	74	93	261	31.5	157	0.6	36.04	0.77	7.9
12-20			57	260	89	293	463	74		261		162	0.6	36.04		8.0
12-21	0.75	2.57	60	265	88	336	470	74	92	262	31.5	162	0.6	36.65	0.74	8.3
12-22	0.76	2.72	62	261	88	310	471	79	93	256	31.3	162	0.6	33.09	0.77	8.2
12-23	0.75	2.63	61	265	88	298	467	78	92	265	31.5	162	0.6	38.54	0.74	8.5
12-24	0.77	2.54	62	261	88	277	463	74	91	264	31.6	159	0.5	37.90	0.72	8.4
12-25	0.78	2.53	61	265	92	276	464	74	94	266	31.5	160	0.6	39.18	0.79	8.4
12-26	0.80	2.56	61	260	87	275	459	75	90	263	31.4	160	0.6	37.27	0.70	8.6
12-27	0.76	2.50	60	261	88	289	456	75	91	263	31.6	159	0.6	37.27	0.72	8.5
12-28	0.75	2.41	56	264	86	275	464	74	88	263	31.5	160	0.5	37.27	0.66	8.6
12-29	0.78	2.44	57	262	86	274	467	74	89	263	31.6	160	0.5	37.27	0.68	8.5
12-30	0.78	2.45	58	262	87	275	467	74	90	263	31.5	160	0.5	37.27	0.70	8.5
12-31	0.77	2.35	57	262	87	275	464	74	89	263	31.2	160	0.5	37.27	0.68	8.6
1-1	0.78	2.35	53	262	85	276	469	71	87	264	31.2	164	0.5	37.90	0.64	8.4
1-2	0.78	2.30	51	262	84	275	466	71	87	264	30.0	163	0.5	37.90	0.64	8.0
1-3	0.77	2.36	52	263	85	276	461	70	88	264	31.5	162	0.5	37.90	0.66	8.4
1-4	0.76	2.30	50	263	84	276	460	69	86	264	31.4	165	0.5	37.90	0.62	8.5
1-5	0.72	2.25	50	262	83	276	464	68	86	264	31.6	166	0.4	37.90	0.62	8.4
1-6	0.74	2.35	51	262	83	288	468	69	87	264	31.7	162	0.5	37.90	0.64	8.5
1-7	0.76	2.41	52	262	84	319	466	70	87	263	31.5	162	0.5	37.27	0.64	8.6
1-8	0.76	2.47	54	266	85	317	465	72	89	262	31.3	161	0.5	36.65	0.68	8.4
1-9	0.78	2.53	55	261	86	314	468	73	89	262	31.2	161	0.5	36.65	0.68	8.5
1-10	0.78	2.43	54	263	84	306	460	71	86	263	31.4	162	0.5	37.27	0.62	8.5
1-11	0.81	2.55	58	263	82	304	459	69	87	263	31.4	161	0.4	37.27	0.64	9.0
1-12	0.78	2.35	56	263	82	308	458	68	86	263	31.3	161	0.4	37.27	0.62	9.5
1-13	0.78	2.45	55	263	82	314	461	68	86	262	31.3	162	0.4	36.65	0.62	9.5
1-14	0.78	2.69	57	263	84	306	459	73	86	263	31.5	160	0.5	37.27	0.62	9.4
1-15	0.78	2.65	57	263	82	307	460	74	86	263	31.5	160	0.4	37.27	0.62	9.4
1-16	0.78	2.65	56	263	82	304	461	74	86	262	31.4	162	0.4	36.65	0.62	9.4
1-17	0.78	2.62	58	263	84	303	460	75	87	263	31.5	160	0.4	37.27	0.64	9.3
1-18	0.76	2.62	59	263	84	313	472	74	87	263	31.4	161	0.5	37.27	0.64	9.3
1-19	0.74	2.53	59	263	84	311	474	75	87	263	31.5	158	0.5	37.27	0.64	9.3
1-20	0.74	2.58	60	263	84	310	464	75	88	263	31.4	161	0.4	37.27	0.66	9.0
1-21	0.74	2.52	57	263	85	314	468	76	89	263	31.0	161	0.5	37.27	0.68	8.2
1-22	0.76	2.67	55	263	85	313	464	75	89	263	31.1	159	0.5	37.27	0.68	8.2
1-23	0.99	2.51	56	248	81	289	459	75	86	248	19.0	165	0.4	28.80	0.62	9.3
1-24	0.81	2.51	55	239	79	313	461	74	84	240	22.8	171	0.3	24.97	0.58	9.3
1-25	0.99	2.65	53	263	107	309	465	75	84	263	31.4	164	0.4	37.27	0.58	9.3
1-26	1.01	2.76	55	263	82	323	467	76	85	262	31.4	164	0.4	36.65	0.60	9.3

Ambient Conditions, Calculated Quantities and Ratios

Date	Dry Bulb Temp. °F Minimum	°F Average	Wind: Str.	Dir.	Precipitation: Form	Int.	Durat. Hours	Extraction Ratio	H_2O Sep. M Lbs.	Condensate in Product M Lbs.	H_2O/Lb. Dow Steam Fed with Cond.	M Lbs. H_2O per kwhr	kwhr per M Lbs. SWF
12-18													
12-19	44	48	Light	N	None			.693	7,851	762	12.8	.690	1.09
12-20	57	60	Light	SE	None						9.9	.416	1.73
12-21	65	65	Light	S	Rain	Mod	16	.708	7,799	748	13.1	.685	1.13
12-22	47	51	Mod	SW	Rain	Mod	16	.721	7,769	633	11.2	.661	1.18
12-23	33	41	Light	S	None			.715	7,722	805	15.5	.658	1.20
12-24	34	44	Light	S	None			.697	7,661	1,237	13.1	.713	1.14
12-25	54	56	Light	S	None			.692	7,605	780	12.8	.672	1.14
12-26	60	62	Light	S	None			.687	7,535	935		.679	1.14
12-27	55	61	Light	S	None			.696	7,297	1,221		.683	1.15
12-28	41	51	Light	S	None			.689	7,234	1,253		.680	1.16
12-29	51	55	Light	S	None			.680	7,344	980		.667	1.16
12-30	60	62	Light	SW	Rain	Light	16	.682	7,366	910	12.7	.663	1.16
12-31	36	40	Light	NW	None			.672	7,290	856	11.7	.640	1.17
1-1	31	38	Light	N	None			.668	7,246	437	11.1		
1-2	42	44	Light	NE	Rain	Light	18	.661	5,049	(932)	9.2	.300	1.82
1-3	45	49	Mod	E	Rain	Mod	7	.674	7,231	1,014	12.2	.563	1.36
1-4	34	37	Light	N	None			.670	7,236	1,132	12.2		
1-5	31.5	40	Light	N	None			.680	7,344	554	11.8		
1-6	41.5	53	Light	N	None			.685	7,266	1,054	12.6		
1-7	51	58	Light	S	None			.685	7,250	1,205	13.9		
1-8	65	65	Light	SE	None			.692	7,308	1,179	13.7		
1-9	44	49	Light	N	Rain	Light	4	.692	7,308	1,147	13.4		
1-10	38.5	44	Light	N	None			.679	7,170	1,200	13.2		
1-11	47	50	Light	N	None			.682	7,202	658	12.3		
1-12	40	50	Light	N	None			.668	7,054	1,216	16.2		
1-13	55	59	Light	NE	None			.682	7,235	1,216	13.5		
1-14	55	56	Light	NE	None			.710	7,651	1,066	14.0		
1-15	58	61	Light	SE	None			.706	7,794	1,008	14.2		
1-16	59	60	Light	SE	Rain	Light	7	.706	7,794	992	14.1		
1-17	55	58	Light	SE	None			.702	7,716	1,063	14.4		
1-18	58	59	Calm	NE	None			.710	7,804	1,017	14.3		
1-19	55	55	Light	NE	None			.708	7,782	1,019	14.1		
1-20	57	58	Light	S	None			.713	7,735	1,177	14.5		
1-21	59	60	Light	S	None			.706	3,106	266	9.6	.275	2.78
1-22	64	64	Light	S	None			.715	7,568	1,015	14.1		
1-23	60	67	Mod	NW	None			.606	5,774	1,348	16.4		
1-24	40	45	Light	N	None			.677	5,914	1,318	15.0		
1-25	38	45	Light	NE	None			.626	7,362	1,385	13.7		
1-26	58	60	Light	SE	None			.634	7,410	1,412	14.3		

REMARKS

1. Scale Inhibitor used was Catalyzed Sodium Sulfite.

RUN TOTALS (WHERE APPLICABLE)

24 HOUR DAILY AVERAGE (WHERE APPLICABLE)

U.S. Department of the Interior

OFFICE OF SALINE WATER
FREEPORT DEMONSTRATION PLANT

Operator Data Sheet — Development Run No. 16

2 of 4

From 12-18-68 To 5-9-69

Prepared By

OPERATING TIME		PRODUCTION (INCLUDING CONDENSATE)					RAW MATERIALS					CHEMICALS		
		M GALLONS				POUNDS	STEAM (DOW)		POWER	SEA WATER FEED		ACID	SC. INH.	CAUSTIC
DATE	HOURS	DOW	FREE-PORT	PLANT	TOTAL	TOTAL	TOTAL LBS. M	MAXIMUM RATE M LBS./HR.	TOTAL kwhr.	TOTAL LBS. M	MAXIMUM RATE M LBS./HR.	POUNDS	POUNDS	POUNDS
1-27	18.3	405	459	29	894	7,462	472	25		8,692	480	552	4.0	46.7
1-28	19.5	351	248	27	627	5,238	319	25	12,480	8,638	456	449	4.1	9
1-29														
1-30														
1-31	9.2	187	140	9	337	2,814	238	22	12,000	3,680	400	122	0.7	
2-1	24	548	403	31	983	8,203	499	22	12,000	9,600	401	312	4.7	9.2
2-2	24	549	402	31	983	8,210	499	22	12,000	9,600	401	312	3.9	9.2
2-3	24	561	444	30	1,036	8,648	559	26	12,000	10,488	496	408	3.8	9.5
2-4	24	553	439	31	1,096	8,987	598	26	12,960	11,808	492	552	6.4	14.1
2-5	24	596	424	30	1,065	8,888	568	25	12,960	11,760	492	552	6.5	14.0
2-6	24	616	417	29	1,064	8,880	578	25	13,200	11,760	492	600	9.0	18.8
2-7	24	600	433	30	1,063	8,877	566	25	12,960	11,808	492	624	9.0	9.4
2-8	24	599	419	28	1,047	8,737	573	25	12,720	11,808	492	624	5.2	18.7
2-9	24	594	427	28	1,050	8,768	568	25	12,720	11,808	492	624	8.0	18.5
2-10	24	592	432	28	1,053	8,793	566	24	12,720	11,808	492	792	7.4	28.2
2-11	24	589	425	31	1,045	8,727	566	25	12,720	11,808	492	1,032	4.6	27.5
2-12	24	593	428	29	1,051	8,776	573	25	12,960	11,808	492	1,080	3.8	53.7
2-13	24	618	412	30	1,061	8,859	594	26	12,960	11,808	492	936	12.0	50.3
2-14	24	601	410	29	1,041	8,690	604	26	12,960	11,832	492	950	12.3	72.4
2-15	24	670	416	29	1,116	9,315	611	26	12,720	11,808	492	950	19.3	12.7
2-16	24	647	414	29	1,092	9,114	607	26	12,480	11,808	492	950	21.3	26.6
2-17	24	646	400	31	1,078	9,001	608	26	12,960	11,808	492	604	18.7	79.1
2-18	24	649	406	29	1,085	9,057	604	26	12,720	11,808	492	604	8.2	8.5
2-19	24	638	403	30	1,073	8,954	591	26	12,720	11,808	492	604	21.4	8.5
2-20	24	643	417	31	1,092	9,115	613	27	12,720	11,808	492	622	14.8	4.3
2-21	24	645	435	33	1,115	9,306	627	27	12,720	11,808	492	622	15.6	4.2
2-22	24	643	415	34	1,092	9,120	598	26	12,480	11,808	492	622	12.6	17.3
2-23	24	647	404	36	1,087	9,078	591	25	12,480	11,808	492	640	11.9	8.7
2-24	24	649	399	36	1,085	9,059	583	25	12,720	11,808	492	622	16.3	8.8
2-25	24	627	417	36	1,080	9,020	617	25	12,480	11,808	492	622	14.7	8.8
2-26	24	639	415	33	1,088	9,082	595	26	12,480	11,808	492	602	9.1	8.8
2-27	24	622	405	31	1,059	8,839	584	26	12,620	11,808	492	636	9.8	8.8
2-28	24	624	432	52	1,109	9,260	604	26	12,680	11,808	492	604	10.9	3.7
3-1	24	626	446	10	1,083	9,040	591	26	12,580	11,808	492	604	16.8	4.7
3-2	15.6	436	275	14	726	6,059	361	26	12,510	7,675	492	392	9.9	4.6
3-3	6.5	133	152	13	298	2,493	181					93	2.6	
3-4	24	646	460	14	1,131	9,444	616	26	12,720	11,760	492	580	14.0	9.0
3-5	24	666	444	17	1,127	9,413	613	26	12,480	11,760	490	585	11.3	3.5
3-6	24	660	416	17	1,095	9,140	610	27	12,720	11,760	490	530	3.9	4.5
3-7	24	702	391	19	1,113	9,294	650	27	12,720	11,760	490	530	15.8	9.4

	PROCESS CONDITIONS															
	CONC. FACTOR		TEMPERATURES								PRESSURES					pH
													318 CONDENSER	VAPOR HEAD psia		
DATE	IN	OUT	SWF TO P-1	SWF TO NO. 1	DISCH. BRINE FROM 17	STEAM TO NO. 1	DOW STEAM	FREEPORT PRODUCT	VAPOR FROM 17	VAPOR FROM 1	TO NO. 1 psig	DOW STEAM psig	psia	NO. 1	NO. 17	FREEPORT PRODUCT
1-27	0.98	2.66	56	262	83	314	463	77	86	262	31.0	163	0.4	36.65	0.62	8.8
1-28	0.82	2.80	58	264	86	311	456	77	89	263	31.3	164	0.5	37.27	0.68	8.2
1-29																
1-30																
1-31	0.64	2.74	58	255	85	264	471	76	89	254	24.0	158	0.5	31.97	0.68	8.1
2-1	0.64	2.65	59	254	85	264	466	78	89	254	24.0	165	0.5	31.97	0.68	8.3
2-2	0.64	2.64	58	254	85	264	468	77	90	254	24.0	165	0.4	31.97	0.70	8.3
2-3	0.74	2.68	59	258	85	269	467	77	89	258	27.6	166	0.4	34.25	0.68	8.4
2-4	0.74	2.30	58	264	85	275	465	75	88	263	31.4	166	0.4	37.27	0.66	8.2
2-5	0.74	2.14	61	263	84	274	465	74	87	263	31.2	165	0.4	37.27	0.64	8.2
2-6	0.74	2.23	61	263	83	274	476	75	88	263	31.2	170	0.4	37.27	0.66	8.4
2-7	0.78	2.42	62	263	85	274	482	77	89	263	31.1	174	0.4	37.27	0.68	8.6
2-8	0.87	2.58	63	263	85	274	481	77	89	263	31.1	174	0.4	37.27	0.68	8.4
2-9	0.87	2.62	65	263	86	275	483	77	89	263	31.1	174	0.4	37.27	0.68	8.4
2-10	0.83	2.55	63	263	86	275	496	77	89	263	31.1	176	0.4	37.27	0.68	8.3
2-11	0.83	2.51	63	263	86	274	475	78	89	263	30.8	169	0.4	37.27	0.68	8.2
2-12	0.81	2.45	60	262	86	274	473	77	89	262	30.8	167	0.4	36.65	0.68	8.4
2-13	0.81	2.45	60	262	86	274	463	78	88	262	30.6	167	0.4	36.65	0.66	9.3
2-14	0.71	2.24	67	262	90	273	463	79	91	261	30.4	163	0.4	36.04	0.72	9.1
2-15	0.71	2.29	58	263	85	274	460	76	88	263	30.7	159	0.4	37.27	0.66	9.2
2-16	0.78	2.27	56	262	84	274	468	75	87	263	30.5	159	0.3	37.27	0.64	9.2
2-17	0.74	2.38	58	262	83	274	468	75	87	263	30.7	159	0.3	37.27	0.64	9.1
2-18	0.73	2.39	61	263	82	274	470	74	86	263	30.8	159	0.3	37.27	0.62	9.1
2-19	0.76	2.46	60	262	82	274	463	74	84	262	31.3	154	0.3	36.65	0.58	9.2
2-20	0.70	2.32	59	262	81	274	460	74	85	262	31.6	163	0.3	36.65	0.60	9.1
2-21	0.64	2.19	59	262	83	274	460	75	87	263	31.7	161	0.3	37.27	0.64	9.3
2-22	0.71	2.32	60	262	85	274	469	75	88	262	31.5	164	0.4	36.65	0.66	9.2
2-23	0.75	2.41	60	262	85	274	462	76	88	262	31.4	165	0.4	36.65	0.66	9.2
2-24	0.73	2.35	60	262	85	274	473	76	89	263	31.3	165	0.4	37.27	0.68	9.3
2-25	0.71	2.30	57	266	84	274	472	77	87	262	31.3	161	0.4	36.65	0.64	9.2
2-26	0.74	2.38	57	262	83	274	465	77	87	262	31.3	159	0.4	36.65	0.64	8.9
2-27	0.68	2.20	57	262	83	274	468	77	86	262	31.5	160	0.4	36.65	0.62	8.1
2-28	0.65	2.07	58	262	84	274	476	77	87	263	31.3	161	0.4	37.27	0.64	8.7
3-1	0.73	2.18	58	262	84	274	468	77	87	262	31.2	166	0.4	36.65	0.64	8.5
3-2	0.64	1.81	57	262	84	274	460	76	87	262	31.2	166	0.4	36.65	0.64	8.2
3-3	0.68	1.97														7.7
3-4	0.68	2.40	55	263	84	274	462	75	87	263	31.3	157	0.4	37.27	0.64	8.1
3-5	0.66	2.36	55	263	84	274	456	75	86	262	31.5	156	0.4	36.65	0.62	8.3
3-6	0.63	2.20	55	262	84	270	464	76	87	262	31.4	156	0.4	36.65	0.64	9.3
3-7	0.64	2.15	56	262	85	303	459	76	88	262	31.4	156	0.4	36.65	0.66	9.2

	AMBIENT CONDITIONS							CALCULATED QUANTITIES AND RATIOS					
	DRY BULB TEMP.		WIND		PRECIPITATION								
DATE	°F MINIMUM	°F AVERAGE	STR.	DIR.	FORM	INT.	DURAT. HOURS	EXTRACTION RATIO	H_2O SEP. M LBS.	CONDENSATE IN PRODUCT M LBS.	H_2O/LB. DOW STEAM FED WITH COND.	M LBS. H_2O PER kwhr	kwhr PER M LBS. SWF
1-27	60	64	Light	S	None			.632	5,494	1,968	14.8		
1-28	60	64	Light	S	None			.707	6,107	(868)	15.4	.419	1.44
1-29													
1-30													
1-31	65	65	Calm	S	None			.766	2,819	(4,000)	10.8	.234	3.26
2-1	60	64	Light	E	None			.758	7,277	927	15.4	.684	1.25
2-2	62	63	Light	SW	Rain	Light	10	.758	7,277	933	15.5	.684	1.25
2-3	46	48	Brisk	N	None			.724	7,593	1,056	14.5	.721	1.14
2-4	40	51	Brisk	N	None			.678	8,006	981	14.0	.693	1.10
2-5	52	57	Brisk	SE	Rain	Light	6	.654	7,691	1,197	14.7	.686	1.10
2-6	59	60	Light	SW	None			.668	7,856	1,024	14.3	.673	1.12
2-7	56	61	Light	SW	None			.678	8,006	872	14.7	.685	1.10
2-8	51.5	55	Brisk	SW	None			.663	7,829	909	15.8	.687	1.08
2-9	40	54	Mod	SW	None			.668	7,888	880	14.4	.689	1.08
2-10	60	60	Light	SW	None			.675	7,970	824	14.5	.691	1.08
2-11	59	68	Light	SW	None			.669	7,900	827	14.4	.686	1.08
2-12	58	64	Light	NE	None			.669	7,900	877	14.3	.677	1.10
2-13	55	58	Brisk	E	Rain	Mod	6	.669	7,900	959	13.9	.684	1.10
2-14	51	53	Hard	N	Rain	Hard	18	.683	8,081	610	13.4	.671	1.10
2-15	47	51	Light	N	Rain	Light	6	.690	8,148	1,167	14.2	.732	1.08
2-16	44	47	Light	E	None			.656	7,746	1,368	14.0	.730	1.06
2-17	43	44	Brisk	N	Rain	Light	4	.689	8,136	866	13.8	.695	1.10
2-18	40	44	Light	NE	None			.695	8,207	850	14.0	.712	1.08
2-19	45	51	Light	NE	None			.691	8,159	796	14.1	.704	1.08
2-20	53	57	Brisk	NE	Rain	Hard	20	.698	8,242	873	13.9	.717	1.08
2-21	50	57	Mod	NE	Rain	Hard	24	.708	8,360	946	13.8	.732	1.08
2-22	49	54	Light	N	Rain	Light	4	.694	8,195	925	14.3	.731	1.06
2-23	55	56	Light	NE	None			.689	8,136	942	14.3	.727	1.06
2-24	55	57	Light	NE	None			.689	8,136	924	14.5	.712	1.08
2-25	52	59	Light	SE	None			.691	8,159	862	13.6	.729	1.06
2-26	59	61	Light	SE	None			.689	8,136	947	14.2	.728	1.06
2-27	64	66	Light	SE	Rain	Mod	2	.691	8,159	680	14.1	.700	1.07
2-28	53	60	Light	SE	Rain	Light	4	.686	8,136	1,125	14.3	.730	1.07
3-1	47	52	Light	N	None			.665	7,852	1,189	14.3	.719	1.07
3-2	51	53	Brisk	NE	Rain	Mod	16	.646	4,958	1,102	15.8	.484	1.63
3-3	45	45	Light	N	None			.655			12.8		
3-4	39	56	Brisk	N	None			.717	8,432	1,013	14.3	.743	1.08
3-5	53	58	Light	S	None			.720	8,467	946	14.3	.754	1.06
3-6	50	63	Light	NE	Rain	Light	5	.714	8,397	744	14.0	.719	1.08
3-7	52	59	Light	E	None			.702	8,256	1,038	13.3	.731	1.08

REMARKS

RUN TOTALS (WHERE APPLICABLE)

24 HOUR DAILY AVERAGE (WHERE APPLICABLE)

U.S. Department of the Interior

OFFICE OF SALINE WATER

FREEPORT DEMONSTRATION PLANT

Operator Data Sheet
3 of 4

Development Run No. 16

From 12-18-68 To 5-9-69

Prepared By

OPERATING TIME		PRODUCTION (INCLUDING CONDENSATE)					RAW MATERIALS					CHEMICALS		
		M GALLONS				POUNDS	STEAM (DOW)		POWER	SEA WATER FEED		ACID	SC. INH.	CAUSTIC
DATE	HOURS	DOW	FREE-PORT	PLANT	TOTAL	TOTAL	TOTAL LBS. M	MAXIMUM RATE M LBS./HR.	TOTAL kwhr.	TOTAL LBS. M	MAXIMUM RATE M LBS./HR.	POUNDS	POUNDS	POUNDS
3-8	24	705	386	24	1,115	9,312	652	28	12,560	11,760	490	530		19.3
3-9	24	689	403	23	1,116	9,315	658	28	12,740	11,760	490	530		13.1
3-10	24	680	409	25	1,114	9,301	653	28	12,760	11,760	490	523		9.3
3-11	24	672	426	25	1,134	9,464	658	28	13,062	11,736	490	550		18.8
3-12	24	677	428	24	1,130	9,430	650	28	13,000	11,712	489	530		29.0
3-13	24	679	482	22	1,184	9,885	637	27	12,940	11,736	490	550		37.3
3-14	24	676	423	20	1,120	9,348	634	27	12,940	11,712	490	563	6.4	37.8
3-15	24	678	428	21	1,129	9,425	655	28	12,720	11,760	490	550	15.5	36.5
3-16	24	672	441	21	1,135	9,473	657	28	12,860	11,736	490	523	11.7	36.2
3-17	24	676	434	22	1,133	9,458	642	27	12,940	11,736	489	523	2.6	51.5
3-18	24	684	414	22	1,122	9,364	633	27	12,720	11,736	489	585	5.5	75.7
3-19	24	711	373	22	1,116	9,318	625	27	13,080	11,736	489	644	11.7	29.1
3-20	11	207	126	16	350	2,923	327	26	12,960	5,379	489	295		
3-21	24	669	393	28	1,092	9,113	665	28	12,980	11,760	490	644	23.5	
3-22	24	633	410	30	1,074	8,970	640	27	12,720	11,760	490	651	17.3	
3-23	24	636	416	30	1,083	9,044	612	26	12,840	11,760	490	651	14.5	
3-24	24	629	415	30	1,075	8,978	623	27	12,960	11,760	490	651	0	0
3-25	24	633	420	30	1,084	8,969	631	27	12,960	11,760	490	669	19.2	0
3-26	24	620	398	30	1,049	8,757	601	27	12,960	11,760	490	695	17.0	0
3-27	24	629	398	31	1,060	8,848	604	26	13,200	11,760	490	644	12.6	0
3-28	24	628	405	29	1,063	8,872	609	26	13,200	11,760	490	1,170	0	0
3-29	24	630	406	32	1,069	8,925	616.	26	12,960	11,712	490	1,181	16.4	0
3-30	24	627	398	36	1,062	8,868	606	26	12,960	11,712	488	1,170	13.8	0
3-31	24	618	385	36	1,040	8,686	597	26	13,200	11,592	488	1,170	19.0	
4-1	24	632	383	36	1,052	8,785	604	26	13,200	11,472	478	1,185	13.6	0
4-2	8.53	216	118	15	352	2,940	199	26	4,100		478	418	2.2	0
4-3	3.75	766	95	17	186	1,557	159						3.2	
4-4	24	615	404	52	1,072	8,954	574	26	12,720	11,472	478	1,061	0	0
4-5	24	614	394	59	1,067	8,912	593	26	12,960	11,496	480	1,042	15.2	0
4-6	24	614	410	56	1,081	9,029	581	25	12,720	11,520	470	1,064	20.0	0
4-7	24	614	407	51	1,073	8,961	578	25	12,720	11,472	479	1,064	12.3	0
4-8	24	612	426	49	1,088	9,088	575	25	12,960	11,520	480	1,031	8.3	0
4-9	17.3	414	290	30	765	6,390	399	25	9,340	8,304	480	738	0	0
4-10	3.3	102	62	2	167	1,401	156					0	2.1	0
4-11	24	639	393	55	1,088	9,063	597	26	12,960	11,664	488	1,024	17.4	0
4-12	20.25	523	330	54	908	7,579	547	25	11,070	9,860	482	922	13.4	0
4-13	24	646	408	56	1,117	9,277	607	26	12,720	11,520	480	988	13.0	0
4-14	24	637	390	56	1,089	9,088	593	26	12,960	11,520	480	1,024	0	0
4-15	24	628	406	56	1,091	9,111	635	27	12,960	11,520	480	1,042	0	0
4-16	24	631	418	55	1,104	9,220	630	27	12,480	11,520	480	1,042	16.7	0

	PROCESS CONDITIONS															
	CONC. FACTOR		TEMPERATURES								PRESSURES					pH
DATE	IN	OUT	SWF TO P-1	SWF TO NO. 1	DISCH. BRINE FROM 17	STEAM TO NO. 1	DOW STEAM	FREEPORT PRODUCT	VAPOR FROM 17	VAPOR FROM 1	TO NO. 1 psig	DOW STEAM psig	315 CONDENSER psia	VAPOR HEAD psia NO. 1	VAPOR HEAD psia NO. 17	FREEPORT PRODUCT
3-8	0.63	2.08	56	262	86	274	472	76	88	262	31.3	158	0.4	36.65	0.66	9.2
3-9	0.63	2.12	56	262	86	274	472	76	89	263	31.4	163	0.4	37.27	0.68	9.2
3-10	0.68	2.23	57	262	85	274	470	75	86	262	31.2	162	0.4	36.65	0.62	9.2
3-11	0.65	2.21	60	262	80	274	469	73	84	262	31.3	158	0.3	36.65	0.58	9.3
3-12	0.64	2.18	58	262	80	271	470	73	84	262	31.3	163	0.3	36.65	0.58	9.2
3-13	0.65	2.19	58	262	80	274	472	75	84	262	31.5	163	0.3	36.65	0.58	9.2
3-14	0.66	2.18	60	262	81	274	467	75	85	262	31.4	162	0.3	36.65	0.60	9.2
3-15	0.63	2.15	60	262	81	274	460	75	85	262	31.2	161	0.3	36.65	0.60	9.3
3-16	0.53	2.00	60	262	81	274	473	75	85	262	31.6	161	0.3	36.65	0.60	9.3
3-17	0.58	2.03	57	262	79	275	475	74	84	262	31.5	161	0.3	36.65	0.58	9.3
3-18	0.66	2.25	55	262	81	274	471	75	85	262	31.4	161	0.3	36.65	0.60	9.0
3-19	0.75	2.56	56	262	82	274	467	77	86	262	31.5	156	0.3	36.65	0.62	8.0
3-20	0.83	2.67	56	262	81	274	465	76	86	262	31.6	162	0.3	36.65	0.62	8.0
3-21	0.83	2.62	57	262	83	287	503	76	87	263	31.4	141	0.4	37.27	0.64	8.3
3-22	0.82	2.49	60	262	85	274	459	78	88	262	31.4	147	0.4	36.65	0.66	9.4
3-23	0.78	2.36	61	261	86	274	466	78	89	262	31.5	165	0.4	36.65	0.68	9.4
3-24	0.74	2.31	61	262	87	274	482	79	89	262	31.5	162	0.4	36.65	0.68	9.4
3-25	0.80	2.46	63	262	83	274	476	77	87	263	31.5	162	0.4	37.27	0.64	9.3
3-26	0.86	2.32	62	262	83	275	475	76	87	263	31.3	163	0.3	37.27	0.64	9.3
3-27	0.88	2.53	61	262	83	274	473	76	87	262	31.1	161	0.3	36.65	0.64	9.2
3-28	0.89	2.66	61	263	84	275	477	77	88	263	31.2	162	0.4	37.27	0.66	9.3
3-29	0.88	2.67	61	263	84	275	472	80	88	263	31.2	161	0.4	37.27	0.66	9.0
3-30	0.89	2.60	62	263	85	275	473	78	88	263	30.7	162	0.4	37.27	0.66	9.3
3-31	0.85	2.50	68	262	88	275	471	80	91	265	31.2	163	0.4	38.53	0.71	9.4
4-1	0.82	2.47	64	263	88	275	472	81	91	265	31.2	162	0.4	38.53	0.71	9.4
4-2	0.83	2.42	65	263	88	275	471	82	92	265		162	0.4	38.53	0.74	9.4
4-3																
4-4	0.75	2.20	67	263	90	274	472	83	93	266	31.0	158	0.5	39.18	0.76	7.7
4-5	0.70	2.12	67	263	91	273	463	84	93	265	31.0	154	0.5	38.53	0.76	8.0
4-6	0.72	2.17	67	263	90	274	469	83	93	266	31.0	165	0.5	39.18	0.76	8.1
4-7	0.73	2.15	69	262	91	274	466	84	94	265	31.1	164	0.5	38.53	0.79	8.2
4-8	0.72	2.14	72	263	91	274	468	85	94	265	31.1	163	0.5	38.53	0.79	8.1
4-9	0.70	2.08	71	263	92	274	466	86	95	266	31.0	163	0.5	39.18	0.81	8.1
4-10																
4-11	0.64	1.90	74	263	95	275	459	87	98	265	30.9	159	0.6	38.53	0.89	8.5
4-12	0.57	1.64	74	262	94	274	458	86	97	265	30.9	159	0.6	38.53	0.86	8.7
4-13	0.53	1.71	73	263	94	274	466	86	96	265	30.9	158	0.6	38.53	0.84	8.3
4-14	0.64	1.98	75	263	91	275	469	84	94	266	31.0	156	0.6	39.18	0.79	8.1
4-15	0.68	2.06	67	263	91	275	465	85	93	266	31.0	152	0.6	39.18	0.76	8.2
4-16	0.61	1.88	69	263	93	275	468	85	95	266	31.0	151	0.6	39.18	0.81	8.1

	AMBIENT CONDITIONS							CALCULATED QUANTITIES AND RATIOS					
	DRY BULB TEMP.		WIND		PRECIPITATION								
DATE	°F MINIMUM	°F AVERAGE	STR.	DIR.	FORM	INT.	DURAT. HOURS	EXTRACTION RATIO	H_2O SEP. M LBS.	CONDENSATE IN PRODUCT M LBS.	H_2O/LB. DOW STEAM FED WITH COND.	M LBS. H_2O PER kwhr	kwhr PER M LBS. SWF
3-8	50	56	Mod	E	None			.697	8,197	1,115	13.3	.741	1.07
3-9	39	49	Brisk	E	None			.703	8,267	1,048	12.5	.731	1.08
3-10	40	46	Brisk	N	None			.695	8,173	1,128	13.2	.729	1.09
3-11	43	45	Light	NE	Rain	Light	6	.706	8,286	1,179	13.4	.724	1.11
3-12	49	53	Light	SE	Rain	Mod	16	.706	8,269	1,162	13.5	.725	1.11
3-13	45	59	Light	E	None			.703	8,250	1,636	14.5	.764	1.10
3-14	57	58	Light	SE	None			.697	8,163	1,186	13.7	.722	1.10
3-15	46	49	Hard	NE	Rain	Hard	24	.707	8,314	1,111	13.4	.741	1.08
3-16	46	58	Mod	NE	Rain	Mod	24	.735	8,626	848	13.4	.737	1.10
3-17	45	49	Light	N	Rain	Light	20	.714	8,380	1,079	13.7	.731	1.10
3-18	52	63	Light	SW	None			.707	8,297	1,068	13.8	.736	1.08
3-19	50	61	Light	S	None			.707	8,297	1,021	13.9	.712	1.11
3-20	55	61	Mod	SE	None			.689	3,706	(782)	8.9	.226	2.41
3-21	60	62	Light	NE	None			.683	8,032	1,082	12.7	.702	1.10
3-22	58	60	Light	SE	None			.671	7,891	1,079	13.0	.705	1.08
3-23	58	58	Mod	NW	Rain	Light	4	.669	7,867	1,177	13.8	.704	1.09
3-24	60	64	Light	NW	None			.680	7,997	982	13.4	.693	1.10
3-25	49	52	Brisk	NW	None			.675	7,938	1,031	13.2	.692	1.10
3-26	46	53	Light	NE	None			.629	7,397	1,360	13.6	.676	1.10
3-27	57	64	Light	NW	None			.652	7,668	1,181	13.6	.670	1.12
3-28	62	66	Light	NW	None			.665	7,820	1,052	13.6	.672	1.12
3-29	59	65	Light	SE	None			.670	7,847	1,078	13.5	.689	1.11
3-30	61	66	Light	SE	None			.658	7,706	1,163	13.6	.684	1.11
3-31	57	61	Light	NE	None			.660	7,651	1,036	13.5	.658	1.14
4-1	59	62	Light	SE	None			.668	7,663	1,123	13.5	.666	1.15
4-2	62	62	Light	SE	None			.657			13.7	.717	
4-3	74	74	Light	SE	None						9.7		
4-4	65	67	Light	S	Rain	Light	1	.659	7,560	1,394	14.6	.704	1.11
4-5	55	67	Light	S	Rain	Light	1	.670	7,702	1,210	14.0	.688	1.13
4-6	60	74	Light	S	None			.668	7,695	1,336	14.5	.710	1.10
4-7	60	69	Light	S	None			.660	7,572	1,390	14.5	.705	1.11
4-8	65	68	Light	S	None			.664	7,649	1,439	14.8	.701	1.13
4-9	70	75	Light	S	None			.663	5,506	884	15.0	.684	1.12
4-10	82	82	Light	S	None						9.0		
4-11	64	66	Light	E	Rain	Mod	12	.663	7,733	1,330	14.2	.699	1.11
4-12	66	68	Brisk	S	Rain	Mod	8	.652	6,429	1,151	12.8	.685	1.12
4-13	65	68	Light	NW	None			.690	7,949	1,348	14.3	.729	1.10
4-14	62	66	Light	NE	None			.677	7,799	1,290	14.3	.701	1.13
4-15	65	65	Light	E	Rain	Light	2	.670	7,718	1,394	13.3	.703	1.13
4-16	70	73	Light	E	Rain	Light	2	.676	7,788	1,433	13.6	.739	1.08

REMARKS

1. Caustic Addition Stopped on 3-20-69.

RUN TOTALS (WHERE APPLICABLE)

24 HOUR DAILY AVERAGE (WHERE APPLICABLE)

U.S. Department of the Interior

OFFICE OF SALINE WATER
FREEPORT DEMONSTRATION PLANT

Operator Data Sheet Development Run No. 16

4 of 4

From 12-18-68 To 5-9-69

Prepared By

Operating Time: Date	Operating Time: Hours	Production (Including Condensate), M Gallons: DOW	M Gallons: Freeport	M Gallons: Plant	M Gallons: Total	Pounds: Total	Raw Materials, Steam (DOW): Total Lbs. M	Steam (DOW): Maximum Rate M Lbs./Hr.	Power: Total kwhr.	Sea Water Feed: Total Lbs. M	Sea Water Feed: Maximum Rate M Lbs./Hr.	Chemicals, Acid: Pounds	Sc. Inh.: Pounds	Caustic: Pounds
4-17	24	626	432	55	1,114	9,297	615	27	12,990	11,520	480	951	0	0
4-18	24	617	426	53	1,097	9,159	609	26	12,800	11,520	480	988	32.7	0
4-19	24	630	411	51	1,095	9,144	570	26	12,600	11,200	480	1,061	23.7	0
4-20	24	624	408	55	1,088	9,079	583	25	12,820	11,520	480	894	0	0
4-21	24	614	415	52	1,082	9,033	572	25	12,589	11,520	480	1,280	25.2	0
4-22	13	345	229	33	608	5,070	319	25	6,950	6,240	480	792	13.3	0
4-23												0	0	0
4-24												0	0	0
4-25	5.7	138	500	68	257	2,148	179					0	0	0
4-26	14.66	369	294	36	702	5,866	470	27	3,040	7,095	485	554	21.2	0
4-27	24	558	436	49	1,044	8,713	623	27	12,720	11,520	480	1,024	28.5	0
4-28	24	590	441	52	1,084	9,050	652	28	12,960	11,520	480	951	0	0
4-29	24	620	436	50	1,106	9,236	617	27	12,480	11,424	476	973	32.7	0
4-30	24	624	434	45	1,104	9,219	604	26	12,620	11,400	475	1,006	6.5	0
5-1	24	624	442	43	1,110	9,270	601	26	12,700	11,400	475	512	14.1	0
5-2	24	617	422	44	1,083	9,044	586	26	12,600	11,328	472	512	24.4	0
5-3	24	589	408	46	1,044	8,716	570	25	12,720	11,400	475	512	23.6	0
5-4	24	589	403	43	1,036	8,650	564	25	12,700	11,400	475	512	23.9	0
5-5	24	592	376	44	1,013	8,458	551	24	12,720	11,376	475	206	21.9	0
5-6	24	585	380	45	1,012	8,445	561	24	12,940	11,324	475	194	18.9	0
5-7	24	582	398	46	1,027	8,571	559	25	12,900	11,256	469	193	0.9	0
5-8	24	583	401	47	1,032	8,619	557	25	12,800	11,232	469	193	3.2	0
5-9	15	390	280	38	710	5,926	381	25	7,950	7,020	469	192	2.1	0

Date	Process Conditions, Conc. Factor: In	Conc. Factor: Out	Temperatures: SWF to P-1	SWF to No. 1	Disch. Brine from 17	Steam to No. 1	DOW Steam		Freeport Product	Vapor from 17	Vapor from 1	Pressures: To No. 1 psig	DOW Steam psig	318 Condenser		318 Condenser: psia	Vapor Head psia: No. 1	Vapor Head psia: No. 17	pH	pH: Freeport Product
4-17	0.50	1.65	71	263	95	276	472		87	97	266	31.1	166			0.6	39.18	0.86		8.0
4-18	0.52	1.64	71	263	96	276	472		87	98	266	31.1	161			0.6	39.18	0.89		8.0
4-19	0.72	2.09	68	263	93	275	468		86	97	266	31.1	163			0.6	39.18	0.86		8.1
4-20	0.78	2.25	67	263	91	275	464		84	94	266	31.0	164			0.5	39.18	0.79		8.1
4-21	0.65	1.95	69	263	94	275	470		86	97	266	31.0	165			0.6	39.18	0.86		8.2
4-22	0.63	1.86	70	264	94	275	472		87	98	266	31.1	165			0.6	39.18	0.89		8.1
4-23																				
4-24																				
4-25																				
4-26	0.65	2.10	72	263	95	274	460		88	98	265	31.0	139			0.7	38.53	0.89		8.0
4-27	0.56	1.93	72	264	96	275	462		88	98	266	31.1	138			0.6	39.18	0.89		7.9
4-28	0.53	1.80	73	264	96	276	468		89	99	266	31.0	139			0.7	39.18	0.91		8.2
4-29	0.57	1.90	75	264	95	275	472		88	97	266	31.2	150			0.6	39.18	0.86		9.0
4-30	0.57	1.95	74	264	94	275	466		87	97	266	31.2	154			0.6	39.18	0.86		9.1
5-1	0.54	1.84	73	264	95	274	464		88	97	266	31.2	155			0.6	39.18	0.86		9.0
5-2	0.67	2.12	73	264	95	275	466		90	97	266	31.2	155			0.6	39.18	0.86		9.0
5-3	0.94	2.69	73	263	94	274	464		91	97	265	31.0	156			0.6	38.53	0.86		9.0
5-4	0.96	2.70	73	263	98	274	465		92	100	265	31.0	156			0.7	38.53	0.95		9.1
5-5	0.98	2.61	73	263	102	274	464		94	104	265	31.0	156			0.8	38.53	0.95		8.9
5-6	0.99	2.70	76	263	101	274	462		93	103	265	30.8	154			0.8	38.53	1.03		8.8
5-7	1.00	2.76	74	263	95	274	460		93	98	265	30.8	154			0.6	38.53	0.89		8.8
5-8	0.99	2.77	75	263	95	274	466		93	99	265	30.8	156			0.6	38.53	0.91		8.9
5-9	0.98	2.76	76	263	96	274	471		94	99	265	30.4	156			0.6	38.53	0.91		9.1

Date	Ambient Conditions, Dry Bulb Temp.: °F Minimum	°F Average	Wind: Str.	Wind: Dir.	Precipitation: Form	Int.	Durat. Hours	Calculated Quantities and Ratios: Extraction Ratio	H_2O Sep. M Lbs.	Condensate in Product M Lbs.	H_2O/Lb. DOW Steam Fed with Cond.	M Lbs. H_2O per kwhr	kwhr per M Lbs. SWF
4-17	70	72	Light	S	None			.697	8,029	1,217	14.1	.719	1.12
4-18	63	68	Light	NW	None			.683	7,868	1,292	14.0	.716	1.11
4-19	66	70	Light	SW	None			.647	7,246	1,899	15.0	.726	1.13
4-20	65	68	Light	NE	Rain	Light	2	.653	7,523	1,557	14.6	.708	1.11
4-21	64	70	Light	NE	None			.667	7,684	1,350	14.8	.718	1.09
4-22	68	72	Light	SW	None			.661	4,125	954	14.9	.730	1.11
4-23	60	60	Light	S	None								
4-24	68	65	Light	S	None								
4-25	71	71	Light	S	None						10.9		
4-26	75	77	Light	S	None			.690	4,896	970	11.5	1.93	4.28
4-27	70	72	Light	SE	Rain	Hard	2	.710	8,179	535	13.0	.685	1.10
4-28	65	72	Light	NE	Rain	Light	1	.706	8,133	917	12.9	.698	1.13
4-29	57	70	Light	NE	None			.700	7,997	1,240	14.0	.740	1.09
4-30	63	70	Brisk	E	Rain	Light	1	.708	8,071	1,149	14.2	.731	1.11
5-1	66	70	Light	E	None			.707	8,060	1,210	14.4	.730	1.11
5-2	66	70	Light	SE	Rain	Light	2	.684	7,748	1,296	14.4	.718	1.11
5-3	68	71	Light	NE	None			.651	7,421	1,606	14.3	.685	1.12
5-4	72	74	Light	E	Rain	Light	2	.644	7,342	1,308	14.3	.681	1.11
5-5	72	75	Light	E	Rain	Light	2	.625	7,110	1,348	14.4	.665	1.12
5-6	74	75	Light	SE	Rain	Light	24	.633	7,168	1,278	14.0	.653	1.14
5-7	70	74	Light	E	Rain	Light	24	.638	7,168	1,403	14.3	.664	1.15
5-8	70	75	Light	NE	None			.643	7,222	1,398	14.5	.673	1.14
5-9	65	70	Light	N	None			.645	4,528	1,398	14.6	.745	1.13

REMARKS

RUN TOTALS (WHERE APPLICABLE)

24 HOUR DAILY AVERAGE (WHERE APPLICABLE)

SECTION VI

APPENDIX

PART IV

A. List of Symbols and Abbreviations

B. Bibliography

SECTION VI

APPENDIX

PART 4

A. LIST OF SYMBOLS AND ABBREVIATIONS

ΔT	Temperature difference, ^{o}F
AA	Atomic Absorption Spectraphotometer
A_o	The active outside heat transfer surface, square feet
ATU	Auxiliary Test Unit
BWG	Birmingham Wire Gage
Cu-Ni	Copper-Nickel
D/A	Deaerator
DO	Dissolved Oxygen
GPM	Gallons per minute
GTD	Greater Temperature Difference, ^{o}F
h	Enthalpy, Btu/#
Hg	Mercury
HX	Heat Exchanger
ID	Inside Diameter
LB/HR	Pounds per hour
#/hr	Pounds per hour
LMTD	Log mean temperature difference
LTV	Long-Tube Vertical
NaCl	Sodium Chloride
ME	Multiple-Effect
MLB/HR	Thousands of pounds per hour
MPPH	Thousands of pounds per hour

SECTION VI

APPENDIX

PART 4

A. LIST OF SYMBOLS AND ABBREVIATIONS (CONTD)

MMGPD	Millions of gallons per day
MPY	Mils per year corrosion rate
OD	Outside diameter
P	Pump
pH	Negative logarithm of hydrogen ion concentration
ppB	Parts per billion
ppM	Parts per million
Q_L	Heat loss, Btu/Hr
Q_T	Heat transferred, Btu/Hr
SS	Stainless steel
SVL	Swirl vane, liquid distribution weirs
T	Temperature, °F
TDS	Total dissolved solids, Wt.%
U_o	The calculated actual overall coefficient of heat transfer in Btu/Hr-Ft^2-°F
V	Vent
VTE	Vertical tube evaporator
W	Weight flow rate, #/Hr

SECTION VI

APPENDIX

PART 4

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