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INSPECTION OF ALUMINUM COMPONENTS FROM FREEZE DESALTING FACILITY AT WRIGHTSVILLE BEACH, NC

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February 1980

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TABLE OF CONTENTS

		Page
ABSTRACT		1
I.	INTRODUCTION	1
II.	PLATE-TYPE HEAT EXCHANGER	1
III.	FREEZER	2
IV.	MELTER-CONDENSER	3
V.	HEAT-REMOVAL CONDENSER	3
REFERENCES		4

LIST OF FIGURES

No.	Title	Page
1	Pilot-plant System	5
2	Overview of AVCO Desalting Pilot Plant	6
3	Appearance of Plate-type Heat Exchanger after Removal of Cover Plate and Tie Rods	7
4	Appearance of Cover Sheet on Top of First Plate of Plate-type Heat Exchanger	7
5	Close-up View of Inlet End of Raw Seawater Side of Plate Showing Build-up of Salts	8
6	Appearance of Plate Showing Crevice Attack at Contact Points between Individual Plates	8
7	Photomicrograph of Cross Section through Plate at Location of Contact Point	9
8	View of Inside of Freezer	9
9	Close-up View of Welded Baffle Plate in Bottom of Freezer	10
10	Close up of Welded Nipple and Baffle in Top of Freezer	10
11	Overall View of Melter-Condenser with Water Box Removed	11
12	Internal View of Melter-Condenser Water Box with Inlet on Bottom	12
13	Appearance of Tube Sheet and Tubes on Melter-Condenser	13
14	Close-up View of Melter-Condenser Showing (A) Corrosion Product between Tube and Tube Sheet and (B) Debris in Tubes	13
15	Inlet Flange on Melter-Condenser Water Box	14
16	Discharge Flange on Melter-Condenser Water Box	14
17	Overall Appearance of Tube Sheet on Heat-removal Condenser	15
18	Appearance of Heat-removal Condenser Water Box	16
19	Close-up View of Heat-removal Condenser Tube Sheet Showing Pitting Corrosion	17
20	Close-up Appearance of Inlet Flange on Heat-removal Condenser Water Box	17

LIST OF FIGURES

No.	Title	Page
21	Close-up Appearance of Inlet Pipe on Heat-removal Condenser Water Box Showing (A) Corrosion Products and (B) Pitting . .	18
22	Overview of Inlet-discharge End of Heat-removal Condenser with Water Box Removed	18
23	Close-up View of Discharge Flange on Heat-removal Condenser Water Box Showing Minimal Corrosion Attack	19

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ABSTRACT

An inspection was made of a freeze-type desalting pilot plant that has operated for approximately four years. The purpose of this inspection was to document the seawater service experience of the various aluminum alloys present in the plant. The components inspected include two tube-type heat exchangers, one plate-type heat exchanger, and the freezing compartment. Photographs are used to illustrate the corrosion behavior of these components.

I. INTRODUCTION

On January 18, 1979, an inspection was performed of components in a desalting pilot plant at the Office of Water Research and Technology (OWRT) at Wrightsville Beach, NC. Those present included F. L. LaQue (consultant), J. E. Draley and J. B. Darby, Jr. (Argonne National Laboratory), J. F. Rynewicz (Lockheed Aircraft Corp.), R. S. Robinson (OWRT), and D. G. Melton and T. S. Lee (LaQue Center for Corrosion Technology). The purpose of the inspection was to document the seawater service experience of the various aluminum alloys present in the plant.

The 240,000-liter-per-day pilot plant constructed by AVCO Systems Division is a direct-contact secondary refrigerant freeze desalting plant utilizing refrigerant R-114 (Dichlorotetrafloroethane) as the working fluid. The performance of this plant is documented in two AVCO reports.[1,2] The simplified operation of this process[1] is shown schematically in Figure 1, with the inspected components shaded for clarity. An overview of the facility is shown in Figure 2.

Initial operation of this pilot plant started in 1974 and was intermittently in operation until 1978. During this period, the plant operated approximately 50% of the time, and the heat exchangers usually were not drained during shut downs.[3]

II. PLATE-TYPE HEAT EXCHANGER

The plate-type heat exchanger utilizes enhanced surface plates and is designed so that the feed water flows counter current to the brine and product water in alternating passages. The unit served the purpose of lowering the temperature of the seawater entering the system.

Filtered seawater (5 μm) with a residual chlorine level of approximately 0.1 mg/liter served as the feed water, and the unit operated at 75 to 225 liters/min with a 100 to 200 kPa pressure drop. The unit has been in service since plant start-up in 1974 with only one intermediate cleaning, which consisted of a flushing with a 5-10% citric acid solution.[4]

The materials of construction include aluminum alloy 6061-T4 cover plates, carbon steel tie rods, and Alclad 3003/7072 heat-exchanger plates.[1] During disassembly of the heat exchanger, however, the producer markings on the top heat-exchanger plate indicated the material to be aluminum alloy 3003-0. Subsequent metallographic examination confirmed the absence of an Alclad layer of 7072 on the plates. An overview of the partially disassembled unit is shown in Figure 3.

As this heat exchanger was disassembled, corrosion attack to a depth of approximately 0.03 mm was measured on the cover sheet in contact with the top plate. Although this area was not a part of the flow pattern, moisture was evidently trapped during assembly. This cover sheet is shown in Figure 4. Figure 5 shows what appeared to be corrosion on the inlet end of the seawater plates, but later cleaning proved this to be a build up of salts from leakage.

When the individual plates were inspected, a regular pattern of crevice sites was noted, with corrosion products at each of these sites. The general appearance of one of these plates is shown in Figure 6. This regular pattern was created by the contact points between plates. Further inspection of these sites has shown crevice-corrosion attack to varying extents, and, in at least two of the six plates inspected, the corrosion had perforated the 1 mm thickness.

Samples of the deposits surrounding these contact points have been analyzed and found to be calcium carbonate. The cause of the black appearance of these deposits is presently unknown. The cross section of one of these contact points is shown in Figure 7.

III. FREEZER

The freezer was supplied with seawater from the plate-type heat exchanger with a water level of 60 to 80 cm while in operation. The freezing of water was accomplished by purging refrigerant R-114 through the seawater. The unit, a 1.7-meter-diameter by 8-meter-long horizontally mounted cylinder, was fabricated from aluminum alloy 5083.[1] The freezer unit has been in operation with the plant since 1974; the only change was in the supply flow distribution. The internal appearance of the freezer is shown in Figure 8.

Minimal corrosion was found during the inspection. Figure 9 is a close-up view of a welded baffle in the bottom of the freezer showing the excellent condition of the aluminum alloy 5083. Some shallow pitting was observed, as evidenced by Figure 10; however, this pitting appeared to be limited to the material exposed in the vapor or upper half of the freezer.

IV. MELTER-CONDENSER

The melter-condenser condensed refrigerant vapor on the shell side while melting an ice slurry from the freezer on the tube side. This unit, as originally constructed, was a 1-meter-OD by 8-meter-long heat exchanger with a U-tube configuration. The tube sheet (Figure 11) and water box (Figure 12) were fabricated from aluminum alloy 5083 and the U-tubes of aluminum alloy 3003 with external fins.[1] Due to many failures attributed to vibration, gas impingement, and corrosion,[2] the melter-condenser was retubed in January 1977 with straight tubes of aluminum alloy 5052.[2] In order to use the straight tubes, a floating head had to be installed, and a row of tube holes in the tube sheet was plugged as shown in Figure 13.

Some minor corrosion was found at the interface between the tubes and tube sheet, as evidenced by the corrosion product shown in Figure 14; however, no corrosion was visible on the inlet ends of the tubes. Depth of attack on the tube sheet was approximately 0.3 mm. Figure 14 also shows some debris that was found in the tubes. There was a large amount of this debris in the discharge side of the water box that was apparently the remains of attempts to coat the pipelines[4] and of iron corrosion products. Figure 15 shows the inlet flange of the melter-condenser water box with minimal corrosion. In Figure 16, the discharge side of the water box exhibited accelerated general and pitting corrosion. The accelerated attack on the discharge flange could be due to galvanic attack resulting from a direct connection to a steel flange and pipe.

V. HEAT-REMOVAL CONDENSER

The heat-removal condenser, a 0.6-meter-diameter by 8-meter-long unit, used seawater on the tube side to condense the remaining refrigerant vapor from the melter-condenser. Originally this unit, a two-pass U-tube heat exchanger, was constructed with aluminum alloy 6061 for the shell and water box and aluminum alloy 3003 for the tubes.[1] Several very small leaks developed between 1974 and 1976 and were reported as being due to corrosion or erosion of the tubes.[2] Therefore, in January 1977, the heat-removal condenser was retubed with aluminum alloy 5052-0.[2,3] This heat exchanger and its water box, as shown in Figures 17 and 18, have been in operation with the pilot plant since 1974.

The heat-removal condenser displayed severe pitting on the tube sheet (approximately 6-mm depth), as shown in Figure 19; however, the tubes in this unit showed no visible corrosion on the inlet ends. Severe pitting also was found on the water-box inlet flange and pipe, as shown in Figures 20 and 21. This pitting corrosion could be attributed to the steel pipe section that was attached directly to the inlet flange (Figure 22). However, as shown by Figure 23, the discharge flange and pipe were free of any signs of pitting corrosion.

REFERENCES

1. Final Report - "Test and Evaluation of 75,000 Gallon Per Day Crystalex Pilot Plant," OWRT Contract 14-30-3255, AVSD-0098-77-CR, Report for Period 1 November 1973-September 1976.

2. R. J. Campbell and E. W. Duvall, Final Report - "Gravity Wash Column Design, Procurement, and Installation; Followed by Development Tests of the Modified Single-Stage Desalting Plant at Wrightsville Beach, North Carolina," OWRT Contract 14-001-7514, AVSD-0160-78-RR, Report from Period 10 October 1976-31 March 1978.

3. Letter - W. J. Hahn to F. L. LaQue, October 12, 1978.

4. R. S. Robinson, OWRT Facility Manager, Oral Communication, January 18, 1979.

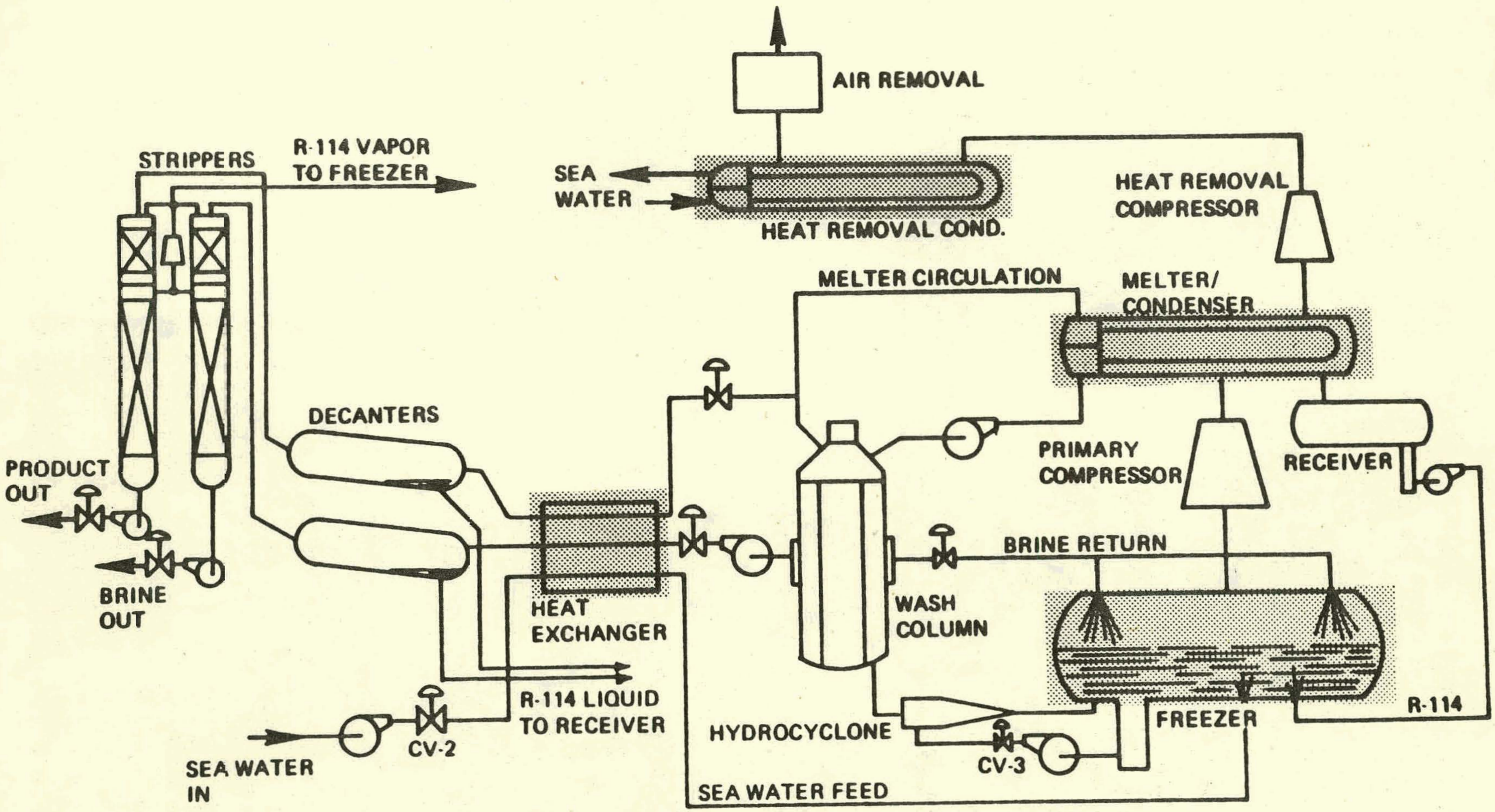
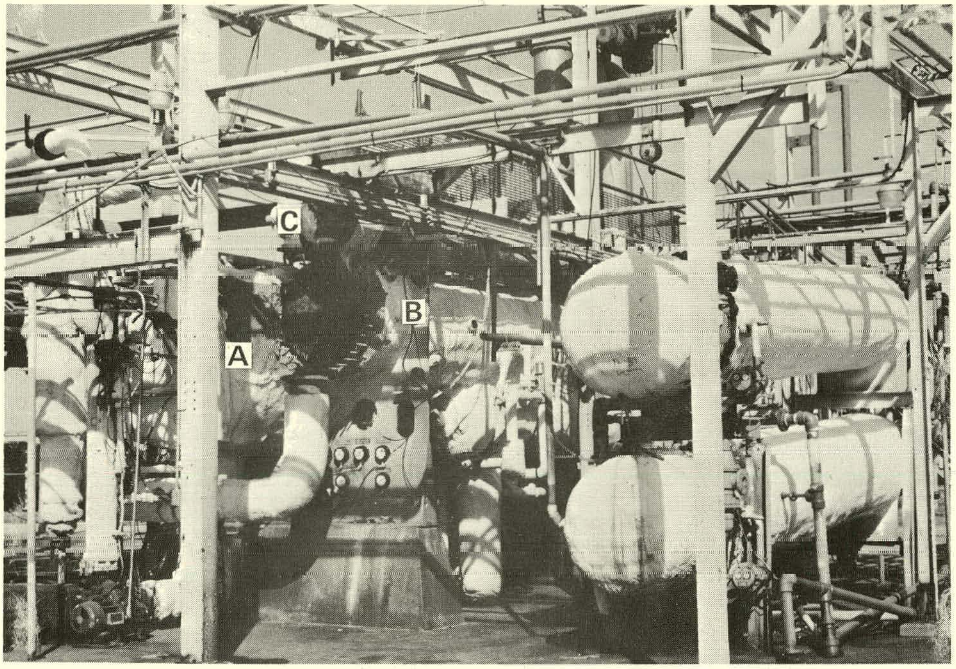


Figure 1. Pilot-plant System



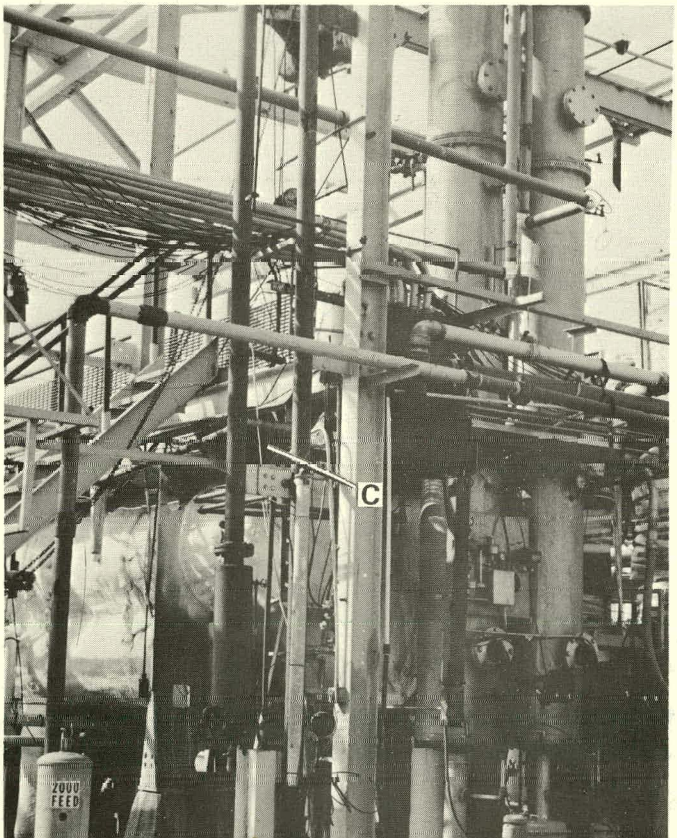


Figure 2. Overview of AVCO Desalting Pilot Plant. (A) Freezer, (B) melter-condenser, and (C) heat-removal condenser.

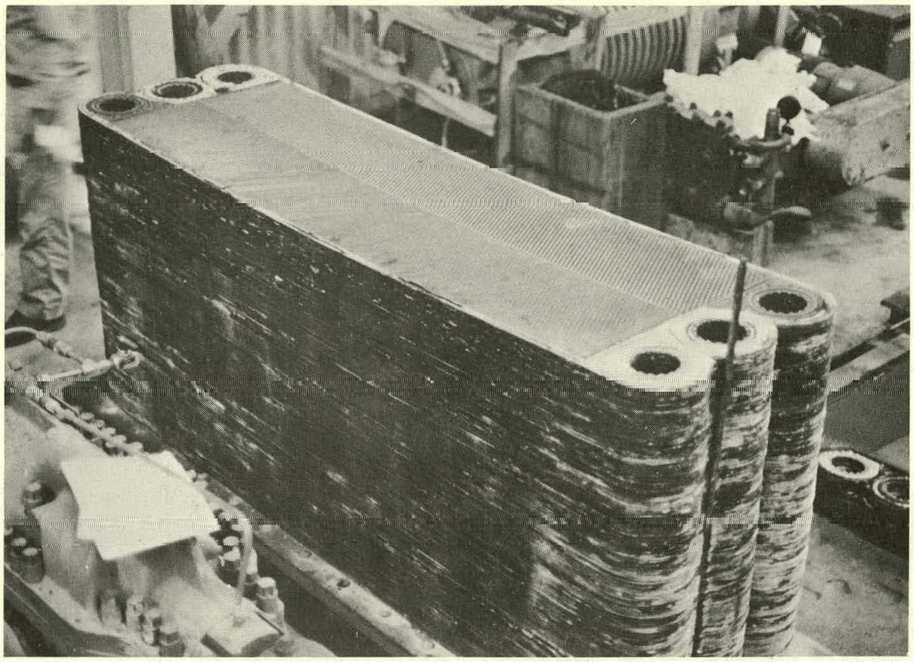


Figure 3. Appearance of Plate-type Heat Exchanger after Removal of Cover Plate and Tie Rods

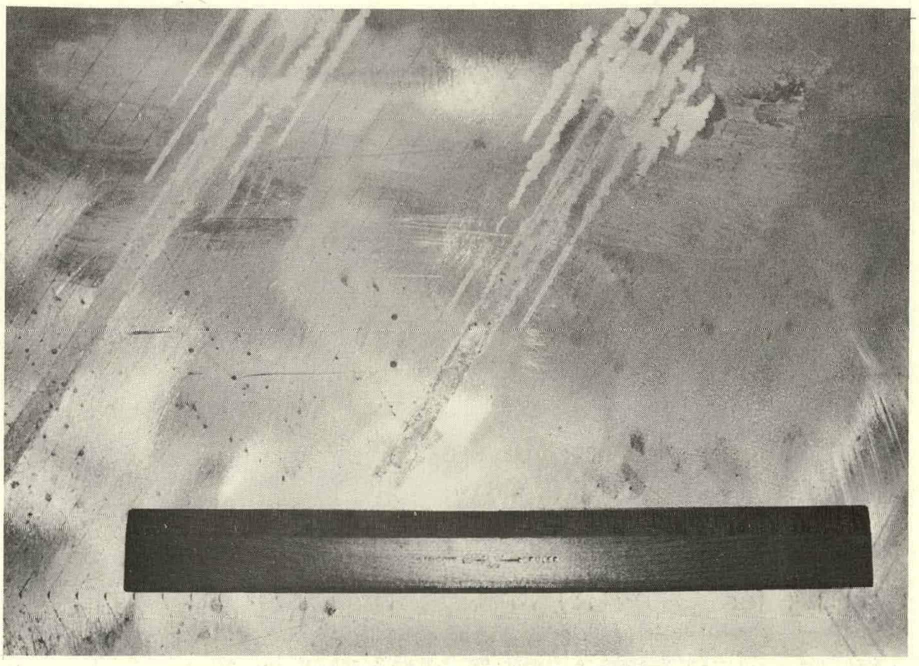


Figure 4. Appearance of Cover Sheet on Top of First Plate of Plate-type Heat Exchanger. Maximum depth of corrosion measured at 0.03 mm.

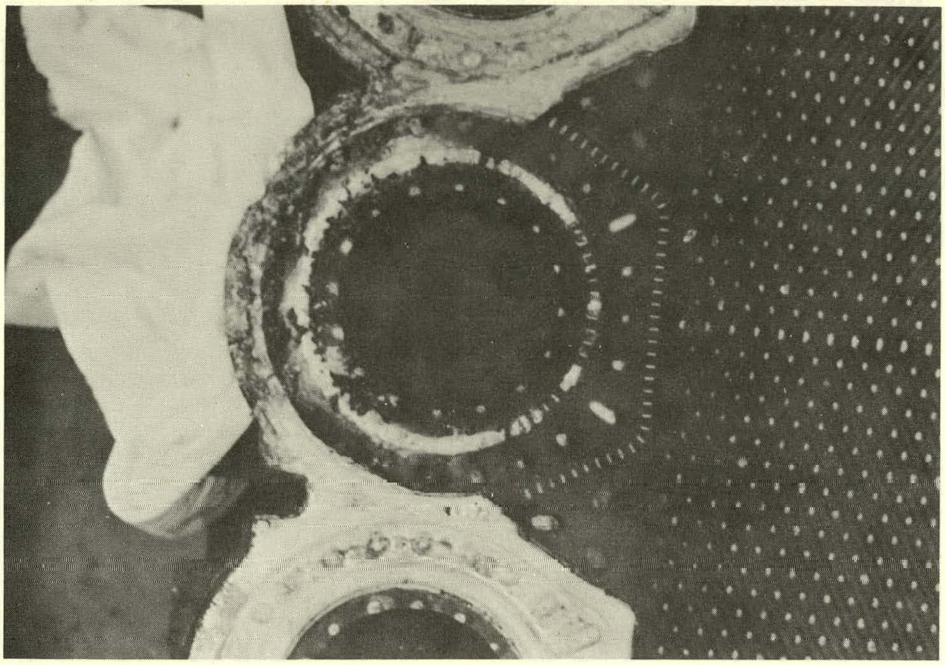


Figure 5. Close-up View of Inlet End of Raw Seawater Side of Plate Showing Build-up of Salts. Cleaning revealed minimal attack to underlying aluminum.

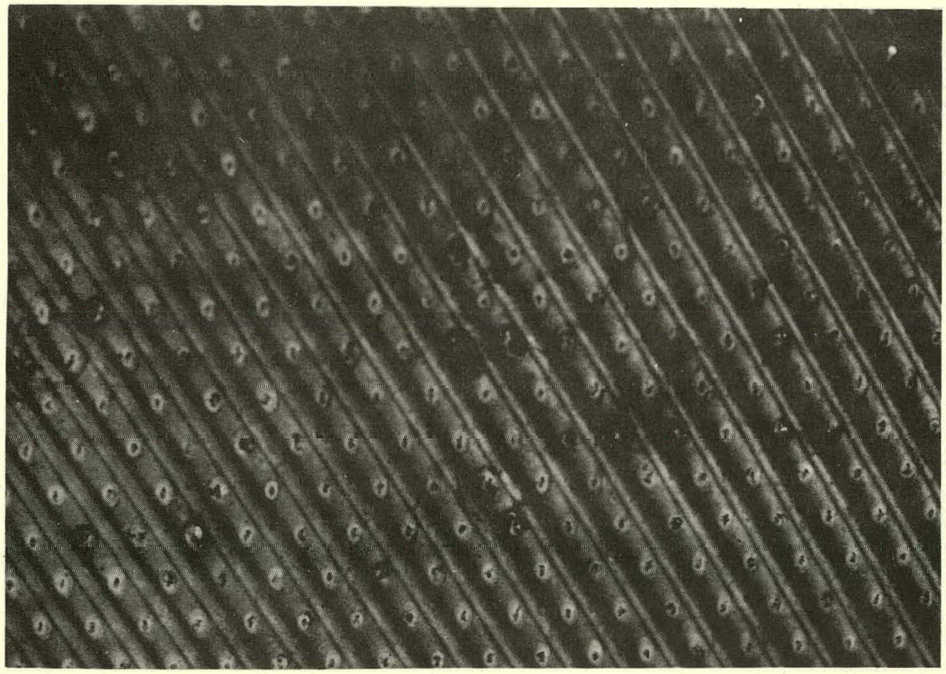


Figure 6. Appearance of Plate Showing Crevice Attack at Contact Points between Individual Plates

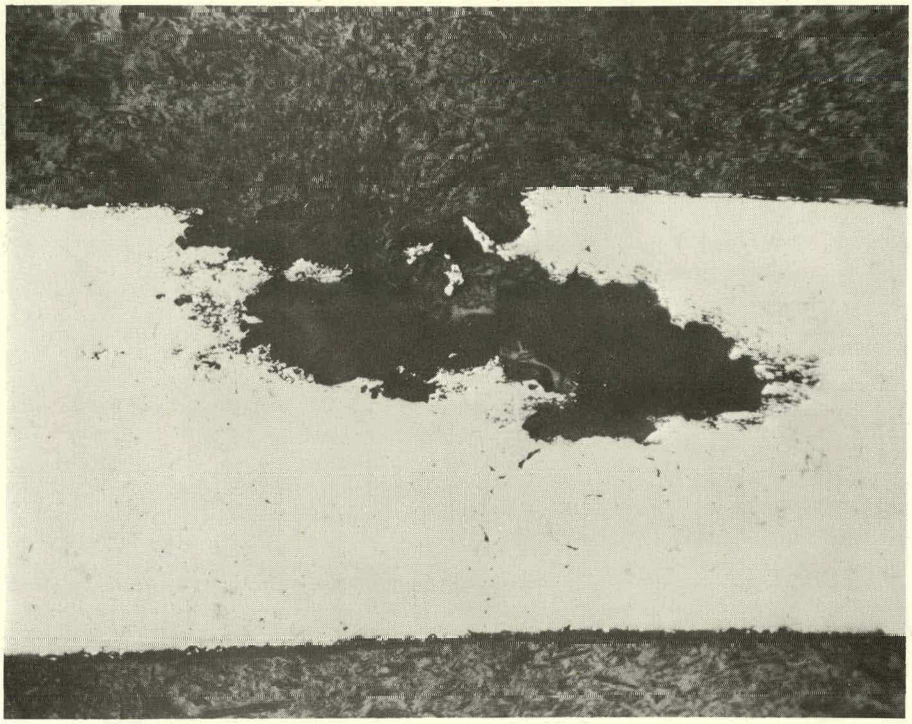


Figure 7. Photomicrograph of Cross Section through Plate at Location of Contact Point. Magnification 55X.

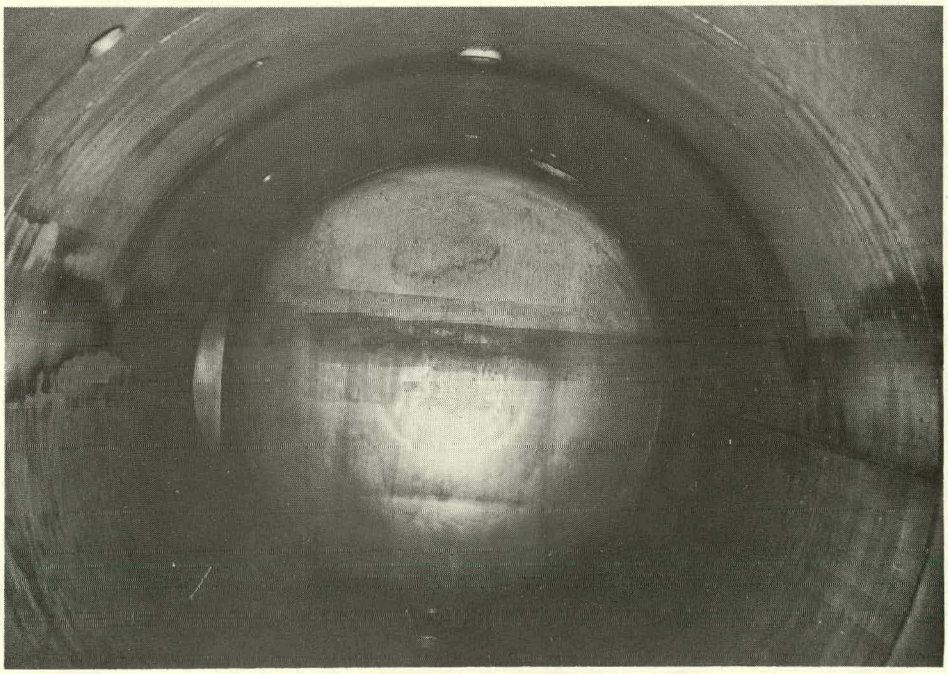


Figure 8. View of Inside of Freezer. Note waterline approximately 80 cm above bottom.

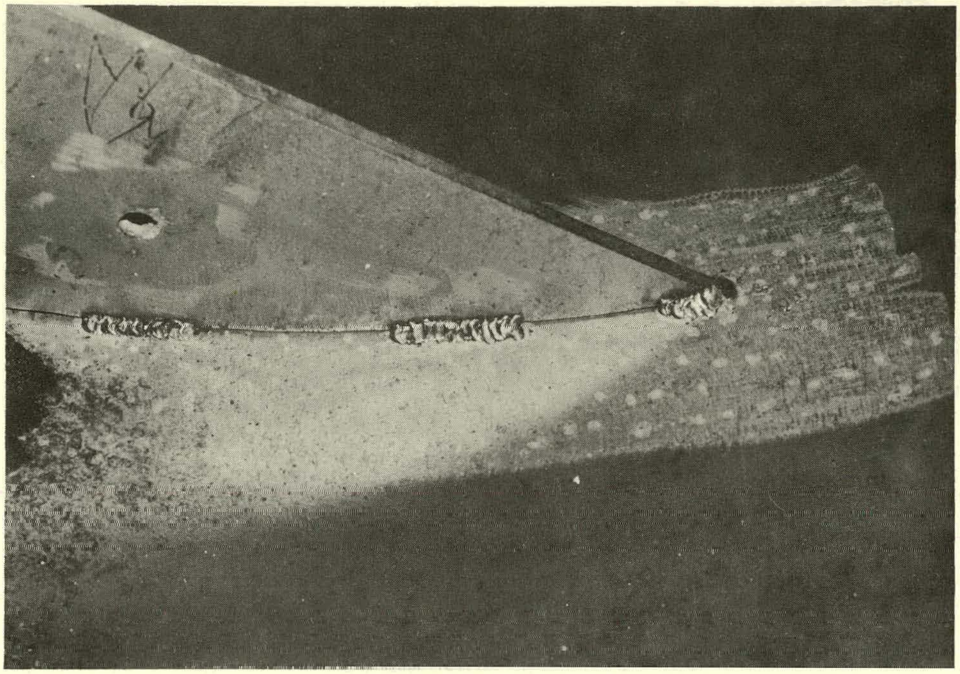


Figure 9. Close-up View of Welded Baffle Plate in Bottom of Freezer

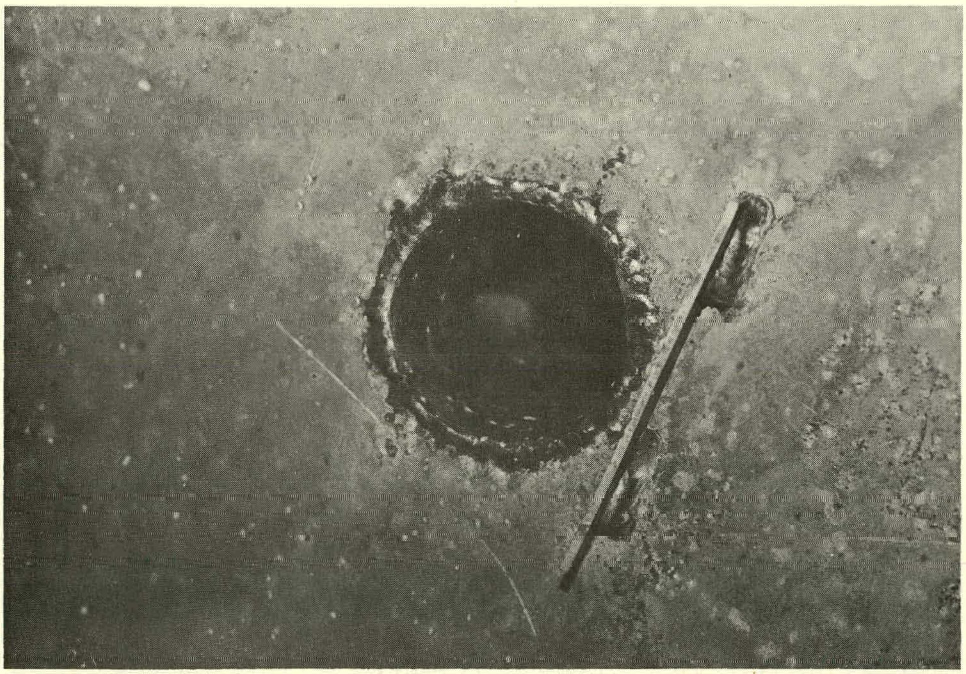


Figure 10. Close up of Welded Nipple and Baffle in Top of Freezer. Note shallow pitting due to refrigerant and chloride vapor environment.

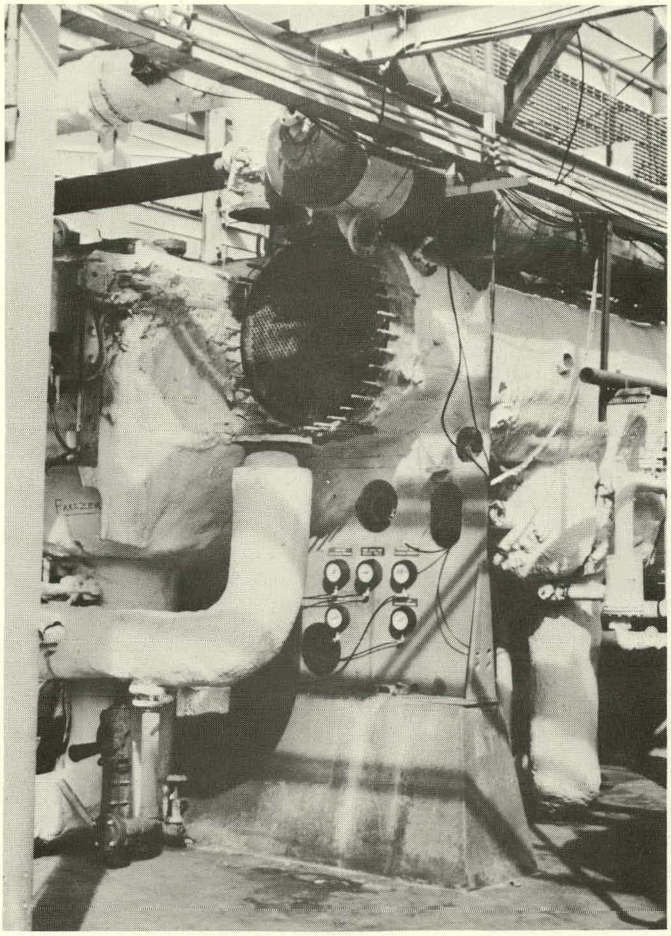


Figure 11. Overall View of Melter-Condenser with Water Box Removed.

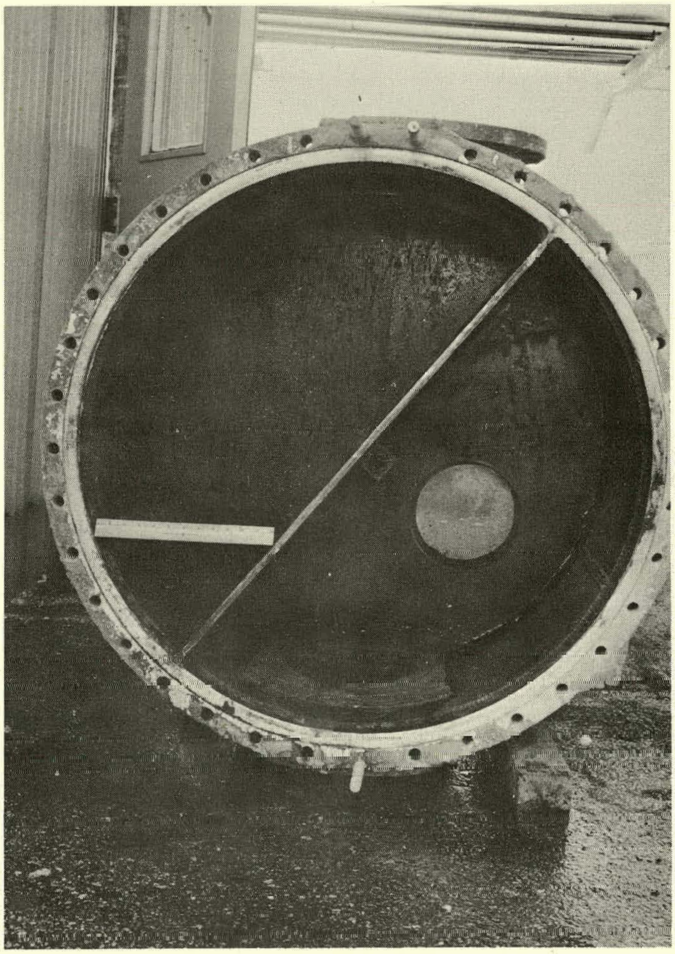


Figure 12. Internal View of Melter-Condenser Water Box with Inlet on Bottom. Note debris from failed coating system and corrosion products from steel pipe lines in system.

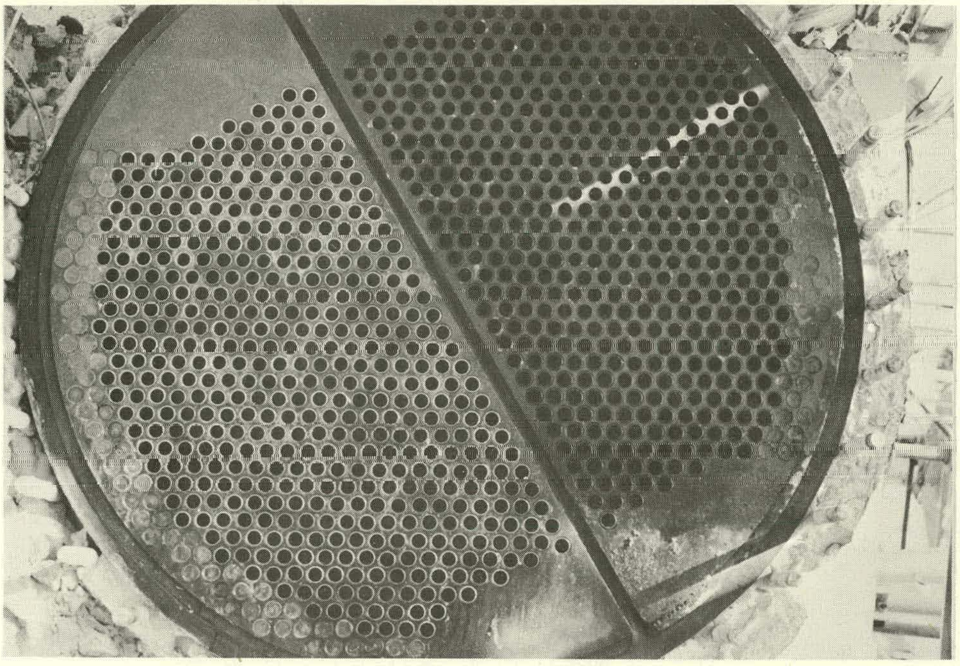


Figure 13. Appearance of Tube Sheet and Tubes on Melter-Condenser. Note tube sheet plugs to allow for installation of floating head on opposite end of condenser.

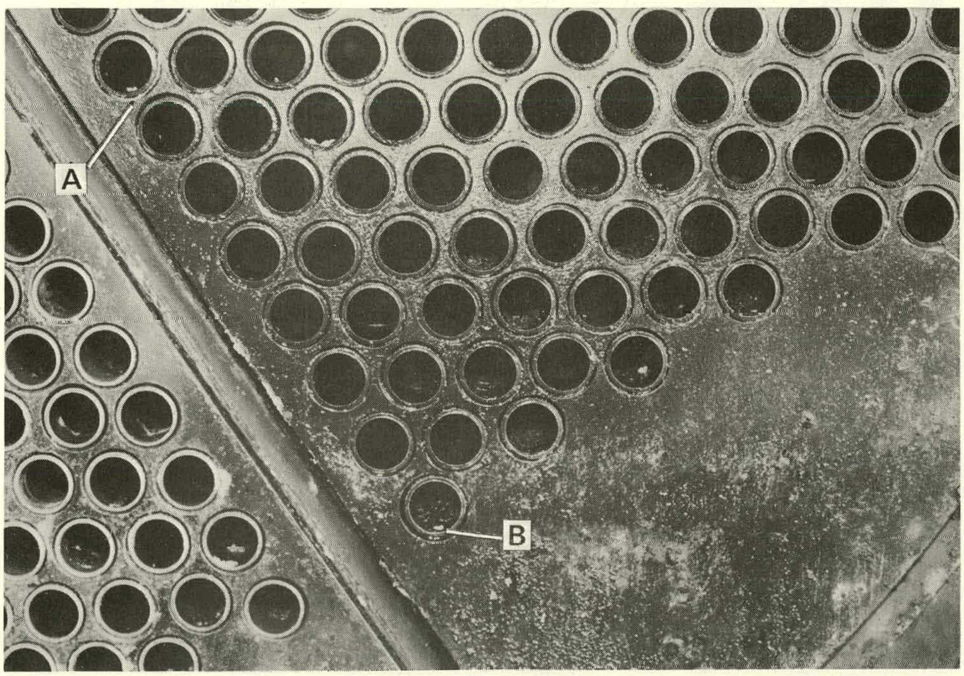


Figure 14. Close-up View of Melter-Condenser Showing (A) Corrosion Product between Tube and Tube Sheet and (B) Debris in Tubes

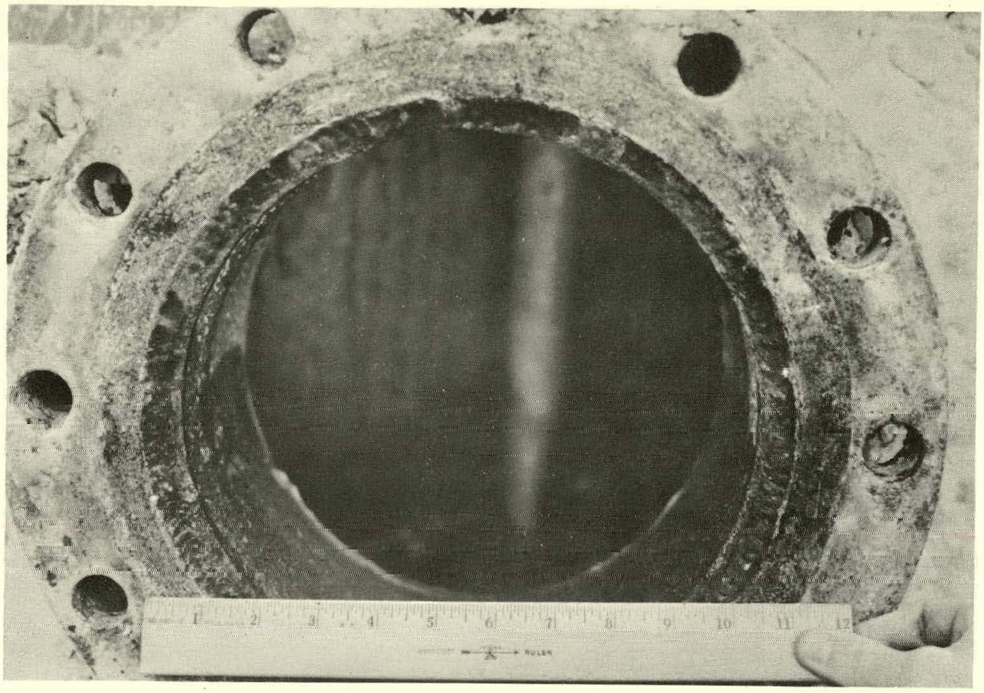


Figure 15. Inlet Flangc on Melter-Condenser Water Box

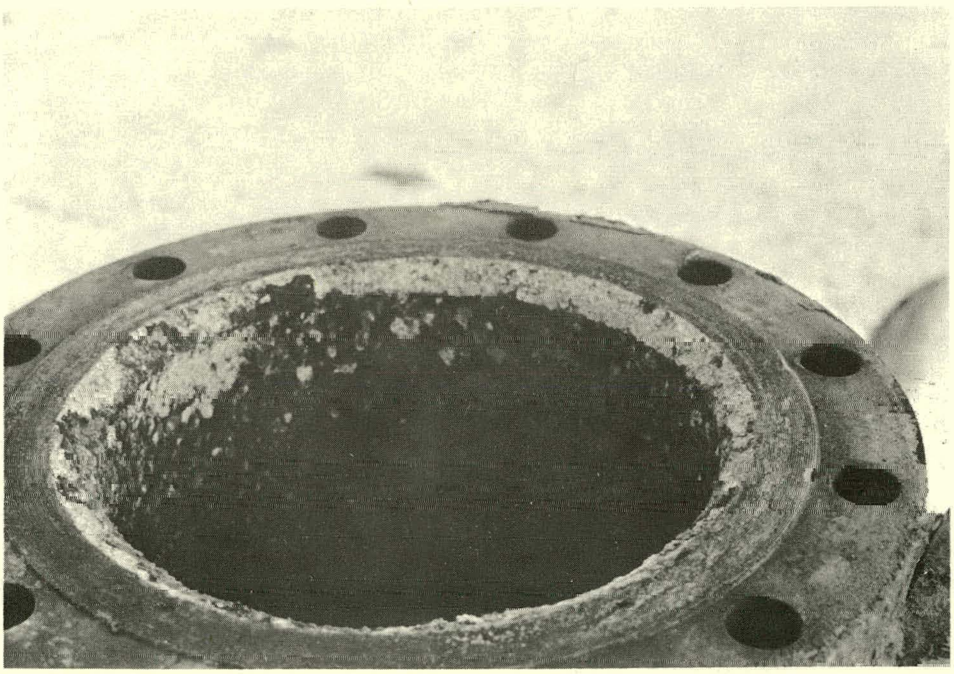


Figure 16. Discharge Flange on Melter-Condenser Water Box

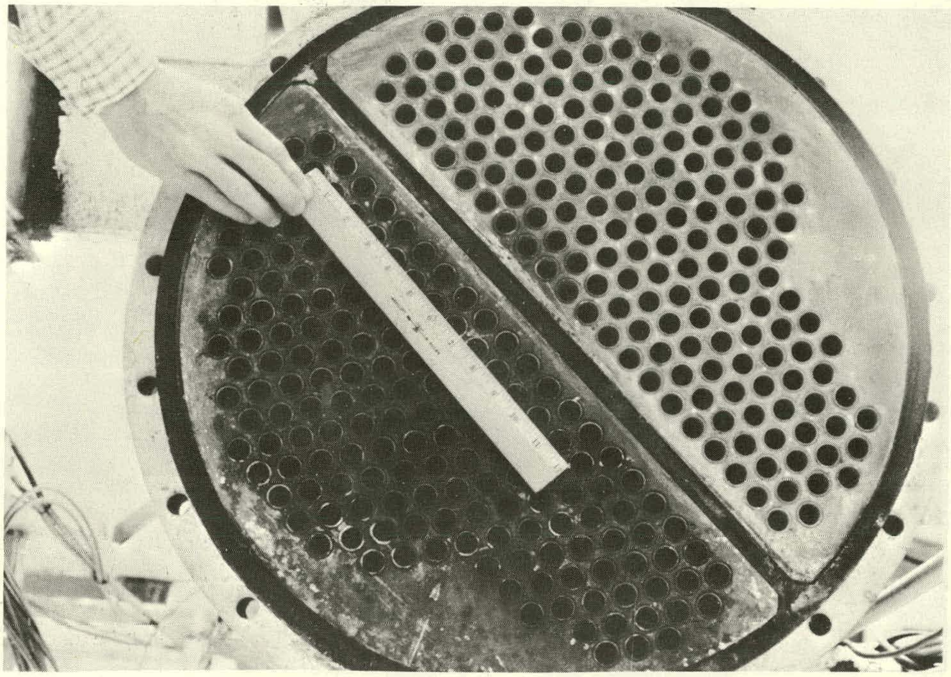
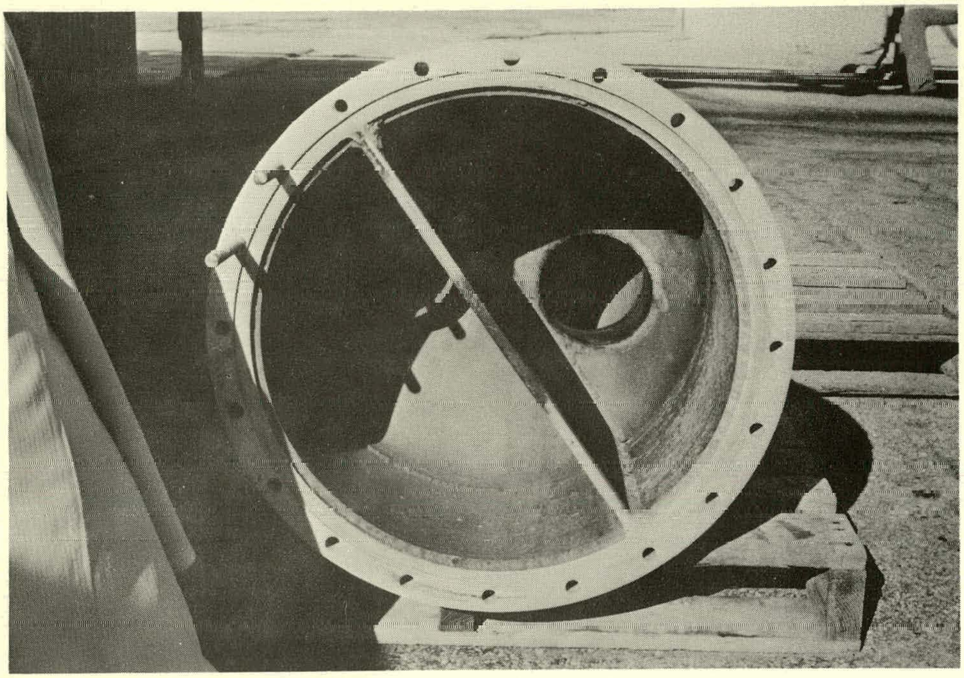


Figure 17. Overall Appearance of Tube Sheet on Heat-removal Condenser



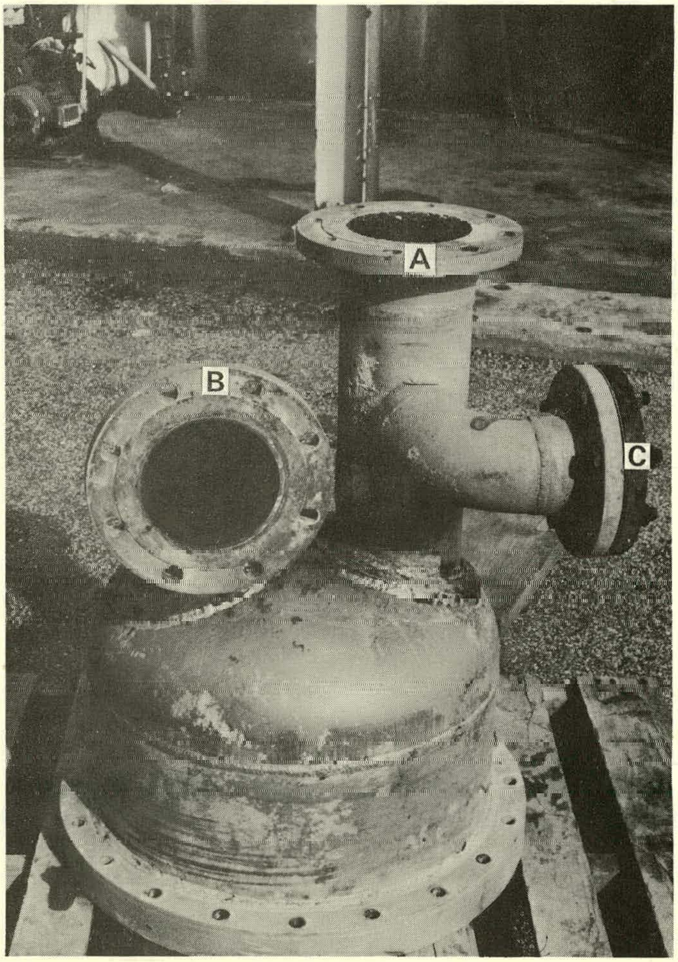


Figure 18. Appearance of Heat-removal Condenser Water Box. (A) Inlet, (B) discharge, and (C) steel blank and bolts.

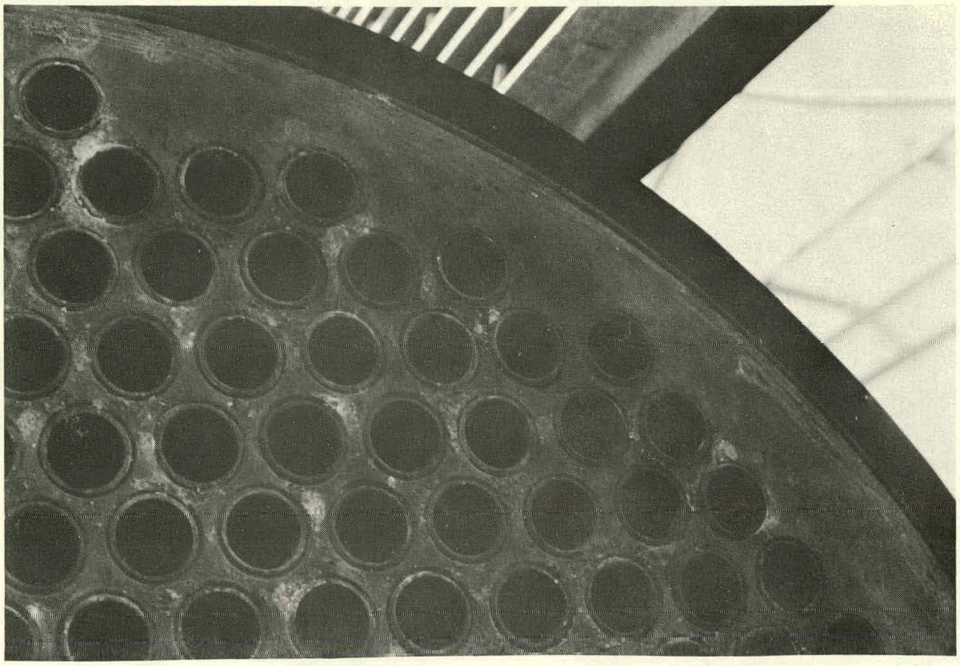


Figure 19. Close-up View of Heat-removal Condenser Tube Sheet Showing Pitting Corrosion. Maximum depth of attack approximately 6 mm.

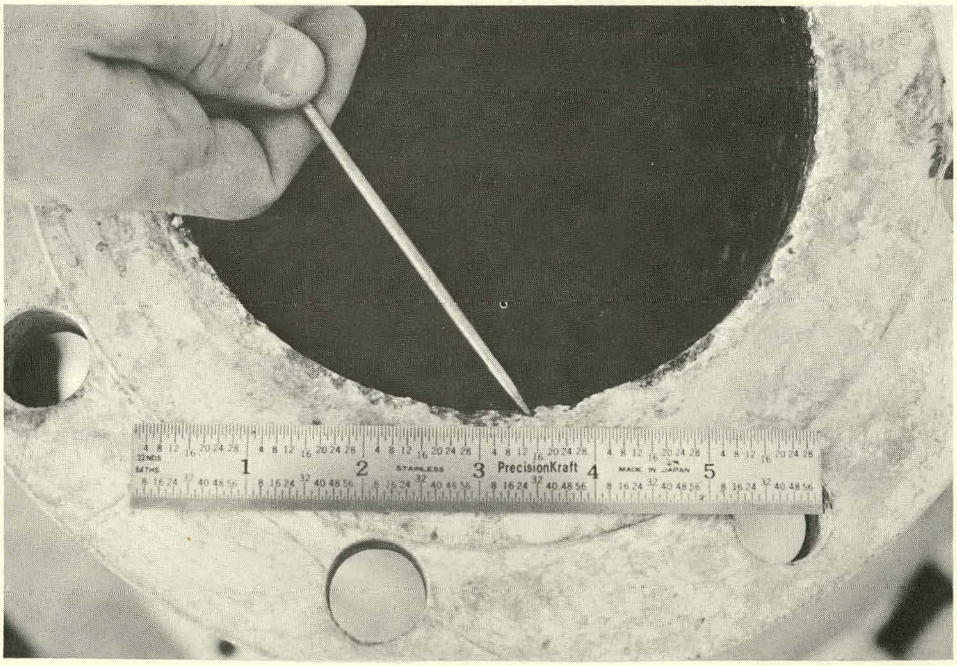


Figure 20. Close-up Appearance of Inlet Flange on Heat-removal Condenser Water Box. Depth of attack approximately 6 mm.

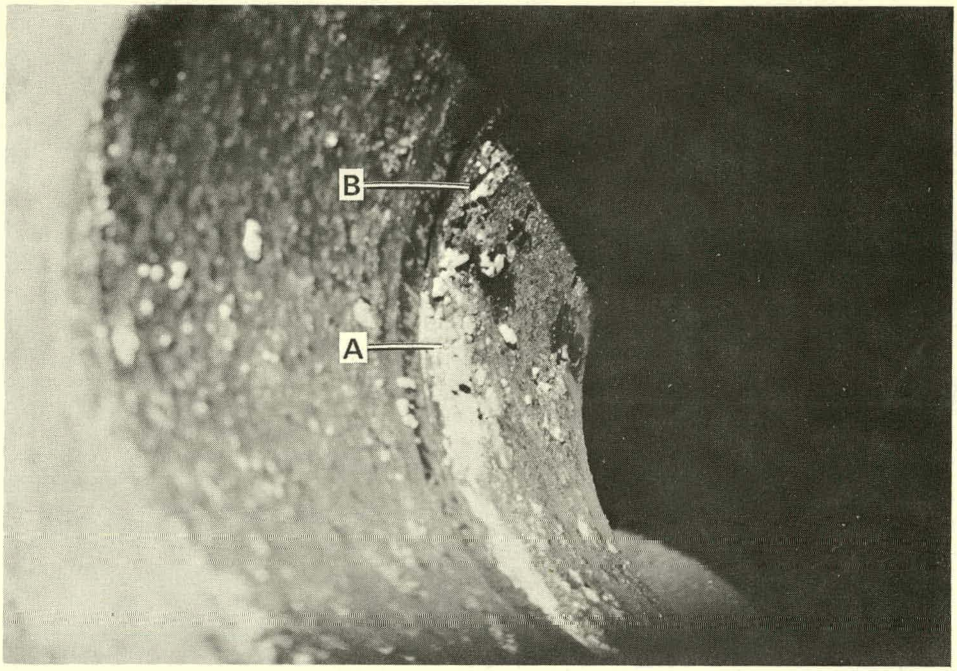


Figure 21. Close-up Appearance of Inlet Pipe on Heat-removal Condenser Water Box Showing (A) Corrosion Products and (B) Pitting

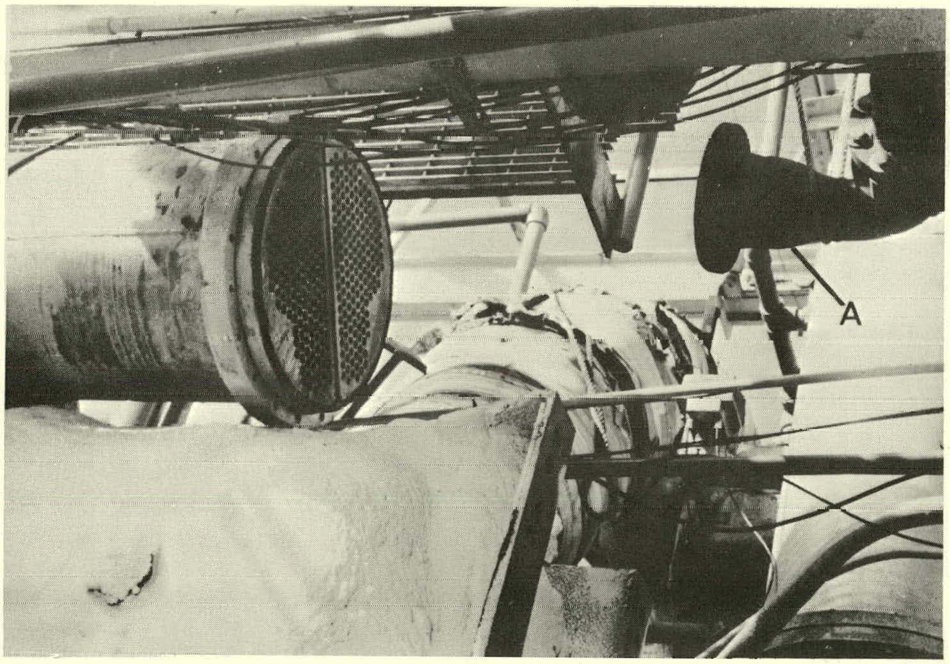


Figure 22. Overview of Inlet-discharge End of Heat-removal Condenser with Water Box Removed. Steel pipe section that supplied seawater to heat exchanger is designated by the symbol A.

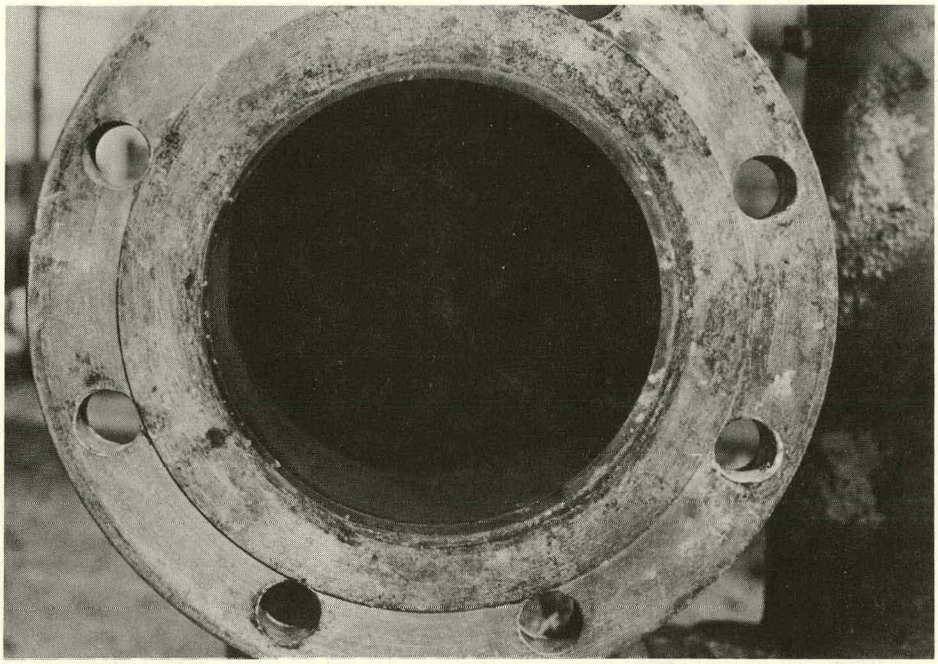


Figure 23. Close-up View of Discharge Flange on Heat-removal Condenser Water Box Showing Minimal Corrosion Attack

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