Corrosion in Potash Solutions

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ABSTRACT

A series of static and dynamic laboratory tests was designed to investigate potential corro- n problems in solution mining and subsequent processing of potash solutions. The corrosion e of mild steel was found to be dependent on a number of variables such as temperature, veloc- magnesium chloride content and presence of salt crystals in the solution. After investigations hese variables a second series of tests was conducted to determine materials of construction those portions of the process where the corrosion rate of mild steel would be excessive. The st problems would be experienced when handling slurries at high velocity where copper-nickel 30 and Type 1 Ni-resist gave the best performance. Protective coatings and linings were also ted but in this series only rubber was satisfactory and only providing it had a good bond to the el base.

INTRODUCTION

Imperial's laboratory work on corrosion in potash solutions was started to aid the Engineer- ; Department in the specification of construction materials for a proposed solution-mining and ocessing plant. A preliminary literature search revealed little useful information on corrosion the environments likely to be encountered. Furthermore, the plant's specific operating condi- ns were not yet known. These two facts necessarily widened the scope of the test program.

The first series of tests was designed to determine if a corrosion problem was likely to be countered with mild steel and, if so, what the causes would be.

The second series was aimed at methods of corrosion control. It involved investigations of sistant materials and protective coatings and linings.

TEST PROCEDURE

lution

The tests were made with synthetic solutions containing potassium, sodium and magnesium lorides. The potassium- and sodium-chloride contents were kept constant, close to what was pected under actual operating conditions. The magnesium-chloride content was varied from ro to four percent, the expected variation throughout the process. The view was that the corro- on rate would be definitely affected by the magnesium-chloride content of the brine solution (1). e effect of adding 8 p. p. m. copper ions to the test solution was also investigated, as Dr. L. A. ubio Felipe (2) had found that the presence of copper ions in a brine solution decreased the

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corrosion resistance of steel. For most of the tests the solutions were saturated at the test temperature. However, supersaturated solutions were used in the second series, to find out how abrasion by the crystals affected the corrosion rate.

Material

The corrosion coupons in the first series of tests were cut from SAE 1020 cold rolled steel strip. The specimens for the second series, which involved the testing of corrosion-resistant alloys were obtained with a certified chemical composition.[2]

Before being exposed in the test, the coupons were sandblasted, cleaned with acetone in our ultrasonic cleaner, and weighed. After exposure they were cleaned first with inhibited hydrochloric acid, then with acetone in the ultrasonic cleaner, and finally reweighed. Any weight losses from the cleaning procedure were considered when computing corrosion rates.

The protective coating and lining materials tested were applied to 8" × 8" × 1/8"-thick steel panels. Whenever possible this was done by the manufacturer; otherwise it was done in the laboratory under the best conditions and with strict adherence to manufacturer's instructions.

Apparatus

Static Test. The apparatus is shown schematically in Fig. 1, which is self-explanatory. The bottles were kept at a constant temperature in either water baths or ovens depending on the test temperature. The test coupons employed were of the strip type, 1/2" × 3".

Dynamic Test. The dynamic tests were conducted in a rotating-spindle corrosion-test apparatus, which contained five test cells immersed in a constant-temperature oil bath. One of these cells is shown schematically in Fig. 2. The coupon drive shafts were driven by 'O' ring belts and were interconnected to provide a constant rotation speed. This speed could be varied and was checked by means of a Stroboscope. The test coupons used were two inches in diameter and cut from the same stock as the coupons in the static test.

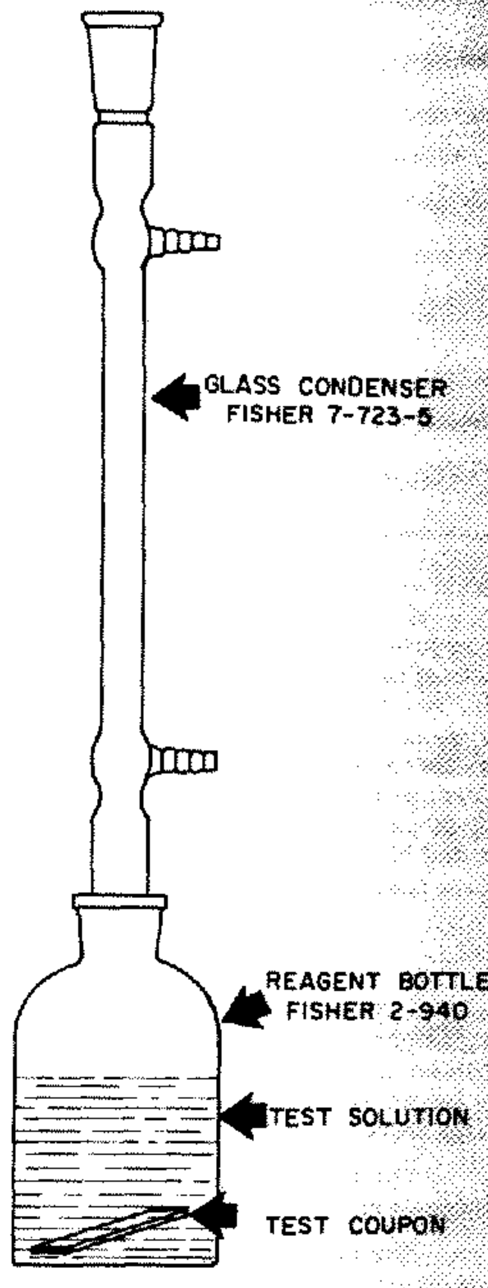

Figure 1. Static test for determining corrosivity of potash solutions.

Coating Test. Protective coating and lining materials were tested in the apparatus shown in Figs. 3 and 4. This apparatus was designed by Torres and Feuer (3). The test panels were sealed to each side of the tester with RTV silicone rubber. A quartz rod-type heater was used to maintain the required test temperature. The tester was filled up to the bottom of the 29/42 neck with the standard test solution. The condition of the coating was monitored by applying a constant 6.3V alternating voltage between the test panel and a carbon rod inserted through the thermometer neck, and measuring the resultant current flow. The performance of the coating could also be observed through the glass walls of the tester.

[2] Obtained from Corrosion Test Supplies Inc., P.O. Box 176, Baker, La.

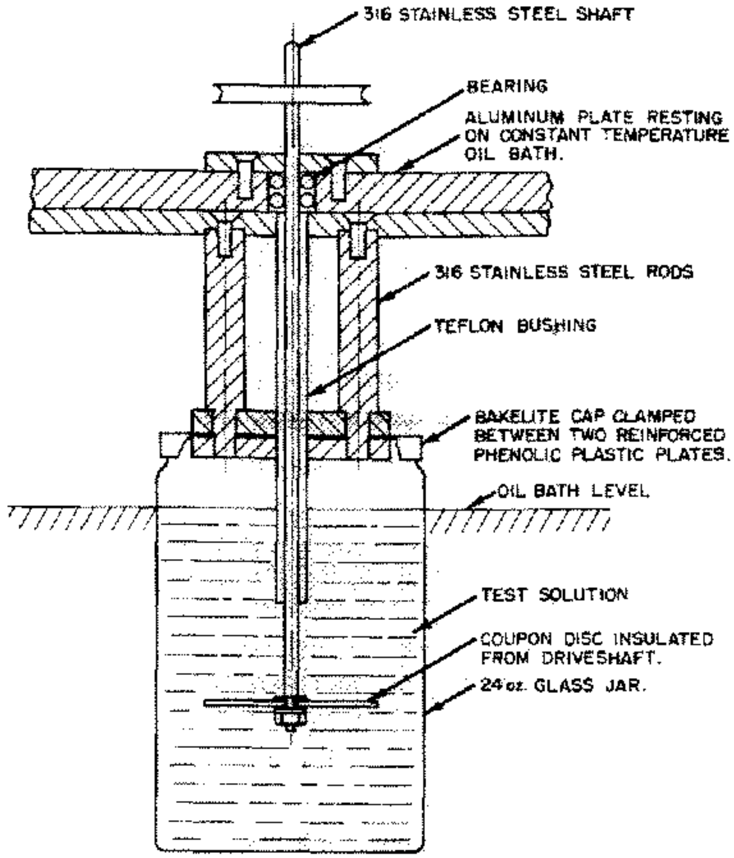

Figure 2. Dynamic Corrosion Test.

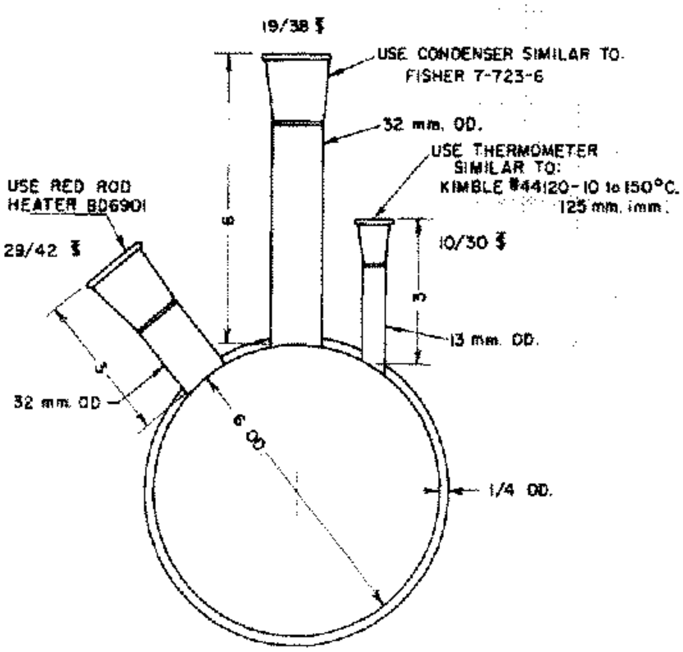

Figure 3. Front view of lining corrosion tester.

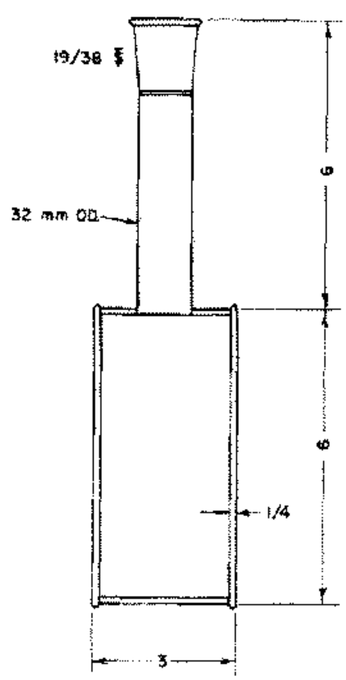

Figure 4. Side view of lining corrosion tester.

TEST RESULTS AND DISCUSSION

Investigative Series

1. Effect of Adding Magnesium Chloride to a Saturated Potassium-Sodium Chloride Solution.

   The results of this test, together with the exposure conditions, are shown graphically in Fig. 5. The potassium- and sodium-chloride contents were kept constant, in proportions close to the expected plant conditions. A complete series of tests was conducted at 190°F and 230°F, with little observable difference in the corrosion rate. The rate shows a linear increase with increase in magnesium-chloride content, to the extent that with a 4% addition it is approximately double.

   Tests at 140°F with 4% magnesium-chloride added showed a resultant corrosion rate of half that at 230°F, or a little over 2 mpy.

   Additional tests at 190°F and 230°F with 8 p.p.m. copper ions added showed that these conditions did not affect the corrosion rate.

2. Effect of Exposure Time.

   a. Static Test. For this test duplicate runs were made with and without magnesium chloride which again demonstrated (Fig. 6) its effect on corrosion rate. After a period of seven days this rate becomes virtually constant.

   b. Dynamic Test. A disc speed of 300 r.p.m. was selected; this gave a peripheral velocity equal to that from a flow of 2,000 barrels/day through a three-inch pipe. Figure 7 shows the results. The corrosion rate stabilizes after seven to fourteen days and closely approaches the static rate.

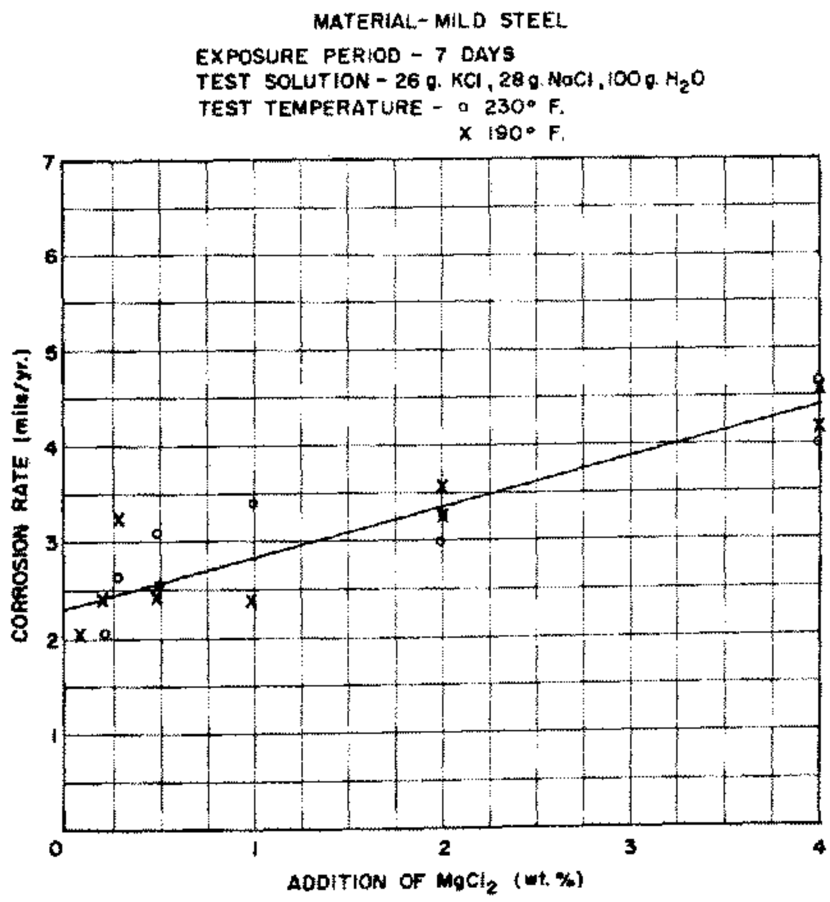

Figure 5. Effect of $MgCl_2$ addition to a saturated KCl-NaCl solution.

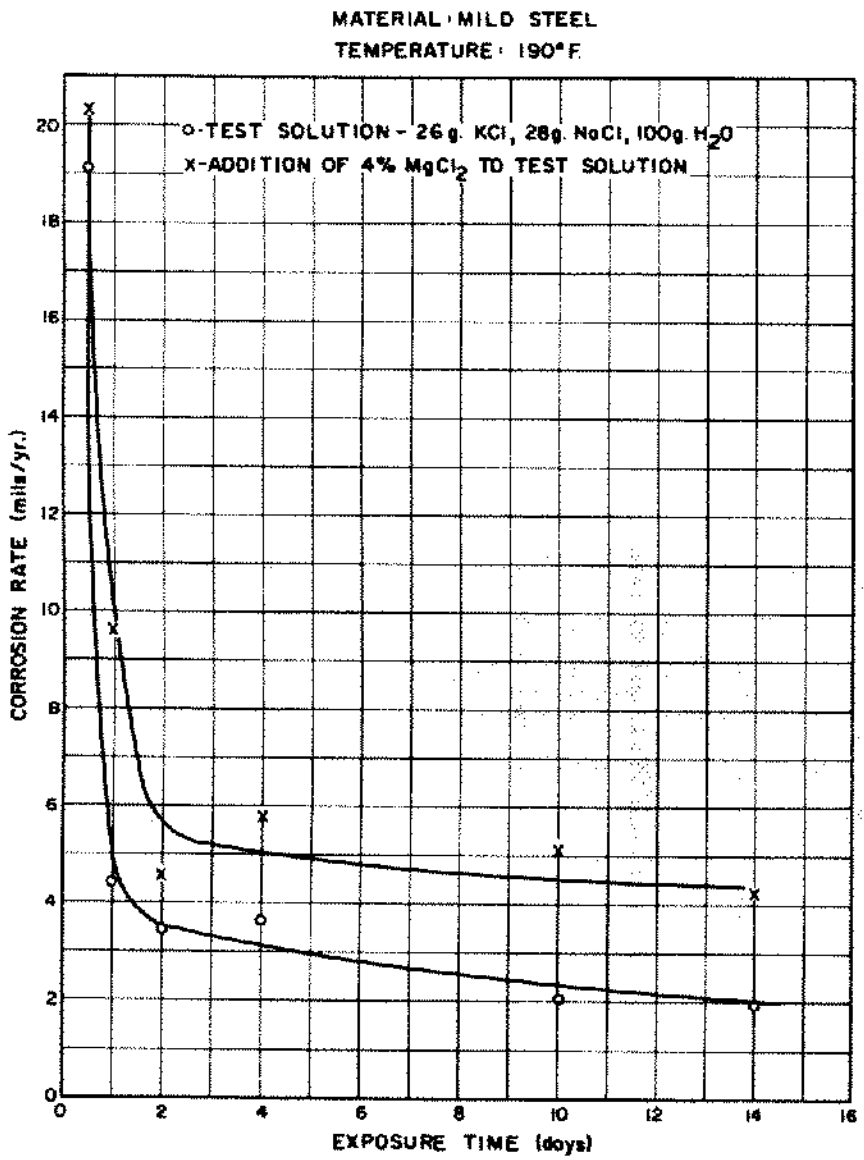

Figure 6. Effect of exposure time on corrosion rate in static test.

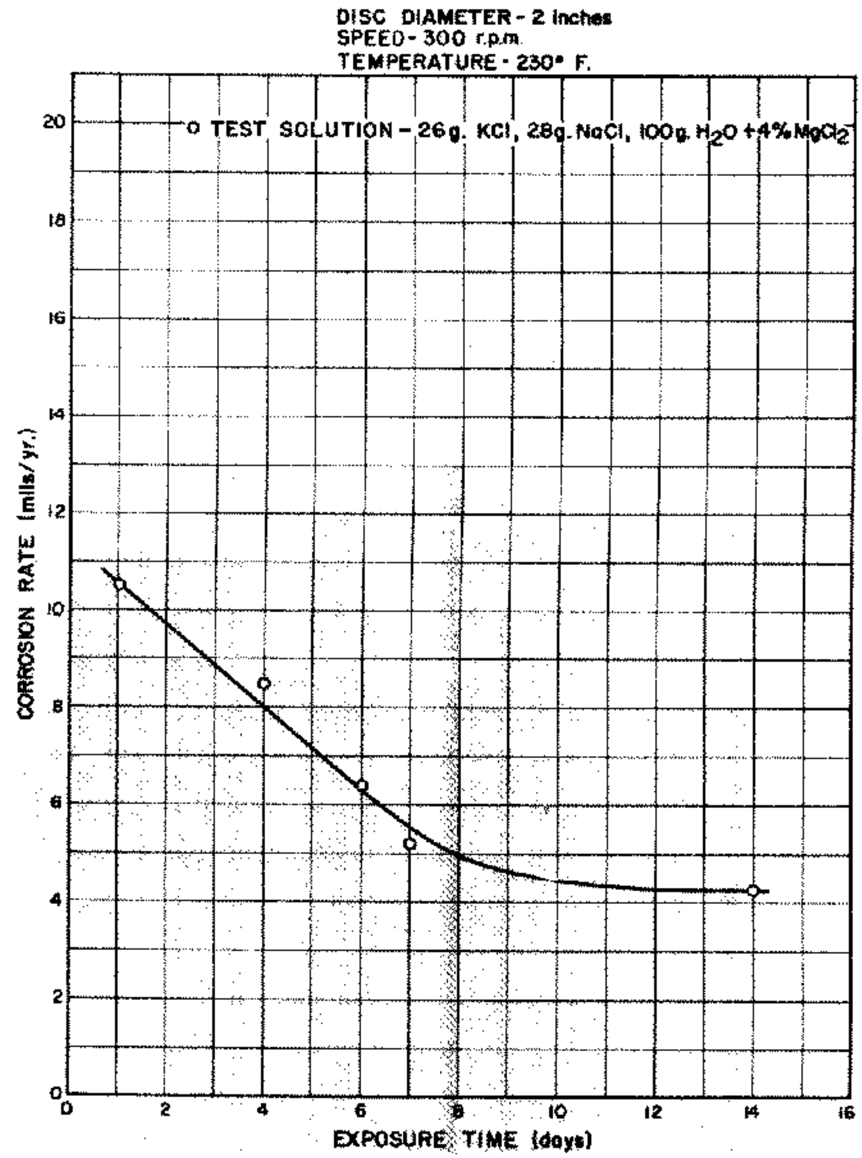

Figure 7. Effect of exposure time on corrosion rate in rotating disc test.

Remedial Series

1. Corrosion-Resistant Material

   Both static and dynamic tests were conducted under the most severe conditions found in the preliminary series of tests (viz. 230°F and with the addition of 4% magnesium-chloride to the sodium-potassium chloride solution). At the test temperature the solution was close to saturation. As seven days appeared to produce a stabilized corrosion rate, this was fixed on as the test period.

   The results of this test are shown in Figs. 8 and 9. Most of the alloy materials selected had corrosion rates equal to or less than 1 m.p.y. Wrought iron gave a surprisingly poor performance. Stainless steel, despite its low corrosion rate, is not recommended in this application because it is liable to stress-corrosion cracking in chloride environments (4). The use of aluminum bronze is also suspect because plug-type dealuminification has been reported under these conditions (5). However, this type of attack was not noted in these particular tests.

   To determine how abrasion by salt crystals suspended in solution would affect the corrosion rate, both mild steel and monel were tested in a supersaturated solution with the rotating-disc tester. The results in Fig. 10 show a fourfold increase in the corrosion rate.

   Several of the materials were checked at higher velocity in the supersaturated solution. In some parts of the system velocities of 6 1/4 ft/sec were expected which is equivalent to a coupon speed of 716 r.p.m. The results in Fig. 11 again show a marked increase in the corrosion rate of copper-nickel 70-30 and monel, both potential heat exchanger-tube materials, the copper-nickel had a slightly lower rate. Type 1 Ni-resist gave the best performance and should be a good material for valves and pumping equipment.

2. Protective Coating and Lining

   In this test a saturated sodium-potassium-magnesium chloride solution at a temperature of 230°F was used. The test period varied from two to ten months, depending on the

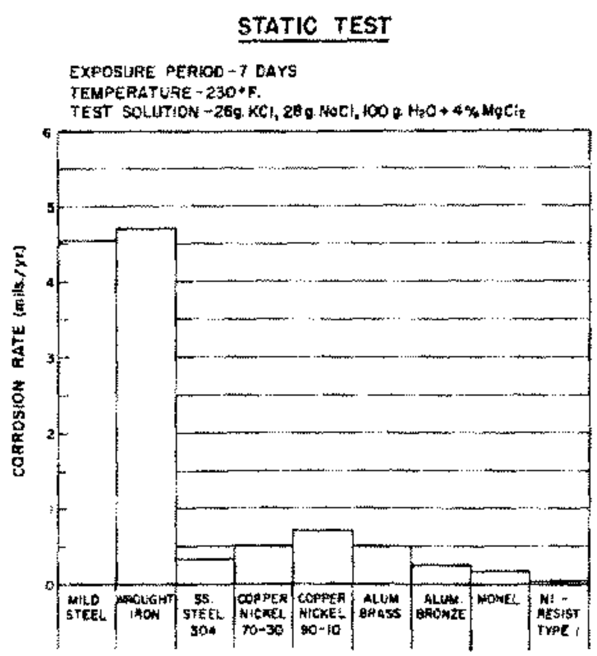

Figure 8. Comparison of the corrosion rate of a number of materials in a saturated KCl-NaCl Solution.

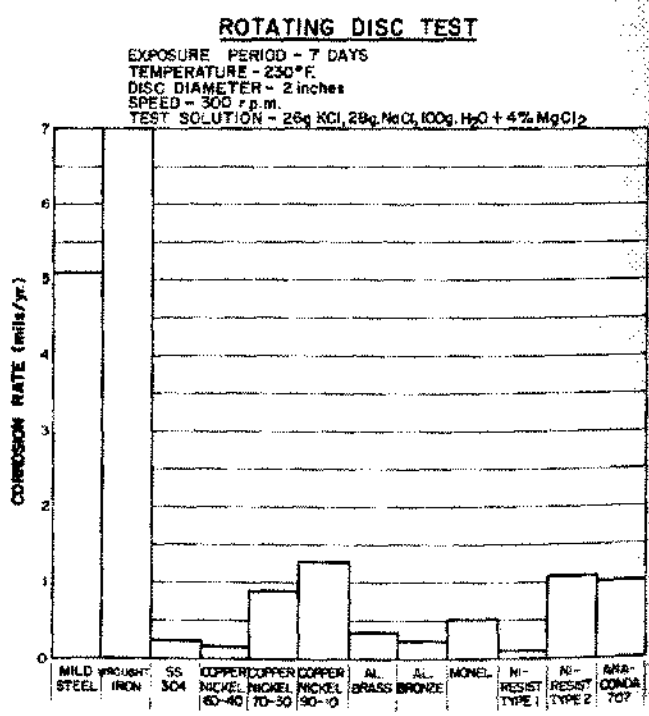

Figure 9. Comparison of the corrosion rate of a number of materials in a saturated KCl-NaCl solution.

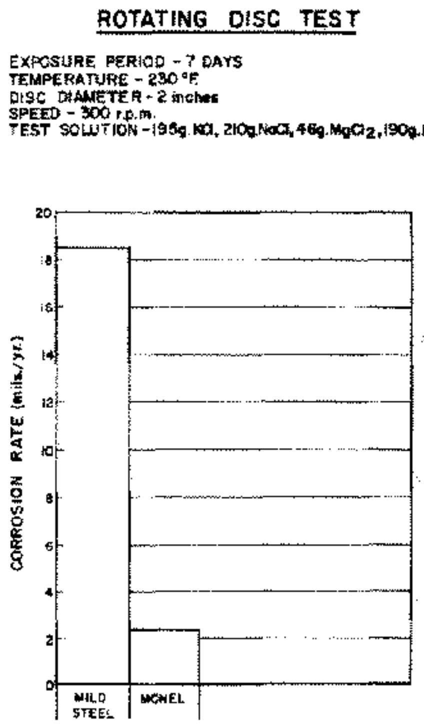

Figure 10. Comparison of the corrosion rate of a number of materials in a supersaturated KCl-NaCl solution.

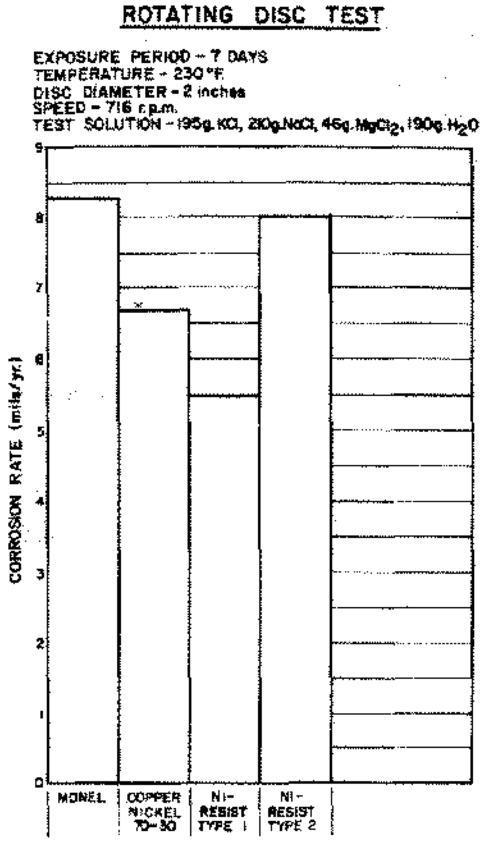

Figure 11. Comparison of the corrosion rate of a number of materials in a supersaturated KCl-NaCl solution.

ilability of the coatings and their performance. The results are tabulated in Table 1. Some of rubber linings are apparently permeable to water and their performance depends greatly on a d bond with the underlying steel. Rubber # 1 and Rubber # 3 were the only lining materials ch performed satisfactorily. The photograph in Fig. 12 of Rubber # 1 after exposure demon- ates its excellent condition. Both the polyester linings tested were permeable to water and could be recommended. The surface of reinforced polyester # 1, as shown in Fig. 13, was discol- d, and a holiday detector gave a signal over the entire area. None of the solvent-type coatings ed were suitable for this service. Even the 100%-solids epoxy shown in Fig. 14 stood up rly, with severe blistering in the vapor zone and holidays in the liquid zone. The baked coat- s performed better and epoxy phenolic # 2 and the polyurethane shown in Fig. 15 could be con- ered seriously for long-term exposure. Their resistance to the abrasive effect of salt crystals not tested.

SUMMARY OF RESULTS

The laboratory tests indicate that at moderate temperatures corrosion problems should not severe. However, even under these conditions, and in any case where long periods between t shutdowns are required, some precautions will be needed. Under conditions of high tempera- and/or abrasion the corrosion rate on unprotected mild steel is excessive. Magnesium- ride content of the salt solution is another important variable that affects the corrosion rate.

There are a number of potentially good corrosion-resistant materials which could be used in sh-processing equipment. Type 1 Ni-resist should be good for valves and pumps. Monel or per-nickel should be satisfactory for heat-exchanger tubing. Monel-clad steel should be con- red for critical equipment.

TABLE 1

COATING OR LINING	TEST PERIOD	CURRENT (MA) START	CURRENT (MA) FINISH	BOND	REMARKS
RUBBER #1 Rubber lining 3/16" sheet	6 mos.	0	0	Good	
RUBBER #2 Rubber lining 3/16" sheet	6 mos.	0	0	Disbonded	The lining has disbonded in both liquid and vapor zones. The blisters were full of relatively fresh water under pressure.
RUBBER #3 Rubber lining 3/16" sheet	6 mos.	0	0	Good	
HYPALON 3/16" sheet	10 mos.	0.03	0.03	Disbonded	Water found behind lining.
REINFORCED POLYESTER #1	10 mos.	0	0.05	Poor	Holiday signal over entire surface. Steel corroded under lining.
REINFORCED POLYESTER #2	10 mos.	0	0.01	Poor	Surface cracks on coating but no holidays detected. Steel slightly corroded.
100% SOLIDS EPOXY	10 mos.	0.6	1.9	--	Coating blistered in vapor zone. Holidays in liquid zone.
BAKED EPOXY PHENOLIC #1	10 mos.	0.01	0.05	Good	Discoloration of coating in liquid zone indicating start of breakdown. Some holidays.
BAKED EPOXY PHENOLIC #2	10 mos.	0	0.1	Good	Excellent condition. No holidays.
BAKED POLYURETHANE	10 mos.	0	0.1	Good	Slight discoloration of coating.
EPOXY PHENOLIC CATALYST CURE	6 mos.	5.0	12.0	--	Coating blistered.
VITON SOLVENT-TYPE COATING	2 mos.	--	--	--	Coating blistered.
ASPHALT NEOPRENE	6 mos.	0	6.0	--	Coating blistered.

Two of the rubber linings tested were satisfactory; these results also showed clearly the importance of a good bond between lining and steel. None of the solvent-type coatings tested proved adequate for constant immersion service. One of the epoxy phenolic baked coatings and the baked polyurethane met the requirements, but their resistance to abrasion by salt crystals was not tested.

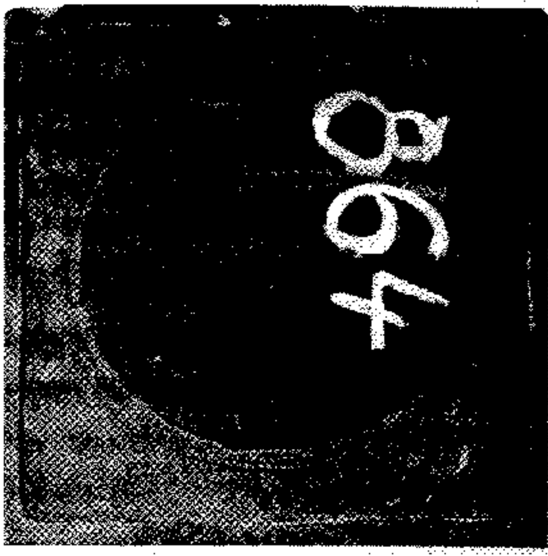

Figure 12. Rubber No. 1.

Figure 13. Reinforced polyester No. 1.

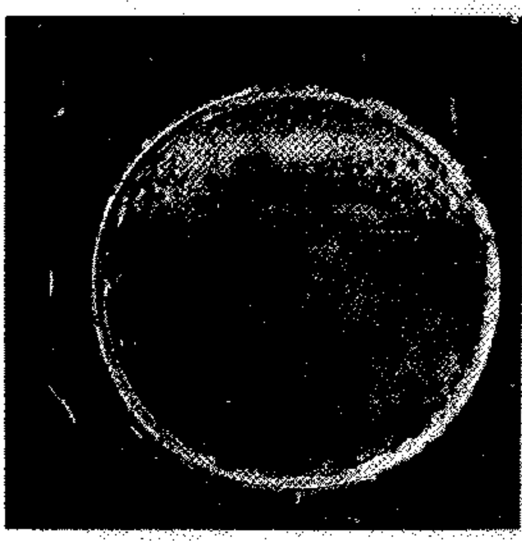

Figure 14. 100%-solids epoxy.

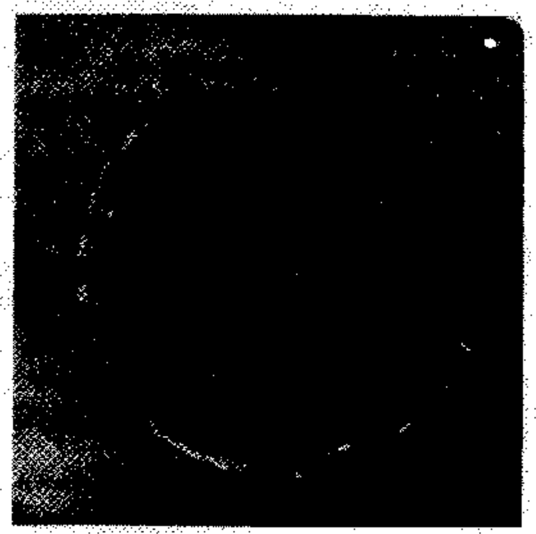

Figure 15. Baked polyurethane.

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