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JOHN F. KENNEDY SPACE CENTER
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CORROSION ACTIVITIES AT THE NASA KENNEDY SPACE CENTER

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ABSTRACT

This report documents summer faculty fellow efforts in the corrosion test bed at the NASA Kennedy Space Center. During the summer of 2002 efforts were concentrated on three activities: a short course on corrosion control for KSC personnel, evaluation of commercial wash additives used for corrosion control on Army aircraft, and improvements in the testing of a new cathodic protection system under development at KSC.

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1. INTRODUCTION

During the summer of 2002 efforts were concentrated on three activities: a short course on corrosion control for KSC personnel, evaluation of commercial wash additives used for corrosion control on Army aircraft, and improvements in the testing of a new cathodic protection system under development at KSC. These three projects will be discussed separately below.

2. CORROSION COURSE

A recent study placed the annual costs of corrosion in the United States at more than $275 billion—approximately 3.2% of the GDP. [1] NASA has millions of dollars in corrosion costs, and it is important that NASA personnel understand this multidisciplinary problem. The corrosion course held at KSC during the summer of 2002 was open to all KSC personnel. Approximately 12 participants would show up each week—the attendance varied depending on the topic. Figure 1, which shows corrosion on the nose of the Statue of Liberty, is one of a series of hundreds of slides used to

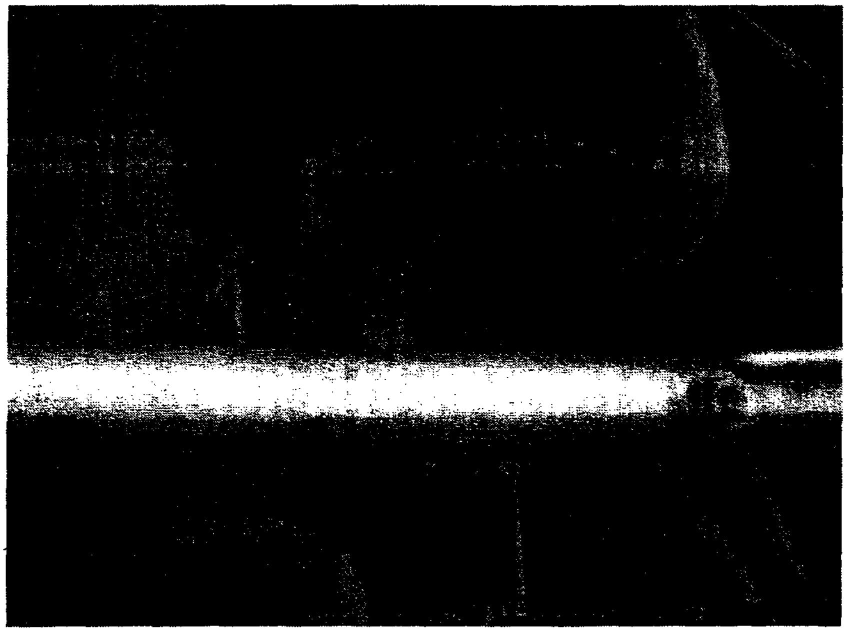


Figure 1: Corrosion on the nose of the Statue of Liberty caused by inadequate drainage of condensation forming on the inside of the statue.

discuss various aspects of corrosion control. Most participants in the course were chemists by training, so the course emphasized materials, a subject where most chemists have little or no formal training. Other subjects included in the course included basic electrochemistry, cathodic protection, and inspection techniques.

3. EVALUATION OF COMMERCIAL WASH ADDITIVES USED FOR CONTROL ON ARMY AIRCRAFT

Corrosion is a major problem facing the Army. Aircraft in use by the Army must be maintained for decades, and Army aircraft are frequently used and maintained under more

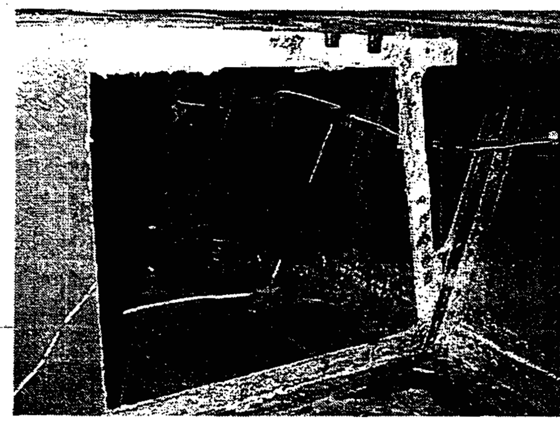


Figure 2: Helicopter corrosion due to the use of an improper cleaning compound

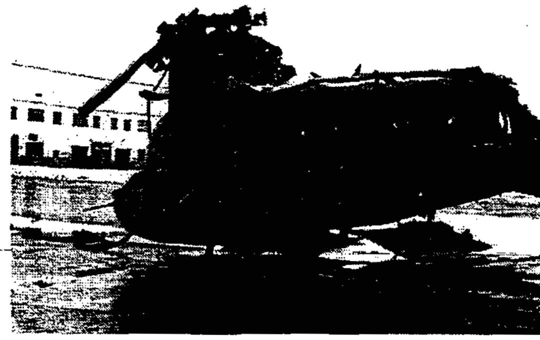


Figure 3: A crashed Chinook helicopter caused by hydrogen embrittlement due to the use of an improper cleaning compound.

corrosive circumstances than civilian aircraft. Figures 2 and 3 show the results of the use of improper cleaning compounds on Army aircraft. Excessive maintenance costs (Figure 2) are bad enough, but the loss of a $12 million helicopter (Figure 3) is even worse. Fortunately, no loss of life was associated with the crash shown in Figure 3.[2]

The Army has funded a multi-year exposure test at the Kennedy Space Center with the objective of determining the effectiveness of a variety of commercial products that are being promoted for washing helicopters and airplanes. Four commercial products are being tested and compared with three controls: washing with seawater, washing with demineralized water, and no washing. Table 1 shows the chemical analyses of the products under test.

Table 1

Chemical analysis of cleaning agents

Sample ID	Concentration, ppm #1	#2	#3	#4
ANIONS				
Fluoride	nd	nd	3,477	nd
Chloride	110	60	nd	232
Nitrite	91	131	nd	314
Nitrate	94	nd	166	9,511
Phosphate	25,191	65	80	nd
Sulfate	1,152	92	227	529
CATIONS				
Sodium	7,930	2,367	1,453	nd
Ammonium	nd	1,919	134	36,053
Potassium	5,537	116	280	1,023
Magnesium	nd	nd	nd	nd
Calcium	48	56	60	nd

Three sets of identical panels are exposed on special racks at the KSC Atmospheric Test Facility. Six of the seven exposure programs require weekly washing with a liquid cleaner mixed according to the manufacturer's specifications. This is shown in Figure 4.

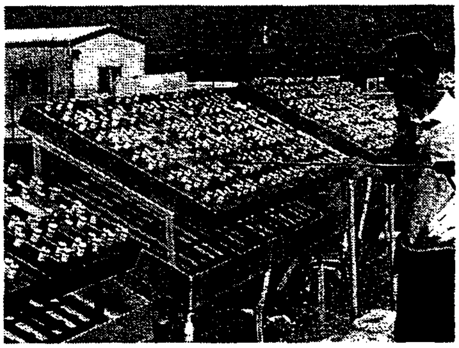
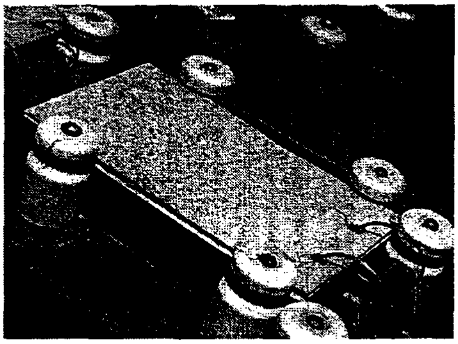
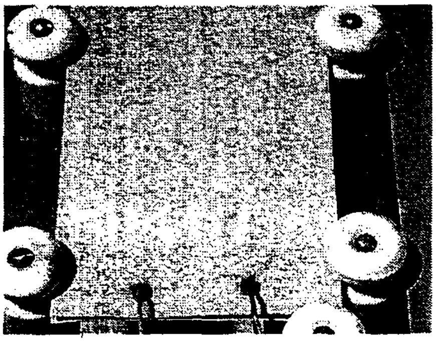


Figure 4: Weekly washing the top surfaces of exposure panels

After almost two years of exposure, some of the panels are corroding and some of them are in relatively better condition. Figure 5 shows exfoliation corrosion of 7075T6 aluminum panels washed with one of the commercial solutions. The condition of these

Figures 5a and 5b: Alternate views of Aluminum 7075T6 panel showing exfoliation corrosion.

panels appears worse than the control panels that were not washed or were washed with seawater. Two of the sets of panels being washed with commercial cleaners were showing exfoliation corrosion in July 2002. The other two sets of panels, washed with different cleaning solutions, seemed to show less corrosion, and no exfoliation was evident. The control exposures with demineralized water washing and with no washing seemed to produce better results than the two solutions that allowed exfoliation of the 7075T6 aluminum.

The samples are still under test, and they are not scheduled for removal from the beach until October 2002. Until this is done, it will be impossible to definitely rank the efficiency of the cleaning solutions, but one of the solutions may be doing better than the rest.
Figure 6 shows all of the alloys under test with one of the cleaning agents. The arrow points to a 6061T6 aluminum panel with a chromate conversion coating. The color of the chromate conversion coating was still apparent when this photo was taken in July 2002. The color was not apparent on similar panels of the same alloy/chemical treatment washed with any of the chemicals or on any of the control exposures.

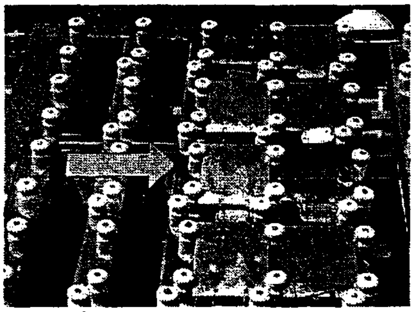


Figure 6: Effective wash additive with residual chromate color showing on middle aluminum panel.

A review of the results of the one-year test showed little weight loss and minimal pitting corrosion. Ranking of the exposure/washing conditions was very difficult.

Preliminary inspection during the summer of 2002 indicates that the extent of corrosion will be substantially greater after two years of exposure and that definite ranking of the exposure/washing conditions will be possible. The ASTM standards used for evaluating the alloys seem adequate for this purpose. Problems identified during the summer include a lack of documentation of how the one-year results were obtained. Photography to show the conditions shown in Figure 4 will also be necessary.

4. CATHODIC PROTECTION OF REINFORCED CONCRETE STRUCTURES

Figures 7a and 7b show failures of reinforced concrete structures due to corrosion. Corrosion of reinforced concrete is a major problem on a variety of structures including buildings, highway bridges, and NASA KSC launch facilities. KSC has developed a new method of cathodically protecting concrete structures to limit/stop corrosion.

Figures 7a and 7b: Structural damage resulting from corrosion of reinforced concrete buildings [4-5]

The concrete samples with a developmental cathodic protection system are under test at the KSC corrosion test site. Review of the test procedure and the experimental setup has indicated that the following ideas should be incorporated into the KSC corrosion test plan:

1. Scanning electron microscopy should be added to the evaluation plan for all concrete corrosion tests at KSC. Concrete is a very inhomogeneous material, and the SEM can be used to determine migration paths, degradation mechanisms, etc. in concrete. Figure 8 shows how the X-ray spectroscopy capability of the SEM is being used by the Oregon Department of Transportation in their collaborative research with the U.S. Bureau of Mines laboratory in Albany, Oregon.

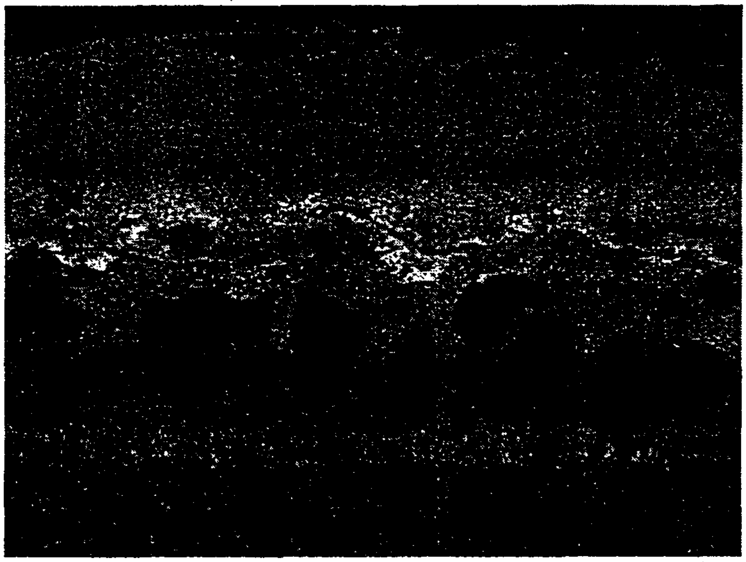


Figure 8: X-ray image map of chorine pattern in cathodically-protected concrete [6]

2. A technique for marking the depth of pH changes associated with either carbonation (reaction of the concrete with the CO2 in moist air) or with the effects of cathodic protection should be practiced and demonstrated. It should then be demonstrated on the initial samples at the start of the cathodic protection testing and at the end of the test.

3. Chloride analysis (ASTM total chloride testing) [7] should be started and documented. Initial efforts on this were underway during the week of 5 August. Wayne Marshall in the Chemistry group will conduct the test and coordinate with Prof. A. Sagues at the University of South Florida on these tests.

5. ACKNOWLEDGEMENTS

Dr. Luz Marina Calle was the NASA colleague whose original ideas started this project. She also obtained funding for its continuation. I thank her for her insight, ideas, and thoughtful contributions and encouragement. Louis McDowell is the NASA researcher most responsible for the continuing vitality of the Corrosion Test Bed efforts at Kennedy Space Center, and I thank him for his foresight and determination in keeping Kennedy Space Center as a major source of government expertise in corrosion research, engineering, and testing. Joe Curran from Dynacs insured that support was available whenever necessary. This work could not have been done without all of their help.

6. REFERENCES

[1] Cost of corrosion: In the U.S.A. $276 billion/yr, http://www.corrosioncost.com/home.html., August 6, 2002.

[2] Aircraft cleaners, http://www.chinook-helicopter.com/maintenance/issues/cleaners/cleaners.html)., August 6, 2002.

[3] Kennedy Space Center Corrosion Technology Test Bed, http://corrosion.ksc.nasa.gov/, August 6, 2002.

[4] Damage from chloride-based deicers, http://www.cryotech.com/imgs/garage.gif, August 6, 2002

[5]. R. Heidersbach, "Corrosion,' Chapter 3 in An Attorney's Guide to Engineering, 1. Kuperstein and N. Salters, eds., Matthew Bender & Company, New York, 1986.

[6] Photo image supplied courtesy of S.Cramer, U. S. Bureau of Mines Albany Research Center, June 2002.

[7] Chemical Analysis of Hydraulic Cement, ASTM Standard C114-00, ASTM, Philadelphia.