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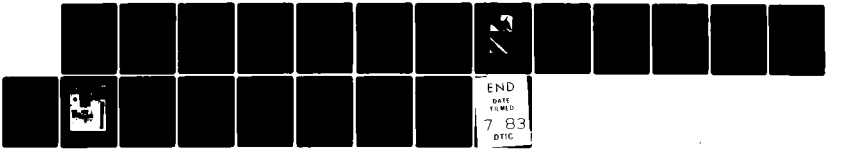

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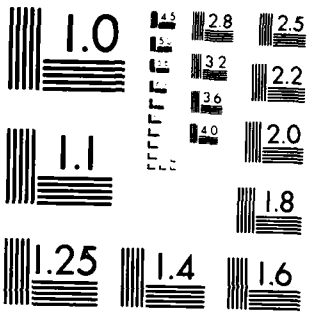

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REPORT SD-TR-83-36

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Nondestructive Tests for Corrosion in Fuel Tanks

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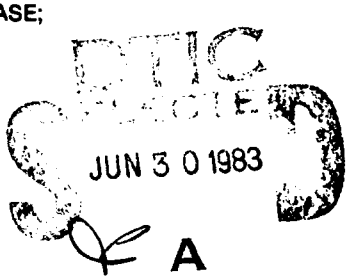
1 June 1983



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This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

James C. Garcia, Capt, USAF
Project Officer

Norman W. Lee, Jr., Colonel, USAF
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In a previous report, a method was presented for detecting corrosion on stainless steel surfaces based on the rapid catalytic decomposition of hydrazine by iron oxides. The feasibility of this method was demonstrated first with the chemical reagent itself as the test sample and later with rusted samples from a fuel tank diaphragm. In this report, we discuss the details of the procedure to test nondestructively an actual fuel tank in the laboratory. As a result of the tests, trace amounts of rust were identified in the tank.

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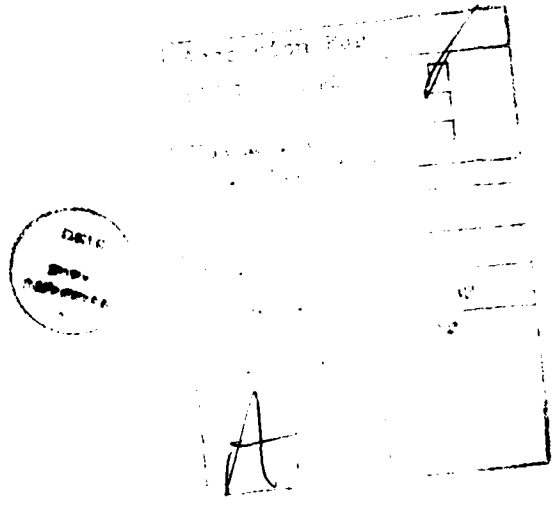

FIGURES

I. INTRODUCTION

A method for using hydrazine vapor as a nondestructive probe for detection of corrosion on stainless steel surfaces was outlined in a previous report*. The feasibility study was undertaken prior to the design and assembly of a laboratory test facility to be used for examining a number of Reactive Control Systems (RCSs) fuel tank assemblies for corrosion. The RCS flight hardware under inspection is a propellant tank assembly with a metallic diaphragm expulsion device for the controlled release of hydrazine to a reaction control thruster. The spherical tank and the diaphragm are made of 304-L stainless steel. A set of metallic reinforcement rings, decreasing in diameter from the outer periphery of the diaphragm, are brazed to the side that is pressurized. Thus, multimetal junctions are formed at the ring contours on the diaphragm surface. (The brazing compound itself, gold-nickel wire, provides a bimetallic interface.) These contact points on the diaphragm surface are more susceptible to corrosion because of galvanic and other effects than the normal inner wall of the tank assembly. Corrosion effects at these multimetal junctions can be accentuated by the presence of trace quantities of water or other rinsing solvents and possible active contaminants in the Freon pressurizing gas itself. Figure 1A and B are two photographs that show corrosion and its enhancement with time when exposed to an adverse simulated environment.

*P. Mahadevan and P. Breisacher, Private Communication, The Aerospace Corporation, 21 January 1982.

(A)

(B)

Fig. 1. Two Photographs That Exhibit Corrosion (A) and Its Enhancement (B)

II. VISUAL AND X-RAY RADIOGRAPHIC EXAMINATION OF THE FUEL TANK

The fuel tank was examined for dents and other impact damage during shipment. The Freon and hydrazine ports on the tank were unplugged and inspected. A reddish brown discoloration/stain was observed on the internal threads of the Freon ports. The diaphragm was observed to be in its normal position with one of the reinforcement ribs close to the bottom of the porthole. Thus, visual inspection of the diaphragm was limited to the cross-sectional area of the porthole only. No attempt was made to clean the stain on the threads. The port on the fuel side of the tank appeared to be clean. An x-ray radiograph of the inner tank configuration was taken at an outside service laboratory. No structural damage to the diaphragm, rib assembly, or weld joints was observed.

A portable wooden support frame was fabricated to mount the tank assembly for further tests.

III. PRELIMINARY ACCEPTANCE TESTS

A. PUMP-DOWN AND LEAK CHECK

During pump-out of the tank, it is required that the pressure differential between the large fuel section and the small Freon section at no time exceeds 50 Torr. This requirement is to prevent undue stressing of the expulsion diaphragm. In the normal unextended position of the diaphragm, the ratio of the volumes of the two sides is about 20. A pumping system was designed and built using a common pump and sets of fixed and variable valves on each side to regulate the pump rate.

The procedure can be explained with the detailed schematic of the test setup shown in Fig. 2. The crescent shaped section of the spherical tank is the pressurized side P_5. The fuel segment is P_6. The metering valve V_4 on the pumping manifold is adjusted manually while all the other valves V_{17}, V_{14}, V_{15}, V_3, V_5, V_{13}, V_8, V_9, V_{11}, V_{10}, V_1, and V_2 are fully open. A pressure differential of $\leq$ 50 Torr is maintained between the two chambers during pump-down. Both sides are pumped down to $<$ 5 Torr pressure.

The tanks are then pressurized with helium through the same pumping lines, maintaining the Δp requirement as just discussed. The settings on V_4 remained the same.

The pump and fill sequence was then repeated several times to ensure good control of the metering valve settings.

B. LEAK CHECKING

Each chamber is checked for leaks by monitoring the pressure change as a function of time after the pump is shut off for about 2 hr. Subsequently, the fuel tank is pressurized to about 20 Torr with helium. Valves V_2, V_3, and V_6 are closed (see Fig. 2). The pressure rise in the Freon tank as a function of time is observed. If the pressure rise exceeds the normal rate recorded earlier, we should suspect a leak(s) across the diaphragm. If a leak occurs, the test is to be repeated at 30 and 40 Torr pressure differentials, respectively.

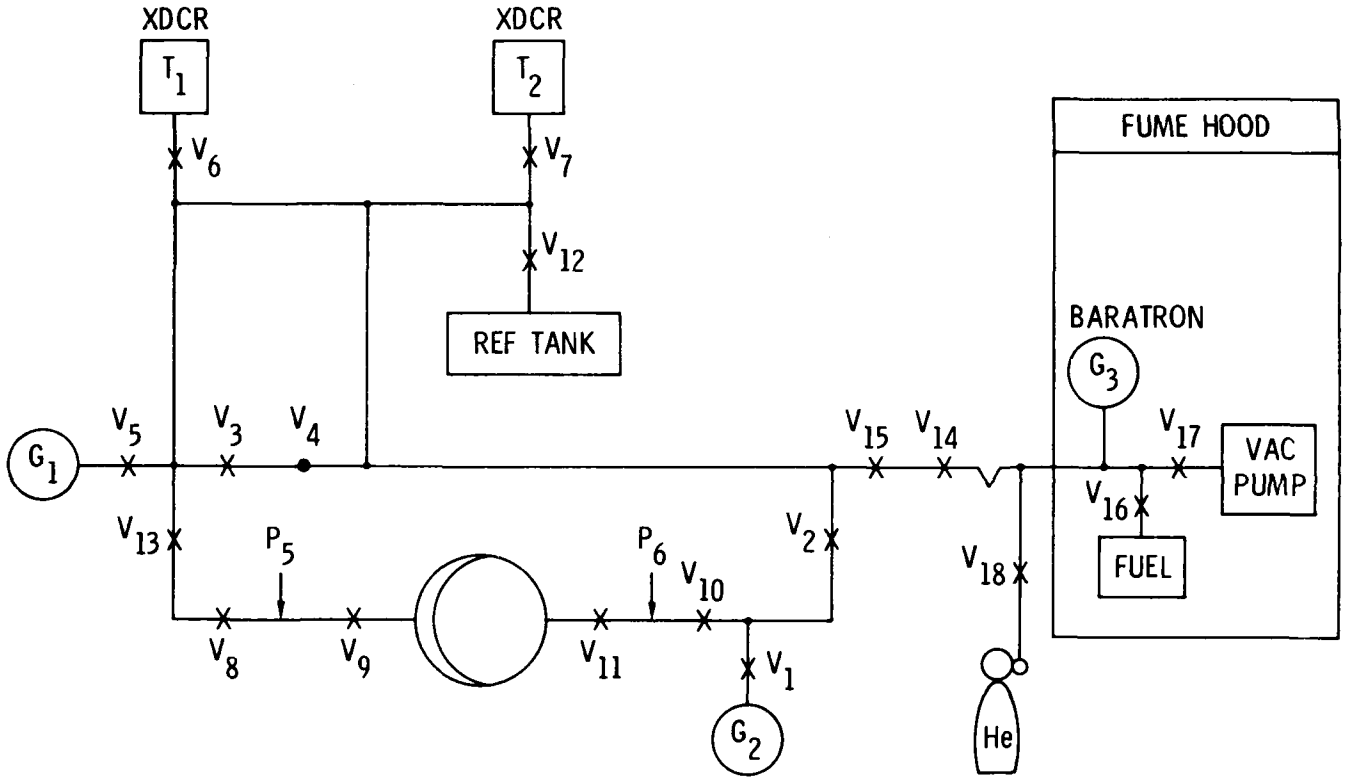

Fig. 2. Schematic of Test Setup

IV. HYDRAZINE PROPERTIES RELEVANT TO THESE TESTS

The decomposition of N_2H_4 to NH_3 and N_2 on an iron oxide catalyst proceeds according to

$$3N_2H_4 \xrightarrow{Fe_xO_y} 4\ NH_3 + N_2$$

Therefore if N_2H_4 is sealed into a closed volume at room temperature and permitted to decompose completely on the catalyst, a pressure rise to 1. times the initial N_2H_4 pressure should occur. If the reaction proceeds further by partially decomposing the NH_3 to H_2 and N_2, then the reaction can be written

$$3N_2H_4 \rightarrow 4(1-X)NH_3 + (1+2X)N_2 + 6\ X\ H_2$$

where X is the fraction of NH_3 decomposed. For example, if 50% of the NH_3 is decomposed, then

$$3N_2H_4 \rightarrow 2NH_3 + 2N_2 + 3H_2$$

and a pressure change of 2.33 times the initial value should result. If all of the NH_3 is decomposed, then

$$3N_2H_4 \rightarrow 3N_2 + 6H_2$$

and a threefold increase in pressure should result.

Because the vapor pressure of hydrazine is only 10-13 Torr near room temperature, a maximum final pressure of 30-39 Torr can be expected if N_2H_4 decomposes entirely to N_2 and H_2. The maximum allowable differential pressure across the diaphragm is about 50 Torr. Therefore, the unlikely but possible complete decomposition of all of the N_2H_4 that contributes to pressurization of the tank would yield an acceptable pressure difference across the diaphragm.

Hydrazine readily absorbs on clean metallic surfaces. In order to obtain meaningful indications of pressure change, it is necessary to thoroughly passivate the surfaces with N_2H_4 prior to the decomposition test. This condition is assumed to be achieved when a fresh N_2H_4 charge placed into the expulsion gas volume does not reveal a demonstrated decrease in pressure over 5 min.

V. APPARATUS

As indicated previously, a schematic of the test assembly is shown in Fig. 2. A photograph of the apparatus is shown in Fig. 3. The reference tank liter is a new 1-ℓ 304-L S.S. bottle. The Heise gauges G_1 and G_2 are isolated from the hydrazine environment by valves V_5 and V_1, respectively. During tests, an absolute pressure gauge G_3 (MKS Baratron, Type 170M-34B 0-1000 Torr) designed for operation in a toxic gas environment was used. A pair of matched transducers T_1 and T_2 were mounted as shown to monitor continuously the pressure differential between the two chambers. The voltage outputs of T_1 and T_2, through a low-gain amplifier, were arranged to cancel each other. A strip chart trace of the null signal with the two sections of the fuel tank at common pressure would then be on center zero. After establishing long-term signal stability, the transducer assembly was calibrated with known overpressure of helium on either side. The transducer locations were interchanged to check for any cumulative signal drift.

The hydrazine source was kept under a fume hood in the laboratory, which also handled the exhaust from the vacuum pump.

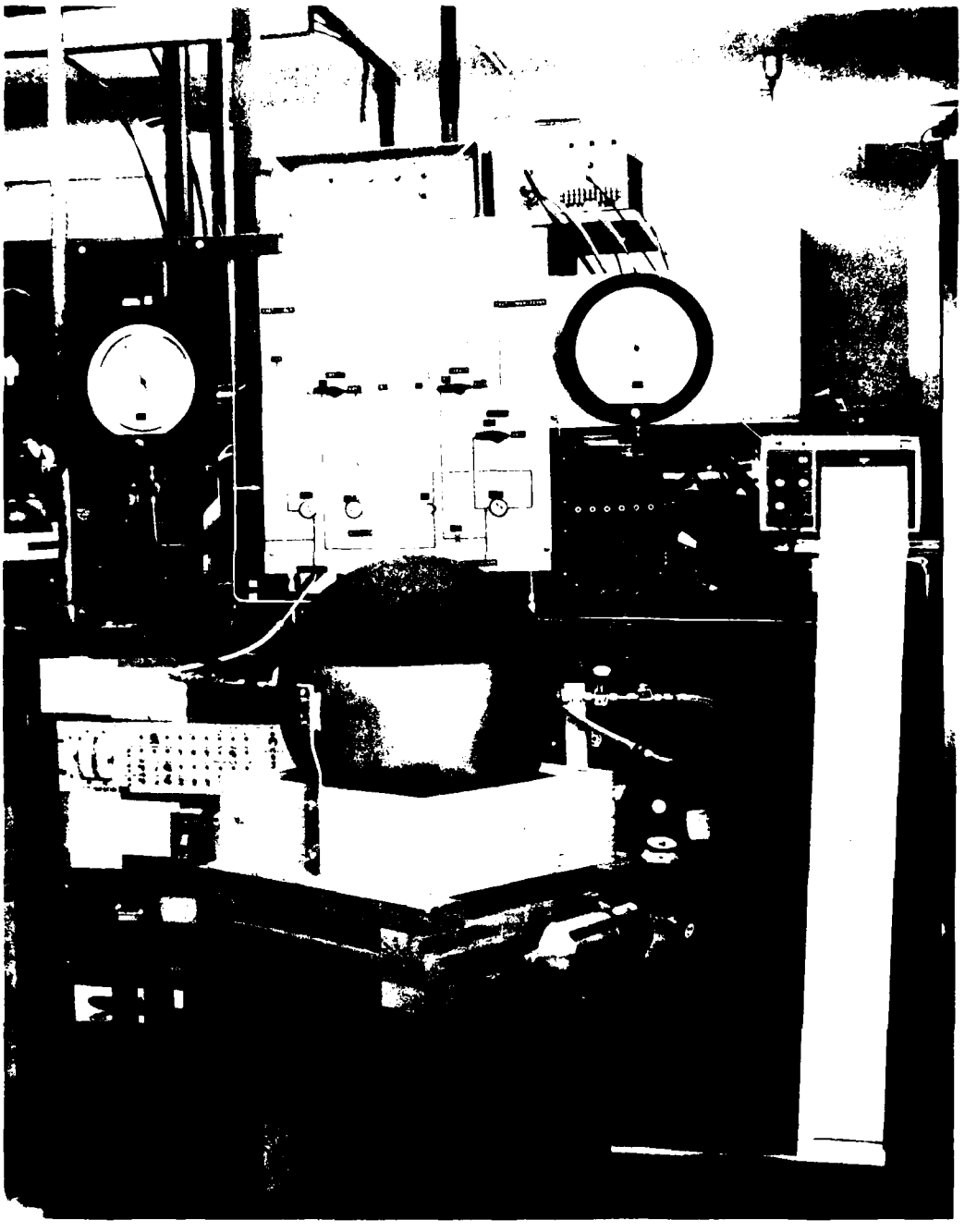

Fig. 3. Photograph of Test Assembly Apparatus

VI. RESULTS

The pressurant tank was conditioned with hydrazine, as discussed previously. After checking stability of the transducer system output, a test run with approximately 12 Torr of fuel vapor in the Freon chamber was started. The fuel side of the tank was pumped down and sealed off. A strip chart trace of a typical test run is shown in Fig. 4. The run lasted 23 hr. The differential Δp is estimated to be about 21 Torr. At the end of this run, the expulsion gas side of the tank was sealed off, and the whole system moved to the analytical laboratory. The residual gas in this side of the tank was analyzed with a Bendix time-of-flight mass spectrometer. Residual fuel was still found in the tank along with NH_3, N_2, and H_2. Accurate quantitative estimates of the extent of decomposition of N_2H_4 are difficult to obtain with the analytical procedure adopted here. A clean reference tank with a few rusted test pieces was substituted for the fuel tank in a subsequent test run over approximately the same amount of time. The pressure increase recorded was almost one and a half times that for the tank. However, this confirmatory test cannot be used to estimate the extent of corrosion in the fuel tank assembly.

Several test runs were made subsequently confirming the presence of rust on the tank. The discoloration on the inner threads of the Freon port was later cleaned with isopropyl alcohol, and the tests were repeated. The tank still exhibited a signal indicating rust spots inside.

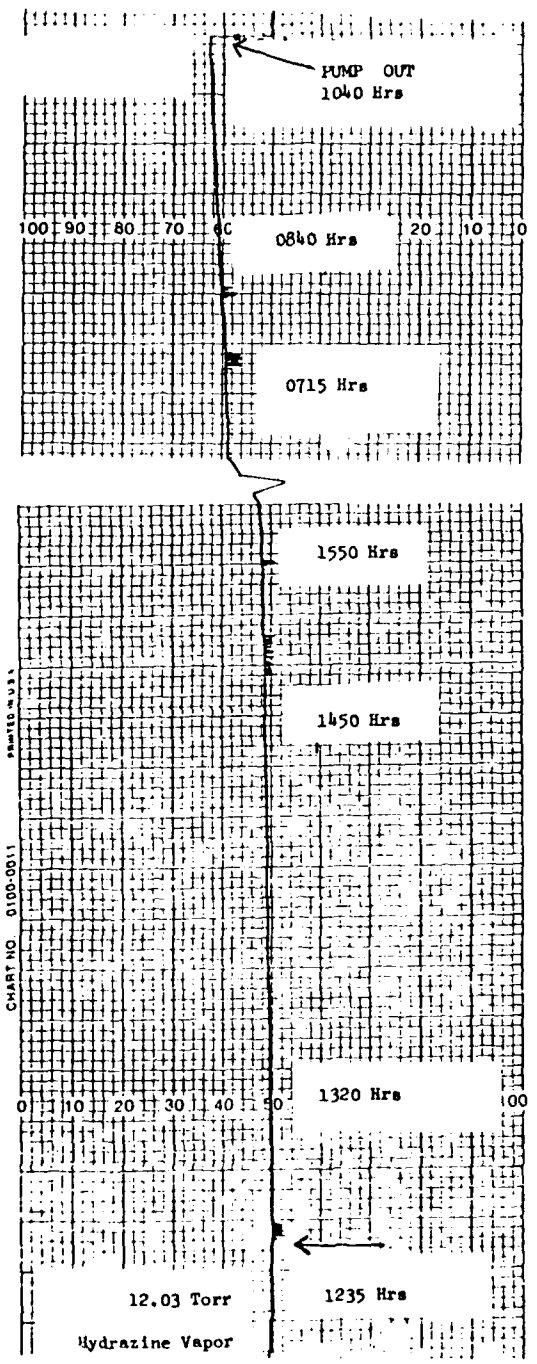

Fig. 4. Strip Chart Trace of Differential Pressure

VII. CONCLUSIONS

A sensitive, nondestructive test for the detection of rust in flight hardware has been developed and tested. Quantitative estimates of corrosion are very difficult to obtain even under normal circumstances. The problem is even greater in this situation because of configurational inaccessibility of the tank inner surface for visual examination.

Commercial applications of this approach for component testing should be explored.

APPENDIX

CORROSION TEST WITH HYDRAZINE

1. Open V1, V2, V3, V5, V6, V7, V8, V9, V10, V11, V12, V13, and V14.
2. Close V6. Open V15. Control pressure difference between G1 and G2, to be less than 50 Torr, by controlling pumping with V4.
3. Pump down entire system to less than 5 Torr, as read on G1, G2, T1, and T2.
4. Close V1 and V5 to prevent damage to gauges G1 and G2 from contact with hydrazine.
5. Close V2 and V17. Open V16 (under fume hood). Read G3. This should read in the range 10 to 15 Torr at room temperature.
6. Passivate system for 10 min. Close V16. Read steady reading of G3. If it reads less than 10 Torr, open V16 again. Repeat until hydrazine pressure in system is steady and greater than 10 Torr.
7. Close V7, V3, V5, and V16. Open V17. Pump out.
8. Record start time and hydrazine initial pressure on strip chart recorder for differential pressure readings.
9. Record differential pressures for at least 4 hr.
10. Record elapsed time and T1 and T2 readings.
11. Close V8, V9, V10, and V11.
12. Disconnect fittings at ports P5 and P6.
13. Connect mass spectrometer (Bendix time-of-flight or equivalent) to P5.
14. Prepare mass spectrometer for analyzing sample before opening V9.
15. Record sample gas data.

16. Close V9.

17. Disconnect mass spectrometer at P5.

18. Reconnect tank to test system at P5 and P6.

19. Go to step 1 and repeat entire test one additional time.

20. After completion of test, go to step 3.

21. Close V17. Open V18 through regulator and backfill entire system with helium to a pressure of 760 Torr. Ensure that at no time during the backfilling process are G1 and G2 reading 50 Torr or more apart.

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