1 November 1971

METALLURGY SECTION
ADVANCED TECHNOLOGY
AEROJET SOLID PROPULSION COMPANY

OCT

23P

MONTHLY PROGRESS REPORT - OCTOBER 1971

DESIGN OF STRESS CORROSION SPECIMEN FOR DETERMINATION OF
 K_{Isc} IN PRESSURIZED GASEOUS HYDROGEN EXPOSED TO IRRADIATION

I. INTRODUCTION

MASTER

Department 4830 has been requested to determine if a synergistic effect will result when Inconel 718, A-286, SAE 9310 and Ti-5Al-2.5Sn are exposed to 1000 psi gaseous hydrogen and a nuclear reactor. The criterion used to determine any synergistic effect will be to measure the susceptibility of each test material to slow crack growth, crack growth rate and/or apparent K_{Isc} , when exposed to the nuclear environment with and without 1000 psi gaseous hydrogen. The reactor environment will include a fast neutron fluence of about 10^{20} and a specimen temperature in the range between 155 and 200°F.

The specimen development and calibration are to be conducted in three phases where Phase 1 is to design and evaluate a test specimen for Phases 2 and 3. Phase 2 will consist solely of a reactor test to determine the noise characteristics as detected by acoustic emission. This test will be conducted to determine the applicability of using acoustic emission to detect slow crack growth in a reactor environment. Phase 3 will involve in-reactor testing to determine the combined effects of 1500 psi GH_2 and the nuclear environment.

II. CURRENT STATUS SUMMARY

The preliminary program outlining objectives and procedures has been submitted.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

A. SPECIMEN CONFIGURATION

1. Stress Corrosion Specimen

Sketches for modified WOL specimen, 1-1/2 and 2.0-in.-thick compact tension (CT) specimen, and encapsulated specimen designs have been submitted. Minor dimensional changes to existing 1.0-in.-thick CT specimen were also made. A tentative design for the stress corrosion specimen has been completed.

2. Encapsulated Specimen

Preliminary stress analysis has been completed for the specimen in Figure 1 and indicates that the encapsulation device had little effect on the stress at the crack tip. Consequently, the encapsulation design shown in Figure 1 will be used for this specimen.

B. INSTRUMENTATION FOR DETECTION OF SLOW CRACK GROWTH

Instrumentation is required to ascertain whether slow crack growth had initiated and arrested during the limited time in the reactor. Without such information, accurate comparisons could not be made between effects due to pressurized hydrogen and those in helium in a reactor environment. Since it will be necessary only to detect crack arrest, a very high system sensitivity will not be required. Two types of instrumentation, acoustic emission and strain gages, are being investigated for this purpose.

1. Stress Wave Analysis Technique (SWAT)

a. Sensors

Preliminary information concerning stress wave emission sensors that could be used in the reactor has been obtained. Comparison test data between a possible sensor (Endevco P-15) for use in the reactor tests and the sensor (Endevco 2213E) presently being used for data collection by ASPC has been obtained. Both sensors (P-15 and 2213E) were connected to voltage amplifiers and the P-15 results compared very favorably to the results obtained using the 2213 sensor. The major problem associated with the P-15 type sensors is low capacitance (on the order of 50 pf). A second sensor fabricated from a P-14 crystal appears to be suitable because it has a higher capacitance (on the order of 300 pf). Tests have not been made on the P-14 sensor to determine its sensitivity as compared to the P-15 or the 2213, but

tests at Endevco have found the P-14 to be approximately 20% as sensitive as the P-15. However, the P-14 sensor is less sensitive to the cable capacitance than the P-15 sensor so that with 15 feet of cable, it is thought that the P-15 sensor would be twice as sensitive as the P-14 unit. Both sensors and cables have been ordered to evaluate the combined sensor-cable sensitivity.

Gulton Industries have agreed to supply ASPC with a sensor so sensitivity measurements could be compared with the P-14 and P-15. The Gulton Industries' sensor has been received and comparison tests are scheduled for next month.

A hard-line triaxial cable has been selected for the tests because of a lower noise level. As the sensors will be exposed to water, it has also been decided to fabricate the cable and sensor as an integral unit in order to eliminate fittings which could be a source of leakage. A supplier for line drivers (preamplifier) that will withstand exposure to radiation and water has been found.

2. Alternate Approaches to Detect Slow Crack Growth

a. Instrumentated Tup

An instrumentated tup suitable for use in water at 200°F has been fabricated but slow crack growth has not occurred in the tests performed to date using this instrumentation. However, difficulties were encountered due to eventual water penetration of the insulation which resulted in a continuously changing zero shift. These difficulties have not been eliminated although an additional test is now in progress.

b. Strain Gages

Strain gages can be placed along the path of slow crack growth but difficulties are anticipated in the design of an acceptable entrance port through the encapsulation device for the lead wires. An alternate approach would be to mount the strain gages on the edge of the encapsulation device, offset from the path of slow crack growth, although the sensitivity attainable using this approach requires definition. As of yet, no tests have been run to determine the sensitivity of the strain gages as a method for detecting slow crack growth.

III. ACTIVITIES DURING THE REPORTING PERIOD

PHASE I - DESIGN AND EVALUATION

A. TESTING

A fatigue-precracked SAE 9310 specimen was loaded and placed in a hot water environment at 94°C; testing was initiated in October 27, 1971 and is still in progress. The test is being monitored using acoustic emission and an instrumentated tup.

B. SLOW CRACK GROWTH DETECTION

1. Instrumentated Tup and Acoustic Emission

Calibration curves as shown in Figures 2 and 3 were developed for the instrumentated tup. Of primary interest was the configuration and sensitivity of the plots on decreasing load. It would be useful if the instrumentated tup would indicate the actual load on the specimen at the end of the test. To accomplish this, it will be necessary to be able to observe that the load is decreasing and then ultimately remains constant. It is anticipated that slow crack growth will be intermittent; therefore, the load will have to remain constant for a time period two to five times greater than the last incubation period to be reasonably sure no significant additional crack growth will occur. To be confident in the ability to detect slow crack growth, a system sensitivity and gain sufficient to produce a strip chart deflection of 1-in. minimum for each 1000 pounds of load was selected.

A fatigue precracked A-286 specimen was loaded to 20 kips using the calibration curve in Figure 2 and the specimen placed in agitated water at 94°C. As a duplicate specimen had previously been loaded to 27.5 kips in hot water for two weeks without cracking, it was anticipated that no crack growth would be observed in this test and it would be a test solely of the ability of the instrumentated tup and the SWAT system sensors to operate in this environment. The strain gages had been water proofed with GA-1 precoat plus 3 coats of GA-5. Also, the lead wires were inserted inside flexible tubing and potted to protect against contact with water. After one hour in the water, the output from the strain gages started drifting badly and continued for the duration of the test. The zero shift was due to the fact that the waterproofing

and the gage make up two different resistance values and as the water gradually penetrates the insulation it breaks down the insulation to ground resistance. As this would occur for each gage and waterproofing coat and the change would be different for each one, the end result is a continuously changing zero shift. Operation of the SWAT system appeared acceptable except that the dental cement used to attach the sensor to the specimen eventually failed.

Another instrumentated tup was waterproofed and inserted in water at 94°C; no instability was noted during a four hour monitoring period. This tup was then inserted into the fatigue cracked SAE 9310 specimen and the specimen loaded. The SWAT sensor was attached to the specimen by a stud thereby eliminating the problems associated with failure of the dental cement. The test has been in progress since October 27, 1971. Preliminary examination of the results indicate the SWAT system detected a single jump of about 20,000 counts; however, nothing detected by the instrumented tup. This test is continuing to provide an additional evaluation period for the waterproofing procedure. Upon termination, the specimen will be examined to determine if crack extension has occurred.

C. ENCAPSULATION DEVICE

No Change.

D. STRESS ANALYSIS OF SPECIMEN-ENCAPSULATION DEVICE

Stress analysis has been initiated to determine the minimum specimen height that can be employed while still meeting the program objectives. Notch widths of 0.5 and 0.6-in., as well as COD openings up to 0.12-in., are also being investigated. The results of this analysis will be reported in the next monthly report.

PHASE II - INITIAL SPECIMEN TESTING AT PLUMBROOK REACTOR

Tests are planned at ASPC to investigate the noise from water flow in a 2-1/2-in. diameter pipe preliminary to the noise tests which are planned in the reactor. The test at ASPC will be conducted to determine the extent and frequency of noise generated by water flow around the test specimen and its effect on the SWAT data collection. The test system has been designed so a water flow of 15 to 25 ft./sec. can be obtained and the specimen placed in a fixture that will fit into the 2-1/2-in. diameter pipe. It is anticipated that the fixture will be quite similar to that needed for the reactor test.

PHASE III - TESTING THE COMBINED EFFECT OF 1000 PSI
H₂ AND THE NUCLEAR REACTOR

Dependent upon completion of Phase I and II.

IV. ANTICIPATED ACTIVITIES DURING THE NEXT REPORTING PERIOD

Fatigue crack two of the modified WOL specimens, weld the encapsulation device to the specimens and perform evaluations to determine the comparative sensitivity between acoustic emission and an instrumentated tup. Since the weldable strain gages were scheduled to be shipped to ASPC on October 29, 1971, at least one instrumentated tup should be available for use in the encapsulated tests.

Complete the mathematical analysis of the specimen height to determine compatibility with reactor tube diameter.

Evaluate the encapsulation design to see if it will withstand the stress imposed by increasing the COD to 0.05-in. or 0.10-in.

W.G. Reuter
W. G. Reuter
Metallurgy

Approved by:

P. P. Crimmins
P. P. Crimmins, Manager
Metallurgy

Figure 1.

Figure 2. Plot of Load Versus Chart Output for Rising and Decreasing Load (0 - 20 kips)

Figure 3. Plot of Load Versus Chart Output for Rising and Decreasing Load (20 - 40 kips)