TRIP REPORT

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PURPOSE OF TRIP: Monitor the Fracture Toughness Testing of ZTA Graphite and Tungsten-2% ThO₂ and Discuss Cyclic Testing of Fracture Toughness Specimens in Hydrogen After Irradiation

SUMMARY:

A. Testing of ZTA Graphite

Eighteen ZTA graphite WOL-1 X-type fracture toughness specimens were scheduled for testing at the Nuclear Aerospace Research Facility of the Fort Worth Division of General Dynamics to determine the effects of nuclear radiation on the fracture toughness properties. Twelve of the specimens received a radiation dose of approximately 10^{19} nvt at liquid nitrogen and were to be tested at liquid nitrogen and room temperature. However, experimental difficulties were encountered at the beginning of the testing program and were the result of an unexpectedly high potential energy stored in the specimens due to radiation damage which caused many specimens to fracture violently prior to tensile testing. The stored energy problem can best be described in a chronological manner by discussing the actual events which were observed on individual specimens during testing. These events are described as follows:

Specimen #818: This specimen was the first in a series of irradiated specimens for annealing studies. The specimen was unloaded from an irradiation fixture into a smaller handling tray under liquid nitrogen. The specimen dropped approximately 6 inches in liquid nitrogen and hit the bottom of the tray. It disintegrated on impact into many small pieces. Violent boiling of the LN₂ in the tray was noted for approximately 20 seconds after disintegration.

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Specimen #819: This irradiated specimen was removed from the LN_2 bath into a styrofoam container and was allowed to come to room temperature in air. After approximately 30 seconds, it disintegrated.

Specimen #809: This specimen was placed into a small glass beaker filled with LN_2 (without being removed from LN_2) and was placed into a styrofoam box. The LN_2 was then allowed to boil off gradually. After all LN_2 boiled off, the waxed cord attached to the specimen melted and burned, and the frost on the beaker disappeared rapidly. The specimen remained intact and was then annealed for one hour at 1540°F . When the specimen was removed from the furnace, considerable deformation of the specimen was noted. The specimen was returned into a LN_2 bath and is ready for testing.

Specimen #808: This specimen was brought to room temperature in the same manner as specimen #809 except that it was placed into a small aluminum container rather than a glass beaker. The specimen disintegrated approximately 1-1/2 minutes after the last LN_2 boiled away.

Specimen #817: This specimen was warmed in a small glass beaker in the same manner as specimen #809. It remained intact. The temperature rise due to energy release was measured with a glass thermometer. A maximum temperature of 453°F was noted. The specimen was allowed to cool to room temperature and was then placed into a furnace for annealing at 540°F for 100 minutes. No appreciable deformation was noted after annealing. The specimen was returned into a liquid nitrogen bath to be tested later.

Specimen #802: This irradiated specimen was tested under liquid nitrogen to failure without any incident. The failure was semistable in the sense that failure did not occur catastrophically. The specimen halves held together at the rear and were placed into a liquid nitrogen bath in a small container. This container was placed into a larger styrofoam box, and the liquid nitrogen was then allowed to boil off. After boil-off occurred, the specimen disintegrated into many small fragments.

Specimen #807: This specimen was warmed in a glass beaker in a similar manner to specimen #809. It disintegrated.

Specimen #804: An attempt was made to heat up this specimen from liquid nitrogen temperature to room temperature in water. It was expected that the initially formed ice layer would be a good insulator to cause a gradual temperature rise to the critical energy release temperature after which time the water would be an efficient medium to conduct the heat from the specimen. However, as the specimen was transferred from the liquid nitrogen bath unit into a water container, it exploded violently.

At this stage, further testing of the remaining specimens was discontinued in order to consider the following: (1) planning experiments to measure the extent of the energy storage phenomenon, (2) assessing the significance of this phenomenon to the NERVA reactor, and (3) to determine a method of treating the irradiated specimens to permit them to be tested as originally planned.

Fracture Toughness Results of ZTA Graphite

As mentioned previously, an irradiated specimen (#802) was tested to failure in LN₂ in a rising load test. It failed at a fracture load of 180 lbs. A control specimen was tested in a similar manner. It failed at 100 lbs. These failure loads correspond to an estimated plane strain fracture toughness parameter K_{Ic} of 1.5 and 0.85 ksi $\sqrt{\text{in}}$ for the irradiated and unirradiated specimen, respectively.

B. Testing of Tungsten - 2% ThO₂ Specimens

Six 0.5 inch thick X-type WOL fracture toughness specimens were provided in a test program to study the effect of radiation damage on the fracture toughness of tungsten-2% ThO₂. Two of the six specimens were reserved for annealing studies at elevated temperature. The irradiation fluence level was 8×10^{18} nvt. One set of control and irradiated specimens was tested at LN₂ and room temperature. No significance differences in failure loads were observed indicating no effect of temperature or radiation damage on the fracture toughness parameter K_{Ic} . In all cases, the fracture toughness parameter was estimated to be in the 8 to 9 ksi $\sqrt{\text{in}}$ range.

One irradiated specimen was annealed at 1440°F for 60 minutes. It formed a greenish oxide layer which was later found to be highly radioactive. The specimen was tested to failure at room temperature. The failure load was similar to the previously-tested specimens.

Because no differences in toughness were found in the tested specimens, it was decided to test one remaining irradiated specimen at 300°F. It is expected that this temperature is above the ductile-brittle transition temperature and thus will cause the specimen to fail at a substantially higher load. The results of this test are not yet available.

C. General Dynamics Hydrogen Test Facility

The newly-constructed hydrogen test facility of the Nuclear Aerospace Research Group is suitable for testing tensile as well as fracture toughness specimens under static, as well as cyclic loading conditions. It has remote control features for testing irradiated specimens in the presence of gaseous as well as liquid hydrogen. The pressure vessel is approximately 20 inches long and has an inside diameter of approximately 7.5 inches. Maximum operating pressure is 1500 psig.

It is recommended to use this facility to study synergistic effects of irradiation and hydrogen embrittlement on materials. At the present time testing is limited to room temperature in molecular hydrogen gas. Testing under ionizing conditions would be desirable. Moderate elevated temperature tests can be carried out by providing appropriate heating elements in the chamber.

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