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Damage Analysis and Fundamental Studies

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CHAPTER 1. IRRADIATION TEST FACILITIES

1. Rotating Target Neutron Source (RTNS)-II Operations (LLNL) 3

Irradiations were done for a total of eight different experimenters from six laboratories. Five "piggy' back" experiments were performed during this period. Major unscheduled outages during this period were due to experiment component failure and functional checks of accelerator equipment.

2. Fusion Materials Irradiation Test (FMIT) Facility (HEDL) 6

Additional evaluation of deuteron-induced activation of gold and aluminum was done to provide dose estimates.

An evaluation was made of the neutron environment at large angles to the 35-MeV deuteron beam in the FMIT test cell for comparison with positions at small angles to a 20-MeV beam.

Predictions of the neutron source characteristics for deuterons incident upon gold were made to aid in estimating dose near the accelerator.

CHAPTER 2. DOSIMETRY AND DAMAGE PARAMETERS

1. Fission Reactor Dosimetry (ANL) 15

A neutron spectral measurement was made in the core of the Omega West Reactor (LASL) on October 21, 1980. All radiometric samples have been analyzed and flux values are presented along with an unfolded spectrum.

The dosimeters were received in December 1980 from the ORR-MFE 2 irradiation. The capsules are now being opened and

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samples prepared for gamma counting.

2. Helium Production by Fast Neutrons (RIES) 22

Helium analyses have been initiated for the helium accumulation dosimetry materials irradiated in the RTNS-11 neutron characterization experiment. Analyses are continuing of multiple samples of molybdenum and its separated isotopes irradiated in the RTNS-I, RTNS-I, and Be(d,n) neutron spectra.

CHAPTER 3. FUNDAMENTAL MECHANICAL BEHAVIOR

1. Microstructural Aspects of Helium Embrittlement (U. Va.) 29

Experimental evidence indicates that a helium-filled, bubble-hardening model can explain helium embrittlement at tensile test temperatures below ~550°C. Critical values for edge-to-edge bubble spacing ($L_c \lesssim 30$ nm) and bubble diameter ($d_c \lesssim 4$ nm) for the onset of brittle fracture were found. In this test temperature regime, those bubbles may be slightly over-pressurized. In contrast, at test temperatures above ~550°C, no critical values of L_c and d_c were discovered. In addition, bubble pressure was not a factor in this temperature range Finally, no critical values for α_R, the area fraction of bubbles covering grain boundaries, could be found at any temperature.

2. Small Specimen Test Development (UCSB) 45

An instrumented microhardness tester was designed, built and tested. It has produced satisfactory predictions of material stress-strain behavior in the strain range of 1-10% from data taken at as few as two penetration locations per sample.

To complement the microhardness tests, two ductility test techniques were investigated; namely, a shear punch test

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and a bulge test. Preliminary results on a variety of sheet materials indicate that both tests are promising for monitoring changes, especially reductions, in material ductility.

Work has proceeded on the development of an indentation load relaxation test to assess time-dependent flow properties.

Work is in progress to develop small specimens and test techniques to determine the fracture resistance of materials.

3. Critical Flaw Size Determination (PNL) 65

Thin-walled 316 SS stress rupture specimens with through wall microcracks have been characterized using scanning electron microscopy and optical metallography. Through wall microcracks less than 100 microns in size may be sufficient to cause plasma contamination and fusion reactor shutdown. Such microcracks are similar to those observed after stress rupture tests.

CHAPTER 4. CORRELATION METHODOLOGY

1. Irradiation Response of Materials (W-R&D)

Annealing Experiments on Ti-Modified 316 SS 75

Comparison of cavity microstructures for pre- and post-anneal dual-ion bombarded specimens of Ti-modified 316 SS suggests that this material could have good microstructural stability if subjected to thermal spikes during reactor operation.

Continuation of Dual-Ion Experiments on Aged 316 SS 77

A second set of dual-ion experiments on aged 316 SS has been completed and specimen evaluation is in progress. Preliminary results indicate qualitative agreement with previous data.

CONTENTS (Cont'd)

2. Microstructural Development of 20% Cold-Worked 316 SS Irradiated in EBR-II (HEDL) 81

Comparative examinations of specimens of DO heat of 316 SS irradiated in both EBR-11 and HFIR are underway. Preliminary examination of specimens irradiaied to 70 dpa in EBR-11 shows that microstructural development is consistent with immersion density measurements. Measured helium concentration is consistent with estimates.

3. The Influence of Dislocation Density and Radiation on Carbon Activity and Phase Development in AISI 316 (HEDL, U. Wisc.) 88

It is proposed that the primary role of cold work on the swelling of AISI 316 is to distribute the element carbon throughout the alloy matrix and increase the apparent solubility of carbon by binding it in the stress field of the dislocation core. The resultant decrease in supersaturation and activity of carbon leads to a decrease in the rate of phase formation which preceeds swelling.

4. Stress-Enhanced Swelling of Metals During Irradiation (HEDL, ANL-WEST) 103

Data are now available which definitively show that stress plays a major role in the development of radiation-induced void growth of AISI 316 and many othar alloys. Stress-affected swelling spans the entire temperature range in fast reactor irradiations and accelerates with increasing irradiation temperature.

5. Dose and Temperature Dependence of Cavity Formation in Single and Dual-Ion Irradiated 9Cr-1Mo Ferritic Alloy (ANL) 126

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The dose and temperature dependence of cavity formation in a 9Cr-1Mo ferritic alloy was studied under dual-ion and single-ion (pre-injected with He) bombardment. For 450°C single-ion irradiation and for 450 and 550°C dual-ion irradiation, there was a correlation between subgrain size and maximum cavity size, suggesting that the boundaries of the small (typically ~0.5 μm) subgrains act as the primary defect sink.

6. Yield Strength Correlation for 20% CW 316 Stainless Steel (HEDL) 139

Yield strength data on 20% cold-worked 316 stainless steel irradiated in fast and thermal reactors and by 14-MeV neutrons were analyzed and a ten-parameter equation was developed to describe the yield streryth behavior for the temperature range 25 < T < 800°C.

7. Spectral Effects Experiments (HEDL) 159

Specimen and test matrices are presented for comparative irradiations with fission and fusion neutrons in the 50 to 300°C temperature range. A 90°C experiment has been prepared for insertion into the Omega West Reactor at Los Alamos. A 90°C/290°C experiment is underway at the RTNS-II.

8. Expanded Matrix of Fe-Ni-Cr Solute Alloys for HEDL Experiments (HEDL) 178

!Thirty-sir different iron-based alloys, previously used on other programs, have been obtained and are being processed into TEM disks.