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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 seven different experimenters. The HEDL two temperature zone furnace was installed and is operational. Unscheduled outages occurred due to major component failure.

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

Neutron and gamma ray spectra data have been obtained from analysis of measurements of the transmission of FMIT-like neutrons through thick iron.

The FMIT neutron activation file has been updated and documented.

CHAPTER 2. DOSIMETRY AND DAMAGE PARAMETERS

1. Fission Reactor Dosimetry (ANL) 17

Dosimetry results are presented for the ORR-TBC07 tritium breeding experiment. Plans are being made to characterize the Omega West Reactor (LASL). The status of all other experiments in HFIR, ORR, OWR, and EBR 11 is summarized.

2. High-Energy Neutron Dosimetry: RTNS-II (ANL, RIES, LLNL) 20

Preliminary results are presented for the joint characterization of RTNS-11 with RIES and LLNL. An isotropic thermal flux appears to fill the target room and intermediate energy room-return neutrons are easily seen beyond 1 meter from the source.

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3. Helium Generation in Fusion Reactor Materials (RIES) 24

Characterization of the RTNS-II Neutron Field 25

A joint Rockwell International-ANL-LLNL irradiation to characterize the RTNS-11 neutron field and to measure total helium generation cross sections of several separated isotopes and pure elements was completed. The experiment is described in some detail.

Helium Production Cross Sections for the Separated Isotopes of Iron 28

Helium production cross sections have been determined for iron and three of its separated isotopes for the 14.8-MeV neutron spectrum of RTNS-I.

4. Damage Parameter for Ceramics (BNL) 34

Damage parameters for a selected group of ceramics have been calculated. The relative importance of neutron, gamma-ray, and ionization-induced damage has been estimated, and directions for future investigations have been identified. The program terminated at the end of this reporting period.

5. The Correlation of Irradiation Effects Data Using Primary Recoil Spectra (HEDL) 41

Primary recoil damage functions for production of Frenkel pairs in copper, silver, molybdenum, and tungsten were deduced from changes in resistivity after irradiation with neutron or charged particles and from computer simulation data on displacement cascade production. In general a linear function of damage energy above approximately 1 keV gives a good correlation of Frenkel pair production in copper, silver, molybdenum, and tungsten for charged particle and neutron irradiations. The damage energy constant is inversely proportional to the square root of the target mass. A logarithmic recoil energy dependence at low energies is adequate for most applications.

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6. 14-MeV Neutron Irradiation of Copper Alloys at RTNS-II (HEDL) 81

The addition of 5% Ni, Mn, or Al does not significantly alter the fraction of defects surviving a cascade, although Al affects the visibility of clusters. A large part of the hardening is produced by clusters not resolved by TEM.

CHAPTER 3 FUNDAMENTAL MECHANICAL BEHAVIOR

1. Effects of Irradiation Pulsing on the SIPA Creep Mechanism (UCSB/HEDL) 95

For the temperatures and pulsing conditions anticipated in the Engineering Test Facility it has been found that both the stress-induced preferential absorption (SIPA) and climb-glide creep mechanisms are essentially unaffected by the pulsing of the irradiation.

2. Irradiation Creep of Ni-4%Si (ANL) 102

The stress dependence of the irradiation creep rate under deuteron bombardment showed a transition from linear to stronger than linear with increasing stress. A linear dependence of creep-rate on damage rate was observed in the linear stress dependence regime. The irradiation creep of this alloy appears to be controlled by the SIPA-driven climb and by the dislocation glide enabled by the SIPA-climb at low and high stresses, respectively.

3. Room Temperature Helium Embrittlement in 316 Type Stainless Steel (U. Va.) 113

Two helium irradiated samples of type 316 stainless steel irradiated to the same fluence, but aged at a different temperature to produce dissimilar microstructures, were tensile tested at room temperature in an HVEM. Embrittlement occurred in the sample with no visible cavities, in contrast to the more ductile failure of the sample with large cavities.

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CHAPTER 4 CORRELATION METHODOLOGY

1. Effects of Minor Elements on the RIS and Swelling in Type 316 SS Alloys (ANL) 125

When Fe20Cr12Ni containing controlled additions of Si and Mo is bombarded by 3 MeV Ni ions, Ni and Si are enriched at the irradiated surface while Cr and Mo are depleted. The temperature dependence of the radiation-induced segregation (RIS) of Si is more complex than that of Cr, Ni and Mo.

2. Microstructural Analysis of Simultaneously Bombarded Ti-Modified 316 SS (W-R&D) 143

Microstructural evaluation of dual-ion bombarded titanium-modified 316 SS from the same heat of material used in previous HFIR studies has been completed. The same helium trapping mechanism operates at He:dpa ratios of 0.2:1, 12:1 and 70:1 corresponding to EBR-11, Tokamak and HFIR conditions when MC carbide particles precipitate. When the MC particles do not form, swelling can be as great as that observed in unmodified 316 SS at identical He:dpa ratios, bombardment temperatures and dpa rates.

3. Development of a Swelling Equation for 20%-CW 316 in a Fusion Device (HEDL/ORNL/U. Wisc.) 159

A set of void and bubble-swelling correlations has been developed which incorporates the limited available data from EBR-11 and HFIR irradiations. It appears that helium may not play quite as large a role in the determination of total swelling as had been previously anticipated.

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4. The Dependence of Flow Stress on Microstructure for Nickel and Niobium Irradiated with High Energy Neutrons and 16 MeV Protons (PNL) 178

The flow stress increase of T(d,n) and Be(d,n) neutron and 16 MeV proton irradiated nickel and niobium is described using a hard barrier model. A hardening coefficient was determined which is consistent with fission neutron irradiated material.

5. Tensile Properties Data on 316 SS Irradiated at RTNS-II (HEDL) 182

The onset of irradiation hardening was observed between 10^{17} and 10^{18} n/cm^2 at room temperature.

6. Development of an Irradiation Creep Correlation for 20% Cold-Worked AISI 316 In Fusion Environments (HEDL) 190

Low temperature fast breeder and thermal reactor data was used to extend the existing breeder correlation to the temperature range of the proposed Fusion Energy Device. Also added was a dependence on displacement rate.