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CALCULATION OF DISPLACEMENT RATE IN EBR-II REACTOR MATERIALS

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Investigation of irradiated materials recovered during decommissioning of the Experimental Breeder Reactor-II (EBR-II) presents an outstanding opportunity to advance the knowledge of irradiation effects in various materials. Many of these materials have been resident in the reactor for more than 20 years in locations that provide various irradiation damage rates at various temperatures. Of primary interest are irradiation damage or displacement rates, sometimes refered to as dose rates, experienced by type 304 stainless steel of various fuel and reflector subassemblies. A careful study of steels exhibiting a wide range of damage rates would provide valuable insight into the poorly understood dependence of irradiation swelling and embrittlement on irradiation damage rate. We present initial results of the calculational efforts to characterize the spectrum of irradiation damage and damage rate to be found in EBR-II materials. The information gained through analysis of EBR-II materials could then be projected to end-of-life conditions expected in light water reactors.[1]

Irradiation induced swelling of type 304 stainless steel is a complex phenomena that is dependant on temperature, irradiation dose (measured in displacements per atom, or dpa), dose rate, and under certain conditions helium production. Limited studies[2,3] have detailed a significant dependence of swelling in type 304 stainless steel on damage rates, as represented in Figure 1 (taken from Reference 2). This dependence of material swelling on damage rate is of particular interest because it indicates that, even at relatively low total dose, materials may exhibit significant void formation if the damage was accumulated at a low rate.[2]

Calculations were performed to determine the range of damage rate information available from EBR-II materials. Irradiation damage rate is calculated as:[4]

$$dpa/s = \frac{1}{2E_d}\int \Phi(E)\,\Sigma(E)\,dE \qquad (1)$$

where E_d is the energy required to displace an atom from its lattice position and Σ is the macroscopic damage energy production cross section. For all constituents of type 304 stainless steel, E_d was taken to be 40 eV.[4] Fluxes were obtained from S_8P_1 transport calculations in RZ geometry using the TWODANT code with 28 group cross sections processed using MC-2/SDX while damage cross sections were obtained from NJOY. The calculations were performed for a representative reactor run.

Results of the dpa rate calculations are summarized in Figure 2, which represents dpa rate at the EBR-II reactor midplane for type 304 stainless steel of the isotopic composition listed in Figure 2. The calculations show that materials are resident in EBR-II that have accumulated irradiation damage at a wide spectrum of rates spanning two orders of magnitude from $\sim 3 \times 10^{-9}$ to $\sim 2 \times 10^{-6}$ dpa/s and total dose up to ~50 dpa. This would suggest that a detailed destructive analysis of a representative sample of these materials is indeed warranted and would yield valuable information on irradiation-induced material swelling dependencies.

With the shut-down and decommissioning of EBR-II, the light water reactor community is presented with a unique opportunity to extract a wealth of beneficial information from irradiated EBR-II materials. Efforts are underway at Argonne National Laboratory-West to characterize the range of irradiation damage and damage rate accumulated in austenitic stainless steels through destructive analyses supported by calculational procedures. Initial calculational results indicate the presence of irradiated materials possessing damage rates from $\sim 10^{-8}$ - 10^{-6} dpa/s. Detailed examination of these materials may therefore yield valuable new insight into irradiation swelling phenomena of materials present in light water reactors.

References:

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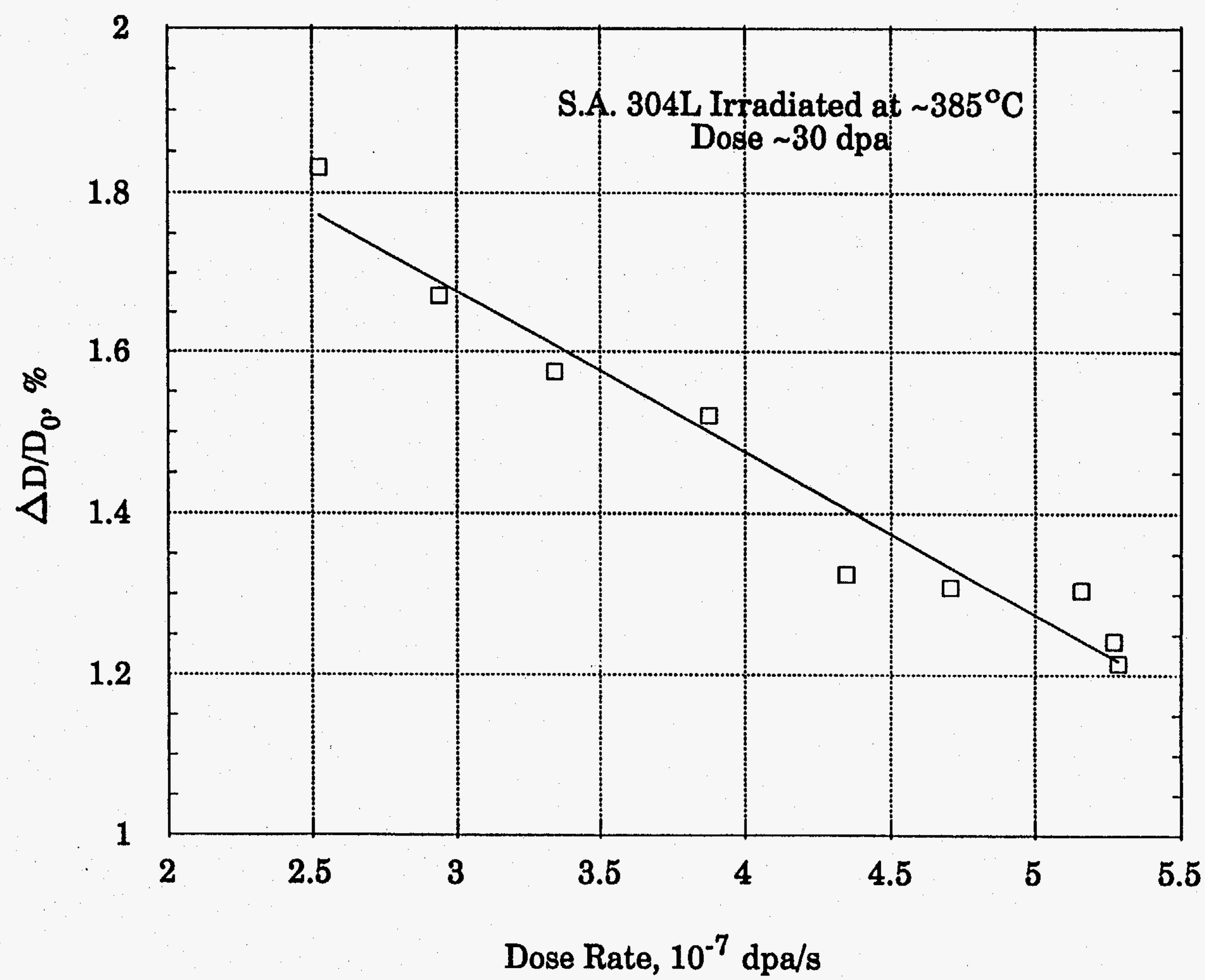
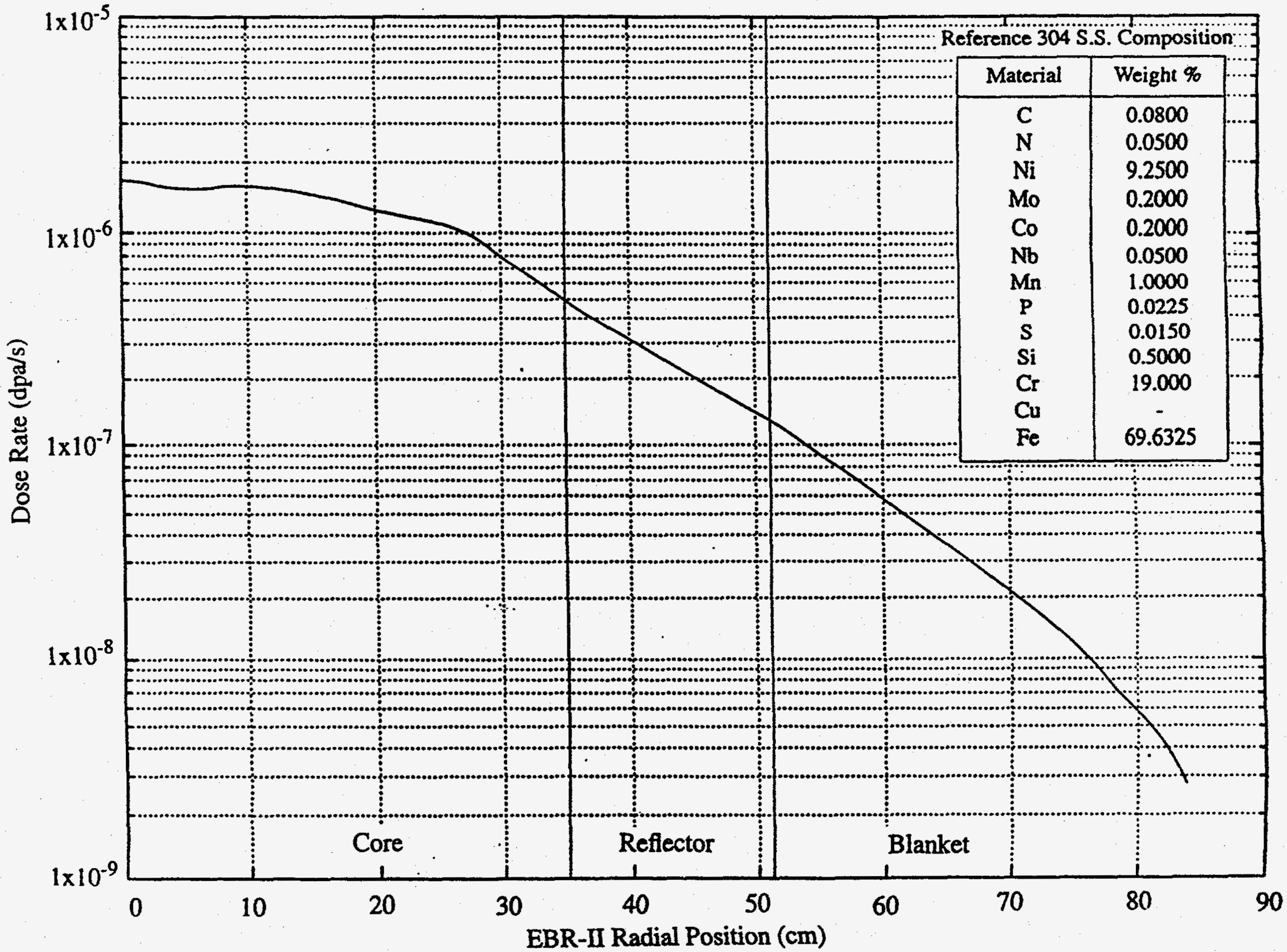


Figure 1. Percent change in diameter versus dose rate. Adapted from reference 2.



Reference 304 S.S. Composition

Material	Weight %
C	0.0800
N	0.0500
Ni	9.2500
Mo	0.2000
Co	0.2000
Nb	0.0500
Mn	1.0000
P	0.0225
S	0.0150
Si	0.5000
Cr	19.000
Cu	-
Fe	69.6325

Figure 2. Dose Rate for EBR-II Reactor Midplane