MEETING REPORT

SUMMARY OF THE 12TH INTERNATIONAL SYMPOSIUM ON EFFECTS OF RADIATION ON MATERIALS, WILLIAMSBURG, VIRGINIA, JUNE 18-20,1984

This biennial symposium series is sponsored by the American Society for Testing and Materials (ASTM) Committee E10 on Nuclear Technology and Applications. The series began in 1960 and has become a major international forum for the exchange and discussion of both the fundamental and technological aspects of behavior change in materials exposed to radiation environments. With a few exceptions, the data presented at this meeting were primarily concerned with the response of metals to neutron or charged-particle irradiation. As in the past, the performance of nuclear fuels was not included since this topic receives adequate treatment in other forums. The following summary is organized in the order that was used to compile the proceedings. Eighty-nine papers were presented and 80 of these are contained in the proceedings.

In the first section, "Irradiation Creep of Structural Metals," a significant amount of recent data is compiled, concentrating on both ferritic and austenitic alloys. Continuing a trend established earlier in this symposium series, several papers detail the creep response of alloys to nonisothermal reactor histories. Two papers in this section concentrate on the microstructural origins of irradiation creep, with one demonstrating conclusively that creep deformation generates and is in turn sustained by the development of an anisotropic distribution of dislocation Burgers vectors.

The second section, "Microstructural Development," explores the changes in microstructure, microcomposition, and phase stability that accompany and cause macroscopic changes in physical properties or dimensions. A significant new observation is that irradiation can induce spinodal decomposition in some alloys that are not known to decompose by this mechanism in nonradiation environments.

In "Neutron-Induced Swelling," a large amount of data is shown that demonstrates that austenitic alloys tend to swell at a rate of ~1%/dpa following a transient regime. While this posttransient regime is very insensitive to composition, temperature, and other variables, the duration of the transient regime is quite sensitive to major element composition, particularly at relatively high-irradiation temperatures. Minor elements such as titanium also exhibit a pronounced influence. There is a minimum transient period, however, of ~10 dpa that cannot be shortened by variations in composition or environmental variables. One new and surprising conclusion is that the application of compressive stress does not lengthen the transient duration as has been routinely assumed. Both compressive and tensile stresses were shown to equally influence void nucleation so as only to shorten the transient regime.

In the section, "Charged Particle Irradiation," the application of tensile stresses was confirmed to operate on void nucleation and the transient duration, but a correspondence between void and Frank loop development was also found. A number of papers explore the influence of helium on radiation-induced microstructural development although some differences of opinion are expressed as to whether the influence of helium observed in the simulation is representative of that experienced in the neutron environment. Several papers in this and the next section explore the possibility that the injected interstitial represented by the bombarding ion not only distorts the swelling response but also the effect of helium. One significant finding presented in this section is that highly focused electron beams cause segregation of alloy components and thereby create phase instabilities in a manner quite atypical of the neutron environment. Charged-particle irradiation was also used to forecast that high-strength copper alloys may undergo a significant degradation in mechanical properties as a result of radiation-affected dislocation recovery and grain recrystallization.

In "Theory of Swelling," most papers focus on the nucleation stage of void formation, exploring the role of impurities, composition, and helium. One paper proposes a model for the formation of void lattices based on two-dimensional diffusion of self-interstitials and the shadowing effect of voids on the diffusion of interstitials in their vicinity.

The "Mechanical Properties" section contains a wide variety of papers. One group of papers explores the radiation-induced changes in fracture toughness of iron-based austenitic and ferritic alloys as well as that of various zirconium alloys. Another group of papers addresses fatigue behavior in thermal and fast reactors while yet another group considers the microstructural origin of radiation-induced mechanical property changes. The data presented in the symposium both confirmed and extended the prevailing perceptions of the effect of radiation on mechanical properties; however, no significantly new or different phenomena were disclosed.

The "Pressure Vessel Steels" section of this conference has grown at each meeting. A review was made of irradiation testing performed over the last 12 years on pressure vessel steels and their weldments. The studies of the last few years confirmed the significance of chemistry control in governing irradiation resistance of ferritic steels. Copper consistently showed up as the principal element over which control must be maintained; however, other elements such as nickel, when combined with copper, enhance copper's effect, and phosphorus and manganese were shown by some investigators to have a measurable influence. The discernment of the actual mechanisms involved for each of these elements is not made easy due to the inability to date to see clear evidence of radiation damage using electron microscopy. Field ion emission microscopy may offer promise over conventional transmission electron microscopy, and small angle neutron scattering has provided evidence of submicroscopic scattering centers in copper- and phosphorus-doped steels. The thought was also offered that boron is significant in the hardening process due to its transmutation where thermal to fast neutron ratios are high.

Although the chemistry issue is not totally resolved, current damage trend curves do show a definitive relationship to the major contributory element, copper, especially at high fluences. The current status appears to be that the irradiation effects data have been exhaustively analyzed and correlation with postulated damage models is reasonably good. Further work is necessary to provide microstructural evidence of damage and establish relatively narrow bounds on alloy composition. The concentration of experiments on commercial pressure vessel alloys, however, has not provided the range and variety of elements necessary to confidently establish these bounds. The concentration of effort on Charpy tests was also questioned, and examination of other properties related to mechanical behavior, including microhardness changes, has been undertaken. The relationship of damage to fracture toughness has been more closely studied, but the significance of the upper shelf energy values provided by Charpy curves still escapes full understanding.

The annealing-out of radiation damage was reviewed in a number of papers. The likelihood of successfully "wet" annealing of pressure vessel damage for extended times at 343°C was shown to be relatively low. A higher temperature "dry" anneal is considered feasible, but its cost effectiveness and the treatment of the vessel nozzles and their attached piping remain as concerns.

In the "Irradiation Facilities" section, only two of the papers presented were provided for these proceedings. These papers involve the Los Alamos Meson Physics Facility. The absent papers addressed the proposed Fusion Materials Irradiation Test facility and the Materials Open Test Assembly, an experimental test facility currently operating in the Fast Flux Test Facility fast reactor in Richland, Washington.

The final section, "Other Radiation Studies," covers three papers that do not easily fit in the other categories. These are a modified method of helium introduction into alloys via the tritium trick, radiation damage aspects of a novel method for providing safe storage of ^{85}Kr from fuel reprocessing, and radiation effects on resins and zeolites forming part of the waste stream from the cleanup effort at the Three Mile Island Nuclear Plant.

Copies of the proceedings will be available in August 1985, and can be ordered directly from ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103.

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