FERRITIC/MARTENSITIC STEELS—OVERVIEW OF RECENT RESULTS—R. L. Klueh (Oak Ridge National Laboratory), D. S. Gelles (Pacific Northwest National Laboratory), S. Jitsukawa (Japan Atomic Energy Research Institute), A. Kimura (Kyoto University), G. R. Odette (University of California at Santa Barbara, B. van der Schaaf (NRG) and M. Victoria (Paul Scherrer Institute)

Paper was presented at the 10th International Conference of Fusion Reactor Materials, October 14-19, 2001, Baden-Baden, Germany, and it will be published in the conference proceedings in the *Journal of Nuclear Materials*

Extended Abstract

Because of their swelling resistance and excellent thermal properties, reduced-activation ferritic/martensitic steels are presently considered the primary structural material for future fusion power reactors. However, there have been questions concerning the feasibility of their use, and to more rapidly address possible problems, an international collaboration involving Europe, Japan, and the United States began in 1992 under the auspices of the International Energy Agency (IEA). The collaboration involves work on large heats of the reduced-activation ferritic/martensitic steels F82H (7.5Cr-2WVTa) and JLF-1 (9Cr-2WVTa) that were produced in 1993, with the first steel plates for testing being delivered to the collaborating parties in 1994.

The testing phase for the large heats of F82H and JLF-1—especially for the unirradiated properties—is nearing completion. These steels have been well characterized to establish recommended procedures for heat treatment and welding, and data have been obtained on a range of mechanical and physical properties. A database has been developed based on the work that has been completed, and that database is available to the international community. In addition to determining the baseline data for the large heats of F82H, this steel was included in over twenty neutron irradiation experiments that were conducted in the High Flux Isotope Reactor (HFIR) in the U.S., in the Japan Research Reactor (JRR-4) and the Japan Materials Test Reactor (JMTR) in Japan, and the High Flux Reactor (HFR) in The Netherlands [10]. The results for the large heat of F82H were in general agreement with results for other experimental heats of 7-9Cr-WV-type reduced-activation steels that show improved properties over conventional Cr-Mo steels. Studies are still in progress to determine the effect of irradiation on a range of properties for base metal and weldments.

There is still uncertainty on the possible effect of transmutation helium on the fracture properties of the steels when irradiated in a fusion neutron environment. Simulation techniques (ion implantation or ^{54}Fe, Ni, and B doping) with their inherent uncertainties are the methods presently available to study helium effects, and these techniques are being used to further our understanding of this potential problem. Each of these simulation techniques has been used in the past few years to study the effect of helium.

In one experiment, F82H doped with ^{10}B and natural boron were irradiated in HFIR at 400ºC to 52 dpa to produce 30, 60, and 330 appm in the steels. There was a large effect of helium, as the steels containing 60 and 330 appm He showed a swelling of about 1.2%, compared to about 0.52% for the steel with 30 appm.

Besides the simulation techniques, the PIREX and the Swiss Spallation Neutron Source (SINQ) facilities were used to simultaneously produce helium and displacement damage by irradiation with protons. Low-temperature nucleation of bubbles at temperatures as low as 217ºC were observed. It is at these temperatures where observations of a helium effect on the impact properties have been observed in the simulation experiments.

This uncertainty with helium makes the need for a 14 MeV neutron source urgent for future materials studies.

Alloy development for fusion has now moved beyond the F82H and JLF-1, and the European and Japanese fusion programs have determined new compositions and processing schedules for the 7-9 Cr class of reduced-activation steel. Based partially on the work performed in the IEA collaboration, the European Union has developed specifications for a new martensitic steel, EUROFER 97, which has been produced and is now being evaluated. Data has been obtained on tensile, creep, and impact behavior, and the results indicate that the EUROFER 97 has properties similar to those of F82H.

The ferritic/martensitic steels presently being considered are limited to ≈600ºC. Higher temperature operation for higher efficiency fusion plants will require further development of the steels if they are to be used. One attractive route to such materials are the oxide dispersion-strengthened (ODS) ferritic/martensitic steels. That option is being pursued in Europe, Japan, and the United States, and progress is being made in solving some of the problems associated with these materials.