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Helium and hydrogen release measurements on various alloys irradiated in SINQ

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Abstract

Three irradiations have been performed in the Swiss Spallation Neutron Source (SINQ) to establish a materials database for mixed proton and neutron fluxes for future spallation neutron and other accelerator sources. Samples of 316LN, F82H, AlMg3, and Zircaloy-2 from STIP-II have been analyzed for their total helium and hydrogen contents and their release characteristics with temperature. Helium and hydrogen release measurements showed considerable levels of deuterium and tritium species which generally mirrored those of hydrogen. Hydrogen release occurred from about 300 °C for the AlMg3 to about 800 °C for the Zircaloy-2. For the Zircaloy-2 and the steels, helium release began to occur at between 1100 and 1200 °C, which is consistent with previous measurements on irradiated steels. Modeling of the hydrogen release data for the 316 and F82H suggests two traps of differing energy dependent on the irradiation dose and temperature. The higher energy traps are probably voids created from vacancy coalescence.

1. Introduction

Three irradiations have been performed in the Swiss Spallation Neutron Source (SINQ) to establish a materials database for mixed proton and neutron fluxes for future spallation neutron and other accelerator sources. The first experiment (STIP-I) was done in SINQ Target 3 (Zircaloy-2) from 1998 to 1999, the second experiment (STIP-II) was done in SINQ Target 4 (Pb-filled 316 SS tubes) from 2000 to 2001, and the third experiment (STIP-III) was done from 2002 to 2003. The results of helium and hydrogen gas measurements on materials from STIP-I have been reported earlier [1].

Materials included in STIP-II were mainly austenitic and martensitic steels, including 316LN, F82H, and T91. Samples of 316, F82H, T91, AlMg3, and Zircaloy-2 from STIP-II have been analyzed for their total helium and hydrogen contents and their release characteristics. These data will provide important comparisons between measurements and calculations for evaluation of current spallation cross sections, and also indications as to the generation and retention of helium and hydrogen under spallation irradiations conditions. The later will be very useful for understanding the helium and hydrogen effects on hardening and embrittlement of the irradiated materials.

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2. SINQ Target-4 and STIP-II

The lower part of the SINQ target is illustrated in Fig. 1. The normal target rods were lead (Pb) clad with SS 316L tubes. Test specimens were included in a number of tubes located in the most intense irradiation zone, i.e. the lower central region. About 10 thermocouples were installed at different positions for monitoring the irradiation temperature in both the normal rods and the specimen rods, and indicated a temperature range of 80–450 °C throughout the two-year irradiation. Temperatures for individual samples were based on calculations. In STIP-II, more than 2000 samples from more than 40 different materials were irradiated up to 20 dpa. Different types of samples such as TEM disks, tensile, bend-fatigue, bend-bar, Charpy, mini-CT, and SANS were used for various measurements. Detailed information has been reported elsewhere [2].

3. Analysis samples

For the present study, a number of samples from the STIP-II irradiation were analyzed for their hydrogen and helium release characteristics. A

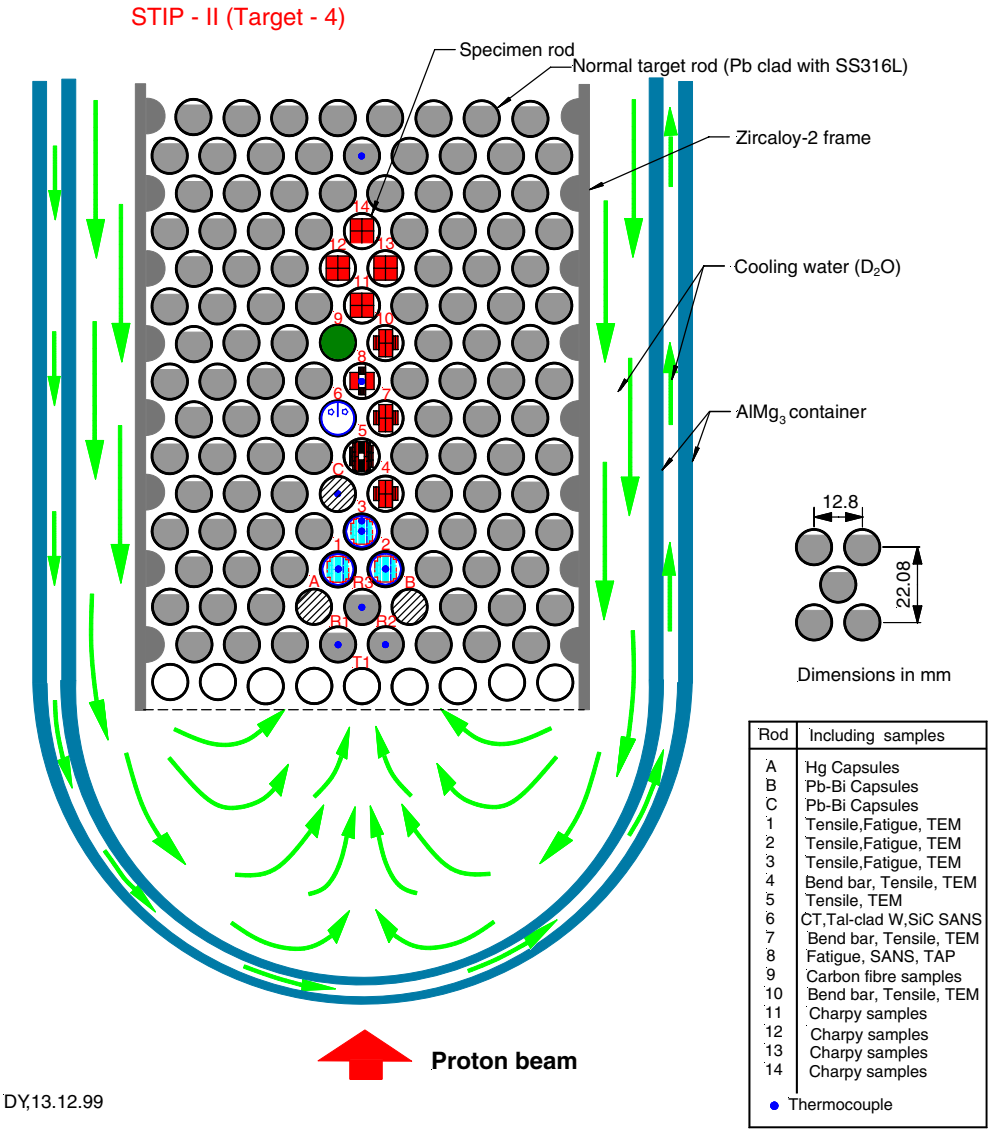

Fig. 1. Positions of the specimen rods in the lower part of the SINQ Target-4.