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- 1.1 REVISED ANL-REPORTED TENSILE DATA FOR UNIRRADIATED AND IRRADIATED (FFTF, HFIR) V-Ti AND V-Cr-Ti ALLOYS — M. C. Billone (Argonne National Laboratory)** 3

The tensile data for all unirradiated and irradiated vanadium alloys samples tested at Argonne National Laboratory (ANL) have been critically reviewed and, when necessary, revised. The review and revision are based on reanalyzing the original load-displacement strip chart recordings by a methodology consistent with current ASTM standards. For unirradiated alloys (162 samples), the revised values differ from the previous values as follows: -11 ± 19 MPa ($-4 \pm 6\%$) for yield strength (YS), -3 ± 15 MPa ($-1 \pm 3\%$) for ultimate tensile strength (UTS), $-5 \pm 2\%$ strain for uniform elongation (UE), and $-4 \pm 2\%$ strain for total elongation (TE). For irradiated alloys (91 samples), the differences between the revised and previous values are: 30 ± 37 MPa ($6 \pm 7\%$) for YS, -1 ± 6 MPa ($0 \pm 1\%$) for UTS, $-5 \pm 2\%$ for UE, and $-4 \pm 2\%$ for TE. Of these changes, the decrease in UE values for alloys irradiated and tested at 400-435°C is the most significant. This decrease results from the proper subtraction of nongauge-length deformation from measured crosshead deformation. In previous analysis of the tensile curves, the nongauge-length deformation was not correctly determined and subtracted from the crosshead displacement. The previously reported and revised tensile values for unirradiated alloys (20-700°C) are tabulated in Appendix A. The revised tensile values for the FFTF-irradiated (400-600°C) and HFIR-irradiated (400°C) alloys are tabulated in Appendix B, along with the neutron damage and helium levels. Appendix C compares the revised values to the previously reported values for irradiated alloys. Appendix D contains previous and revised values for the tensile properties of unirradiated V-5Cr-5Ti (BL-63) alloy exposed to oxygen.

- 1.2 IMPACT PROPERTIES OF VANADIUM-BASE ALLOYS IRRADIATED AT $<430^\circ\text{C}$ — H. M. Chung and D. L. Smith (Argonne National Laboratory)** 62

Recent attention to vanadium-base alloys has focused on the effect of low-temperature ($<430^\circ\text{C}$) neutron irradiation on the mechanical properties, especially the phenomena of loss of work-hardening capability under tensile loading and loss of dynamic toughness manifested by low impact energy and high ductile-brittle-transition temperature (DBTT). This paper summarizes results of an investigation of the low-temperature impact properties of V-5Ti, V-4Cr-4Ti, and V-3Ti-1Si that were irradiated in several fission reactor experiments, i.e., FFTF-MOTA, EBR-II X-530, and ATR-A1. Irradiation performance of one production-scale and one laboratory heat of V-4Cr-4Ti and one laboratory heat of V-3Ti-1Si was the focus of the investigation. Even among the same class of alloy, strong heat-to-heat variation was observed in low-temperature impact properties. A laboratory heat of V-4Cr-4Ti and V-3Ti-1Si exhibited good impact properties, whereas a 500-kg heat of V-4Cr-4Ti exhibited unacceptably high DBTT. The strong heat-to-heat variation in impact properties of V-4Cr-4Ti indicates that fabrication procedures and minor impurities play important roles in the low-temperature irradiation performance of the alloys.

- 1.3 TENSILE AND IMPACT PROPERTIES OF VANADIUM-BASE ALLOYS IRRADIATED AT LOW TEMPERATURES IN THE ATR-A1 EXPERIMENT — H. Tsai, L. J. Nowicki, M. C. Billone, H. M. Chung, and D. L. Smith (Argonne National Laboratory)** 70

Subsize tensiles and Charpy specimens made from several V-(4-5)Cr-(4-5)Ti alloys were irradiated in the ATR-A1 experiment to study the effects of low-temperature irradiation on mechanical properties. These specimens were contained in lithium-

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- 1.4 STRAIN RATE DEPENDENCE OF THE TENSILE PROPERTIES OF V-(4-5%) Cr-(4-5%)Ti IRRADIATED IN EBR-II AND HFBR — S. J. Zinkle, L. L. Snead, J. P. Robertson and A. F. Rowcliffe (Oak Ridge National Laboratory) 77

Elevated temperature tensile tests performed on V-(4-5)Cr-(4-5)Ti indicate that the yield stress increases with increasing strain rate for irradiation and test temperatures near 200°C , and decreases with increasing strain rate for irradiation and test temperatures near 400°C . This observation is in qualitative agreement with the temperature-dependent strain rate effects observed on unirradiated specimens, and implies that some interstitial solute remains free to migrate in irradiated specimens. Additional strain rate data at different temperatures are needed.

- 1.5 SUMMARY OF THE INVESTIGATION OF LOW TEMPERATURE, LOW DOSE RADIATION EFFECTS ON THE V-4Cr-4Ti ALLOY — L. L. Snead, S. J. Zinkle, D. J. Alexander, A. F. Rowcliffe, J. P. Robertson, and W.S. Eatherly (Oak Ridge National Laboratory) 81

Experimental details, raw data, method of analysis, and results are presented for the low-temperature, low-dose HFBR-V1 through V4 irradiation experiments conducted at ORNL on V-4Cr-4Ti specimens (U.S. Fusion Program Heat #832665). Four separate capsules were irradiated in the V-15 and V16 In-Core Thimbles of the High Flux Beam Reactor at the Brookhaven National Laboratory to doses of 0.1 or 0.5 dpa at temperatures between 100 and 505°C . Testing included microhardness, electrical resistivity, tensile properties, and Charpy impact properties.

- 1.6 THERMOPHYSICAL AND MECHANICAL PROPERTIES OF V-(4-5)%Cr-(4-5)%Ti ALLOYS — S. J. Zinkle (Oak Ridge National Laboratory) 99

Solid solution V-Cr-Ti alloys exhibit a good combination of high thermal conductivity, adequate tensile strength, and low thermal expansion. The key thermophysical and mechanical properties for V-(4-5)%Cr-(4-5)%Ti alloys are summarized in this report. Some of these data are available in the ITER Materials Properties Handbook (IMPH), whereas other data have been collected from recent studies. The IMPH is updated regularly, and should be used as the reference point for design calculations whenever possible.

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- 1.12 RESEARCH AND DEVELOPMENT ON VANADIUM ALLOYS FOR FUSION APPLICATIONS — S. J. Zinkle (Oak Ridge National Laboratory), H. Matsui (Tohoku University), D. L. Smith (Argonne National Laboratory), A. F. Rowcliffe (ORNL), E. van Osch (NERF-Petten), K. Abe (Tohoku University), and V. A. Kazakov (RIAR-Dimitrovgrad) 126
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A systematic study has been initiated to evaluate the performance of several V-Cr-Ti alloys after exposure to environments containing hydrogen at various partial pressures. The goal is to correlate the chemistry of the exposure environment with the hydrogen uptake in the samples and its influence on the microstructure and tensile properties of the alloys. At present four heats of alloys (BL-63, BL-71, and

T87, plus 44 from General Atomics) are being evaluated. Other variables of interest are the effect of initial grain size on hydrogen uptake and tensile properties, and the synergistic effects of oxygen and hydrogen on the tensile behavior of the alloys. Experiments conducted thus far on specimens of various V-Cr-Ti alloys exposed to p_{H_2} levels of 0.01 and 3×10^{-6} torr showed negligible effect of H_2 on either maximum engineering stress or uniform/total elongation. Further, preliminary tests on specimens annealed at different temperatures showed that grain size variation by a factor of ≈ 2 had a negligible effect on tensile properties.

- 1.14 TENSILE PROPERTIES OF V-Cr-Ti ALLOYS AFTER EXPOSURE IN OXYGEN-CONTAINING ENVIRONMENTS — K. Natesan and W. K. Soppett (Argonne National Laboratory) 130

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Maximum engineering stress for 44 alloy at room temperature was 421.6-440.6 MPa after ≈ 250 h exposure at 500°C in environments with a p_{O_2} range of 1×10^{-6} to 760 torr. The corresponding uniform and total elongation values were 11-14.4% and 14.5-21.7%, respectively. Measurements of crack depths in various specimens showed that depth is independent of p_{O_2} in the preexposure environment and was of 70-95 μm after 250-275 h exposure at 500°C.

- 1.15 LASER-WELDED V-Cr-Ti ALLOYS: MICROSTRUCTURAL AND MECHANICAL PROPERTIES — K. Natesan, D. L. Smith, P. G. Sanders, and K. H. Leong (Argonne National Laboratory) 136

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- 1.16 PERFORMANCE OF V-4Cr-4Ti MATERIAL EXPOSED TO THE DIII-D TOKAMAK ENVIRONMENT — H. Tsai, D. L. Smith, H. M. Chung (Argonne National Laboratory), W. R. Johnson and J. P. Smith (General Atomics), and W. R. Wampler (Sandia National Laboratory) 141

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- 2.3 FIBER CREEP RATE AND HIGH-TEMPERATURE PROPERTIES OF SiC/SiC COMPOSITES — C. A. Lewinsohn, R. H. Jones, G. E. Youngblood, and C. H. Henager, Jr. (Pacific Northwest National Laboratory) 171

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- 3.1 RADIATION HARDENING AND DEFORMATION BEHAVIOR OF IRRADIATED FERRITIC-MARTENSITIC STEELS — J. P. Robertson, R. L. Klueh (Oak Ridge National Laboratory), K. Shiba (Japan Atomic Energy Research Institute), and A. F. Rowcliffe (ORNL) 179

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- 3.2 A REASSESSMENT OF THE EFFECTS OF HELIUM ON CHARPY IMPACT PROPERTIES OF FERRITIC/MARTENSITIC STEELS — D. S. Gelles and M. L. Hamilton (Pacific Northwest National Laboratory), and G. L. Hankin (Loughborough University, England) 188

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- 3.5 EFFECT OF HEAT TREATMENT AND IRRADIATION TEMPERATURE ON IMPACT BEHAVIOR OF IRRADIATED REDUCED-ACTIVATION FERRITIC STEELS — R. L. Klueh and D. J. Alexander (Oak Ridge National Laboratory) 198

Charpy tests were conducted on eight normalized-and-tempered reduced-activation ferritic steels irradiated in two different normalized conditions. Irradiation was conducted in the Fast Flux Test Facility at 393°C to ≈ 14 dpa on steels with 2.25, 5, 9, and 12% Cr (0.1% C) with varying amounts of W, V, and Ta. The different normalization treatments involved changing the cooling rate after austenization. The faster cooling rate produced 100% bainite in the 2.25 Cr steels, compared to duplex structures of bainite and polygonal ferrite for the slower cooling rate. For both cooling rates, martensite formed in the 5 and 9% Cr steels, and martensite with ≈ 25% δ-ferrite formed in the 12% Cr steel. Irradiation caused an increase in the ductile-brittle transition temperature (DBTT) and a decrease in the upper-shelf energy. The difference in microstructure in the low-chromium steels due to the different heat treatments had little effect on properties. For the high-chromium martensitic steels, only the 5Cr steel was affected by heat treatment. When the results at 393°C were compared with previous results at 365°C, all but 5Cr and 9Cr steel showed the expected decrease in the shift in DBTT with increasing temperature.

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- 9.6 CALCULATION AND MEASUREMENT OF HELIUM GENERATION AND SOLID TRANSMUTANTS IN Cu-Zn-Ni ALLOYS — L. R. Greenwood, B. M. Oliver, and F. A. Garner (Pacific Northwest National Laboratory), and T. Muroga (National Institute of Fusion Science, Nagoya 464-01, Japan) 328

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- 9.7 NEUTRON DOSIMETRY AND DAMAGE CALCULATIONS FOR THE HFIR-MFE-200J-1 IRRADIATION — L. R. Greenwood (Pacific Northwest National Laboratory) and C. A. Baldwin (Oak Ridge National Laboratory) 329

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- 9.8 NEUTRONICS ASPECTS OF A DHCE EXPERIMENT — I. C. Gomes, H. Tsai, and D. L. Smith (Argonne National Laboratory) 333

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energy to trigger the Helium producing reactions. A DHCE experiment involves the decay of Tritium to Helium-3 to produce the required Helium during irradiation. This paper describes an analysis of the most important aspects of a DHCE experiment and compares different types of fission reactors and their suitability for performing such an experiment. It is concluded that DHCE experiments are feasible in a certain class of mixed-spectrum fission reactors, but a careful and detailed evaluation, for each facility and condition, must be performed to ensure the success of the experiment.

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- 11.2 SUMMARY OF THE U.S. SPECIMEN MATRIX FOR THE HFIR 13J VARYING TEMPERATURE IRRADIATION CAPSULE — S. J. Zinkle (Oak Ridge National Laboratory) 352**

The U.S. specimen matrix for the collaborative DOE/Monbuscho HFIR 13J varying temperature irradiation capsule contains two ceramics and 29 different metals, including vanadium alloys, ferritic/martensitic steels, pure iron, austenitic stainless steels, nickel alloys, and copper alloys. This experiment is designed to provide fundamental information on the effects of brief low-temperature excursions on the tensile properties and microstructural evolution of a wide range of materials irradiated at nominal temperatures of 350 and 500°C to a dose of ~5 dpa. A total of 340 miniature sheet tensile specimens and 274 TEM disks are included in the U.S.-supplied matrix for the irradiation capsule.

- 11.3 SCHEDULE AND STATUS OF IRRADIATION EXPERIMENTS — A. F. Rowcliffe, M. L. Grossbeck, and J. P. Robertson (Oak Ridge National Laboratory) 356**

The current status of reactor irradiation experiments is presented in tables summarizing the experimental objectives, conditions, and schedule.