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MASTER

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2.4 SUMMARY OF THE EBR-II AD-2 FERRITICS IRRADIATION EXPERIMENT - A. M. Ermi (Westinghouse Hanford Company)

2.4.1 ADIP Task

ADIP Program Task: Ferritic Steels Development (Path E).

2.4.2 Objectives

The objective of the AD-2 experiment is to provide baseline, high fluence data at several temperatures for the ferritic alloys HT-9 and 9Cr-1Mo. Developmental 2-1/4Cr-1Mo is also being scoped in this experiment. The AD-2 experiment is designed to yield data concerning the irradiation effects on the mechanical properties of these alloys with emphasis on their tensile, fatigue, fracture toughness and weld properties. Characterization of the irradiation effects on the microstructure of these alloys will also be performed.

2.4.3 Summary

Six uninstrumented B-7c capsules were removed from the EBR-II after undergoing irradiation during Cycles 109-113 (August 1980 to June 1981). Several specimens were removed and distributed for interim examination, while the remaining specimens were re-encapsulated into four new B-7c capsules. In addition, some unirradiated specimens were included in the new capsules. These capsules were removed after undergoing irradiation during Cycles 118-121 and 123 (February 1982 to April 1983).

2.4.4 Progress and Status

2.4.4.1 Introduction

The AD-2 experiment has been designed to provide mechanical properties data on selected ferritic alloys for application in fusion reactor first walls and blankets. Of particular concern are the irradiation effects on the fracture and weld properties of the materials. Alloy selection and irradiation temperatures have been specified by the Alloy Development for Near Term Applications Working Group. This is the final report on the AD-2 experiment, which summarizes the experimental parameters for both the initial and reconstitution test matrices.

2.4.4.2 Test Matrices

Details regarding specimen preparation, heat treatments, test matrices and capsule loadings have been reported in previous ADIP Progress Reports. The initial specimen preparation and loading were reported in June 1980,¹ while the reconstitution test matrix was reported in March 1982.^{2,3} The complete AD-2 test matrix encompassing both irradiations is detailed in Table 2.4.1.

2.4.4.3 Irradiation Parameters

The initial irradiation utilized six uninstrumented B-7C capsules, two at both 390°C and 500°C, and one at each 450°C and 550°C. These capsules were inserted into the EBR-II in August 1980 for Cycle 109 and were removed in June 1981 after Cycle 113. Specimens in the peak flux position accumulated a fluence of 13.5 dpa (based on $4.8 \text{ dpa}/10^{22} \text{ n/cm}^2$ for HT-9).

The second irradiation, including reconstituted specimens plus new, unirradiated specimens, utilized four B-7c capsules, one at each of the four temperatures. These capsules were inserted in February 1982 for Cycle 118 and were removed in April 1983 after Cycle 123. (The capsules were removed during the transient cycle, 122). Specimens in the peak flux position during the second irradiation accumulated a fluence of 16.2 dpa. Reconstituted specimens in the peak positions for both irradiations accumulated 29.7 dpa.

A summary of the experimental parameters for the entire AD-2 experiment is given in Table 2.4.2. Included are the fluences for each irradiation as a function of the seven levels along the B-7c capsules. Details of fluences for particular specimens are available from the author on request.

Specimens from the AD-2 experiment were distributed as follows: ORNL received all tensile, Grodzinski fatigue and fatigue initiation specimens; WHC received all fracture toughness and fatigue crack growth specimens; the Charpy specimens were distributed to both ORNL and WHC; and the TEM disk specimens were distributed to various participants in the ADIP and DAFS programs.

2.4.5 Future Work

This concludes the irradiation phase of the AD-2 experiment.

2.4.6 References

1. R. J. Puigh and N. F. Panayotou, "Specimen Preparation and Loading for the AD-2 Ferritics Experiment", pp. 260-293 in *ADIP Semiannu. Prog. Rep. June 1980*, DOE/ER-0045-3, U.S. DOE, Office of Fusion Energy.
2. D. T. Peterson, "TEM Specimen Matrix for the AD-2 Reconstitution", pp. 13-16 *ADIP Semiannu. Prog. Rep. March 1982*, DOE/ER-0045/8, U.S. DOE, Office of Fusion Energy.
3. A. M. Ermi, "Reconstitution of the AD-2 Ferritics Experiment", pp. 431-441 in *ADIP Semiannu. Prog. Rep. March 1982*, DOE/ER-0045/8, U.S. DOE, Office of Fusion Energy.

Table 2.4.1. AD-2 Test Matrix

Material [Code]	Initial Test Matrix				Interim Examination				Recon of Irradiated Spec.				Recon of Unirradiated Spec.				Total Recon Test Matrix			
	390C	450C	500C	550C	390C	450C	500C	550C	390C	450C	500C	550C	390C	450C	500C	550C	390C	450C	500C	550C
<u>TENSILE [T]</u>																				
HT-9(#1)[UH]	20	10	20	10	10	5	10	5	10	5	10	5	--	--	--	--	10	5	10	5
HT-9(#2)[TW]	10	5	10	5	10	2	10	2	--	3	--	3	--	--	--	--	--	3	--	3
HT-9(XAA-3587)[SB]	--	--	--	--	--	--	--	--	--	--	--	--	4	4	1	4	4	4	1	4
HT-9,1Ni[SC]	--	--	--	--	--	--	--	--	--	--	--	--	4	4	--	2	4	4	--	2
HT-9,2Ni[SD]	--	--	--	--	--	--	--	--	--	--	--	--	4	4	1	4	4	4	1	4
HT-9,2Ni Adj [SE]	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--	4	--	--	--
9Cr-1Mo(30182)[XT]	9	3	9	6	4	1	4	3	5	2	5	3	--	--	--	--	5	2	5	3
9Cr-1Mo(XA-3590)[TA]	--	--	--	--	--	--	--	--	--	--	--	--	4	4	--	4	4	4	--	4
9Cr-1Mo-2Ni[TB]	--	--	--	--	--	--	--	--	--	--	--	--	4	4	1	4	4	4	1	4
9Cr-1Mo-2Ni Adj[TC]	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--	4	--	--
2-1/4Cr-1Mo[ZT]	6	3	6	3	3	1	3	1	3	2	3	2	--	--	--	--	3	2	3	2
LRO-16D [6]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	2
LRO-42 [VH]	--	--	--	--	--	--	--	--	--	--	--	--	2	2	--	2	2	2	--	2
<u>CRACK GROWTH [CG]</u>																				
HT-9(#1)[HT]	22	11	22	11	10	4	13	4	12	7	9	7	--	--	--	--	12	7	9	7
HT-9(#2)[MR]	10	5	10	5	10	2	10	2	--	3	--	3	--	--	--	--	--	3	--	3
9Cr-1Mo(30182)[AS]	10	5	10	5	4	2	4	2	6	3	6	3	--	--	--	--	6	3	6	3
2-1/4Cr-1Mo[ZC]	10	5	10	5	4	2	10	2	6	3	--	3	--	--	--	--	6	3	--	3
HT-9(W)[RW]	10	--	10	10	4	--	5	4	6	--	5	6	--	--	--	--	6	--	5	6
HT-9(HAZ)[WR]	5	--	5	5	2	--	2	2	3	--	3	3	--	--	--	--	3	--	3	3
HT-9(W/HAZ)[RW]	2	--	2	2	2	--	2	2	--	--	--	--	--	--	--	--	--	--	--	--
9Cr-1Mo(W)[WM]	6	--	6	6	2	--	2	2	4	--	4	4	--	--	--	--	4	--	4	4
<u>FATIGUE INITIATION [FI]</u>																				
HT-9(#4)[SF]	6	3	6	3	4	3	4	3	2	--	2	--	--	--	--	--	2	--	2	--
9Cr-1Mo(30182)[SI]	6	3	6	3	4	3	4	3	2	--	2	--	--	--	--	--	2	--	2	--
<u>GRODZINSKI FATIGUE [GF]</u>																				
HT-9(#1)[SG]	10	5	10	5	10	3	10	3	--	2	--	2	--	--	--	--	--	2	--	2
9Cr-1Mo(30182)[SH]	2	--	2	2	2	--	2	2	--	--	--	--	--	--	--	--	--	--	--	--

continued

Table 2.4.1. AD-2 Test Matrix (cont'd)

Material [Code]	Initial Test Matrix				Interim Examination				Recon of Irradiated Spec.				Recon of Unirradiated Spec.				Total Recon Test Matrix			
	390C	450C	500C	550C	390C	450C	500C	550C	390C	450C	500C	550C	390C	450C	500C	550C	390C	450C	500C	550C
<u>FRACTURE TOUGHNESS [FT]</u>																				
HT-9(#3)[T4]	10	6	10	6	6	6	6	6	4	--	4	--	--	--	--	--	4	--	4	--
HT-9(#4)[T5]	6	--	6	--	4	--	4	--	2	--	2	--	--	--	--	--	2	--	2	--
9Cr-1Mo(30182)[T6]	6	6	6	--	6	6	6	--	--	--	--	--	--	--	--	--	--	--	--	--
HT-9(W)[T7]	7	6	7	3	6	6	6	3	1	--	1	--	--	--	--	--	1	--	1	--
HT-9(W/HAZ)[HT],[TA]	7	6	7	3	6	6	6	3	1	--	1	--	5	7	5	5	6	7	6	5
<u>CHARPY [C]</u>																				
HT-9(#1)[KT]	--	--	--	--	--	--	--	--	--	--	--	--	8	8	--	8	8	8	--	8
HT-9(#3)[TT]	10	8	10	8	6	4	6	4	4	4	4	4	--	--	--	--	4	4	4	4
HT-9(XAA-3587)[SB]	--	--	--	--	--	--	--	--	--	--	--	--	5	--	--	--	5	--	--	--
HT-9,1Ni[SC]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--	3	--
HT-9,2Ni[SD]	--	--	--	--	--	--	--	--	--	--	--	--	3	--	3	--	3	--	3	--
9Cr-1Mo(30176)[AF]	--	--	--	--	--	--	--	--	--	--	--	--	8	8	6	8	8	8	6	8
9Cr-1Mo(30182)[TV]	8	4	8	4	4	4	4	4	4	--	4	--	--	--	--	--	4	--	4	--
9Cr-1Mo(XA-3590)[TA]	--	--	--	--	--	--	--	--	--	--	--	--	--	5	--	5	--	5	--	5
9Cr-1Mo-2Ni[TB]	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	3	--	3	--	3
HT-9(W)[T1]	7	4	7	4	7	4	7	4	--	--	--	--	--	--	--	--	--	--	--	--
HT-9(W/HAZ)[TX]	7	--	7	--	7	--	7	--	--	--	--	--	--	--	--	--	--	--	--	--
9Cr-1Mo(W)[NL]	--	--	--	--	--	--	--	--	--	--	--	--	8	8	8	8	8	8	8	8
<u>DISK PACKETS [D]</u>																				
Various Alloys	8	4	8	4	4	2	4	2	4	2	4	2	2	2	2	2	6	4	6	4

Table 2.4.2. Summary of the EBR-II AD-2 Experiment

	AD-2	AD-2 RECON		
Date In Reactor:	August 1980 - June 1981	February 1982 - April 1983		
Cycle Numbers:	109 - 113	118 - 121 & 123		
Reactor Power:	57.25 MW	57.25 MW		
Accumulated Exposure:	10,680 MWD	12,780 MWD		
Capsules/ Temperature:	B-317/390°C B-318/500°C B-319/550°C B-320/390°C B-321/450°C B-322/500°C	B-317a/390°C B-318a/450°C B-319a/500°C B-321a/550°C		
Subassembly:	X-344B	X-344B		
Core Position:	4C2	4B2		
Peak Fluence ^a :	2.82×10^{22} n/cm ² (13.5 dpa)	3.37×10^{22} n/cm ² (16.2 dpa)		
Reactor Level Number Within Each Capsule	Distance From Core Mid-Plane	Fluence ^b 10^{22} n/cm ² (dpa)	Distance From Core Mid-Plane	Fluence ^b 10^{22} n/cm ² (dpa)
1	158 mm	1.88 (9.0)	159 mm	2.24 (10.8)
2	108 mm	2.35 (11.3)	109 mm	2.80 (13.5)
3	56 mm	2.67 (12.8)	56 mm	3.20 (15.4)
4	0 mm	2.82 (13.5)	0 mm	3.37 (16.2)
5	-54 mm	2.76 (13.3)	-53 mm	3.31 (15.9)
6	-102 mm	2.53 (12.1)	-102 mm	3.02 (14.5)
7	-152 mm	2.10 (10.1)	-155 mm	2.48 (11.9)

^aBased on a nominal value of peak flux for Row 4 of 1.75×10^{15} n/cm²-s, E > 0.1 MeV (from dosimetry); dpa values based on $4.8 \text{ dpa}/10^{22} \text{ n/cm}^2$ for HT-9 (HEDL TC-160-1, 1974).

^bBased on the Row 4 flux profile from HEDL TME 78-84, 1979.