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Westinghouse Advanced Reactors Division

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UC-25, Metals, Ceramics, and Materials

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VANADIUM ALLOY CLADDING DEVELOPMENT
QUARTERLY PROGRESS REPORT
FOR THE PERIOD ENDING MARCH 31, 1970

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Approved by:

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P. Murray

Contract AT(30-1)-3791
U. S. Atomic Energy Commission

Submitted to AEC-NY00 in April 1970

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SECTION 1 INTRODUCTION

GENERAL

This is the eleventh quarterly progress report on Vanadium Alloy Cladding Development Project being performed under AEC Contract AT(30-1)-3791, and covers the work performed during the third quarter of the fiscal year (FY) 1970.

SUMMARY OF OBJECTIVES

The project objectives are to further the development and to characterize the properties of vanadium-based alloys that may offer certain advantages over stainless steel for fuel cladding in a liquid-metal-cooled fast breeder reactor (LMFBR). For this application, the alloys must:

1. Have sufficient strength to contain the fuel at temperatures up to 800°C
2. Be resistant to liquid-sodium corrosion
3. Be compatible with mixed uranium-plutonium ceramic fuels
4. Be resistant to embrittlement by fast flux irradiation
5. Be readily fabricated into high-quality tubing at reasonable cost
6. Have acceptable nuclear physics characteristics

This development project is being accomplished under Commission sponsorship to supplement and extend the favorable data on novel vanadium-based alloys obtained under AEC Contract AT(30-1)-3487. The work is specifically directed to the identification of an alternate LMFBR fuel cladding that has improved mechanical properties and irradiation damage resistance compared to stainless steels.

The project consists of the following seven technical tasks and one administrative task.

UPVA-105 Fuel Element Design Evaluation

VCAA-110 Alloy Selection and Fabrication

VCAA-120 Structural and Mechanical Properties Evaluation

VCBA-125 Alloy Optimization

VCBA-130 Sodium Corrosion Evaluation

VCBA-140 Cladding Alloy-Fuel Compatibility Evaluation

VCBA-150 Irradiation Performance Evaluation

VCBA-160 Project Administration

UPVA-105 is an assessment of the technical and economic potential of the successful development of an advanced vanadium alloy cladding for a prototypical LMFBR fuel element. This task has been completed.

In VCAA-110, five vanadium alloy compositions have been melted into 4-inch ingots from which sheet, rod, and tubing have been fabricated (see Table 1).

Table 1. Five Vanadium Alloy Compositions		
Nominal Composition	Original Designation	New Designation ^(a)
V-9Cr-3Fe-1.3Zr-0.05C	HSV 207	VANSTAR-7
V-6Fe-5Cb-1.3Zr-0.05C	HSV 209	VANSTAR-9
V-8Cr-10Ta-1.3Zr-0.05C	HSV 208	VANSTAR-8
V-15Cr-5Ti		
V-20Ti		
(a) VANSTAR - General term for the family of Westinghouse developed alloys.		

VANSTAR-7, VANSTAR-8, and VANSTAR-9 are Westinghouse compositions developed under AEC Contract AT(30-1)-3487. V-15Cr-5Ti and V-20Ti are alloys developed by the Argonne National Laboratory (ANL).

The VANSTAR alloys were selected for the characterization, compatibility, corrosion, and irradiation phases. A limited characterization of the other alloys (V-15Cr-5Ti, and V-20Ti) has been performed. A stock of all five alloys, in the form of rod, sheet, and tubing, has been made available to other Commission contractors. This task has been terminated.

VCAA-120 was aimed at characterization of the VANSTAR-8 and VANSTAR-9 alloys, including structure analysis, response to heat treatment, creep in vacuum, welding, and thermal stability of welds. In addition, limited characterization was performed on the other three alloys. This task was terminated due to absence of funding.

VCBA-125 objectives are to determine the degree of reactivity of selected vanadium alloys with interstitial elements at low interstitial activity levels, and to evaluate the effect of these interstitials on the mechanical behavior of the alloys.

VCBA-130 is an evaluation of corrosion resistance of the VANSTAR-7, VANSTAR-8, VANSTAR-9, and V-20Ti alloys in pumped sodium loops, investigating the variables of temperature, flow rate, time, and containment material.

VCBA-140 is an evaluation of the compatibility of the same alloys with single, UC, and mixed, (U,Pu)C, carbide fuels at varying fuel stoichiometry.

VCBA-150 is a preliminary examination of the effect of fast flux irradiation on the mechanical and structural properties of the two selected alloys, VANSTAR-8 and VANSTAR-9.

VCBA-160, Project Administration, coordination and control will be furnished for the timely within-budget completion of the contract, meeting of AEC contract administration requirements, and coordination with other Commission-sponsored LMFBR R&D projects.

SUMMARY OF PRIOR WORK

All work related to the present investigations and performed prior to the present period has been fully reported in:

WCAP-3487-16, W. Pollack, K. C. Thomas, K. R. Jordan, R. T. Begley, R. W. Buckman, and E. C. Bishop, "Development of High Strength Vanadium Alloys," (June 1967).

WCAP-3791-9, E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending September 30, 1967."

WCAP-3791-13, E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending December 31, 1967."

WARD-3791-17, E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending March 31, 1968."

WARD-3791-20, E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending June 30, 1968."

WARD-3791-25, E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending September 30, 1968."

WARD-3791-30, E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending December 31, 1968."

WARD-3791-34, E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending March 31, 1969."

WARD-3791-38, E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending June 30, 1969."

WARD-3791-42, E. C. Bishop, R. W. Buckman, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending September 30, 1969."

WARD-3791-45, E. C. Bishop, R. W. Buckman, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending December 31, 1969."

SUMMARY OF CURRENT PROGRESS

A summary of current progress is shown below. Detailed progress is reported in the individual task sections of this document.

1. The first three experimental runs in the task designed to examine the degree of reactivity of vanadium alloys with oxygen, nitrogen, and carbon have shown a linear rate of weight gain of unalloyed vanadium due to oxygen pickup.
2. The rebuilt sodium corrosion loop systems (VTL-3 and -4) designed to compare the effects of stabilized versus unstabilized stainless steel loop containment tubing on vanadium alloys over the temperature range 600 to 750°C, have each logged over 500 hours of operation at reference sodium conditions.
3. The vanadium alloy samples inserted in EBR-II, in the WARD/BNW High Flux Program, have accumulated 53 percent of the desired exposure of 15,000 MWd during a reactor residence time of approximately 11 months.

SECTION 2

VCBA-125 ALLOY OPTIMIZATION

R. W. Buckman, Jr. and R. C. Svedberg

OBJECTIVE

The objectives of this program are to determine the degree of reactivity of selected vanadium alloys, at low interstitial activity levels, with the interstitial elements oxygen (O), nitrogen (N), and carbon (C), and to evaluate the effect of these interstitials on mechanical behavior of the alloys

Four vanadium alloys will be exposed to oxygen, nitrogen, and carbon via gas-metal reactions at elevated temperatures (600-800°C) and low partial pressures (10^{-4} to 10^{-8} torr). The rate of interstitial pick-up by the alloys will be measured, using vacuum microbalance techniques. The alloys to be investigated are:

1. Pure Vanadium
2. V-10Mo
3. V-10Cr
4. VANSTAR-7 (V-9Cr-3Fe-1.3Zr-0.05C)

PRIOR WORK

This portion of the vanadium alloy cladding development program was begun during the first quarter of FY-1970, and is an extension of the Structural and Mechanical Property Evaluation Program (VCAA-120).

Plans were made and equipment ordered for a program to determine the degree of activity of selected vanadium alloys with interstitial elements at low interstitial activity levels. An evaluation is being made of the effects of these interstitials on the mechanical properties of these alloys.

Tube reducing and drawing of the vanadium alloys for AEC Contractors' use and for use in lining the corrosion loop in Task VCBA-130 has been completed.

The alloys being evaluated in this program have been prepared by double arc melting of electrefined vanadium with the suitable alloy additions. The ingot was then sectioned, canned in stainless steel containers for oxidation protection, and Dyna-pak forged. The forgings were removed from the cans, pickled, vacuum annealed, and cold rolled to 0.032-inch-thick sheet.

CURRENT PROGRESS

Alloy Melting and Processing

A re-evaluation was made of the carbon analyses for the alloys. The amounts initially reported were five to ten times higher than those reported for the electrorefined vanadium raw materials from which the alloys were made. It seemed unlikely that this much carbon could have been picked up in any of the processing steps. A re-evaluation revealed that the surface of the samples, as submitted, had been contaminated with carbon. The standard analytical laboratories cleaning procedure is a solvent rinse, using benzene and acetone. However, this procedure was apparently unsatisfactory for removing the surface contamination from the vanadium alloy samples. However, a light etch in a 50 percent HCl solution did remove the contamination as indicated in Table 2. The new carbon analyses are shown in Table 3, along with the complete chemical characterization of the experimental alloys.

Table 2. Effect of Cleaning Procedures on the Carbon Analyses of the Vanadium Alloy		
Material	Old Value Solvent Cleaning (ppm)	New Value Acid Etch (ppm)
V	75	55
V-10Mo	170	49
V-10Cr	220	62
VANSTAR-7	450	328

Table 3. Chemical Analyses of the Vanadium Alloys				
Element	Ingots (Weight-%)			
	Vanadium	V-10 Mo	V-10 Cr	VANSTAR-7
C	0.0055	0.0049	0.0062	0.0328
O	0.0310	0.0240	0.0180	0.0220
N	0.0003	0.0006	0.0010	0.0014
H	0.0011	0.0027	0.0009	0.0012
Cr	-	-	10.4	9.7
Mo	-	9.5	-	-
Fe	-	-	-	3.3
Zr	-	-	-	1.34

A slice from each ingot was polished for micro and macro structure characterization. A radial hardness traverse was made on the polished ingot section for each of the alloys. The average hardness of the respective ingots in the as-cast condition is given in Table 4.

Table 4. Average Hardness of As-Cast Ingots	
Alloy	DPH Hardness
Pure Vanadium	58
V-10Mo	131
V-10Cr	130
VANSTAR-7	182

Sample Preparation

Experimental samples are prepared from 0.032-inch-thick cold rolled sheet as follows.

1. The as-rolled sheet is sheared to produce 5.0-inch x 1.125-inch samples.
2. A 3/32-inch hole is drilled near the top of the sample to accept the quartz hang-down hook.
3. The sheared sheets are then polished to a 600 grit finish, and 0.030-inch thickness.
4. The samples are wrapped in tantalum foil and annealed for one hour in a 10^{-6} torr vacuum at temperatures ranging from 900 to 1200°C (the temperature depending on the particular alloy).
5. After annealing, the samples are weighed and placed into the experimental apparatus.

The dimensions of the test sample are illustrated in Figure 1. Two sheet tensile, and 4 DBTT test specimens will be cut from each sample after exposure to the contaminating interstitials for evaluation of the effect of the pickup on the mechanical behavior of the alloy; an additional sample is also available for metallographic examination.

Experimental Results

Three runs have been made in the experimental system during this reporting period. The parameters for the runs are listed in Table 5.

Run 1 was made at 610°C in oxygen at a pressure of 1.5×10^{-5} torr. During this run, 8270 ppm of oxygen were dissolved into the vanadium sheet as indicated by the microbalance and verified by comparison of before and after weighings. The rate of weight gain was linear with time, but dependent on slight pressure fluctuations in the system. Run No. 2 at 790°C and at a pressure of 3×10^{-5} torr, showed a pick up of 19,750 ppm during the 100-hour run. The weight gain was also linear with time, indicating that the oxidation mechanism was controlled by the rate of arrival of molecules at the surface and not by diffusion through an oxide layer.

Figure 1. Configuration of Vanadium Alloy Microbalance Sample Showing Outline of Mechanical Test Specimens

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Table 5. Experimental Parameters						
Run No.	Sample Composition	Run Duration (hr)	Temperature (°C)	Atmosphere	Pressure ^(a) (torr)	Linear Oxidation Coefficient (mg/hr)
1	Vanadium	100	610	O ₂	1.5×10^{-5}	1.4
2	Vanadium	100	790	O ₂	3×10^{-5}	3.38
3	Vanadium	20	615	O ₂	1×10^{-5}	1.0
(a) Uncorrected for gauge modulation factor.						

Due to the flow regime (molecular), oxygen flowing through the furnace tube caused a pressure drop across the length of the specimen of about $5 - 7 \times 10^{-6}$ torr. This pressure drop was sufficiently large over the length of the sample to cause a considerable oxygen gradient. Figure 2 shows the DPH hardness readings as a function of distance along the specimen for Runs 1 and 2. These readings were made on the surface of the sample along the line indicated in Figure 2. The hardness profile and correlated oxygen composition are also indicated. The correlation between oxygen and solubility and hardness readings have been reported by Bradford and Carlson^[1] and Seybolt and Sumsion.^[2]

The hardness readings for Run 1 at 610°C were made with a 10 kg load, and resulted in DPH values more indicative of the surface hardness than the interior hardness. This is verified by the three DPH readings with a 50 kg load, which indicate that there was, in fact, an oxygen concentration gradient through the thickness of the sample. This behavior is expected at 600°C for a 0.030-inch-thick section based on existing diffusion data.^[3]

Run 2 at 790°C showed no hardness difference across the thickness as indicated by hardness measurements with 10 and 50 kg loads. Again, the diffusion data indicates that, for 100 hours at 790°C, a sample 0.030-inch thick should have a very small concentration gradient. The oxygen is evenly distributed throughout the thickness of the sample.

In order to overcome the longitudinal pressure gradient mentioned earlier, a technique proposed by Kofstad and Espevik^[4] was utilized. In addition to inletting oxygen into the top of the system and pumping on the bottom of the system, oxygen was also leaked into the bottom of the system to eliminate the pressure drop across the sample. The hardness profile of Run 3 indicates that the technique is successful in minimizing the oxygen profile along the sample.

Discussion

These results have shown that the rate of weight gain is linear at the pressures of this experiment. Also, the oxygen pickup after 100 hours is

TRAVERSE OF HARDNESS READINGS
ON SAMPLE SURFACE

Figure 2. Traverse Hardness Profile Along the Length of the Samples After Exposure to Conditions Listed in Table 5.

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quite large, thus making meaningful mechanical property evaluation difficult. The length of exposure time of the samples in the future will be adjusted to allow interstitial contamination to occur to a pre-selected level. The mechanical properties of the alloys will be compared at a constant contamination level, while the relative reactivity of the alloys will be compared by using the linear rate constant. In this manner, comparison of the mechanical properties of the alloys can be made on a standardized basis.

SECTION 3

VCBA-130 SODIUM CORROSION EVALUATION

S. L. Schrock and G. A. Whitlow

OBJECTIVE

The objectives of this task are to evaluate the effects of flowing sodium in the temperature range of 600 to 800°C on the corrosion and mechanical properties of the vanadium-based alloys (VANSTAR-7, VANSTAR-8, and VANSTAR-9) and the V-20Ti alloy, and to gain some understanding of the mechanism of the corrosion process. The study is being conducted in pumped loops, investigating the variables of temperature, flow rate, and time. In addition, the effects on the loop containment materials under these conditions are being examined.

PRIOR WORK

All work related to the present investigation and performed prior to the present period was fully reported in the ten previous Vanadium Alloy Cladding Development Quarterly Progress Reports (see page 3).

In the first two loop runs (VTL-1 and VTL-2), it was found that the VANSTAR-7, -8, -9, and the V-20Ti alloys gained weight when exposed to flowing sodium containing less than 10 ppm oxygen at 675 to 800°C. The increases in weight were accompanied by microstructural changes and hardness increases.

Chemical analyses of corroded VANSTAR-9 and V-20Ti samples revealed that large quantities of the interstitials (nitrogen, carbon, and oxygen) were absorbed during corrosion, resulting in the observed weight gains. Parabolic kinetics were assigned to the corrosion processes up to 1500-hours exposure time, and "activation energies" for VANSTAR-7, -9, and V-20Ti were calculated. However, this was not the case for samples exposed to sodium for 2650 hours.

Due to interstitial absorption, considerable reductions in mechanical properties of corroded samples, especially at room temperature, were observed. Analysis of the stainless steel loop tubing revealed carbon and nitrogen depletion at the sodium exposed surface. At the air exposed surface, results indicated that nitrogen had diffused into and through the tubing. Calculations based on diffusion data confirmed these results.

The design was completed for the current two loop runs (VTL-3 and VTL-4), in which the test sections are lined with vanadium alloy tubing, and in which stabilized stainless steel containment tubing was used (VTL-4). The design and the philosophy behind these changes were fully described in two previous quarterly reports (WARD-3791-34 and WARD-3791-38). The problems encountered in the fabrication of the vanadium alloy loop tubing liners at Superior Tube Co. made it necessary to produce the material for this purpose at Westinghouse by swaging ANL extruded material.

CURRENT PROGRESS

General

Preparation and characterization of the vanadium alloy samples for the rebuilt loop systems VTL-3 and -4 were completed. Each loop test section contains 28 samples (3 in. x 0.058 in. x 0.25 in.), seven each of VANSTAR-7, -8, -9, and V-20Ti alloys. After cutting to size, each sample was hand polished to a "six naughts" surface finish, cleaned with "Alkanox," methanol and distilled water, vacuum dried, and weighed. Satisfactory insertion of samples into the vanadium alloy tubular test section liner, and insertion of the liner into the stainless steel containment tubing were accomplished. The assembled test sections were then welded into position in the loop systems; all welds were then leak checked. Installation of clam-shell and Glo-bar heaters, thermocouples, and insulation was completed.

The systems were then baked out at approximately 300°F under a dynamic vacuum, prior to filling with sodium. After flow was established, each system was cold trapped for 48 hours at 250 to 275°F, with the loop system at low temperature. A sodium sample was removed from each system, and after mercury amalgamation analysis revealed that the oxygen level in the sodium was as desired (below 10 ppm), operation at reference sodium conditions was initiated. Table 6 compares these conditions to those of the previous two runs.

Table 6. Comparison of Loop System Operating Conditions and Parameters				
	Present Runs		Previous Runs	
	VTL-3	VTL-4	VTL-1	VTL-2
Containment material	316SS	321SS	316SS	316SS
Sodium Velocity, fps	14	14	7	14
gpm	1.8	1.8	0.64	1.8
Test Section Inlet, °C (°F)	600 (1110)		675 (1250)	
Test Section Outlet, °C (°F)	750 (1380)		800 (1470)	
Oxygen Content of Sodium, ppm	10		10	
Exposed Surface Area Ratio, SS/V	1.0		7.7	

Both loop system (VTL-3 and VTL-4) have successfully operated under reference sodium conditions. As of March 31, 1970, VTL-3 has logged approximately 700 hours of the scheduled 1500 hours operation, and VTL-4 approximately 500 hours. The sodium from both systems was sampled for oxygen content after approximately 250 and 300 hours respectively, and found to be less than 10 ppm by weight. No further post start cold trapping has been employed. As anticipated, the gettering action of the vanadium alloys appears to have been more than adequate in maintaining the desired low oxygen values.

Data Evaluation

Proposals have been made for the renewal of the subcontract with Metcut Research Associates of Cincinnati for the tensile testing of the corroded vanadium alloy samples from loop systems VTL-3 and VTL-4.

Some further chemical analyses on the Type 316 stainless steel loop tubing from VTL-1 and VTL-2 have been obtained. Similar carbon and nitrogen gradients to those reported previously^[5] were observed (see Figures 3 through 6). In a sample that was exposed to sodium flowing at 5 fps for 1500 hours at 675°C (Figure 3), there was no evidence of nitrogen diffusion into the stainless steel at the air exposed surface. Nitrogen diffusion was observed in the sample exposed to sodium flowing at 14 fps (Figure 4). Reduced levels of carbon and nitrogen were observed at the sodium exposed surface of tubing exposed for 1500 hours at 800°C (Figure 6).

Approximate diffusion coefficients for carbon and nitrogen have been calculated from these concentration gradients using the expression,

$$D = x^2/t \text{ at } \frac{C_s + C_o}{2}$$

where: D = diffusion coefficient, cm²/sec

x = distance from exposed surface at $\frac{C_s + C_o}{2}$, cm

t = exposure time, sec

C_s = surface concentration after exposure, ppm

C_o = initial unexposed concentration, ppm

Table 7 shows the values that were obtained. Generally speaking, the values in Table 7 are, with one exception, roughly half an order of magnitude lower than values from a best fit of the available data in the literature on carbon and nitrogen diffusion in stainless steel.

Table 7. Carbon and Nitrogen Diffusion Coefficients In Type 316 Stainless Steel Loop Tubing						
Loop	Sodium Exposure Conditions			Tube Wall Thickness (in.)	Diffusion Coefficient (10 ⁻¹⁰ cm ² /sec)	
	Temp. (°C)	Time (hr)	Velocity (fps)		Carbon	Nitrogen
VTL-1	800	1500	5	0.083	0.49	0.49
VTL-1	675	1500	5	0.035	-	0.11
VTL-2	800	1500	14	0.083	0.34	9.27
VTL-2	675	1500	14	0.035	0.12	0.19

Figure 3. Measured Nitrogen Concentration Gradient Across the Wall of the Type 316 Stainless Steel Containment Tubing for the Vanadium Alloy-Sodium Corrosion Loop System. (VIL-1: .5 fps., <10 ppm Oxygen).

3638-1

Figure 4. Measured Nitrogen and Carbon Concentration Gradients Across the Wall of the Type 316 Stainless Steel Containment Tubing for the Vanadium Alloy-Sodium Corrosion Loop System (VTL-2: 14 fps., <10 ppm Oxygen).

3638-2

Figure 5. Measured Nitrogen and Carbon Concentration Gradients Across the Wall of the Type 316 Stainless Steel Containment Tubing for the Vanadium Alloy-Sodium Corrosion Loop System (VIL-1: 5 fps., <10 ppm Oxygen).

3638-3

Figure 6. Measured Nitrogen and Carbon Concentration Gradients Across the Wall of the Type 316 Stainless Steel Containment Tubing for the Vanadium Alloy-Sodium Corrosion Loop System (VTL-2: 14 fps., ≤ 10 ppm Oxygen).

3638-4

SECTION 4

VCBA-140 CLADDING ALLOY - FUEL COMPATIBILITY EVALUATION

R. C. DeKlever, M. French, and G. A. Whitlow

OBJECTIVE

The objectives of this task are to assess the compatibility of the VANSTAR alloys and V-20Ti with mixed uranium-plutonium carbide fuels, and with sodium bonded uranium carbide fuels for times up to 5000 hours. The V-20Ti alloy has been selected as a reference so that these results may be compared with prior ANL work in this field.

PRIOR WORK

Two compatibility capsules have been tested. The first (No. 7), containing three pellets of unmodified hypostoichiometric UC, six pellets of unmodified hyperstoichiometric (U,Pu)C fuel, and samples of VANSTAR-8 and -9, and V-20Ti, accumulated 4650 hours at 800°C. The second capsule (No. 12), containing nine pellets of chromium stabilized (U,Pu)C fuel, and samples of VANSTAR-8 and -9, and V-20Ti, accumulated 2500 hours at 800°C. Both capsules were sodium bonded. Based solely on metallographic examination (microhardness will be performed in the near future), certain general observations, which are valid for these particular experimental conditions (>2500 hours at 800°C), may be made.

In the first capsule, containing hypostoichiometric UC and hyperstoichiometric (U,Pu)C, no reaction was observed in the fuel at the alloy/fuel interface. All the vanadium alloy samples showed reaction, generally in the form of a harder acicular type phase, near the contact surface. The degree of incompatibility (in decreasing depth of reaction) was VANSTAR-9, V-20Ti, and VANSTAR-8. No significant difference was detected between reactions with the single or mixed carbide fuel.

In the second capsule, containing chromium stabilized (U,Pu)C fuel, no reaction was seen in the fuel at the contact surfaces. In addition, very little reaction was seen in the VANSTAR-8 and VANSTAR-9 samples in contact with its fuel. However, the V-20Ti alloy did exhibit some incompatibility (reaction at the fuel contact surface).

CURRENT PROGRESS

No progress has been made due to delays in the installation of the microhardness tester in the glove box. However, installation is now set for the first week in April and microhardness of the vanadium alloy samples will commence as soon as practical.

SECTION 5
VCBA-150 IRRADIATION PERFORMANCE EVALUATION

P. J. Levine and G. A. Whitlow

OBJECTIVE

The objective of this task is to examine the effects of fast flux irradiation on the mechanical properties and structures of VANSTAR-8 and -9. Exposures of $1 - 2 \times 10^{22}$ n/cm² above 0.1 Mev will be achieved in EBR-II.

PRIOR WORK

All work related to this phase of the investigation was reviewed and fully reported in previous quarterly progress reports (see page 3). The irradiation program for this project consists of two parts:

1. The WARD/BNW High Flux Program - An irradiation pin composed of six subcapsules containing vanadium alloys, and designed in conjunction with BNW for insertion in Row 2 of EBR-II, was assembled and shipped to the reactor site. This pin was inserted in the reactor in Run 33 during March 1969. It was placed in position 2B1, and was designated as subassembly No. X057. At the end of the last reporting period, these samples had reached approximately half their goal exposure.
2. The CDAA-500, (a) EBR-II Program - Vanadium alloy tensile specimens (one per capsule) were contained in the bottom of each Phase I - EBR-II fuel capsule under Task CDAA-500. These specimens were contained in sodium-filled, stainless steel capsules, and were to be irradiated at reactor coolant ambient temperature (360°C). Two fueled capsules, each containing a VANSTAR-9 sample, were inserted in EBR-II in March 1969.

CURRENT PROGRESS

WARD/BNW High Flux Program

As of January 15, 1970, subassembly No. X057, containing the WARD vanadium alloy samples and other materials, had accumulated 8078 Mwd exposure. This subassembly, which was inserted in EBR-II, (position 2B1) on February 23, 1969, has therefore, accumulated approximately 53 percent of the desired exposure

(a) CDAA-500 Fast Flux Irradiation Studies Task of Uranium Plutonium Carbide Development.

of 15,000 MWd during a reactor residence time of approximately 11 months.

CDAA-500, EBR-II Program

Removal of the first two capsules (W2X and W8X) from EBR-II has been rescheduled to June 1970. It is anticipated that this rescheduling will result in an increased fluence up to approximately $3-4 \times 10^{22}$ nvt.

An additional capsule (W8F) was inserted in pile in February 1970; three or four of the additional seven fueled capsules should be inserted in EBR-II during the next reporting period.

SECTION 6
VCBA-160 PROJECT ADMINISTRATION

F. A. Brassart, W. B. Heubel, and P. Murray

OBJECTIVE

The objectives of this task are to assure that the project is successfully completed, on schedule, within the budget, and to the satisfaction of the Atomic Energy Commission; to assure compliance with contracted obligations and to coordinate this project with other AEC and Westinghouse-sponsored LMFBF development projects.

Overall project direction and day-to-day administration will be provided under this task. Plans and controls will be established and maintained, periodic reviews will be held with the Commission, correspondence and reports will be coordinated, and day-to-day technical and administrative liaison with the Commission will be provided.

CURRENT PROGRESS

Work programs for FY-1970 were submitted to the Commission in June 1969. Technical work has continued on the basis of those work programs.

The quarterly progress report (WARD-3791-45), for the period ending December 31, 1969, was prepared and distributed.

SECTION 7
LIST OF REFERENCES

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