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VANADIUM ALLOY CLADDING DEVELOPMENT
QUARTERLY PROGRESS REPORT
FOR THE PERIOD ENDING SEPTEMBER 30, 1969

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

Submitted to AEC-NY00 in November 1969

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INTRODUCTION

GENERAL

This is the ninth quarterly progress report on Vanadium Alloy Cladding Development Project being performed under AEC Contract AT(30-1)-3791. It covers the work performed during the first quarter of (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:

- Have sufficient strength to contain the fuel at temperatures up to 800°C
- Be resistant to liquid-sodium corrosion
- Be compatible with mixed uranium-plutonium ceramic fuels
- Be resistant to embrittlement by fast flux irradiation
- Be readily fabricated into high-quality tubing at reasonable cost
- 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 seven technical tasks and one administrative task as follows:

- 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 are being fabricated. (Table 1)

Table 1. Five Vanadium Alloy Compositions		
Nominal Composition	Original Designation	New Designation *
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		
*VANSTAR is the 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, is being made available to other Commission contractors, whereupon this task will be 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, and time.

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.

Under VCBA-160, project planning coordination and control necessary for timely within-budget completion will be furnished; AEC Contract Administration requirements will be met; and this project will be coordinated with other Commission-sponsored LMFBR R&D projects.

PRIOR WORK

All work related to the present investigations and performed prior to the present period has been fully reported in WCAP-3487-16^[1] and the previous eight quarterly reports.^[2-9]

SUMMARY OF CURRENT PROGRESS

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

- Plans have been made and equipment ordered for a program to determine the degree of reactivity of selected vanadium alloys with interstitial elements at low interstitial activity levels. An evaluation of the effects of these interstitials on the mechanical properties of these alloys will also be made.
- Tube reducing and drawing of the vanadium alloys for AEC Contractors use and for use in lining the corrosion loop in Task VCBA-130 is proceeding at Superior Tube Company.
- Preliminary interstitial analyses of sodium exposed vanadium alloy samples has revealed that at lower temperatures ($\sim 700^{\circ}\text{C}$) less interstitial absorption occurs than previously observed at $\sim 800^{\circ}\text{C}$.
- Reaction zones were observed in the alloys VANSTAR-8, -9, and V-20Ti when tested at 800°C in compatibility capsules containing hyperstiochiometric mixed (U, Pu)C sodium bonded fuel.

Related Activities

A paper entitled "The Effects of Exposure to Sodium on the Metallurgical and Mechanical Properties of Vanadium Alloys" by G. A. Whitlow, R. J. Hornak, S. L. Schrock, and E. C. Bishop was presented at the Fall meeting of TMS/AIME in Philadelphia.

VCBA-125 ALLOY OPTIMIZATION

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

OBJECTIVE

The objectives of this program 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.

Oxygen, nitrogen, and carbon will be introduced into four vanadium alloys by gas-metal reactions at elevated temperatures (600 to 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,

- Pure Vanadium
- V-10 Mo
- V-10 Cr
- 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, FY1970. It is an extension of the Structure and Mechanical Property Evaluation Program VCAA-120. During the VCAA-120 program, the VANSTAR alloys were characterized through tensile and creep tests. This new program will extend the alloy characterization to study the effects of the interstitial elements (carbon, nitrogen, and oxygen) on the tensile properties and ductile-brittle transition properties of the VANSTAR -7 and additional binary V alloys. This has been fully reported in the previous eight quarterly reports on this contract.[2-9]

CURRENT PROGRESS

Alloy Melting and Processing

A 17 pound lot of electro-refined vanadium has been received from the United States Bureau of Mines, Boulder City, Nevada. The analysis of the vanadium is listed in Table 2.

The current plan for producing the alloy will consist of trough melting the electro-refined dendritic crystals into electrodes and consumably melting the electrodes in an arc furnace to produce 3 to 3.5 pound, 2 inch diameter

ingots. These ingots will be canned and extruded to sheet bar and rolled to strip material for testing.

The pure vanadium electrodes will be melted first and an analysis made on the electrode material to insure that no contamination has occurred during trough melting.

Table 2. Analysis of Refined Vanadium (99.97% Pure)	
Element	Analysis (ppm)
Aluminum	*
Carbon	20
Chromium	*
Cobalt	*
Copper	98
Iron	*
Hydrogen	10
Magnesium	4
Manganese	*
Molybdenum	*
Nickel	6
Nitrogen	10
Oxygen	100
Silicon	15
Hardness	53R _f
*Below Detection Limit	

Experimental Apparatus

Assembly of the apparatus is continuing. The completed system is shown schematically in Figure 1. A brief description of the system components is given below:

Balance--Cahn UHV RH microbalance has a capacity of 100 gram and a 2 micro-gram sensitivity on a 10 gram sample.

Furnace--Lindberg Hevi-duty Furnace is non-inductively wound with a 24-inch heater length and a 6-inch constant temperature zone.

Figure 1 Vacuum System for Gas Metal Equilibrium Studies

Vacuum System--Varian components: Nude ion gauge with thoriated iridium filament for service in oxygen partial pressure. The gauge will be calibrated for variable leak valves of 10^{-10} cc/sec minimum leak rate. Ion pumps are for 10^{-7} torr and lower pressure operation. Liquid N₂ cooled 4-inch diffusion pump is for higher partial pressure runs and to handle excess gas loads when degassing alloys. (Heraeus-Engelhard).

The sample will be suspended from a small diameter quartz rod which will in turn be hung from the balance arm. The entire balance chamber will be raised to load and unload the alloys into the hot walled reaction zone.

Production of Tubing for Task VCBA-130 and for USAEC Contractors

An order was placed with Superior Tube Company for tube reducing and drawing of the 2-inch O.D. x 0.25-inch wall extrusions produced at ORNL. Two 8-to-12-inch pieces of V-15Cr-5Ti and VANSTAR-7, -8, and -9 were supplied for fabrication to 0.875-inch O.D. x 0.080-inch wall for LASL and Battelle Memorial Institute (Columbus), and to 0.386-inch O.D. x 0.050-inch wall for WARD corrosion programs. Prior to fabrication, the VANSTAR alloys were annealed for one hour at 1200°C, while the V-15Cr-5Ti extrusions were heat treated for two hours at 800°C as recommended by Argonne National Laboratory for improved ductility.

The first tube reduction of one piece of each alloy was attempted and no particular problems were encountered with VANSTAR-8 and VANSTAR-9, which were fabricated using normal commercial practice. Although VANSTAR-7 appeared to be quite ductile, extensive cracking was observed after tube reduction, and it appears that little, if any, of this first piece will be of satisfactory quality. Evaluation of the VANSTAR-7 material has indicated that the defects previously observed in the as-cast extrusion billet were not completely healed during extrusion. While the VANSTAR alloys were fabricated at room temperature using a full flow of lubricant, on the basis of ANL experience, the V-15Cr-5Ti alloy was heated to 300°C and processed with a dry film lubricant to prevent chilling of the material. Despite these precautions, the V-15Cr-5Ti exhibited no ductility, and fabrication was halted when pieces began to circumferentially crack off the extrusion.

Further tube reduction and drawing of VANSTAR-8 and VANSTAR-9 is expected to progress in a normal manner. The pieces already put through the initial tube reduction were annealed and have been scheduled, along with the other pieces of these alloys, for full processing. The remaining piece of VANSTAR-7 was reannealed at 1200°C in hopes of improving its ductility; however, salvation of this material probably depends more on the level of defects in the remaining piece than of any other factor. The two pieces of V-15Cr-5Ti were reannealed at 1000°C, which gave much improved ductility for tube drawing during earlier work at Superior Tube. These pieces are now scheduled for warm tube reducing.

VCBA-130
SODIUM CORROSION EVALUATION

R. J. Hornak, S. L. Schrock, and G. A. Whitlow

OBJECTIVES

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 eight previous Vanadium Alloy Cladding Development Quarterly Progress Reports.^[2-9]

In the first two loop runs (VTL-1 and VTL-2), it was found that when exposed to flowing sodium containing <10 ppm oxygen at 675 to 800°C, samples of the VANSTAR-7,-8,-9, and the V-20Ti alloys gained weight. 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 the interstitial absorption, considerable reductions in mechanical properties of corroded samples, particularly 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 of the next two loop runs (VTL-3 and VTL-4) in which the test sections will be lined with vanadium alloy tubing and in which stabilized stainless steel containment tubing will be used (VTL-4), was completed. The design and the philosophy behind these changes is fully described in the previous two quarterly reports (WARD-3791-34 and WARD-3791-38).

CURRENT PROGRESS

Loop Reconstruction

Both loop rebuilds are complete with the exception of the test section which cannot be assembled and welded into position until material for the vanadium alloy liners is received from Superior Tube Company. It is anticipated that this material will be received at Westinghouse in November (see further details in Section VCBA-125).

Meanwhile, sample bends containing the 0.300-inch O.D. x 0.010-inch wall vanadium alloy liner in the cooler sections have been made to establish a technique for minimizing distortion of the liner material and this material has been successfully installed in the loop systems. In addition, a satisfactory mock-up technique has been designed for holding the vanadium alloy strip samples in place in the test section thereby eliminating the need for sample holders.

Interstitial Analysis

Further interstitial layer analysis of vanadium samples from the previous high velocity system has been performed. In a VANSTAR-9 sample exposed to flowing sodium (14fps) for 1500 hours at $\sim 690^{\circ}\text{C}$, the carbon and nitrogen levels near the exposed surface (1600 and 4300 ppm) were much lower than had been observed in samples exposed at higher temperatures ($\sim 780^{\circ}\text{C}$). In addition, the slope of the interstitial profile from surface to sample center changed so that nitrogen and carbon values decreased less rapidly with distance from the exposed surface. However, analytical results on a V-20Ti alloy exposed to virtually the same conditions reveal high levels ($\sim 38,000$ ppm) of nitrogen and carbon in the surface layers (0 - 0.003 inch). Little pickup was observed at depths greater than 0.003 inches from the exposed surface. These preliminary findings are subject to confirmation or modification by additional analytical determinations now in progress. Oxygen analyses from these samples will be obtained shortly. The explanation of these effects is related to the decrease in interstitial diffusion rates with decrease in temperature, but the significant difference between the two alloys may be a function of the quantity of reactive element; i.e., zirconium or titanium in each alloy.

Some of the preliminary data from the surface analysis studies of vanadium alloys before and after exposure to sodium are now available. X-ray diffraction and chemical milling have indicated that the corroded surface is essentially saturated in carbon and nitrogen with hexagonal VC, cubic VC, tetragonal VN phases, and V metal (cubic) predominating. With the techniques and instrumentation available, it was impossible to establish the presence of carbide and nitride compounds with the other elements present, e.g., in a VANSTAR-9 alloy. Qualitative observations showing a layer up to 0.001 inch from the exposed surface saturated in carbon and nitrogen confirms similar observations made using techniques such as conventional chemical analysis and microhardness.

Additional gradient analysis of the stainless steel containment tubing from the vanadium alloy loop systems has been initiated. This work is designed to examine the effects of sodium velocity on interstitial diffusion out of stainless steel and the relation between this effect and weight changes observed in the vanadium alloys at different sodium flow rates.

VCBA-140
CLADDING ALLOY-FUEL COMPATIBILITY EVALUATION

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

OBJECTIVE

The objective of this task is to assess the compatibility of the VANSTAR alloys and V-20Ti with mixed uranium-plutonium carbide fuels and with sodium bonded uranium carbide fuel 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 (#7), containing three pellets of unmodified hypostoichiometric UC and six pellets of unmodified hypostoichiometric (U, Pu)C fuel with samples of VANSTAR-8, -9, and V-20Ti, accumulated 4,650 hours at 800°C. The second capsule (#12) contained nine pellets of Cr_{23}C_6 - modified (U, Pu)C fuel and samples of VANSTAR-8, and -9, and V-20Ti and accumulated 2,500 hours at 800°C. Both capsules were sodium bonded. Disassembly of the first capsule was initiated during the last reporting period.

CURRENT PROGRESS

Both compatibility capsules have been disassembled, and evaluation of the first capsule containing UC and (U, Pu)C fuel was initiated. Although chemical analysis of fuel samples prior to compatibility testing indicated that both materials were hypostoichiometric, subsequent metallographic examination revealed that the (U, Pu)C was hyperstoichiometric and the UC was stoichiometric. It is considered unlikely that this change in stoichiometry occurred during testing. A more probable explanation for this discrepancy may be in chemical analysis where the accuracy of the equivalent carbon figure is only ± 0.1 w/o.

Evaluation of the components of the first capsule (#7) which now contains stoichiometric UC pellets and six hyperstoichiometric (U, Pu)C pellets, is in progress. Of the vanadium alloy samples so far examined, reaction zones at the fuel/vanadium interface have been observed in samples of the VANSTAR-9 and VANSTAR-8 alloys and the V-20Ti alloy after contact with mixed carbide. Examples of the type of reaction layers seen in the alloys in a metallographic examination are shown in Figures 2 and 3. In the VANSTAR alloy, the reaction layer bears a considerable resemblance to the layers seen on samples after exposure to sodium in the corrosion loops. It is acicular in nature and appears to be present both at grain boundaries and within the grains. From the photomicrograph, the affected depth is approximately 50 microns. The reaction layer in the V-20Ti alloy sample has a similar kind

Figure 2 Reaction Zone in a VANSTAR-9 Alloy (V-Fe-Nb-Zr-C) After Contact with Sodium Bonded Hyperstoichiometric (U,Pu)C Fuel for 4650 hours at 800°C

Figure 3 Reaction Zone in a V-20Ti Alloy After Contact with Sodium Bonded Hyperstoichiometric (U,Pu)C Fuel for 4650 hours at 800°C

3412-2

of appearance although the precipitation cannot be described as acicular. The affected depth in this alloy is approximately 125 microns. Better estimates of depths of contamination will be obtained shortly using a micro-hardness tester.

Since the metallographic appearance of the contaminated reaction layer resembles similar layers on sodium corroded samples, it might be postulated that these layers are rich in carbon as a result of diffusion across the contact area between the carbide fuel and alloy. Some evidence of reaction at the other face of these alloy samples (i.e., the face not in contact with fuel but exposed to the sodium bond) was observed suggesting that the sodium bond has acted as a carrier medium for carbon transportation. The depth of attack will depend on several factors, some of which are the diffusion rates of interstitials in the alloys and ease of carbide formation with the respective alloying elements.

No evidence of reaction zones was observed in the fuel surfaces in contact with the vanadium alloy samples in this capsule. The two types of microstructure consisted of single phase UC, and a (U,Pu)C matrix containing islands of sesquicarbide.

The second capsule containing Cr_{23}C_6 stabilized mixed (U,Pu)C fuel and vanadium alloy samples has been disassembled. Both fuel batches exhibited a well sintered structure. Batch 85 consisted of an angular grained matrix interspersed with rod shaped Cr_xC_y second phase material, while well rounded matrix grains with intergranular Cr_xC_y was typical of the batch 509 material. No microstructural changes were observed in the fuel samples, but progress in evaluation of the vanadium alloy samples has been delayed due to higher priority oxide work and box atmosphere problems at the WARD Plutonium Laboratory Cheswick, Pa.

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 the alloys VANSTAR-8 and VANSTAR-9. Exposures of 1 to 2×10^{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.^[2-9] The irradiation program on this project consists of two parts:

1. The WARD/BNW* High-Flux Program - designed for insertion in Row 2 of EBR-II in conjunction with BNW (irradiation pin, composed of six subcapsules containing vanadium alloys) was assembled and shipped to the reactor site. This pin was inserted in the reactor in Run 33 in March 1969. It was placed in position 2BI and was designated sub-assembly number X057.
2. The CDAA-500,** 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 stainless steel capsules filled with sodium 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

The irradiation pin inserted in EBR-II in March 1969 continued to accumulate fluence. As of August 15, 1969, the capsule accumulated exposure was 5,245 MWd compared to an estimated goal exposure of 15000 MWd.

CDAA-500, EBR-II Program

Eight additional carbide fueled capsules, each containing one vanadium alloy sample have been assembled, shipped, and are awaiting insertion in EBR-II. It is anticipated that the first two capsules will be removed from the reactor in the first few months of 1970.

*Battelle Northwest

**CDAA-500 Fast Flux Irradiation Studies Task of Uranium Plutonium Carbide Development.

VCBA-160
PROJECT ADMINISTRATION

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

OBJECTIVES

The objectives of this task are to assure that the project is successfully completed on schedule, within the budget, to the satisfaction of the Atomic Energy Commission, to assure compliance with contracted obligations, and to coordinate this project with other AEC-sponsored and Westinghouse-sponsored LMFBR 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-3791-38) for the period ending June 30, 1969, was prepared and distributed.

REFERENCES

1. W. Pollack, K. C. Thomas, K.R. Jordan, R. T. Begley, R. W. Buckman, and E. C. Bishop, "Development of High Strength Vanadium Alloys," WCAP-3487-16, June 1967.
2. 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-3791-9.
3. E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending December 31, 1967," WCAP-3791-13.
4. E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending March 31, 1968," WCAP-3791-17.
5. E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending June 30, 1968," WCAP-3791-20.
6. E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending September 30, 1968," WCAP-3791-25.
7. E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending December 31, 1968," WCAP-3791-30.
8. E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending March 31, 1969," WCAP-3791-34.
9. E. C. Bishop, R. A. Nadler, and G. A. Whitlow, "Vanadium Alloy Cladding Development Quarterly Progress Report for the Period Ending June 30, 1969," WCAP-3791-38.

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