JAN 11 1968

OAK RIDGE NATIONAL LABORATORY
operated by

UNION CARBIDE CORPORATION
NUCLEAR DIVISION

for the
U.S. ATOMIC ENERGY COMMISSION

ORNL - TM - 2010

78

COMPATIBILITY OF DISPERSION STRENGTHENED ALUMINUM WITH URANIUM MONOCARBIDE

J. T. Vernard

NOTICE This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Contract No. W-7405-eng-26

METALS AND CERAMICS DIVISION

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

COMPATIBILITY OF DISPERSION STRENGTHENED
ALUMINUM WITH URANIUM MONOCARBIDE

J. T. Venard

JANUARY 1968

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

	Page
Abstract	1
Introduction	1
Sample and Capsule Preparation	9
Experimental Procedure	12
Experimental Results and Discussion	14
Conclusions	18
Acknowledgments	19
References	21

COMPATIBILITY OF DISPERSION STRENGTHENED ALUMINUM WITH URANIUM MONOCARBIDE

J. T. Venard

ABSTRACT

A series of experiments on the compatibility between sintered aluminum products and uranium monocarbide have been performed. These experiments tested sintered aluminum products containing 10 wt % oxide against hypostoichiometric, stoichiometric, and hyperstoichiometric uranium monocarbide over the temperature range 450 to 625°C. The activation energy for the growth of the reaction product layer was determined to be approximately 84 kcal/mole for 4.8 wt % C fuel and approximately 92 kcal/mole for 5.1 wt % C fuel. A survey of earlier experiments in this system is included.

INTRODUCTION

Heavy-water moderated organic-cooled reactors have been receiving considerable attention in the United States and abroad. The advantage of such a system arises from the use of high-density uranium carbide fuel having natural or very low enrichment. This fuel should result in a good neutron economy, may extend fuel burnup limits, and would be likely to have low manufacturing costs.

One such reactor, the Heavy-Water Moderated Organic-Cooled Reactor, has been designed to use slightly hyperstoichiometric uranium monocarbide (approx 5.1 wt % C) clad in dispersion strengthened aluminum (10 wt % Al_2O_3). Nominal operating criteria for the helium-bonded fuel elements call for fuel-cladding interface temperatures of 454 to 465°C and core-residence times of approximately 25,000 hr at design-power level.¹

A survey of the literature has produced information from several investigations related to the compatibility between sintered aluminum products and uranium monocarbide.² The highlights of the experimental findings of the earlier investigations³⁻¹⁴ are presented in Tables 1 and 2.

Table 1. Summary of Compatibility Experiments Reported in the Literature

Type of Experiment	Materials	Temperature (°C)	Atmosphere	Time (hr)	Observations	Reference
50-50 mixtures of metal and fuel powders blended and cold pressed	Al vs UC (4.46 wt % C)	620	Vacuum	4	Sample disintegrated	3
	Al vs UC (4.86 wt % C)	520	Vacuum	4	No growth	
	Al vs UC (4.86 wt % C)	520	Vacuum	10	87% increase in volume	
	Al vs UC (5.75 wt % C)	620	Vacuum	4	No growth	
	Al vs UC (5.75 wt % C)	620	Vacuum	10	71% increase in volume	
	Al vs UC (5.75 wt % C)	620	Vacuum	10	71% increase in volume	
Solid diffusion couple	Al vs UC	600		24	0.005-in. reaction zone	4
	1100 Al vs UC (5.1 wt % C)	593		210	Reaction	5
Solid metal against powdered fuel	Al vs UC (5.1 wt % C)	500	Vacuum		Rapid reaction	6
Solid diffusion couple	Al vs UC	620		100	40-50- μ penetration	7
	Al vs UC	630		300	1-mm-thick Al disk completely reacted	
	SAP 930 (7 wt % Al_2C_3) vs UC	525		500	2-3- μ diffusion layer	
	SAP 930 (7 wt % Al_2C_3) vs UC	450		14,300	Appeared compatible	8
	SAP 930 (7 wt % Al_2C_3) vs UC (4.8 wt % C)	450-500			Various degrees of reaction	

Table 1 (continued)

Type of Experiment	Materials	Temperature (°C)	Atmosphere	Time (hr)	Observations	Reference
Solid diffusion couple (continued)	SAP vs UC (4 .8 wt % C)	454		12,000	No reaction	9
		510		12,000	Slight reaction	
UC clad with SAP for irradiation experiment	SAP 930 (7 wt % Al ₂ O ₃) vs UC (4.66-4.82 wt % C)	399-499		~ 3,500	Little or no reaction	
Solid diffusion couple	SAP 930 (7 wt % Al ₂ O ₃) vs UC	450	Helium	7,300	Slight reaction	10
		525	Helium	7,300	Marked reaction	
		600	Helium	100	Marked reaction	
	SAP 930 (7 wt % Al ₂ O ₃) vs hot-pressed UC (4.5-4.6 wt % C)	450	Helium	1,000	Marked reaction	11
		450	Helium	7,300	Slight reaction, 90-μ penetration	
		450	Helium	8,500	No reaction	
		450	Helium	11,900	No reaction	
		450	Helium	14,300	No reaction	
		525	Helium	7,300	Severe reaction, 800-μ penetration	
		525	Helium	14,300	Severe reaction, 830-μ penetration	
		525	Helium	8,500	No reaction	11
		600	Helium	11,900	No reaction	
		600	Helium	100	Severe reaction 560-μ penetration	
		600	Helium	1,000	Severe reaction, 1500-μ penetration	

Table 1 (continued)

Type of Experiment	Materials	Temperature (°C)	Atmosphere	Time (hr)	Observations	Reference
Solid diffusion couple (continued)	SAP 93C (7 wt % Al_2O_3) vs arc-cast UC (4.8-5.0 wt % C)	450	Helium	14,300	No reaction	11
		525	Helium	7,300	Severe reaction, 600- μ penetration	
		525	Helium	14,300	Severe reaction, 840- μ penetration	
		525	Helium	8,500 } 11,900 }	No reaction	
		600	Helium	100	Severe reaction, 550- μ penetration	
		600	Helium	1,000	Severe reaction, 1350- μ penetration	
	SAP 930 (7 wt % Al_2O_3) vs cold-pressed and sintered UC (4.8-5.0 wt % C)	450	Helium	14,300	No reaction	12
		525	Helium	14,300	No reaction	
		600	Helium	250	Severe reaction, 350- μ penetration	
		600	Helium	1,000	Severe reaction, 700- μ penetration	
Hot-pressed diffusion couple	AMP (M-257) with 5 wt % Al_2O_3 vs UC (4.8 wt % C)	399	Vacuum	1,000 } 3,000 }	No reaction	12
		510	Vacuum	1,000	Edge reaction, infusion	
		510	Vacuum	2,000	Heavier edge reaction, infusion	
		510	Vacuum	3,000	Gross infusion	
		593	Vacuum	60	Edge reaction	
		593	Vacuum	100	Infusion reaction	
		593	Vacuum	200	Gross infusion	

Table 1 (continued)

Type of Experiment	Materials	Temperature (°C)	Atmosphere	Time (hr)	Observations	Reference
Hot-pressed diffusion couple (continued)	SAP 930 (7 wt % Al_2O_3) vs UC (4.8 wt % C)	398	Vacuum	1,500 } 3,000 }	No reaction	13
		454	Vacuum	1,500 } 2,754 }	No reaction	
		454	Vacuum	5,656	Local reaction	
		510	Vacuum	1,500	Local reaction	
		510	Vacuum	2,692 } 5,656 }	Complete reaction	
		566	Vacuum	1,500 } 2,757 } 5,656 }	Complete reaction	
		621	Vacuum	101 } 524 }	Complete reaction	
		SAP 930 (7 wt % Al_2O_3) vs UC (5.2 wt % C)	Vacuum	1,500 } 503 } 1,506 } 2,958 }	No reaction	
				5,920 } 503 }		
				1,506 } 3,206 }	No reaction	
				5,900 } 503 }	No reaction	
			Vacuum	1,506 } 3,023 }	Local reaction	
				5,900 } 495 }	Local reaction	
				1,496 } 2,957 }	Complete reaction	
				5,900 }		

Table 1 (continued)

Type of Experiment	Materials	Temperature (°C)	Atmosphere	Time (hr)	Observations	Reference
Hot-pressed diffusion couple (continued)	SAP 930 (7 wt % Al_2O_3) vs UC (5.2 wt % C)	621	Vacuum	503 1,524 3,000	Complete reaction	13
		398	Vacuum	12,000	Local reaction	14
		454	Vacuum	12,000	Local reaction	
		454	Vacuum	12,000	No reaction	
		510	Vacuum	12,000	Complete reaction (2 capsules)	
		566	Vacuum	12,000	Complete reaction (2 capsules)	

Table 2. Identification of Reaction Products
for SAP or Aluminum Versus Uranium
Monocarbide Diffusion Couples

Products	References
UAl ₃ , UAl ₄	3
UAl ₃	7
UAl ₃ , UAl ₄ , graphite ^a	6
UAl ₃ , UAl ₄ ^a	11
UAl ₄	12
UAl ₃ , UAl ₅ C ₄ ^a	13

^aTentative identification only.

Figures 1 and 2 represent an attempt to evaluate the temperature-time compatibility limits for the SAP-UC system in which the carbon content is 4.8 and > 4.8 wt %, respectively. It should be recognized that the decision to label a particular test as having demonstrated an acceptable or nonacceptable degree of reaction was based solely on the comments of the original investigators. Lacking a definition of what constitutes compatibility, the curves shown on these figures can only be taken as approximate. There are insufficient data to allow a similar plot for the hypostoichiometric case. These data and thus the conclusions drawn from them stem from experiments performed, with the exception of one, in the absence of irradiation and therefore do not consider any enhancement or degradation of compatibility as a result of neutron bombardment.

As seen in Table 2, the various investigators all agree that a uranium-aluminum intermetallic is formed during reaction between SAP and UC. Whether the intermetallic is UAl₃ or UAl₄ is not clear. The other two tentatively identified reaction products, graphite and UAl₅C₄, give rise to some uncertainty in defining the reaction or reactions occurring.

The experiments in this investigation were performed to allow refinement of the curves in Figs. 1 and 2, and add to the knowledge of reaction kinetics and products.

Fig. 1. Temperature-Time Compatibility Limits for the SAP Versus UC (4.8 wt % C) System.

Fig. 2. Temperature-Time Compatibility Limits for the SAP Versus UC (> 4.8 wt % C) System.

Sample and Capsule Preparation

The dispersion strengthened aluminum was prepared from spherical aluminum powder (approx 99.9% pure) ball-milled using stearic acid lubricant. The ball-milled flake (approx 0.5- μ thick by 40- μ diam) was hot pressed at 600°C in a vacuum of less than 10 μ Hg. The hot-pressed billet was then extruded at 500°C through a 30:1 ratio shear die to give a 0.375-in.-diam rod. Compatibility disks were cut to length and given a series of grindings ending with wet 600-grit SiC paper. The samples were washed in acetone, then in alcohol, dried, and stored in a helium-filled dry box pending loading into capsules.

The UC was prepared using the techniques described by Bourgette.¹⁵ The starting materials were spectrographic grade carbon and uranium having the impurity analysis given below. Typical impurity analyses

Element	Concentration (ppm by weight)
Aluminum	3
Barium	< 0.02
Beryllium	1
Bismuth	< 0.03
Boron	0.05
Cadmium	< 0.05
Calcium	2
Carbon	90
Cerium	< 0.02
Copper	1
Hydrogen	12
Iron	2
Magnesium	4
Manganese	0.7
Nickel	4
Nitrogen	27
Oxygen	140
Phosphorus	< 10
Silicon	10
Silver	< 0.03
Thorium	< 0.03
Tin	< 0.05
Tungsten	< 0.6
Uranium	Balance
Zinc	2

for the UC specimens are given in Table 3. The compatibility specimens (0.375 in. in diameter) were cut and ground under oil with the final grinding on 600-grit SiC paper. These samples were stored under oil in a helium-filled dry box. Just prior to capsule assembly, the samples were washed in alcohol, rubbed lightly on 600-grit SiC paper with alcohol vehicle, then rinsed in alcohol and dried.

Photomicrographs of typical UC and SAP structures are given as Figs. 3-6.

Table 3. Impurity Analysis of UC Samples

Sample Number	Carbon (wt %)	Contents, ppm				
		Copper	Tungsten	Hydrogen	Oxygen	Nitrogen
1A-3	4.6	< 3	131	12	280	230
2A-2	4.6	< 3	13	7	310	380
2B-4	4.8	< 3	26	9	250	270
1C-7	5.1	< 3	78	8	310	250
2C-7	5.1	< 3	119	6	160	140

Fig. 3. Typical As-Cast Structure of UC with 4.6 wt % C. Note the free HNO_3 , and 30 parts acetic acid.

Fig. 4. Typical As-Cast Structure of UC with 4.8 wt % C. Etchant: 30 parts H_2O , 30 parts HNO_3 , and 30 parts acetic acid.

Fig. 5. Typical As-Cast Structure of UC with 5.1 wt % C. Second phase material (white) is UC_2 . Etchant: 30 parts H_2O , 30 parts HNO_3 , and 30 parts acetic acid.

Fig. 6. Longitudinal Section of SAP-152 Showing Typical Structure.
Etchant: 1% HF.

A sketch of the compatibility capsule, which is similar to that used by Murdock,¹⁶ appears as Fig. 7. The Inconel X springs were given a heat treatment which consists of 2 hr at 1149°C, air cool, plus 24 hr at 843°C, air cool, and 20 hr at 704°C, air cool. The capsules were loaded and welded under a helium atmosphere. Table 4 is an outline of the experiments performed. The 10,000-hr tests listed are not yet complete and will be discussed in a supplementary report issued on their completion.

Experimental Procedure

The capsules were soaked at temperature in horizontal tube furnaces for the appropriate lengths of time. Temperatures were controlled to $\pm 2^\circ\text{C}$.

After heat treatment the capsules were opened and the diffusion couples mounted in clear epoxy resin. These samples were then sectioned longitudinally for metallographic and x-ray examination.

Fig. 7. Cutaway View of the Compatibility Capsule.

Table 4. Temperatures and Times for SAP-UC Compatibility Capsules

UC Chemistry, wt %					
< 4.8 C		4.8 C		> 4.8 C	
Temperature (°C)	Time (hr)	Temperature (°C)	Time (hr)	Temperature (°C)	Time (hr)
600	10	575	100	625	100
575	10	550	100	600	100
550	10			575	100
		525	1,000		
500	100	500	1,000	575	1,000
475	100	475	1,000	550	1,000
450	100			525	1,000
		475	10,000		
		450	10,000	550	10,000
		425	10,000	525	10,000
				500	10,000

Experimental Results and Discussion

The photomicrographs shown as Figs. 8-10 illustrate typical reaction zones found in these samples. The amount of reaction product seen in these photos is not, however, necessarily typical of a randomly selected field. They were deliberately chosen because they show fairly large amounts of reaction product. Notice in particular Fig. 10 showing the reaction product extending quite deeply into the UC sample following what was probably a shrinkage crack in the original drop-casting. The reaction product has also been observed to penetrate via grain boundaries containing free uranium in hypostoichiometric UC.

It was disconcerting to realize that these samples show considerably less reaction product than had been expected. The reasons for the small amount of reaction can probably be narrowed to two. First of all, the spring loaded capsules employed in this investigation applied only a very light load to ensure SAP-UC contact during annealing. The load was not sufficient to break a surface film on either the SAP or the UC as would

Fig. 8. Sintered Aluminum Products (10 wt % Oxide) Versus UC (4.8 wt % C) Annealed at 575°C for 100 hr in Helium. As polished.

Fig. 9. Sintered Aluminum Products (10 wt % Oxide) Versus Uranium Monocarbide (5.1 wt % C) Annealed at 600°C for 100 hr in Helium. As Polished.

be the case in either the powder compacts or the heavily torqued, threaded capsules used in earlier investigations.^{10,11,13,14} Secondly, it is not at all certain that a completely fresh UC surface was provided by the brief 600-grit SiC paper grinding which was done just prior to assembly. In either case one concludes that diffusion may be taking place across a barrier film between the two disks. However, that barrier is one that may also be present in many reactor applications.

Whatever the reason for the small amount of reaction product, the main purpose of the investigation, verification of Figs. 1 and 2, has not been accomplished. None of these samples exhibited reaction zones that would pose a problem for a reactor fuel element. If, in fact, these capsules with their light loading, are more representative of actual fuel rod operating conditions than earlier experiments, then these data should be heartening to a designer of a SAP-clad UC-fueled reactor.

Fig. 10. Sintered Aluminum Products (10 wt % Oxide) Versus Uranium Monocarbide (4.6 wt % C) Annealed at 550°C for 100 hr in Helium. As Polished.

The metallographic samples were examined at 500X and the amount of visible reaction product measured. Assuming that the area of reaction product observed is representative and that the cross section viewed was across the widest point of the compatibility couple, a uniform thickness for the reaction product can be calculated

$$h = \frac{A}{D},$$

where

A = measured area of reaction product (μ^2),

h = average thickness of reaction product (μ),

D = diameter of compatibility samples ($9.53 \times 10^3 \mu$).

These data and the testing conditions are given in Table 5.

Table 5. Summary of Results from SAP-UC Compatibility Couples

UC (wt % C)	Temperature (°C)	Time (hr)	Reaction Product	
			Area (μ^2)	Average Thickness (μ)
5.1	625	100		
5.1	600	100	29,400	3.086
5.1	575	100	23,520	2.469
5.1	575	1000		
5.1	550	1000	18,500	1.942
5.1	525	1000	2,852	0.299
4.8	575	100	36,725	3.855
4.8	550	100	19,110	2.006
4.8	525	1000	11,436	1.201
4.8	500	1000	10,971	1.152
4.8	475	1000	8,005	0.840
4.6	600	10	5,490	0.576
4.6	575	10	12,600	1.323
4.6	550	10	18,090	1.899
4.6	500	100	1,909	0.200
4.6	475	100	320	0.034
4.6	475	100	2,304	0.242
4.6	450	100	5,747	0.603

Clearly the results for the reaction between substoichiometric UC and SAP are inconclusive. This is apparently because of the presence of free uranium resulting in very erratic reaction kinetics.

Assuming that the compatibility reaction is diffusion controlled over the temperature range, the data for 5.1 and 4.8 wt % C samples have been plotted in Fig. 11 as h^2/t versus $1000/T$. The relationship

$$h^2/t = K \exp(-Q/RT)$$

has been assumed to be a valid fit of the data where

- t = time (sec),
- Q = activation energy (cal/mole),
- R = the gas constant,
- T = absolute temperature,
- K = a constant.

Fig. 11. Temperature Dependence of the Diffusional Growth of the Reaction Product Formed by SAP-UC Compatibility Couples.

As noted on Fig. 11, a calculation of the slope of the lines drawn to fit the experimental data yields values of the activation energy for growth of the SAP-UC reaction product of 83.6 and 92.4 kcal/mole, respectively, for 4.8 and 5.1 wt % C uranium monocarbide.

CONCLUSIONS

The spring loaded compatibility capsules used in this experiment did not produce reaction product volumes comparable with that produced by other techniques. The amount of reaction product observed and the capsule loading are, however, probably representative of a fuel rod in an unpressurized reactor core assuming there is no effect of irradiation on the compatibility.

The activation energy for the growth of the reaction product in 4.8 wt % C uranium monocarbide was found to be approximately 84 kcal/mole.

The value for 5.1 wt % C uranium monocarbide was found to be approximately 92 kcal/mole.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to G. L. Copeland, L. Queener, and J. K. Alley for sample preparation; C. W. Houck, C. P. Haltom, and L. A. Amburn for metallography; O. B. Cavin for x-ray analysis; W. R. Laing for analytical chemistry; W. C. Colwell for figures; and the Metals and Ceramics Division Reports Office for document preparation.

The author is especially indebted to J. F. Murdock for the discussions and suggestions made during the planning and execution of these experiments.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

REFERENCES

1. S. O. Arnesson, Atomics International, personal communication to J. E. Cunningham, Oak Ridge National Laboratory. (1966)
2. J. T. Venard, Compatibility of Dispersion Strengthened Aluminum With Uranium Monocarbide - A Review of the Literature, ORNL-TM-1705 (January 1967).
3. W. C. Thurber and R. J. Beaver, "Dispersions of Uranium Carbides in Aluminum for Plate-Type Fuel Elements Requiring High-Uranium Concentrations," J. Nucl. Mater. 3, 226-232 (1959).
4. W. Chubb and R. R. Dickerson, "Properties of Uranium Carbides," Am. Ceram. Soc. Bull. 41, 564-569 (1962).
5. D. I. Sinizer, "Application of Uranium Monocarbide to Power Reactors," Uranium Carbides as Reactor Fuel Materials, TID-7614 (1961).
6. S. Katz, "High-Temperature Reactions Between Refractory Uranium Compounds as Metals," J. Nucl. Mater. 6(2), 172-181 (1962).
7. European Atomic Energy Community, EURATOM'S Scientific Activities, Orgel Program, Experimental Studies, EUR 1830.e, Part II, Chap. 5 (1964).
8. Danish Atomic Energy Commission, Metallurgy Department Annual Progress Report for the Period Ending March 31, 1965, Risø Report 110, p. 32.
9. J. E. Frank, R. D. Hahn, and P. S. Olson, Fuel Element Design, Analysis, Specifications and Examination Procedures for the HWOOR EXP-NRU-305 Experiment, NAA-SR-Memo-11135 p. 17 (Mar. 9, 1965).
10. N. Hansen, P. Knudsen, A. C. Winther, and E. Adolph, "Sintered Aluminum Products for Organic-Reactor Application," Proc. Intern. Conf. Peaceful Uses At. Energy: 3rd, Geneva, 1964 9, 122-137 (1965).
11. T. Lauritzen and P. Knudsen, "The Reaction of Sintered Aluminum Products with Uranium Dioxide and Monocarbide," J. Nucl. Mater. 16(2), 173-183 (1965).
12. J. L. Ballif, A Preliminary Study of AMP-UC Compatibility, NAA-SR-Memo-8934 (Aug. 1, 1963).
13. P. E. Elkins and W. R. Kerr, Compatibility of Uranium Carbide with Dispersion Strengthened Aluminum, AI-64-103 (May 15, 1964).
14. W. R. Kerr, Compatibility of Uranium Carbide with Dispersion Strengthened Aluminum, AI-64-103 Addendum (Nov. 20, 1964).
15. D. T. Bourgette, Preparation of Stoichiometric Uranium Monocarbide Cylinders, ORNL-TM-309 (Oct. 4, 1962).
16. J. F. Murdock, "Reaction Between Beryllium and Uranium Monocarbide," J. Nucl. Mater. 7(2), 192-196 (1962).

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

INTERNAL DISTRIBUTION

1-3.	Central Research Library	35.	J. E. Cunningham
4.	Reactor Division Library	36.	J. H. Frye, Jr.
5-6.	ORNL - Y-12 Technical Library	37.	J. L. Gregg
	Document Reference Section	38-40.	M. R. Hill
7-26.	Laboratory Records Department	41.	P. R. Kasten
27.	Laboratory Records, ORNL R.C.	42.	T. S. Lundy
28.	ORNL Patent Office	43.	M. M. Martin
29.	R. E. Adams	44.	W. R. Martin
30.	G. M. Adamson, Jr.	45.	W. C. Robinson
31.	G. E. Boyd	46.	J. L. Scott
32.	O. B. Cavin	47.	D. A. Sundberg
33.	G. L. Copeland	48-60.	J. T. Venard
34.	F. L. Culler	61.	T. N. Washburn

EXTERNAL DISTRIBUTION

- 62. G. M. Anderson, AEC, Washington
- 63. D. F. Cope, RDT, SSR, AEC, Oak Ridge National Laboratory
- 64. W. J. Larkin, AEC, Oak Ridge Operations
- 65. J. F. Murdock, Puerto Rico Water Resources Authority,
P. O. Box 608, Rincon, Puerto Rico
- 66. M. A. Rosen, AEC, Washington
- 67-68. Milton Shaw, AEC, Washington
- 69-72. J. M. Simmons, AEC, Washington
- 73. E. E. Sinclair, AEC, Washington
- 74. E. E. Stansbury, University of Tennessee
- 75. A. N. Tarcliff, AEC, Washington
- 76. E. A. Wright, AEC, Washington
- 77. Laboratory and University Division, AEC, ORO
- 78-92. Division of Technical Information Extension