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AEC Research and
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UC-81, Reactors - Power
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**determination of maximum
permissible irradiation of
type 3 (SM-2) fuel plates**

Contract No. AT[30-1]-2639
with U. S. Atomic Energy Commission
New York Operations Office

ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPARTMENT

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**DETERMINATION OF MAXIMUM PERMISSIBLE
IRRADIATION ON TYPE 3 (SM-2) FUEL PLATES**

By:

A. S. Wilder

R. W. Kelleman

Approved by:

M. H. Dixon, Project Engineer

Issued: March 17, 1962

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ALCO PRODUCTS, INCORPORATED
Nuclear Power Engineering Department
Post Office Box 414
Schenectady, N. Y.

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		48	R. E. Neville

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ABSTRACT

Two methods were used for predicting the maximum permissible burnup in Type 3 (SM-2) fuel plates: use of analytical models, and use of existing irradiation data on UO_2 stainless steel dispersion fuel plates. Results with two analytical models indicated that burnups above 100 percent U-235 are permissible. Comparison of the expected burnup with available irradiation data indicates that successful performance of Type 3 replacement cores in SM-1, SM-1A, and PM-2A can be expected.

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SUMMARY

Two methods were used for predicting the maximum permissible burnup of Type 3 (SM-2) fuel plates. The first technique employed two analytical models to predict the allowable burnup. Results showed that in both models the allowable burnup was greater than 100% depletion of the U-235 in the fuel matrix. The second method used analysis of existing irradiation data on UO₂-stainless steel dispersion fuel plates.

This data was plotted as the atom % matrix burnup versus surface temperature during irradiation. A curve separating the successful and unsuccessful irradiations was drawn on this graph. The expected location of the maximum burnup of matrix atoms for Type 3 replacement cores falls within the non-failure area. This indicates that the Type 3 fuel plate can successfully withstand the maximum burnup expected for operation as replacement cores in the SM-1, SM-1A and PM-2A plants.

Recommendations for further investigations are presented.

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1.0 INTRODUCTION

A replacement core development program is being carried out by Alco Products as part of Task 3 of the Program Plan for Engineering Support and Development of Army PWR Power Plants.⁽¹⁾ This program makes use of the fuel-plate technology developed in the SM-2 program.^{(2), (3), (4), (5).}

This technology, along with that from SM-1 Core I^{(6), (7)}, has been the basis of the definition of four core types⁽⁸⁾ that represent various advances in development. The characteristics of the four types are given in Table 1. Type 1 core is used in SM-1 Core I and Core II, and PM-2A and SM-1A Core I, and is considered to be a proven core type. Type 2 core is a minor extension of Type 1 core technology. Type 2 cores, which have already been manufactured, are used in SM-1A and PM-2A Core II. It is expected⁽³⁾ that the next replacement cores for these three plants will use Type 3 fuel plates which are an outgrowth of the SM-3 program.

The purpose of this report is to determine the maximum permissible burnup* of Type 3 (SM-2) fuel plates, and relate it to the burnup expected for Type 3 cores in SM-1, SM-1A, and PM-2A plants.

There has been a fairly extensive irradiation program of miniature fuel plates^{(2), (3)} for Type 3 fuel plates in MTR and ETR as part of the SM-2 development program. Furthermore, two elements incorporating Type 3 and advanced plates are being irradiated in SM-1.⁽⁹⁾ In addition, preliminary information⁽¹⁰⁾ is now available from hot cell examination of fuel elements removed from SM-1 Core I at two-thirds of, and at end of life. This information is supplemented by irradiation tests and information gained at other laboratories as part of specific reactor projects.

In order to predict the maximum permissible burnups for Type 3 elements, two methods were used. The first method employed analytical predictions of allowable burnup; and the second interpreted the expected operating conditions of Type 3 fuel plates in light of existing irradiation results. The results of the first study are given in a companion report.⁽¹¹⁾

* Burnup as used herein refers to total U-235 depletion unless noted.

TABLE 1
CORE TYPES AND CHARACTERISTICS

DESCRIPTION OF CORES	TYPE 1	TYPE 2	TYPE 3	TYPE 5
Plate thickness, mils	30	30	40	70
Fuel	Geneva UO_2	Spherical UO_2	Spherical UO_2	Spherical UO_2 or UN
Loading in matrix, w/o UO_2	26	26	25	38 or 34
Poison Type	B_4C	B_4C	ZrB_2	?
Loading in matrix, w/o B	0.08	0.09	0.17	~ 0.42
Cladding, SS type	304	347	347	?
Assembly method	braze	braze	weld	?
Loading in 45 elements, kg U-235	22.5	22.5	36.3	~ 119
Loading in 45 elements, gms B-10	15.8	17.8	56.8	~ 295
Energy release (440°F), MWYR	16.4	16.4	28	~ 115
Avg. a/o U-235 burnup, in core	36	36	39	~ 48
Max. a/o U-235 burnup, in core*	~ 54	~ 54	~ 59	~ 72
Avg. a/o burnup in matrix	2.1	2.1	2.2	~ 4.2
Atom a/o U-235 in matrix	5.5	5.5	5.3	7.9
Atom a/o B-10 in matrix	0.09	0.09	0.19	~ 0.46

* Maximum burnup based on ratio of maximum to average burnup of 1.5 measured at ORNL on SM-1 Core I elements (preliminary)

2.0 DISCUSSION

A survey of literature on the techniques for predicting maximum safe U-235 burnup in stainless steel UO_2 dispersions was made. It was found that there had been only one analytical model developed⁽¹²⁾ for predicting allowable burnup in UO_2 stainless steel dispersion systems.

This model, developed by ORNL⁽¹²⁾, is based upon the assumptions that the matrix of the fuel plate is composed of a uniform, close-packed array of spherical UO_2 particles, each contained in the central core of a hollow, stainless steel sphere.

Equations were developed for computing the pressure resulting from the accumulation of fission gas released from the UO_2 particle into the void space of the core. This accumulation was assumed to result exclusively from recoil of fission fragments at the relatively low temperature (less than 1000°F) considered in the analysis. Because diffusion and radioactive decay are not considered, the accumulation increases linearly with burnup. The pressure is assumed to obey a specified real-gas-law. The formula for pressure incorporates are, burnup, fuel density, temperature, and UO_2 particle size. The failure criterion was defined to be the condition at which the idealized stainless steel sphere becomes completely plastic under the action of the internal pressure. In addition to the previously mentioned parameters, the predicted burnup at failure depends on Young's modulus, the yield strength of the steel, and on the fraction of UO_2 in the matrix.

The ORNL model was applied to the Type 3 (SM-2) fuel matrix. For an assumed set of parameters chosen to describe the matrix, the predicted burnup (fission only) was found to be 151 percent of the uranium atoms⁽¹¹⁾. The fact that the prediction exceeds 100 percent does not condemn the model because this result implies only that the system can withstand the pressure that results from the corresponding amount of fission gas. The many simplifying assumptions associated with the development of the model indicate that quantitative results must be accepted with caution. The model is nevertheless very valuable because it presents the first detailed analytic method of predicting failure burnups and because it provides an indication of the relative effects of the several parameters of the system.

A model developed at Alco⁽¹¹⁾ is in many respects similar to the ORNL model. The principal differences are in the failure mechanism and in the description of the matrix geometry. In the Alco model, the matrix is assumed to remain elastic, until the maximum tensile stress reaches the fracture strength of the material. This condition is defined to be the failure criterion. The stress calculations treat each individual particle cavity as an isolated spherical cavity in an infinite medium. A simplified thermal stress analysis provides a contribution, due to temperature variation across the width of the fuel plate, to be superimposed on the stress due to fission gas pressure. The description of fission gas accumulation and the corresponding pressure follows that of the ORNL model. A prediction of 140 percent burnup (fission only) of uranium atoms at failure was obtained with the Alco model.

The quantitative results from the Alco model, as with the ORNL model, must be used with caution. The model's value is that an alternative point of view is presented for estimating allowable burnups. The actual failure process is quite complex. Both plastic flow and brittle fracture may contribute to the ultimate failure of the system. Further refinements of the analytical models are in order (11).

A semi-empirical method⁽¹³⁾ for predicting the burnups due to failure in dispersion fuel elements, was proposed by BMI⁽¹⁸⁾. Two models were suggested: one in which the failure occurs through a creep mechanism; and the other, in which short-time plastic deformation causes failure. Each of these models has the unusual feature that the system parameters are not explicitly incorporated. Instead, an evaluation of the burnup due to failure under a set of known irradiation conditions is used to predict the burnup due to failure of an element of the same design under a different set of conditions. It is, therefore, unnecessary to postulate the details of the failure process.

The BMI method is not considered as appropriate for the present analysis. Neither long-term creep nor short-term stress peaks are considered important at the relatively low temperatures and operating conditions expected. Furthermore, the method does not provide any a priori information about the failure of an untested design.

As indicated above, both applicable analytical models, one developed by ORNL and the second by Alco, indicate that the Type 3 fuel element at surface temperatures of about 640°F will be capable of withstanding over 100% burnup of U-235. The development of an analytical model of treatment of UO₂ particles imbedded in the matrix is subject to extreme assumptions in order to make the model mathematically soluble. For this reason, it is desirable to utilize the available radiation experience to support the conclusion in regard to maximum permissible burnup of Type 3 fuel plates.

The available irradiation data[/] on UO₂ stainless steel dispersions from Oak Ridge National Laboratory⁽¹⁴⁾, Battelle Memorial Institute⁽¹⁸⁾, Knolls Atomic Power Laboratory, (14) Nuclear Development Associates⁽¹⁴⁾, Pratt & Whitney Aircraft⁽¹⁴⁾, General Electric⁽¹⁴⁾, and Alco^(2, 3, 16, 17) were reviewed and the results plotted as a graph of percent burnup of matrix atoms versus surface temperatures (°F). The results are shown in Figure 1. The data is tabulated in Appendix A. It must be understood that these samples represent a wide variety of geometries and fabrication processes. They all, however, consist of UO₂ dispersed in the stainless steel matrix. The problems associated with the use of this data for determining limiting radiation conditions for Type 3 fuel plates are many. A few of the more important of which are listed below:

[/] Tabulation provided by R. W. Kelleman

1. Variations in UO_2 particle size (both before and after fabrication)
2. Process used for specimen fabrication.
3. The great difference in burnup rate between specimens and actual fuel elements in core operation.
4. The variation in specimen temperature during irradiation.
5. Possible size effects between miniature fuel plates and full size fuel plates.

Also shown in Fig. 1 is the preliminary information (10) available from ORNL hot cell examinations of one of the elements removed from SM-1 Core I at end of life. The maximum burnup point for this element is plotted at the calculated hot spot temperature.

Fig. 2 shows curves of atom % fission in the matrix versus atom % U-235 fission for various weight % UO_2 in the matrix. The densification of the matrix is taken as 95% of theoretical. This figure is used for converting data in Table 2 to atom % burnup (fission) in the matrix. A capture to fission ratio of 0.225 is used to convert from % U-235 depletion to % U-235 fission.

It should be noted that the final capsules of the SM-2 program have received burnups in the range 40 to 90% U-235 (9) and will, when examined, add significant data to information now available on this fuel system.

Table 2 shows an estimate of the expected hot spot temperature (18), (9) and burnup for Type 3 fuel plates operating in SM-1, SM-1A, and PM-2A. The information in Table 2 indicates that the maximum surface temperature expected for Type 3 cores is 610°F and occurs in the PM-2A. The maximum burnup is estimated as 62 atom % U-235 for this core.

On Fig. 1, an attempt has been made to draw a curve that separates the samples that have been successfully irradiated versus those that have failed in irradiation. The uncertainty in the location of this curve is obvious. Indicated on Fig. 1 is the data taken from Table 2 of expected operating points for Type 3 cores in SM-1, SM-1A, and PM-2A. If one accepts the location of the curve, Fig. 1 indicates that the Type 3 fuel plate can successfully meet its design objectives as a replacement core in SM-1, SM-1A, and PM-2A.

It is noted that the Type 3 fuel plates represent the latest technology of stainless steel UO_2 dispersions and are a significant improvement over the dispersions used in SM-1 Core I. Most important of these improvements is the use of a spherical UO_2 particle and a reduced rolling schedule. This combination results in an improved distribution of UO_2 particles in the steel matrix. Stringer which

is known to reduce matrix strength is considerably reduced in Type 3 plates relative to SM-1 Core I plates.

TABLE 2
OPERATING CONDITIONS OF TYPE 3 CORES IN SM-1,
SM-1A, AND PM-2A

	<u>SM-1</u>	<u>SM-1A</u>	<u>PM-2A</u>
Hot Spot Surface Temperature, °F	576	578	610
Hot Spot Temperature, °F	605	638	632
Average U-235 Burnup, %	45	43	41
*Maximum U-235 Burnup, %	67	64	62
*Maximum atom % Burnup of Matrix, %	3.0	2.9	2.8

* Maximum burnup $\sim 1.5 \times$ average burnup

FIGURE 1. ATOM PERCENT BURNUP (FISSION ONLY) VS SURFACE TEMPERATURE FOR 93% ENRICHED UO₂ - S.S. DISPERSIONS

FIGURE 2. ATOM % BURNUP IN MATRIX FISSIONED VS % U-235 FISSIONED

3.0 CONCLUSIONS

Based upon the available irradiation data on UO_2 stainless steel dispersions, it is believed that the Type 3 fuel plate will successfully withstand the maximum burnup expected for operation as replacement cores in SM-1, SM-1A and PM-2A.

The final capsules of the SM-2 program have received burnups in the range 40 to 90% U-235 ⁽⁹⁾ and will when examined, add significant data to information now available on this fuel system.

4.0 RECOMMENDATIONS

1. The development of maximum allowable burnup for Type 3 fuel plates as well as Type 5 fuel plates should be re-performed following the hot cell examination of the final miniature fuel plates from the SM-2 program. This estimate should be based on theoretical analysis recommended in reference (11) and the method of this report.
2. An investigation is needed to properly relate the performance of miniature fuel plates to full size fuel plates. This investigation should take into account size effects, differences in fission rate, difference in temperature variation with life, and differences in heat flux.
3. An investigation is needed to determine the ratio of maximum to average burnup expected for Army replacement cores. This ratio is needed for fuel plate areas corresponding to that present in miniature fuel plates.

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APPENDIX A

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APPENDIX A
IRRADIATION DATA ON STAINLESS STEEL UO₂ DISPERSION FUEL SPECIMENS

UO ₂ Loading (wt. %)	UO ₂ Particle Size (Microns)	Cladding Thickness (Inches)	Surface Temperature (°F)	Atoms % Burnup Fission Only		Results	Source of Data
				U ²³⁵	Matrix Total		
17.9	_____	0.007"	186°F	20	0.75	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	52.5	1.93	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	40.0	1.48	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	45.4	1.68	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	10.5	0.39	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	40.0	1.48	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	53.5	1.98	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	51.2	1.89	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	13.1	0.48	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	56.9	2.10	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	53.1	1.96	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	48.1	1.78	No failure	ORNL - Samples (14)
17.92	_____	0.005"	190°F	29.2	1.08	No failure	ORNL - Samples (14)
25	75-150	0.006"	1725°F	5.4	0.29	No failure	BMI - Samples (19)
25	75-150	0.006"	1430°F	12.7	0.67	No failure	BMI - Samples (19)
25	75-150	0.006"	1550°F	16.6	0.88	No failure	BMI - Samples (19)
25	75-150	0.006"	1400°F	20.4	1.08	Large blister	BMI - Samples (19)
25	75-150	0.006"	1417°F	20.7	1.10	Small blister	BMI - Samples (19)
25	75-150	0.006"	1650°F	2.2	0.12	No failure	BMI - Samples (19)
25	75-150	0.006"	1650°F	2.6	0.14	No failure	BMI - Samples (19)
25	_____	0.010"	932°F	5.11	0.27-0.58	Good Stability	KAPL - Samples (14)
25	_____	0.010"	977°F	12-25	0.64-1.3	Swelled, but Retained	KAPL - Samples (14)
25	_____	0.010"	1112°F	12	0.64	Fission Gas Slight Swelling. No Cracks.	KAPL - Samples (14)
25	_____	0.010"	1112°F	25	1.23	Swelled Cracked, Released	KAPL - Samples (14)
25	_____	0.010"	1112°F	21	1.11	Fission Gas Swelled Cracked, Released	KAPL - Samples (14)
						Fission Gas	

IRRADIATION DATA ON STAINLESS STEEL UO₂ DISPERSION FUEL SPECIMENS (CONT'D)

UO ₂ Loading (wt. %)	UO ₂ Particle Size (Microns)	Cladding Thickness (Inches)	Surface Temperature (°F)	Atoms % Burnup Fission Only		Results	Source of Data
				U235	Matrix Total		
25	—	0.010"	1112°F	8	0.42	Good Stability Swelled, Cracked, and Released Fission Gas	KAPL - Samples (14)
25	—	0.010"	1472°F	48	1.33		KAPL - Samples (14)
25	—	0.010"	2192"	33	1.75	Swelled, Cracked, and Released Fission Gas	KAPL - Samples (14)
30	>44	0.006"	550°F	5.3	0.35	8 pcs. None failed	P & W Samples (14)
30	>44	0.004"	650°F	4.4	0.29	8 pcs. None failed	P & W Samples (14)
30	>44	0.004"	650°F	5.4	0.36	8 pcs. None failed	P & W Samples (14)
30	>44	0.004"	700°F	12.1	0.79	8 pcs. None failed	P & W Samples (14)
30	>44	0.004"	650°F	39.7	2.6	8 pcs. None failed	P & W Samples (14)
30	>44	0.004"	800°F	23.5	1.54	8 pcs. None failed	P & W Samples (14)
30	>44	0.004"	766°F	33.3	2.17	8 pcs. None failed	P & W Samples (14)
30	>44	0.004"	1080°F	28.6	1.86	8 pcs. None failed	P & W Samples (14)
30	>44	0.004"	1400°F	12.9	0.84	8 pcs. 2 Cracked	P & W Samples (14)
30	>44	0.004"	1765°F	17.4	1.14	8 pcs. All failed	P & W Samples (14)
30	>105	0.005"	1260°F	4.6	0.30	2 pcs. None failed	NDA Samples (14)
30	>105	0.005"	1420°F	4.8	0.31	2 pcs. None failed	NDA Samples (14)
30	>105	0.005"	1560°F	1.8	0.12	2 pcs. None failed	NDA Samples (14)

IRRADIATION DATA ON STAINLESS STEEL UO₂ DISPERSION FUEL SPECIMENS (CONT'D)

UO ₂ Loading (wt. %)	UO ₂ Particle Size (Microns)	Cladding Thickness (Inches)	Surface Temperature (°F)	Atoms % Burnup Fission Only		Results	Source of Data
				U ²³⁵	Matrix Total		
30	>44	0.004"	1550°F	1.1	0.09	2 pcs. None failed	NDA Samples (14)
30	>44	0.004"	1290°F	17	1.12	No failure	ORNL Samples (14)
30	75-150	0.006"	1240°F	15.1	1.00	No failure	BMI Samples (19)
30	75-150	0.006"	1190°F	15.4	1.02	No failure	BMI Samples (19)
30	75-150	0.006"	1130°F	14.2	0.94	No failure	BMI Samples (19)
30	75-150	0.006"	970°F	12.0	0.79	No failure	BMI Samples (19)
30	75-150	0.006"	1360°F	11.8	0.78	No failure	BMI Samples (19)
30	75-150	0.006"	1400°F	11.8	0.78	No failure	BMI Samples (19)
30	75-150	0.006"	1270°F	11.5	0.76	No failure	BMI Samples (19)
30	75-150	0.006"	1140°F	10.4	0.69	No failure	BMI Samples (19)
30	75-150	0.006"	1655°F	4.9	0.32	Small blister	BMI Samples (19)
30	75-150	0.006"	1533°F	17.5	1.15	Small blister	BMI Samples (19)
30	75-150	0.006"	1395°F	15.6	1.04	Ruptured	BMI Samples (19)
30	75-150	0.006"	1475°F	25.1	1.66	Ruptured	BMI Samples (19)
30	75-150	0.006"	1300°F	22.2	1.47	Ruptured	BMI Samples (19)
30	_____	0.005"	1260°F	4.6	0.30	2 plates, No failure	NDA Samples (14)
30	_____	0.005"	1420°F	4.8	0.31	2 plates, No failure	NDA Samples (14)
30	_____	0.005"	1200°F	2.7	0.18	2 plates, No failure	NDA Samples (14)
30	_____	0.005"	1280°F	2.8	0.18	2 plates, No failure	NDA Samples (14)
30	_____	0.005"	1470°F	3.0	0.20	2 plates, No failure	NDA Samples (14)
30	_____	0.005"	1560°F	1.8	0.12	2 plates, No failure	NDA Samples (14)
30	_____	0.006"	700°F	13.3	0.87	8 plates, No failure	P & W Samples (14)
30	_____	0.006"	550°F	5.31	0.35	8 plates, No failure	P & W Samples (14)
30	_____	0.004"	650°F	4.4	0.29	8 plates, No failure	P & W Samples (14)

IRRADIATION DATA ON STAINLESS STEEL UO₂ DISPERSION FUEL SPECIMENS (CONT'D)

UO ₂ Loading (wt. %)	UO ₂ Particle Size (Microns)	Cladding Thickness (Inches)	Surface Temperature (°F)	Atoms % Burnup Fission Only		Results	Source of Data
				U ²³⁵	Matrix Total		
30	—	0.004"	650°F	5.38	0.35	8 plates, No failure	P & W Samples (14)
30	—	0.004"	700°F	12.1	0.79	8 plates, No failure	P & W Samples (14)
30	—	0.004"	850°F	12.4	0.81	8 plates, No failure	P & W Samples (14)
30	—	0.004"	650°F	39.7	2.6	8 plates, No failure	P & W Samples (14)
30	—	0.004"	800°F	23.45	1.54	8 plates, No failure	P & W Samples (14)
30	—	0.004"	766°F	33.3	2.17	8 plates, No failure	P & W Samples (14)
30	—	0.004"	1080°F	28.6	1.86	8 plates, No failure	P & W Samples (14)
30	—	0.004"	1400°F	12.9	0.84	8 plates, 6 no failure 2 cracked	P & W Samples (14)
30	—	0.004"	1765°F	17.4	1.14	8 plates, all swelled and cracked	P & W Samples (14)
30	—	0.004"	1650°F	0.65	0.04	1 plate, No failure	GE ANP Samples (14)
30	—	0.004"	1780°F	0.85	0.06	1 plate, No failure	GE ANP Samples (14)
30	—	0.004"	1650°F	1.57	0.10	1 plate, No failure	GE ANP Samples (14)
30	—	0.004"	1600°F	0.51	0.03	1 plate, Ruptured	GE ANP Samples (14)
30	—	0.004"	1550°F	1.09	0.09	2 stage No failure	GE ANP Samples (14)
30	—	0.004"	1650°F	0.58	0.04	2 stage No failure	GE ANP Samples (14)

IRRADIATION DATA ON STAINLESS STEEL UO₂ DISPERSION FUEL SPECIMENS (CONT'D)

UO ₂ Loading (wt. %)	UO ₂ Particle Size (Microns)	Cladding Thickness (Inches)	Surface Temperature (°F)	Atoms % Burnup Fission Only		Results	Source of Data
				U ²³⁵	Matrix Total		
30	—	0.004"	1650°F	0.93	0.06	4 stage	GE ANP Samples (14)
30	—	0.004"	797°F	35	2.28	No failure Swelled Released	KAPL Samples (14)
30	—	0.010"	932°F	8.9	0.59	Fission Gases Good	KAPL Samples (14)
30	—	0.010"	932°F	3.7	0.24	Stability Good	KAPL Samples (14)
30	—	0.010"	977°F	12-25	0.78	Stability Swelled	KAPL Samples (14)
30	—	0.004"	977°F	32-55	1.63	Retained	
30	—	0.008"	325°F	2.3	0.15	2.08 Fission Gas Good	KAPL Samples (14)
30	—	0.008"	325°F	5.2	0.34	Stability Good	KAPL Samples (14)
30	—	0.006"	662°F	19	1.24	Stability Good	KAPL Samples (14)
30	—	0.004"	662°F	33-35	2.21	Stability Good	KAPL Samples (14)
30	—	0.007"	797°F	28	1.82	Stability Good	KAPL Samples (14)
30	—	0.010"	797°F	24	1.56	Slight Swelling	KAPL Samples (14)
30	—	0.010"	797°F	28	1.82	Swelled, Released	KAPL Samples (14)
30	—	0.007"	797°F	34	2.21	Fission Gas Slight Swelling	KAPL Samples (14)

IRRADIATION DATA ON STAINLESS STEEL UO₂ DISPERSION FUEL SPECIMENS (CONT'D)

UO ₂ Loading (wt. %)	UO ₂ Particle Size (Microns)	Cladding Thickness (Inches)	Surface Temperature (°F)	Atoms % Burnup Fission Only		Results	Source of Data
				U235	Matrix Total		
30	_____	0.007"	797°F	40	2.60	Swelled Released Fission Gas	KAPL Samples (14)
30	_____	0.010"	797°F	35	2.28	Swelled Released Fission Gas	KAPL Samples (14)
30	_____	0.004"	977°F	8.7	0.57	Good Stability	KAPL Samples (14)
30	_____	0.004"	977°F	7.2	0.47	Good Stability	KAPL Samples (14)
30	_____	0.004"	977°F	17	1.11	Good Stability	KAPL Samples (14)
30	_____	0.004"	977°F	14	0.91	Good Stability	KAPL Samples (14)
30	_____	0.004"	1292°F	17	1.11	Good Stability	KAPL Samples (14)
30	_____	0.004"	1832°F	19-20	1.30	Good Stability	KAPL Samples (14)
26	44-88	0.005"	~545	18.6	1.07	No failure	SM-1 Plates in VBWR (16)
26	44-88	0.005"	~545	17.7	1.00	No failure	SM-1 Plates in VBWR (16)
26	44-88	0.005"	~545	15.8	0.90	No failure	SM-1 Plates in VBWR (16)
26	44-88	0.005"	~545	15.5	0.89	No failure	SM-1 Plates in VBWR (16)
26	75-150	0.005"	~500	32.6	1.80	No failure 3 Samples	SM-2 Samples (3)
26	75-150	0.005"	~500	37	2.04	No failure	SM-2 Samples (3)
26	_____			36.6	2.03	No failure	SM-2 Samples (3)
26	_____			33.3	1.83	No failure	SM-2 Samples (3)
26	_____			37.8	2.09	No failure 4 Samples	SM-2 Samples (3)
26	_____			36.9	2.02	No failure 2 Samples	SM-2 Samples (3)
26	_____			30.4	1.68	No failure	SM-2 Samples (3)

IRRADIATION DATA ON STAINLESS STEEL UO₂ DISPERSION FUEL SPECIMENS (CONT'D)

UO ₂ Loading (wt. %)	UO ₂ Particle Size Microns)	Cladding Thickness (Inches)	Surface Temperature (°F)	Atoms % Burnup Fission Only		Results	Source of Data
				U ²³⁵	Matrix Total		
26	_____			29.3	1.62	No failure 3 Samples	SM-2 Samples (3)
26	_____			31.1	1.72	No failure 3 Samples	SM-2 Samples (3)
26	75-150	0.005"	~500	32.9	1.80	No failure 5 Samples	SM-2 Samples (3)
26	75-150	0.005"	~500	17.3	0.97	No failure	SM-2 Samples (3)
26	44-88	0.005"	~567	40	2.23	No failure Maximum of Many Samples	SM-1 Core I (16.4 MWYR) (10)