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By
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FROM R. C. Westphal

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SUBJECT Thermal Conductivity of
Reactor Fuel Element
Materials

The available sources have been searched for data on the thermal conductivity of fuel element materials, a summary of which is presented. In addition, H. W. Deem of BMI has been kind enough to forward information on some recent unpublished work at that laboratory on uranium alloys. The data are in most instances presented in all three of the most commonly used units for your convenience.

Zirconium, low hafnium crystal bar:
Ref. Deem, BMI-711

$$k = 0.051 \text{ cal/sec/cm}^2/^{\circ}\text{C/cm at } 25^{\circ}\text{C}$$

$$0.215 \text{ watts/cm}^2/^{\circ}\text{C/cm}$$

$$12.4 \text{ BTU/hr/ft}^2/^{\circ}\text{F/ft}$$

At elevated temperatures k decreases linearly at the rate of $2.05 \times 10^{-4} \text{ cal/sec/cm}^2/^{\circ}\text{C/cm per degree C.}$

Zircaloy-2:

Ref. WAPD-T-43

25°C	0.0347 cal/sec/cm ² /°C/cm	0.145 watts/cm ² /°C/cm	8.4 BTU/hr/ft ² /°F/ft
100	0.0335	0.140	8.1
200	0.0331	0.138	8.0
300	0.0335	0.140	8.1
400	0.0339	0.142	8.2

Zircaloy-B:

Ref. Deem, EMI-849

K is essentially constant from 50 to 400°C

0.0335 cal/sec/cm ² /°C/cm
0.140 watts/cm ² /°C/cm
8.1 BTU/hr/ft ² /°F/ft

Uranium - 8% Mo:

Ref. WAPD-MM-389

K = 0.0341 cal/sec/cm ² /°C/cm at 50°C
0.143 watts/cm ² /°C/cm
8.3 BTU/hr/ft ² /°F/ft

Uranium - 12% Mo:

Ref. WAPD-MM-389

K = 0.330 cal/sec/cm ² /°C/cm at 50°C
0.138 watts/cm ² /°C/cm
8.0

Uranium:

Ref. CRR-438; ISC-314; ISC-393

The thermal conductivity is unstable and generally increases on thermal recycling. This is probably due to the extreme anisotropy of uranium. As an example values from 0.087 to 0.121 cal/sec/cm²/°C/cm have been observed at 600°C, the value increasing with each cooling and reheating cycle. The effect at lower temperatures is less pronounced. The values obtained for initial heating of a specimen are:

64°C	0.066 cal/sec/cm ² /°C/cm	0.275 watts/cm ² /°C/cm	16.0 BTU/hr/ft ² /F/ft
93	.067	.281	16.2
107	.067	.281	16.2
266	.075	.313	18.2
315	.077	.323	18.7
336	.080	.336	19.4
420	.087	.364	21.1

THERMAL CONDUCTIVITY OF URANIUM, ZIRCONIUM
AND URANIUM ALLOYS, WATTS cm⁻¹ C⁻¹

Ref. Private Communications with H. W. Deem 6-11-54

Nominal Composition weight per cent, Balance Uranium	Temperature C									
	20	100	200	300	400	500	600	700	800	900
0(1)	0.26	0.27	0.29	0.31	0.33	0.36	0.39	0.43	0.48	0.52
5 Zr	0.19	0.21	0.23	0.25	0.28	0.31	0.34	0.37	0.41	0.44
20 Zr	0.11	0.13	0.15	0.17	0.20	0.22	0.25	0.28	0.31	0.34
40 Zr	0.07	0.08	0.10	0.12	0.14	0.17	0.20	0.24	0.28	0.33
70 Zr	0.09	0.10	0.11	0.12	0.14	0.16	0.18	0.21	0.25	0.29
86 Zr	0.11	0.12	0.12	0.13						
97 Zr	0.14	0.14	0.14	0.15	0.15					
100 Zr ⁽²⁾	0.21	0.20	0.19	0.19	0.18	0.18	0.18	0.18		
5 Cr ⁽³⁾	0.29	0.30	0.32	0.34	0.36	0.38	0.40	0.43	0.46	
97 Th	0.39	0.39	0.39	0.40	0.40					

(1) Average values for two uranium specimens measured

(2) Average values for four zirconium specimens measured to 300 C and for one specimen above 300 C

(3) Average values for four specimens measured

UO₂:

The thermal conductivity varies considerably depending on the following factors: 1) density, 2) powdered, 3) sintered, 4) atmosphere, 5) temperature. Examples for several conditions are given.

63% theoretical density powdered UO₂ in argon:

Ref. McCreight, KAPL-822; WAPD-TR-1110

200°C	.00115 cal/sec/cm ² /°C/cm	.0048 watts/cm ² /°C/cm	0.278 BTU/hr/ft ² /F/ft
500	.00148	.0062	0.359
1000	.00177	.0074	0.428

63% theoretical density powdered UO₂ in helium:
Ref. McCreight, KAPL-822; WAPD-TR-1110

The conductivity is effectively that of the gas and is constant from room temperature to 1000°C.

$$K = 0.00359 \text{ cal/sec/cm}^2/\text{°C/cm}$$

$$0.015 \text{ watts/cm}^2/\text{°C/cm}$$

$$0.87 \text{ BTU/hr/ft}^2/\text{°F/ft}$$

73% theoretical density sintered UO₂:
Ref. Kingery and Vasilos - MIT, unpublished

$$K = .107 e^{-1.207T} \times 10^{-3} \text{ watts/cm}^2/\text{°C/cm} \text{ where } T = \text{°K}$$

100°C	.022 cal/sec/cm ² /C/cm	.092 watts/cm ² /C/cm	5.3 BTU/hr/ft ² /F/ft
200	.019	.080	4.6
400	.0141	.059	3.4
600	.0112	.047	2.7
800	.0091	.038	2.2
1000	.008	.033	1.9

95% theoretical density sintered UO₂:
Ref. Kingery and Vasilos - MIT, unpublished

$$K = .143 e^{-1.207T} \times 10^{-3} \text{ watts/cm}^2/\text{C/cm} \text{ where } T = \text{°K}$$

A combination of 71% UO₂ and 29% BeO, sintered to 80% theoretical density results in a material having an unusually high value of thermal conductivity for a ceramic, it being even higher than some of the metals mentioned above. Reported values are: (Ref. McCreight, KAPL-822)

200°C	0.100 cal/sec/cm ² /C/cm	0.42 watts/cm ² /C/cm	24 BTU/hr/ft ² /F/ft
500	0.067	0.28	16
1000	0.060	0.25	14

This completes the information to date. Apparatus is being assembled in this laboratory for making comparative measurements of thermal conductivity at elevated temperatures (to 650°F). Uranium-molybdenum alloys will be among the first materials checked.

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