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THERMAL DIFFUSIVITY OF MTR-ETR TYPE FUEL PLATES

FINAL REPORT

MASTER

by

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THERMAL DIFFUSIVITY OF MTR-ETR TYPE FUEL PLATES

FINAL REPORT

Purpose of Study

The purpose of this study was to determine the thermal diffusivity of aluminum clad MTR-ETR type fuel plates* from room temperature to 600°C.

Description of Fuel Plates

The fuel plates were approximately 0.13 cm (0.05 inch) thick with a 0.051 cm (0.020 inch) fuel core clad on both sides with 0.038 cm (0.015 inch) aluminum. A description of the fuel plates and core material are described in Table I.

TABLE I

Sample Number	Thickness		Fuel Core
	cm	in.	
P-1-1048	0.130	(0.051)	52.6 wt% UAl_3 + 0.19 wt% B_4C + X8001 Al
P-2-555	0.130	(0.051)	41.6 wt% U_3O_8 + 0.19 wt% B_4C + X8001 Al
0-4-833	0.128	(0.0505)	63.15 wt% Nb coated UO_2-ZrO_2 + X8001 Al
P-5-576	0.130	(0.051)	57.7 wt% UAl_3 + 0.19 wt% B_4C + X8001 Al
P-1-1047	0.132	(0.052)	52.6 wt% UAl_3 + 0.19 wt% B_4C + X8001 Al
79-11	0.082	(0.032)	50 wt% U + 3 wt% Sn + Al P.A APM-257

Samples for thermal diffusivity measurements were 0.635 cm (0.25 inch) diameter. No changes were made in the fabricated thickness of plates. Some samples were coated with water suspension of graphite to improve transient temperature measurements.

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*Measurements were made for and samples were furnished by Phillips Petroleum Company, NRTS, Idaho Falls, Idaho, under related services Purchase Order AEC-74953.

Thermal Diffusivity Apparatus

A single pulse, transient method(1) was used to measure the thermal diffusivity. The technique was similar to the "flash" method originally described by Parker, et al.(2) A laser produces the pulse of radiant energy to the specimen and the temperature transient on the back surface of the specimen was measured with liquid N_2 cooled indium antimonide detector. The signal from the detector was displayed on a cathode ray oscilliscope and recorded on Polaroid film.

The pulse was supplied by a ruby crystal [1.27 cm (0.5 inch) diameter and 15.25 cm (6.0 inch) long with TIR end] laser. Measurements were made using pulse energies between 2 and 5 joules and wavelength of 6943° A. The duration of the laser pulse was 0.54×10^{-3} seconds.

The wafer specimens were inserted into a lavite holder having a tapered center hole into which the specimens are lightly pressed. The holder was positioned in a tantalum tube which was heated by electrical resistance. Temperatures were measured by Pt versus Pt-Ph and chromel-alumel thermocouples inserted into the specimen holder through a hole in the tantalum tube.

The atmosphere during the measurements was purified argon containing < 1 ppm O_2 and <10 ppm H_2O.

Correction for Heat Losses and Finite Pulse Time

Corrections to thermal diffusivity data for radiation losses and finite pulse time were made using methods of Cape and Lehman(3) and Taylor, et al.(4)

Because of the low temperatures, <600°C, no radiation loss corrections were required. However, corrections were made for finite pulse time effects.

When the heat pulse (τ) is of infinitesimal duration, the thermal diffusivity (α) is given by

$$\alpha = 1.37\ a^2/\pi^2 t_{1/2};$$

where $t_{1/2}$ is the time required for the back surface to reach half the maximum temperature, a is the sample thickness and

$$t_c = \frac{a^2}{\pi^2 \alpha}$$

where t_c is the characteristic rise time of the back surface of the sample. When τ is much smaller than t_c, $\frac{t_{1/2}}{t_c} = 1.37$. However, when $\tau \underset{-}{\sim} t_c$, it is apparent that $t_{1/2}/t_c > 1.37$ and α should be corrected for the finite pulse time effect.

The shape of the pulse is important. Since the laser pulse more closely approximates a square wave, Taylor's method for finite pulse time correction was used. Estimated error for the thicker specimens (0.130 cm thick) was approximately 5% where $t_{1/2}/t_c = 1.44$.

Results

Data are given in Table II.

An estimate of the accuracy of the thermal diffusivity data was obtained using published thermal conductivity data for wrought aluminum alloys.

The thermal diffusivity is defined as

$$\alpha = k\,C_p^{-1}\,\rho^{-1},$$

where k is thermal conductivity, C_p is heat capacity, and ρ is the density.

Assuming nominal values of 0.223 cal/g for C_p, 2.7 g/cm^3 for ρ, and 1.2 watt/cm °C for k, at room temperature,

$$\alpha_{cal} = \frac{1.2\ \text{watt/cm}\ ^\circ\text{C}}{0.223\ \text{cal/g/}^\circ\text{C} \times 4.186\ \text{watt/cal/sec} \times 2.7\ \text{g/cm}^3}$$

$$\alpha_{cal} = 0.475\ \text{cm}^2/\text{sec}.$$

Although higher than the experimental values, differences in density and heat capacity could explain these variations. It is interesting to note that the samples cores which contained ceramic, (P-2-555 and P-4-833) exhibited higher thermal diffusivity values than the all metallic cores.

TABLE II

P-1-1048
(Coated

Temperature °C	α cm²/sec
25	0.383
97	0.366
100	0.366
201	0.358
200	0.372
301	0.356
300	0.358
400	0.348
500	0.336
500	0.324

P-1-1048
(Noncoated)

Temperature °C	α cm²/sec
105	0.390
105	0.376
202	0.372
200	0.376
301	0.348
308	0.342
400	0.339
400	0.342
500	0.311
502	0.328

P-2-555
(Coated)

Temperature °C	α cm²/sec
20	0.462
20	0.487
105	0.449
106	0.449
195	0.437
200	0.442
300	0.417
302	0.425
402	0.417
400	0.417
496	0.404
494	0.383

0-4-833
(Noncoated)

Temperature °C	α cm²/sec
105	0.469
102	0.484
195	0.442
190	0.445
298	0.433
298	0.433
395	0.390
395	0.406
503	0.440
503	0.402
105	0.495
195	0.490
305	0.474
303	0.433
402	0.433
500	0.464

TABLE II (Cont)

P-5-576
(Coated)

Temperature °C	α cm^2/sec
25	0.331
25	0.336
92	0.306
107	0.311
210	0.278
202	0.282
300	0.274
297	0.269
305	0.278
402	0.274
400	0.247
500	0.251
500	0.254

P-1-1047
(Coated)

Temperature °C	α cm^2/sec
25	0.311
25	0.335
105	0.298
100	0.294
195	0.290
200	0.298
295	0.278
297	0.288
404	0.265
398	0.268
500	0.265
503	0.250
551	0.233

79-11
(Coated)

Temperature °C	α cm^2/sec
25	0.423
25	0.415
100	0.372
102	0.378
195	0.366
200	0.360
300	0.337
295	0.347
400	0.332
400	0.327
500	0.317
500	0.320
560	0.300

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