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EFFECTS OF MULTIPLE TRANSIENTS  
ON FAST REACTOR FUEL  
PIN CLADDING MECHANICAL PROPERTIES

D.R. Duncan  
G.D. Johnson  
C.W. Hunter

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by

D. R. Duncan, G. D. Johnson, and C. W. Hunter  
Westinghouse Hanford Company

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*The effects of various TREAT and simulated transient events on subsequent burst strength of 20% cold worked AISI 316 irradiated fast reactor fuel pin cladding were evaluated. Cladding strength after transient exposure was compared to strength prior to transient exposure, using a HEDL correlation<sup>(1)</sup> of failure temperatures with irradiation and test parameters. The simulated transients and post-transient strength tests were performed in the Fuel Cladding Transient Tester (FCTT), which was developed at HEDL to simulate cladding conditions during in-reactor transient events by pressurizing tubing specimens under transient heating conditions. Test procedure details are reported elsewhere.<sup>(2)</sup>*

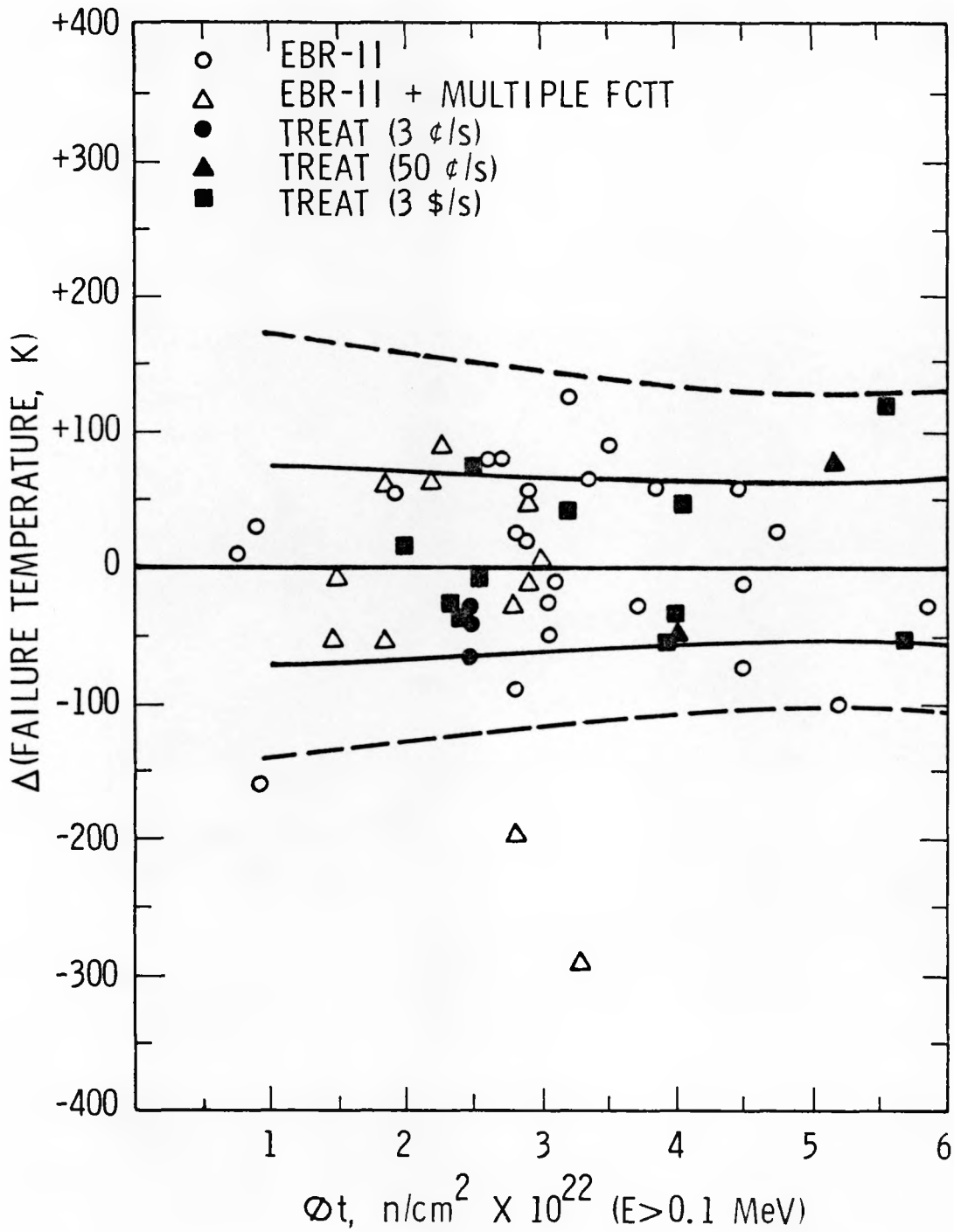
*Specimens were sectioned from the fuel column of fuel pin cladding of FFTF geometry (5.84 mm O.D. x 5.08 mm I.D.). The relative severity of the various TREAT transients, in terms of cladding temperature rise and expected cladding stress, increased from the 3¢/s tests to a maximum for the 3\$/s tests. None of the TREAT transients resulted in pin failure. The untermi-nated TREAT tests received a longer power ramp than those terminated at the simulated FFTF Plant Protective System trip point. Cladding heating rates during the TREAT exposures varied from approximately 5 K/s for the 3¢/s and*

Continuous Flow Reduction (CFR) tests to approximately 1000 K/s for the 3\$/s unterminated events. Specimens from pins with no TREAT exposure were given FCTT heating ramps terminated prior to failure. The heating rates for the latter simulated transient specimens were 5.6 and 111 K/s.

The failure temperature results from specimens with TREAT transient exposure were well within the 2 $\sigma$  confidence limits of the FCTT failure temperature expression, and within the data field of the results from specimens with no transient exposure. The multiple FCTT ramp test results displayed similar behavior, with the exception of two data points that were considerably lower in failure temperature than the lower bound of data from specimens with no transient exposure. These results are given in the attached table and figure.

Thus, TREAT exposure did not damage the fuel pin specimens examined in this work. Two of eleven multiple FCTT heating ramp tests did result in damage. The trends exhibited by the data are due to the large dependence of damage accumulation on temperature during a reactor transient or simulated transient. Transient exposure must be quite close to failure before damage will be apparent in subsequent testing.

# PREDICTED VS ACTUAL FAILURE TEMPERATURE



FCTT FAILURE TEMPERATURE RESULTS

Terminated FCTT Ramp Specimens

<u>Pin</u>	<u>Specimen</u>	<u>Midwall Irr. Temp., K</u>	<u><math>\phi t</math>, n/cm<sup>2</sup> x 10<sup>22</sup> (E 0.1 MeV)</u>	<u>Terminated Ramp Heating Rate, K/s</u>	<u>Terminated Ramp Hoop Stress, MPa</u>	<u>Terminated Ramp Maximum Temp, K</u>	<u>No. of Terminated Ramps</u>	<u>Final Ramp Heating Rate, K/s</u>	<u>Final Ramp Hoop Stress, MPa</u>	<u>Failure Temp, K</u>
P-23B-49C	E	692	1.48	5.6	199	811	4	111	199	1210
"	L	799	1.86	"	"	922	"	"	"	1262
"	Q	888	1.84	"	"	950	"	"	"	1207
"	T	961	1.44	"	"	1005	"	"	"	1211
P-23C-83H	G	676	2.20	"	"	811	"	"	"	1254
"	K	797	2.88	"	"	922	"	"	"	1150
"	I	745	2.79	"	"	866	2	5.6	"	819
P-23C-47C	K2	740	3.00	111	138	1022	100	111	138	1227
P-23C-94JL	G	672	2.25	"	"	1089	180	"	"	1339
"	I	740	2.80	"	"	1061	60	"	"	1200
"	K	797	2.90	"	"	1061	60	"	"	1272
P-23C-2A	M	744	3.30	"	"	922	32	"	"	922

Treat Specimens

<u>Pin</u>	<u>Specimen</u>	<u>TREAT Test</u>	<u>Simulated Reactor Transient</u>	<u>Incremental Treat Strain, %</u>	<u>Midwall Irr. Temp., K</u>	<u><math>\phi t</math>, n/cm<sup>2</sup> x 10<sup>22</sup> (E&gt;0.1 MeV)</u>	<u>FCTT Heating Rate, K/s</u>	<u>FCTT Hoop Stress, MPa</u>	<u>Failure Temp.,K</u>
P-23B-22A	L	HOP-PTO 1-2A	4 3¢/s (PPS)*	0.06	877	2.43	111	199	1234
P-23C-18A	H	HUC-PTO 2-2A	3 3¢/s(PPS)+CFR(PPS)	0	775	2.47	"	"	1111
"	L	"	"	0.03	874	2.43	"	"	1222
P-23C-20A	H	HOP-PTO 3-2E	2 3¢/s(PPS)+3\$/s(PPS)	0.08	778	2.49	"	"	1250
"	L	"	"	0.12	869	2.39	"	"	1224
PNL-10-20	D	HUT 3-5A	3\$/s(UT)**	0.08	668	3.19	"	"	1191
"	G	"	"	0.40	723	4.05	"	"	1180
"	J	"	"	0.49	767	3.93	"	"	1081
PNL-9-45	G	HUT 3-7A	"	0.29	710	5.69	"	"	1076
"	J	"	"	0.26	752	5.54	"	"	1245
PNL-11-28	F	HUT 5-3A	50¢/s(UT)	0.19	724	3.99	"	"	1087
PNL-9-25	D	HUT 5-7A	"	0.09	703	5.16	"	"	1201
PNL-17-21	A2	HOP 3-2B	3\$/s(PPS)	0	694	2.35	"	"	1156
"	A3	"	"	0	714	2.55	"	"	1165
P-23A-27	C	HOP 3-1B	"	0	783	2.00	5.6	"	1080
P-23A-30	D	HOP 3-2C	"	0.04	783	4.00	5.6	"	933

\*PPS designation indicates termination of TREAT power ramp at FFTF Plant Protective System secondary trip point

\*\* UT designation indicates TREAT power ramp termination beyond PPS secondary trip point

## REFERENCES

1. G. D. Johnson and C. W. Hunter, "Mechanical Properties of Transient-tested Irradiated Fast Reactor Cladding," to be presented at ANS 1978 Winter Meeting, Washington D.C., Nov. 12-17, 1978.
2. C. W. Hunter, R. L. Fish and J. J. Holmes, "Mechanical Properties of Unirradiated Fast Reactor Cladding during Simulated Overpower Transients, Nuclear Technology, 27, pp. 376-388, November 1975.