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DT-IP-434-D: IRRADIATION EFFECT
ON CERAMIC MATERIALS

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AUTHOR

D. E. Cooley

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Page 1

DT-IP-434-D: IRRADIATION EFFECT ON CERAMIC MATERIALS

By

D. E. Cooley
Reactor Design
Facilities Engineering Operation
IRRADIATION PROCESSING OPERATION

April 21, 1964

*Classified By
G. E. Wade*

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DT-IP-434-D: IRRADIATION EFFECT ON CERAMIC MATERIALS

The purpose of this test was to determine the effect of production reactor flux on ceramic materials being considered for lining the vertical safety rod channels at the production reactors.

This document is being written to describe the test, the results to date, and the work which remains to be done. The materials being evaluated in the test are: 1) Aluminum Silicate (Maryland Lava Co.); 2) Silicon Nitride bonded Silicon Carbide (Norton Co. "Crystalon"); and 3) Aluminum Oxide 85% (Norton Co. "Alundum RA-98").

The samples were charged into the B test hole at C Reactor in 15 graphite "boats". Each boat contains three flexure specimens of each material and five compression specimens of each material. Appendix 1 shows a typical boat loading diagram and gives the dimensions of all samples at charging. The test specimens have been periodically discharged, starting with two boats during June 1962, and continuing with one boat about every two months thereafter. To date, nine boats of samples have been discharged and eight have been tested, leaving six in the reactor and one discharged but not tested.

The samples now in the reactor have received about 8100 MWD/AT exposure, and if the remaining boats are discharged at the present rate, the final boat should have received about 12,000 MWD/AT. The temperature in the "B Test Hole" at C Reactor is 550 C to 600 C.

The flexure samples are 6 inches long by 1-1/8 inch diameter, and are used for length change measurements as well as in flexural tests. The compression samples are 1-1/8 inches long by 1-1/8 inch diameter with the exception of the Aluminum Oxide samples which are 1/2 inch long by 1/2 inch diameter. The smaller size was used in the latter case since the available compression test apparatus was not capable of crushing the 1-1/8 inch Aluminum Oxide samples. The testing method used in the flexural tests is that described in ASTM C 328-56 (also see D 667-44), and the compression tests have been performed as per ASTM D 667-44. The results of the various experiments that have been performed on the eight tested boats are shown in graphical form in Figures 1, 2, 3, and 4.

The induced activity of the samples has been measured only once. Samples from boats 4 and 5 (first ones discharged) after a two month aging period after discharge are given in Table I.

TABLE I

Al ₂ O ₃	1.5 Rad. @ 12"
Al ₂ SiO ₃	30 Rad. @ 12"
SiC	1.5 Rad. @ 12"

These materials are no longer being considered for lining the VSR channels. The costs to date and estimated costs to complete the tests are given in Table II.

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TABLE II

	<u>Cost to Date</u>	<u>Cost to Complete</u>
Irradiation Services	\$11,132	\$ 4,200
Radiometallurgy	\$15,124	\$12,500
New Compression Facility ⁽¹⁾		\$ 2,400
TOTAL	\$26,256	\$19,100

Reactor Design, FES cannot justify the expenditure of this amount of money to complete the tests. Therefore action has been initiated to transfer the tests to another organization or to stop all work.

D. E. Cooley

D. E. Cooley
Reactor Design
Facilities Engineering Subsection
IRRADIATION PROCESSING OPERATION

DEC:kmm

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(1) Letter, "FMA-459, Irradiation Effect on Ceramic Materials", R. D. Widrig to D. E. Cooley, March 26, 1964.

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FIGURE 2

MODULUS OF RUPTURE
VS
EXPOSURE

A = Al_2O_3
O = $AlSiO_3$
□ = SIC

FIGURE 3

COMPRESSION STRENGTH
VS.
EXPOSURE

○ = Al_2SiO_5

□ = SiC

REPLACEMENT

F (MWD/AT)

FIGURE 4

COMPRESSION STRENGTH
VS
EXPOSURE

A - Al₂O₃

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APPENDIX I

HAFO-250 BOAT LOADING DIAGRAM
AND SAMPLE DIMENSIONS

IRRADIATION PROCESSING DEPARTMENT

GENERAL ELECTRIC

RICHLAND, WASHINGTON

F. J. Kempf
Reactor Modification Design

December 15, 1961

HAPO-250 BOAT LOADING DIAGRAM AND SAMPLE DIMENSIONS

A total of fifteen sample boats were loaded with three types of ceramic specimens. Each boat contains three flexure specimens of each type of ceramic and five compression specimens of each type of ceramic.

Marking of the ceramic samples was not feasible, so a loading scheme was designed which will permit identity of the samples after irradiation.

The length and diameter of each specimen was measured, $\pm$.001 inch.

The measurements, boat loading diagram, and the specimen position data are attached.

A. E. DeMers
Irradiation Testing

A. E. DeMers/rch

cc: AE DeMers
FJ Kempf(2)
CG Lewis
R Neidner
WB Olson

Attachments

HAP0 250 BOAT LOADING DIAGRAM

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BOTTOM LAYER

TOP LAYER

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BOAT NO. 1

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.133	1.135	1.135	6.025
2	Al ₂ O ₃	1.131	1.132	1.134	6.031
3	Al ₂ O ₃	1.132	1.134	1.135	6.024
4	Al ₂ SiO ₃	1.127	1.126	1.126	6.012
5	Al ₂ SiO ₃	1.125	1.125	1.127	6.009
6	Al ₂ SiO ₃	1.124	1.125	1.126	6.015
7	SiC	1.142	1.139	1.138	6.026
8	SiC	1.137	1.150	1.143	5.955
9	SiC	1.119	1.129	1.141	6.022
10	Al ₂ SiO ₃	1.132	1.130	1.130	1.125
11	Al ₂ SiO ₃	1.128	1.128	1.129	1.124
12	Al ₂ SiO ₃	1.129	1.128	1.128	1.126
13	Al ₂ SiO ₃	1.130	1.131	1.131	1.126
14	Al ₂ SiO ₃	1.129	1.130	1.128	1.125
15	SiC	1.149	1.132	1.124	1.133
16	SiC	1.142	1.127	1.134	1.133
17	SiC	1.133	1.128	1.132	1.141
18	SiC	1.148	1.143	1.141	1.140
19	SiC	1.115	1.121	1.123	1.136
20	Al ₂ O ₃	.500			.499
21	Al ₂ O ₃	.501			.498
22	Al ₂ O ₃	.500			.497
23	Al ₂ O ₃	.500			.499
24	Al ₂ O ₃	.499			.497

BOAT NO. 2

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.131	1.129	1.132	6.001
2	Al ₂ O ₃	1.131	1.129	1.132	6.019
3	Al ₂ O ₃	1.129	1.128	1.129	6.010
4	Al ₂ SiO ₃	1.124	1.125	1.127	6.011
5	Al ₂ SiO ₃	1.129	1.127	1.126	6.013
6	Al ₂ SiO ₃	1.128	1.127	1.125	6.010
7	SiC	1.154	1.143	1.147	6.022
8	SiC	1.121	1.117	1.121	6.021
9	SiC	1.135	1.130	1.129	6.022
10	Al ₂ SiO ₃	1.127	1.127	1.127	1.125
11	Al ₂ SiO ₃	1.129	1.127	1.127	1.124
12	Al ₂ SiO ₃	1.124	1.125	1.124	1.130
13	Al ₂ SiO ₃	1.129	1.129	1.128	1.125
14	Al ₂ SiO ₃	1.127	1.128	1.127	1.124
15	SiC	1.146	1.148	1.146	1.132
16	SiC	1.120	1.121	1.120	1.130
17	SiC	1.121	1.118	1.119	1.148
18	SiC	1.148	1.152	1.149	1.136
19	SiC	1.120	1.137	1.139	1.139
20	Al ₂ O ₃	.502			.499
21	Al ₂ O ₃	.501			.500
22	Al ₂ O ₃	.499			.497
23	Al ₂ O ₃	.501			.501
24	Al ₂ O ₃	.501			.499

BOAT NO. 3

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>Length</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.128	1.126	1.129	6.004
2	Al ₂ O ₃	1.128	1.126	1.130	6.004
3	Al ₂ O ₃	1.132	1.131	1.131	6.012
4	Al ₂ SiO ₃	1.125	1.126	1.128	6.007
5	Al ₂ SiO ₃	1.129	1.126	1.125	6.008
6	Al ₂ SiO ₃	1.127	1.126	1.127	6.011
7	SiC	1.128	1.131	1.125	6.013
8	SiC	1.132	1.120	1.128	6.036
9	SiC	1.158	1.164	1.173	6.011
10	Al ₂ SiO ₃	1.128	1.128	1.127	1.125
11	Al ₂ SiO ₃	1.128	1.128	1.128	1.125
12	Al ₂ SiO ₃	1.129	1.129	1.130	1.122
13	Al ₂ SiO ₃	1.126	1.126	1.126	1.124
14	Al ₂ SiO ₃	1.129	1.129	1.130	1.131
15	SiC	1.128	1.127	1.121	1.118
16	SiC	1.131	1.134	1.129	1.118
17	SiC	1.131	1.135	1.139	1.117
18	SiC	1.122	1.118	1.115	1.125
19	SiC	1.145	1.149	1.135	1.123
20	Al ₂ O ₃	.499			.499
21	Al ₂ O ₃	.500			.500
22	Al ₂ O ₃	.500			.500
23	Al ₂ O ₃	.500			.498
24	Al ₂ O ₃	.501			.498

BOAT NO. 4

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.128	1.129	1.130	6.022
2	Al ₂ O ₃	1.134	1.130	1.132	6.017
3	Al ₂ O ₃	1.132	1.131	1.130	6.030
4	Al ₂ SiO ₃	1.127	1.125	1.126	6.002
5	Al ₂ SiO ₃	1.125	1.124	1.126	6.003
6	Al ₂ SiO ₃	1.128	1.126	1.125	6.005
7	SiC	1.136	1.140	1.150	6.012
8	SiC	1.155	1.160	1.164	6.020
9	SiC	1.144	1.143	1.149	6.016
10	Al ₂ SiO ₃	1.128	1.128	1.128	1.123
11	Al ₂ SiO ₃	1.127	1.127	1.126	1.126
12	Al ₂ SiO ₃	1.128	1.129	1.128	1.127
13	Al ₂ SiO ₃	1.129	1.128	1.127	1.124
14	Al ₂ SiO ₃	1.125	1.125	1.125	1.129
15	SiC	1.140	1.120	1.134	1.135
16	SiC	1.131	1.136	1.129	1.133
17	SiC	1.135	1.132	1.138	1.112
18	SiC	1.137	1.124	1.120	1.116
19	SiC	1.126	1.129	1.124	1.129
20	Al ₂ O ₃	.501			.499
21	Al ₂ O ₃	.502			.498
22	Al ₂ O ₃	.501			.499
23	Al ₂ O ₃	.501			.498
24	Al ₂ O ₃	.502			.499

BOAT NO. 5

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.134	1.134	1.133	6.009
2	Al ₂ O ₃	1.133	1.129	1.131	6.000
3	Al ₂ O ₃	1.132	1.128	1.131	6.005
4	Al ₂ SiO ₃	1.126	1.127	1.129	6.015
5	Al ₂ SiO ₃	1.127	1.126	1.129	6.011
6	Al ₂ SiO ₃	1.125	1.126	1.128	6.009
7	SiC	1.151	1.146	1.149	6.038
8	SiC	1.134	1.117	1.129	6.022
9	SiC	1.113	1.115	1.108	6.021
10	Al ₂ SiO ₃	1.130	1.130	1.129	1.124
11	Al ₂ SiO ₃	1.128	1.128	1.128	1.126
12	Al ₂ SiO ₃	1.130	1.129	1.128	1.127
13	Al ₂ SiO ₃	1.130	1.131	1.131	1.128
14	Al ₂ SiO ₃	1.131	1.130	1.132	1.125
15	SiC	1.148	1.135	1.146	1.134
16	SiC	1.107	1.119	1.113	1.113
17	SiC	1.126	1.111	1.133	1.130
18	SiC	1.113	1.120	1.128	1.110
19	SiC	1.118	1.120	1.114	1.115
20	Al ₂ O ₃	.501			.499
21	Al ₂ O ₃	.502			.500
22	Al ₂ O ₃	.501			.499
23	Al ₂ O ₃	.501			.500
24	Al ₂ O ₃	.501			.500

BOAT NO. 6

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.130	1.128	1.134	6.018
2	Al ₂ O ₃	1.131	1.130	1.135	6.009
3	Al ₂ O ₃	1.134	1.133	1.134	6.024
4	Al ₂ SiO ₃	1.126	1.127	1.128	6.014
5	Al ₂ SiO ₃	1.125	1.127	1.128	6.001
6	Al ₂ SiO ₃	1.124	1.125	1.126	6.012
7	SiC	1.125	1.137	1.144	6.012
8	SiC	1.138	1.135	1.140	6.028
9	SiC	1.132	1.124	1.124	5.971
10	Al ₂ SiO ₃	1.126	1.126	1.127	1.125
11	Al ₂ SiO ₃	1.128	1.127	1.127	1.125
12	Al ₂ SiO ₃	1.128	1.129	1.130	1.123
13	Al ₂ SiO ₃	1.124	1.124	1.125	1.127
14	Al ₂ SiO ₃	1.129	1.129	1.130	1.124
15	SiC	1.106	1.108	1.117	1.140
16	SiC	1.123	1.117	1.119	1.137
17	SiC	1.111	1.115	1.108	1.115
18	SiC	1.125	1.130	1.127	1.123
19	SiC	1.125	1.135	1.129	1.139
20	Al ₂ O ₃	.501			.499
21	Al ₂ O ₃	.500			.498
22	Al ₂ O ₃	.502			.499
23	Al ₂ O ₃	.500			.501
24	Al ₂ O ₃	.500			.500

BOAT NO. 7

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.127	1.126	1.126	5.992
2	Al ₂ O ₃	1.127	1.125	1.128	5.999
3	Al ₂ O ₃	1.132	1.133	1.133	6.031
4	Al ₂ SiO ₃	1.125	1.126	1.127	6.017
5	Al ₂ SiO ₃	1.124	1.126	1.127	6.009
6	Al ₂ SiO ₃	1.126	1.127	1.128	6.006
7	SiC	1.138	1.146	1.134	5.999
8	SiC	1.146	1.149	1.144	6.029
9	SiC	1.131	1.124	1.122	6.017
10	Al ₂ SiO ₃	1.125	1.126	1.126	1.126
11	Al ₂ SiO ₃	1.129	1.129	1.130	1.127
12	Al ₂ SiO ₃	1.128	1.129	1.128	1.125
13	Al ₂ SiO ₃	1.129	1.127	1.128	1.123
14	Al ₂ SiO ₃	1.129	1.129	1.129	1.117
15	SiC	1.110	1.103	1.112	1.135
16	SiC	1.135	1.141	1.135	1.151
17	SiC	1.115	1.113	1.110	1.114
18	SiC	1.110	1.120	1.124	1.117
19	SiC	1.146	1.145	1.148	1.135
20	Al ₂ O ₃	.500			.499
21	Al ₂ O ₃	.500			.498
22	Al ₂ O ₃	.501			.501
23	Al ₂ O ₃	.501			.499
24	Al ₂ O ₃	.501			.498

BOAT NO. 8

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.132	1.131	1.129	6.010
2	Al ₂ O ₃	1.137	1.136	1.136	6.042
3	Al ₂ O ₃	1.136	1.130	1.139	6.013
4	Al ₂ SiO ₃	1.129	1.126	1.125	6.015
5	Al ₂ SiO ₃	1.128	1.127	1.125	6.015
6	Al ₂ SiO ₃	1.128	1.126	1.125	6.008
7	SiC	1.150	1.149	1.165	6.034
8	SiC	1.160	1.148	1.129	6.037
9	SiC	1.126	1.137	1.148	6.017
10	Al ₂ SiO ₃	1.129	1.129	1.127	1.139
11	Al ₂ SiO ₃	1.126	1.126	1.125	1.141
12	Al ₂ SiO ₃	1.125	1.126	1.126	1.141
13	Al ₂ SiO ₃	1.129	1.127	1.128	1.126
14	Al ₂ SiO ₃	1.125	1.124	1.125	1.145
15	SiC	1.164	1.169	1.155	1.145
16	SiC	1.115	1.113	1.113	1.133
17	SiC	1.121	1.125	1.121	1.112
18	SiC	1.124	1.117	1.122	1.145
19	SiC	1.125	1.131	1.128	1.115
20	Al ₂ O ₃	.500			.499
21	Al ₂ O ₃	.500			.499
22	Al ₂ O ₃	.500			.500
23	Al ₂ O ₃	.500			.498
24	Al ₂ O ₃	.501			.499

BOAT NO. 9

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.131	1.133	1.130	6.008
2	Al ₂ O ₃	1.138	1.131	1.132	6.008
3	Al ₂ O ₃	1.133	1.135	1.129	6.012
4	Al ₂ SiO ₃	1.126	1.126	1.126	6.011
5	Al ₂ SiO ₃	1.126	1.127	1.128	6.013
6	Al ₂ SiO ₃	1.126	1.127	1.129	6.017
7	SiC	1.127	1.124	1.117	6.019
8	SiC	1.132	1.118	1.129	6.017
9	SiC	1.138	1.130	1.136	6.028
10	Al ₂ SiO ₃	1.126	1.126	1.127	1.141
11	Al ₂ SiO ₃	1.126	1.126	1.125	1.141
12	Al ₂ SiO ₃	1.125	1.125	1.125	1.142
13	Al ₂ SiO ₃	1.123	1.123	1.123	1.146
14	Al ₂ SiO ₃	1.125	1.124	1.124	1.141
15	SiC	1.128	1.121	1.126	1.118
16	SiC	1.117	1.124	1.113	1.132
17	SiC	1.128	1.125	1.128	1.125
18	SiC	1.130	1.125	1.128	1.131
19	SiC	1.132	1.132	1.134	1.113
20	Al ₂ O ₃	.500			.500
21	Al ₂ O ₃	.503			.500
22	Al ₂ O ₃	.502			.500
23	Al ₂ O ₃	.500			.500
24	Al ₂ O ₃	.500			.499

BOAT NO. 10

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.133	1.132	1.133	6.022
2	Al ₂ O ₃	1.138	1.137	1.139	6.028
3	Al ₂ O ₃	1.130	1.128	1.129	6.004
4	Al ₂ SiO ₃	1.128	1.129	1.124	6.006
5	Al ₂ SiO ₃	1.128	1.128	1.130	6.015
6	Al ₂ SiO ₃	1.129	1.127	1.126	6.006
7	SiC	1.140	1.128	1.119	6.024
8	SiC	1.129	1.139	1.137	6.016
9	SiC	1.110	1.121	1.136	6.028
10	Al ₂ SiO ₃	1.129	1.127	1.128	1.146
11	Al ₂ SiO ₃	1.126	1.125	1.126	1.140
12	Al ₂ SiO ₃	1.126	1.126	1.126	1.143
13	Al ₂ SiO ₃	1.124	1.123	1.124	1.148
14	Al ₂ SiO ₃	1.125	1.125	1.125	1.141
15	SiC	1.123	1.125	1.126	1.139
16	SiC	1.134	1.131	1.126	1.145
17	SiC	1.130	1.139	1.142	1.111
18	SiC	1.129	1.126	1.120	1.129
19	SiC	1.132	1.137	1.134	1.138
20	Al ₂ O ₃	.502			.500
21	Al ₂ O ₃	.501			.501
22	Al ₂ O ₃	.503			.500
23	Al ₂ O ₃	.501			.500
24	Al ₂ O ₃	.501			.499

BOAT NO. 11

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.127	1.128	1.127	6.007
2	Al ₂ O ₃	1.126	1.128	1.127	5.996
3	Al ₂ O ₃	1.130	1.130	1.129	6.000
4	Al ₂ SiO ₃	1.124	1.126	1.126	6.009
5	Al ₂ SiO ₃	1.125	1.126	1.127	6.015
6	Al ₂ SiO ₃	1.124	1.126	1.127	6.010
7	SiC	1.120	1.114	1.109	6.020
8	SiC	1.129	1.115	1.121	6.015
9	SiC	1.142	1.150	1.165	6.021
10	Al ₂ SiO ₃	1.128	1.127	1.127	1.142
11	Al ₂ SiO ₃	1.129	1.125	1.125	1.142
12	Al ₂ SiO ₃	1.129	1.130	1.128	1.146
13	Al ₂ SiO ₃	1.131	1.130	1.130	1.141
14	Al ₂ SiO ₃	1.131	1.130	1.130	1.142
15	SiC	1.140	1.125	1.129	1.143
16	SiC	1.125	1.123	1.114	1.111
17	SiC	1.117	1.131	1.126	1.107
18	SiC	1.128	1.126	1.118	1.109
19	SiC	1.152	1.151	1.124	1.131
20	Al ₂ O ₃	.502			.520
21	Al ₂ O ₃	.501			.501
22	Al ₂ O ₃	.501			.501
23	Al ₂ O ₃	.502			.499
24	Al ₂ O ₃	.500			.499

BOAT NO. 12

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.136	1.135	1.141	6.035
2	Al ₂ O ₃	1.134	1.136	1.130	6.002
3	Al ₂ O ₃	1.130	1.129	1.132	5.999
4	Al ₂ SiO ₃	1.128	1.126	1.125	6.015
5	Al ₂ SiO ₃	1.127	1.127	1.125	6.009
6	Al ₂ SiO ₃	1.128	1.128	1.128	6.013
7	SiC	1.123	1.111	1.110	6.040
8	SiC	1.133	1.140	1.131	6.021
9	SiC	1.139	1.132	1.140	6.029
10	Al ₂ SiO ₃	1.128	1.127	1.127	1.124
11	Al ₂ SiO ₃	1.125	1.123	1.125	1.135
12	Al ₂ SiO ₃	1.127	1.126	1.126	1.126
13	Al ₂ SiO ₃	1.126	1.126	1.126	1.136
14	Al ₂ SiO ₃	1.125	1.124	1.124	1.137
15	SiC	1.151	1.161	1.145	1.164
16	SiC	1.122	1.117	1.117	1.133
17	SiC	1.151	1.140	1.146	1.137
18	SiC	1.110	1.113	1.124	1.117
19	SiC	1.116	1.113	1.129	1.125
20	Al ₂ O ₃	.501			.501
21	Al ₂ O ₃	.499			.518
22	Al ₂ O ₃	.501			.498
23	Al ₂ O ₃	.502			.498
24	Al ₂ O ₃	.500			.499

BOAT NO. 13

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.128	1.124	1.125	5.990
2	Al ₂ O ₃	1.131	1.132	1.133	6.019
3	Al ₂ O ₃	1.132	1.136	1.133	6.031
4	Al ₂ SiO ₃	1.126	1.125	1.124	6.010
5	Al ₂ SiO ₃	1.127	1.126	1.125	6.009
6	Al ₂ SiO ₃	1.128	1.128	1.130	6.014
7	SiC	1.127	1.123	1.113	6.025
8	SiC	1.169	1.159	1.173	6.036
9	SiC	1.137	1.141	1.122	6.023
10	Al ₂ SiO ₃	1.126	1.124	1.125	1.143
11	Al ₂ SiO ₃	1.127	1.126	1.127	1.141
12	Al ₂ SiO ₃	1.126	1.126	1.125	1.141
13	Al ₂ SiO ₃	1.124	1.122	1.123	1.148
14	Al ₂ SiO ₃	1.124	1.124	1.124	1.148
15	SiC	1.104	1.120	1.106	1.116
16	SiC	1.136	1.143	1.151	1.139
17	SiC	1.136	1.128	1.126	1.142
18	SiC	1.128	1.133	1.127	1.140
19	SiC	1.113	1.110	1.122	1.135
20	Al ₂ O ₃	.500			.500
21	Al ₂ O ₃	.500			.498
22	Al ₂ O ₃	.501			.499
23	Al ₂ O ₃	.501			.500
24	Al ₂ O ₃	.501			.498

BOAT NO. 14

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.128	1.129	1.127	6.019
2	Al ₂ O ₃	1.134	1.134	1.128	6.033
3	Al ₂ O ₃	1.131	1.130	1.133	6.015
4	Al ₂ SiO ₃	1.126	1.127	1.128	6.017
5	Al ₂ SiO ₃	1.124	1.126	1.129	6.015
6	Al ₂ SiO ₃	1.128	1.127	1.125	6.001
7	SiC	1.142	1.151	1.151	6.047
8	SiC	1.122	1.129	1.131	6.039
9	SiC	1.133	1.132	1.123	6.035
10	Al ₂ SiO ₃	1.129	1.130	1.127	1.130
11	Al ₂ SiO ₃	1.128	1.127	1.126	1.147
12	Al ₂ SiO ₃	1.128	1.126	1.126	1.146
13	Al ₂ SiO ₃	1.128	1.128	1.128	1.139
14	Al ₂ SiO ₃	1.123	1.124	1.123	1.139
15	SiC	1.108	1.107	1.111	1.124
16	SiC	1.117	1.119	1.116	1.109
17	SiC	1.120	1.120	1.123	1.111
18	SiC	1.121	1.130	1.114	1.139
19	SiC	1.123	1.111	1.119	1.113
20	Al ₂ O ₃	.501			.498
21	Al ₂ O ₃	.500			.501
22	Al ₂ O ₃	.501			.498
23	Al ₂ O ₃	.501			.500
24	Al ₂ O ₃	.500			.499

BOAT NO. 15

<u>POSITION</u>	<u>TYPE</u>	<u>DIAMETER</u>			<u>LENGTH</u>
		<u>1</u>	<u>2</u>	<u>3</u>	
1	Al ₂ O ₃	1.129	1.127	1.131	5.990
2	Al ₂ O ₃	1.128	1.127	1.130	6.007
3	Al ₂ O ₃	1.127	1.131	1.137	6.025
4	Al ₂ SiO ₃	1.128	1.128	1.125	6.012
5	Al ₂ SiO ₃	1.125	1.126	1.128	6.012
6	Al ₂ SiO ₃	1.126	1.125	1.126	6.024
7	SiC	1.133	1.128	1.131	6.006
8	SiC	1.132	1.132	1.136	6.032
9	SiC	1.122	1.122	1.128	6.019
10	Al ₂ SiO ₃	1.127	1.128	1.128	1.122
11	Al ₂ SiO ₃	1.126	1.127	1.129	1.124
12	Al ₂ SiO ₃	1.126	1.127	1.127	1.125
13	Al ₂ SiO ₃	1.127	1.127	1.127	1.124
14	Al ₂ SiO ₃	1.130	1.130	1.130	1.122
15	SiC	1.163	1.165	1.155	1.139
16	SiC	1.164	1.154	1.150	1.150
17	SiC	1.159	1.176	1.174	1.148
18	SiC	1.137	1.135	1.133	1.130
19	SiC	1.121	1.122	1.123	1.130
20	Al ₂ O ₃		.500		.502
21	Al ₂ O ₃		.500		.499
22	Al ₂ O ₃		.499		.500
23	Al ₂ O ₃		.500		.499
24	Al ₂ O ₃		.500		.498

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