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STATUS OF HARVEY ALUMINUM COMPONENT
EVALUATION - PRODUCTION TEST IP-12-A

AUTHOR

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PRODUCTION TEST IP-12-A

W. A. BLANTON

February 13, 1963

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STATUS OF HARVEY ALUMINUM COMPONENT EVALUATION
PRODUCTION TEST IP-12-A

INTRODUCTION

The initial large-scale evaluation⁽¹⁾ of Harvey "O" size natural I&E aluminum components received prior to May, 1961, was unsatisfactory.^(2,3) Substantial quantities of this vendor's components were rejected for poor dimensional control, large grain size, and surface inclusions resulting from copper contamination. Irradiation of about half (75,000) of the Harvey components scheduled for evaluation to goal exposure indicated their performance was essentially two-fold worse than the control material. In order to improve an obviously sub-standard product, Harvey curtailed component fabrication during the second quarter of CY 1961 to make major process and fabrication facility modifications as required to upgrade component quality. Components received subsequent to these changes, and processed at HAP0 after July 1, 1961, met specifications. Recognizing that the quality of components remaining on order was inadequate to reach a decision on vendor qualification, procurement and evaluation of an additional 150,000 Harvey OIIIIN components were authorized.⁽⁴⁾

This document reviews the evaluation status of Harvey improved components as of December 31, 1962, and includes recommendations based on the over-all test data which lead to a recent decision on this vendor's qualification.⁽⁵⁾

SUMMARY

Approximately 298,000 OIIIIN aluminum components were received from Harvey for evaluation after major steps were taken in the vendor's Plant to upgrade product quality. This material met HAP0 specifications and was comparable to the Alcoa control components with respect to physical, chemical, and metallurgical properties. Finished fuel elements (non-bumper and bumper) canned in the test and control components to complete the initial and extended Harvey evaluation programs are summarized by uranium core type and canning month in Tables I and II. Historical records show good conformance to the alternate day canning of the two vendors' products to minimize any bias of the test results from fuel assembly variables. In addition, ingot and dingot cores were about equally distributed between the test and control material to reduce uranium variables. Use of dingot uranium was discontinued prior to the receipt of Harvey components for extended evaluation. Over-all non-destructive and destructive test data did not indicate any significant differences in test and control clad fuel elements that could be attributed to component quality.

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The irradiation status of non-bumper and bumper fuel elements clad in Harvey improved components as of December 31, 1962, is shown in Table III. Seven (7) Harvey non-bumper ruptures have been experienced, as compared to three (3) non-bumper and two (2) bumper control ruptures. Refer to Table IV for a summary of these ruptures. Although the irradiation data obtained thus far does not support a conclusion that the performance of Harvey components is equivalent or two-fold worse than the Alcoa control components with a 10 percent chance of error (see Figures 1 and 2), there is no evidence that the two vendors' products differ. Further, it is unlikely that the size of the present test will be adequate to reach a decision based on the above test parameters. Conceivably, the quantity of components required could be several times that of the present test.

Since both the ex-reactor and in-reactor data obtained thus far on Harvey improved components do not differ significantly from the control material, the indicated risks of accepting this vendor's product appear to be low enough to warrant at least partial qualification. Therefore, it is recommended that the Harvey Aluminum Company be permitted to bid competitively on all future aluminum component orders except for the KVN and KVE component models. The integrity of these models is sufficiently critical under the scheduled K reactor tube change-out program to delay the use of Harvey components until additional quantities of less critical models have been irradiated. Any potential risks associated with the use of other Harvey component models can be minimized through the following:

- 1) Reject marginal or sub-standard components and return to the vendor.
- 2) Consider adverse irradiation performance of one or more component models as cause for loss of qualification until quality is restored.
- 3) Since evaluation has been confined to the OIIIN component model, any risks incurred in the use of other models can be reduced by expediting initial quantities of Harvey clad fuels for irradiation.
- 4) In the immediate future, maintain adequate inventories of all component models from previously approved vendors for back-up purposes and to assure that no reactor is over 50 percent loaded with Harvey clad fuel elements.

DISCUSSION

Test Procedure

A sequential test procedure is being used to evaluate the relative performance of natural uranium fuel elements clad in Harvey (test) and Alcoa (control) components in the old reactors. This procedure was selected because, on

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the average, a minimum number of ruptures would be required to reach a decision on alternate vendor qualification. The test is designed to show either: 1) performance of the test and control material are equal, or 2) the performance of the test material is two-fold worse than the control material. Risk of rejecting either hypothesis when true was set at 0.10. As originally designed, the test was limited to non-bumper fuel. However, since many of the test and control lots were "bumpered", both fuel types were included in the program.

Recognizing that certain fuel manufacturing and irradiation variables would compromise or invalidate the test results if ignored, an attempt was made to equalize the effects of these variables insofar as feasible through the following provisions:

- 1) Can test and control material on alternate days to minimize bias from fuel assembly variables.
- 2) Distribute ingot and dingot uranium core lots equally between test and control material to reduce uranium variables.
- 3) Reactor charge test and control material concurrently, distributing the two materials similarly throughout each reactor to minimize bias from unmeasured reactor variables.
- 4) Compute rupture index (ΔRI) for the test and control material to adjust for differences in measured reactor conditions (average tube power, average tube outlet temperature and exposure).

Pre-Irradiation Testing and Results

Component Quality

Components received from Harvey after major steps were taken by the vendor to improve product quality were as follows:

	<u>Quantity</u> <u>(Sets)</u>	<u>Type</u>
To complete initial evaluation	144,000	OIIIIN
For extended evaluation	154,000	OIIIIN

Based on random statistical samples, the above components met dimensional and surface specifications. There was no evidence of non-uniformity or surface inclusions, and the over-all physical characteristics of the Harvey components were comparable to the control product. Random component samples analyzed from each alloy "drop" also indicated comparable quality in terms of chemical composition and metallurgical properties. Average grain size was well within

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the specified maximum and the alloying constituents were uniformly dispersed. Annealed samples (1/2 hour @ 575°C) did not show any evidence of abnormal grain growth or secondary recrystallization.

Eleven (11) statistical samples taken from Harvey can shipments were tested with control samples to compare AlSi wettability. This test essentially duplicates the canning process except for fuel core insertion. Areas of non-wetting were measured and rated according to a standard scale ranging from 10 (perfect wetting) to 0 (gross non-wetting). Average over-all ratings for the test and control samples were 7.2 and 7.3, respectively. Average individual ratings of the test samples ranged from 2.9 less to 0.6 above the control samples. Since the reproducibility of the wetting test is adversely affected by process variables, it is not possible to attach any real significance to the test results.

Canning Experience

A summary of the finished non-bumper and bumper OIIIN fuel elements clad in test and control components by core type and month is shown in Table I and II. During the period from July, 1961, through December, 1961, approximately 114,000 (75,000 non-bumper and 39,000 bumper) fuel elements were canned in improved Harvey components to fulfill commitments under the initial evaluation program. From June, 1962 through November, 1962, an additional 120,000 (72,000 non-bumper and 48,000 bumper) fuel elements were processed in Harvey components under the extended program.

Alternate day canning of the test and control material was maintained to minimize test bias from process variables, except for a brief period in December, 1961. Because of an excessive AlSi slopover reject rate sustained using control cans, four lots (10,877 pieces) of Harvey clad bumper fuel elements were canned on successive days without controls. This material was excluded from the test.

The proportions of ingot and dingot cores were about equally distributed between the test and control pieces canned to complete the initial vendor evaluation program. Actual percentages of ingot, dingot and mixed cores (unknown) are shown below:

Fuel Elements Canned July, 1961 through December, 1961

	<u>Test</u>	<u>Control</u>
Percent Dingot	49	50
Percent Ingot	34	33
Percent Unknown	17	17

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Use of dingot cores was discontinued prior to processing the Harvey components received under the extended program.

Canning yields for the test and control material were comparable. Non-destructive and destructive test data did not indicate any significant differences in fuel quality that can be attributed to components. Quality Certification total bond count data for the test and control material shows only normal variation within lots and between lots.⁽⁶⁾

Irradiation Status and Results

The irradiation status of non-bumper and bumper OIIIN fuel elements clad in improved Harvey components as of December 31, 1962, is shown in Table III. Seven (7) non-bumper ruptures have occurred in the Harvey clad material, as compared to three (3) non-bumper and two (2) bumper ruptures in the Alcoa control material. No Harvey bumper ruptures have occurred. The ruptures are summarized in Table IV. It will be noted that the Harvey non-bumper ruptures were predominantly of the "side hot spot" type normally associated with fuel element warp and misalignment in the process tubes. Classifications of the control ruptures are distributed between the "end", "hole" and "side other" types. Recent rupture examination data indicate that there is a high probability that these types of failures are caused by groove and/or ledge corrosion rather than fuel quality oriented defects, particularly those sustained in high power columns in the upper exposure range. Further, a definitive analysis of the test and control ruptures is confounded by the inability to distinguish between those failures caused by fuel assembly and/or irradiation variables and those caused by component vendor oriented variables.

Based on rupture experience and computed ΔRI (rupture index), values for the test and control pieces,⁽⁷⁾ the sequential test status of Harvey components falls well within the continue test region (see Figures 1 and 2). Therefore, some risk remains that this vendor's components will not perform as well as the control material, even though the test data does not support a conclusion that the two materials are significantly different. A statistical analysis of the data shows that the true ratio of test to control rupture rates falls within the following intervals at a 95 percent confidence level:⁽⁸⁾

	Interval (Test/Control Rupture Rate)
Harvey Non-Bumper	0.6 - 11.3
Combined Harvey (Non-Bumper + Bumper)	0.8 - 4.8

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Unless there is a large change in the ratio of the test to control rupture rates, the size of the present test will not be adequate to demonstrate that Harvey components are equivalent or two-fold worse than the controls at a 90 percent confidence level.

It is not possible to predict how many additional components would have to be irradiated to reach a decision; however, the quantity conceivably could be several times that of the current test.

RECOMMENDATIONS

Since both the ex-reactor and in-reactor data obtained to date on Harvey improved components do not differ significantly from the control material, the risks associated with using this vendor's product appear low enough to justify at least partial qualification. In addition, the demonstrated capability of this vendor to produce high quality components is expected to advance with fabrication experience. Therefore, it is recommended that the Harvey Aluminum Company be permitted to bid competitively on all future aluminum component orders except for the KVN and KVE component models. Since these models will be used in conjunction with the scheduled K reactor tube change-out program, their quality and performance is considered to be sufficiently critical to delay the use of Harvey components until additional quantities of this vendor's product have been irradiated. Any potential production or inventory risks incurred in the use of other Harvey component models can be minimized through the following:

- 1) Reject and return any marginal or sub-standard components to the vendor.
- 2) Consider adverse irradiation performance of one or more component models as cause for loss of qualification until quality is restored.
- 3) Since irradiation experience has been confined to the OIIIN model, any possible risks originating from the use of other models can be reduced by expediting initial quantities of Harvey clad fuel elements for evaluation.
- 4) In the immediate future, adequate inventories of components fabricated by previously authorized vendors should be maintained for back-up purposes and to assure that no single reactor is over 50 percent loaded with Harvey clad material.

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TABLE I

NON-BUMPER CANNING HISTORY

Canning Month	Fuel Type	HARVEY TEST				ALCOA TEST			
		Finished Fuel Elements				Finished Fuel Elements			
		<u>Ingot</u>	<u>Dingot</u>	<u>Unknown*</u>	<u>Total</u>	<u>Ingot</u>	<u>Dingot</u>	<u>Unknown*</u>	<u>Total</u>
<u>(Initial Program)</u>									
7/61	OIIIN	-----	5,407	-----	5,407	-----	8,128	2,813	10,941
8/61	OIIIN	8,594	10,944	-----	19,538	4,586	7,394	5,108	17,088
9/61	OIIIN	8,367	3,544	4,085	15,996	3,341	5,383	1,696	10,420
10/61	OIIIN	11,844	9,232	6,081	27,157	20,061	9,254	3,114	32,429
11/61	OIIIN	1,882	-----	912	2,794	4,360	-----	-----	4,360
12/61	OIIIN	4,502	-----	-----	4,502	-----	-----	-----	-----
TOTAL		35,189	29,127	11,078	75,394	32,348	30,159	12,731	75,238
PERCENT		46	38	15	100	43	40	17	100
<u>(Extended Program)</u>									
6/62	OIIIN	10,774	-----	2,247	13,021	7,202	-----	3,195	10,397
7/62	OIIIN	7,266	-----	3,083	10,349	10,053	-----	-----	10,053
8/62	OIIIN	12,485	-----	5,473	17,958	5,127	-----	2,678	7,805
9/62	OIIIN	4,673	-----	6,508	11,181	6,709	-----	3,581	10,290
10/62	OIIIN	-----	-----	-----	-----	-----	-----	-----	-----
11/62	OIIIN	6,770	-----	13,100	19,870	16,190	-----	4,650	20,840
TOTAL		41,968	-----	30,411	72,379	45,281	-----	14,104	59,385
PERCENT		58	-----	42	-----	76	-----	24	100
COMBINED TOTAL		77,157	29,127	41,489	147,773	77,629	30,159	26,835	134,623

*Mixed material and recovered lots.

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TABLE II

BUMPER CANNING HISTORY

Canning Month	Fuel Type	HARVEY TEST Finished Fuel Elements				ALCOA CONTROL Finished Fuel Elements			
		Ingot	Dingot	Unknown*	Total	Ingot	Dingot	Unknown*	Total
(Initial Program)									
7/61	OIINB	-----	-----	-----	-----	-----	-----	-----	-----
8/61	OIIIINB	-----	4,823	-----	4,823	1,001	5,776	-----	6,777
9/61	OIIIINB	5,239	1,874	3,845	10,958	7,286	-----	6,296	13,582
10/61	OIIIINB	-----	-----	-----	-----	7,586	-----	-----	7,586
11/61	OIIIINB	-----	2,598	-----	2,598	5,698	-----	-----	5,698
12/61	OIIIINB	15,855	-----	4,700	20,555	1,781	-----	-----	1,781
TOTAL		21,094	9,295	8,545	38,934	23,352	5,776	6,296	35,424
PERCENT		54	24	22	100	66	16	18	100
(Extended Program)									
6/62	OIIIINB	-----	-----	-----	-----	4,587	-----	-----	4,587
7/62	OIIIINB	4,268	-----	-----	4,268	4,230	-----	-----	4,230
8/62	OIIIINB	8,676	-----	2,706	11,382	18,732	-----	2,859	21,591
9/62	OIIIINB	7,967	-----	2,030	9,997	9,891	-----	3,024	12,915
10/62	OIIIINB	4,316	-----	-----	4,316	7,274	-----	-----	7,274
11/62	OIIIINB	13,242	-----	4,720	17,962	9,087	-----	5,599	14,686
TOTAL		38,469	-----	9,456	47,925	53,801	-----	11,482	65,283
PERCENT		80	-----	20	100	82	-----	18	100
COMBINED TOTAL		59,563	9,295	18,000	86,859	77,153	5,776	17,778	100,707

Mixed material and recovered lots.

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TABLE III

IRRADIATION STATUS
HARVEY IMPROVED COMPONENTS
(as of December 31, 1962)

	<u>To Complete</u> <u>Initial Program</u>	<u>Extruded</u> <u>Program</u>	<u>Total</u>
1) Discharged at Goal			
Non-Bumper	75,000	10,000	85,000
Bumper	39,000	2,000	41,000
2) In-Reactor			
Non-Bumper	0	43,000	43,000
Bumper	0	24,000	24,000
3) To Be Charged			
Non-Bumper	0	19,000	19,000
Bumper	0	22,000	20,000
4) Estimated Test Completion Date - May, 1963			

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TABLE IV

RUPTURE SUMMARY

NON-BUMPER RUPTURES

Harvey Test

<u>Date of Failure</u>	<u>Tube & Reactor</u>	<u>Exposure (MWD/T)</u>	<u>Tube Power at Failure (KW)</u>	<u>Rupture Type</u>	<u>Canning Date</u>	<u>Lot No.</u>	<u>Core</u>
12/14/61	3264 DR	780	1229	Side Hot Spot	7/14/61	HZ036H	Dingot
1/7/62	2088B	208	1195	Unclassified	9/5/61	UZ057H	Dingot
3/11/62	1078DR	469	1123	Side Hot Spot	10/17/61	KZ152H	Ingot
3/15/62	1584DR	486	1056	Side Hot Spot	10/17/61	CZ884H	Unknown
5/12/62	1068B	627	1166	Unclassified	11/29/61	KZ142H	Ingot
9/8/62	2068B	385	1018	Side Hot Spot	6/14/62	CZ019H	Unknown
10/24/62	1577F	416	1018	Side Hot Spot	7/30/62	KZ444H	Ingot

Alcoa Control

3/9/62	2378D	289	1234	End (Cap)	10/20/61	UZ060A	Dingot
11/22/62	3867F	591	1085	Side Other	7/12/62	KZ440A	Ingot
12/23/62	3162B	459	1134	Unknown	7/31/62	KZ446A	Ingot

BUMPER RUPTURES

Harvey Test - No Ruptures

Alcoa Control

11/27/62	2777D	783	1214	Hole	6/25/62	KZ418D	Ingot
12/27/62	1077D	657	1240	Side Other	8/6/62	KZ453D	Ingot

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SEQUENTIAL IRRADIATION TEST HARVEY NON-BUMPER & BUMPER

$$\alpha = \beta = 0.10$$

$$u_1 = 2$$

K = Control Ruptures

M = Test Ruptures

ΔRI_c = Control ΔRI

ΔRI_t = Test ΔRI

	Non-Bumper	Bumper
ΔRI_t	16.2	24.0
ΔRI_c	16.7	22.6

$$\lambda = u_1^K \left[\frac{1 + \frac{\Delta RI_c}{\Delta RI_t} \left(\frac{1}{u_1} \right)}{1 + \frac{\Delta RI_c}{\Delta RI_t}} \right]^{K+M}$$

FIGURE 1

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SEQUENTIAL IRRADIATION TEST COMBINED HARVEY (NON-BUMPER + BUMPER)

$$\alpha = \beta = 0.10$$

$$u_1 = 2$$

K = Control Ruptures

M = Test Ruptures

ΔRI_c = Control ΔRI

ΔRI_t = Test ΔRI

$$\lambda = u_1^K \left[\frac{1 + \frac{\Delta RI_c}{\Delta RI_t} \left(\frac{1}{u_1} \right)}{1 + \frac{\Delta RI_c}{\Delta RI_t}} \right]^{K+M}$$

FIGURE 2

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