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OF PRODUCTION FUELS

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OF PRODUCTION FUELS

by

A. G. Blasewitz

May 17, 1963

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RADIOGRAPHIC EXAMINATION OF PRODUCTION FUELS

I. INTRODUCTION

A radiographic examination has been made of the cap end of AlSi I&E fuel elements since the first production of these models. The base end has never received a radiographic examination; previous attempts to develop equipment to enable an examination of the base end have not been successful. During the past three years there have been several significant changes in regard to the integrity of the end closure: 1) process modifications have been introduced which have markedly improved closure quality (pressure quench is the most notable change but spire pulsing and direct current welding are likewise contributors); 2) a nondestructive tester (UT-4) for checking closure integrity has been incorporated into the control system; 3) the number of autoclave failures resulting from closure defects has dropped from an average of one to two per month to essentially zero; 4) the number of irradiation failures caused by closure defects has decreased markedly. The presence and combination of all these factors compel a consideration of whether the present multiple testing of closure integrity is still required. The purpose of this memorandum is to present the available information concerning the value of radiographic testing and to recommend any appropriate change.

II. SUMMARY AND CONCLUSIONS

Currently there are four separate tests which are conducted to assure the integrity of the end closures of the fuel elements. These tests are: 1) an ultrasonic test of the end braze zones; 2) a visual inspection of the weld beads; 3) an autoclaving; and 4) a radiographic examination of the cap end. This duplication is not only cumbersome but it is expensive. The total cost of these tests is approximately 250,000 dollars per year.

Process modifications which have been made during the past three years have significantly reduced the porosity of the braze and consequently have led to a marked improvement in the integrity of the end closures. This improvement is dramatically illustrated by the reduction in autoclave and irradiation failures associated with end closure defects.

Radiography is the least valuable of the present closure testing techniques. This is particularly true since the porosity of the base closure zone is much higher than that of the cap closure but equipment limitations permit a radiographic test of only the cap end. (The fact that there is no performance problem with the base end of the fuel elements which are not given a radiographic test, is one of the strongest justifications for eliminating radiography). The annual cost of operating the radiograph station is \$80,000 per year.

It must be recognized that there is some degree of risk associated with eliminating radiography. Radiograph rejects were accumulated for an extended period of time and examined; and a few of these pieces were in the poorer end of the quality spectrum for cap braze. In no instance, however, was there a radiograph reject which contained an apparent water path entirely through the closure zone. A consideration and weighing of all the available information leads to the conclusion that the radiographic examination of the cap end of

the fuel elements can be eliminated at a savings of \$80,000 per year and that the associated performance risk is minimal. It can also be stated that the amount of information which is at hand for this evaluation is considerably more than is often available regarding possible process modifications.

III. DISCUSSION

Background Information

At the present time, there are four distinct tests which are made of the integrity of the end closures of the fuel elements.

These tests include:

1. The UT-4 test which is an ultrasonic test designed to reject longitudinally oriented braze defects. In this test, the braze zones are divided into 25 successive "discs" and each disc is checked for the presence of a void or water path. The test is operated on the basis that a piece will be rejected if there are 15 successive discs which contain defects or a total of 22 discs which contain defects. The equipment is new and complex and it certainly does not have the degree of reproducibility and accuracy which would be fully desired--particularly in terms in using the equipment for variables or quality grading measurements. It is, however, a screening tool. The reject rate for the past 12 months has averaged 1.6 per cent for normal material and 2.5 per cent for enriched material.
2. All welds are given a visual inspection. In the case of the enriched material which will be used in particular loadings, all of the welds are brushed and examined under three power magnification. In the case of other material, brushing and/or three power magnification is used whenever there is any question during normal visual examination. No visual examination will ever have a 100 per cent efficiency. The detecting of minute defects which occur randomly and infrequently constitutes the most difficult of visual inspections. Again, however, the technique is a valid screening tool. The reject rate for the past 12 months has averaged 1.6 per cent for normal material and 3.2 per cent for enriched material.
3. Each fuel element is autoclaved for a period of 20 hours at a temperature of 175 C. (these are not very severe conditions compared to maximum irradiation conditions). Any piece which does have a direct water path to the uranium core will fail during this autoclaving. The autoclave tests also produces an oxide film which improves (to a small degree) the resistance of the jacket to subsequent mechanical scratching and damage. During the past 12 months, there has been one autoclave failure which resulted from a water path through an end closure (male end).
4. The cap end, and only the cap end, of each piece is given a radiograph test. The cap end test consists of visually examining negatives exposed with X-rays. The X-ray penetrates the closure zone at a 60 degree angle to the longitudinal core axis and three separate 120 degree

increments are exposed. Rejection is based upon the following criteria:

- (a) Individual voids, grouped voids or porosity masses greater than one-half the width of the radiograph zone (edge of core to outer edge weld bead).
- (b) Voids with a circumferential length greater than three-eighths of an inch.
- (c) Any void which penetrates the surface of the weld bead.

The reject rate for the radiographic examination of the cap closure has been in the range of 0.01 to 0.02 per cent during the past 12 months.

Multiple testing of a single characteristic, such as has just been described, is a form of redundancy and is valid and justified whenever there is no single test which has sufficient reliability and accuracy to do the job, when the quality level is quite low, and when the consequences of failure are grave. As noted in the description of the four tests which are presently used to assess closure quality, each of them has its limitations and it is certainly not proposed that only one test be used at the present time. The necessity for all four tests, however, is open to questions and is, of course, the subject of this memorandum.

End Closure Integrity

The first point which should be considered is the quality and consequently the risk associated with the end closure of the fuel elements. There have been process modifications instituted during the past three years for the purpose of improving the integrity of the end closures. The most important of these modifications are: 1) pressure quench¹; 2) spire pulse^{2,3}; 3) direct current welding⁴. Development data and early production data have been obtained for all three of these modifications. The data are quite detailed and are reported in the reference memoranda; consequently the data will not be repeated here. Suffice it to say, the information which was obtained showed that significant improvements in quality level were achieved. Of greater importance, is the effect which these modifications have had upon fuel performance. The change in performance can be graphically illustrated by the change in both the autoclave failure rate and the irradiation failure rate.

Table I contains the total number of autoclave failures and those which resulted from closure defects for the period of the past four and one-half years.

T A B L E I		
<u>AUTOCLOVE FAILURES</u>		
<u>Calendar Year</u>	<u>Total Number of Autoclave Failures</u>	<u>Autoclave Failures Caused by Closure Defects</u>
1959	22	16
1960	20	14
1961*	10*	9*
1962	5	1
1963	0	0

*All of the 1961 failures occurred prior to September 1, (complete conversion to pressure quench).

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Table II lists the results for all fuel element failures which were examined in Radiometallurgy during calendar years 1962 and 1963.

T A B L E I I
FAILURE CAUSE AS DETERMINED BY
RADIOMETALLURGICAL EXAMINATION

<u>Failure Cause</u>	Number of Failures	
	<u>1962</u>	<u>1963</u>
Groove Corrosion	8	4
Charging Damage	5	0
Dingot	4	0
Overheating	2	0
Closure Defect (Pinhole)	1	0
Impurity	1	0
Spire Failure	1	0
Unclassified	1	0

Both sets of data clearly demonstrate that closure quality has improved to the point where it has not constituted a performance problem for a considerable length of time.

Cap Closure Quality versus Base Closure Quality

Following the introduction of spire pulsing and pressure quench, an extensive study was made of the incidence of voids in the cap and base braze zones. A random sample of all fuel element models was taken over a five month period and the braze areas were examined after the facing operation to determine the incidence of voids. A total of 52,801 fuel elements were involved in this study. An over-all summary of the void rate in the cap and base braze zones is presented in Table III.

T A B L E I I I
VOIDS VISIBLE IN BRAZE AFTER FACING

<u>Fuel Model</u>	<u>Number of Fuel Elements Inspected</u>	Per Cent of Fuel Elements Containing Voids	
		<u>CAP</u>	<u>BASE</u>
G2N	6787	0.38	1.96
G3E	7881	0.76	2.26
K4N	9821	0.11	1.86
K4E	8693	0.09	5.47
O3N	8715	0.02	1.50
O3E	8283	0.04	3.70
O3W	2721	0.18	1.13
Total	52801	0.22	2.74

The data demonstrate that the porosity of the base closure zone is much higher than the cap closure. Yet it is only the cap end which is given the radiographic test. Previous development efforts to provide equipment which would enable a satisfactory test of the base closure have not been successful and the base end is not tested. The other three testing techniques do check both closures.

Radiographic Rejects

A very significant factor is the quality level and the expected performance of the fuel elements which are currently being rejected by the radiographic

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examination. The trend in the radiographic defective rate for approximately the past two years is shown in Figure I. The data show that there has been a ten-fold reduction in the defective rate during this period and that the rate has been in the range of .01 to .02 per cent for the past several months. The trend is consistent with the large reduction in autoclave and irradiation failures associated with end closure defects.

As a means of obtaining information concerning the integrity of the cap closure of fuel elements rejected at the radiograph station, all of the rejects were accumulated for a four month period; a total of 140 fuel elements were collected. A visual inspection of the cap weld and a multiple UT-4 testing were performed upon these fuel elements. In no instance did the visual inspection reveal a pinhole or other penetration of the weld bead. As mentioned previously, all of the fuel elements were given a multiple UT-4 testing. The data for the ten poorest pieces are presented in Table IV.

TABLE IV
SUMMARY OF UT-4 MEASUREMENTS
UPON RADIOGRAPH REJECTS

Piece Number	11	39	63	72	83	95	98	108	134	137
Total Bad Disc (Average)	26	23	18	18	22	24	20	24	23	22
Maximum Successive Bad Disc (Average)	26	22	15	11	19	12	13	22	16	15

The reject criteria are 15 successive bad discs or 22 total bad discs; these pieces are, therefore, certainly in the poorer end of the quality spectrum for the cap braze. The cap closures of these ten pieces were examined metallographically. The first sectioning was made approximately 75 mils from the top of the weld bead to coincide with the point at which the UT-4 test begins and successive sections were then cut through the remainder of the closure zone at approximately 20 mil increments. All of the exposed discs had some evidence of porosity or cracking. It was difficult to determine whether these defects constituted a continuous water entry path. The best estimate is that pieces 11 and 39 contained continuous cracking (possibly non wetting) and piece number 108 contained a continuous void throughout the 220 mil section of braze closure which was examined; the defects in the other pieces appeared to be discontinuous.

This study of the rejects which were accumulated over a four month period presents two major points: 1) in no case was there a reject which contained an apparent water path entirely through the closure zone to the core (the weld closure appeared sound on all of these pieces); 2) the condition of the closure braze in the worst pieces was certainly undesirable and therefore there is some risk associated with eliminating radiography. This factor must be taken into consideration when weighing and judging all the available information.

Economic Considerations

The annual cost for operating the radiograph station is listed below:

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Film	\$35,000
Man Power	32,000
Direct Maintenance	11,000
Chemicals	2,500
Rejected Material	1,000
Total	\$81,500

Using a reactor rupture cost of approximately \$40,000 per fuel element in the case of the old reactors and \$100,000 per fuel element for the K reactors, a justification for radiographic inspection would be the prevention of one K reactor failure or two old reactor failures during a year's period. Based upon the defective rate at the radiograph station for the past six months, approximately 250 fuel elements would be rejected during the course of a year. The operation of the radiograph station would be justified if the rupture probability of these rejects was approximately 75-fold greater for the K size elements and approximately 200-fold greater for the O size fuel elements as compared to normal rupture probability. Unfortunately, there is no certain means of predicting irradiation performance of these fuel elements (or for that matter, whenever a process modification is made). Again, it must be recognized that there is some degree of risk involved. In view of all of the information and particularly the facts that the base end has approximately a ten-fold greater porosity level, the base is not receiving a radiographic examination, and there is no performance problem resulting from base closure defects, the risk associated with eliminating the radiographic examination of the cap end of the fuel element appears to be quite small.

U. 17-4

Manager, Quality Control Operation

AGB:fm

REFERENCES:

1. HW-71095 "Production Evaluation of Pressure Quench," B. K. Boyd, September 18, 1961.
2. HW-65800 "Cap-Spire Pulsing," C. A. Burgess, June 15, 1960.
3. HW-66299 "Production Evaluation of Spire Pulse Preheating Technique," E. G. Powers, August 2, 1960.
4. HW-70770 "An Analysis of Direct-Current Welding for Hanford Aluminum-Glad Fuel Elements," G. R. Hanson, August 28, 1961.
5. HW-73923 "The Effect of Braze Voids on the Weld Quality of AlSi Bonded Fuel Elements," John J. Wick, June 13, 1962.

RADIOGRAPH DEFECTIVE RATE

GRAPH SHOWS THE TREND IN RADIOGRAPH
REJECT RATE DURING THE PERIOD
JULY 1961 TO APRIL 1963