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HANFORD ATOMIC RECORD

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DATE

December 20, 1960

HANFORD ATOMIC PRODUCTS OPERATION, RICHLAND, WASHINGTON

TITLE

OPTIMUM CANNING CONDITIONS
FOR FOUR-INCH I&E FUEL ELEMENTS

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OPTIMUM CANNING CONDITIONS
FOR FOUR-INCH I & E FUEL ELEMENTS

This document consists of 12 pages,

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December 20, 1960

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OPTIMUM CANNING CONDITIONS
FOR FOUR-INCH I & E FUEL ELEMENTS

INTRODUCTION

Because of difficulties in charging eight-inch fuel elements in bowed process tubes in the upper parts of the old reactors, IPD has requested that four-inch I & E fuel elements be provided for these tubes early in CY1961. Approximately 30,000 fuel elements of this design, Model OVN, will be required per year. Since most of these fuel elements will be charged in the upper fringe zones, they will be in-reactor for an extended period of time. For this reason, the quality of this material should be as high as possible. This report contains a summary of tests made to determine optimum canning conditions and to establish process specifications for canning four-inch I & E fuel elements.

SUMMARY

Statistically designed tests were run in the AlSi pilot plant to determine optimum canning cycles for the assembly of four-inch I & E fuel elements. Prototypical cores, cap-spires, and contoured base cans and sleeves were fabricated for these tests from eight-inch Model OIIN components in inventory to facilitate process optimization prior to the receipt of standard four-inch components for fuel element production early next year. Variations of cycle times were evaluated in both the duplex and AlSi canning baths to establish the optimum combinations of cycles to produce four-inch I & E fuel elements having minimum braze porosity and maximum bond strength. Based on the test data, it is concluded that four-inch I & E fuel elements of uniformly high quality may be assembled according to Process Specifications, HW-47029, except for core preheat and can-sleeve preheat. Test results indicated the optimum nominal core preheat time in the duplex bath should be 24 seconds and the nominal can-sleeve preheat time in the AlSi bath should be 65 seconds. Reference is made to Fig. 5.

Results of these tests indicate that further improvements in both six-inch and eight-inch fuel element quality may be expected by optimizing canning bath conditions in a similar manner.

DISCUSSION

Cores and components for tests designed to determine optimum canning conditions for four-inch I & E fuel elements were fabricated from eight-inch components in

inventory. Aluminum components were made by cutting Model OIIN caps and cans to the proper length. Cores were made by cutting Model OIIN cores in two and finishing each piece to the proper length. Since it was recognized that can base heating for four-inch cans would be a problem, contoured base, rather than flat base components were ordered. For this reason Model OIIN contoured base cans and sleeves were cut down for development work.

With the assistance of Industrial Statistics, a two-stage test was designed to determine optimum canning conditions. The first stage consisted of a cuboctahedron experiment utilizing the three canning variables under study at each of three time cycles as follows:

Duplex Lead Time	23, 28, 33 seconds
AlSi Brazing Time	2, 4, 6 seconds
Can-sleeve Preheat Time	45, 60, 75 seconds.

The test design is illustrated in Fig. 1.

Analysis of total bond count data and bond strength measurements indicate that the region yielding optimum results was in the direction of lower lead time, slightly higher can-sleeve preheat time, and an AlSi time of three seconds. A graphic representation of results is shown in Fig. 2 which illustrates the response surfaces depicting fuel element quality. The response surfaces represent a combination of minimum external porosity, minimum internal porosity, and maximum bond strength. Values for points on the surface were determined by summation of the standard deviations from the test mean for each of the three test variables. In this case, the lower the response surface, the higher the quality in terms of low braze porosity and high bond strength.

Based on the initial test data, it was concluded that the optimum AlSi time in the duplex bath was about three seconds and further experimentation could be restricted to the effects of lead time and can-sleeve preheat time in the following ranges:

Lead Time	18 to 26 seconds
Can-sleeve Preheat Time	55 to 75 seconds.

This stage of the test was a 3^2 factorial experiment with two replicates, each being performed on a different day.

Results of the second test were consistent with the first test. External bond counts were low throughout the range of cycle times investigated. However,

there were indications that the combinations of low lead time-high sleeve preheat time and high lead time-low sleeve preheat time within the range should perhaps be avoided. There were no significant effects on internal porosity within the cycle times tested, the whole range giving very good results. A significant peak occurred within the test for bond strength measurements at a lead time of 24 seconds and a sleeve preheat of 63 seconds giving a predicted stud pull of 782 pounds. Response surfaces showing effects of lead time and can-sleeve preheat time upon external braze porosity and external bond strength are shown in Fig. 3 and 4, respectively.

When results of the second test were combined in the same manner as for the first stage of the test, the combined optimum occurs at a lead time of 24 seconds and a can-sleeve preheat time of 65 seconds. This combination is illustrated graphically in Fig. 5 by showing a response surface obtained by a summation of the standard deviations from the test mean for bond strength and total external bond count. Total internal bond count was not included because there were no significant differences observed. As in the case for stage one, the lower the value, the higher the quality. Predicted values for porosity and bond strength at optimum conditions are as follows:

External Bond Count	3.8 Counts
Internal Bond Count	7.9 Counts
Bond Tensile Strength	15,560 psi*

*Corresponds to 778 lb. stud pull

Core temperatures during lead preheat were measured at points two inches from the end of the core by inserting thermocouples at three locations: (1) external surface; (2) internal surface; and (3) midway between the internal and external surfaces. Four-inch I & E cores reach duplex bath temperature ten seconds faster than regular eight-inch models. Core temperatures measured at the three points are shown in Fig. 6.

In addition to bond strength measurements, bonding layers from representative test samples were examined metallographically. It was found that within the entire test region, external compound layer formation was equivalent or better than normal quality. Internal compound layers showed much less cracking within the bond than regular eight-inch models. Results of metallographic examination of compound layers are summarized briefly in Table I. Percentages of UAl₃-type compound layer formation for the second stage of the test are given, which represent the averages of estimates for two sets of samples for each possible set of conditions. The higher the percentage UAl₃-type compound, the better the bond.

TABLE I

Estimated Percentage of UAl_3 -type Compound Layer
Formed in Four-inch I & E Fuel Element Bonds

A - Outer Surface

Lead Time (Seconds)	<u>Estimated Percentage UAl₃ Formed</u>			<u>Overall Lead Effect</u>
	<u>Sleeve Preheat</u>			
	<u>55</u>	<u>65</u>	<u>75</u>	
18	30	60	50	47
22	50	88	75	71
26	98	72	98	89
Overall Sleeve Preheat Effect	59	73	74	--

B - Inner Surface

Lead Time (Seconds)	<u>Estimated Percentage UAl₃ Formed</u>			
	<u>Sleeve Preheat</u>			<u>Overall</u>
	<u>55</u>	<u>65</u>	<u>75</u>	<u>Lead Effect</u>
18	88	72	95	85
22	62	100	74	79
26	100	98	100	99
Overall Sleeve Preheat Effect	83	90	90	--

As the percentage of UAl_3 -type compound increases, the bond strength increases to a point and then drops as the UAl_3 layer becomes thicker. For this reason, it is desirable to obtain maximum bond strength values, but it is not necessarily detrimental to quality if bond strength drops slightly because of a thicker UAl_3 -type compound layer. However, should the bond strength drop suddenly as a result of a thick UAl_3 -type compound, there may be cause for concern because, at this point, gross microporosity within the UAl_3 -type compound permits easy fracture.

Based on the overall test data, it is recommended that four-inch I & E fuel elements be assembled by the F process except for the following duplex and canning furnace conditions:

1. Core preheat (lead) - 23 to 26 seconds.
2. Core braze ($AlSi$) - 2 to 5 seconds.
3. Can-sleeve preheat with contoured base components - 60 to 70 seconds.

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In order to obtain the recommended can-sleeve preheat, auxiliary preheat baskets will be required in the canning furnace. The reduced duplex lead time may be compensated for by a longer load and unload dwell time, or by use of a reduced canning cycle.

C. A. Strand

C. A. Strand, Engineer
AlSi Product Engineering
Fuels Preparation Department

CAS:gw

Fig. 1. Cuboctahedron experimental design with four replications of the center point.

- A - Core lead preheat time.
- B - Core AlSi braze time.
- C - Can-sleeve preheat time.

Fig. 2. Effect of lead time, ALSi time and can-sleeve preheat time upon four-inch I & E fuel element quality. The lower the surface, the higher the quality - low braze porosity plus high bond strength.

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Fig. 3. Response surface showing the effect of can-sleeve preheat and duplex lead preheat time upon external braze porosity.

Fig. 4. Response surface showing the effect of can-sleeve preheat and duplex lead preheat time upon bond strength.

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Fig. 5. Response surface showing effect of can-sleeve preheat and lead preheat upon the combination of braze porosity and bond strength. (The lower the surface, the higher the quality.)

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Fig. 6. Four-inch I & T fuel element core temperatures at points two inches from the cap end during lead preheat.

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