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March 30, 1964

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PRODUCTION TEST IP-665-A,
EVALUATION OF HOT-DIE-SIZED END BONDING
PROCESSES

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EVALUATION OF HOT-DIE-SIZED END BONDING
PROCESSES

K. L. Hladek

March 30, 1964

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PRODUCTION TEST IP-665-A,
EVALUATION OF HOT-DIE-SIZED END BONDING PROCESSES

INTRODUCTION

Investigations of possible operational limitations of the AlSi bonded fuel elements and the need for a replacement or alternate fuel fabrication process have been under way for several years. Recently, one fuel manufacturing process, hot-die-sized diffusion bonding, has been intensely examined and irradiation testing of this new fuel type began in 1963. This production test is one additional step in evaluating the new fuel fabrication process.

OBJECTIVE

The objective of this test is to evaluate the effect of end-bonding techniques on the irradiation behavior of hot-die-sized diffusion bonded fuel elements.

TEST SUMMARY

Three types of fuel elements will be used in this test: 1) hot-die-sized diffusion bonded elements which have been end bonded by the resistance heating method; 2) hot-die-sized diffusion bonded elements which have been end bonded by the induction heating method; and 3) standard production AlSi bonded fuel elements. Twelve columns of fuel containing the three element types alternated throughout the columns will be irradiated in the test. Twelve smooth-bore Zircaloy-2 process tubes in the C Reactor will be utilized for this test; consequently, all fuel elements of this test are self-support models. These fuel columns will be irradiated to average exposures of 800 Mwd/t. Examination and measurement of the elements of this test will take place in the 105-C Metal Examination Facility.

BASIS AND JUSTIFICATION

The initial irradiation of hot-die-sized diffusion bonded fuel elements began in July 1963. This first test, a pilot irradiation of twenty columns of elements in the smooth-bore Zircaloy tubes at the C Reactor compared the irradiation behavior of the hot-die-sized elements with that of AlSi bonded elements.^[1] The fuel columns were irradiated to 900 Mwd/t at which time considerable difficulty was encountered in discharging the irradiated columns, with forces up to 6000 pounds required to initiate column movement. Post-irradiation measurements of these elements revealed that the hot-die-sized elements had, during the irradiation, increased in diameter on the average eight mils more than the companion AlSi elements.^[2] Since this initial test was designed to permit direct comparison of the dimensional behavior of the two element types, the problem was attributed to the differences in fuel

[1] Hladek, K. L., and C. A. Burgess. Production Test IP-546-A, Irradiation of Hot-Die-Size Diffusion Bonded Fuel Elements, HW-75465. June 21, 1963. ()

[2] Bloomstrand, R. R. Post-Irradiation Measurements of PT-546 Fuel Elements, HW-80281 RD. January 5, 1964. ()

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element fabrication techniques. A second test, involving enriched uranium cores, had also been under irradiation.[3] Results from this enriched uranium test confirmed previous test results.

A step-by-step analysis of the entire hot-die-sizing process was then undertaken to attempt to identify steps in the fabrication which could induce sufficient change in the uranium grain structure to account for the large difference in irradiation behavior. X-ray diffraction studies and metallography of the uranium grain structure did reveal that slight changes in the uranium occurred during the end bonding stage of fabrication. In end bonding, as performed for the elements of the initial irradiations, the core-cladding assembly, which has been bonded, is heated in a pre-heat furnace to about 400 C, placed in the end bonding press, additional heat applied to raise the uranium temperature to about 575 C, and then a pressure of 8000 pounds per square-inch applied on the ends of the element along the longitudinal axis of the piece for about 4 1/2 minutes. This temperature-pressure combination produces the diffusion bond.

Since end bonding produced a significant physical change in the uranium, a change of this process was undertaken. The original end bonding process utilized resistance heating of the fuel element to the necessary temperature, thus heating the element through its full length. New equipment was procured which would permit induction heating of the element and eliminate two undesirable features of the previous method: 1) heating of the elements in a furnace before being placed in the end bonding press, and 2) heating of the entire element while in the press. The total time at the elevated temperatures is reduced with the induction method; 4 minutes 10 seconds versus 10 minutes 15 seconds with the resistance techniques.

Examination of elements produced by the induction end bonding process has shown that the uranium core dimensional changes are less than with the resistance end bonding process.

With these results in hand, an irradiation test has been designed to permit an evaluation of the irradiation behavior of the induction end bonded elements. This test compares the behavior of induction end bonded and resistance end bonded hot-die-sized diffusion bonded fuel elements with AlSi control elements. This test uses resistance end bonded hot-die-sized fuel to provide a basis on which to compare the new process. The behavior of the resistance end bonded elements should be no better than before if, indeed, end bonding is the culprit. It is likely, therefore, that discharge difficulties could be encountered with the columns of this test, although lower than normal fuel element support heights will be used on all elements.

Use of the lower support heights increases the fuel element - process tube eccentricity and, hence, increases the coolant temperature unbalance in the outer annulus. Thermocouple probe measurements on the hot-die-sized elements of Production Test IP-546-A, Supp. A,[4] indicate that even with the lower support heights a maximum R value of 1.20 is sufficiently conservative to be used in limit calculations. To monitor the coolant temperature unbalance that exists with the elements to be

[3] Hladek, K. L. Production Test IP-616-A, Irradiation of Enriched Hot-Die-Size Diffusion Bonded Fuel Elements, HW-78960. August 17, 1963. ()

[4] Hladek, K. L. Supplement A to Production Test IP-546-A, Irradiation of Diffusion-Bonded Fuel Elements, HW-75465 E. February 4, 1964. ()

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irradiated with this test, a minimum of five downstream thermocouple probes will be used. Daily readings of these coolant temperatures will be taken.

The corrosion behavior of hot-die-sized elements has not been fully evaluated with the previous irradiations. Although no large differences in the corrosion characteristics of this fuel are expected, effects of higher coolant temperatures have not been evaluated.

The risks of operational difficulty with this test are greater than for normal reactor operation; these risks appear warranted, based on the objectives of the alternate fuel fabrication program. Time is of importance in providing a suitable fabrication process; delays in the irradiation testing of this alternate fuel concept could have a detrimental effect on future process development work.

TEST DETAILS

1. Reactor

Since the existing equipment for fabricating hot-die-sized fuel produces elements corresponding to the CVNS model, irradiation of the elements of this test will take place in the C Reactor.

2. Fuel Elements

a. Model

All AlSi fuel elements used in this test will be of the CVNS model; all hot-die-sized diffusion bonded elements will be of the CDBIIN model.

b. Fabrication

The hot-die-sized elements used in this test will be fabricated according to the detailed procedures outlined in the process specifications,^[5] with exception of the end bonding. No process specifications for the induction end bonding now exist, and to meet the schedule established for this test, no formal specifications can be issued. The techniques developed for induction end bonding will serve as guide lines for fabrication of elements of the test.

All AlSi elements used in this test will be fabricated according to the "F" process^[6] and shall meet all fabrication and quality specifications in effect at the time of manufacture.

Aluminum components will be of 8001-F alloy; all fuel element cores will be of natural uranium formed by the ingot process.

[5] Schweikhardt, G. M. Provisional Specifications for Hot-Die-Sizing Process, HW-77683. July 15, 1963. ()

[6] Process Specifications, Fuel Element Manufacturing Processes, HW-47029. ()

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c. Self-Supports

All supports used on elements of this test will be fabricated in accordance with Drawing H-3-7948 for CVNS fuel elements.

Minimum support heights for both AlSi and hot-die-sized elements will be 0.077 inches; the maximum circumscribed support circle will be 1.656 inches.

d. Quantity

A total of 384 fuel elements are required for this test. Ninety-six elements of each hot-die-sized end bonding type will be used; 96 AlSi control elements, elements containing uranium cores from the same uranium ingots, and 96 normal production AlSi elements, to be used as "fillers," are required. Spare elements of each type will be supplied with the test elements.

e. Pre-Irradiation Testing and Measurement

In addition to all the normal quality tests and measurements, fuel elements of this test will have O.D. and I.D. at the three standard locations, warp-ellipticity, and length measurements taken and recorded. The weight of all of the test elements, three types, will be recorded. All fuel element support heights will be recorded. Uranium core history will be maintained on all elements of this test.

f. Fuel Columns

A total of 12 fuel columns are required for this test. Each fuel column shall contain eight induction end bonded hot-die-sized elements, eight resistance end bonded hot-die-sized elements, eight AlSi control elements, and eight AlSi "filler" elements, a total of 32 elements. Three specific fuel column types with each fuel column consisting of the four types of elements as described by Stewart [7] will be used.

All elements of this test will be identified as to position number within the fuel column and a series number will identify each fuel column. In addition, each column type, as described by Stewart, will be identified. These identifying letters and numbers will be stamped on the base end of the elements.

3. Process Tubes

The elements to be used in this test are self-supported and of the CVN model; hence, use of the regular size smooth-bore Zircaloy-2 process tubes is mandatory. The three fuel columns of each group of this test must be irradiated under similar conditions. This necessitates irradiating the fuel columns in adjacent process tubes. The following tubes are selected to be used for this test: 3583, 3584, 3585, 3586, 3588, 3683, 3684, 3685, 3686, 3687, and 3688. Discharge of fuel columns in these process tubes at sub-goal exposures are authorized to permit charging of test material.

[7] Letter, K. B. Stewart to C. A. Strand, "Design of PT Test," February 14, 1964.

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4. Thermocouple Probes

A minimum of five downstream thermocouple probes will be used in this test, with up to ten thermocouple probes authorized by this test. Fabrication schedules for the probes will determine the final quantity to be used, as assembly of five probes has already been completed. The tubes into which thermocouple probes are to be installed will be specified by the test author. All thermocouple probes will be installed during the same outage--no delayed installations are authorized.

5. Irradiation

a. Charging

All test columns will be hand charged in numerical order, number one piece downstream. Each column series number and type will be recorded as to the tube into which the fuel was charged. The particular column locations will be specified by the test author prior to scheduling the charging. A representative of Research and Engineering will monitor the fuel charging.

b. Data

Daily flow and temperature data for the tubes of this test will be recorded on data sheets provided by the test author.

c. Goal Exposure

All fuel columns of this test will be irradiated to 800 Mwd/t. Changes in this goal exposure plan may be made by the test author with the concurrence of the Manager, C Processing.

d. Discharge

All fuel columns of this test will require special pickup and subsequent transfer to the 105-C Metal Examination Facility. No more than four fuel columns may be combined in one bucket.

No fuel failures are anticipated in this test. Should a fuel failure occur, however, all fuel columns of this test may be discharged, providing they can be specially picked up.

e. Operating Limits

The fuel columns of this test will operate with maximum R values up to 1.20. Process Standard A21.03 dictates use of a 1.15 R value in calculating operating limits for CIVNS fuel. For the fuel columns of this test, Process Standard A21.03 is temporarily waived and an R value of 1.20 shall be used in calculating the operating limits. All other operating conditions and limits that apply to the CIVNS fuel element model will be applicable to this test material. Existing Process Standards will be used as the basis for these operating conditions and limits. Water shutoff times shall be obtained from Process Technology Operation.

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6. Hazards

No new or unusual hazards are associated with this test.

7. General

a. Schedule

The elements for this test have been fabricated and are now ready for reactor use. Charging of the test material is therefore requested for the first C Reactor outage following approval of this test document.

b. Duration

The elements are expected to achieve the goal exposure in less than four months from the time of charging. This test authorization will expire on June 1, 1965.

c. Post-Irradiation Examinations

All fuel elements of this test will receive the normal post-irradiation visual and dimensional measurements in the 105-C Metal Examination Facility. Weight of all test elements will also be required. Selected elements may require additional measurements as requested by the test author. Upon completion of the post-irradiation measurements, all fuel elements are to be retained by the Metal Examination Facility until released by the test author.

d. Costs

The outage time lost as a direct result of this test may be charged to cost code XXXX-5R23-XXX.71. An estimate of outage time required:

Charge-discharge	10 hours
Thermocouple Installation	5 hours
Special Pickup	<u>2 hours</u>
Total	17 hours

RESPONSIBILITIES

Production Fuels Section shall be responsible for canning, finishing, testing, quality control, and pre-irradiation measurements of fuel elements used in this test.

Research and Engineering Section

Process and Reactor Development Subsection shall be responsible for over-all coordination of the test, reporting in-reactor performance of test material, and analysis of the reactor operating data.

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Process Technology Subsection shall be responsible for providing assistance to both Processing Operation and Process and Reactor Development Subsection in the pre-shutdown scheduling, for forwarding operating data to the author, and for specification of operating limits.

Testing Subsection shall be responsible for post-irradiation fuel element examination and measurement.

Manufacturing Section

Production Scheduling shall be responsible for maintaining accurate records of material charged under this program and for scheduling discharge of the test columns.

C Processing Operation shall be responsible for operational safety and production continuity of the reactor, for charging and special pickup of the test material, for recording operating data as requested, and for installation of downstream thermocouple probes.

K.L. Hladek

Engineer, Reactor Engineering
Process and Reactor Development
Research and Engineering Section

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