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PRODUCTION TEST-IP-610-A
EVALUATION OF INDUCTION HEAT
TREATED FUEL CORES

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PRODUCTION TEST-IP-610-A
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TREATED FUEL CORES

By

K. L. Hladek

November 19, 1963

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HANFORD ATOMIC PRODUCTS OPERATION
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PRODUCTION TEST-IP-610-A
EVALUATION OF INDUCTION HEAT
TREATED FUEL CORES

OBJECTIVE

The objective of this test is to evaluate the irradiation dimensional stability of uranium fuel cores produced by an induction heat treating process.

TEST SUMMARY

Ten columns of natural uranium OIIN fuel elements will be irradiated in DR Reactor to exposures of 600 Mwd/t. The fuel columns will contain both elements with cores fabricated by an induction heat treating process and elements with cores fabricated by the standard salt-bath heat treatment. The elements of this test are paired; one induction heat treated and one salt heated core from adjacent ingot rod positions will be charged into alternate fuel column positions. The elements will be specially picked-up after discharge and sent to the 105-C Metal Examination Facility for post-irradiation examination and measurements.

BASIS AND JUSTIFICATION

An alternate uranium core heat treatment technique has been under development at National Lead (Fernald) for many years. Heat treatment of each uranium core into the beta phase, a temperature greater than 660 C, has been found to substantially improve the irradiation dimensional stability of the uranium. The current heat treatment process involves the submersion of each core into a heated salt bath. Changes in this process could reasonably have an effect on the irradiation behavior of the uranium.

Certain manufacturing problems exist in using the current salt-bath heating process for heating uranium fuel cores. Among these problems, sludge build-up in the bath container is of considerable importance. This sludge build-up changes the heat transfer characteristics of the bath and increases the chance of producing only partially transformed (not fully heated into the beta phase) uranium cores. Draining and cleaning the salt bath is a difficult and expensive process, and is undertaken only when absolutely required. Induction heat treating, while having potential problem areas itself, certainly eliminates the major problem of salt-bath sludge build-up. The induction heat treating process basically consists of transporting the uranium core into the center of an induction coil, heating the core in air for a predetermined time, and transporting the core into a quench media. The largest variable associated with this process will probably be the control of the actual temperature obtained by the core during the heating. Although the induction heating method eliminates the sludge problem of the salt bath causing localized heat transfer difficulty, the chance of variability of the actual core

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temperature reached may be increased. In fabricating elements of this test, the temperatures attained by the induction treated cores ranged from 1300 F to 1385 F; the temperatures obtained with the salt heated cores ranged from 1350 F to 1360 F. This variability is not alarming as the temperatures and all are well within an acceptable region.

The measurement of heat treatment warp for the elements of this test have shown that the induction heat treated cores warped an average of 0.005 inches, while the average salt heat treated cores' warp was 0.009 inches. Although a correlation of heat treatment induced warp and irradiation induced warp has been found, it is not sufficiently understood to predict the expected dimensional stability during irradiation of these cores.

No large incentives from the irradiation standpoint are visualized for converting the heat treating facilities at National Lead to the induction method. Fairly large economic incentives do exist, however, in the fabrication of the cores. The approximate heating time required for cores induction heated is 80 seconds while the salt method, although using a batch technique, requires about eight minutes. The induction method also offers some possibility for an automated process.

While induction heat treatment has not demonstrated substantial achievements of uniformity or indications of increased irradiation performance, no serious areas of concern have been encountered. The process needs to be evaluated with regard to the irradiation behavior of the cores before investment of a large amount of money in an induction heat treating facility in the National Lead plant.

TEST DETAILS

A. Reactor

Irradiation of the test elements will take place in DR Reactor.

B. Fuel Elements

1. Model

All fuel elements of this test will be of the OIIIN model. All of the elements will contain natural uranium fuel cores.

2. Fabrication

The fuel cores of this test are divided into two groups—induction heat treated and salt-bath heat treated. The induction heat treated cores were heated in an electric induction coil, 3000 cycles per second, 36 inches long, to a temperature range of 1300 F to 1385 F. The temperature of these cores was monitored by a Thermodot total radiation-scanning technique, an infra-red radiation detector. The temperature of every fiftieth core heated was also monitored by six thermocouples imbedded in the core. The salt heated cores followed all of the normal fabrication procedures.

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All cores will be canned by the "F" process⁽¹⁾ and clad in 8001-F aluminum alloy. The cores and finished fuel elements of this test will meet all fabrication and quality specifications in effect at the time of fabrication.

Identification of all fuel elements with regard to heat treating history and ingot position history of the cores will be maintained throughout the fabrication of these elements.

3. Quantity

This test requires three hundred ten (310) fuel elements. Included with the test elements will be about twenty spare elements and ten water-mix elements.

4. Column Make-up

The elements of this test will be formed into ten fuel columns of thirty-two fuel elements each. The columns will be formed from paired elements, a pair consisting of an induction heat treated core and a salt-bath heat treated core from adjacent positions in the uranium ingot rod. Water mixing fuel elements will be included in the test columns in fuel element position number seven; use of the water mixers will be at the discretion of the Manager, DR Processing.

All elements of this test will be identified as to position number within the fuel column, number one piece being downstream, and a series number will identify each fuel column. These identifying numbers will be stamped on the base end of the fuel element. All spare pieces will also be identified by numbers stamped on the base end.

5. Pre-Irradiation Testing and Measurements

In addition to all the normal quality tests and measurements, all fuel elements of this test will have O.D. and I.D. at the three standard locations, warp-ellipticity, and length measurements recorded. The weight of all fuel elements of this test will be recorded.

C. Irradiation

1. Charging

All columns of this test will be machine-charged in numerical sequence, number one piece downstream. The fuel identification numbers, series and lot number, of each fuel column will be recorded to correspond to the tubes into which the elements were charged.

(1) Callen, A. C. Process Specifications, Fuel Element Manufacturing Processes, HW-47029. March 15, 1957.

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The use of water-mixer elements in these fuel columns will be as specified by the Manager, DR Processing. If water-mixers are not to be used with these columns, the mixer element supplied with each charge will be removed from the column and a spare element inserted into this position. Changes to the location of the mixer element position within the column may be accomplished as required to conform to the requirements of the Manager, DR Processing. The quantity of perforated aluminum spaces normally used with fuel columns of this length will be used to position the test fuel columns within the process tubes.

The assigned Process Engineer and the test author, with the concurrence of the Manager, DR Processing, will select the actual process tubes to be used for this test.

2. Operating Limits

The operating conditions and limits that apply to the OIIIIN fuel elements will be applicable to this test material. Existing process standards will be used as the basis for all operating conditions and limits.

3. Data

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

4. Goal Exposure

The scheduled goal exposure for the fuel columns of this test will be 600 Mwd/t. This exposure will permit analysis of differences in irradiation behavior of the two core types while limiting the effect of fuel cladding corrosion on the dimensional changes of the fuel.

5. Discharge

All fuel columns of this test will require special pick-up after discharge and subsequent shipment to the 105-C Metal Examination Facility. No more than four tubes of elements may be combined in one bucket, but element identification within the bucket need not be maintained.

No fuel failures are anticipated in this test. Should a fuel failure in these elements occur, the remaining columns of elements will be treated as normal production fuel with regard to discharging prior to goal exposure.

D. Hazards

No new or unusual hazards are associated with this test.

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E. General

1. Schedule

Charging of the fuel columns of this test is requested for the first outage of DR Reactor following approval of this test.

2. Duration

Irradiation of the test material will require about three months. This test authorization will expire on January 1, 1965.

3. Post-Irradiation Examination

All fuel elements of this test will be examined after discharge in the 105-C Metal Examination Facility. A comprehensive visual examination of the external surface, measurement of inside and outside diameters, warp-ellipticity, and length of all pieces of this test will be made. Two independent sets of measurements of each element are required. All pieces will also be weighed. Fuel elements of special interest may be sent to the Radiometallurgy Laboratory for destructive examination.

All fuel elements of this test must be retained by the Metal Examination Facility until released by the test author.

4. Costs

The primary outage time losses resulting from this test will be associated with charge-discharge and special pick-up of the test elements. The outage time lost as a direct result of this test may be charged to cost code XXXX-5R23-XXX.71. Anticipated times for charge-discharge and special pick-up are:

Charging - 15 min. per tube	2 1/2 hours
Special Pick-up - 10 min. per tube	<u>1 1/2 hours</u>
Total	4 hours

RESPONSIBILITIES

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

Research and Engineering Section

Process and Reactor Development Subsection will be responsible for coordination of the test, analysis of operating data, reporting of in-reactor performance, and for provision of bases for operating limits.

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Process Technology Subsection will be responsible for providing assistance to both the Processing Operation and the Process and Reactor Development Subsection in pre-shutdown scheduling, in charging the test materials, in selection of test channel locations, for forwarding operating data to the author, and for specification of operating limits.

Testing Subsection will be responsible for post-irradiation fuel element examination and measurements.

Manufacturing Section

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

DR Reactor Operation

DR Processing Operation will be responsible for scheduling, for operational safety and production continuity of the reactor, and for charging the test material.

K. L. Hladek

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

KL Hladek:go

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